DICARBOXYLIC ACID POLYMER (AVAIL®) PHOSPHORUS FERTILIZER ADDITIVE: REVIEW

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ABSTRACT

Improving P use efficiency (PUE) is desirable but difficult due to poor P solubility in soils. A dicarboxylic acid copolymer (AVAIL®) fertilizer additive may enhance PUE due to increased P solubility as a result of sequestering of interfering cations. Field trials have been conducted on a wide variety of crops, with results to AVAIL addition to P fertilizer mixed—seemingly related primarily to soil test P concentrations and fertilizer P rate. Positive results were seen in many of these studies, but generally only when the trials were conducted on soils with low to medium P concentrations and/or with lower rates of fertilizer P. When negative results were reported, it is suggested that these responses could be from P-induced micronutrient deficiency.

MODE OF ACTION

Efficient fertilization is essential for providing adequate food, fiber, and fuel for society (Hopkins et al., 2008). Increasing the percentage of phosphorus (P) from fertilizer that is utilized by plants (P-use efficiency or PUE) is critical 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 lead 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 (Hopkins and Ellsworth, 2005; Hopkins et al., 2010a, b, c). In addition to the cultural practices that may enhance P uptake and utilization, fertilizer manufacturers have sought to engineer materials to enhance PUE, such as with slow release coatings. Another approach to enhance PUE is to minimize the concentration of potentially reactive cations in the immediate vicinity of the P fertilizer when applied to 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 Stevens, 2008b; Gordon and Tindall, 2006; 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. Several fertilizer field trials with AVAIL are reviewed by Hopkins (2011) and summarized below.

RICE

As AVAIL is relatively new in the fertilizer market, there is a void in published research. In only one of two referred publications on AVAIL®, Dunn and Stevens (2008b) showed consistent

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

increases in rice yields, tissue and soil test P concentration, and net returns with AVAIL treated treble superphosphate (TSP) broadcast applied, but only at the lowest rate (25 lb-P_2O_5/ac) of P fertilizer used in their three-year study (Dunn and Stevens, 2008a, b). There was no additional benefit due to AVAIL at the higher rates (50 and 100 lb-P_2O_5/ac). There was a continued rate response for untreated TSP application, but the lowest rate of AVAIL+TSP resulted in yields equal to those at the highest rate of untreated TSP—suggesting an improvement PUE.

CORN AND SOYBEANS

Gordon showed corn yield and tissue P concentration increases with both monoammonium phosphate (MAP; Gordon, 2006) and ammonium polyphosphate (APP; Gordon 2008, 2009) starter fertilizer applications. However, Randall and Vetsch (2004) reported response in one year of testing with APP+AVAIL applied as a starter even though they did show responses to diammonium phosphate (DAP) plus AVAIL in two of three years at 25 and 50 lb-P2O5/ac broadcast rates. In a similar study, Gordon (2007) showed that there was an increase in yield and tissue P concentration with broadcasted MAP+AVAIL over untreated MAP when applied to soybeans.

Other research has concluded with mixed results with AVAIL applied to corn. Heiniger (2008) reported some sites giving a positive yield response but others had no response when AVAIL was added to a liquid starter fertilizer, with low soil test P sites typically being more responsive. University of Delaware researchers (Binford, 2008; Tingle et al., 2009) found no additional response when AVAIL was added to starter P fertilizer in their corn trials. This lack of response was likely due to very high soil test P in many of their sites, but some sites that were relatively lower in soil test P and showing response to starter P fertilizer also did not show response to AVAIL. In fact, some sites also resulted in a negative response to AVAIL. Ward and Mengel (2009) also showed no response to starter P plus AVAIL at low soil test P sites.

POTATO

Hopkins (2011) reported on a two-year study on Russet Burbank potato with MAP at 50 lb-P_2O_5/ac applied with or without AVAIL addition 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. 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.

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 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 has 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, 2007, 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..

COTTON, BERMUDAGRASS, SOYBEAN, BARLEY, SUGARBEET, AND CANOLA

The same researchers that found significant yield increases in rice showed no response to AVAIL treated P fertilizer with cotton (David Dunn, personal Communication, 2010). However, the soil test concentrations in their cotton trials were extremely high, whereas their rice studies were conducted on low soil test P soils. Stewart et al. (2008) found confounding results with DAP+AVAIL on Bermudagrass with no response for the first harvest, negative response for second, and a positive response for third harvest. Mooso et al. (2010) summarized the work of other researchers by calculating increases in agronomic efficiency with AVAIL treated fertilizers—showing increases of 57-77% in barley, canola, corn, and rice. Franzen et al. (2008) showed significant yield response with AVAIL added to starter fertilizer in just three of 18 sugarbeet trials conducted on low P testing soils.

SUMMARY

Chemical studies by multiple researchers suggest that AVAIL does impact P solubility in the soil (Hopkins, 2011). As a result, there are several reported studies showing that AVAIL addition to P fertilizer 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 AVAIL—with responses more likely with low soil test P and/or at low fertilizer P rates. There are notable exceptions to this statement, with Ward and Mengel (2009) and Franzen et al. (2008) both showing a surprising lack of response to AVAIL treated P fertilizer in low P test soils. Other factors could be at work in these situations that resulted in some other factor being more limiting that P fertility and/or conditions not being ideal for a P response. Another potential concern for the Franzen et al. (2008) studies is direct seed contact, which may have been a problem for this species (sugarbeet) that is known to be sensitive to salts at the seed and seedling stages.

There is another potential mechanism for causing no and, especially, negative response to AVAIL addition to P fertilizer. In potato, 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 Zn and/or Mn (Barben et al., 2010a, b, c, d) or possibly Cu and/or Fe (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 has been shown to enhance P solubility, it is entirely possible that AVAIL increased P solubility to the point of causing a P-induced micronutrient deficiency in some of these trials, such as the negative responding field in Hopkins (2011) study, which had relatively high soil test P and marginal soil test Zn and Mn concentrations. Further studies need to be conducted to determine if AVAIL results in P loading in roots and, as a result, reduces translocation of Zn, Mn, Fe, and/or

Cu when these nutrients are found in marginal concentrations in soils (Barben et al., 2010a, b, c, d).

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