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MANAGEMENT OF SOILS
IN **SOUTHWESTERN** MINNESOTA
A Correspondence Course

Unit 2: Understanding Phosphorus and Potassium

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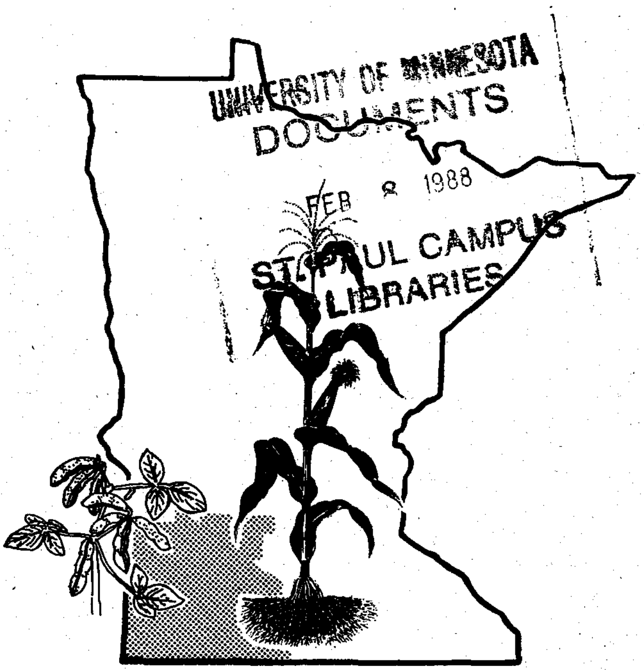
Objectives

- Gain a basic understanding of the importance of phosphorus (P) and potassium (K) for crop production in southwestern Minnesota.
- Gain an understanding of how fertilizer recommendations for phosphate and potash change as the soil test values change for these two nutrients.
- Understand, in a general way, the various fertilizer sources of phosphate and potash for crop production.



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IMPORTANCE OF PHOSPHORUS AND POTASSIUM

Both phosphorus (P) and potassium (K) are essential for plant growth and development. In plants, P is needed to stimulate early growth, give a good and vigorous start, and hasten maturity. Potassium is needed to aid in disease resistance, reduce lodging, and improve the winter hardiness of perennial legumes like alfalfa.

PHOSPHORUS AND POTASSIUM IN THE SOIL

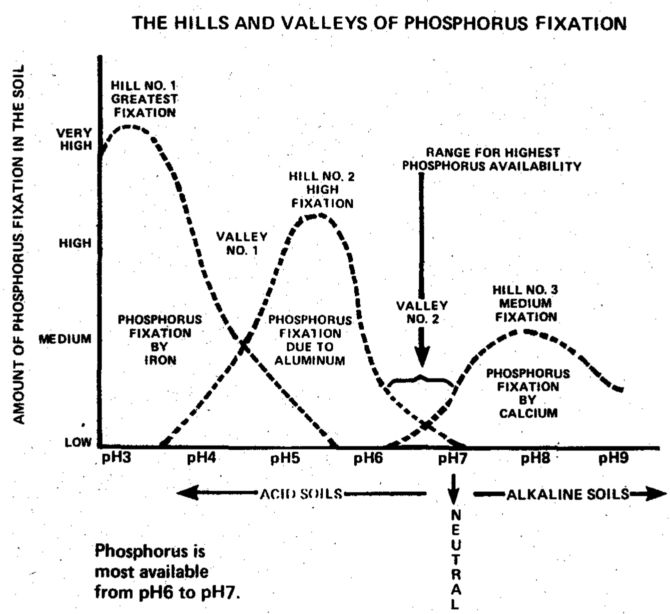
There are many complex reactions that involve P in the soil system. Rather than try to explain all of these reactions, we will attempt to simplify the system in the following paragraphs.

Phosphorus in soil is always combined with oxygen to form what is referred to as "phosphate." This phosphorus/oxygen combination is the form of P absorbed by the plant roots.

The total P content of soil usually ranges from about 100 pounds per acre to about 4,000 pounds per acre. Only about 1 percent of this, however, is available to plants at any one time. The amount of P removed by crops is usually greater than this available supply, so available P must be replenished near an actively growing root. As P is absorbed by growing plants, the concentration near the root drops. When this happens, P in other parts of the soil system moves toward the root surface to the area of lower concentration. This process is called diffusion. If the total supply of available P in the soil system is adequate, enough P reaches the root by the diffusion process. Also, roots intercept some of the needed P as they grow.

