Nutrient Management Guidelines for Agronomic Crops Grown in Mississippi

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Introduction to Nutrient Management

The goal of nutrient management is to maximize plant productivity while minimizing environmental consequences. Nutrient management plans document available nutrient sources, production practices, and other management practices that influence nutrient availability, crop productivity and environmental stewardship. This publication brings together many years of science regarding the economic and environmentally responsible use of plant nutrients in Mississippi.

Nutrient Management Planning (NMP) is a Best Management Practice, or BMP. While the term "nutrient management"often is associated with manure management, it applies to all nutrient inputs, including organic materials, livestock byproducts, and inorganic commercial fertilizers. When animal manures are a nutrient source for a farm, NMP includes Comprehensive Nutrient Management Plans, or CNMP, particularly when developed by Natural Resource Conservation Service personnel.

What is Nutrient Management Planning?

Nutrient management planning principles are the same as good business management principles:

- Know what you have,
- Know what you need,
- Manage wisely, and
- Document the management.

Nutrient management plans must be site-specific, tailored to the available inputs, soils, landscapes, and management objectives of the farm.

Steps in Nutrient Management Planning

1) Obtain accurate soil information for each field or management unit.
    a. Create farm maps that include soil series, surface water bodies, and other resource concerns present in the landscape.
    b. Sample the soil in each field or management unit and process through a reputable soil-testing laboratory. Some government programs in the state require testing through the Mississippi State University Extension Service Soil Testing Laboratory.
2) Develop fair, realistic estimated crop yield goals for each field based on recent production history, agronomic practices, and soil characteristics. The key is to be realistic. The past three to five years of production data may be used to develop an average baseline.
3) Using the soil test analyses, determine the plant nutrients required to reach the yield goal. In some cases, you may need to take into consideration nutrient uptake and removal data for common crops. This information is available from various sources, including Chapter 3 of this manual. It is important to distinguish between crop uptake and nutrient removal in harvested biomass.
4) Determine plant-available nutrients from any livestock byproduct amendments that will be used to fertilize the crop. The BMP is to sample manure that will be used. General values are available, but accurate nutrient content of manure is specific to site, animal, diet, and management. See also Chapter 7. More information on testing broiler litter is available at Soil and Broiler Litter Testing Basics (MSU Extension Service Information Sheet 1614)

5) Estimate nutrient contributions from manures that were applied in previous seasons. Usually 50 to 60 percent of nitrogen in animal manures is available to growing plants the first year following application. Residual nutrients are usually available on a declining scale for about three growing seasons. In some circumstances, the MSU Extension Service credits carryover from earlier inorganic fertilizer applications. (See individual crop recommendations for specifics.)
6) Environmental assessment tools, such as the Mississippi Phosphorus Index (PI), can calculate the potential risk of offsite phosphorus movement on a field-by-field basis. The PI incorporates site-specific soil conditions and applied BMPs in the evaluation. Soil test phosphorus levels, soil permeability, field slopes, litter application rates, distance to surface water, and other factors are used to determine the probability of nutrient movement. If the PI shows low risk, NMP may be based on crop nitrogen needs for optimal production. If the PI is medium risk, additional BMPs may be necessary. If the PI shows high potential risk for P movement in the landscape, NM should be based on crop P requirements as determined by the soil test recommendations.
7) Apply animal manures and commercial fertilizers based on soil-test recommendations and the risk assessment. Over-application does not improve yields and increases the risk of environmental problems.
8) Keep records of nutrient sources, application dates, rates, methods, and general climatic conditions. Good records simplify planning.

Nutrient Management Summarized:

- Know your soils and fields.
- Be realistic about yield potential.
- Determine nutrient removal.
- Find out what is available from this year's application.
- Find out what is still available from previous applications.
- Assess environmental risk of nutrient movement.
- Use common sense when applying fertilizers.
- Keep relevant field records.

This guide is a brief introduction to nutrient management in Mississippi. Practices used on particular farms will vary throughout the state due to soils, weather conditions, and other localized considerations. More information concerning specific crops is available through www.msucares.com, county Extension offices, or through the MSU Extension Service Area Agronomy Agent for your region.

The Soils of Mississippi

Soils develop over time from parent materials, weather conditions, biological factors, and topography. These factors are diverse in Mississippi, resulting in a wide variety of soils. Soils are classified into 12 soil orders; seven of these have been found in Mississippi. To date, about 250 individual soil series (the most specific soil classification) have been mapped in the state.

Mississippi has three general land resource regions: 1) river flood plains in the Delta area; 2) a loess region that has soils formed in windblown material that adjoins the Delta; and 3) the Coastal Plain in eastern Mississippi. The Mississippi loess and Coastal Plain regions are divided into smaller units based on common soils, geology, climate, water resources, and land use called Major Land Resource Areas (Figure 1). Humans' influence on the land has changed – for example, Americans are now replanting the forest they once cleared – but one thing remains the same: the surface activities within a region reflect that region's soil. For example, about 75 percent of Mississippi's annually seeded crops, such as cotton, corn, and soybeans, are planted in the Delta's flat, deep, alluvial soils, which allow for mechanized farming. Most of the state's animal production and forestry occurs in the hills in east and south Mississippi, where the soils are shallower. Federal soil conservation efforts since the 1980's have significantly reduced crop acreage in the hill region, where the soil is prone to erosion. Much of this acreage has been planted in pine trees.

Southern Mississippi Valley Alluvium: The Delta

Mississippi Delta soils originate from sediments left by river floods; however, the Mississippi Delta is not a traditional delta fan at the mouth of a river. Much of the Delta region is farmed. Three-fourths of the total cropland is in the northern counties. In the southern counties, less of the land is used for agronomic crop production. Controlling surface water and drainage are major soil management issues.

Because Delta soils are alluvial – that is, they came from river sediment – their particle sizes vary. The farther the particles are from the originating stream, the smaller they will be. In other words, soils closer to running water have proportionally more large silt and sand particles than soils farther from the stream. Another factor in Delta soil formation is surface water movement over time: soils formed under standing water have different properties than soils formed under running water.

Clay particles are the smallest basic soil solid, and soils with lots of clay particles have some unique features. When these soils dry, small, round balls form at the surface. The masses look like shotgun buckshot, which is why Delta clay soils are often called "buckshot." Soils with large clay content absorb water very slowly, making these soils good for aquaculture and rice production.

Southern Mississippi Valley Uplands: Brown Loam Hills and Thin Loess Areas

When ancient floodwaters receded in what is now the Delta, strong winds blew the dry sediment left by flooded rivers to the nearby uplands. The deposited material is called loess, and it is the parent material of the soils in the hilly region along the eastern edge of the Delta. The depth of loess decreases from west to east across the state as the distance from the originating flat lands increases.

The Brown Loam region, or Bluff Hills, has some very deep loess deposits, such as the bluffs outside Yazoo City. Natchez silt loam, a soil that covers about 170,000 acres in the area, was designated the Mississippi state soil. Agriculture is diverse in the region, but erosion is a concern because the soil tends to erode when tilled.

Coastal Plain

Coastal plain soils in Mississippi are part of an arc along the United States' coast from New Jersey to Texas. These soils form on unconsolidated river or marine sediments deposited at the edges of ancient seas. These soils usually are best suited to pastures and forests but can support other crops.

The northern portion of the Coastal Plain is commonly called the Mississippi Sand Clay Hills. The southern Coastal Plain is the Piney Woods region of the state.

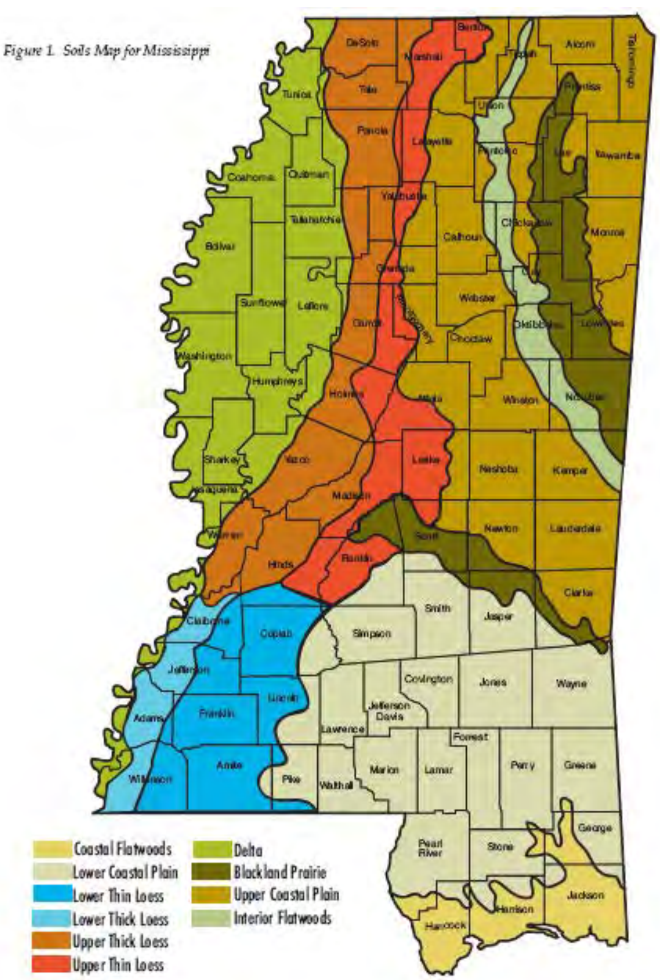
Blackland Prairie

There are two Blackland Prairies in Mississippi. One is in northeastern Mississippi near Tupelo, Aberdeen, and Columbus; the other is smaller, in south central Mississippi near Scott County. Many of the soils are very dark, prone to developing wide cracks when dry, and may look like Midwestern prairies. The Mississippi Blackland soils form from soft limestone or chalk in humid conditions. The black Midwestern prairie soils form in glaciated areas predominated by grasslands under drier, less humid conditions. Centuries of nutrient cycling in the Midwest soils result in very high organic matter content. The Mississippi soils have lower organic matter levels. The Blackland Prairies of Mississippi support a range of agriculture, such as livestock, poultry, hay, and row crop production. Scott County often has the highest agricultural income in the state each year.

Gulf Coast Marsh

Zones of marsh vegetation along the Gulf of Mexico are almost treeless and are uninhabited. It is part of the estuarine complex that supports Gulf marine life. Most of the soils of the Gulf Coast Marsh are very poorly drained, and the water table is at or above the soil surface most of the time. These soils are susceptible to frequent flooding. They formed in organic accumulations and alluvial and marine sediments.

Figure 1. Soils Map for Mississippi



Eastern Gulf Coast Flatwoods

The area between the marshes and the Coastal Plain is chiefly forest. Pulp and paper companies and the military have large holdings in the region.

For the Soils on Your Farm

The above is only a brief introduction to the soil regions of Mississippi. These few regions contain about 250 different soils with a wide range of properties. For nutrient management planning, get specific information on soils from the online resource Web Soil Survey at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. It is an easy-to-use application that can provide an incredible amount of information on the soils at a particular location and how to manage them. Local offices of the Natural Resource Conservation Service and the MSU Extension Service can also help you identify the soils on your farm.

Plant Nutrients

Plants require 18 different nutrients, or chemical elements, to complete their life cycles. Three nutrients – carbon, hydrogen, and oxygen – are derived through photosynthesis. All other plant nutrients come from the soil. Insufficient nutrients may limit or end plant growth, decrease yields, and lower profitability. Excessive nutrients may limit or end plant development, decrease yields, lower profits, and increase environmental risks. Nutrient management planners must work to optimize nutrient relationships and lower undesirable outcomes.

In nature, nutrients cycle from plants to soils and back again through constant turnover. Agricultural production usually changes this situation, and supplemental nutrients may be required for economical production. For example, removing harvested crop biomass also removes nutrients from fields. Fertilizers, manures, legumes, and other sources may provide supplemental nutrition for growing crops.

The essential nutrients traditionally are classified in three categories: macronutrients, secondary nutrients, and micronutrients. These categories refer more to the amount of nutrients typically available to plants than to the actual quantity required by the plants. Again, by definition, lack of any of these nutrients leads to growth problems or death.

Macronutrients

Nitrogen

Nitrogen (N) is required for protein production in plants and animals and is a component of the nucleic acids DNA and RNA. It is a component of chlorophyll, which gives the green color to plants and is vital for photosynthesis. Crops do not use N very efficiently, and significant quantities are often lost to leaching, volatilization, or denitrification. Legume plants, such as soybeans and clovers, produce almost all their N through a symbiotic, or beneficial, relationship with bacteria *Rhizobium* species. The bacteria infect their roots and convert nitrogen in the air into a form the plants can use. Therefore, legumes that have active N-fixing bacteria do not need additional N fertilization. The bacteria will produce less N if it is provided. It is important to inoculate legumes with proper N-fixing bacteria if that particular crop has not been grown in the field for several years.

