NEWS & VIEWS

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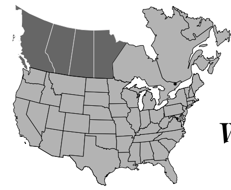

Dr. Adrian Johnston,
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October 2001

Phosphorus Fertilization – Sources and Efficiency

SELECTION of a phosphorus (P) nutrient source should always be based on an understanding of residual soil nutrient levels determined by soil testing, the total requirements and pattern of uptake of the crop being grown, and the supply of plant-available P from the nutrient source.

The production of water-soluble, plant-available fertilizer P requires reacting rock phosphate (RP) with acid. Applied to the soil alone, RP is incapable of meeting crop requirements under the high pH, calcareous soil conditions common to western Canada. While there are a number of fertilizer P sources to choose from, little difference in crop response to fertilizer form should be expected when the fertilizer is applied in an appropriate manner and at the optimum time for crop uptake.

Livestock manures are excellent sources of plant nutrients. Making the most of their use requires an understanding of the nutrient content in the manure source, the availability of these nutrients in the year of application and thereafter, and the impact of processing manure on its composition and use.

The behavior of P in soil, whether from fertilizer or manure sources, is of agronomic and environmental interest. Knowing the amounts and forms of nutrients that are applied, being able to predict their fate, and managing them to obtain maximum crop benefit are critical issues in nutrient management planning.

PHOSPHORUS is one of the 17 essential elements required for plant growth and development. It contributes to many vital functions in the plant, such as early root and seedling growth, improving winter hardiness, promotion of early heading and uniform maturity, seed formation and quality, and increased water-use efficiency.

While these effects are more visible, P also plays a number of unseen roles such as photosynthesis, energy storage and transfer, respiration, and cell division. Crops deficient in P tend to develop slower, exhibit limited growth potential, and yield less than expected.

On the Canadian prairies, soil test P levels have been found to be low to medium in about 60 percent of Alberta fields, 86 percent of Saskatchewan fields, and 74 percent of Manitoba fields. Such P levels indicate that a crop response to P is highly likely, and in cases where high levels of soil or fertilizer nitrogen (N) also exist, response to P is almost guaranteed. As a result, fertilizer P consumption is significant in this region of North America.

Sources of Phosphorus

Most people think of fertilizer P when discussing sources of this nutrient, but there is a growing supply of P available in livestock manure because of the rapid expansion of the swine and beef cattle feeding industry in western Canada. Each of the commercial fertilizer and manure sources provides differing levels of total P and soluble (inorganic) P that is plant-available in the year of application (**Table 1**).

Rock Phosphate

Rock phosphate is derived from processing and concentrating the sedimentary minerals known as apatites. Apatites are stable calcium phosphate minerals, similar to

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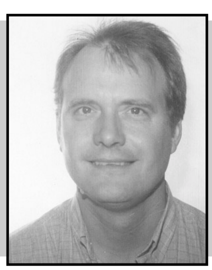

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Table 1. Phosphorus content and plant-available P of various P sources.

Source	Total P_2O_5	Water-soluble P_2O_5, %
Rock phosphate (RP)	27 to 41%	0
Monoammonium phosphate (MAP)	48 to 55%	90-100
Diammonium phosphate (DAP)	46 to 53%	90-100
Ammonium polyphosphate (APP)	34%	100
Livestock manures[1]		Plant-available, %
Swine manure - liquid	9 lb/1,000 gal	50
Swine manure - solid	9 lb/ton	50
Beef - solid	4 lb/ton	50
Dairy – liquid	6 lb/1,000 gal	50
Poultry - solid	26 lb/ton	50

[1] Nutrient value of manure sources from Saskatchewan Agriculture & Food survey, published in *Nutrient values of manure*, FarmFacts, March, 1999, Regina, SK.

the insoluble calcium phosphates naturally occurring in prairie soils. Phosphate ions (PO_4) are strongly bound to calcium (Ca) ions, and must be released to soil solution before plant uptake. Similarly, RP fertilizers are not available unless their solubility can be increased, either by an acidic soil environment or by treating with acid. As a result, RP will be more effective on acid (low pH) soils with a low Ca concentration. Because most of our prairie soils have neutral or higher pH, and because they are also rich in Ca, RP is a poor choice for a P fertilizer.

The poor performance of RP is illustrated in **Figure 1.** It shows the response of barley and canola grain yield in Alberta to application of MAP and RP on a P-deficient soil. Even when RP was applied at 80 lb P_2O_5/A, the crop yield response was still less than with 20 lb P_2O_5/A applied as MAP.

