IMPROVING PHOSPHORUS USE EFFICIENCY WITH CARBOND® P AND DICARBOXYLIC ACID POLYMER (AVAIL®) FERTILIZER ADDITIVES

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ABSTRACT

Improving phosphorus (P) use efficiency (PUE) is desirable but difficult due to poor P solubility in soils. Two relatively new fertilizer additives possibly increase PUE by increasing P solubility. A dicarboxylic acid copolymer (AVAIL®) increases P solubility by sequestering interfering cations. An organic acid based fertilizer (Carbond® P; 7-24-0) increases P solubility through complexation of P. The mode of action of both additives is thought to be related to minimization of P precipitates in soil. Field trials on potatoes with both products have shown significant results. AVAIL trial: Monoammonium phosphate (MAP; 11-52-0) at 67 kg P_2O_5 ha^{-1} was applied with or without AVAIL addition and compared to an untreated check applied to five potato field sites. MAP+AVAIL resulted in significant US No. 1 and total yield increases at two and three sites, respectively. Generally, the other sites showed similar trends. However, MAP+AVAIL resulted in a significant decrease in yields at one site, possibly due to a P-induced micronutrient deficiency. Petiole P concentration of MAP+AVAIL-treated plants was significantly greater than the other treatments at mid and late season sampling dates at all sites. Carbond P trials: A replicated strip trial was performed in a commercial potato field in 2009 with Carbond Ignite (3-12-12) applied in-furrow at planting and compared to untreated strips. The plant canopy closed 3-5 days earlier in the calcareous areas, tuber numbers were increased 13-28%, and yield increased 61 to 153 hundredweight per acre with Ignite application. Strip trials performed in three Idaho fields in 2010 showed positive results for Carbond P over ammonium polyphosphate (APP; 10-34-0) and MAP. The MAP was broadcast applied at 200 lb P_2O_5 per acre incorporated with tillage. Both APP and Carbond P were applied in a concentrated band 2-4 inches to the side of the seed piece at 30 or 50 gallons per acre of APP and Carbond P, respectively. The low rate of Carbond P had the greatest increases of all treatments; yielded 52, 51, and 57 hundredweight per acre more than the low rate of APP for US No. 1, marketable, and total yields, respectively. Petiole P concentration increased significantly with Carbond P over APP. These results are similar to those observed in other crops in both greenhouse and field trials with maximum yields being reached at relatively lower rates of P when supplied as Carbond P. Both enhanced efficiency fertilizer products, Carbond P and Avail, seem to effectively increase P solubility and have the potential to increase yields in low to medium P testing soils, especially with reduced rates of P fertilizer and if other nutrients are not out of balance.

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PHOSPHORUS USE EFFICIENCY AND MANAGEMENT

Efficient fertilization is essential for providing adequate food, fiber, and fuel for society (Hopkins et al., 2008, 2010a, b, c). Increasing the percentage of phosphorus (P) from fertilizer that is utilized by plants is important for reducing environmental impacts and consumption of non-renewable P mineral resources. However, improving PUE is challenging due to inherent inefficiencies in the soil-plant system that leads to precipitation of fertilizer P with interfering cations—resulting in recoveries of near zero to less than 30% of applied P fertilizer (Murphy and Sanders, 2007). A number of rate, timing, and placement options can be used to improve PUE.

Applying a rate of P that is neither deficient or excessive is important in optimizing maximum economic yield for potato production. Ideally, research based recommendations validated through on-farm yield trials should be followed. University of Idaho fertilizer recommendations (Stark et al., 2004) for potato suggest and Hopkins et al. (2010a) found that potato grown in low to medium P concentrations should receive a combination of dry P fertilizer broadcast and incorporated and liquid P fertilizer in a concentrated band at three inches to the side and below the seed piece in order to achieve maximum economic yield. The broadcast application can be reduced to zero at higher soil test levels (Stark et al., 2004), but a removal rate (~40-50 lb P_2O_5 per acre) should likely be applied even at moderately high soil test P levels. No P fertilizer should be applied at excessively high soil test P levels.

Although many nutrients are mobile in soil and are effectively applied in-season in an effort to spoon-feed the plant, P is not mobile in soil due to the rapid formation of calcium and magnesium phosphate precipitates in alkaline soils common in Idaho (Hopkins et al., 2008). As such, in-season applications are less effective than when P is incorporated into the rooting zone (Hopkins et al., 2010a, b, c). If petiole tissue samples indicate P deficiency, in-season applications can be made with resulting increases in yield and tuber quality. However, adjustments should be made in future years to add relatively higher amounts of P fertilizer to soils in which plants growing in them tend to be P deficient despite following the generic P fertilizer recommendations. In effect, this process represents a customization of the P fertilizer recommendations for the specific soil, environment, and management conditions unique to each field. In addition to the practices suggested above, fertilizer manufacturers have sought to engineer materials to enhance PUE. Two such products have recently been evaluated are discussed below.