Most P in the soil system is "fixed"—tied up in chemical forms that cannot be used by plants. The relationship of the availability of P to soil pH is shown in Figure 1. In acid soils (pH less than 6.5), the P is tied up as iron and aluminum phosphates. When soil pH is high (greater than 7.3), the P is tied up as calcium phosphate. Thus, P is most readily available in a pH range from 6.5 to 7.3.

Figure 1. Relationship between P availability and soil pH.



Some of the P added in fertilizers also is fixed. The unavailable products formed are determined by the pH of the soil. The process of tie-up that takes place is the same for all P fertilizers applied to soil. Some of the fixed phosphate does become available for plant use with time. However, the conversion from unavailable to available forms is very slow.

Unless fertilized heavily in the past, most soils in southwestern Minnesota will have low or medium levels of phosphorus in the surface with low or very low levels in the subsoil. Most of the soils also have a high pH. Therefore, some soil and fertilizer phosphorus will react with the calcium to form calcium phosphate products, which are not readily available for crop use. This "fixation" of fertilizer phosphorus can be minimized if contact between soil and fertilizer is minimized.

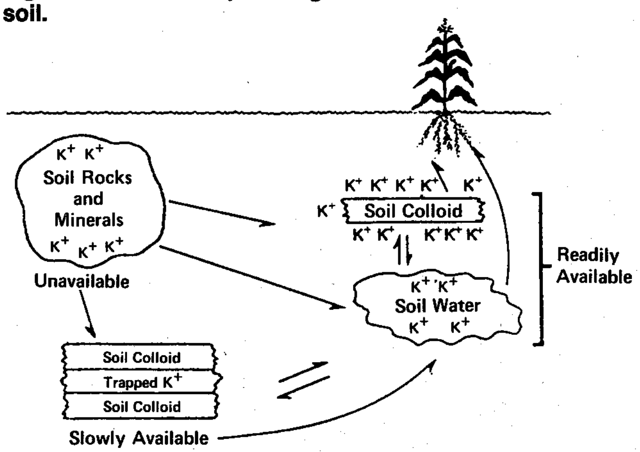
A general relationship of the forms of K in soils is illustrated in Figure 2. Like P, not all K that exists in soils is available for crop use at any one time. The total amount of K present in most soils amounts to thousands of pounds per acre. However, only about 2 percent of this total is present in soil water or attached to the clay particles, the forms available for use by plants.

Some types of clay particles are capable of trapping K. When the K is trapped it is not totally available for plant growth. With time, some of this trapped K becomes available for plant use. This K is considered to be slowly available.

Some soils in southwestern Minnesota do not have a high percentage of clays that are capable of trapping K. When K is added from fertilizers, it dissolves in the soil water and some becomes attached to the clay particles.

In general, surface soils in southwestern Minnesota, if not fertilized, will have medium to high levels of K that can be used by plants. Levels of K in the subsoil also are high. These levels will, of course, change as phosphate and potash fertilizers are used.

Figure 2. Relationship among the various forms of K in the soil.



MANAGING PHOSPHATE AND POTASH FERTILIZERS

When you use phosphate and potash in a total fertilizer program, remember these important points:

- Neither nutrient is mobile in Minnesota soils. Both remain close to where they are placed unless disturbed by some tillage operation.
- As contact between the soil and fertilizer containing P and/or K decreases, fixation decreases. Therefore, fertilizer containing these two nutrients applied in a band will be used more efficiently than fertilizer that is broadcast and incorporated.
- Phosphorus in adequate amounts is very important for the early growth of plants as well as for early regrowth of perennial crops.

Grain Crops and Soybeans

For grain crop and soybean production, phosphate and potash fertilizers can be broadcast and incorporated before planting or applied in a band near the seed at planting (starter). A combination of both methods also can be used.

Fertilizer recommendations are based on a measurement of the relative level of P and/or K in the soil by a routine soil test and the grower's yield goal. Relative levels for soil test P and K for Minnesota soils are listed in Table 1. When relative levels for P and/or K are high or very high, there is only a small probability that applied phosphate and/or potash will increase crop yield. On the other hand, there is a high probability that there will be an economic yield increase when phosphate and/or potash fertilizers are used if relative soil test levels are low or very low.

Table 1. Relative levels for soil test P and K in Minnesota soils.

Relative Level	Phosphorus	Potassium
	..............lb/A	....
Low	0-10	0-100
Medium	11-20	101-175
Medium-high	21-30	176-250
High	31-40	251-300
Very high	40+	300+

When a starter fertilizer is used, there is less contact between soil and fertilizer, reducing fixation of P and K. As a result, lower rates of both nutrients are needed when they are applied in a starter rather than broadcast and incorporated (Tables 2 and 3). The use of phosphate and potash in a starter fertilizer also places these two nutrients close to the seed early in the growing season, promoting early growth and development.

