G82-601 Using Phosphorus Fertilizers Effectively

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Using Phosphorus Fertilizers Effectively

For most effective use of phosphorus, the fertilizer needs to be placed to ensure quick contact by growing roots and minimal contact with the soil.

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Phosphorus (P) fertilizers are second only to nitrogen fertilizers in importance for growing crops in Nebraska. However, the principles affecting efficient phosphorus use are totally different. Nitrogen is a mobile nutrient both inside the plant and in the soil, while phosphorus moves very little in the soil. In addition, total plant phosphorus requirements are much lower than those of nitrogen. Plant leaves commonly contain ten times more nitrogen than phosphorus. However, phosphorus is concentrated in the grain so that only about 2.5 times more nitrogen is removed in harvested grain compared to phosphorus.

Nebraska soils are generally well supplied with phosphorus. Total phosphorus contents average about 4,700 lbs P_2O_5 (phosphorus pentoxide) per acre for each foot of soil. Assuming a root zone of six feet, most Nebraska soils contain about 28,000 lbs of total phosphorus as P_2O_5. If our crops could use all of this phosphorus, we would have a 500-year supply for growing 150 bushels of corn per acre each year. Unfortunately, only a very small amount of this total phosphorus supply is available each year because it must undergo weathering before it becomes available to plants. Even with 28,000 lbs of total phosphorus present in the root zone, phosphorus may be deficient for maximum crop yields. Our problem is to determine the amount of phosphorus available to a crop and then use phosphorus fertilizers most effectively to maximize economic crop returns.

Know Your Phosphorus Fertilizer

The original source of phosphorus fertilizer is rock phosphate that is mined in Florida and in the western United States. This phosphorus is similar in form to much of the total phosphorus found in Nebraska soils. Its availability to the crop is very low and must be changed to available forms by chemical processes. While rock phosphate is sometimes used as a phosphorus fertilizer, research indicates that its low availability restricts its economic use.

To increase the availability of phosphorus in rock phosphate, it is treated with acid. However, the amount of available phosphorus in a fertilizer varies depending on the kind and amount of acid used. Therefore, laws have been passed to guarantee phosphorus content and availability in fertilizers. These laws require the manufacturer to state the amount of "available phosphorus" the fertilizer contains. The percent of "available phosphorus" is called the grade and is shown as the middle number of the standard grade designation. For example, an 18-46-0 grade designation means that this fertilizer contains 18 percent nitrogen, 46 percent phosphorus as P_2O_5, and 0 percent potassium as K_2O. The 46 percent grade designation is referred to as "available phosphorus" and is expressed as P_2O_5. It may also be expressed as percent P. Percent P_2O_5 can be converted to percent phosphorus by dividing by 2.3; percent phosphorus can be converted to percent P_2O_5 by multiplying percent phosphorus by 2.3. Availability is not affected regardless of how the phosphorus content is reported.

The term "available" can be confusing. "Availability" infers plant availability, but no one knows how to actually measure true plant availability. Therefore fertilizer phosphorus availability is expressed in terms of weak acid solubility. The available phosphorus designated by grade is measured by extracting with a weak citric acid solution. This extraction is related to plant availability.

The available phosphorus shown by grade designation in a fertilizer is citric acid soluble but not necessarily also water soluble. Water solubility of the phosphorus in a fertilizer has been shown to be a better expression of fertilizer phosphorus performance than citric acid soluble phosphorus for row or banding applications. Nearly all phosphorus fertilizers sold today contain very highly water soluble phosphorus. Because of this, it is of no concern when selecting the best phosphorus fertilizer to use, but could be a factor in the future.

Phosphorus Sources

Most of the phosphorus in present day fertilizers is water soluble because these fertilizers are made by treating rock phosphate with sulfuric acid. This acid is called "green or wet process acid" and contains about 55 percent P_2O_5. It is used either with rock phosphate to make dry triple superphosphate (0-46-0) or reacted with ammonia to form dry ammonium phosphates. Fertilizers made from 55 percent P_2O_5 acid are called "orthophosphates."

If 55 percent P_2O_5 acid is concentrated to 79 percent P_2O_5, superphosphoric or polyphosphoric acid is formed. Ammonia is reacted with this highly concentrated acid to form the 10-34-0 liquid fertilizer grade commonly used. The fertilizers produced from these superphosphoric acids are often referred to as polyphosphates because of the chemical arrangements of the phosphate molecules. The removal of water in the concentrating process results in two or more molecules of orthophosphate combining to form a "poly-molecule."