AVAIL

One approach to enhance PUE is to minimize the concentration of potentially reactive cations in the immediate vicinity of the P fertilizer in soil. A new fertilizer additive (AVAIL®[1], Specialty Fertilizer Products, Leawood, Kansas) purportedly creates a water-soluble shield that surrounds the P in fertilizer when it is applied to soil (Dunn and

[1] Mention of a trade name or commercial company does not imply endorsement by the author or his institution.

Stevens, 2008; Murphy and Sanders, 2007). Hopkins (2011) reviewed the proposed mode of action for AVAIL, which purportedly is a high-charge density compound that sequesters interfering cations, thus, reducing the interaction with P by reducing crystalline structure and minimizing precipitate formation.

Hopkins (2011) reported on a two-year study with Russet Burbank potato fertilized with monoammonium phosphate (MAP; 11-52-0) at 50 lb-P_2O_5/ac applied with or without AVAIL addition and compared to an untreated check on five field sites. MAP+AVAIL resulted in significant US No. 1 and total yield increases at two and three sites, respectively. Generally, the other sites showed similar trends. In fields with positive increases, MAP+AVAIL yields were 12-36 and 35-50 hundredweight per acre greater than MAP without AVAIL for US No. 1 and total yields, respectively. However, MAP+AVAIL resulted in a significant decrease in yields at one site (128 and 92 hundredweight per acre)—possibly due to a P-induced micronutrient deficiency. Petiole P concentration of MAP+AVAIL-treated plants was significantly greater than the other treatments at mid and late season sampling dates at all sites.

Research performed at the University of Idaho on Russet Burbank potato during 2005-2009 resulted in MAP+AVAIL having generally greater US No. 1, marketable, and total yields than MAP without AVAIL for both fall and spring P applications (Jeff Stark, personal communication, 2010; Murphy and Sanders, 2007). The P uptake and petiole concentrations in these studies were not statistically different for AVAIL treatment, although Stark states that, similar to Hopkins (2011), the trends were in the same direction as those for yield. Stark also states that there is evidence of enhanced PUE with MAP+AVAIL in his studies (i.e. yields optimized at lower rates of AVAIL-treated P fertilizer as compared to untreated).

However, studies with Ranger Russet potato at Oregon State University have shown no improvement from MAP+AVAIL treatment applied to medium soil test P soils (Don Horneck, personal communication, 2010). At the University of Wisconsin, researchers found mixed results with AVAIL treatment of TSP and MAP (Laboski et al., 2007; Laboski and Andraski, 2009; Repking and Laboski, 2008). In these studies, AVAIL treatment with P fertilizer did not generally result in increased yields or tuber quality. However, most of these fields had very high soil test P concentrations. The only field showing a distinct yield response was also the lowest soil test P field in these studies, suggesting that enhanced P availability is only likely to improve potato yields on low P testing soils.

CARBOND P

A relatively new product (Carbond® P; 7-24-0; Land View Inc., Rupert, Idaho) engineered to enhance PUE is a complexation of P with organic acids. This complexation is thought to keep P more readily plant available after applied to the soil. Hill et al. (2011) showed substantial and consistent increases in P solubility with Carbond P over ammonium polyphosphate (APP; 10-34-0) and MAP during sampling times ranging from 24 to 365 days. The trial was conducted on three different Idaho soils (alkaline sand,

calcareous sand, and calcareous loam) with both broadcast and banded applications; with the results similar for all soils and application methods. Follow up greenhouse studies showed that several species increased early season biomass growth and P uptake with Carbond P over APP (Hill et al., 2011).

A replicated strip trial was performed in a commercial potato field in 2009 with Carbond Ignite (3-12-12), which has identical P chemistry as Carbond P. Ignite was applied in-furrow at planting and compared to untreated strips. The plant canopy closed 3-5 days earlier in the calcareous areas of the field with Ignite application. Tuber numbers were increased 13-28%. Early harvest (12 days prior to grower harvest) results showed a 61 hundredweight increase in total yield with Ignite application. Final harvest results (conducted by the grower and Land View) showed a 153 hundredweight per acre increase in yield with Ignite application.

