RECENT ADVANCES IN P FERTILIZER TECHNOLOGIES—POLYMER COATINGS

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Phosphorus fertilizers are an essential part of plant production and have been recognized as such for well over 100 years. Phosphorus utilization by crops is related to both soil availability as well as an individual plants metabolic process that allows P to be taken up by a plant as well as utilized for a wide variety of developmental processes.

Growers and researchers have always been interested in the ability to deliver P to plants in a more productive efficient form or manner. Because of this interest P fertilizers are much more available to plants than they have ever been in modern production agriculture. However, P fertilizer recovery within the initial years of application still remains within the range of 5 to 25%. With this being said----The ability to increase the relative P fertilizer use efficiency has increased, but can still be improved.

Phosphorus soil relationships are complex and even after 50 years of research remain difficult to explain and to account for what a grower applies to a field and what is recovered within a plant. Phosphorus is adsorbed to the clay particles of soil and form aluminum or iron oxides in acid soils or precipitated with $CaCO3$ in calcareous soils. It appears that P sorption occurs across the face of calcite surfaces creating a multi-layer affect. As the process progresses there become lateral bonds or interactions with other Ca compounds or precipitates creating P/ Ca clusters. As these clusters continue to develop through additional P sorption, they become the heterogeneous nucleus of calcium phosphate crystallites on the calcite surface. Western soils with high amounts of exchangeable Ca will have a tremendously large capacity to create unavailable forms of P. It has been estimated by Lindsey and others that there are over 32 forms of phosphate that can be identified by soil x-ray crystallography. The nature of the reaction compounds formed when phosphorus fertilizers are added to the soil depends in part by the soil characteristics. In acid soils aluminum and iron will usually precipitate the P. In calcareous soils Ca and Mg will form insoluble or slowly soluble precipitates of di-calcium or tri-calcium phosphates. It also appears that the longer the P remains in the soil the more likely it is to decrease in availability and move towards more insoluble forms including appatite.

Concerns have always been to increase P uptake in a plant and relate these increases to plant growth and development. These same concerns take on new meaning as the fertilizer industry and agriculture practices are becoming more scrutinized relative to environmental concerns. Anything growers, researchers and policy makers can do to improve P availability can decrease community concerns associated with P fertilizer applications on non-target areas.

Phosphorus fertilizer becomes available to a growing plant by means of diffusion. Root contact with soils and soil water that have adequate levels of available P at critical plant developmental times are essential for reaching a crops maximum yield potential. Historically changes have taken place in either P fertilizer chemistry to increase P fertilizer solubility or P placement to create better P to root contact with developing roots of a growing plant. Many management strategies include combinations of both practices. These strategies over the years have served growers and crop advisors well. However, even under the best of conditions P recoverability from the initial seasons P applications remain relatively low. The question remains: what else can be done to improve P fertilizer uptake when growers are focused on high yields and high net dollar returns?

Sanders and Murphy (2004) have indicated promise in helping to answer this question by focusing some attention on the use of high exchange resins or polymers. Additional efforts by Grant et al (2005) and Westermann (2003) indicate that temperature dependent coatings allow P fertilizer to move slowing from the P fertilizer granule into the soil by osmosis. This process by-passes some of the immediate precipitates that normally form when soluble P fertilizer granules are introduced into a calcareous soil. Preliminary work done by Agriculture Canada in MB and SK, shows promise in some cropping systems for this P fertilizer technology (Table 1). This P fertilizer product is being developed by Agrium and called Controlled Release Phosphorus (CRP). Stark (2000) has also indicated some promise with this technology within a potato cropping system. He indicates the challenge is releasing the P fertilizer within the first few stages of plant growth when the initial root system is being developed. A suggestion would be to combine both a soluble portion of the P fertilizer with a CRP. This management strategy would combine immediate P availability with long-term P nutrient demands within the growing season. Westermann, also indicates that the CRP would also have availability into the second season of application. David McArthur working with University of British Columbia suggests that CRP maybe dependent on soil type as well as moisture movement through porous materials 2005.

