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PHOSPHORUS for minnesota soils

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There can be large quantities of phosphorus in the soil, but much of it is fixed or in various ways unavailable to plants. Added phosphorus for most soils has been quite profitable over the years. Understanding both soil and applied phosphorus takes many years of research.

Phosphorus in the soil

Phosphorus in the soil can be either in organic or mineral forms. Phosphorus release from organic matter will vary with weather conditions which affect soil micro-organisms. The weather can cause too much, too little, or a just right moisture situation. Organisms have difficulty functioning with very wet or dry soils. When too wet in the spring, slow soil warmup occurs. This cold temperature reduces phosphorus release and also retards the plant's ability to absorb it. Besides weather, soil pH also affects the rate of organic matter decay and subsequent phosphorus release, again because of the relationship to soil organisms.

Mineral phosphorus is also affected by pH. In acid soils, aluminum and iron are quite soluble which allows a reaction with phosphorus to form compounds in which the phosphorus becomes unavailable. An alkaline pH also affects phosphorus availability. The calcium and magnesium compounds react with phosphorus making it less available.

Phosphorus has a negative charge the same as nitrates, but it doesn't move the same way in the soil. It reacts with other elements to become fixed and is stationary. Phosphorus can be a contaminant of lakes or streams. If incorporated shortly after application on fields however, there will be no movement off the field unless the soil itself erodes. There is evidence that phosphorus moved to lakes or rivers comes from frozen plants with plant cells that have been ruptured. This material is water soluble and could move from any sod crop such as hayfields, pastures, or lawns unless it has first come into contact with the soil.

Phosphorus buildup

Table 1 shows the great increase in phosphate (P_2O_5) application since 1945.

These figures do not include phosphorus in manure applied during these years.

Table 1. Increase in phosphate use in Minnesota since 1945*

Year	tons P_2O_5	Year	tons P_2O_5
1945	16,434	1965	186,816
1950	46,198	1970	223,126
1955	78,244	1975	290,000
1960	114,365	1978	274,678

*TVA data.

Soil test summaries comparing 1964 figures with the 1979 summary[1] show that the number of samples testing very high have increased from 27 percent to nearly 50 percent. These figures indicate that phosphorus levels in the soil have been built up over the last 15 years perhaps much more on some farms than others. Except for small amounts of row application, no phosphorus is recommended for crops where soil tests are very high. Recent field trials on corn show little immediate crop benefit from broadcast applications on these soils. *Phosphorus and Potassium Experiments on Well-Managed Soils in South Central Minnesota,* Miscellaneous Report 135, shows effect of broadcast phosphorus on corn yield over several years in field trials on high fertility land.

Methods of application

Phosphorus can be applied in three ways: broadcast, in the row near the seed, or directly with the seed; none of these presents specific seed damage hazards. Even though applications of phosphorus with the seed present very few problems, most fertilizer mixtures include nitrogen and potassium: the latter two can harm germination if the rate is too high.

Studies in growth control chambers show that phosphorus uptake in young plants increases about 6 times faster at 77° F than at 59° F from broadcast phosphorus applications. It is possible to partially offset cold temperature effect by application methods. Under cold soil conditions, the efficiency of phosphorus use is much greater when applied with or close to the seed. In the growth chamber study with a 100 pound rate at 59° F early uptake of phosphorus from a row application was more than doubled compared to a broadcast treatment. With warmer temperatures, the uptake was much higher and didn't vary with application method.

Based on soil temperature trials, row phosphorus is recommended on fine-textured soils that have slow internal drainage and tend to warm slowly in the spring. For farmers who have large acreages, only small amounts with the seed may be desirable. This means fewer stops for filling fertilizer boxes. With this method, larger amounts should be broadcast.

Phosphate materials

Just as ammonia is the basis for most nitrogen fertilizers, rock phosphate is the source for most phosphate materials. Rock phosphate is very low in available phosphorus, but is converted to more available forms by acid treatment which in the process is neutralized so that little acidity remains in the finished product.

Phosphoric acids used in the manufacture of fertilizers by the "wet" process acid are called either "green" or

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[1] Grava et al. 1964, 1979.

"black" acid. Another method, the electric furnace process which produces a "white" acid can also be used. Phosphorus in liquid fertilizers are 100 percent water soluble regardless of whether from the "wet" process or electric furnace process. Field trials comparing these phosphorus sources currently on the market have shown no significant difference in yield increases. No one liquid fertilizer has been demonstrated superior nor are they superior to commonly used dry forms. Field trials with phosphorus have shown consistently that only 15 to 20 percent is absorbed in the year applied. In subsequent years, much of the unused phosphorus will eventually be used. This is true with all forms of phosphorus on the market.

Field evaluation of phosphorus needs

DEFICIENCY SYMPTOMS

A shortage of phosphorus reduces plant size. Mild deficiencies appear in stunted growth in soybeans, small grains, and corn. If the deficiency is severe, translocation of carbohydrates to other parts of the plant is reduced, and these compounds build up in the leaves. These compounds convert to anthocyanins, giving plants a purple hue. Purpling in young plants is more pronounced because of the demand for phosphorus early in growth.

The period of greatest phosphorus need is in early growth. With adequate phosphorus during this period a plant seldom develops a deficiency later. Attempting to correct a deficiency in midseason has not been successful.

PLANT ANALYSIS

With all the complex soil problems involving phosphorus availability, plant analysis is one reliable way to determine the adequacy of phosphorus nutrition. It is important to relate stage of growth to the interpretation of the test. As a plant ages, phosphorus content lowers. Table 2 shows interpretation of phosphorus content for several crops.

Table 2. Interpretation of phosphorus lack found in several crops*

Crop	Plant part and sampling stage	Threshold levels: deficient	low	sufficient	high
		% P			
Corn	Whole plant 12-inch height			.40	> .80
	Ear leaf at tasseling	< .16	.16	.25	> .50
Small grain	Top leaves, boot stage	< .16	.16	.21	> .50
Alfalfa	Upper 1/3 early bloom	< .20	.25	.25	> .70
Sunflowers**	5th leaf, flowering	< .15	.15	.30	> .50

*Adapted from soil testing and plant analysis, SSSA '73.
**Values subject to modification as research develops.

SOIL ANALYSIS

Testing for soil phosphorus is the only practical way to determine rates of application; plant analysis is usually too late to correct a deficiency that year. The University of Minnesota soil testing laboratory uses the Bray P_1 test with 10 parts of reagent to 1 part of soil. If the pH is above 7.4 and the P_1 test is below 11 pounds, an additional 50 parts of reagent are used to 1 part of soil because high pH soils can neutralize the 10 to 1 ratio reagent and a misleading low test will occur. Recommendations based on soil tests are in *Guide to Computer Soil Test Recommendations in Minnesota,* Extension Bulletin 416 (formerly Special Report 1).

An overview

A phosphorus deficiency retards growth, delays maturity, and lowers quality as animal feed. Soils should be tested for current phosphorus status, application should be made to build up the soil level, and row applications should be made where cold soil temperatures prevail during early growth. Plant analysis is helpful in trouble shooting where a combination of factors restricting uptake are hard to interpret.

More detailed explanations can be found in the following publications. All numbered bulletins and folders mentioned can be requested from county agricultural extension offices.

Fertilizer for Wheat in Minnesota's Red River Basin. Extension Folder 254.

Fertilizer for Alfalfa. Extension Folder 255.

Soils, Soil Management, and Fertilizer Monographs. Extension Bulletin 431 (formerly Special Report 24).

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