Several years ago research scientists with Agriculture and Agri-Food Canada conducted a series of greenhouse studies to compare 17 sources of RP to MAP and triple superphosphate (TSP; 0-45-0). They found that the effectiveness of the various RP sources differed considerably. The most and least effective RP products are compared to MAP and TSP in **Table 2**. It is important to note

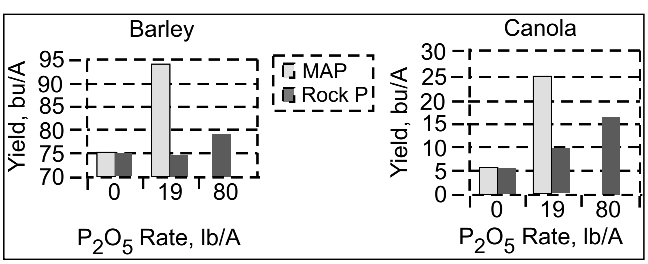

Figure 1. Influence of MAP and RP on yield of barley and canola at two locations in Alberta.
Alberta Agriculture Data (1994)

that the soil pH in this study was low (pH = 5.3), giving an advantage to the RP with regards to solubility relative to the more common high pH, calcareous soils found in most of western Canada. When applied at 10 times the rate of MAP or TSP, the RP from Christmas Island was almost as available to the test wheat plants, while the RP from Idaho was less than half as available.

Table 2. Phosphorus fertilizer source influences wheat dry matter yield and P uptake in a southern Alberta soil.

P source	P_2O_5 rate, mg/pot	Yield, g/pot	P uptake, mg
Control	0	0.89	1.50
MAP (11-48-0)	25	2.51	4.19
TSP (0-45-0)	25	2.78	4.21
RP (Christmas Island)	250	2.39	3.59
RP (Idaho)	250	1.08	2.22

Soil pH = 5.3; soil test P = 0.5 parts per million (ppm).
Agriculture and Agri-Food Canada Data.

This type of response is typical, as the mineral composition of the various RPs differ, with some being more chemically reactive and available than others. Fine grinding the RP in an attempt to improve its effectiveness has resulted in an improved rate of dissolution. However, problems in application of this fine powder lead to granulation and subsequent decreased effectiveness. Regardless of its reactivity, RP is still not as available as P fertilizer and as a result needs to be applied at much higher rate to meet crop requirements.

Commercial Fertilizer

Phosphate fertilizers such as MAP, DAP, and APP are formulated by treating RP with strong acids (acidulation) to increase water solubility and plant availability. The result of this reaction is phosphoric acid (green acid), which, when reacted with ammonia, results in ammonium-based fertilizers like MAP and DAP. Production of APP requires pyrophosphoric acid (made by dehydration of green acid), ammonia and water. Ammonium phosphate fertilizers are 90 to 100 percent water soluble, and their high plant-available P content minimizes shipping, handling, and storage costs. Fertilizers containing combinations of P and ammonium N are important. Research has shown increased P uptake by crops when combined with ammonium. While DAP (with 18 to 21 percent N) is the most common P fertilizer in the U.S., MAP (with 11 to 13 percent N) application with the seed is favored on the Canadian prairies because DAP can cause germination problems due to ammonium toxicity. Also, in the high pH soils of western Canada, DAP forms reaction products that are of lower solubility, reducing plant uptake relative to MAP.

How efficient is fertilizer P? Agronomists often tell farmers that crops utilize 10 to 30 percent of the fertilizer P in the year that it is applied, with the remaining believed to become rapidly fixed or bound within the soil in forms unavailable for plant uptake. These so-called fixed forms of P are often forgotten and thought to be of negligible economic value to future crops. However, research in western Canada has shown that total P use is far more efficient over time than we might think, and much of the fixed P in fact becomes slowly available for plant growth for many years to come.

To understand the role of residual fixed P in meeting crop nutrient requirements, we need to first consider the fate of applied fertilizer P. When P is added to the neutral or calcareous soils common to western Canada, the fertilizer granule quickly dissolves in the soil water, forming a P-saturated solution. As this solution moves into the surrounding soil, it can dissolve other ions, like Ca or magnesium (Mg). The P may then precipitate with these ions, forming less soluble forms (Ca and Mg phosphates), or may be adsorbed to the surfaces of clay particles. Both adsorbed P and newly formed Ca and Mg phosphate minerals, also referred to as labile P, readily supply P to the soil solution for uptake by plants. However, a routine soil test typically measures only a component of the labile P.

