MISSISSIPPI STATE UNIVERSITY
EXTENSION

Inorganic Fertilizers for Crop Production

Most nutrients needed by plants are supplied solely by soil. Insufficient supply of any of these nutrients may limit plant growth. In natural conditions, nutrients are recycled from plants to soil to meet plant needs. However, agricultural crops may require more nutrients than natural vegetation.

Significant amounts of nutrients are also removed in harvested crops. Optimal crop growth and profitability may require fertilization with inorganic fertilizers, animal manures, green manures, or legume management. This publication concentrates on commonly used inorganic fertilizers important in improving plant growth.

When managing fertilizers, stick to the four Rs: the **right amount** of the **right fertilizer** at the **right place** at the **right time**.

The four Rs begin with soil testing. Soil tests assess the current nutrient status of the soil and indicate whether these levels are sufficient for crop production. If adequate amounts of nutrients are present in the soil, the **right amount** to apply is none.

If the laboratory results show response to added fertilizers is likely, there will be a rate recommendation. This is the **right amount**. The **right time** and **right place** depend on site-specific agronomic factors accounting for crop biology and growth stage, and current environmental conditions. Follow the best management practice appropriate for your situation.

Conventions, Conversions, and Definitions

Fertilizer is labeled as nitrogen (N), phosphate (P_2O_5), and potash (K_2O), respectively N-P-K, which are the oxide forms for elemental phosphorus (P) and potassium (K). In some cases, nutrients may be expressed either way. These are the simple conversions between the oxide and elemental forms:

Phosphorus

$P \times 2.3 = P_2O_5$ $\quad$ $P_2O_5 \times 0.44 = P$

Potassium

$K \times 1.2 = K_2O$ $\quad$ $K_2O \times 0.83 = K$

Fertilizer recommendations by the Mississippi State University Extension Service Soil Testing Laboratory are listed as pounds of either phosphate or potash per acre.

Fertilizer grade or analysis is the weight percent of available nitrogen, phosphate, and potash in the material, expressed in the order N-P-K. For example, 10-20-10 indicates the material is 10 percent nitrogen, 20 percent phosphate and 10 percent potash by weight.

Fertilizer ratio is the ratio of the weight percents of nitrogen-phosphate-potash and is calculated by dividing the three numbers by the smallest of the three. Again using 10-20-10 fertilizer as an example, the ratio is 10/10-20/10-10/10 = 1-2-1.

If soil test-based recommendations call for certain amounts of plant food, calculate the total fertilizer needed based on the grade of product.

A given weight of two fertilizers with different analyses (grades) has different amounts of actual plant food. One hundred pounds of a 10-30-10 fertilizer contains 10 pounds of nitrogen, 30 pounds of phosphate, and 10 pounds of potash. One hundred pounds of a 7-21-7 fertilizer has 7 pounds of nitrogen, 21 pounds of phosphate, and 7 pounds of potash. These fertilizers have the same nutrient ratio (1-3-1) but are different grades (10-30-10 versus 7-21-7), so different total amounts of fertilizer will have equal amounts of plant food. Application rates will be higher on a lower grade of product than a higher grade to supply the same amount of plant food.

Straight materials are the basic materials used in fertilizer manufacture. Many can be applied directly such as anhydrous ammonia, urea, urea-ammonium nitrate solutions, triple superphosphate, ammonium phosphates, and muriate of potash (potassium chloride).

Compound fertilizers are chemical or physical mixtures of the straight materials.

Considerations in Using Fertilizers

If the soil test-based recommendations include supplemental fertilizer, several factors must be considered to select the **right source**. These include physical and chemical properties, environmental stewardship, and economics.

Fertilizer Formulations

Many different physical and chemical forms of commercial fertilizer are available (see Table 1). Forms include solids, liquids, and gases. Each form has its own uses and limitations to consider when selecting the best material for the job.