The high capacity exchange resins have been initially evaluated by Kansas State University (Lamond 2003, and Gordon 2005). The polymers they evaluated are composed of long-chain molecules with highly active adsorbent sites. They are within the family of dicarboxylic acid co-polymers and marketed by J.R. Simplot Company and in cooperation with Specialty Fertilizer Products under the name of AVAIL®**.** Avail is water soluble, but appears to move only a small distance from the point of contact. The uniqueness of the chemistry allows the polymer to be applied at fairly small application rates and to the outside of a P fertilizer granule. The technology can be applied at either the point of manufacture or within the P fertilizer distribution chain including the local retail outlets. Avail is applied on dry P fertilizer at a rate of .5 gallons (2.4 liters)/ton of fertilizer material. It is suggested that Avail only be applied on the P fertilizer and then combined with other nutrients for a complete blend. The process is similar to impregnating a pesticide onto a fertilizer.

A substantial data set has been developed over the past few years at various Universities, private and federal research groups. Some of this information will be presented in the following figures and tables.

Corn responses have been observed over a five year period that extends the initial efforts from Kansas State University (Gordon 2005). Gordon observed increased plant P uptake, initial plant developmental vigor as demonstrated by increased early corn growth and development. These efforts also demonstrated consistent yield benefits from both added P and the Avail treated P fertilizer (Figure 1). Blevins and Randall in separate studies evaluated P technology across different soils with similar improvements in both P uptake and yield improvements (Tables 2 and 3). There are year by treatment interactions that are normal when dealing with P fertilizer nutrition. However, the overall data set clearly demonstrates yield potential improvements when Avail is compared to similar P fertilizer treatments without the Avail.

Wheat responses have also been observed in Arkansas, Texas, Kansas and Australia. Increases in P removed within the biomass indicate early P uptake that is sustained through crop development and can be reflected in yield and quality improvements as well as change in soil test P (Table 4).

Internal field evaluations have also been conducted on many crops over the 2004 and 2005 growing season across several geographic areas. While not all trials indicated a positive response to applied Avail, many did. The most impressive data was obtained on irrigated potatoes being produced on a medium to high soil test P with high background levels of Ca. Avail was applied in combination with 10-34-0 and Zn as part of a planter band at a rate of 25 gallons/ac. Avail was compared to the grower's standard practice that did not include Avail. These treatments were applied with three replications. Yield improvements of over 2 tons/ac were observed in both Russet Burbank and Russet Norkotah potatoes. The latter variety is an earlier maturing potato that is harvested the middle of August while the Russet Burbank is harvested the end of September. Both varieties showed a significant increase in larger > 8 oz tubers that are more profitable for the producer, when the Avail material was applied. Research efforts by Jeff Stark and Bryan Hopkins also support these efforts with the University of ID (Table 5).

Sugarbeets also have shown improvements in sugar content, yield and ROI with Avail technology combining P fertilizer solutions with Avail in North Dakota (Table 6).

We continue to be encouraged with both replicated studies as well as field studies where Avail or controlled release phosphorus has been used. Current number of acres where the material has been applied is approaching 100,000. Work will continue to evaluate rates, timings and polymer formulations as efforts continue to explore the opportunities for these types of P efficiency improving products.

Table 1--AGRIUM CRP EFFECTS ON CROP EMERGENCE

Rate of P	% Emergence 20 days After Planting					
	Canola		Flax		Alfalfa	
lb P_2O_5/ac	MAP	CRP	MAP	CRP	MAP	CRP
0	96a	90a	69a	60a	71a	64a
20	90ab	92a	64ab	56a	66a	60a
40	69c	96a	44c	60a	45b	63a
60	48d	92a	23d	60a	26c	51a
80	46d	94a	10e	50a	11d	71a

$P < 0.05$, Soil pH = 7.4. Jeff Schoenau et al., U. of Saskatchewan.

