PHOSPHORUS

Phosphorus is considered a primary (macro) nutrient along with nitrogen and potassium. Plants contain less phosphorus than nitrogen or potassium yet removal of phosphorus by good yielding crops is sizeable, especially if the total above ground portion of the crop is harvested. Even though P is not required in as great of amounts by crops as N and K, it is considered a primary nutrient because of widespread deficiencies that occur across the globe. In fact, P deficient soils are more common throughout Kansas and the Great Plains than any other nutrient except nitrogen.

Functions of Phosphorus in Plants

Phosphorus is an essential part of metabolic processes that occur within the plant, such as photosynthesis, the synthesis and breakdown of carbohydrates, and energy transfer. If the soil level of available phosphorus is not adequate for these plant processes, then production will be reduced unless fertilizer phosphorus is added.

The role that phosphorus plays in energy reactions in plants is very important. Phosphorus may be thought of as the 'batteries' of the plant – a way to store and transfer energy within the plant.

Phosphorus also influences flowering and fruiting habits of plants; hastens maturity; increases grain production; encourages root development; increases disease resistance; improves resistance to drought and cold temperature; encourages early spring growth; improves seeding vigor, strengthens stalk and straw; improves crop quality, increases yield; and balances other plant nutrients.

Phosphorus is absorbed by roots as orthophosphates, primarily $H_2PO_4^-$ and $HPO_4^=$. In young plants, phosphorus is most abundant in tissue at the growing point. It is readily transferred or moved about from older tissue to younger tissue, and as plants mature, most of the element moves into the seeds and/or fruits.

Phosphorus Deficiency Symptoms

A deficiency of phosphorus can be manifested in plants by a poor root system; retarded growth, spindly stalks and stems; poor ear and head set; poor filling of grain; delayed maturity and reduced yield. The leaves of phosphorus deficient plants most often appear dark bluish green, frequently combined with tints of purple or bronze. On corn, purpling occurs around the margins of the leaf and the plant is short and dark green. Deficient small grains are almost purple green. However, mild symptoms of P deficiency are difficult to diagnose.

It is not unusual in early stages of growth for the plant to have considerable purpling color. This is due to the inability of the plant to utilize the sugars made in the leaves. Since disease, insect damage, cold weather and a number of other things can also produce this purple coloring. it is not a conclusive symptom. Small grains do not tiller properly without a good supply of phosphorus, and ear set of corn often fails. Maturity of all crops is delayed by a shortage of phosphorus.

DRY MATTER AND NUTRIENTS ACCUMULATION AS GRAIN SORGHUM PLANTS DEVELOP (MEDIUM MATURITY HYBRID)

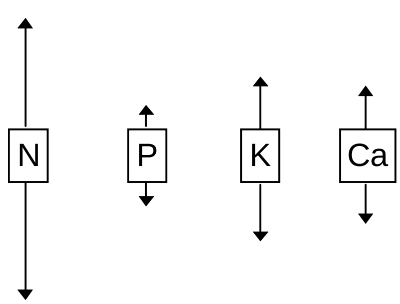
	Seedling 0-20 days	Rapid Growth 21-40 days	Early Bloom 41-60 days	Grain Formation 61-85 days	Mature 86-95 days
	%	%	%	%	%
N	5	33	32	15	15
P_2O_5	3	23	34	26	14
K_2O	7	40	33	15	5
Dry Matter	2	15	32	32	19

From: R. L. Vanderlip. 1972. How a Sorghum Plant Develops. Kansas Extension Circular. C-447.

Phosphorus deficiency is usually most apparent in young plants early in the growing season. The most critical time for P nutrition is for seedlings since the demand for P relative to total root length is very high. Plant uptake of phosphorus, like other nutrients, proceeds at a faster rate than does dry matter production in the early stages of plant growth. For example, in the first 20 days, only 3 percent of the phosphorus needed by a mature grain sorghum crop has accumulated. By early bloom (about 60 days after emergence), 60 percent of the phosphorus that it will accumulate in the entire season has been taken up while only 49 percent of the dry matter has accumulated. In spite of this relatively low amount of the total uptake that occurs early, nutrient availability early in the season is important and phosphorus fertilizer should be applied early to get the most benefit

