IMPROVING PHOSPHORUS USE EFFICIENCY WITH CARBOND P

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ABSTRACT

Phosphorus (P) fertilizer is integral for maximizing crop production and is used abundantly to achieve desired yields. However, reduction of P fertilizer is warranted, as it is the primary source of nutrient pollution in surface waters (eutrophication leading to hypoxia) and is derived from non-renewable mineral resources. Two research studies were conducted in 2009 to evaluate a new fertilizer product, Carbond® P against traditional fertilizers ammonium polyphosphate (APP) and monoammonium phosphate (MAP). A P solubility trial to determine P flux through the soil was conducted using 7 inch soil columns with fertilizers applied either as a band or mixed with three soils at 18 or 71 lb-P_2O_5/ac. Mobility of P was evaluated at 24, 48, and 110 days after application by applying two pore volumes of water to the soil columns and analyzing for P. Carbond® P consistently had significantly greater P flux across all soil types and application rates for the banded application. For applications mixed with soil, Carbond® P and MAP had greater solubility than APP at 24 days after application, but by the later evaluation dates the Carbond® P was significantly higher than both. A glasshouse study was conducted on corn (Zea maize L.) to evaluate the plant availability of Carbond® P. Carbond® P was compared to an unfertilized control, MAP and APP at 7, 21, 63, and 154 lb-P_2O_5/ac applied diagonally (45^o), 5 cm below the seed. On average, the Carbond® P treated plants were taller (2 inches), darker green (12% more chlorophyll), and thicker stemmed (14%) than APP treated plants for all but the highest rate. The Carbond P treated plants had significantly greater (40-64%) dry matter yield than the APP plants at the lower rates as well. These growth increases were likely due to improved P uptake (43-56% more P), which is especially remarkable in that the Carbond® P product had nearly one-third less P than APP (24 and 34%, respectively). No differences between P sources were observed at the highest rate. These results suggest that at least 30% less P can be utilized when using Carbond® P in place of APP; with net increases in P uptake by corn plants resulting in enhanced growth. Further work is underway to evaluate Carbond P in field conditions, with initial results in agreement with those reported in these studies.

INTRODUCTION

Efficient fertilization is essential for providing adequate food, fiber, and fuel for society (Hopkins et al., 2008). Phosphorus (P) is an essential plant nutrient (Bennett, 1993) and an integral component in nutrient management for achieving maximum crop yields (Hopkins et al. 2008). Since P begins to precipitate instantaneously with soil application of traditional fertilizers, growers find it necessary to apply superfluous amounts in order to meet crop demands. Plants utilize from near zero to less than 30% of applied fertilizer in plant uptake (Hopkins, 2011; Randall et al., 1985). It is desirable to enhance efficiency of P because it is derived from limited nonrenewable mineral resources and is a source of nutrient pollution in surface waters (Davenport et al., 2005; Mueller and Dennis, 1996; Sharpley et al., 2003).

Increasing the percentage of 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. 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. One such approach has been developed by Landview Inc. They have developed a P fertilizer that has been complexed with organic acids in a sophisticated manufacturing process. This complexation is thought to keep P more readily plant available after applied to the soil. The purpose of our studies is to investigate Carbond® P (7-24-0) and examine P solubility and plant uptake compared to traditional fertilizers.

METHODS

P Mobility Trial

Three fertilizers were evaluated: ammonium polyphosphate (APP; 10-34-0), monoammonium phosphate (MAP; 11-52-0), and Carbond® P (CB-P; 7-24-0). The fertilizers were applied as either a banded or mixed application to three different soil types (alkaline sand, calcareous sand, and calcareous loam) at 224 or 448 lb-P_2O_5/ac and compared to an untreated control. Soil was placed in six inch soil columns and packed in uniform bulk density similar to native soils. The banded treatment was injected at 2 inches below the soil surface while the mixed treatment was applied to the soil in a separate container and mixed thoroughly before being placed and packed in the soil columns. The three replicates of each treatment were established in a RCBD. Each soil column was initially wetted to field capacity with minimal leaching and then cycled between this moisture level and a nearly constant mass air dry state through the trial—avoiding loss of moisture from the bottom of the column. Mobility of P was evaluated at 24, 48, and 110 days after application by applying two pore volumes of water to the soil columns and collecting the leachate through a soil filter attached to the bottom of the soil columns. After 110 days, each soil was removed from the column and mixed thoroughly to simulate a tillage operation and then stored under outside conditions to have freezing and thawing similar to field conditions. At the end of 365 days, the soils were extracted for a final time. The collected leachate was analyzed by ICP for P and other mineral nutrients. Statistical analysis showed no significant interactions for soil type and rate and, therefore, results were combined across these parameters.