Table 2. Corn Response To Enhanced P Availability--Missouri

Treatment	Grain Yield bu/A	ROI
Control, no P	135	
MAP broadcast	132	
MAP + polymer broadcast	151	
MAP banded	132	
MAP + polymer banded	157	90:1
LSD (0.10)	13	

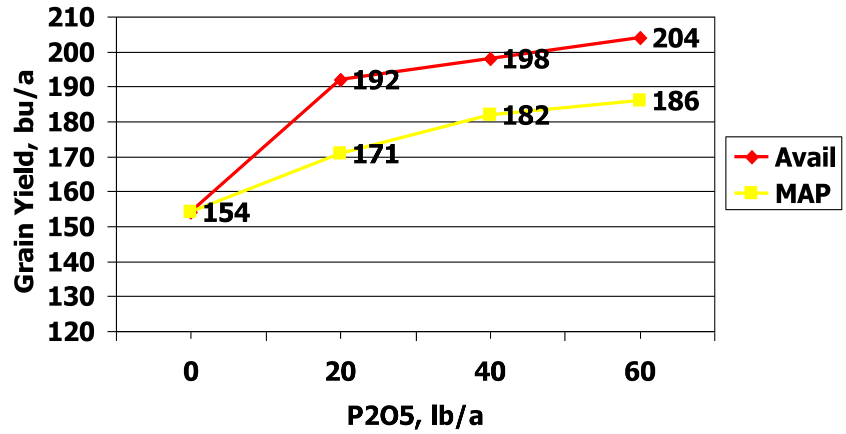
1% polymer coating Dale Blevins, Univ. of Missouri
20 lb P_2O_5/A Soil test Bray P-1: 7 ppm pH: 5.9

Table 3. ENHANCING P AVAILABILITY FOR CORN Minnesota

P Source lb P_2O_5/A	P Uptake V-6 g/12 plants	Yield bu/A
0	1.85	136
25 DAP	1.77	151
25 DAP + polymer	2.72	172
50 DAP	2.17	155
50 DAP + polymer	2.47	175
LSD (0.10)	0.71	18

P broadcast, 0.25 % polymer coating. Randall, Univ. of Minnesota
Soil pH: 7.3 Soil test P: 7 ppm Olsen.

Avail Effects on Corn Grain Yield 2001-2003 Kansas—Fig. 1



Barney Gordon, KSU

Table 4. AVAIL EFFECTS ON SOIL TEST P

Treatment lb P_2O_5/A	Bray P-1 lb/A
0	29.5
50	54.0
50 + Avail	73.2
$LSD_{.10}$	6.7

Soybeans. pH = 6.0 D. Dunn, U. of Missouri

Table 5. Potato Yield and Return Responses to Enhanced P Availability

Treatment Applied	Yield CWT/A	Petiole P%	Gross Return
Control	311a	.225d	1456
MAP 60 lb P205/Ac	330ab	.253cd	1546
MAP 120 lb P205/Ac	344bc	.275bc	1591
MAP + Exp 60 lb P2O5/A	339ab	.288ab	1575
MAP + Exp 120 lb P2O5/A	369c	.308a	1791

Calcareous soil, Aberdeen, ID   Jeff Stark, University of Idaho

Net $ return SSP w/Avail at 120 lbs/ac P2O5==$190.40

Table 6. Avail on Sugarbeets – SGS 2005 N. Dakota

Avail Test	Tons/Acre	Sugar %	RSA	Net $/A
Check	25.98	17.86	8654	$ 987.23
Avail 1%	26.44	17.78	8784	$ 993.01
Avail 1.5%	28.37	17.61	9236	$ 1028.74
Avail 2%	27.26	17.75	8943	$ 1004.47

- Increased yield due to better plant vigor and better plant population