Granulated fertilizer materials are solid, homogenous mixtures of fertilizer 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-sized fertilizer particle contains the nutrients listed in the grade; each particle in a 10-20-10 granulated fertilizer contains 10 percent nitrogen, 20 percent phosphate, and 10 percent potash. The chief advantage of granulated materials is this uniform nutrient distribution. They are not separated in handling or spreading, and the applied nutrients are potentially available to plant roots. Granulated fertilizers are usually very simple to handle, with 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, or granulated compound fertilizer materials mixed together, or a combination of the two.

In blended fertilizers, the individual particles remain separate in the mixture, and the nutrients also may physically separate. This can be less problematic if materials are the same size. Properly made blends are generally as effective as other compound fertilizers. Blends have the advantage of allowing a very wide range of fertilizer grades to be mixed. This allows fertilizers to meet a soil test recommendation.

Blends are often used as starter fertilizers, but urea and diammonium phosphate should not be used as starter fertilizers placed close to seeds because both materials produce free ammonia, which hinders seed germination and seedling growth.

Fluid fertilizers are used widely in Mississippi. These may be either straight materials, such as nitrogen solutions, or compound fertilizers of various grades. The major advantage is ease of handling. 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.

Fluid fertilizers are either clear solutions or suspensions. In clear solutions, nutrients are completely dissolved in water. Phosphorus in these materials is highly water soluble. Clear solutions are equal in agronomic effectiveness to other types of fertilizers, when equal amounts of plant food are compared.

Suspension fertilizers are fluids in which solubility of the components has been exceeded; clay is added to keep the very fine, undissolved fertilizer particles from settling out. The advantages are that 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 with clear solutions, the agronomic effectiveness of suspensions is equal to other types of fertilizer materials when equal nutrient levels are applied.

Table 1. Common inorganic fertilizers used for agronomic crop production in Mississippi. Not including granulated fertilizers (such as 13-13-13 or 7-21-7).

	N	P_2O_5	K_2O	Form
Ammonium nitrate	33.5–34	0	0	Solid
Ammonium polyphosphate – a	10	34	0	Liquid
Ammonium polyphosphate – b	11	37	0	Liquid
Ammonium sulfate	21	0	0	Solid
Ammonium thiosulfate	12	0	0	Liquid
Anhydrous ammonia	82	0	0	Gas
Aqua ammonia	20	0	0	Liquid
Calcium nitrate	16	0	0	Solid
Diammonium phosphate	18	46	0	Solid
Monoammonium phosphate	11	48–55	0	Solid
Muriate of potash (potassium chloride)	0	0	60–62	Solid
Ordinary superphosphate	0	20	0	Solid
Potassium nitrate	13	0	44	Solid
Potassium sulfate	0	0	50	Solid
Potassium-magnesium sulfate	0	0	20	Solid
Sodium nitrate	16	0	0	Solid
Triple superphosphate	0	46	0	Solid
Urea	45–46	0	0	Solid
Urea-ammonium nitrate	28–32	0	0	Liquid

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. More detailed information on fluid fertilizers is available in MSU Extension Publication 1466 Fluid Fertilizers (http://extension.msstate.edu/publications/fluid-fertilizers).

Gaseous fertilizer requires special considerations for handling and use. Anhydrous ammonia is high-analysis nitrogen gaseous fertilizer used directly in crop production. It is also the precursor material for manufacturing most common nitrogen-containing fertilizers.

Once in the soil, anhydrous ammonia behaves similarly to any other ammonium-based source, but because anhydrous ammonia is stored as a compressed liquid, special handling methods and safety precautions are required. Anhydrous ammonia expands immediately into a gas when released. Thus, it must be injected into the soil to prevent the gas from escaping. Anhydrous ammonia can cause serious chemical burns and asphyxiation if it escapes, so follow safety precautions.

Fertilizer Properties

The specific chemical properties of fertilizers are complex and varied; this publication provides only an introduction. The fertilizer properties to consider are solubility, particle size, soil pH, chemical form, and soluble salts.