Researchers have shown the formation of Ca and Mg phosphates is very rapid and largely complete within four to eight weeks. With time, and depending on the soil environment, other less soluble fertilizer reaction products will eventually form. Over several years the fertilizer P could form an apatite-like product, a stable, insoluble Ca phosphate mineral that will not supply enough P to support crop growth.

How long will fertilizer P remain available for crop growth? Researchers in Manitoba have reported that large batch applications of P are effective in supplying the annual needs of crops for extended periods of time. A high rate of P applied at the beginning of the study supplied P to wheat for the next eight years as efficiently as P applied at planting with the seed (**Figure 2**). Over the eight years of this study, 40 lb P_2O_5/A applied annually at seeding gave the same yields as 205 lb P_2O_5/A broadcast-applied only once at the beginning of the study. Annual application of P_2O_5 in addition to the initial broadcast application in 1966 did not provide any additional yield response. These results show that P was not permanently fixed to the soil in an unavailable form and effectively met crop requirements.

Residual P in the soil may also build up with regular additions of small amounts of fertilizer over an extended period of years. Research conducted in Alberta evaluated annual applications of 34 to 41 lb P_2O_5/A to direct-drilled barley from 1979 to 1986 (**Figure 3**). In the first four years of the study, seed-placed P produced a better yield response than broadcast application. However, after four years of building soil P from repeated applications, broadcast treatments during the period 1983-86 were as effective as P applied with the seed.

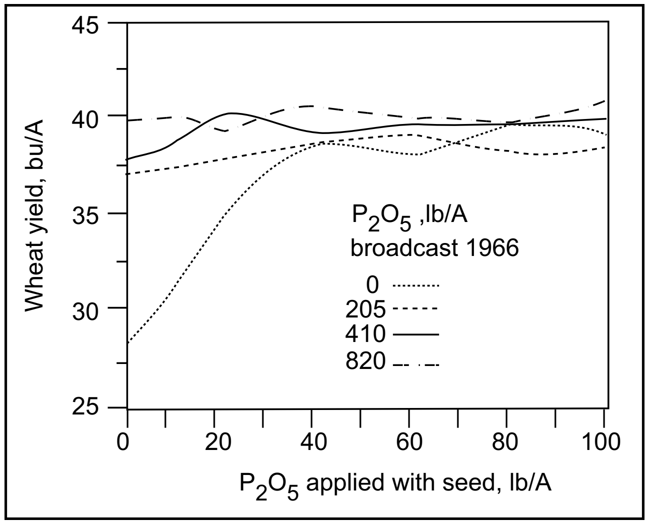

Figure 2. Wheat response to batch applications of P broadcast once was as effective as eight annual applications at planting with the seed in Manitoba. (Read et al. 1973)

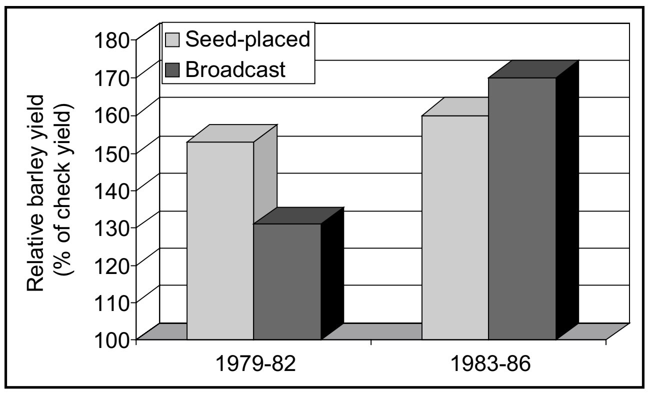

Figure 3. Low rates (34 to 41 lb P_2O_5/A) of seed-placed and broadcast P build soil P and increase barley yield relative to the unfertilized check in Alberta. (Mayko et al., 1987)

When using low rates, it is more effective to band-place fertilizer P than to broadcast. Since P fertilizer reacts readily with soil constituents to become fixed, it cannot move very far in the soil to plant roots. In fact, at best, P moves through the soil only a few inches or less from where it is placed. Therefore, placement of low rates close to where early root growth takes place, such as in the seed row or side band, is most effective for plant uptake.

Do ammonium phosphate fertilizers vary in their field performance?

