

CORN NATIONAL CORN HANDBOOK

CROP FERTILIZATION

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Phosphorus Sources for Corn Fertilization

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Phosphorus is an essential nutrient for corn production in the United States. TVA-NFDC figures show that, in 1989, over 4.1 million tons of fertilizer P_2O_5 were applied to crops.

This publication examines the common phosphorus fertilizer materials, including how produced, analysis ranges, nutrient P availability, advantages and drawbacks, conditions for best use, etc. At the end of the publication, Figure 1 diagrams the pathways and materials used in producing the various P fertilizers, while Table 1 provides a summary conclusion of their characteristics.

DEFINING AND MEASURING AVAILABLE PHOSPHORUS IN FERTILIZERS

Before looking at specific P fertilizer sources, there is perhaps need to clear up some confusion over terminologies associated with phosphate materials and how P availability is defined and measured. The terms "analysis," "available phosphorus," and "water-soluble phosphorus" are often used but not always understood. The term that expresses the amount of available P in fertilizers—i.e. " P_2O_5 equivalent"—further confuses the issue.

The P_2O_5 nomenclature was derived from a method used to conveniently express chemical analytical results of materials such as fertilizers. Actually, phosphorus is not present as P_2O_5 in fertilizers, but " P_2O_5 equivalent" is still used today because of tradition and the fact that most state fertilizer regulatory laws require the amount of phosphorus in a fertilizer be labeled as "percent P_2O_5 ."

The amount of available P (expressed as P_2O_5) is an estimate of plant-available P in a fertilizer and is the same as the analysis of the material. Available P is actually composed of water-soluble P and citrate-

soluble P. Water-soluble P is the fraction of the available P that will dissolve in water, while citrate-soluble P is the fraction of available P not soluble in water but soluble in a neutral ammonium citrate solution. For example, 100 pounds of a material with analysis of 18-46-0 contains 46 pounds (46 percent) P_2O_5 which is available. Of this 46 pounds, 95 percent may be soluble in water and 5 percent water insoluble but soluble in ammonium citrate.

The important thing to remember is that all fertilizer materials must be labeled with the amount of available P_2O_5 present in the product. Most P fertilizers sold in the U.S. contain nearly all of the available P_2O_5 as water-soluble P_2O_5 .

PHOSPHORUS FERTILIZER MATERIALS

Phosphate Rock

Essentially all of the commonly available P fertilizers are made from phosphate rock. In the past, unprocessed phosphate rock was applied directly as a fertilizer material. Today, however, very little is used as a direct-application source of P. Studies over the years have shown that the P available to growing plants from phosphate rock is quite low; thus, phosphate rock must be processed to increase the P availability.

Finely ground phosphate rock and colloidal phosphate rock are somewhat effective on acid soils, but only if applied at very high rates. Because of the low P availability, relatively low (30-33 percent) P_2O_5 content, and problems associated with handling and applying a finely ground material, other P sources made from phosphate rock have been developed.

Most commercial P fertilizers now on the market are made by treating phosphate rock with certain acids or, to a smaller degree, with heat. The result has

been products with improved agronomic and physical properties. The rest of the publication deals with these materials.

Phosphoric Acid

Phosphoric acid is produced by two methods. "Furnace acid" (white or food-grade) is made by heating phosphate rock to form relatively pure elemental P and then converting that elemental P to phosphoric acid. Furnace acid is costly to produce and is used primarily for food and other industrial processes since it contains very few impurities. Some furnace acid is used to make fertilizers, but such products are no more effective agronomically than those made from less expensive wet-process acid.

"Wet-process acid" (green, if carbonaceous impurities are removed, black if not) is made by treating phosphate rock with sulfuric acid and removing the gypsum that forms. Impurities in the wet-process acid, including metals and organic matter, do not impair the agronomic effectiveness of resulting fertilizers, but may affect storage characteristics of those in liquid form.

Phosphoric acid is a good P source for plants. However, because of handling and application problems, it is normally processed into other P fertilizers.

Normal Superphosphate

Normal superphosphate (NSP), also called single or ordinary superphosphate, has been a popular P fertilizer, but its importance is diminishing. It is made by treating phosphate rock with sulfuric acid, the resulting product being largely a mixture of monocalcium phosphate (MCP) and gypsum.