The fertilizer values of orthophosphates and polyphosphates are considered to be equal. Whether a phosphorus fertilizer is a polyphosphate or an orthophosphate should not dictate fertilizer choice. Other factors such as price per pound of nutrient are more important. However, there are some applications, such as the use of micronutrients zinc and iron, where availability of the micronutrient can be increased by using a liquid polyphosphate. A reaction between the polyphosphate and zinc or iron increases the availability of some zinc and iron compounds that normally have low water solubility and plant availability. This allows the use of relatively cheap zinc and iron compounds, such as zinc oxide and iron sulfate, to correct deficiencies.

The development of polyphosphates revolutionized the liquid fertilizer industry. The ability of this fertilizer to hold zinc and iron compounds in available form also has permitted the mixing of larger amounts of other nutrients with polyphosphate than with orthophosphates. Thus, liquid mixed fertilizers have become more competitive in cost with dry materials. Contrary to popular belief or advertising claims, liquid fertilizers do not have increased availability or agronomic value over their dry counterparts. There is essentially always adequate water in the soil to dissolve dry fertilizers. Therefore, a liquid or a dry phosphate fertilizer should be judged on the cost of its nutrient content and not on a difference in phosphorus availability.

Liquid phosphorus fertilizers cost more than an equal amount of phosphorus in the dry form because liquids require greater processing and a higher purity to prevent settling or "gunking out" in the liquid formulations. This disadvantage has been largely overcome by the more recent use of "suspensions." Suspension fertilizers use clay to help suspend fertilizer particles and impurities, thus permitting the use of less pure phosphorus sources. Agronomic value of suspensions as well as liquid and dry phosphorus fertilizers are considered equal. Suspensions are usually priced more nearly like dry phosphorus fertilizers than liquid forms. However, they are more difficult to apply without special equipment that provides agitation.

Soil and Phosphorus Availability

While a phosphorus fertilizer may be completely water soluble (completely plant available) when manufactured, it does not remain this way very long after it is applied to the soil. This process of available phosphorus being made unavailable to plants is called "phosphorus fixation."

Fixation Concepts

The reversion of plant-available fertilizer phosphorus to plant-unavailable phosphorus is a process that cannot be avoided, but fertilizer phosphorus efficiency can be increased by proper management. As previously discussed, most of the phosphorus in soils is in forms varying in solubility. Much is in mineral forms that must be weathered before available phosphorus is released. When applied to the soil, all water soluble phosphorus fertilizers change back to the less soluble native soil phosphorus forms. When we apply phosphorus to the soil, we hope to increase the temporary supply adequately to reduce crop deficiencies and increase yields. We must recognize, however, that the available fertilizer phosphorus decreases with time and ultimately is changed back to unavailable soil forms.

The degree of fixation is regulated to a large extent by soil pH. Phosphorus availability is least at high and at low soil pH. At a soil pH above 7.2 to 8.5, fixation occurs as insoluble calcium phosphates; at a soil pH below about 6.0, phosphorus availability is reduced by the presence of iron and aluminum phosphates. Phosphorus availability is greatest at a pH of between 6.5 and 7.0.

We can do four things to reduce phosphorus fixation and increase phosphorus availability to plants: 1) acid soils can be limed to increase soil pH to between 6.5 and 7.0; 2) we can apply small amounts of phosphorus fertilizer frequently rather than large amounts at one time; 3) we can try to reduce soil fertilizer contact; and 4) we can try to place phosphorus fertilizers in soil areas where roots are most active.

Organic Phosphorus

Phosphorus deficiencies for growing crops are believed to be more critical during wet, cold soil conditions. These conditions not only reduce root growth and limit phosphorus availability, but also reduce mineralization of phosphorus from the soil organic matter. Organic soil phosphorus may represent from 30 to 40 percent of the phosphorus available to crops in Nebraska, and thus may be a major factor affecting phosphorus availability during wet, cold springs.

Determining Your Phosphorus Need

Soil Testing

The need for phosphorus fertilizer can best be predicted by soil test. Chemical analysis is used to assess the soil's ability to supply phosphorus. A soil test value for phosphorus is not a measure of the total amount of phosphorus available for plant use--it is only an index.

Although several extraction procedures can be used, two methods are commonly used for Nebraska soils. The weak acid method, known as Bray & Kurtz No. 1, is most commonly used since it is well correlated with plant available phosphorus in acid and neutral soils. The sodium bicarbonate extraction procedure is better adapted for calcareous soils (soils containing excess or free lime).

Table I shows the calibration of these two extraction procedures and the expected probability of crop response to applied phosphorus. For soils testing very low, a response to applied phosphorus is not certain but is highly probable. For soils testing high, a response to applied phosphorus can occur but is very unlikely. Thus, a soil test phosphorus value is only an indication of the relative availability of phosphorus in the soil. It does not measure either the total amount of phosphorus in the soil, or the total amount of available phosphorus in the soil.