Phosphorus in Soils

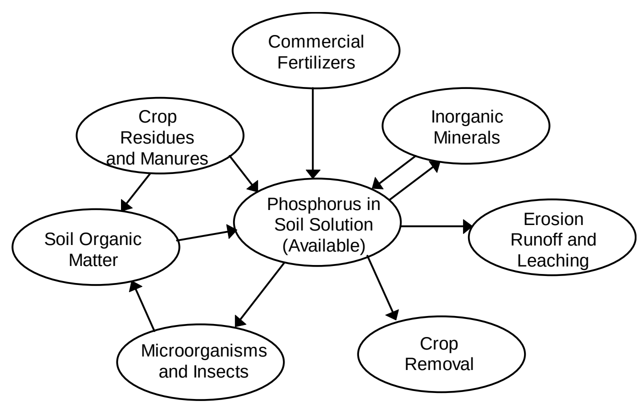
Phosphorus (P) does not exist in soils in the simple elemental form, but is found combined with other elements forming complex minerals (inorganic) and organic compounds. The total phosphorus content of the surface six inches may be as little as 200 pounds per acre on very sandy soils to over 2,500 pounds per acre on fine textured soils. However, only a small fraction of this total phosphorus is in a form that is readily available to plants. Thus, application of phosphorus fertilizer, or agricultural or municipal wastes are necessary on many soils to meet plant phosphorus needs



Relative Mobility In Soil

The reason for the low availability of soil phosphorus compounds is that phosphates react strongly with many soil chemicals to form relatively insoluble compounds. Phosphorus moves very little in most soils, because of the very small amounts found in the soil water (solubility). In this sense, the negatively charged phosphate ion differs from more soluble anions such as nitrate and sulfate. Phosphorus movement in soils is also much less than for other cations such as potassium and calcium.

Research into the chemistry of soil inorganic phosphorus has shown a very complex system of reactions and compound formation dependent on such factors as soil pH, type and amount of soil minerals, amount of phosphorus in the soil, and other soil factors. Likewise, the chemistry of organic soil phosphorus is very complex and probably less understood than inorganic soil phosphorus chemistry; however, breakdown (mineralization) of organic matter and crop residue by soil microorganisms is recognized as being a major contributor in many soils to plant available phosphorus.



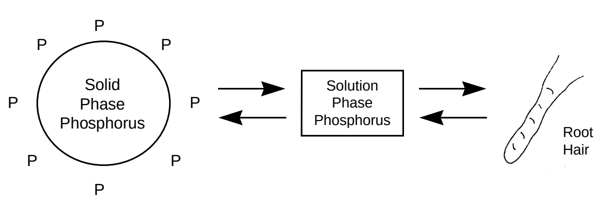
Soil phosphates exist in mineral and organic compounds. Soil organic matter contains from 25% to 90% of the phosphorus in soils., thus soil organic matter content and other factors which influence its rate of decomposition affect phosphorus availability.

Because inorganic phosphorus compounds are quite insoluble in soil water, organic phosphorus may compose a large portion of the phosphorus occurring in the soil solution. In a study of 21 soils of Southern and Central United States, the soluble organic phosphorus (as P_2O_5) in the soil solution was 0.176 ppm while the inorganic phosphorus content was only 0.034 ppm.

Since all types of organic matter in soils contain phosphorus and the microorganisms release this phosphorus in a form that plants can use, it is evident that soil organic matter is a very important reservoir for this important nutrient. More important, as long as it is in the organic form it cannot be rendered insoluble to plants by the calcium, iron, aluminum or manganese in the soil. The same temperature ranges in which plants flourish are optimum for activity of microorganisms; thus, nature provides a balance for the phosphorus nutrition of the crops as long as adequate amounts of phosphorus exist in the form of organic matter in the soil.

Mineral and organic P compounds provide a reservoir of P that replenishes the plant available forms as soon as they are removed. Even phosphorus fertilizers quickly revert to these relatively insolubleforms of phosphorus (also refered to as fixation. Over time, much of the sparingly soluble P will be available to plants through a chemical equilibrium system that allows phosphorus to move from one form to another.

The low solubility of phosphorus bearing mineral and organic compounds means that there is very little phosphorus in the soil solution available for plant absorption from soil water at any one time. For most soils, the amount of phosphorus dissolved in the soil solution is no more than a fraction of a pound per acre. Crops need much more phosphorus than what is dissolved in the soil water and a rapid replenishment of the solution phosphorus must occur as plants absorb phosphorus.