Corn Glasshouse Trial

A glasshouse trial was conducted with corn (*Zea maize* L.) planted in containers with a calcareous sandy loam soil. An untreated control was compared to four rates of CB-P and APP at 0.6, 1.8, 5.4, and 16.2 gallons/ac of each product (based on row-foot calculations with 20 inch row spacing) resulting in 1.5, 4.4, 13.3. and 40.0 lb-P_2O_5/ac for CB-P and 2.4, 7.2, 21.5, and 64.4 lb-P_2O_5/ac for APP applied as a starter fertilizer two inches below and two inches to the side of the seed. N rate was balanced across all pots with urea ammonium nitrate—adjusted to the highest rate of APP with a total of 19 lb-N/ac. Six seeds were planted and best management practices were followed for plant growth in a glasshouse, although no additional fertilizers beyond those used in this study were applied. No pesticides were applied. Plants in each pot were thinned down to one plant per pot at 30 days after planting and fertilization. The shoots of the thinned plants were analyzed for shoot P concentration. At 42 days after planting, plants were evaluated for chloryphll with a SPAD meter, stem thickness, total shoot and root biomass, and shoot P concentration.

RESULTS AND DISCUSSION

P Mobility Trial

Results of the mobility experiment showed similar increases in P solubility for CB-P over APP and MAP for all soils and rates and, therefore, results were combined and shown for the different dates in Figure 1. The concentrated band applications, simulating a starter fertilizer application, showed that CB-P treatments consistently had significantly greater P solubility than APP and MAP for all but the comparison with APP at 365 days after application (bottom graph; Figure 1). For the mixed applications, simulating a broadcast and incorportated application, CB-P and MAP had greater solubility than APP at 24 days after application, but by the later evaluation dates the CB-P was significantly higher than both APP and MAP (top graph; Figure 1).

Corn Glasshouse Trial

On average, the CB-P treated plants were taller (2 inches), darker green (12% more chlorophyll), and thicker stemmed (14%) than APP treated plants for all but the highest rate (data not shown). The CB-P treated plants had significantly greater (40-64%) dry matter yield than the APP plants at the two lower rates (Figure 2). These growth increases were likely due to improved P uptake as shown in Figure 3 (43-56% increase in P concentration), which is especially remarkable considering that the CB-P treated corn had less total P applied than APP (same gallonage was applied to each, but APP is 34% P_2O_5 and CB-P is 24%). The second highest rate showed no difference in biomass and the highest rate showed a significant loss of biomass for CB-P in comparison to APP, possibly due to a P induced micronutrient deficiency. These results suggest that at least 38% (CB-P treatments had less 38% less P than APP in this study) can be utilized when using CB-P in place of APP; with net increases in P uptake by corn plants resulting in enhanced growth.

SUMMARY

This data shows highly significant differences between solubility of CB-P and traditional fertilizers over a period of up to one year. If P is remaining in a more soluble state in the soil solution, this would lead us to believe that it is also more readily available for plant uptake, thus ameliorating the impediment of rapid precipitation of applied P fertilizers. Results of the glasshouse experiment bolster this hypothesis. Fertilizer use efficiency is increased substantially and, although additional trials are needed, these results suggest that banded P fertilizer application rates can be cut by approximately 38% without any loss of yield. In fact, these data also suggest that crop yield/quality improvements can be realized with use of Carbond Technology over use of normal fertilizer sources. Differences between CB-P and APP likely disappear at very high P rates due to the principle of Diminishing Return. Further work is underway to evaluate season-long impacts, as well as refined recommendations regarding P fertilizer reduction possibilities. Initial field results over the last two growing seasons show that Carbond® P is an effective source of P, especially when crops are grown in P deficient soils.