Strip trials performed in three Idaho fields in 2010 also showed positive results for Carbond P over APP and MAP on medium P testing calcareous soils. The MAP was broadcast applied at 200 lb P_2O_5 per acre incorporated with tillage and the APP and Carbond P were applied in a concentrated band 2-4 inches to the side of the seed piece at 30 or 50 gallons per acre, resulting in 119 or 199 and 74 and 124 lbs P_2O_5 per acre for APP and Carbond P, respectively. The highest US No. 1, marketable (US No. 1 and US No. 2), and total yields were all highest for the low rate of Carbond P. The low rate of Carbond P yielded 52, 51, and 57 hundredweight per acre more than the low rate of APP for US No. 1, marketable, and total yields, respectively. These results are similar to those observed in other crops in both greenhouse and field trials with maximum yields being reached at relatively lower rates of P when supplied as Carbond P.

DISCUSSION

Both Carbond P and Avail result in increased P solubility and increases PUE. As a result, there are several reported studies showing that AVAIL addition to P fertilizer and Carbond P results in a yield and/or crop quality increase, often with increases in plant tissue P concentration. It is not surprising that most of these studies show that soil test P and P fertilizer rate does have a role in whether or not there is a response to these enhanced efficiency P fertilizer products—with responses more likely with low soil test P and/or at low fertilizer P rates.

Using these enhanced efficiency fertilizer products can, however, result in negative responses if P is excessive. With potatoes, excessive plant available P has been shown to reduce yields (Barben et al., 2010 a, b, c, d; Christensen and Jackson, 1981; Hopkins et al., 2010a; Soltanpour, 1969). This effect is most likely due to induced deficiencies of zinc (Zn) and/or manganese (Mn) (Barben et al., 2010a, b, c, d) or possibly copper and/or iron (Barben et al., 2010a; Moraghan and Mascagni, 1991). Barben et al. (2010a) thoroughly discusses the many other species where this effect has been observed, along with possible explanations for the effect. Loneragan et al. (1979) and Moraghan and Mascagni (1991) discuss the possible mechanisms for this apparent P toxicity (or more aptly described as a P induced micronutrient deficiency). In light of these many

observations of P-induced micronutrient deficiencies in potato and the fact that AVAIL and Carbond P have been shown to enhance P solubility, it is entirely possible that they can increase P solubility to the point of causing a P-induced micronutrient deficiency. We believe this was the case in the negative responding field in Hopkins (2011) study, which had relatively high soil test P and marginal soil test Zn and Mn concentrations. Although not as dramatic as the AVAIL study, Carbond P studies consistently show yield drop off at high rates of P. We recommend that: 1) P fertilizer be applied based on soil test and research based recommendation tables, 2) excessive P be avoided, 3) Zn and Mn fertilizer be applied based on soil test, especially when using high rates of P, and 4) reduced rates (~30% reduction) of P fertilizer be used when using enhanced efficiency fertilizer products, such as AVAIL and Carbond P.

REFERENCES

Barben, S.A., B.G. Hopkins, V.D. Jolley, B.L. Webb, and B.A. Nichols. 2010a. Optimizing phosphorus and zinc concentrations in hydroponic chelator-buffered nutrient solution for Russet Burbank potato. *Journal of Plant Nutrition* 33: 557-570.

Barben, S.A., B.G. Hopkins, V.D. Jolley, B.L. Webb, and B.A. Nichols. 2010b. Phosphorus and manganese interactions and their relationships with zinc in chelator-buffered solution grown Russet Burbank potato. *Journal of Plant Nutrition* 33: 752-769.

Barben, S.A., B.G. Hopkins, V.D. Jolley, B.L. Webb, and B.A. Nichols. 2010c. Phosphorus and zinc interactions in chelator-buffered solution grown Russet Burbank potato. *Journal of Plant Nutrition* 33: 587-601.

Barben, S.A., B.G. Hopkins, V.D. Jolley, B.L. Webb, B.A. Nichols, and E.A. Buxton. 2010d. Zinc, manganese and phosphorus interrelationships and their effects on iron and copper in chelator-buffered solution grown Russet Burbank Potato. *Journal of Plant Nutrition* (Accepted for publication March 25, 2010).

Christensen, N.W. and T.L. Jackson. 1981. Potential for phosphorus toxicity in zinc-stressed corn and potato. *Soil Science Society of America Journal* 45: 904-909.

Dunn, D.J. and G. Stevens. 2008. Response of rice yields to phosphorus fertilizer rates and polymer coating. Available at http://www.plantmanagementnetwork.org./cm/element/sum2.aspx?id=6946 (verified 5 October 2010). *Crop Management*. doi:10.1094/CM-2008-0610-01-RS.

Gordon, W.B., and T.A. Tindall. 2006. Fluid P performance improved with polymers. *Fluid Journal* 14: 12-13.