The Mississippi environment is warm and humid, so nitrogen usually lasts only one growing season. A very unusual weather trend may result in some carryover in some circumstances. Nitrogen soil testing in Mississippi has rarely been successful due to the continuous N species transformations even within a collected sample. The species turnover makes it difficult for laboratories to determine how much N plants actually have available.

Phosphorus

Phosphorus (P) enables plants to convert solar energy into chemical energy, and plants need chemical energy to synthesize sugars, starches, and proteins. According to soil testing, soils of the Delta usually contain high or very high levels of plant-available P, so P fertilization is minimal in those 18 counties. Soil tests indicate that phosphorus levels in other regions of the state vary but are usually lower than in the Delta region.

Phosphorus is relatively immobile in soils. Substantial loss normally occurs only with erosion. Therefore, P may build up over time if more P is present in the soil than the amount removed by harvested crops. Plants may have deficient P early in the season if P is too far away from the roots or if root growth is inhibited. Phosphorus fertilization is inefficient, as it reacts in the soil with iron, aluminum, and calcium and becomes unavailable for plant use. Therefore, the amount of plant-available phosphorus is much lower than the total quantity of phosphorus in the soil. Soil testing is the best way to assess available P.

Potassium

Plants use potassium (K) to photosynthesize, transport sugar, move water and nutrients, synthesize protein, and form starch. Adequate K improves disease resistance, water stress tolerance, winter hardiness, tolerance to many plant pests, and uptake of other nutrients.

Under good growing conditions, crops remove quite a bit of potassium from the soil. K uptake is often equal to N uptake, and several times the uptake of P. Where levels of soluble K in the soil are high, plants may take up more K than needed as a "luxury consumption" that does not increase yields.

Potassium mobility is strongly related to soil texture, and movement is greatest in soils with high sand content. K is most likely to build up in clay soils, followed by loam and coarse-textured sands.

Secondary Nutrients

Sulfur

Sulfur (S) is a component of some amino acids used in building proteins. Plants need about the same quantity of S as they do P. In Mississippi, the Extension Service Soil Testing Laboratory reports S levels for some crops. The amount reported is based on the soil organic matter content and is not a separate analysis.

Like N, S is mobile in soils and can be lost by leaching. Within plants, however, S is immobile. Therefore, S deficiency symptoms are first found in younger tissue, while N deficiency symptoms are found in older tissues. Many older fertilizers contained both S and the primary nutrient, and for many years, rainfall deposited about 25 pounds of S per acre on the state annually. Thus, the only soils in Mississippi with S problems were coarse, sandy soils prone to leaching and containing low organic matter levels. Fertilizer materials have changed over the past few decades, and scrubber technology in automobiles and industry has reduced atmospheric S. S deficiencies are much more common now than in the past.

Calcium

Calcium makes up part of the cell wall and stabilizes cell membranes. Calcium deficiencies are usually found in growing points of the plant at the fruit, stem, leaf, and root tips. Calcium deficiency is rare in Mississippi soils, but some crops, such as peanuts, may use more calcium in one season than the soil can supply.

Magnesium

Magnesium is the central part of the chlorophyll molecule, where photosynthesis occurs. It also helps the plant metabolize energy and form protein. Magnesium deficiency is rare in Mississippi but has been diagnosed on sandy soils with low cation exchange capacities and high soil test potassium. Magnesium deficiencies in the soil may lead to magnesium deficiencies in grazing animals.

Micronutrients

Copper

Copper (Cu) is involved in respiration, protein synthesis, seed formation, and chlorophyll production. It is immobile in soils and thus can accumulate when more is applied than used. Organic matter holds copper tightly.

Zinc

Zinc is (Zn) necessary for starch formation, protein synthesis, root development, growth hormones, and enzyme systems. As is copper, Zn is relatively immobile in soils and tends to accumulate. Zinc deficiencies are most common on sandy soils that have low organic matter and high pH and P levels, especially under cool, wet conditions. Zinc deficiency symptoms are evident on small plants as interveinal light striping or a whitish band beginning at the base of the leaf.

Manganese

Manganese (Mn) is involved in chlorophyll formation, nitrate assimilation, enzyme systems, and iron metabolism. Manganese deficiency is generally caused by a high soil pH, whereas Mn toxicities occur at low soil pH.

Boron

Boron (B) is involved in sugar and starch balance and translocation, pollination and seed production, cell division, N and P metabolism, and protein formation. Boron, like N and S, is highly mobile, especially on sandy surface soils. Because of this mobility, B must be added annually for crops sensitive to deficiencies of it. In Mississippi, B is recommended for all alfalfa production and for cotton production in all non-Delta areas. In Delta areas, B may boost yields on non-irrigated soils in dry weather, particularly if the soil has been recently limed. However, excessive rates of B should be avoided.

Molybdenum

Molybdenum (Mo) is involved in protein synthesis, legume N fixation, enzyme systems, and N metabolism. Deficiencies of Mo generally occur on acidic soils with high levels of iron (Fe) and aluminum oxides. Soil pH largely controls the availability of Mo to the plant. Mississippi State University Extension Service recommends applying ½ to 1 ounce of sodium molybdate or equivalent annually per bushel of soybean seed when soil pH is less than 7.0.

Iron

Iron (Fe) is used in chlorophyll and protein formation, enzyme systems, respiration, photosynthesis, and energy transfer. Iron deficiency is believed to be caused by an imbalance of metallic ions, such as Cu and Mn; excessive amounts of P; and a combination of high pH, high lime, cool temperatures and high levels of carbonate in the root zone.

Chlorine

Chlorine (Cl) is involved in photosynthesis, water-use efficiency, crop maturity, disease control and sugar translocation. While chloride leaches quite readily in coarse-textured soils, deficiencies are not very common.

Nickel

Plants require Nickel (Ni) for proper seed germination. Ni is also a component in urease, which helps convert urea to ammonium. Nickel is relatively newly defined as an essential element, so specific deficiency symptoms are unclear beyond chlorosis.

Table 1. Macronutrient removal by selected crops. Data derived from International Plant Nutrition Institute Nutrient Database, North Carolina State University Extension Service Publication AG-439, Section 4 of the Mississippi NRCS Field Office Technical Guide, and http://plants.usda.gov/.

Crop	Units	N	P_2O_5	K_2O
Alfalfa	lb/ton	51	12	49
Bahiagrass	lb/ton	43	12	35
Barley	lb/bu	0.89	0.41	0.28
Barley straw	lb/ton	15	5	30
Bermudagrass - common	lb/ton	25	8	34
Bermudagrass - hybrid	lb/ton	50	12	43
Clover-grass	lb/ton	50	15	60
Clover - Crimson	lb/ton	47	9	59
Clover - Red	lb/ton	41	10	40
Clover - White	lb/ton	56	15	49
Coastal Bermuda	lb/ton	50	12	43
Corn (grain)	lb/bu	0.90	0.44	0.27
Corn (silage, 67% water)	lb/ton	10	3.1	7.3
Corn stover	lb/ton	22	8	32
Cotton (lint)	lb/bale	32	14	19
Eastern Gamagrass	lb/ton	40	4	40
Fescue	lb/ton	27	12	54
Lespedeza - Korean	lb/ton	42	10	21
Lespedeza - Striata	lb/ton	40	29	22
Oats grain	lb/bu	0.77	0.28	0.19
Oats straw	lb/ton	13	8	40
Orchardgrass	lb/ton	36	13	54
Peanuts - nuts	lb/ton	70	11	17
Peanuts - vines	lb/ton	43	6.6	20.5
Rice	lb/bu	0.57	0.30	0.16
Ryegrass	lb/ton	60	16	50
Sorghum - grain	lb/bu	0.66	0.39	0.27
Sorghum-sudangrass	lb/ton	40	15	58
Soybeans	lb/bu	3.8	0.84	1.30
Sweet potatoes	lb/cwt	0.52	0.23	1.00
Tomatoes	lb/ton	3	1.3	6.2
Watermelons	lb/cwt	0.42	0.12	0.74
Wheat - grain	lb/bu	1.3	0.60	0.34
Wheat - straw	lb/ton	13	3	23

Introduction to Soil Testing

Soil sampling and testing are the most important steps for successful nutrient management. Testing assesses soil nutrient levels and availability in the immediate growing season. Soil testing should

1. Accurately determine the nutrient status of a soil,
2. Convey the seriousness of any nutrient deficiency or excess,
3. Form the basis for fertilization managements, and
4. Allow an economic assessment of the options.

Soil testing services are available through the Mississippi State University Extension Service and commercial laboratories. While soil testing forms a basis for environmentally sensitive stewardship of nutrient resources, it is important to remember that soil tests were developed for crop response, not environmental prediction. The applicability of soil testing for environment assessment is limited; when you use soil testing to assess the environment, remember to take other soil aspects into consideration as well, such as soil series, slopes, and erosion potential.

Successful soil testing requires sound field sampling procedures. The soil collected should be a good representation of the area of interest, as the quality of the sample determines the accuracy of the test results. Soil itself is heterogeneous, and that variability in vegetation, terrain or slope, drainage, organic matter content, texture, and previous fertilizer should be reflected in the samples. Errors in test results are usually caused by poor sampling, not by the chemical analysis. Providing representative samples is the only way to get reliable test results and interpretation, which will lead to optimum production, maximum investment return, and improved environmental quality.

Defining areas to soil sample

Soil sampling should always begin with a field plan or map that defines different areas to be tested. Farmers always have used their knowledge of soils, soil characteristics, crop growth patterns, drainage, and other factors to decide which areas to sample. Thanks to today's technology, you can create more elaborate sampling patterns based on either grid patterns or self-defined soil management zones. Soil management zones can be identified by soil series, texture, drainage, yield maps, or use history. You can work with crop consultants, Extension Service personnel, or others to determine the best sampling pattern for your situation.

Soil sampling

Good soil sampling that generates accurate recommendations requires attention to details:

- use the proper equipment;
- random sample the field, grid, or zone;
- account for previous banded fertilizer applications;

- sample the appropriate soil depths for the situation;
- mix enough subsamples;
- consistently sample during the same season from year to year; and
- handle collected samples appropriately.

Equipment

Soil may be collected in several ways. Specialized soil test probes are available but not absolutely necessary for soil sampling. However, only stainless steel or other non-reactive metal tools, whether probes or other devices, should be used to extract the subsamples in the field. Stainless steel is best because some other materials react with the soil and produce skewed results for some metals.

Random Sampling

When sampling a whole field, gather subsamples randomly from across the area. Mix the subsamples thoroughly, and transfer the mixture to boxes or bags. Identify the field on the outside of the container.

Many growers and consultants use intense soil sampling to test the soil fertility of smaller areas. Two soil sampling techniques have been researched extensively in recent years. In the "grid cell" option, each grid or management zone is considered a separate field and is best sampled with a random walk. In the "grid point" option, samples are gathered from a relatively small radius of the midpoint of the grid. Where in-field nutrient levels are thought to be relatively high and variable, grid cell is the better option. Where in-field nutrient levels are relatively consistent, grid point is better. Fields with a history of banded phosphorus or potassium fertilizer applications should be noted.

Depth of Sampling

Fertilizer recommendations are generally based on the assumption that the samples are collected from the top 6 inches of soil. However, broadcast application of immobile phosphorus and potassium fertilizers in minimum tillage production systems means these nutrients stay in layers near the soil surface. When minimum or no till is used, a soil sample depth of 4 inches is typically recommended.

Pastures and hay fields may need double sampling if nutrient or pH stratification exists: a 2-inch depth for pH and lime testing, and the regular 6-inch depth for other nutrient testing.

Number of Cores

Properly sampling a field area requires a number of subsamples to be mixed together. The levels of some nutrients, such as P and K, often vary because of lack of uniformity of previous years' fertilizer applications. Soil on the surface is generally the most variable, so more cores should be collected. In general, a composite sample of 20 to 30 individual borings should be taken to represent a 20-acre field. Even 10-acre fields should have 15 to 20 cores composited.

Time of Sample Collection

MSU Extension Service offers three crop years of recommendations for each sample submitted, but it is better to collect samples every year in fields that grow multiple crops. Yearly testing will allow you to monitor trends and manage the fertility program more accurately. For less intensive cropping sequences, sampling every two to three years is enough. In either case, fields should always be sampled during the same month because results for some nutrients, pH, and lime requirement will vary seasonally due to climate, crop growth, and other factors.

Sample Handling and Record Keeping

Soil samples should be collected into clean plastic buckets and mixed well. Galvanized metal buckets should not be used because they can contaminate samples, particularly if Zn and other micronutrients will be tested. Break up and mix cores well before taking a composite subsample for laboratory analysis. Most soil testing laboratories provide small moisture-resistant boxes, sacks or bags that hold about half a liter of soil. Laboratories prefer these, but if none are available, samples may be submitted in plastic bags. Each sample box or bag should bear a unique identification that corresponds to the sample information given on the submission form.