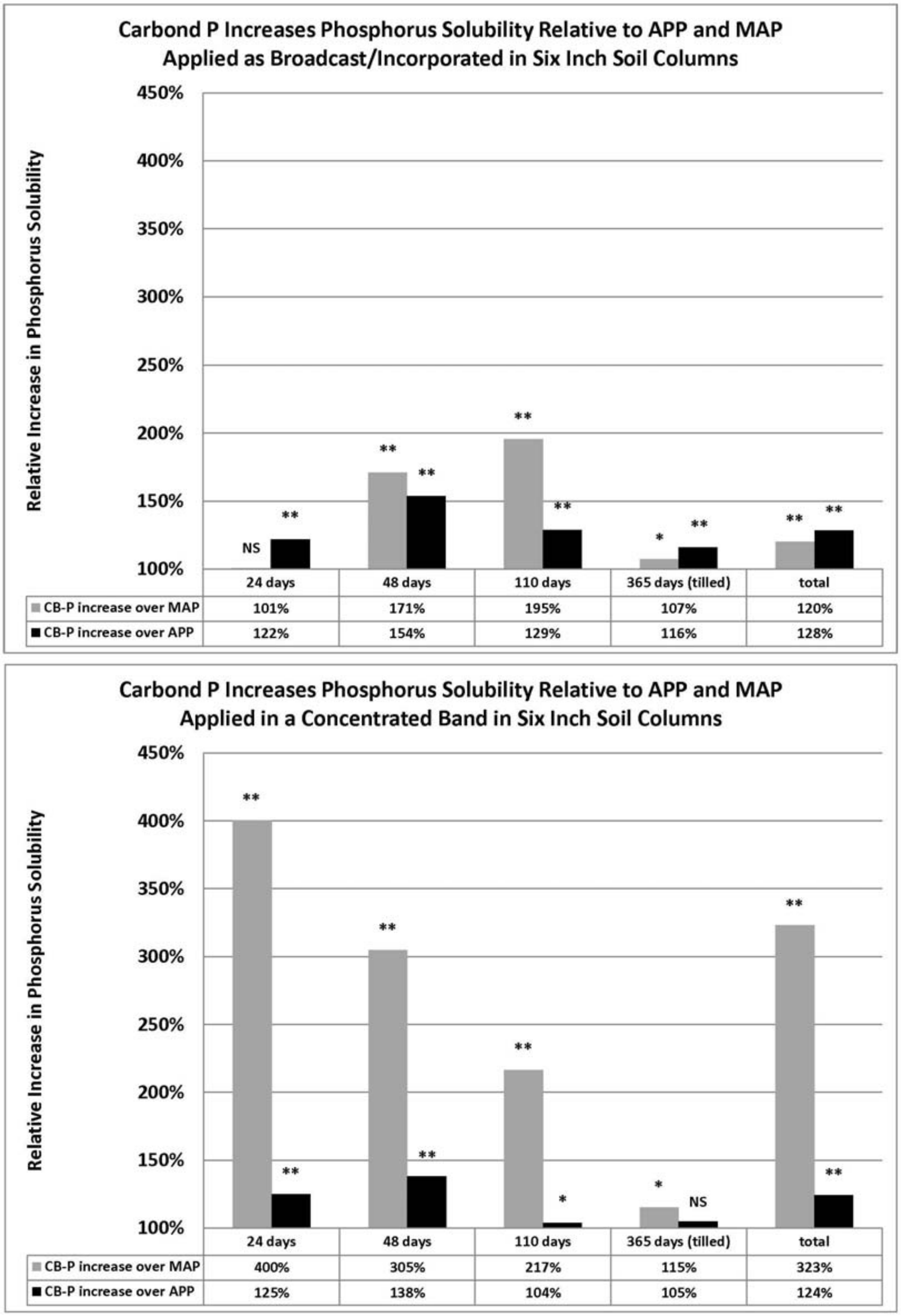

Figure 1. Relative increase in P solubility with application of Carbond P (CB-P) compared to ammonium polyphosphate (APP) and monoammonium phosphate (MAP) band (bottom) or mixed (top) applications to three soils at two rates (results shown combined across rates and soils). Increase in P solubility signified by “NS” = not significant, “*” = significant at $P < 0.05$ and “**” significant at $P < 0.01$.