Thus, the amount of phosphorus available for plant uptake by crops depends on the quantity of phosphorus in the soil solution and on the continued dissolving of phosphorus minerals to maintain the soil solution phosphorus levels. This maintenance of phosphorus in the soil solution by dissolving of phosphorus minerals is the key to the phosphorus nutrition of plants is what is estimated by phosphorus soil tests.

Soil test methods used by laboratories do not measure the total quantity of plant available phosphorus in the soil, but rather measure a part of those compounds that maintain plant available phosphorus in the soil solution. The amount of phosphorus measured with a soil test is therefore an index that is related to the phosphorus supplying ability of soils. This index is also related to crop response to phosphorus fertilizer by conducting many phosphorus fertilizer rate experiments for various crops.

Factors Affecting P Uptake

Because of phosphorus reversion reactions in soils, crops typically only recover 5% to 30% of applied fertilizer P during the first year following application. However, it is these same reversion reactions that prevent leaching of applied phosphorus and provide for residual benefits for years after application. Recovery percentage varies widely, with higher P recoveries in the year of application for soils low in soil test P and band applications. Relatively lower P recoveries in the year of application are associated with high P soil test values and broadcast applications.

There are many factors which affect P availability and/or uptake by crops.

- Plants take up phosphorus almost entirely as the orthophosphate anion (HPO_4^{-2} or $H_2PO_4^-$). The relative amount of each ion in the soil solution depends on soil pH. Acidic soils favor the $H_2PO_4^-$ species, and alkaline soils favor presence of HPO_4^{-2} Plants are able to absorb both forms effectively.

- While alkaline soils (especially calcareous soils) increase the rate of P reversion to relatively insoluble compounds, low soil pH levels can have an even greater effect on P availability. Soils with low soil pH values reflects the likely presence of soluble iron and aluminum which readily reacts with phosphorus resulting in a reversion to relatively insoluble iron and aluminum phosphates. Soil P availability is greatest in the soil pH range of 6 to 7.

- Absorption of the orthophosphate anions, like other nutrients, occurs primarily from the soil solution. Phosphorus uptake is reduced considerably by dry soil favoring deeper incorporation where dry surface soil conditions develop.

- Because the soil solution concentration of orthophosphate ions is quite low, absorption of the orthophosphate ions in most cases occurs against a concentration gradient (known as active absorption) as the phosphorus concentration is greater within the root than in the soil solution phase. This active absorption requires energy derived from root respiration of carbohydrates. Thus, conditions like wet or cold soils that reduce root metabolic activity will also slow phosphorus absorption.

  The late Dr. Roscoe Ellis, Department of Agronomy, KSU, researched temperature effects on P uptake by corn in greenhouse experiments showing that soil temperatures of 55^{o}F depressed vegetative yields of corn even when adequate to high levels of phosphate are applied. Phosphorus levels in the corn were much lower at 55^{o} compared to 75^{o}, except when excessively high P rates are applied. This reduced uptake of phosphorus was related to lowered root activity rather than chemical reactions of phosphorus in soil.

Temperature Effect On Corn P Uptake.

P_2O_5 Rate	Yield (gm/pot)		P Content (%)	
	75°	55°	75°	55°
Low	3.7	1.2	0.28	0.13
High	5.6	2.7	0.34	0.35

Ellis, KSU

- Absorption of nutrient ions and moisture is greatest near the actively growing tip of each root. Root exploration through the soil as plant roots develop allows for new areas of the soil to become nutrient sources. The total root surface area and the mass of soil explored by the roots both are important for potential nutrient absorption. Plant roots have been estimated to occupy no more than one to two percent of the total soil volume.

- Other nutrient ions are absorbed by plants at the same time as the orthophosphate ions. Although most ions are thought to be absorbed independently, there are some demonstrated interactions between nutrients as competition for absorption sites on roots occurs. The plant strives to maintain electrical balance by absorption of positively and negatively charged ions and by exchange of ions from the roots with the soil solution. The presence of ammonium ions (NH_4^+) has been shown to have an enhancement effect on phosphorus uptake especially with starter fertilizers.

- The concentration of the orthophosphate ions in the solution also is important to potential absorption. Thus, placement of fertilizer in bands or as granules develop temporary zones of higher solution phosphorus concentration allowing for greater uptake.