Maintain complete field records, including field maps and names, sampling points and timing, cropping and fertilization history, and other management activities. This information, along with the soil test reports, will allow you to monitor changes in field fertility over time.

Soil test recommendations

The MSU Extension Service Soil Testing Laboratory generates three growing seasons of P and K recommendations for each sample submitted. These recommendations are based on many years of research by the Mississippi Agriculture and Forestry Experiment Station. The correlations for P and K are summarized in Tables 2 and 3.

Soil test results are given in terms of pounds per acre of either P or K; the soil test also gives a score of very low, low, medium, high, or very high based on the pounds per acre. The results also include a potassium value indexed by the soil Cation Exchange Capacity (CEC), a measure of the soil's ability to store positively charged nutrients such as K, Ca, Mg, and sodium (Na). In the MSU system, the CEC represents soil texture, as sandier textures typically have lower CEC. The CEC is given because research on Mississippi soils indicates that crops respond differently to potash based on soil CEC.

While the soil test results are given in terms of pounds per acre of P and K, the fertilizer recommendations are given in terms of pounds of phosphate or potash fertilizer per acre. Recommendations are reported this way because fertilizers are usually marketed this way. See Chapter 5 for more information on converting between the two systems.

More information

More information on soil sampling is available in the following MSU ES publications available through www.msucares.com or at local Extension offices: Information Sheet 346 Soil Testing for the Farmer, Information Sheet 1294 Soil Testing for the Homeowner, Publication 2078 Soil Sampling in Reduced Tillage, and Information Sheet 1614 Soil and Broiler Litter Testing Basics.

Table 2. Soil testing indices for phosphorus used by the MSU Extension Service Soil Testing Laboratory for all crops.

Soil Test Level Pounds per acre, P	Index
0 -18	Very Low
19 – 36	Low
37 – 72	Medium
73 – 144	High
> 144	Very High

Table 3a. Soil test potassium levels (pounds K per acre) and indices using the Mississippi Soil Test Extractant for these crops: perennial winter grass pasture (fescue or orchard grass); small grains for pasture; peanuts, perennial summer grass pasture (bahia, dallis, or bermuda); rice, or annual legumes with ryegrass.

Index	CEC < 7	CEC 7 - 14	CEC 14 - 25	CEC >25
Very Low	0 - 40	0 - 50	0 - 60	0 - 70
Low	41 - 80	51 - 110	61 - 130	71 - 150
Medium	81 - 120	111 - 160	131 - 180	151 - 200
High	121 - 210	161 - 280	181 - 315	201 - 350
Very High	> 210	> 280	> 315	> 350

Table 3b. Soil test potassium levels (pounds K per acre) and indices using the Mississippi Soil Test Extractant for these crops: dryland corn for grain, soybeans, oats, wheat, barley, summer pastures (bahia, dallis, or Bermuda) with annual legumes (white clover, red clover, lespedeza, arrowleaf clover, ball clover, or subterrean clover); temporary summer grass pastures (millet, sorghum, sudangrass, sorghum-sudangrass hybrids, or johnsongrass); forage legumes; perennial winter grass pasture with clover (white clover, red clover, subterranean clover with fescue or orchardgrass); pasture grass with annual legumes (crimson clover, annual lespedeza, arrowleaf clover, ball clover, or subterrean clover with bermuda, dallis, or bahia grass); Johnsongrass hay; mixed grass hay; annual or sericea Lespedeza hay; or sunflowers.

Index	CEC < 7	CEC 7 - 14	CEC 14 - 25	CEC >25
Very Low	0 - 50	0 - 60	0 - 70	0 - 80
Low	51 - 110	61 - 140	71 - 160	81 - 180
Medium	111 - 160	141 - 190	161 - 210	181 - 240
High	161 - 280	191 - 335	211 - 370	241 - 420
Very High	> 280	> 335	> 370	> 420

Table 3c. Soil test potassium levels (pounds K per acre) and indices using the Mississippi Soil Test Extractant for these crops: alfalfa; cotton; corn or sorghum for silage; sweet potatoes; irrigated corn; or hybrid Bermudagrass hay.

Index	CEC < 7	CEC 7 - 14	CEC 14 - 25	CEC >25
Very Low	0 - 70	0 - 90	0 - 120	0 - 150
Low	7 - 150	91 - 190	121 - 240	151 - 260
Medium	151- 200	191 - 240	241 - 290	261 - 320
High	201 - 350	241 - 420	291 - 510	321 - 560
Very High	> 350	> 420	> 510	> 560

Table 4. Magnesium calibrations for the Mississippi Soil Test.

	If CEC < 5	If CEC > 5
Index	Mg, lbs/acre	Percent Mg Saturation
Very Low	0 – 12	< 0.85
Low	12.1 – 24.0	0.86 – 1.75
Medium	24.1 – 48.0	1.76 – 3.30
High	48.1 – 96.0	3.31 – 6.60
Very High	> 96.1	> 6.61

Table 5.

Zinc recommendations				
Soil Test Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre		
		Corn	Rice	Pecans
		Zinc		
Very High	Very High	0	0	0
High	High	0	0	0
Medium	Medium	1-2	1-2	10-20
Low	Low	2-3	2-3	20-30
Very Low	Very Low	3-4	3-4	30-40

Introduction to Inorganic Fertilizers

Low soil levels of any nutrient may limit plant growth. Under natural conditions, nutrients are recycled from plants to soil to meet plant needs. This balance shifts when agricultural crops are grown because crops demand more nutrients than would be needed for natural vegetation. Significant amounts of nutrients are also removed in harvested crops. Because of these factors, supplemental nutrients may be necessary to ensure optimal crop growth and profitability. Supplemental nutrients may include fertilizers, animal manures, green manures, and legumes. Annual and perennial crops have responded to phosphorus and potassium fertilization in many situations. In some other crops and locations, there have been responses to other nutrients. Supplemental nitrogen is needed for almost all agronomic crops grown in the state except legumes. Many other factors can limit crop yields, including soil physical problems, low or excessive rainfall, other climate issues, poor stands, inappropriate variety selection, weeds, insects and diseases, and crop genetic potential.

The macronutrients, or primary nutrients, are expressed on fertilizer labels as elemental nitrogen (N), or the oxide equivalents of phosphate (P_2O_5), and potash (K_2O) in the order N-P_2O_5- K_2O. This is termed the fertilizer grade, or analysis. The numbers in a fertilizer grade, such as 10-20-10, indicate the nitrogen, phosphate, and potash percentages. For example, a 10-20-10 fertilizer contains 10 percent N, 20 percent P_2O_5, and 10 percent K_2O by weight. To convert between the oxide and elemental forms, use the following formulas:

Phosphorus: $P \times 2.29 = P_2O_5$ and $P_2O_5 \times 0.44 = P$.

Potassium: $K \times 1.21 = K_2O$. and $K_2O \times 0.83 = K$.

As noted earlier, the soil test results from the Mississippi State University Extension Service Soil Testing Laboratory are given in pounds of P and K per acre; however, the fertilizer recommendations are in pounds of phosphate or potash per acre.

Fertilizer Formulations

Many different physical and chemical forms of commercial fertilizer are available. Fertilizer materials can be solids, liquids, or gases. Each physical form has its own uses and limitations, which must be considered when selecting the best material for the job.

Granulated fertilizer materials are solid, homogenous mixtures of fertilizer materials. Granulated fertilizer is generally produced by combining raw materials, such as anhydrous ammonia, phosphoric acid, and potassium chloride. Granulated materials are N-P or N-P-K grades of fertilizer. Each uniform-size fertilizer particle contains all of the nutrients in the grade. For example, each particle in a 10-20-10 granulated fertilizer should contain 10 percent nitrogen, 20 percent phosphate, and 10 percent potash. The main advantage of granulated materials is its uniform distribution of nutrients. There is no segregation of the nutrients in handling or spreading, and there is little tendency to cake or dust.

Blended fertilizers are mixtures of dry fertilizer materials. The ingredients of a blended fertilizer can be straight materials, such as urea or potassium chloride; they can be granulated compound fertilizer materials mixed together; or they can be a combination of the two. In blended fertilizers, the individual particles remain separate in the mixture, and there is a potential for segregation of the nutrients. Properly made blends are generally equal in effectiveness to other compound fertilizers. Blends have the advantage of allowing a very wide range of fertilizer grades that makes it possible to match a fertilizer exactly to a soil test recommendation. Blends are often used as starter fertilizers; however, urea and diammonium phosphate should not be used as starter fertilizers placed in close proximity to seeds, because both materials produce free ammonia, which can hinder seed germination and seedling growth.

Fluid fertilizers are used widely in Mississippi. Fluids can be either straight materials, such as nitrogen solutions, or compound fertilizers of various grades. Fluid fertilizers are categorized into two groups: (1) clear solutions, and (2) suspensions.

Clear solutions have the nutrients completely dissolved in water, which offers the advantage of easy handling. In addition, the phosphorus in these materials is highly water soluble. The disadvantages are that only relatively low analyses are possible, especially when the material contains potassium, and the cost per unit of nutrients is generally higher. When equal amounts of plant food are compared, clear solutions are just as effective as other types of fertilizers.

Suspension fertilizers are fluids to which more nutrients have been added than can dissolve; clay is added to keep the very fine, undissolved fertilizer particles from settling out. They can be handled as a fluid and can be formulated at much higher analyses than clear solutions. These formulations may contain analyses as high as dry materials. Suspensions require constant agitation, even in storage, and suspension fertilizer cannot be used as a carrier for certain chemicals. As in the case of clear solutions, when equal amounts of plant food are compared, suspension fertilizers are just as effective as other types of fertilizers.

Gaseous fertilizer, such as anhydrous ammonia, requires special handling. Anhydrous ammonia is stored as a compressed liquid that expands during application, becoming a gas that must be injected into the soil to prevent release to the atmosphere. Special handling methods and safety precautions are required because the material can cause serious chemical burns and asphyxiation if it escapes from compressed storage.

Solubility indicates how readily nutrients are dissolved in the soil water and taken up by plants. Solubility usually is not a consideration; however, materials such as raw rock phosphate have very low water solubility.

Particle size of a fertilizer material can be important for both agronomic and handling reasons. In agronomic applications, particle size is most important for sparingly soluble materials, such as rock phosphate. These materials must be very finely ground to ensure sufficient solubility. For most soluble fertilizers, particle size is not critical for agronomic purposes but is very important for handling purposes.

Inorganic Fertilizer Calculations

Calculating proper application rates is critical to optimal management of inorganic fertilizers.

- Fertilizer grade or analysis is always referred to on ***a weight percent basis, not on a volume (gallon) basis.*** Thus, to determine the actual plant nutritive value, you must know the weight per gallon of the material. Most fluids weigh between 10 and 12 pounds per gallon. The following example illustrates the calculations:

10 - 34 - 0 weighs 11.4 pounds per gallon

Therefore one gallon contains

11.4 × .10 = 1.14 pounds nitrogen per gallon

11.4 × .34 = 3.88 pounds phosphate per gallon

It takes about 9 gallons of this fluid to equal 100 pounds of fertilizer. To compare fluids by price on a per ton basis, divide the weight per gallon into 2,000 to get the number of gallons per ton. In the above example, the calculation is as follows:

$2000 \div 11.4 = 175$ gallons per ton

This calculation can be used to compare a liquid priced in dollars per gallon with a solid priced in dollars per ton.

- Here's how to determine how much N, P, or K is in a particular fertilizer:

As described above, the fertilizer label identifies the percent by weight of N, P_2O_5 , and K_2O in the fertilizer.

- 70 pounds of a 7-14-7 fertilizer would contain 4.9 pounds of N (70 X 07.), 9.8 pounds of P_2O_5 (70 X 0.14), and 4.9 pounds of K_2O (70 X 0.07).
- 40 pounds of a 0-14-28 fertilizer would contain no N, 5.6 pounds of P_2O_5 (40 X 0.14), and 11.2 pounds of K_2O (40 X 0.28).

- The formula for calculating how much fertilizer to apply to a given area for a specific amount of nutrient is as follows:

Amount of fertilizer = (Amount of nutrient needed ÷ Percent nutrient in the fertilizer).

- How much 34-0-0 is needed to apply 50 pounds of N?
  - 147 pounds (50 ÷ 0.34) of 34-0-0 supplies 50 pounds of N.
- If 20-10-15 was used to apply 45 pounds of N, how much P_2O_5 and K_2O also would be applied?
  - It would take 225 pounds (45 ÷ 0.20) of 20-10-15 to apply 45 pounds of N. Therefore, a 225 pound application of 20-10-15 would supply 22.5 pounds of P_2O_5 (225 X 0.10) and 33.75 pounds of K_2O (225 X 0.15).