Hill, M., B.G. Hopkins, C. Ransom, B.L. and Webb, B. L. 2011. Improving phosphorus use efficiency with Carbond P. In: J. Davenport (ed.) *Western Nutrient Management Conference Proceedings*, 9th, Reno, Nevada. 3-4 March 2011. (*In Press*).

Hopkins, B.G. 2011. Russet Burbank potato phosphorus fertilization with dicarboxylic acid copolymer additive (AVAIL®). *Journal of Plant Nutrition* (*Accepted for Publication*).

Hopkins, B.G., and J.W. Ellsworth. 2005. Phosphorus availability with alkaline/calcareous soil. In: W.B. Stevens (ed.) *Western Nutrient Management Conference Proceedings*, 6th, pp. 88-93, Salt Lake City, Utah. 3-4 March 2005. Potash and Phosphate Institute. Norcross, Georgia.

Hopkins, B.G., J.W. Ellsworth, T.R. Bowen, A.G. Cook, S.C. Stephens, A.K. Shiffler, and D. Eggett. 2010a. Phosphorus fertilizer timing for Russet Burbank potato grown in calcareous soil. *Journal of Plant Nutrition* 33: 529-540.

Hopkins, B.G., J.W. Ellsworth, A.K. Shiffler, T.R. Bowen, and A.G. Cook. 2010b. Pre-plant vs. in-season application of phosphorus fertilizer for Russet Burbank potato grown in calcareous soil. *Journal of Plant Nutrition* 33: 1026-1039.

Hopkins, B.G., J.W. Ellsworth, A.K. Shiffler, A.G. Cook, and T.R. Bowen. 2010c. Monopotassium phosphate as an in-season fertigation option for potato. *Journal of Plant Nutrition* 33: 1422-1434.

Hopkins, B.G., C.J. Rosen, A.K. Shiffler, and T.W. Taysom. 2008. Enhanced efficiency fertilizers for improved nutrient management: potato (*Solanum tuberosum*). *Crop Management* doi:10.1094/CM-2008-0317-01-RV.

Laboski, C.A.M., M.J. Repking, and T.W. Andraski. 2007. Potato response to phosphorus fertilizer: 2006 results. In: *Proceedings 2007 Wisconsin's Annual Potato Meeting*, 20th, pp. 177-195, Steven's Point, Wisconsin. 1-3 February 2007. University of Wisconsin, Madison, Wisconsin.

Laboski, C.A.M. and T.W. Andraski. 2009. Potato response to phosphorus fertilizers: 2008 results. In *Proceedings 2009 Wisconsin's Annual Potato Meeting*, 22nd, pp. 139-154, Steven's Point, Wisconsin, 3-5 February 2009. University of Wisconsin, Madison, Wisconsin.

Loneragan, J.F., Y.S. Grove, A.D. Robson, and K. Snowball. 1979. Phosphorus toxicity as a factor in zinc-phosphorus interactions in plants. *Soil Science Society of America Journal* 43: 966-972.

Moraghan, J.T. and H.J. Mascagni, Jr. 1991. Environmental and soil factors affecting micronutrient deficiencies and toxicities. In: *Micronutrients in Agriculture*, 2nd edition, eds. J.J. Mortvedt, F.R. Cox, L.M. Shuman, and R.M. Welsh, pp. 371-425. Madison, Wisconsin: Soil Science Society of America.

Murphy, L. and L. Sanders. 2007. Improving N and P use efficiency with polymer technology. In: *2007 Indiana CCA Conference Proceedings* (CD-AY-330), ed. T. Vyn, pp. 1-13, Indianapolis, Indiana, 18-19 December 2007. Available at http://www.agry.purdue.edu/CCA/2007/ (verified 5 October 2010). Purdue University, West Lafayette, Indiana.

Soltanpour, P.N. 1969. Effect of N, P and Zn placement on yield and composition of potatoes. *Agronomy Journal* 61: 288-289.

Stark, J.C., D.T. Westermann, and B.G. Hopkins. 2004. Nutrient management guidelines for Russet Burbank potatoes. University of Idaho Bulletin 840. University of Idaho, Moscow, Idaho.

Repking, M.J. and C.A.M. Laboski. 2008. Effectiveness of AVAIL for improving potato yield. In: *Proceedings of the 2008 Wisconsin Fertilizer, Aglime & Pest Management Conference*, 47th, pp. 133-142, Stevens Point, Wisconsin. 2-4 February 2008. Available at http://www.soils.wisc.edu/extension/wcmc/2008/pap/Repking.pdf (verified 5 October 2010). University of Wisconsin, Madison, Wisconsin.