- Phosphorus is known to move very little in soil (non-mobile nutrient) and roots must be very close to phosphorus in the soil for uptake to occur. Diffusion of phosphorus to roots will occur over no more than a quarter of an inch. For this reason, placement of phosphorus fertilizer close to the seed is important for efficient early season use of the applied phosphorus.

Losses of Phosphorus From Soil

Crop removal of phosphorus varies with crop, yield level, and other factors. As with other nutrients, more phosphate is removed when the whole plant is harvested than when only grain or fruit are removed. Over time, crop removal rates influence the rate of phosphorus fertilization required.

Since very little phosphate is soluble in solution, leaching losses are very low. Soil erosion accounts for more significant losses. Even though these losses may be relatively low in terms of diminished fertility, as little as 0.025 ppm of phosphate in streams and lakes can result in excessive growth of algae and weeds resulting in oxygen depletion (eutrophication). Thus phosphate is considered a serious water pollutant. Avoiding excessive rates of manure and controlling soil erosion are practices that reduce the potential for P movement off fields.

Fertilizer Application Method

Phosphorus fertilizers can be broadcast or band-applied. Broadcasting distributes the fertilizer uniformly on the surface of the soil where it can remain or be incorporated with a tillage tool. Banding places the phosphorus in a concentrated zone.

There are several terminologies used in discussions of band applying phosphorus fertilizers. Additionally, there are several variations of some of these methods in use today. Following are a few definitions of some common band application terms.

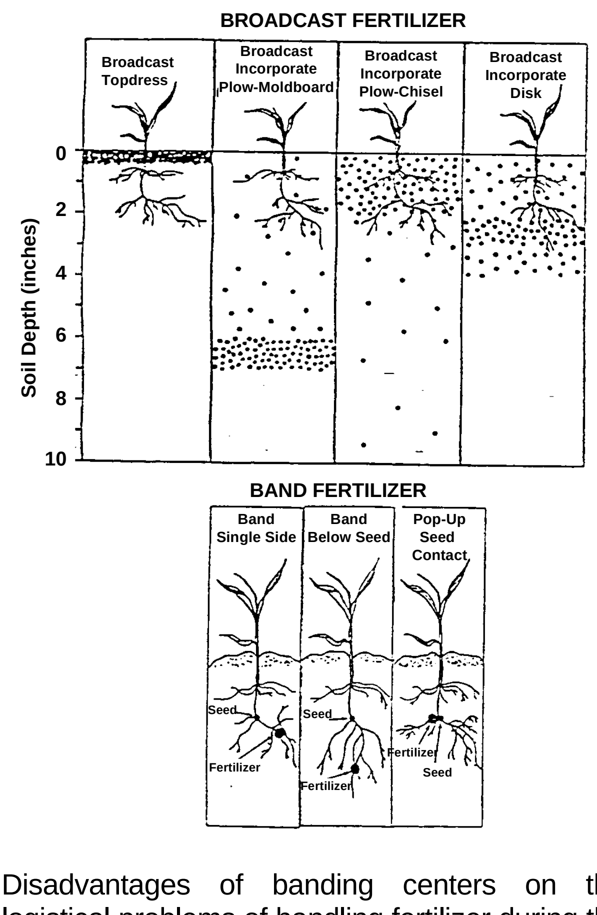
Starter. Refers to applications made at planting. Normally refers to applications in which P fertilizer is placed in direct seed contact or below and to the side of the seed. However, starter applications where the fertilizer material is placed in a band on the soil surface at planting are also utilized.

Seed-placed, Drill-row or In-furrow. Refers to fertilizer applications made in direct seed contact. Also referred to as 'pop-up' applications for row crops. Only limited amounts of fertilizer can be safely applied in this manner in order to avoid emergence or stand establishment problems. Fertilizer placed with the seed can not speed up emergence since the germinating seed only relies on nutrient found in the seed.

Deep Band. Typically refers to band applications made before planting in a separate field operation. 'Deep' normally means a depth of 4-8 inches. Oftentimes, both P fertilizer and N fertilizer are applied simultaneously in a single band and is referred to as 'dual NP application' or 'dual deep band' applications.

Dribble. Most commonly refers to coarse streams of liquid fertilizer materials applied to the soil surface without incorporation. May be made as preplant, topdress or starter applications; with or without supplemental N fertilizer.