The recommendations for corn listed in Tables 2 and 3 are just a part of the total set of recommendations for all soil test levels. A complete set can be found in AG-BU-0519, *Guide to Computer Programmed Soil Test Recommendations for Field Crops in Minnesota,* available from your county extension office.

Table 2. Recommendations for phosphate use for corn production for selected soil test levels for P.

	Soil Test P (lb/A)			
	11-20		21-30	
Yield Goal (bu/A)	Broadcast	Starter	Broadcast	Starter
	.... phosphate to apply (lb/A)			
175 +	80	40	50	25
156-175	75	35	45	25
136-155	70	35	40	20
116-135	65	30	35	20
96-115	60	30	30	20
76-95	55	25	25	15

Table 3. Recommendations for potash use for corn production for selected soil test levels for K.

	Soil Test K (lb/A)			
	101-175		176-250	
Yield Goal (bu/A)	Broadcast	Starter	Broadcast	Starter
	.... potash to apply (lb/A)			
175 +	150	40	100	30
156-175	130	35	80	25
136-155	110	35	60	25
116-135	90	30	40	20
96-115	70	30	30	20
76-95	50	25	30	15

When using these recommendations, remember that amounts of P and K suggested for starter application are less than the amounts removed by a good crop, so if starter only is used for a number of years soil test values for P and/or K will decline slowly. This is not a problem because fertilizer rates are easily adjusted in future years. A regular soil testing program will indicate when changes in rates of phosphate and potash are needed.

The use of starter fertilizer to supply small amounts of phosphate (10 to 15 pounds per acre) and potash (8 to 10 pounds per acre) is considered a good management practice even though soil test values for P and K are in the high range. Minnesota trials have shown that the use of a starter will produce economical increases in yield about 50 percent of the time when soil test values for P and K are in the high range.

Conservation Tillage

Recently, there has been increased interest in the use of conservation tillage systems for crop production. In systems where no major tillage is done (no-till and ridge-till), any phosphate and potash fertilizer that is broadcast without incorporation will remain relatively close to the soil surface. This stratification, or development of high concentrations of nutrients near the soil surface, does not seem to be ideal because a large portion of the root system does not grow and develop there. Therefore, starter fertilizer is very important in no-till and ridge-till planting systems.

When soil test values for P and/or K are low or medium, the P and K needed for optimum production can be applied in a starter. A starter fertilizer also is recommended for these planting systems if the soil test values for P or K are in the medium-high to high range. Starter fertilizer will not be needed where P or K levels are very high.

In recent years, a new method for placement of phosphate and potash fertilizers has been introduced. In this method, liquid or dry fertilizer is placed in a concentrated band below the soil surface, usually below the depth of the starter fertilizer band but not necessarily close to the seed. The application of fertilizer in this way eliminates concerns about stratification.

Studies to evaluate this method of placement were started in Minnesota in 1983. Although information is limited at this time, it appears that subsurface placement of phosphate and potash in a band has not reduced yield. In fact, there may be advantages for this method of placement for both no-till and ridge-till planting systems.

Alfalfa, Grasses, and Other Perennials

For alfalfa, grasses, and other perennial crops, management of fertilizers to supply the requirements for P and K is quite different. For these crops, the portion of the root system that is active in nutrient absorption is close to the soil surface. Therefore, fertilizers containing P and/or K can be topdressed to the existing stand.

Thick stands are essential if maximum production is to be obtained from these crops. Therefore, it is usually best to broadcast and incorporate needed P and K before seeding to stimulate early growth and better establishment.

Rates should be based on the results of a soil test. After establishment, phosphate and potash (with rates adjusted to soil test) can be topdressed as needed.

FERTILIZER MATERIALS

Fertilizer sources of K are somewhat limited. Potassium chloride, commonly referred to as 0-0-60, is the chief source of K in Minnesota. Potassium chloride is used to supply K in both dry and liquid fertilizers. For the liquid fertilizer industry, a purified source of potassium chloride (0-0-62) is used.

A fertilizer composed of potassium sulfate and magnesium sulfate also is used as a source of potassium. This source is sold under the trade name of "Sul-Po-Mag" or "K-Mag." This fertilizer supplies sulfur (S) and magnesium (Mg) in addition to K.

Before we discuss phosphate fertilizers, a number of terms that are frequently used in association with these fertilizers need some explanation. These terms are: water soluble, citrate soluble, citrate insoluble, available phosphorus, and total phosphorus.