- Calculations for liquid fertilizers are similar, but the density of the liquid fertilizer must be known before doing any calculations.

- How much N, P_2O_5 , and K_2O would be in a 2.5 gallon jug of a 9-18-6 liquid fertilizer that weighs 11.1 pounds per gallon?
  - First, calculate the fertilizer in the 2.5 gallons. There would be 27.75 pounds of fertilizer (11.1 lb/gal X 2.5 gal). So, there would be 2.5 pounds of N (27.75 X 0.09), 5 pounds of P_2O_5 (27.75 X 0.18), and 1.7 pounds of K_2O (27.75 X 0.06) in this 2.5-gallon container of fertilizer.

- This is how to calculate the amount of fertilizer needed for a specific area:

- How much urea (46-0-0) is needed to apply 135 pounds of N to 25 acres?
  - Begin by calculating how much urea is needed to provide 135 pounds of N per acre. This would be 293.5 pounds (135 ÷ 0.46). So, the total urea needed for 25 acres would be 7337.5 pounds (293.5 X 25) or 3.67 tons at 2,000 pounds per ton.

◆ This is how to calculate how much a fertilizer really costs:

Bulk fertilizer is sold by the ton; convert the cost per ton to the cost per pound of a specific nutrient so that price comparisons can be made between various fertilizer options.

- If urea (46-0-0) is $450 per ton, ammonium sulfate (21-0-0) is $380 per ton, and UAN (32-0-0) is $350 per ton, what is the price of each of these fertilizers when priced per unit of N?
  - There are 920 pounds (2000 X 0.46) of N in a ton of urea, 420 pounds (2000 X 0.21) of N in a ton of ammonium sulfate, and 640 pounds (2000 X 0.32) of N in a ton of this UAN. This means that the cost per pound of N is $0.49 for urea ($450 ÷ 920), $0.90 for ammonium sul fate ($380 ÷ 420), and $0.55 for UAN ($350 ÷ 640).
- Diammonium phosphate (18-46-0) is $600 per ton. What is the cost per pound of N and per pound of P2O5?
  - A ton of 18-46-0 contains 360 pounds of N (2000 X 0.18) and 920 pounds of P_2O_5 (2000 X 0.46); therefore, the cost per pound of N is $1.67 ($600 ÷ 360), while the cost per pound of P_2O_5 is $0.65 ($600 ÷ 920). This example demonstrates that if N is the only nutrient needed, diammonium phosphate would be an expensive fertilizer choice. However, if the crop needs both P and N, then diammonium phosphate would be an excellent fertilizer choice because the P and some of the N required by the crop would be supplied by the same fertilizer. Diammonium phosphate is typically used to meet the P need rather than the N need of a crop. The N supplied by diammonium phosphate application is then deducted from the crop's N requirement.
- If UAN (32-0-0) is selling for $360 per ton, what is the cost per gallon it weighs 11.06 pounds per gallon?
  - A ton of 32-0-0 would consist of 180.8 gallons (2000 ÷ 11.06); so, one gallon of 32-0-0 would cost $1.99 ($360 ÷ 180.8). The cost per pound of N is $0.56 [$1.99 ÷ (11.06 lb/gal X 0.32)].



Lime, Liming Materials, and Regulations in Mississippi

Introduction

Soil acidity reduces crop yields. From 1989 to 2009, 56 percent of the soil samples analyzed by the MSU Extension Service Soil Testing Laboratory had pH values lower than 5.9. Historically, most Delta soils have not been acidic or needed lime, but 36 percent of the Delta samples were less than 5.9. Phosphorus and Mo are less available to plants in acidic soils. On the other hand, Al and Mn can become available to the point of plant toxicity in very acid soils. Some micronutrients, including Fe, Mn, and Zn, are less available as soil pH increases above 6. Lime decreases soil acidity. Most lime used in Mississippi, other than marl, or chalk, must be imported from other states, so liming programs can be expensive.

What is Soil pH?

Soil pH measures soil acidity, which is considered the master variable of soil fertility. It is the concentration of hydrogen ions reported on a logarithmic scale that goes from 0 to 14. The number is actually the power to which 10 is raised; therefore, pH 7 means there are 10 to the seventh power hydrogen ions in the solution. In almost all natural situations in Mississippi, soil pH is in the range of 4.0 to 8.3. Soils with a pH lower than 7 are considered acidic; a pH higher than 7 is alkaline. Aluminum also contributes to soil acidity and is more important in some soils than in others. Due to the exponential nature of pH, a soil at pH 6 is 10 times more acid than a soil pH of 7, pH 5 is 100 times more acidic than pH 7, and pH 4 is 1000 times more acidic than pH 7.

Most natural Mississippi soils become more acidic over time. Carbon dioxide reacts with water in the soil to form carbonic acid. The carbonic acid then reacts with Ca, forming calcium bicarbonate and releasing two hydrogen ions. The decomposition of organic matter and the reaction of some fertilizers also increase the hydrogen ion concentration. Cations, such as Ca and K, are lost from the soil via leaching, or the percolation of water through the soil, leaving a higher concentration of hydrogen in the surface soil.

What is Lime Requirement?

Every year, about half the soil samples processed by the Mississippi State University Extension Service Soil Testing Laboratory indicate lime is needed. Most crop plants are less productive in acid soils. Lime may be necessary to benefit crop production in the following ways:

- Preventing aluminum or manganese toxicity,
- Increasing phosphorus and molybdenum availability,
- Improving nitrogen fixation by legume crops,
- Improving the efficiency of applied phosphorus and potassium fertilizers, and
- Increasing the volume of soil explored by roots.

The need for lime is measured separately from pH and is reported as lime requirement, which is the amount of liming material required to change the soil pH to a specific value. Mississippi State University Extension Service Soil Testing Laboratory suggests the number of tons of lime needed per acre. Other laboratories may report a buffer pH value.

Lime

"Agricultural liming materials" are products containing calcium and magnesium compounds that can neutralize soil acidity. Limestone is mostly calcium carbonate or a combination of calcium carbonate and magnesium carbonate. It can neutralize soil acidity. The lime essentially floods the soil with alternative cations.

Two types of hard limestone transported from other states are available widely in Mississippi. Calcitic limestone, or calcite, is calcareous rock composed of calcium carbonate. Dolomitic limestone, or dolomite, is calcareous rock composed of both calcium and magnesium carbonates, and has at least 6 percent magnesium content. Marl, or chalk, is a softer material mined within the state. It is granular or loosely consolidated earthy material made mostly of seashell fragments and calcium carbonate.

These other lime materials may also be available:

- "burnt lime" is made from limestone that consists of calcium oxide or a combination of calcium oxide and magnesium oxide;
- "hydrated lime" is made from burnt lime and consists of calcium hydroxide, magnesium oxide, or both;
- "ground shells" are ground mollusks;
- "basic slag" is an industrial byproduct that neutralizes soil acidity; or
- "pelletized lime" is finely ground limestone coated with cementing agents.

Lime Neutralizing Value

Hard limestone is an expensive investment in Mississippi because it must be transported into the state.

Lime quality, or value, depends on three factors: purity, fineness, and moisture content. The purity factor is Calcium Carbonate Equivalent (CCE), which gives the acid neutralizing capacity of the material. The CCE is expressed as the percentage of pure calcium carbonate by weight. Calcitic and dolomitic lime sources are not very soluble. Smaller lime particles have more surface area to interact with soil and soil solution, so smaller particles are better at neutralizing soil acidity. The moisture content of liming materials affects handling and spreading ease and influences how valuable the customer considers the lime.

Vendors of liming products are subject the Mississippi Agricultural Liming Materials Act of 1993. Regulations state that marl, which is a "softer" material than calcitic or dolomitic limestones, must meet both of these specifications: it must have a CCE of 70 percent or higher, and at least 90 percent of the material must pass a 10-mesh screen.

Calcite and dolomite sold in Mississippi must meet also criteria for quality. Relative Neutralizing Value (RNV), also known as Effective Calcium Carbonate Equivalent (ECCE), uses particle size and CCE to estimate lime value. The Mississippi State Chemical Laboratory analyzes RNV of required samples. The particle size analysis determines the percentage of lime that passes 10-mesh and 50-mesh sieves. That data is combined with the CCE analysis to determine the RNV. The calculations assume that particles larger than 10-mesh do not neutralize soil acidity in a reasonable timeframe. It is also assumed that all

particles smaller than 50-mesh will dissolve to neutralize soil acidity, and half the particles in between these two sizes will react. Calculation instructions for RNV are available in MSU-ES Information Sheet 1587 Limestone Relative Neutralizing Value.

Comparing Lime Values

The RNV, or ECCE, allows you to compare value between materials from different sources. For example, suppose you find two agricultural liming materials.

- One has an RNV of 66 percent and costs $40 per ton. The other has an RNV of 85 percent and costs $55 per ton. Which is the better buy? By dividing the price per ton by the RNV decimal value, you can estimate the agronomic value of the materials.
- ($45/0.66) = $68, as compared to ($55/0.85) = $65. In this example, the material that is cheaper per ton actually ends up costing about $3 more per ton to neutralize the soil's acidity.

Adjusting Lime Recommendations

The lime recommendations from the soil-testing laboratory assume that the neutralizing value is 100 percent. The following example calculates how much material would be required to meet the 100 percent level:

- Purchased lime has an RNV of 70 percent and the recommendation is 2 tons per acre:
- (2 tons recommended) /.70 = 2.9 tons per acre of material is required to provide the recommended neutralizing value.

In reality, most spin spreader trucks used for lime application cannot be this precise, so the actual application rate is 3 tons per acre. More information about this subject is available in MSU-ES Information Sheet 1587 Limestone Relative Neutralizing Value. Other than marl, all agricultural liming materials sold in Mississippi must have a minimum RNV of 63.

Using Poultry Litter to Fertilize Agronomic Crops

Every year, Mississippi ranks among the top five states in both numbers of broiler chickens grown and quantity of meat produced. Most broilers are produced in south-central Mississippi. Individual growers contract with commercial integrators to grow chicks for a few weeks to slaughter weight. The production houses usually have smoothed soil floors covered with 4 to 6 inches of wood shavings. Wet material, or cake, is removed from the house floor after each flock is removed, usually 5 to 6 times a year. Periodically, all the material is removed in a house cleanout. The removed material is often called litter and is a mixture of bedding material, manure, feathers, and spilled feed.

Poultry litter has long been used to provide nutrients for pastures, hay, and other crops in south-central Mississippi. Today, more and more growers in other areas of the state are interested in using broiler litter to fertilize annual agronomic crops. Litter applications can both provide plant nutrients and improve soil properties, such as tilth, water holding capacity, and nutrient holding capacity. Many claim litter can be a good liming material. However, while there is significant calcium in litter, and it seems to increase pH over very long time spans, it is not a predictable liming material.

Nutrient Management Plans (NMP's) are required for all livestock operations in Mississippi that operate under General or Site-Specific Operating Permits. NMP's are recommended for others. The NMP or individual farm management may call for off-site removal of the litter. Growers interested in using broiler litter can contact suppliers through the Mississippi Farm Bureau Federation clearinghouse at http://www.msfb.net/PCH.aspx. The value of the litter is determined by the open market and factors in nutrient contents, demand, supply, transportation, storage, competition, and other details.

Nutrient Content

Litter is an excellent source of plant nutrients. It contains all the essential plant nutrients because it is derived from living organisms. The nutrient content of litter varies, particularly N, due to different bird-growing management techniques (Table 6). Because of this variability, the Best Management Practice is analyzing the actual litter to be used. The Mississippi State Chemical Laboratory or commercial laboratories can analyze litter samples. More information on this process is available in MSU Extension Information Sheet 1614, Soil and Broiler Litter Testing Basics. The Mississippi State Chemical Laboratory price sheet is at http://www.mscl.msstate.edu/pdf/prices.pdf.

Litter Transportation

Litter weighs about 31 pounds per cubic foot. It is a light material compared to inorganic fertilizers, which weigh 46 to 70 pounds per cubic foot. However, transportation costs are a factor. Some years, financial assistance is available through the Natural Resource Conservation Service under the Environmental Quality Incentive Program for transporting litter from a poultry production county to a nonpoultry county in the state.

Quarantines were placed on litter movement in 2011, both within the state and between Mississippi and Alabama, because of a disease issue. The affected region was checked weekly, and the quarantines were adjusted as needed. A litter transport permit system was initiated in Mississippi to track litter movement. If you are considering moving litter away from a production farm, check with the Mississippi Board of Animal Health for the current situation.

Litter Storage

Litter storage is an important issue because the timing of litter cleanout and the timing of field application do not always match. Many poultry growers have dry stack sheds to store litter, but farmers who purchase litter may need to store it temporarily. Litter should be covered while stockpiled outside a storage facility, and it should not get wet. Protect it from water and place a berm around any outside storage area.