For a soil test to have meaning, it must be correlated and calibrated with crop response to phosphorus fertilizer on many different soils. *Table I* shows the most recent interpretation of these two methods for various crops on different soil phosphorus levels in Nebraska. While predicting response to applied phosphorus by soil tests is far from an exact science, a highly probably (HP) category means one can expect a yield response to applied phosphorus from 75 to 100 percent of the time. Similarly, probable (P) would be about 50 to 75 percent, possible (PO) would be about 10 to 50 percent, while a doubtful (D) would have only about a 10 percent or less chance for obtaining an economic yield response.

Table I. Interpretation of soil tests for phosphorus (Bray P-1 and Sodium Bicarbonate-P) and the probability of crop response.

			Likelihood of Crop Response to Phosphorus Fertilizer Application**					
Soil Test Range, ppm*		**Calibration Range**	**Corn**	**Grain Sorghum**	**Small Grains**	**Soybeans**	**Seeding Alfalfa**	**Sugar Beets**
Bray P-1	**SB-P**							
0 - 5	0 - 3	Very low	HP	HP	HP	P	HP	HP
6 - 15	4 - 10	Low	P - PO	P - PO	P	PO - D	P	P
16 - 24	11 - 16	Medium	D	D	PO	D	PO	D
25 - 30	17 - 20	High	D	D	D	D	D	D
> 30	> 20	Very high	D	D	D	D	D	D

*Bray P-1 for acid and neutral soils, SB-P for calcareous soils.
** HP means highly probable; P, probable; PO, possible; and D, doubtful.

Soil Sampling

How the soil samples are taken for soil testing can have a profound influence on the test results. Generally, the soil sample is taken to give the average phosphorus status for a given field or part of a field. Thus, fields must be divided in such a way that each sample represents a uniform tract of land. Soil parent material, degree of erosion, past cropping history, and fertilizer and manure application should all be uniform. Usually, 10 to 15 cores are collected from each soil area (not to exceed 20 acres) and are composited for one sample. This assumes that previous phosphorus fertilizers have been broadcast uniformly. If phosphorus has been applied in bands, many more cores should be taken to better approximate the average phosphorus level in the soil. If phosphorus has been applied in bands beside the seed, and the crop is planted in the same rows each year, separate samples from the row and between the rows may be desirable.

Soil tests for phosphorus are calibrated on topsoil samples, and the soil cores must only be from the topsoil or tillage depth. Thus, a sampling depth of 0 to 6 inches, or 0 to 8 inches, or of the tilled layer is suggested. Subsoil phosphorus probably influences crop response to applied phosphorus fertilizer; however, research information is not adequate at this time to use subsoil samples to modify phosphorus fertilizer recommendations. It is known for example, that Sharpsburg soils in eastern Nebraska often contain relatively high soil test phosphorus at depths below 3 to 4 feet.

Interpreting Soil Tests

Several methods are used to interpret soil tests. These different methods are responsible for the great difference in kinds and amounts of fertilizer recommended by various soil testing laboratories.

The method used by UN-L Soil Testing Lab and several other western plains states is called "deficiency correction." Kinds and rates of fertilizer are suggested to correct those nutrient deficiencies which are likely to limit yield. For phosphorus, fertilizer is suggested for crops grown on those soils where the response to applied phosphorus is possible or probable (*Table I*). For soils that test high, a response to applied phosphorus is doubtful, and no phosphorus is suggested. This method of making fertilizer recommendations results in minimum fertilizer usage with optimum yields. It requires accurate soil sampling and analysis, and soil test correlation and calibration information must be adequate for proper interpretation.

The "crop removal" or "maintenance" method of making fertilizer recommendations may or may not require a soil test. Nutrients are applied in quantities equal to crop removal. However, the recommendations are usually adjusted for high or low levels in the soil or to allow for losses. This method results in much higher fertilizer recommendations which increase as yield level is increased. Research in Nebraska has not supported increasing phosphorus rates for higher yields. Even the deficiency correction recommendations will tend to increase the soil test values for phosphorus in most Nebraska soils because crop uptake of fertilizer phosphorus is often less than 10 percent, especially for corn and soybeans.

Most commercial labs and several university labs in eastern states use a modified crop removal concept for phosphorus fertilizer recommendations. Phosphorus fertilizer is suggested at rates equal to crop removal on soils testing between 15 and 30 ppm Bray P-1. For soils below 15 ppm, additional phosphorus is suggested to build soil levels. Above 30 ppm, phosphorus rates are reduced to use more of the soil phosphorus. This approach can be used, but it appears to be inefficient and needlessly expensive.

Use Proper Application Methods

The method of applying phosphorus fertilizer has a great influence on its efficiency.