Solubility indicates how readily nutrients are dissolved in the soil water and taken up by plants. Since nitrogen and potassium in fertilizers are essentially completely soluble in water, their solubility is not an issue for common fertilizer sources.

Phosphorus must be dissolved in water to be taken up by plants. The water solubility of available phosphorus can vary from 0 to 100 percent. Generally, the higher the water solubility, the more effective the phosphorus source is for short-season, fast-growing crops, starter fertilizer, crops with restricted root systems, and situations where less than optimal rates of phosphorus are applied to low-fertility soils. Water solubility of the available phosphorus is less important in other applications. Thus, phosphorus soluble in neutral ammonium citrate (which includes water-soluble phosphorus) is counted as available phosphorus on the fertilizer label.

Fortunately, most common phosphorus sources (triple superphosphate and the ammonium phosphates) contain highly water-soluble forms of phosphorus. There is no apparent difference in agronomic effectiveness whether a highly water-soluble phosphorus source is applied as a fluid fertilizer or as a dry fertilizer. Note, however, that raw rock phosphate has very low water solubility, so it is very slow to react.

The particle size of fertilizers is important for both agronomic and handling reasons. In the field, particle size is most important for sparingly soluble materials such as rock phosphate. These must be very finely ground to promote solubility by increasing the surface area that reacts with water. For most soluble fertilizers, particle size is important in determining ease of handling the materials. Very fine materials, which become dusty and cake up, are difficult to handle; granular materials do not have these problems and are easier to handle. While there is no official standard particle size, many fertilizers pass through a No. 6 (coarse) screen but not a No. 18 (finer) screen. Particle size is an important consideration for materials in blended products. Differently sized materials segregate as the fertilizer is handled and spread. The most important factor in stable, high-quality blended fertilizers is compatible particle sizes.

Soil pH can be changed by fertilizers. The most important reaction is the microbial oxidation of ammonium nitrogen to nitrate nitrogen. This occurs regardless of the source of ammonium nitrogen (fertilizer, manure, or organic residues). There is a short-lived soil pH reduction in the vicinity of anhydrous ammonia injection slits.

The acidity of a fertilizer is usually given as the amount of pure limestone that would be required to offset the acidity produced by the reaction of the fertilizer. Equivalent acidities can be used to compare materials, but the actual amount of limestone required to neutralize the acidity from the fertilizer is probably greater than shown in Table 2.

Table 2. Equivalent acidity of some fertilizer materials.

Material	Equivalent acidity (lb $CaCO_3$ per lb of N)
Anhydrous ammonia	1.8
Urea	1.8
Ammonium nitrate	1.8
Manure	1.8
Diammonium phosphate (DAP)	3.5
Ammonium sulphate	5.3
Monoammonium phosphate (MAP)	5.3

Another temporary pH change occurs with the superphosphate materials. The initial reaction lowers the pH around the fertilizer particle, but the residual effect of the superphosphates is very little change in soil pH. The common potassium materials are neutral salts that have little effect on the soil pH.

Chemical forms of the nutrient in the fertilizer are critical for agronomic crops only in specific situations. There is generally little practical difference, for example, between an ammonium and a nitrate nitrogen source in bulk situations. However, if leaching or denitrification are potential issues, then the ammonium form is preferred as it attaches to the soil cation exchange sites. Nitrate will stay in soil solution longer.

A consideration between orthophosphates and polyphosphates is whether insoluble micronutrients are added to a liquid fertilizer. In this situation, polyphosphates are preferred. Potassium sulfate should be considered if the crop (e.g., tobacco) is sensitive to soil chloride.

High concentrations of soluble salts in soil solution injure or kill plants or prevent seed germination. Normally, fertilizers that are uniformly distributed at recommended rates do not cause soluble salt levels high enough to damage plants. Concentrated applications of fertilizer or manure in contact with, or in a band near, plants can damage a germinating seed or growing plant. A salt index is used to estimate potential injury from different fertilizers. It is a relative scale to compare fertilizers for special placement, such as drilling with the seed, banding at high rates, or doing pop-up treatments. Table 3 shows the salt index for several common fertilizer materials.