There are several positive aspects of band applying phosphorus fertilizers. First, band applications reduce the soil to P contact which reduces the rate of P reversion to less soluble phosphate forms. This also increases the soil solution P concentration in the band which aids in P uptake. Second, starter band applications places fertilizer in a zone more readily accessible to seedling roots. Also, band applications such as deep banding place the fertilizer P where soil is likely to have more consistent moisture present.



Disadvantages of banding centers on the logistical problems of handling fertilizer during the busy planting time. Also, significant investment in equipment is required as compared to having fertilizer P broadcast applied by dealers.

Incorporation of the broadcast phosphorus into the plant root zone is important to assure good utilization under Kansas climatic conditions which frequently result in extended periods of dry surface soil. An exception is broadcasting of phosphorus on permanent sod and alfalfa fields. These perennial crops have an extensive surface root system and are able to effectively utilize surface applied phosphorus. No improvement in utilization has been observed from incorporation.

While broadcasting P fertilizers results in increased P fixation and reduced P use efficiency in the year of application, as compared to band applications, there are several advantages. Unincorporated broadcast applications are suitable for permanent sod and alfalfa since these perennial crops have an extensive root system near the soil surface. As such, they are able to effectively utilize surface applied phosphorus. Also, since broadcast applications are not made while planting, they do dot slow down the planting operation.

With the use of conservation tillage practices, less opportunity exists for incorporation of fertilizer. Under these conditions, the use of starter fertilizer or deep band placement may be better than broadcasting. Another alternative on soils of medium phosphorus soil tests or above is to apply higher broadcast rates in years where incorporating tillage operations are done with no application or low rates of starter in other years.

In general, banding is considered more efficient than broadcasting. Application of a given rate of P in a band often results in a greater yield than the same rate broadcast, particularly if marginal application rates are used. Phosphorus rates can often be reduced when banding without reducing yield, particularly when soil tests are relatively high. However, if the rate of application is less than the crop removal rate, the soil test level may eventually fall, lowering yields. When a soil test is low in P, low rates of P, even though applied in a band often do not produce maximum economic yields. In these fields, banded rates of P should be equal to or greater than broadcast rates.

In general, it is best to use starter band applications to complement a broadcast P fertilization program if fertilizer attachments are available. On soils that are low in phosphorus, a combination of broadcast and banded phosphate will maximize yields. On soils that test higher in phosphorus, either banding or broadcasting is suitable.

Early season crop growth response to starter placed P in not uncommon even on soils with high P soil test levels. The likelihood of early season growth response increases with cool, early season soil temperatures. Minimum tillage and early planting are practices that enhance the possibility of starter P yield response. Starter P can also enhance grain dry down in the fall. If starter attachments are available, it is often best to include starter phosphorus, even on soils testing high in soil test P.

Phosphorus Fertilizer Terminology

Historically, phosphorus content of fertilizers has been expressed on the oxide basis (P_2O_5) rather than the elemental basis (P). As a result, the term *phosphate*, referring to P_2O_5, is used to describe the phosphorus content of fertilizers.

The Kansas fertilizer law requires that any product sold as a commercial fertilizer must show on the label, or bill of sale for bulk material, a guarantee of minimum percentages of total nitrogen, (N), available phosphoric oxide (P_2O_5) and water soluble potassium oxide (K_2O), commonly referred to as nitrogen, phosphate, and potash.

Although phosphorus does not exist as P_2O_5 in fertilizer materials, phosphorus contents of fertilizer materials, crop nutrient recommendations and nutrient removals in the harvested portions of crops are commonly made in terms of P_2O_5 equivalent.

<u>Water Solubility</u>. Water solubility of phosphorus fertilizer has been studied for years and it is generally agreed that water solubility is a desirable trait in phosphatic fertilizer. Water solubility is most important where availability of the phosphorus for immediate plant uptake is needed, such as starter fertilizer. Even with

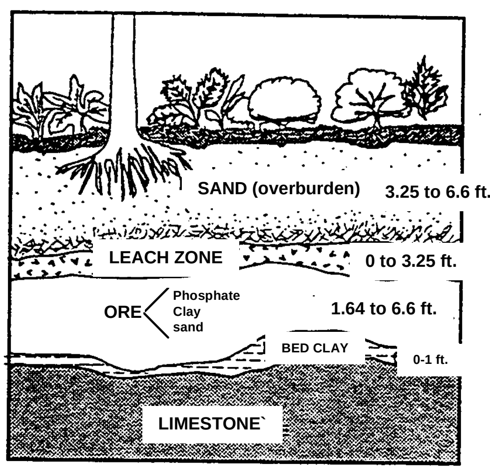
starter fertilizers, 100 percent water solubility of the phosphorus is not necessary. Based on past research with phosphatic fertilizers of varying water solubility, phosphatic fertilizers with water soluble phosphorus contents of 50 percent or greater are equal for the most responsive crops even on soils testing low in available phosphorus. Modern phosphorus fertilizer products have a water soluble phosphorus content of 85% or more, making water solubility as a selection criteria unimportant.