Weed-and-Feed

This concept involves applying a fluid fertilizer to which a herbicide has been added. The mixture is applied on the soil surface after the crop has been planted or is established. This practice does not make efficient use of phosphorus fertilizers on annual crops because phosphorus does not move appreciably in soils. Thus, it is positionally unavailable for annual crops such as corn, sorghum, soybeans, and small grains. A fertilizer that contains only nitrogen is a better choice than one which contains phosphorus for a surface applied weed-and-feed program. Where the fertilizer and herbicides are incorporated into the soil prior to planting, adding the herbicide to the fertilizer can be a good practice for reducing application costs. Fertilizers containing phosphorus can be used for a weed-and-feed program on perennial crops such as alfalfa and bromegrass. Application needs to be made in early spring when the crop is beginning growth for maximum effectiveness from the phosphorus fertilizer.

Row vs Broadcast

As previously discussed, readily available fertilizer phosphorus is reverted to less available forms in the soil. To reduce this reversion process, phosphorus can be applied in bands to limit soil-fertilizer contact and place fertilizer in a soil where root contact is probable. Field research has shown that the application of phosphorus fertilizer in bands at the time of planting can result in more efficient fertilizer use. Crops such as wheat are known to be more responsive to banding than corn or sorghum. The greatest advantage to banding occurs on very low phosphorus soils, especially if the soil is calcareous or moderately to strongly acid. For soils that are neutral to slightly acid in pH and only slightly deficient in phosphorus, performance of row and broadcast may be similar. Banding for wheat is generally more profitable than broadcasting and should be applied at similar rates depending on soil test level.

Research has shown that surface broadcast application of phosphorus fertilizers where no tillage or cultivation is performed can be effective. Effectiveness of surface applications is dependent on having high root activity in the soil surface-residue contact area. Therefore, to be effective, the surface of the soil below the crop residue must remain moist. This is most likely to occur under sprinkler irrigation in Nebraska.

Preplant Bands

Applying phosphorus fertilizer in bands prior to planting the crop has been evaluated in corn, soybeans, and wheat. For wheat, 10-34-0 liquid fertilizer was applied both with and without anhydrous ammonia. Both methods are effective. Efficiency of preplant bands is equal to row application and superior to broadcast application for wheat. Also for corn and soybeans, preplant band application of phosphorus fertilizer is effective and is often more efficient than broadcast.

For maximum effectiveness, bands should be spaced 12-24 inches, especially when applied across the row direction. The closer spacing is necessary for wheat to obtain uniform growth. For corn and soybeans slightly wider spacing can be used. A common practice is to place two bands per row; thus, spacing for row crops will be 15-20 inches, which is effective. Row spacing widths can be used in ridge plant or no-till systems where row position is relatively constant and bands can be placed near where the row will be planted.

Starter Fertilizer

Starter fertilizer is a term commonly interchanged with row applied fertilizer, but it does not mean the same thing. Row applied fertilizer refers to placing fertilizer in bands either with the seed or beside the seed row to correct a deficiency. The intent of starter fertilizer application with the seed or in bands near the seed is to stimulate early growth. This stimulation may or may not be reflected in increased crop yields.

When crops are grown on soils where the probability of yield increase from applied phosphorus fertilizer is doubtful (*Table I*), no phosphorus is suggested either as row applied or broadcast. If the grower desires, he can apply a small amount of an ammonium phosphate fertilizer to stimulate early growth. Generally, about 45 pounds of 18-46-0, or 60 pounds of 10-34-0, per acre banded beside the row is effective. See NebGuide *G77-361, Using Starter Fertilizers for Corn, Grain, Sorghum, and Soybeans*, for more information.

Time of Application

Although the time of applying phosphorus fertilizer may not influence performance as greatly as with nitrogen fertilizer, there are some guidelines to follow to enhance the efficiency of phosphorus fertilizer use. Generally, the longer phosphorus is in contact with soil, the greater the fixation that occurs.

For annual crops, apply phosphorus before planting, or row apply it at the time of planting. Topdressing phosphorus after the planting of an annual crop is not usually effective. Since phosphorus is not subject to leaching losses like nitrogen, it can also be applied in the fall, but not on frozen soil. Phosphorus losses can occur from runoff where phosphorus fertilizer is applied on frozen soil or where soil erosion occurs.

Topdressing phosphorus is effective for perennial crops such as alfalfa and bromegrass. These crops have very vigorous crowns from which many fine roots originate, thus phosphorus uptake can occur. Make applications in early spring when crown growth is most active.

For new seedings of alfalfa, the annual rate of phosphorus fertilizer application can be tripled and applied prior to seeding. This should be effective for three to four years of alfalfa. However, it is suggested only on soils that are near neutral in pH where fixation is least. For high lime soils, annual or every-other-year topdress applications are suggested for alfalfa.

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