Comparing fertilizer materials

Agronomy Facts 6, Penn State Cooperative Extension

Nutrients are often a limiting factor for plant growth. Under natural conditions, an equilibrium is established that depends on recycling of nutrients to meet plant needs. This equilibrium is disturbed when agricultural crops are grown. Soils must provide greater amounts of plant nutrients than would be needed for natural vegetation. Also, a significant portion of the nutrients are no longer recycled but are removed in the harvested crops. Farmers must supply supplemental nutrients to the soils to ensure optimal crop growth. These supplemental nutrients come in many forms including fertilizers, animals' manures, green manures, and legumes. This fact sheet concentrates on the properties of commonly used fertilizers that are important in achieving optimal plant growth.

Soil testing should be the basis for any fertilizer application. A good soil testing program indicates the current fertility status of the soil and provides sound guidelines for managing fertility to achieve optimal yields. Good records of soil test results and fertilizer, lime, and manure applications are also very important to proper fertility management.

Important conventions, conversions, and definitions

Nutrients are expressed on fertilizer labels as nitrogen (N), phosphate (P2O5), and potash (K2O). This is called the oxide form for elemental phosphorus (P), and potassium (K). In some cases, nutrients may be expressed in either form. Following are simple conversions between the oxide and elemental forms:

Phosphorus	Potassium
P × 2.3 = P2O5	K × 1.2 = K2O
P2O5 × .44 = P	K2O × .83 = K

Fertilizer grade or analysis is the weight percent of available nitrogen (N), phosphate (P2O5), and potash (K2O) in the fertilizer, usually expressed as N-P2O5-K2O. For example, 10-20-10 indicates 10 percent N, 20 percent P2O5, and 10 percent K2O by weight.

Fertilizer ratio is the ratio of weight percents of N-P2O5-K2O and is determined by dividing the three numbers by the smallest of the three.

Again using 10-20-10 as an example, the ratio is 10/10-20/10-10/10 = 1-2-1.

A given weight of two fertilizers can contain different amounts of actual plant food. After soil tests indicate the need for a certain amount of plant food, you must determine the total amount of fertilizer needed, based on the grade of product. For example, 100 pounds of a 10-30-10 fertilizer contains 10 pounds of N, 30 pounds of P2O5, and 10 pounds of K2O, whereas 100 pounds of a 7-21-7 fertilizer contains 7 pounds of N, 21 pounds of P2O5, and 7 pounds of K2O. Both of these fertilizers have the same ratio (1-3-1) but different grades (10-30-10 versus 7-21-7). Different total amounts of fertilizer are required to provide equal amounts of plant food. Application rates must be determined on the basis of the plant food needed.

Straight materials are the basic materials used in fertilizer manufacture. Many of these materials can be applied directly. Examples include anhydrous ammonia, urea, nitrogen solution, triple superphosphate, ammonium phosphates, and muriate of potash (potassium chloride).

Compound fertilizers are made by chemically or physically combining the straight materials.

Once soil test results have established the need for fertilizer, several important factors should be considered in selecting the proper fertilizer material. These factors are physical and chemical properties, economics, and dealer service.

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Fertilizer properties

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 provide the basis for selecting the best material for the job.

Granulated fertilizer materials are solid, homogenous mixtures of fertilizer materials generally produced in ammoniation granulation plants 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 theoretically contains 10 percent nitrogen, 20 percent phosphate, and 10 percent potash. The principle advantage of granulated materials is this uniform distribution of nutrients. There is no segregation of the nutrients in handling or spreading, and plant roots absorb a complete set of the applied nutrients. Granulated fertilizers generally have good handling properties, with little tendency to cake or dust.

Blended fertilizers are simple physical 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. This problem can be reduced by using materials that are the same size. 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 have been used effectively as starter fertilizers; however for this purpose, urea and diammonium phosphate should be avoided because both materials produce free ammonia, which can hinder seed germination and seedling growth.

Fluid fertilizers are becoming more commonly used. 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.

In Clear solutions, the nutrients are completely dissolved in water. The major advantage is ease of 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. Clear solutions are equal in agronomic effectiveness to other types of fertilizers; then equal amounts of plant food are compared.

Suspension fertilizers are fluids in which solubility of the components has been exceeded and clay has been added to keep the very fine, undissolved, fertilizer particles from settling out. The major advantage is that they can be handled as a fluid. Another advantage of suspensions is that they can be formulated at much higher analyses than clear solutions. Analyses as high as those of dry materials are possible. The major disadvantages ae that suspensions require constant agitation, even in storage, and suspension fertilizer cannot be used as a carrier for certain chemicals, for example Paraquat. As in the case of clear solutions, the agronomic effectiveness of suspensions is equal to other types of fertilizer materials when equal amounts of plant food are compared.

When making calculations on fluid fertilizers, remember that the grade or analysis is given on a weight percent basis, not on a per gallon basis. Thus to determine the actual plant food content, 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 total fertilizer. For comparing fluids on price 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:

2000 ÷ 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.