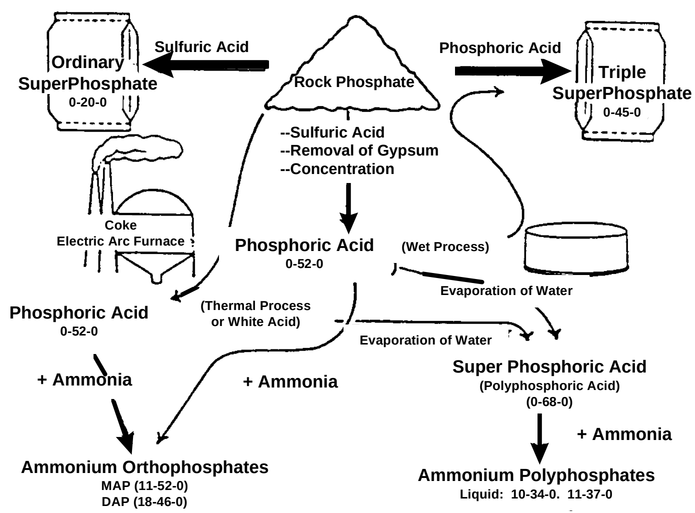
Water solubility is, however, is still a topic of discussion in some areas. Terms frequently used in discussing fertilizer phosphorus are water-soluble, citrate-soluble, citrate insoluble, available and total P_2O_5. equivalent.

phosphorus in the fertilizer available to plants and is the amount reported in the guaranteed analysis.

Citrate Insoluble: The phosphorus not easily dissolved in the normal ammonium citrate. By law, this fraction is not included in the guaranteed analysis.

Total: The sum of the available and citrate insoluble phosphate is the total phosphorus. Most commercial fertilizers have very little of the phosphorus in the citrate insoluble fraction. Total phosphate analyses are only required on the label of rock phosphate, basic slag, bone meal, tankage, and other natural organic phosphate materials sold as phosphate sources.





Water-Soluble P: Fertilizer samples analyzed by the State Control Laboratory are first dissolved in water under standardized conditions. The amount of phosphorus readily dissolved in water is measured and expressed as a percentage P_2O_5 by weight of the sample.

Citrate-Soluble P: The phosphorus that is not easily dissolved in water but is readily dissolved in an ammonium citrate solution is measured and expressed as a percentage P_2O_5 by weight of the sample.

Available: The sum of the water-soluble and citrate-soluble phosphate is considered

Phosphate Fertilizers

Rock phosphate is the basic material used in most phosphate production. Rock phosphate marine deposits exist in many parts of the world. The most important deposits in the United States are located in Florida, which supply about 70% of the rock phosphate produced in the United States, North Carolina and the western deposits in Idaho, Wyoming and Montana.

In its natural mineral form, rock phosphate consists primarily of a relatively insoluble calcium phosphate called *apatite*. The phosphorus content of rock phosphate varies but averages 33% to 36% total P_2O_5 (14% to 16% P). However, none of this phosphorus is water soluble and only about 3% is citrate soluble. Rock phosphate was used as a P fertilizer at one time, but the low availability to plants has virtually eliminated its use as a commercial fertilizer. Today, rock phosphate is processed into more soluble fertilizer sources

Phosphoric Acid: H_3PO_4

Phosphoric acid is the starting point for all common phosphate fertilizers. Additionally, phosphoric acid is used in many industrial processes, the food industry and for producing animal feed supplements. Although not common, a small amount of this phosphoric acid is used for direct application in some areas.