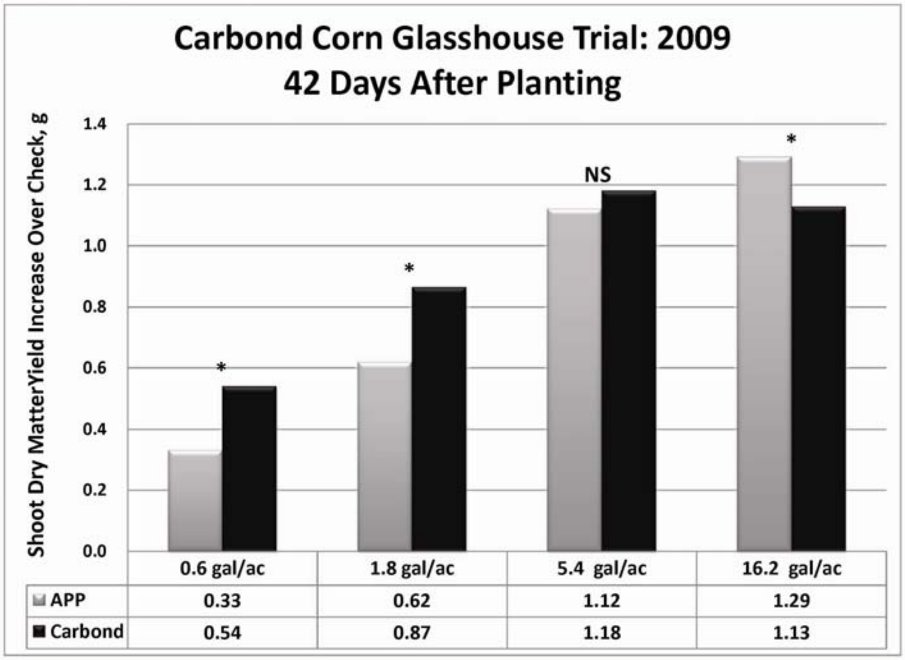

Figure 2. Increase in shoot dry matter with application of Carbond P compared to ammonium polyphosphate (APP) applied to corn in a glasshouse trial at four rates. Increase in biomass signified by “NS” = not significant or “*” = significant at $P < 0.05$.

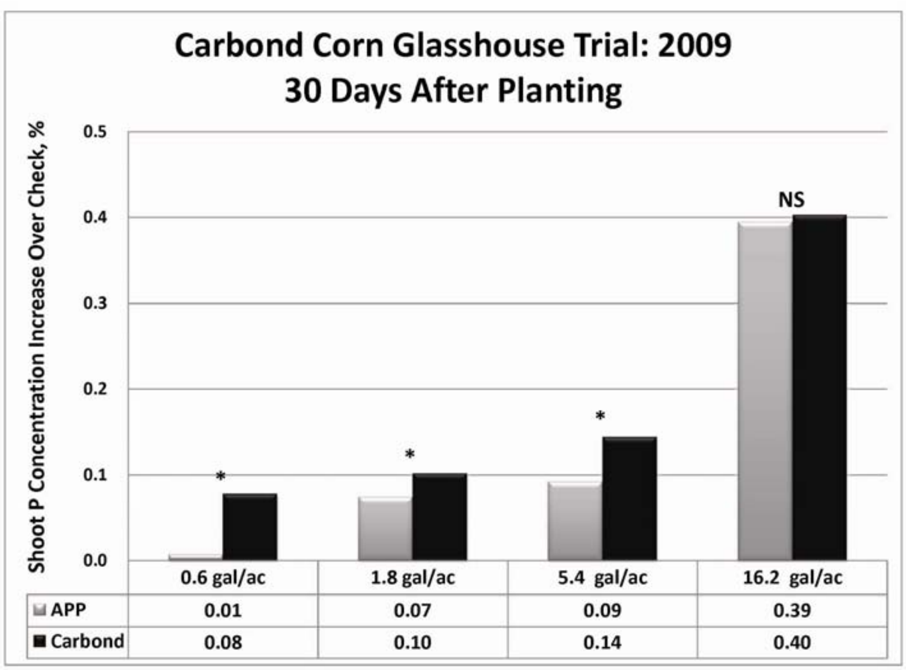

Figure 3. Increase in shoot tissue phosphorus concentration with application of Carbond P compared to ammonium polyphosphate (APP) applied to corn in a glasshouse trial at four rates. Increase in phosphorus concentration signified by “NS” = not significant or “*” = significant at $P < 0.05$.

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