Do not stack litter in fields for more than a few days. Litter loses mass while sitting in storage, which increases P concentrations. Nitrogen is lost from both covered and uncovered piles, but 50 percent more is lost in uncovered piles. Potash leaches out.

Litter Application Equipment

Specialized litter spreaders are widely available in the poultry-growing area but may be hard to find in other areas. The proper spreading equipment is necessary and should be calibrated and maintained regularly. For more information on poultry-litter spreading equipment, see Calibrating Poultry Litter Spreading Equipment.

Litter Use in Row Crops

Litter is most effective as a plant nutrient when applied close to the time that the crop will use the nutrients. Nitrogen in the litter must convert to plant-available forms, nitrate or ammonium, which will begin one to three weeks after application. Litter should be applied a few days before planting row crops. Fall applications are inefficient if there is no actively growing cool-season crop. No N from the litter will be available to a spring-planted crop. Each year, plants use only about 50 to 60 percent of N in spring-applied litter.

USDA and MAFES research in Mississippi has shown broiler litter is most effective as fertilizer for cotton when 2 tons per acre are applied a few days before planting, and then sidedressed with an additional 60 pounds of inorganic fertilizer N. This seems to suggest that cotton needs about 180 pounds N applied per acre. However, if about 120 pounds of N is added in the preplant litter application, only about half of it (60 pounds) is plant available in the course of the growing season. Another 60 pounds N should be sidedressed using inorganic fertilizers at layby; thus, the net application rate is 120 pounds of N per acre from both sources.

If litter is applied in spring, much of its P and nearly all of its K are plant-available. Any P unused by plants will be stored in the soil, but K does not carry over to subsequent crops.

Litter Use in Pasture and Hay Crops

To make the most of litter as a fertilizer, it is best to analyze the material (see above) and to base the application rates on the Extension Service recommendations for the particular crop. The application rates and management recommendations for the various forages are provided in Appendix A of this publication. Again, it is important to credit only half the N found by analysis. An example is provided below.

Litter Calculations

The laboratory analysis will report the nutrient contents as percent N, P_2O_5, K_2O, and moisture. From this report it is simple to calculate the macronutrient fertilizer equivalency of the litter on a per ton basis.

- For an analysis of 3.5 percent N, 2.1 percent P_2O_5, and 3.8 percent K_2O with 20 percent moisture content:
  - 2000 * (1-0.2) = 1600 lbs dry matter per ton of "as-is" litter.
  - 1600 * 0.035 = 56 lbs N per ton of dry litter.
  - 1600 * 0.021 = 34 lbs P_2O_5 per ton of dry litter.
  - 1600 * 0.038 = 61 lbs K_2O per ton of dry litter.

While it adds error, the fertilizer content can be approximated on an "as-is" basis if the moisture content is not readily available:

- "As-is" nutrient calculations (no adjustment for moisture) for an analysis of 3.5 percent N, 2.1 percent P_2O_5, and 3.8 percent K_2O:
  - 2000 * 0.035 = 70 lbs N per ton of litter "as-is."
  - 2000 * 0.021 = 42 lbs P_2O_5 per ton of litter "as-is."
  - 2000 * 0.038 = 76 lbs K_2O per ton of litter "as-is."

If you know the fertilizer content of the litter and use calibrated spreading equipment, you can calculate litter application rates. It is important to remember that only about 50 percent of the N in the litter will be available to growing plants during the season of application. (Note that current MS Natural Resource Conservation Service planning standards assume 60 percent N availability.)

- The target N for Bermudagrass pasture is 75 pounds in each of two applications, one in the early spring and one in midsummer. The litter in the previous example contains 56 pounds of N per adjusted ton. The actual target application rate is 300 pounds of N in two equal applications because N is only about 50 percent available.
  - (150 lbs N/ac/application) / (56 lbs N/ton) = 2.7 tons per application.
- Using the "as-is" value for N content:
  - (150 lbs N/ac/application) / (70 lbs N/ton) = 2.1 tons per application.

Other Livestock Manure

This chapter has focused on the use of poultry litter as a crop nutrient. Other livestock in Mississippi are operated under General Operating Permits or other regulations of MDEQ. However, the confined poultry production industry is more widespread than the other farm types, which often use the manure near the originating location. Information on using those manures is available from the local offices of the MSU Extension Service and the Natural Resource Conservation Service.

Table 6.

Effect of integrator on moisture content and nutrient content of fresh Mississippi broiler litter (Chamblee and Todd).

Effect of integrator on moisture content and nutrient content of fresh Mississippi broiler litter.

Integrator	Moisture	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
	%	lb/ton	lb/ton	lb/ton
1	21a	57b	32a	55b
2	21a	50c	29a	56b
3	20a	64a	30a	64a
4	19a	67a	32a	64a
5	18a	43d	21b	51b
6	20a	57b	28a	63a

Best Management Practices for Nutrients in Agronomic Crop Production

The soils, environment, and crop systems used in Mississippi offer unique challenges for fertilizer management. Management plans should both protect our water resources and produce agronomic crops economically. Best Management Practices (BMPs) are research-proven, achievable management options. BMPs are site-specific, depending on current and past soil management, climate, crops grown, and operator expertise.

Recent concerns about plant nutrients in the landscape have increased interest in economically sound, environmentally sustainable fertilizer management. The fertilizer industry focuses on four R's for fertilizer management: right fertilizer source, right rate, right time, and right place.

Fertilizer management has three primary goals:

1) Match fertilizer nutrients to crop nutrient requirements,
2) Manage fertilizer applications wisely, and
3) Minimize the transport of nutrients from fields to water bodies.

There are five basic questions that each nutrient manager addresses in planning for the next crop:

- Are the fertilizers necessary?
- How much fertilizer is economical?
- What fertilizers are available?
- When is the best time to apply the fertilizer?
- How can I maximize effectiveness?

The BMPs offered below address these questions. Check with local offices of the Mississippi State University Extension Service, the Natural Resource Conservation Service, or Delta F.A.R.M. for additional information.

1. Match Nutrients Supplied by Fertilizers to Crop Nutrient Requirements

- ***Soil testing***

Fields should be tested for pH, P, K, and other nutrients at least every three years and preferably more often. Information for first-time soil testers is available in Chapter 4, at local Extension offices, and at http://msucares.com/pubs/infosheets/is0346.pdf.

- ***Analyze animal byproducts***

Poultry production is the only consistent source of animal byproducts available in bulk in Mississippi to provide crop nutrients. Nutrient contents vary due to different bird and litter management programs. Application rates should be based on analysis of the actual litter used. The Mississippi State Chemical Laboratory or commercial laboratories can complete this analysis. Information on sampling litter for nutrient analysis is available at http://msucares.com/pubs/infosheets/is1614.pdf.

- ***Nutrient budgeting***

Soil testing, manure analysis, nutrient uptake, and nutrient removal data accounts for all nutrient sources and outflows. This information makes it possible to calculate application rates, particularly if animal manures are to be used, and allows "what-if" analysis of different rate application scenarios.

- ***Develop and use realistic yield goals***

The Mississippi State University Extension Service bases fertilizer recommendations or N on yield goals for agronomic crops. Including yield goals makes the recommendations site-specific; soil texture differences are included in the rate calculations for cotton. Some cooler, drier states no longer use yield goals when recommending N, but yield goals are important in Mississippi, where the humid climate makes predicting levels of residual N more difficult.

It is important to use realistic yield goals when you calculate application rates. Average the crop yields from the past 3 to 5 years. Add 10 percent for a realistic projection of the production potential of your soils, management, and climate. If past yields are not available, contact the local offices mentioned above for information on the specific capabilities of different soil series.

- ***Plant nutrient analysis***

Chemical analysis of plant nutrient concentrations in tissue, along with soil testing, may evaluate the soil fertility program and nutrient availability. It is most valuable when "good" and "bad" sections of a growing field can be contrasted. Information on plant diagnostic sampling is available at http://msucares.com/pubs/publications/p1224.pdf.

2. Manage fertilizer applications wisely

- ***Soil test based recommendations***

Each soil test phosphate and potash result is rated with a category or index. MSU uses five: very low, low, medium, high, and very high. The category compares the amount measured in the soil to the amount needed by the plants. A score of very high means plants probably will not respond to additional fertilizer; a score of very low means plants probably will respond to the addition of the nutrient.

If the soil is rated high or very high, P or K fertilizers are not needed for most Mississippi crops (Appendices A and B). Medium means there may or may not be a response; for soil in this category, MSU recommends maintenance levels of P and K. Soils in the very low or low categories should respond to fertilizer; therefore, the decision depends on the relative risks of fertilizing versus not fertilizing. If the soil tests medium, low, or very low, the MSU Extension Service will make P and K application rate recommendations based on soil fertility maintenance for the next scheduled crop. If the soil tests very low, the MSU ES recommendations also include a small amount of fertilizer for buildup. Other soil testing laboratories in Mississippi may provide different recommendations from the public laboratory.

When the soil tests high, the only agronomic crop that the MSU ES recommends K for is cotton. Research has found K stress in midseason for newer varieties.

- ***Using the right fertilizer for the situation***

Usually, when different fertilizer sources of the same nutrient appear to work differently, it's because the inherent differences between the fertilizer materials are not taken into consideration. Plants cannot tell the difference between sources of a particular nutrient. Nutrient ions, such as nitrate or phosphate, are all the same when they are in the soil solution, no matter what their source. N fertilizer efficiency especially depends on the product and how it is managed.

Mississippi State University Extension Service recommendations for N fertilizer management are not based on soil tests. The state is warm and humid, so N soil testing techniques have had limited usefulness. Nitrogen recommendations are based on the crop to be grown and, whenever possible, realistic yield goals.

Some N fertilizers are volatile; that is, they change from urea or urea-ammonium nitrate into ammonia gas, which drifts away from the field. This loss increases when these fertilizers are applied at temperatures higher than 65 °F, on fields with a large amount of organic matter or surface residues, or in high humidity.

Much more information on commercial fertilizer properties and management issues is available in the Mississippi State University Extension Service Publication Inorganic Fertilizers for Crop Production.

- ***Proper placement of fertilizers***

Correct fertilizer placement is crucial to efficiency. Avoid broadcast sprays of UAN solutions on hot, dry days unless the material will be cultivated in, irrigated in, or rain is imminent. Incorporating animal manure fertilizers helps prevent their movement in the landscape. Avoid applying fertilizer materials too near to surface water bodies.

- ***Proper application timing***

The timing of fertilizer applications is important because the nutrients' availability to the plants decrease over time. Nitrogen is especially efficient when it is applied close to the time of crop up take. Applying N too early increases the probability it will leave the field, and supplemental N fertilizer may be necessary later in the growing season. Fall application of N is not practical in Mississippi for crops seeded in the spring, whether the fertilizer is organic or inorganic. Recent Mississippi research has confirmed that the N in poultry litter is much less efficient for row crops when the litter is applied in the fall.

Inorganic P fertilizers may be applied in the fall before a spring-seeded crop, as phosphorus is not mobile in the soil. However, P fixation in soils is common, so P is not very efficient no matter when it is applied.

In contrast to P fertilizers, K fertilizer effectiveness is not affected by soil fixation except in some high clay content soils. Inorganic potash fertilizers for spring crops may be field applied in the fall if the soil Cation Exchange Capacity (CEC) is 8 or higher; it may be lost via leaching at lower CEC values.

- ***Equipment maintenance and calibration***

Equipment maintenance and calibration are key to efficient nutrient applications. Know the correct application width for the equipment and the material being applied; avoid overlaps within the field and onto field borders. Ensure that belts and chains are properly maintained and adjusted. The Mississippi Department of Agriculture and Commerce Bureau of Plant Industry can teach you more about calibrating commercial spreaders, including aerial equipment.

- ***Precision technology***

Precision technologies may allow more efficient fertilizer management of nutrient deficient, acidic, or more responsive soil areas. However, these tools, which can include management software, special equipment, consultants, soil maps, and training, may be very expensive.

3. Minimize the potential transport of nutrients from fields to water bodies

- ***Conservation tillage***

Some nutrients, such as P ions, are closely bound to soil particles, so soil management that minimizes erosion also minimizes movement of those nutrients. These management practices include strip-tillage, mulch tillage, no-tillage, or ridge-tillage. More information about conservation tillage is available through local Extension Service or Natural Resource Conservation Service offices.

- ***Proper storage of animal by-products***

Proper storage of poultry litter is important. Many poultry growers have dry stack sheds to store litter, but farmers acquiring litter may need to store it temporarily. Recent research by Auburn University found that litter should be covered with plastic or other materials to protect its nutrient content. See Chapter 7 for more information.

- ***Control water flow on and off fields***

Controlling water flow with surface and subsurface drainage management reduces nutrient, pathogen, and pesticide runoff into downstream waters. Proper water control also reduces wind erosion and dust and may provide seasonal wildlife habitat. More information about conservation tillage and other water control devices, such as weirs, is available through local Extension Service or Natural Resource Conservation Service offices.