NSP is an excellent P source for plants and has the added advantage of containing about 12 percent sulfur as calcium sulfate. Its main disadvantage, compared with other P sources, is the low analysis (0-20-0-12S) that increases transportation costs per unit of P_2O_5 . NSP is used as a direct-application material and as an ingredient in some mixed fertilizers.

Triple Superphosphate

Triple superphosphate (TSP), also called treble or concentrated superphosphate, is made by treating phosphate rock with phosphoric acid. The resulting product is mainly MCP, with very little sulfur present since sulfuric acid is not directly used in the production process.

TSP is an excellent P source, has the highest analysis of the straight P fertilizers (0-44-0, 0-45-0, 0-46-0), and has good handling and storage qualities. Because of its higher analysis, which results in reduced shipping and handling costs, TSP is favored over NSP when sulfur is not needed.

Ammonium Phosphates

Ammonium phosphates constitute a large class of P fertilizers produced from phosphoric acid and anhydrous ammonia. Some ammonium phosphates contain additional materials, such as sulfuric acid and urea. Three of the common ammonium phosphates

are monoammonium phosphate, diammonium phosphate, and ammonium polyphosphate.

Monoammonium phosphate (MAP). This product is made by reacting one part (mole) ammonia with one part (mole) phosphoric acid. Several grades of MAP can be produced, with analyses usually in the range of 10-12 percent N and 50-55 percent P_2O_5 . The lower-analysis products generally indicate that more impurities were present in the phosphoric acid; however, these impurities do not affect agronomic effectiveness.

When sulfuric acid is included in the production process, ammonium phosphate-sulfate (APS) results. While several grades are available, the most common product has an analysis of 16-20-0-15S, the phosphate being present as MAP and the sulfur as ammonium sulfate. Both MAP and APS are excellent P sources, have good handling and storage characteristics, and have a high analysis, with APS also providing sulfur.

Diammonium phosphate (DAP). Produced by reacting two parts (moles) ammonia with one part (mole) phosphoric acid, DAP is one of the most important fertilizers in both U.S. and foreign markets. It normally has an analysis of 18-46-0. Although an excellent, high-analysis source of P with superior handling characteristics, DAP can cause germination damage if high rates are placed in direct contact with the seed. Such damage results from the formation of free ammonia, especially on high-pH soils. For applications other than direct seed contact, however, DAP, MAP, and APS are comparable and excellent P fertilizers.

Ammonium polyphosphates (APP). These materials have been developed during the last 20 years. Polyphosphates are formed when two or more phosphoric acid molecules are chemically combined by removing water. These materials are generally made from wet-process acid, but some furnace acid was used before the late 1970s. The most common APP fertilizer available today is a liquid material having an analysis of 10-34-0. It is made by reacting polyphosphoric (superphosphoric) acid with ammonia and adding water. Typically, liquid 10-34-0 contains about 65-70 percent of the total P in the polyphosphate form, with the remaining 30-35 percent as orthophosphate.

While not as common, there are other materials that contain polyphosphate. Until recently, the Tennessee Valley Authority produced experimental material having an analysis of 11-55-0 and containing 20-25 percent of the total P as polyphosphate. Currently, three similar materials are in TVA's fertilizer development and introduction program—granular urea-ammonium phosphate (35-17-0 and 28-28-0) and ammonium polyphosphate suspension (9-32-0). All are made by reacting ammonia and orthophosphoric acid and using the released heat to form polyphosphate.

Advantages of the APPs include their relatively high analyses and the ability to sequester (dissolve) impurities and micronutrients in solution. They are also sometimes used to produce suspensions, since the presence of some polyphosphate allows a suspension to be stored for a longer time. However, polyphosphate materials made from superphosphoric

acid have the disadvantage of a large every requirement for concentrating the acid.

Liquid APPs are often credited as being superior to orthophosphates as P sources, but research has shown them to be equally effective. Research also indicates that polyphosphates are rapidly broken down (hydrolyzed) in soils, providing orthophosphate to growing plants. Thus, any advantages of liquid APPs over orthophosphates as P sources would be related to storage and handling characteristics, and *not* to any agronomic effect.