Table 3. Salt indices of various fertilizers, assuming equal weights of the nutrient.

Material	Salt index
Nitrogen (N)	
Ammonium sulfate	54
Ammonium nitrate	49
Urea	27
Anhydrous ammonia	10

Material	Salt index
Phosphate (P_2O_5)	
Triple superphosphate	4
Monoammonium phosphate (MAP)	7
Diammonium phosphate (DAP)	8
Potash (K2O)	
Potassium chloride	32
Potassium sulfate	14

Environmental Responsibility

Nutrient management using the four Rs (the **right amount** of the **right fertilizer** at the **right time** in the **right place**) should minimize detrimental environmental effects while maximizing agronomic and economic benefits. Proper nutrient management planning evaluates all potential nutrient sources, soil test levels, crop management needs, and environmental risk factors.

Implementing the four Rs includes these best management practices:

- Regular soil tests. The Mississippi State University Extension Service recommends soil testing at least every 3 years. Sample at the same time of year for year-to-year comparisons.
- Use realistic yield goals to determine nitrogen application rates if they are part of the recommendations.
- Select the most suitable nitrogen fertilizer for the crop, application method, and climatic conditions.
- Use the proper application technique for the situation.
- Maintain and calibrate application equipment.
- Avoid application to surface waters.
- Time nutrient applications appropriately for the most agronomic benefit and minimal environmental impact.
- Control soil erosion because many nutrients move when soil particles move.
- Properly control water flow. Slow water down when appropriate with conservation practices, or speed water movement when appropriate.
- Use cover crops.
- Maintain residue on the soil surface.

More information on best management practice selection and implementation is available at your local MSU Extension office, local offices of the Natural Resources Conservation Service, and the MSU REACH program (https://www.reach.msstate.edu/index.php). More resources are listed at the end of this publication.

Economics

Fertilizer is a significant investment of money and time. Fertilizers work best when provided to growing plants when they need them using appropriate technology and careful decisions. The final decision about which fertilizer to use should be based on economics. Compare materials on the price per pound of actual plant food. Use this formula:

(Price per ton of fertilizer) / (2000 × plant food content as decimal value) = per pound of plant food

For example: Urea costs $385 per ton. Each ton of urea is 45 percent nitrogen, so each ton contains 900 pounds of nitrogen (2000 × 0.45). Dividing $385 by 900 shows the cost is $0.43 per pound of nitrogen in the fertilizer.

The maximum return per dollar invested in fertilizer is achieved from the first increment of needed nutrients applied to a deficient soil or crop. The maximum profit depends on site-specific factors such as weather or pest challenges. Using unnecessary amounts of fertilizer as insurance drains profitability.

Additional Resources

More information on managing nutrients with either inorganic or organic sources, soil testing, nutrient management planning, best management practices, and landscape environmental stewardship is available online at http://extension.msstate.edu/publications.

Look for these publications:

- Information Sheet 767 Nitrogen in Mississippi Soils
- Information Sheet 871 Phosphorus in Mississippi Soils
- Information Sheet 894 Potassium in Mississippi Soils
- Information Sheet 1620 Useful Nutrient Management Planning Data
- Publication 1466 Fluid Fertilizers
- Publication 2647 Nutrient Management Guidelines for Agronomic Crops Grown in Mississippi
- Publication 3050 Natural Resource Conservation in Agriculture
- Publication 3681 Best Management Practices for Plant Nutrient Management
- Publication 3726 Micronutrients in Mississippi Soil and Plant Nutrition
- Publication 3727 Calcium and Magnesium in Mississippi Crop Production
- Publication 3749 Soil and Broiler Litter Testing Basics
- Publication 3858 Soil Testing for the Farmer

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