Gaseous fertilizer requires some special considerations in handling and use. Anhydrous ammonia is a high nitrogen content gaseous material used both in the manufacture of all other common nitrogen-containing fertilizers and in direct applications to the soil. Once applied, anhydrous ammonia behaves similarly to any other ammonium nitrogen source. However, special handling methods and safety precautions are required because anhydrous ammonia is stored as a compressed liquid. When expansion occurs during application to the soil, it immediately becomes a gas. Thus, it must be injected into the soil to prevent the gas from escaping.

The Cold-flo™ System developed at Penn State is an alternative to injecting the ammonia in a gaseous form. In this system, gaseous ammonia is converted to a cold (-28° F) liquid with a low vapor pressure. The liquid can then be injected or incorporated with conventional tillage equipment.

Some hazards are involved in handling anhydrous ammonia. Since the material can cause serious chemical burns and asphyxiation, proper safety precautions are necessary. Anhydrous ammonia is an excellent nitrogen fertilizer, but it must be handled properly.

Organic materials that are commonly used as fertilizers have many varied properties. Therefore, the physical properties of these materials should be evaluated on an individual basis.

Since the specific chemical properties of fertilizers also are very complex and varied, a detailed discussion of all their chemical properties is not possible here. But several important chemical properties should be considered in selecting a fertilizer material. These properties 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. The fertilizer law in Pennsylvania specifies certain solubility criteria that must be met by a fertilizer nutrient in order for that nutrient to be included on the fertilizer label. Since the nitrogen and potassium in fertilizers are essentially completely soluble in water, their solubility is not a major consideration for the common fertilizer sources. Only phosphorus that is soluble in neutral ammonium citrate (this includes the water soluble phosphorus) is counted as available phosphorus on the fertilizer label.

Phosphorus must be dissolved in water to be taken up by plants. However, the water solubility of the 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, for crops with restricted root-systems, for starter fertilizers, and for 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. 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 when a highly water soluble phosphorus source is applied as a fluid fertilizer or as a dry fertilizer. 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. Agronomically, particle size is most important for the 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 in determining ease of handling of the materials. Very fine materials, which often become dusty and can cake, are difficult to handle; granular materials are sized to avoid these problems and to promote handling convenience. While there is no standard for particle size, most fertilizers are sized to pass through a No. 6 screen but be retained on a No. 18 screen. Particle size is most critical for materials that are used in blended products. Materials of different sizes tend to segregate as the fertilizer is handled and spread. Particle size has been identified as the most important factor is producing a stable, high quality, blended fertilizer.

Soil pH can be changed by the reaction of fertilizer materials. The most important such 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). The acidity of a fertilizer is usually given by convention as the amount of pure limestone that would be required to offset the acidity produced by the reaction of the fertilizer.

Material	Equivalent acidity (lb. CaCO3 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

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 here. Remember the residual effect of the materials. Many of these materials greatly, but temporarily, increase the soil pH. Another example of this temporary pH change is the reaction of the superphosphate materials. The initial reaction is a drastic lowering of the pH around the fertilizer particle, but the residual effect of the superphosphates changes the soil pH very little. The common potassium materials are neutral salts that have no effect on the soil pH.

Chemical forms of the nutrient itself are critical for agronomic crops only in special situations. There is generally little practical difference for example between an ammonium and a nitrate nitrogen source (if leaching or denitrification are serious potential problems, then the ammonium form is preferred) or between orthophosphates and polyphosphates (unless insoluble micronutrients ae added to a liquid fertilizer, in which case the polyphosphates are preferred) or between potassium chloride and potassium sulfate (some crops such as tobacco are sensitive to chloride, in which case the sulfate is preferred).

Soluble salts, at high concentrations in soil solution, can cause injury or death to plants or prevent germination of seeds. Under normal conditions, fertilizers uniformly distributed at recommended rates do not cause soluble salt levels that are high enough to damage plants. However, a concentrated application of fertilizer or manure placed in contact with the seed or in a band near the germinating seed or growing plant can cause damage. An estimate of potential salt injury from different fertilizers is given as the salt index for that material. The salt index is a relative scale useful for comparing materials for special placement (such as for drilling with the seed, banding at high rates, and for pop-up treatments) when a low salt index is preferred. The salt index for several common fertilizer materials is give here:

Material	Salt index*
Nitrogen (N)	
Ammonium sulfate	54
Ammonium nitrate	49
Urea	27
Anhydrous ammonia	10
Phosphate (P2O5)	
Triple superphosphate	4
Monoammonium phosphate (MAP)	7
Diammonium phosphate (DAP)	8
Potash (K2O)	
Potassium chloride	32
Potassium sulfate	14

*The salt index assumes equal weights of the primary nutrient are being compared.

Economics

When conditions are appropriate for a given fertilizer material, the final decision about which fertilizer to use should be based on economics. Compare materials on the basis of a price per unit of actual plant food. Remember that the maximum return per dollar invested in fertilizer is achieved from the first increment applied to a deficient soil or crop. However the maximum profit is achieved at a rate of fertilization that produces near maximum yield. At this economic optimum, the value of any yield increase produced by higher fertilizer rates just covers the cost of the additional fertilizer.

Dealer service

Most fertilizer dealers handle high quality products, often at similar prices. The quality of dealer service (reliability, timeliness, agronomic knowledge, other services offered) is a major consideration in choosing a fertilizer.

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