Ammoniated Superphosphates

Ammoniated superphosphates, made by reacting ammonia with TSP or NSP, are often the basis for producing many mixed fertilizers containing combinations of N, P, K, and possibly micronutrients. When ammonia is reacted with NSP and TSP, products containing dicalcium phosphate, ammonium phosphates and less soluble phosphates are produced.

Increasing the amount of ammonia added to NSP and TSP lowers the amount of water-soluble P in ammoniated superphosphates. However, since ammonia additions are carefully monitored, ammoniated superphosphates generally have a high enough water-soluble P content to be comparable with other P sources. An exception might be when an ammoniated superphosphate containing less than 60 percent water-soluble P is applied to a high-pH, low-P soil. Most ammoniated superphosphates contain more than 60 percent water soluble P and are considered excellent P sources.

Nitric Phosphates

Nitric phosphates are produced by treating phosphate rock with nitric acid or a combination of nitric/sulfuric

or nitric/phosphoric acids. Very little nitric phosphate is produced in the U.S.; consequently, very little is used here. Final products may contain several components, such as dicalcium phosphate, ammonium phosphate, some less soluble phosphates, calcium sulfate, and ammonium nitrate, depending on the production process.

A major characteristic of nitric phosphates is that the final product typically contains less water-soluble P than do other common P fertilizers—the amount normally ranging between 10 and 70 percent, depending on the process used. Effectiveness of these products is usually related to the amount of water-soluble P and crop growing conditions.

SUMMARY

Many phosphorus fertilizers have been developed over the years to provide P that is available to growing plants. All of these fertilizers are made from phosphate rock, which, as it is mined, is very low in available P. To increase P availability, it is treated with acids or heat to provide high-analysis fertilizer materials with improved agronomic and physical properties.

Generally, P fertilizers containing greater than 60 percent water-soluble P are effective and should be considered equal in plant availability. Conditions favoring high water-soluble P fertilizers (greater than 60 percent) might be low-P soils, high pH soils, short-season crops, and starter applications.

Orthophosphate and polyphosphate fertilizers are equal P sources under most conditions. Any advantage of one form over another (e.g., polyphosphate vs. orthophosphate) would be related to handling and storage characteristics of specific materials and not to increased agronomic effectiveness.

Comparisons of the different classes of P fertilizers have shown that superphosphates, ammonium