Phosphoric acid is manufactured by two main processes. *Wet-process acid* is produced by reacting rock phosphate with concentrated sulfuric acid and removing the phosphogypsum that results. The resulting phosphoric acid is called *wet-process acid*. As originally produced, this acid contains approximately 37% to 44% P_2O_5. By heating of the acid and subsequent evaporation of water, the acid is concentrated to 52% to 54% P_2O_5. Wet-process acid contains impurities from the rock phosphate and sulfuric acid used in its production. Wet-process acid is green if the rock phosphate is calcined to removed organic materials or brown/black if the phosphate rock has not undergone calcination.

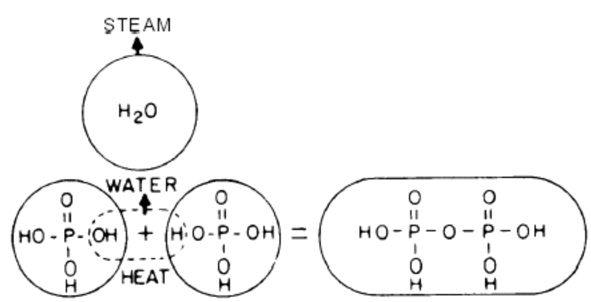
Typically, phosphoric acid, and subsequent products made from the acid, is green if the rock phosphate was from North Carolina or the western states since these deposits are high in organic matter. Phosphoric acid and other phosphate fertilizer made from Florida rock, however, may be black, brown or tan since the rock phosphate from which it was produced contains only small amounts of organic materials and does not need to be calcined.

Furnace or food grade phosphoric acid is made by converting the phosphorus in rock phosphate to elemental P by applying large amounts of energy, burning the elemental phosphorus to form P_2O_5 and then hydrated to pure phosphoric acid. Acid produced by this method contains no impurities and is very expensive to produce. Typically, food grade phosphoric acid is used to make many of the products often purported to be 'salt-free', 'made from the highest quality ingredients', 'premium fertilizer products' or other such claims. These products contain no impurities, but have no agronomic advantage over common phosphate fertilizer products.

Superphosphoric Acid

The development of superphosphoric acid (SPA), as well as subsequent discoveries about the value of polyphosphates in producing high analysis solutions with superior storage characteristics, revolutionized the liquid phosphate fertilizer industry. Superphosphoric acid is a mixture of polyphosphoric and orthophosphoric acids and contains no free water. Polyphosphoric acid (polyphosphate) is formed by heating orthophosphoric acid. Two orthophosphoric acid molecules combine to form a single polyphosphoric acid molecule and water is released.

Superphosphoric acid is most commonly made from wet-process acid but a little is also made from food grade acid. Superphosphoric acid typically contains 68% to 70% P_2O_5. with about 20-30% of the phosphate is present as polyphosphate while 75-80% is present as orthophosphate. Superphosphoric acid is used to produce high analysis liquid ammonium polyphosphate (10-34-0 & 11-37-0).



Ortho **Ortho** **Poly**

Ammonium Phosphates

Ammonium phosphates include several fertilizer materials produced from phosphoric acid and anhydrous ammonia. If one mole of ammonia is reacted with one mole of phosphoric acid, monoammonium phosphate (MAP) is produced. If two moles of ammonia are combined with one mole of phosphoric acid, diammonium phosphate results. While ammonium phosphates were known to be an effective source of nutrients to plants as far back as the early 1900's, it wasn't until the 1960's that they began to dominate the market place. At the present time, greater than 85% of P_2O_5 production in the U.S. is as ammonium phosphates.

Monoammonium Phosphate(MAP, $NH_4H_2PO_4$)MAP is made reacting 1 molecule ammonia with 1 molecule of phosphoric acid. Several grades of MAP can be produced, with analyses usually in the range of 10% to 12% N and 50% to 55% P_2O_5. The lower-analysis products generally indicate that more impurities were present in the phosphoric acid from which it was produced. However, these impurities do not affect agronomic effectiveness. The most common grade is 11-52-0, but other grades are common in the marketplace.

When sulfuric acid is included in the production process, ammonium phosphate sulfate (APS) results. 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.

The pH of a dissolved MAP granule is acidic, about 4.0. This effect on soil pH in the vicinity of the MAP granule has sometimes been used to promote MAP over DAP (18-46-0), especially on alkaline soils. However, there is no real agronomic difference between MAP and DAP – they both are equal in agronomic performance.

Diammonium Phosphate

(DAP, $(NH_4)_2HPO_4$) DAP is produced by reacting 2 molecules of ammonia with 1 molecule of phosphoric acid. Since the 1960's, DAP has become the international standard for phosphate products and only has an analysis of 18-46-0. Both MAP and DAP are considered agronomically equal on an applied P_2O_5 basis.