Water Soluble. When fertilizer samples are analyzed in a laboratory, they are first dissolved in water under standardized conditions. The amount of P in the fertilizer that is dissolved under these conditions is defined as water-soluble P.

Citrate Soluble. The fertilizer not dissolved in the water is then placed in a solution called 1 Normal ammonium citrate. The amount of P from the fertilizer that dissolves in this solution is called citrate-soluble P.

Citrate Insoluble. This is the P in the fertilizer that is not dissolved in the 1 Normal ammonium citrate.

Available Phosphorus. The sum of the water-soluble and citrate-soluble P is considered to be the available P in the fertilizer and is the amount guaranteed on the fertilizer label.

Total Phosphorus. This is the sum of the available and the citrate-insoluble P.

The percentages of total and available P in several common P fertilizers are listed in Table 4. Nearly all of the total P in the fertilizers listed is in the available form.

There has always been a debate over the advantages and disadvantages of liquid and dry fertilizers. Since the source of K is the same for both liquid and dry materials, any discussion of liquid and dry fertilizers usually revolves around the phosphate materials used to make the various fertilizers.

The phosphate used in dry fertilizers can come from one or two materials. The long-time standard is 18-46-0, called diammonium phosphate or DAP. The analysis is constant at 18 percent N and 46 percent phosphate. More recently, dry fertilizer materials have used a phosphate source called monoammonium phosphate, or MAP. The N percentage in MAP varies from 11 percent to 12 percent while the phosphate percentage varies from 50 percent to 52 percent.

Table 4. Total and available P in common P fertilizers.

Phosphorus Source	P Total	P Available	% of Available P That Is Water Soluble
	%	%	%
superphosphate (0-20-0)	21	20	85
concentrated superphosphate (0-46-0)	45	45	85
monoammonium phosphate (11-52-0)	52	51	92
diammonium phosphate (18-46-0)	46	45	90
ammonium polyphosphate (10-34-0)	34	34	100

Source: Ohio Agronomy Guide

In both DAP and MAP, the phosphate is present as orthophosphate, the form absorbed by plants. Research has shown that both MAP and DAP are equal as sources of phosphate in Minnesota. These two products are nearly always used in the formulation of dry fertilizer blends that are applied to annual crops.

Legumes require no nitrogen. Therefore, 0-46-0 is usually used as the dry material to supply P for these crops. The phosphate in this material is also present in the orthophosphate form.

The product 10-34-0 is the long-time standard source of phosphate for liquid fertilizers. The P in 10-34-0 is present in both orthophosphate and polyphosphate forms.

It's important to understand the difference between P in the orthophosphate form and P in the polyphosphate form. Phosphoric acid is the starting point for the manufacture of 10-34-0. The P in phosphoric acid is in the orthophosphate form. If phosphoric acid is heated, water is removed and several orthophosphate units combine to form a polyphosphate unit. The phosphoric acid that is the end result of this heating process is called a "super-acid." Anhydrous ammonia is added to this "super-acid" to form 10-34-0. Since about two-thirds of the phosphate in 10-34-0 is in the polyphosphate form, this fertilizer material is usually referred to as ammonium polyphosphate.

When fertilizers that contain P in the polyphosphate form are added to soils, the polyphosphate unit absorbs water from the soil and breaks down to several orthophosphate units. This process usually takes 10 to 14 days, so one to two weeks after application the polyphosphate source of P is completely available for plant use.

Some liquid fertilizers are made from a very purified standard phosphoric acid. The expense involved in purifying this phosphoric acid contributes to the higher price of these liquid fertilizers. The P in these materials is in the orthophosphate form.

There are advertising claims that the liquid fertilizers with P in the orthophosphate form are superior to fertilizers that contain the P in the polyphosphate form. Several research trials conducted throughout the north-central states to compare these materials have shown that both sources have an equal effect on yield.

The fertilizers used to supply phosphate for crop production today have been evaluated in several research trials. The results of these trials can be summarized as follows:

- MAP and DAP have an equal effect on production in environmental conditions similar to those in southwestern Minnesota.
- Liquid and dry fertilizers have the same effect on plant growth.
- Fertilizers containing P in the polyphosphate form are just as effective for crop production as those containing P in the orthophosphate form.

RELATED READING

AG-FO-0793, *Potassium for Minnesota Soils*
AG-FO-0792, *Phosphorus for Minnesota Soils*
AG-FS-2933, *Using Starter or Row Applied Fertilizer for Minnesota Crops*

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