- ***Maintain buffers***

Planted buffers between nutrient applications and nearby water bodies reduce sheet and rill erosion and lower the rate of sediment delivery. Planted buffers may use nutrients that move from planted areas and would otherwise enter surface waters. As with other BMP's, contact local agency offices or groups such as Delta F.A.R.M. for more detailed information on buffer installation and cost-share programs.

- ***Use cover crops as nutrient scavenger and erosion control***

Cover crops and crop residue reduce erosion. Cover crops also reduce N movement in the landscape by "scavenging" N left in the soil by the previous crop. Using the residual N increases cover crop dry matter production, which improves soil quality, including organic matter levels and tilth.

- ***Use environmental risk assessment procedures where appropriate***

There is an imbalance between the P content of poultry litters and the P requirements of growing plants. Repeated applications of litter can lead to buildup of P in the soil to extremely high levels. This buildup increases the likelihood that P will move into water bodies. Too much P in surface waters, also called eutrophication, can harm water quality and aquatic life.

A risk assessment procedure called the Phosphorus Index (PI) uses factors including soil test phosphorus levels, soil permeability, field slopes, litter application rates, and distance to surface water to determine the probability of nutrient movement in the landscape. Based on this evaluation, further organic or inorganic P applications may be limited or eliminated in the fields deemed to be high risk. As of 2011, Nutrient Management Planning using the PI in Mississippi has been limited to poultry production farms and non-poultry farms that may utilize litter as specified by a particular poultry farm.

Appendix A

Mississippi State University Extension Service Soil Testing-Based Recommendations for Hay and Pasture Crops

Alfalfa					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3c.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	60	120	60	180
Low	Low	120	120	Year 2: 100 Year 3: 60	180
Very Low	Very Low	180	180	Year 2: 100 Year 3: 90	180
Potassium, boron, and magnesium note:		Apply 3 lbs boron/acre annually. Loss of stand may occur due to K deficiency. Apply additional 40 lbs K_2O/acre for each ton of hay harvested. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Bermudagrass, dallisgrass, or bahiagrass pastures, with annual legumes such as white clover, red clover, lespedeza, arrowleaf clover, ball clover, or subterranean clover.					
Soil Test P Rating	Soil Test K Rating	Establishment Year of Grass Component		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	60	120
Nitrogen, magnesium, and additional potassium note:		Where the legume provides less than 1/3 ground cover, apply 60 lbs N/acre each time the forage is grazed down or cut for hay. Loss of stand is sometimes due to K deficiency. If pasture is regularly cut for hay, apply additional 40 lbs K_2O/acre for each ton of hay harvested. For reseeding clover or clover seed harvest, apply 1-1.5 lbs boron/acre. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Hybrid Bermudagrass hay.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3c.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	50	50	50	150
Low	Low	50	100	63	200
Very Low	Very Low	100	100	Year 2: 100 Year 3: 63	200
Nitrogen, potassium, and magnesium note:		If stand has been established for hay, apply recommended maintenance N, P, and K fertilizer(s) before growth starts (Year 2 recommendation in the first year). Apply an additional 60-80 lbs N/acre after each successive cutting until the last one. In the establishment year, apply any recommended P and K fertilizer(s), and 60-100 lbs N/acre before sprigging. Apply an additional 50 lbs N/acre before Aug. 1 if additional growth is desired. Loss of stand may be due to K deficiency. Apply additional 40 lbs K_2O/acre for each ton of hay harvested. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Bahiagrass, Bermudagrass, and Dallisgrass perennial summer pastures.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3a.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	25	25	25	25
Low	Low	50	50	50	50
Very Low	Very Low	100	100	50	50
Nitrogen and magnesium note:		Apply all P and K fertilizer(s), if recommended, and 60-80 lbs N/acre before growth starts. Repeat N application by mid-July if more growth is desired. Loss of stand may occur due to K deficiency. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Perennial winter grass pasture, fescue and orchardgrass (orchardgrass only in northern Mississippi).					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3a.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	25	25	25	25
Low	Low	50	50	50	50
Very Low	Very Low	100	100	50	50
Nitrogen, magnesium, and additional potassium note::		For perennial winter grass pasture (fescue and orchard grass), 50 lbs N/acre and all P and K fertilizer(s) should be applied by 9/1. Apply the remainder of the N in 2 applications: one in Feb. and one in early to mid-April. If pasture is regularly cut for hay, apply additional 40 lbs K_2O/acre for each ton of hay harvested. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Temporary summer grass pasture: millet, sorghum, sudangrass, sorghum-sudangrass hybrids, and johnsongrass.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	60	Year 2: 120 Year 3: 60
Nitrogen and magnesium note:		Apply recommended P and K fertilizer(s) and 60 lbs N/acre preplant. Apply an additional 60-80 lbs N/acre after forage is grazed or cut down If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Small grain winter pasture.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3a.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	80	Year 2: 120 Year 3: 90
Nitrogen and magnesium note:		Apply recommended P and K fertilizer(s) with 60-80 lbs N/acre at seeding. Apply another 60-80 lbs N/acre between mid-Jan. and mid-Feb. In south Mississippi, increased forage yield and more uniform distribution may be realized by 3 applications of N: 60-80 lbs/acre at planting, 60 lbs December 1, and 60 lbs February 15. Do not graze until crops are 8-12 inches high. Do not graze closer than 2-3 inches. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Forage legumes.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	60	Year 2: 120 Year 3: 60
Boron and magnesium note:		For reseeding clover or clover seed harvest, apply 1-1.5 lbs boron/acre. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Annual legumes with ryegrass.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment, retest soil after Year 3)	
Use Table 2.	Use Table 3a.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	60	Year 2: 90 Year 3: 60
Nitrogen and magnesium note:		Apply any recommended P and K fertilizer(s) before seeding. Where the legume provides less than 1/3 ground cover, apply 60 lbs N/acre each in late winter or very early spring. Do not graze until grass is about 8-12 inches tall. Do not graze closer than 2-3 inches. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Fescue or orchardgrass pasture with white clover, red clover, or subterranean clover.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	120	120	60	Year 2: 120 Year 3: 60
Nitrogen, boron, and magnesium note:		If legume covers less than 1/3 of the ground, apply 60 lbs N/acre in early fall; repeat if needed in early spring. For reseeding clover or clover seed harvest, apply 1-1.5 lbs boron/acre. Orchardgrass is recommended only for north Mississippi. When both soil test P_2O_5 and K_2O levels are M, an application of 60 lbs P_2O_5 and 60 lbs K_2O on alternate years is acceptable.			

Bermudgrass, dallisgrass, or bahiagrass pasture with crimson clover, annual lespedeza, arrowleaf clover, ball clover, or subterranean clover.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	30	30	30	30
Low	Low	60	60	60	60
Very Low	Very Low	90	90	Year 2: 90 Year 3: 60	Year 2: 90 Year 3: 60
Nitrogen, potassium, boron, and magnesium note:		Where the legume provides less than 1/3 ground cover, apply 60 lbs N/acre each time the forage is grazed down or cut for hay. Loss of stand is sometimes due to K deficiency. If pasture is regularly cut for hay, apply additional 40 lbs K_2O/acre for each ton of hay harvested. For reseeding clover or clover seed harvest, apply 1-1.5 lbs boron/acre. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Johnsongrass hay.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	50	50	50	150
Low	Low	50	100	63	200
Very Low	Very Low	100	100	Year 2: 100 Year 3: 63	200
Nitrogen, potassium, and magnesium note:		For established stands of johnsongrass, apply any recommended N, P, and K fertilizer(s) before growth begins. Apply 80 lbs N/acre after each successive cutting. The recommended N rate assumes an established stand. For the establishment year, use 60 lbs N/acre instead. Loss of stand may be due to K deficiency. Apply additional 40 lbs K_2O/acre for each ton of hay harvested. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Johnsongrass hay.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	50	50	50	150
Low	Low	50	100	63	200
Very Low	Very Low	100	100	Year 2: 100 Year 3: 63	200
Nitrogen, potassium, and magnesium note:		For established stands of johnsongrass, apply any recommended N, P, and K fertilizer(s) before growth begins. Apply 80 lbs N/acre after each successive cutting. The recommended N rate assumes an established stand. For the establishment year, use 60 lbs N/acre instead. Loss of stand may be due to K deficiency. Apply additional 40 lbs K_2O/acre for each ton of hay harvested. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Lespedeza hay annual.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	35	70	35	70
Low	Low	70	70	70	70
Very Low	Very Low	105	105	70	105
Boron and magnesium note:		For annual lespedeza hay, apply any recommended P and K fertilizer(s) plus 1-1.5 lbs boron/acre in early spring. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Lespedeza hay annual.					
Soil Test P Rating	Soil Test K Rating	Establishment Year		Maintenance (annual after establishment; retest soil after Year 3)	
Use Table 2.	Use Table 3b.	Recommended fertilizer rate, pounds per acre			
		P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0
High	High	0	0	0	0
Medium	Medium	35	70	35	70
Low	Low	70	70	70	70
Very Low	Very Low	105	105	70	105
Boron and magnesium note:		For annual lespedeza hay, apply any recommended P and K fertilizer(s) plus 1-1.5 lbs boron/acre in early spring. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).			

Appendix B

Mississippi State University Extension Service Soil Testing-Based Recommendations for Annual Agronomic Crops

Cotton							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3c.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	40	0	0	0	0
Medium	Medium	40	60	40	40	40	40
Low	Low	80	90	80	80	40	80
Very Low	Very Low	120	120	80	80	80	80
Cotton Inorganic Nutrient Management Notes		Use 50-60 lbs N per bale of yield goal per acre on light-textured soils; 60-70 lbs N per bale yield goal on medium-textured soils; and 70-80 lbs N per bale yield goal on clay soils. The yield goal **must** be realistic: additional N will not increase yields unless N deficiency is limiting yields. Increase potash rates by 50% from the above if there is a realistic probability of producing more than two bales per acre. Add 40 lbs of potash per acre with high soil test K levels to maintain the existing high soil tests. In non-Delta areas, use 1/3-½ lb boron per acre annually. In Delta areas, boron may boost yields on non-irrigated soils in dry weather, particularly if the soil has been recently limed.					

Corn and Sorghum for Grain, dryland							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3b.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	35	35	35	35	35	35
Low	Low	70	70	70	70	70	70
Very Low	Very Low	105	105	70	70	70	70
Corn and Sorghum for Grain Inorganic Nutrient Management Notes		Nitrogen rates for corn in Mississippi are 1.3 lbs of N per bushel of realistic yield goal (e.g., for 150 bushels of corn per acre, apply 195 lbs of actual N per acre). Nitrogen rates for sorghum for grain in Mississippi are 1.1-1.15 lbs of N per bushel of realistic yield goal. Apply all phosphate and potash fertilizers, and one third to one half of the N preplant on corn or sorghum for grain. Apply the rest of the N about a month later. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).					

Corn, irrigated							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3c.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	$_2$O K
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	80	60	80	60	80	60
Low	Low	90	90	90	90	90	90
Very Low	Very Low	90	134	90	134	90	90
Corn Inorganic Nutrient Management Notes		Nitrogen rates for corn in Mississippi are 1.3 lbs of N per bushel of realistic yield goal (e.g., apply 260 lbs of actual N per acre for a 200 bushel yield goal). Apply all phosphate and potash fertilizers and one third to one half of the N preplant. Apply the rest of the N as sidedressing approximately one month later or when the corn is 16-18 inches high. If a winter cover crop such as clover or vetch is grown, lower the recommended N rate by 30-60 lbs per acre depending on the condition of the cover crop. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4). If you use crop rotation, base fertilization on the crop with the highest nutrient demand in the rotation. This may require additional soil sampling or a maintenance application even nothing is recommended for the current crop. Corn or sorghum grown in fields following rice production or winter flooding often experiences serious phosphorus deficiency due to a conversion of soluble ferrous P to insoluble ferric P in flooded soils. The P is unavailable for plant uptake for several months after flood removal.					

Corn and sorghum for Silage							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3c.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	$_2$O K	P_2O_5	$_2$O K
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	60	120	60	120	60	120
Low	Low	80	120	80	120	80	120
Very Low	Very Low	120	120	80	120	80	120
Corn and Sorghum for Silage Inorganic Nutrient Management Notes		Nitrogen rates for corn in Mississippi are 1.3 lbs of N per bushel of realistic yield goal. Apply all phosphate and potash fertilizers and one third to one half of the N preplant. Sidedress the rest of the N about a month later. If a winter cover crop such as clover or vetch is grown, lower the recommended N rate by 30-60 lbs per acre depending on the condition of the cover crop. If soil test Mg is L or M, use 10-20 lbs Mg/acre of a Mg source (see Table 4).					