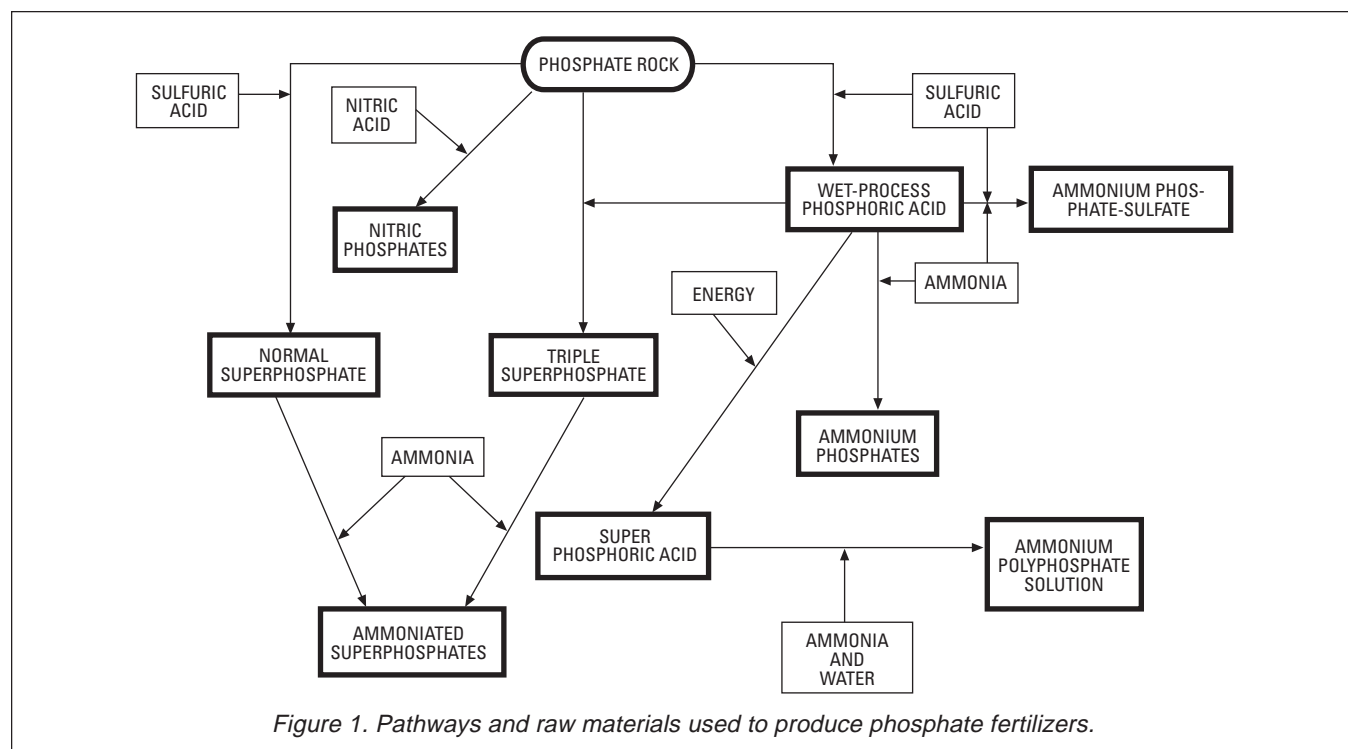


Figure 1. Pathways and raw materials used to produce phosphate fertilizers.

phosphates, ammoniated superphosphates, nitric phosphates, and phosphoric acid are equally effective under most conditions. (Diammonium phosphate may cause germination problems if high rates are applied in direct contact with seed.)

Also, the physical form of a P fertilizer (dry, liquid, or suspension) does not affect P availability or its agronomic effectiveness. Most liquid and suspension P fertilizers contain ammonium phosphates (or are

made from materials used to make ammonium phosphates) and, consequently, are no more effective than similar dry materials.

Since phosphorus fertilizer materials can generally be considered equal sources of P when applied in a similar manner, purchase decisions should be based on such factors as fertilizer application practices, compatibility of the material with the production program, product availability from dealers, and its cost.

Table 1. Summary of Common Phosphate Materials and Their Characteristics.

Phosphate material and typical analysis	Raw materials for production (see Figure 1)	Water-soluble P₂O₅	Comments
PHOSPHATE ROCK (25-35% P ₂ O ₅)	—————	0-10%	Very low P plant availability. Used to make other phosphate materials.
PHOSPHORIC ACID (40-54% P ₂ O ₅)	Phosphate rock Sulfuric acid	100%	Used to make many phosphate materials. Very little used for direct application.
SUPERPHOSPHORIC ACID (69-72% P ₂ O ₅)	Phosphoric acid Energy	100%	Used to make liquid ammonium polyphosphate. Normally contains about 30% polyphosphate.
NORMAL SUPERPHOSPHATE (0-20-0-15S)	Phosphate rock Sulfuric acid	85-95%	Used for direct application or making ammoniated superphosphates. Low analysis; contains sulfur.
TRIPLE SUPERPHOSPHATE (44-46% P ₂ O ₅)	Phosphate rock Phosphoric acid	85-95%	Highest analysis straight P fertilizer. Used for direct application/blending or making ammoniated superphosphates.
AMMONIUM PHOSPHATES Monoammonium Phosphate (11-52-0, 11-53-0, etc.)	Phosphoric acid Ammonia	90-95%	DAP is dominant phosphate material worldwide. All are high analysis. APS also provides sulfur. Mainly used for direct application/blending. MAP and DAP used in suspensions.
Ammonium Phosphate-Sulfate (16-20-0-15S)	Phosphoric acid Sulfuric acid Ammonia	90-95%	
Diammonium Phosphate (18-46-0)	Phosphoric acid Ammonia	90-95%	
Ammonium Polyphosphate (10-34-0)	Superphosphoric acid Ammonia Water	100%	High quality, high analysis liquid material. Normally contains 65-70% polyphosphate. Used for direct application and liquid base material.
AMMONIATED SUPERPHOSPHATE (Variable analysis)	Superphosphates Ammonia	30-95%	Used in many mixed fertilizers. Low water-soluble P possible.
NITRIC PHOSPHATES (Variable analysis)	Phosphate rock Nitric acid	10-70%	Low water-soluble P possible. Other acids can also be used.

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