Evaluations of ammonium P sources have found that those fertilizers containing greater than 60 percent water-soluble P are effective in meeting plant requirements during the growing season. However, those soil and production conditions that favor fertilizer products with a water-solubility of greater than 60 percent include low-P soils, high pH soils, short-season crops and starter P applications…all factors of concern on the Canadian prairies. So, selecting a P fertilizer source with a solubility of 90 to 100 percent is critical to achieving suitable agronomic responses.

Research trials have shown orthophosphate fertilizers (MAP and DAP) have been found to be equally effective as a P source with polyphosphates (APP) under most production conditions. Any advantage to one form over another would be related to handling and storage characteristics of the specific materials, and not any improved agronomic performance. The exception would be where seed placement of the fertilizer P could result in germination damage. The physical form of a P fertilizer (dry, fluid or suspension) does not affect P availability or agronomic effectiveness. As always, fertilizer placement and application timing are much more important than P fertilizer form.

Livestock Manure

Animal manures are a valuable source of plant nutrients, but their use as fertilizers and soil amendments requires special management. A major difference between animal manure and fertilizer is that some of the nutrients in manure are in the organic form and must go through a decomposition process (mineralization) before they are converted to plant-available inorganic forms. In some instances, such as solid manure forms, this organic fraction can be large and have a significant impact on changing soil organic matter, tilth, and long-term fertility status.

While manure is an excellent source of nutrient, it does come with challenges to the farmer intending to use it as part of a nutrient management plan.

Manures are variable in their nutrient content, forms and balance. Factors such as animal type, feed and feed supplements used, and manure storage, handling and processing all influence manure composition and characteristic behavior when applied to the soil as a fertilizer (**Table 3**). This requires that where manure is being used, a good knowledge of its composition is needed before application, thereby allowing application rates to be adjusted for crop production requirements.

The balance and supply of nutrients from manure are not like those found with commercial fertilizer and may not match the pattern of uptake for many annual crops. Manures, especially cattle manure, may be higher in P relative to N than would commonly be applied to a cereal or oilseed crop. As a result, if manure is applied based on meeting crop N requirements year after year, an excessive amount of P may be applied. Also, given that a large proportion of the P in manure is in the organic form (50 to 90 percent), crop recovery of the total P is in the range of 50 percent of a similar rate of inorganic fertilizer P (**Table 1**). Manure P tends to be readily fixed in calcareous soils (common to the western Canadian prairies) by sorption and precipitation reactions. Repeated application of manure at high rates over a number of years would be expected to eventually saturate the P sorption sites in the soil and lead to potentially large increases in the labile, plant-available portion of P detected by soil testing (**Table 4**).

Table 3. Typical manure contents in liquid swine effluent and fresh cattle pen manure samples in Saskatchewan.

Nutrient	Liquid swine manure (feeder hogs), lb/1,000 gal	Fresh cattle penning manure (straw bedding), % on dry weight basis
Nitrogen (N)	15 – 50	0.5 – 1.5
Phosphorus (P_2O_5)	2.3-46	1.2-3.5
Potassium (K_2O)	9.6-24	1.0-1.8
Sulfur (S)	0.1 – 3.0	0.08 – 0.15
Copper (Cu)	0.05 – 0.5	0.01
Manganese (Mn)	0.05 – 0.5	0.02
Zinc (Zn)	0.05 – 1.0	0.02
Boron (B)	0.01	0.005

Source: Schoenau, 1998-00

Table 4. Labile soil P in a loamy Black Chernozemic soil (0 to 6 in.) after four years of feedlot cattle penning manure application at 3.6 t/A/yr. and 14.4 t/A/yr.

Manure treatment	Resin P, lb/A	Olsen P, lb/A
Control	28.8	19.2
3.6 t/A/yr. for 4 years	62.6	26.4
14.4 t/A/yr. for 4 years	119.8	49.0

Source: Qian and Schoenau, University of Saskatchewan, 2001.

The low nutrient content per unit or volume of manure often limits the economic transport to a small area around the livestock facility. Very seldom is fresh manure hauled greater than 10 miles in any direction, something that can pose a problem of nutrient accumulation around intensive livestock facilities where feed is imported from outside the farm. Composting manure, while an added cost, has the potential to reduce hauling costs by as much as 75 percent compared to fresh manure. The accumulation of high levels of P in surface soils poses a major challenge to livestock producers, particularly in areas where the soils are prone to erosion.

Knowing the amounts and forms of nutrients in manure, being able to predict their fate, and managing the manure nutrient to obtain maximum crop benefit are critical issues in nutrient management planning.■