Soybeans							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3b.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	30	60	30	60	30	60
Low	Low	60	60	60	60	60	60
Very Low	Very Low	120	120	120	120	120	120
Soybeans Inorganic Nutrient Management Notes		Soybeans: Apply ½-1 ounce of sodium molybdate or equivalent annually per bushel of seed if the soil pH < 7.0.					

Soybeans in Small Grain Rotation							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3b.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	80	80	80	80	80	80
Low	Low	80	80	80	80	80	80
Very Low	Very Low	120	120	120	120	80	120
Soybeans in Small Grain Rotation Inorganic Nutrient Management Notes		These recommendations are for small grain/soybean rotation. The phosphate and potash rates are sufficient for both crops and should be applied in the fall. Where wheat follows soybeans, no preplant N is necessary; otherwise apply 20-30 lbs of N at preplant. In Feb., apply 80-100 lbs of N. Increase these N rates 20-30% on clay soils.					

Peanuts, vines, nuts removed							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3a.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	Not applicable		Not applicable	
High	High	0	0				
Medium	Medium	60	120				
Low	Low	12	120				
Very Low	Very Low	120	120				
Inorganic Nutrient Management Notes		For Spanish peanuts, include 20 lbs N per acre with P and K fertilizer(s). Apply 0.3-0.5 lb of boron per acre in the fertilizer or disease control spray. Second and third year recommendations are not given because peanuts should not be planted after peanuts because of disease issues. Peanuts should be rotated with non-leguminous crops, such as corn or grain sorghum, to aid disease control. Fertilizing the previous crop is better than fertilizing peanuts directly. For the best production, keep soil test levels at or near the high range. If lime is recommended, it will increase the calcium level of the soil to an acceptable level for peanuts. If lime is not recommended, apply 250 lbs of gypsum per acre at bloom.					

Rice							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3a.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	30	30	30	30	30	30
Low	Low	40	40	40	40	30	30
Very Low	Very Low	80	80	80	80	60	60
Rice Inorganic Nutrient Management Notes		Generally no lime is recommended for rice production regardless of the soil pH. If rice is grown in rotation with soybeans and lime is recommended, use 1 ton for soybeans. Zinc fertilizer may be recommended based on the soil test. Nitrogen fertilizer rates are based on the variety grown; see Rice Production Handbook. Apply half to 2/3 of the actual N immediately before permanent flood. Apply the rest at midseason. On leveled soils cut more than 12 inches, an additional 40 lbs of phosphate may be beneficial the first year after the cut was made even if the soil test indicates an adequate amount.					

Sunflowers, for grain							
Soil Test P Rating	Soil Test K Rating	Recommended fertilizer rate, pounds per acre					
Use Table 2.	Use Table 3b.	Year 1		Year 2		Year 3	
		P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
Very High	Very High	0	0	0	0	0	0
High	High	0	0	0	0	0	0
Medium	Medium	30	30	30	30	30	30
Low	Low	60	60	60	60	60	60
Very Low	Very Low	90	90	60	90	60	90
Sunflowers for Grain Inorganic Nutrient Management Notes		Apply all phosphate and potash fertilizers, and one half of the N preplant. Apply the remaining N about 1 month later.					

Appendix C

Glossary•
Adopted from the International Certified Crop Adviser Performance Objectives

•Note that not all terms in the glossary are included in previous text; however, they may be encountered in other literature concerning the management of plant nutrients in the landscape.

Acidic soil: A soil that has a pH value less than 7.0.

Aerobic: A condition identified by the presence of oxygen.

Aggregate, soil: A mass of fine soil particles held together by clay, organic matter, or microbial gums. Aggregates are part of soil structure.

Agronomic nutrient rate: Amount of nutrients required by a crop for an expected yield after all the soil, water, plant, and air credits are considered. Agronomic rates consider nutrient credits from all soil tests, legumes, manure residuals, and other nutrient credits supplied from any other source.

Alkaline soil: A soil that has a pH value greater than 7.0.

Alluvium: A general term for all eroded material deposited by running water, including gravel, sand, silt, and clay.

Alum: A potassium aluminum sulfate or ammonium aluminum sulfate

Ammonia (NH_3): See anhydrous ammonia

Ammonium (NH_4^+): A form of nitrogen that is available to plants from fertilizer and organic matter decomposition.

Ammonium nitrate solution: Non-pressure solution of ammonium nitrate in water; usually standardized to 20 percent nitrogen. Used for direct application or for making multinutrient liquid fertilizer. Analysis is 20-0-0.

Ammonium phosphate: A group of phosphorus fertilizer manufactured by the reaction of anhydrous ammonia with superphosphoric acid to produce either solid or liquid fertilizer.

Ammonium sulfate: Fertilizer material with an analysis of 21-0-0. It also contains 24 percent sulfur. Anaerobic: A condition identified by the absence of oxygen.

Anhydrous ammonia (NH_3): Fertilizer in pressurized gas form, made by compressing air and natural gas under high temperature and pressure in the presence of a catalyst. Value is 82-0-0.

Animal unit: 1000 pounds of live animal weight; a term used to determine volumes of animal manure produced.

Anion: An ion with a negative charge.

Application rate: The weight or volume of a fertilizer, soil amendment, or pesticide applied per unit area.

Aqua ammonia: 20 percent anhydrous ammonia dissolved in water.

Aquifer: Layers of underground porous or fractured rock, gravel, or sand through which considerable quantities of groundwater can flow and which can supply water at a reasonable rate. May be classified as perched, confined, or unconfined.

Available nutrient: A nutrient in a form that a plant can absorb.

Available water: Portion of water in soil that can be readily absorbed by plant roots.

Banded nutrients: Fertilizer nutrients placed in a strip near the seed at planting, or surface or subsurface applications of solids or fluids in strips before or after planting.

Base saturation percentage: The proportion of the soil's cation exchange capacity occupied by basic cations.

Biological oxygen demand (BOD): The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water; used as a measure of water pollution.

Biomass: Plant and plant-derived material, including manure. Includes forestry products; woodprocessing wastes; wastes associated with food-processing operations; energy crops, such as switchgrass and poplar trees; and agricultural crop residues, such as corn stover and wheat straw.

Biosolid: Any organic material, such as livestock manure, compost, sewage sludge, or yard wastes, applied to the soil to add nutrients or for soil improvement.

Blocky: Soil structure classification in which aggregates are in the shape of blocks or polyhedrons.
Buffer pH: A soil test procedure whereby the pH of the soil is measured in buffer solution. This measurement is used in estimating the lime requirement of the soil.

Buffer strip: Areas or strips of land maintained in vegetation and strategically located on the landscape to help control runoff, erosion, and entrap contaminants.

Buffering: The ability of a solution, such as the soil solution or irrigation water, to resist changes in pH when acid or alkaline substances are added. Often used when to describe a soil's resistance to pH changes when limed or acidified.

Buildup and maintenance: Nutrients applied to build up a target nutrient level and then maintained by annual addition of the quantity of nutrients expected to be removed in the harvested portion of the crop.

Bulk density: The mass of oven-dry soil per unit volume, usually expressed as grams per cubic centimeter.

Calcitic lime: Limestone consisting of $CaCO_3$-based material with very low magnesium content.

Calcium carbonate equivalent (CCE): The liming potential of a material as compared to $CaCO_3$.

Capillary action: Movement of water in the soil through small soil pores.

Cation exchange capacity: The amount of exchangeable cations that a soil can adsorb at a specific pH, expressed as centimoles of charge per kilogram (cmolc/kg) of soil or milliequivalents per 100 g of soil (meq/100 g soil).

Cation exchange sites: Negative charged sites on the surfaces of clays and organic matter.

Cation: An ion that has a positive electrical charge. Common soil cations are calcium, magnesium, hydrogen, sodium, and potassium.

Chelated molecule: A large, water-soluble organic molecule that binds with a free metal ion to form a water-soluble compound. This process increases the amount of metal ion or atom dissolved in the water and the availability of that ion to plants.

Clay: 1) The class of smallest soil particles, smaller than 0.002 millimeter in diameter. 2) The textural class with more than 40% clay and less than 45% sand, and less than 40% silt.

Colloid: A very tiny particle capable of being suspended in water without settling out. Soil colloids have a charged surface that attracts ions.

Compaction (soil): Increasing the soil bulk density, thereby decreasing the soil porosity, by the application of mechanical forces to the soil.

Composite soil sample: A soil sample resulting from mixing together many individual samples.

Conservation tillage: A general term for tillage practices that leave crop residues on the soil surface to reduce erosion.

Contaminant: Any physical, chemical, biological, or radiological substance that is above background concentration but does not necessarily cause harm.

Contour tillage: Tillage that follows the contours of a slope, rather than running up and down a slope. Helps prevent erosion and runoff.

Contour: An imaginary line perpendicular to the slope that represents the same elevation.

Critical value: The point between sufficiency and deficiency levels for a nutrient.

Crop nutrient requirement: The amount of nutrients needed to grow a specified yield of a crop plant per unit area.

Crop removal rate: The amount of nutrients that are removed from the field in the plant harvest, including harvested fruit, grain, forage, and crop residues that are removed from the field.

Crop rotation: A planned sequence of crops growing in a regularly recurring succession on the same field.

Crop sequence: The order of crops planted and harvested in a field over a period of time.

Crop utilization rate: The total amount of nutrients required by the crop to produce both vegetation and grain, including nutrients used to produce roots, stems, crowns, and other unharvested plant parts as well as the harvested portion that is removed from the field.

Crust: A thin layer of poorly aggregated surface soil formed by wetting and drying.

Deep tillage: Tillage deeper than that needed to produce loose soil for a seedbed, usually used to loosen compacted subsoil.

Denitrification: The transformation of nitrates or nitrites to nitrogen or nitrogen oxide gas, occurring under anaerobic conditions.

Diammonium phosphate (DAP): Fertilizer containing both nitrogen and phosphorus with an analysis of 18-46-0.

Diffusion: The movement of particles from an area of higher concentration to an area of lower concentration.

Discharge: Flow of surface water in a stream or the flow of ground water from a pipe, spring, ditch, or flowing artesian well.

Dolomitic lime: A naturally occurring liming material composed chiefly of carbonates of magnesium and calcium.

Drainage: Rate and amount of water removal from soil by surface or sub-surface flow.

Ecosystem: Community of animals and plants and the physical environment in which they live.
Effluent: Discharge or emission of a liquid or gas.

Elemental sulfur: Sulfur in the elemental form that must be oxidized by soil microbes to the sulfate form for plant uptake.

Environmentally sensitive area: Places on the landscape that are easily degraded by human or natural activity.

Erosion: The wearing away of the land surface by running water, wind, ice, geological agents or mechanical actions, such as tillage or land leveling.

Essential plant nutrients: Inorganic elements required for growth and development of plants.

Eutrophication: A natural process of enrichment of aquatic systems by nutrients, primarily nitrogen (N) and phosphorus (P). Accelerated, or cultural, eutrophication is caused by the addition of excess nutrients to a system. This results in excessive vegetative growth. Decomposition of this plant material can result in the depletion of oxygen in water, leading to the death of aquatic organisms.

Evapotranspiration (ET): Loss of water to the atmosphere from the earth's surface by evaporation and by transpiration through plants.

Fertilizer: Organic or inorganic material added to a soil to supply one or more nutrients essential to plant growth.

Fertilizer analysis: The composition of a fertilizer, expressed as a percent of total nutrients; for example, total N, available phosphoric acid (P_2O_5), and water-soluble potash (K_2O).

Fertilizer suspension: A fluid fertilizer containing dissolved and undissolved plant nutrients. The undissolved nutrients are kept in suspension, usually by swelling-type clays.

Field capacity: The amount of water a soil holds after free water has drained because of gravity.

Flood plain: Land near a stream that is commonly flooded when the water levels are high. Soil is built from sediments deposited during flooding.

Foliar fertilization: Application of a dilute solution of fertilizer to plant foliage, usually made to supplement soil-applied nutrients.

Friable: The ease by which a moist soil can be crumbled.

Granular: Soil structure where the units are approximately spherical or polyhedral.

Gravitational water: Water that moves through the soil because of gravity.

Green manure: Plant material incorporated into the soil while green or at maturity, for soil improvement.

Groundwater: Water in the saturated zone below the soil surface.

Guaranteed analysis: Minimal percentages of available nutrients as stated on a fertilizer label.

Gully: A large channel in the soil, caused by erosion that is deep and wide enough that it cannot be crossed by tillage equipment.

Gypsum: Calcium sulfate ($CaSO_4 \bullet 2H_2O$) used to supply calcium and sulfur and to improve sodic soils.

Hardpan: A dense, hard, or compacted layer in soil that slows water percolation and movement of air and obstructs root growth. Pans may be caused by compaction, clay, or chemical cementation.