DAP production dominates in the U.S., with about 5,200,000 tons of P_2O_5 produced as DAP in 2000 while 2,20,0000 tons of P_2O_5 were produced as MAP. The dominance of DAP in the international marketplace is even greater.

Triple Superphosphate (0-45-0, $Ca(H_2PO_4)_2$) Triple superphosphate ushered in the era of high analysis phosphate fertilizers in the 1950's. World TSP production peaked about 1980 and has rapidly declined since then. U.S. production of TSP has declined over 67% since 1980. Triple superphosphate (TSP), is manufactured by treating rock phosphate with phosphoric acid. The resulting product is then granulated to provide good physical handling qualities.

Currently, TSP typically contains 45% P_2O_5 .It is an excellent source of fertilizer phosphorus, but production economics, certain physical/chemical characteristics and international trade issues have resulted in the large production declines experienced over the past 20 years.

Liquid Ammonium Polyphosphate (10-34-0, 11-37-0, APP). Ammonium polyphosphates have been developed over the past 25-30 years. Liquid APP is made from wet-process superphosphoric acid, anhydrous ammonia and water. The most common APP fertilizer available is a liquid 10-34-0 although 11-37-0 is common in some regions of the country.

Typically, liquid 10-34-0 contains about 65% to 70% of the total P in the polyphosphate form with the remaining 30% to 35% as orthophosphate.

Advantages of the polyphosphates in liquid materials include; 1) relatively high analysis solutions are possible and 2) the ability of polyphosphate to sequester (dissolve) impurities and micronutrients in solution. The main limitation of liquid APP is the cost per pound of P_2O_5 as compared to solid materials. However, liquid products can be pumped and metered with relatively inexpensive pumps and metering systems.

Liquid APP's 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 ammonium polyphosphates over orthophosphates as P sources would be related to storage and handling characteristics, not agronomics.

Fluid fertilizers in general offer several advantages to the user in the form of labor and time savings, ease of handling and application, and fewer stops to refill planting equipment. The use of fluid phosphorus as liquid starter fertilizers in Kansas and the rest of the Midwest and Great Plains is gaining in popularity.

Putting it all Together

Phosphorus is second only to nitrogen as the essential plant nutrient deficient in soil. While there is typically large amounts of phosphorus present in soils, phosphorus is quickly converted to only sparingly soluble compounds in soils (reversion or fixation). As a result, recovery (utilization) of the fertilizer phosphorus by plants is usually less than 30 percent in the first year after application and in some cases is 10 percent or less. This low recovery is the result of very low phosphorus concentrations in the soil solution and the fact that plant roots explore only a small percentage of the soil volume. However, much of the phosphorus not recovered in the year of application will be taken up by crops in succeeding years.

The first step in putting a phosphorus fertilization program together is to soil test to determine the need for phosphorus. Once the need for phosphorus is established, application methods should be considered. Band placement can improve uptake on low and very low testing soils. Band applications of phosphorus can improve utilization of the fertilizer phosphorus especially in years with cold, wet conditions after planting. As a result, starter applications should be used to complement broadcast applications. Also, starter applications are suggested even on soils testing high in soil test phosphorus.

Knowing that phosphorus is generally equally available from various products, selection of a phosphorus fertilizer should be based on its suitability for the application method selected, compatibility with the overall production program, product availability and cost per pound of P_2O_5.

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 rock phosphate, 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. All modern phosphate fertilizers should be considered agronomically equal if application rates and methods are the same.

Generally, P fertilizers containing greater than 60% water soluble P are effective and should be considered equal in plant availability.

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

Common Phosphate Fertilizers In Kansas				
Phosphate Material	Typical Analysis	% Water Soluble	Polyphosphate %	Comments
Diammonium Phosphate	18-46-0	90-100	0	Dominant P Product in US and world
Monoammonium Phosphate	11-52-0 10-50-0	90-100	0	Equal to DAP agronomically
Liquid APP	10-34-0 11-37-0	100	65-70	The main liquid P fertilizer
Liquid Starter Grades	7-21-7 9-18-9 8-22-4-3S Etc.	100	0-70 .	All are agronomically equal
Triple Superphosphate	0-45-0	85-90	0	Quickly going out of market