Highly erodible land: A soil-mapping unit with an erodibility index of 8 or more.

Horizon (soil): A horizontal layer of soil, created by soil-forming processes, that differs in physical or chemical properties from adjacent layers.

Humus: Highly decomposed organic matter that is dark-colored and highly colloidal.

Hydrologic cycle: Movement of water in and on the earth and atmosphere through processes such as precipitation, evaporation, runoff, and infiltration.

Hygroscopic water: Water held tightly by adhesion to soil particles. Cannot be used by plants and remains in soil after air-drying. Can be driven off by heating.

Immobile nutrient: A plant nutrient that moves slowly in the soil or plant.

Immobilization: The conversion of an element from the inorganic to the organic form in microbial tissues, resulting in that element not being readily available to other organisms or plants.

Impermeable layer: Soil layers, either natural or man-made, that resist penetration by fluids or roots.

Infiltration: Entry of water from precipitation, irrigation, or runoff into the soil profile.

Injection: Placing something below the surface of soil by mechanical means.

Inorganic nitrogen: Mineral forms of nitrogen.

Inorganic phosphorus: A salt of phosphoric acid or any of its anions, usually orthophosphate or polyphosphate.

Irrigation: Application of water to supplement natural rainfall.

Landscape position: Using topography, slope characteristics, or both to separate a field into different zones that have similar soil characteristics and crop productivity.

Lateral flow: Movement of water horizontally below the soil surface, usually along an impervious layer.

Leaching: The movement of material in solution along with movement of water through the soil.

Lime fineness: The particle size of limestone determined by the fineness of grinding. The finer the grind, the better the material neutralizes acidity.

Lime material: A material capable of neutralizing soil acidity.

Lime purity: The measure of impurities in a given liming material; used to estimate its neutralizing value.

Liming requirement: The amount of liming material required to change the soil pH to a specific value.

Loading: Amount of a substance entering the environment (soil, water, or air).

Luxury consumption: The absorption by plants of an essential nutrient in excess of their need for growth. Luxury concentrations in early growth may be used in later growth.

Macronutrient: A nutrient that a plant needs in relatively large amounts. Essential macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S).

Mapping unit (soil): Basis for setting boundaries in a soil map. May include one or more soil series.

Mass flow: The movement of solutes associated with net movement of water.

Massive soil: A structureless soil.

Micronutrient: Nutrients that plants need in only small or trace amounts. Boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) are considered micronutrients.

Mineral soil: A soil whose traits are determined mainly by its mineral content; mineral soils contain less than 20 or 30 percent organic matter in the US and Canada, respectively.

Mineralization: The conversion of an element by soil organisms from an organic form to an inorganic form.

Minimum tillage: Tillage methods that involve fewer tillage operations than clean tillage does.

Mobile nutrient: A nutrient that moves readily in the soil or plant.

Monoammonium phosphate (MAP): A fertilizer composed of ammonium phosphates, resulting from the ammoniation of phosphoric acid; typically 11 percent N with an analysis of 11-52-0.

Mulch: Natural or artificial layer of plant residue or other material that conserves soil moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Mulch till: A full-width tillage and planting combination that leaves some plant residues or other material on the soil surface.

N-based nutrient application: The rate of application of a nitrogen containing material so the desired amount of nitrogen is applied, regardless of the amounts of other nutrients being applied in the material.

Nitrate (NO_3^-): An inorganic nitrogen form that is very soluble, easily leached from soils, and readily available to plants.

Nitrification inhibitor: A chemical inhibitor that slows the conversion of ammonium to nitrate in the soil, reducing the risk of nitrogen loss from the field.

Nitrification: The microbial process of converting ammonium to nitrite to nitrate.

Nitrite (NO_2^-): A form of nitrogen that is the result of the first step in nitrification in soil as microbes convert NH_4 to NO_2. It is subsequently oxidized to nitrate (NO_3) by microbes.

Nitrogen: An essential plant nutrient that is part of many compounds, including chlorophyll, enzymes, amino acids, and nucleic acids.

Non-point source (NPS) contamination: Water contamination derived from diffuse sources such as construction sites, agricultural fields, and urban runoff.

No-till/Direct seeding/Zero-till: Method of growing crops that involves no seedbed preparation prior to planting.

Nutrient buildup: An increase in soil analysis levels of a nutrient due to application of that nutrient at levels that exceed crop removal.

Nutrient drawdown: A decrease in soil analysis levels of a nutrient due to crop removal.

Nutrient management plan (NMP): A written plan that specifies the utilization of fertilizer, animal manures, and other biosolids.

Organic matter: The organic fraction of the soil exclusive of undecayed plant and animal residues.

Organic nitrogen: Nitrogen that is bound with organic carbon and forms organic molecules.

Organic phosphorus: Phosphorus that is bound with organic carbon and forms organic molecules.

Organic soil: Soil containing more than 20 or 30 percent organic matter in the US and Canada, respectively.

Orthophosphate: Inorganic form of plant available phosphorus.

P index: An environmental risk assessment tool for assessing the potential for phosphorus movement from agricultural lands. It is usually based on an estimation of potential soil erosion, the phosphorus soil test level, and phosphorus management practices, such as rate of application, source of phosphorus, and timing and method of application.

P_2O_5: Phosphorus pentoxide; designation on the fertilizer label that denotes the percentage of available phosphorus expressed as P_2O_5.

P-based nutrient application: The rate of application of a phosphorus-containing material so that the desired amount of phosphorus is applied, based on balancing the agronomic rate or crop removal rate of the crop with the amount of phosphorus contained in a material. This amount is regardless of the amounts of other nutrients being applied in the material.

Ped: A natural soil aggregate, such as a granule or prism.

Percolation: Downward movement of water through soil or rock.

Permanent wilting point: The soil water content at which most plants cannot obtain sufficient water to prevent permanent tissue damage.

Permeability: Capacity of soil, sediment, or porous rock to transmit water and gases.

pH: Numerical measure of hydrogen ion concentration, with a scale of 0 to 14. Neutral is pH 7, values below 7 are acidic, and values above 7 are alkaline.

Phosphorus: Essential nutrient for plants and animals. Component of cell walls, nucleic acids, and energy transfer molecules.

Plant available nitrogen (PAN): A calculated quantity of nitrogen made available during the growing season after application of fertilizer. PAN includes a percentage of the organic nitrogen, a percentage of the ammonium N, and all the nitrate nitrogen in the fertilizer.

Plant residues: Plant material that remains in the field after harvest.

Platy: A soil structure consisting of soil aggregates that are developed predominantly along the horizontal axis; laminated; flaky.

Point source contamination: Water contamination from specific sources, such as leaking underground storage tanks, landfills, industrial waste discharge points, or chemical mixing sites.

Potash (K_2O): Term used to refer to potassium or potassium fertilizers.

Potassium: An essential plant nutrient involved in energy metabolism, starch synthesis, and sugar degradation.

Preferential flow: The rapid movement of water and its constituents through the soil via large and continuous pores.

Prismatic (columnar): Soil structure where the individual units are bounded by flat or slightly rounded vertical faces. Units are distinctly longer vertically, and the faces are typically casts or molds of adjoining units. Vertices are angular or sub-rounded; the tops of the prisms are somewhat indistinct and normally flat.

Recharge area: Land area over which surface water infiltrates into soil and percolates downward to replenish an aquifer.

Recharge: Downward movement of water through soil to groundwater.

Recommended rate: Amount of nutrients recommended on a soil test report or plant tissue analysis for a specific crop that meets but does not exceed the crop nutrient requirements. Recommended rates can also include nutrients used for soil test buildup.

Remote sensing: The collection and analysis of data from a distance, using sensors that respond to different heat intensities or light wavelengths.

Restrictive layer: A nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restricts roots or otherwise provide an unfavorable root environment.

Rhizobia: Bacteria capable of living symbiotically with higher plants by receiving food and carbon and providing nitrogen to the plant.

Rill: A channel in the soil caused by runoff water erosion that is small enough to be erased by tillage.

Riparian zone: Land adjacent to a body of water that is at least periodically influenced by flooding.

Root interception: Method by which ions in the soil are intercepted by root growth.

Runoff: Portion of precipitation, snowmelt, or irrigation, which moves by surface flow from an area.
Saline soil: A non-sodic soil containing enough soluble salt to adversely affect the growth of most crops.

Salinity: An index of concentration of dissolved salts in the soil.

Secondary nutrients: Those macronutrients (calcium, magnesium, and sulfur) used less often as fertilizers than the primary elements.

Sediment: Eroded soil and rock material and plant debris transported and deposited by wind or water.

Sheet and rill erosion: A water erosion process caused by raindrop impact on the soil surface and a thin layer of water (sheet) moving over the soil surface.

Sidedress: To apply a fertilizer, pesticide, or soil amendment to one side of a growing plant, either by surface application or injection.

Single grain: A structureless soil in which each particle exists separately, as in sand.

Sodic soil: Soil high in sodium and low in soluble salts.

Soil analysis: A chemical, physical, or biological procedure that estimates the plant availability of nutrients and soil quality characteristics to support plant growth.

Soil drainage: The process where water is moved by gravity, either by surface channels or internal pores in the soil profile.

Soil organic matter: The organic fraction of the soil exclusive of undecayed plant and animal residues. Often used synonymously with “humus.”

Soil pH: The degree of acidity or alkalinity of a soil, expressed on a scale from 0 to 14, with 7.0 indicating neutrality, increasing values indicate increasing alkalinity, while decreasing values indicate increasing acidity.

Soil productivity: A measure of the soil's ability to produce a particular crop or sequence of crops under a specific management system.

Soil reaction: A quantitative term that describes how acidic or alkaline the soil is.

Soil sampling: Process of obtaining a representation of an area of the soil or field by collecting a portion of the soil.

Soil solution: The aqueous liquid phase of the soil and its solutes contained in soil pores.

Soil structure: The combination or arrangement of primary soil particles into secondary soil particle units, or peds.

Soil survey: The examination, description, and mapping of soils of an area according to the soil classification system.

Soil test interpretation: Using soil analysis data to manage soil fertility and monitor environmental conditions.

Soil test level: The nutrient status of the soil, as indicated by analysis of a soil sample.

Soil test recommendation: The suggested amount of nutrients or soil amendment to be added to the soil to achieve expected crop yields.

Soil texture: The relative proportions of sand, silt, and clay in the soil.

Solubility: Amount of a substance that will dissolve in a given amount of another substance, typically water.

Solute: A substance that is dissolved in another substance, thus forming a solution.

Starter fertilizer: A fertilizer applied in relatively small amounts with or near the seed at planting.

Subsurface band: To apply nutrients, pesticides, or soil amendments in narrow bands below the surface of the soil.

Sufficiency level: a) For interpretation of plant analysis: A nutrient concentration in the plant tissue above which the crop is amply supplied, and below which the crop is deficient. b) For interpretation of soil analysis: A soil test level above which economic responses to applied fertilizers are unlikely to occur.

Surface band: To apply nutrients, pesticides, or soil amendments in narrow bands over the surface of the soil.

Surface broadcast: To apply nutrients, pesticides, or soil amendments uniformly over the surface of the soil.

Surface creep: Movement of sand-sized particles/aggregates by wind, in which the particles roll along the soil surface. Surface creep may account for 7 to 25 percent of total transport by wind.

Symbiotic N fixation: Conversion of molecular nitrogen (N_2) to ammonia and subsequently to organic nitrogen forms by organisms.

Tillage erosion: The downslope displacement of soil through the action of tillage operations.

Tillage pan: Also known as a plow pan; a subsurface layer of soil that has a higher bulk density than the layer either above or below it. The compaction is caused by tillage operations.

Tilth: Physical condition of the soil in terms of how easily it can be tilled, how good a seedbed can be made, and how easily seedling shoots and roots can penetrate.

Topdress: To surface broadcast nutrients, pesticides, or soil amendments on the soil surface after crop emergence.

Total nitrogen: The sum of the organic and inorganic forms of nitrogen in a sample.

Toxicity level: A quantity of a material in plants, soil, or water that can harm or impair the physiological function of plants or soil.

Triple superphosphate: A product that has a guaranteed analysis between 40 and 50 percent available phosphoric acid. The most common analysis is 0-46-0.

Uptake antagonism: When the excess of one nutrient interferes with the uptake of another nutrient. Usually the nutrients in question have a similar uptake mechanism by the plant.

Urea ammonium nitrate solution (UAN): A non-pressure nitrogen fertilizer solution containing urea and ammonium nitrate in approximately equal proportions dissolved in water. The nitrogen content of the fertilizer solution ranges from 28 percent to 32 percent.

Urea: A nitrogen fertilizer that is a white crystalline solid, is very soluble in water, and has an analysis of 46-0-0.

Volatilization: The loss of a compound in gaseous form from a solid or liquid phase.

Watershed: All land and water that drains runoff to a stream or other surface water body.

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