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Crop Response to Phosphorus in Fertilizer and Struvite Recovered from Corn Fiber Processing for Bioenergy

Abstract

There is interest in recovering nutrients from the stream of processing of crop biomass for bioenergy so that they can be efficiently utilized as fertilizers. Phosphorus (P) can be recovered as struvite [NH₄Mg(PO₄)₆H₂O]. A low P water-solubility in the mineral struvite and research with the mineral or struvite precipitated from liquid animal manure handling suggests a slow-release of P. However, a recent greenhouse study in Iowa reported similar P availability of struvite and superphosphate (0-46-0) for corn and ryegrass. Also, more information is needed about P rates that should be applied in low-testing soils to maximize corn and soybean yield. Although two long-term P experiments are being conducted at this farm, they do not include many P rates. Therefore, a new study was established in 2009 to investigate these issues.

Keywords

Agronomy

Disciplines

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Crop Response to Phosphorus in Fertilizer and Struvite Recovered from Corn Fiber Processing for Bioenergy

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Introduction

There is interest in recovering nutrients from the stream of processing of crop biomass for bioenergy so that they can be efficiently utilized as fertilizers. Phosphorus (P) can be recovered as struvite [$\text{NH}_4\text{Mg}(\text{PO}_4)_2 \cdot 6\text{H}_2\text{O}$]. A low P water-solubility in the mineral struvite and research with the mineral or struvite precipitated from liquid animal manure handling suggests a slow-release of P.

However, a recent greenhouse study in Iowa reported similar P availability of struvite and superphosphate (0-46-0) for corn and ryegrass. Also, more information is needed about P rates that should be applied in low-testing soils to maximize corn and soybean yield. Although two long-term P experiments are being conducted at this farm, they do not include many P rates. Therefore, a new study was established in 2009 to investigate these issues.

Materials and Methods

The experiment was established in an area with Floyd soil, which is commonly found in northeast Iowa. The study was evaluated four years with a corn-soybean rotation. Initial soil test P (STP) was Low (11 ppm Bray-1), organic matter was 3.9 and pH was 5.7 (6-in. depth). Treatments for the first year were struvite and triple superphosphate (TSP) applied at seven rates (0, 25, 50, 75, 100, 150, and 250 lb $\text{P}_2\text{O}_5/\text{acre}$). Both sources were granulated. The struvite had 4.7 percent moisture, 27 percent total P_2O_5 , 1.4 percent

water-soluble P, 16 percent P soluble in 2 percent citric acid, and pH 6.9. Both sources were broadcast in spring to soil with soybean residue, and were incorporated into the soil by two passes of a field cultivator. Non-limiting rates of N, K, S, and Mg were uniformly applied across all plots. No P treatment was applied for the 2nd year, but before the third year, a rate 150 lb P for both P sources was applied to plots that had received 25 $\text{P}_2\text{O}_5/\text{acre}$. This was done to assure maximum crop yield while we evaluated residual effects on yield and STP of the higher rates. However, data for this rate was excluded from data shown for the third and fourth years because yields were as high as for the highest P rates applied the first year.

In the first year (corn), measurements were aboveground plant dry weight (DW), P concentration, P uptake at the V6 growth stage, grain yield, grain P concentration, grain P removal, and post-harvest STP. In other years, the small plant samples were not collected and other measurements were similar to the first year. In this report, we summarize results for early corn growth the first year, grain yield for all four years, and post-harvest STP for the first three years (analysis of samples taken last fall have not been completed at this time).

Results Discussion

1st-year corn early growth and P uptake. Study of P treatment effects on early plant growth and P uptake is important because low rates or initial availability of P in some material could limit growth, and as a consequence, grain yield. Figure 1 shows that there were large P rate effects on early growth, P concentration, and P uptake. The two highest struvite application rates increased

early corn growth slightly more than the similar TSP rates. Effects of the P sources on early corn tissue P concentration were similar. The P uptake results were similar to those for early plant growth, and for the higher P rates struvite increased P uptake further than the TSP. We did not expect struvite to be better than TSP for any application rate, and in any case expected struvite to be worse than TSP for the low P rates. Data for the lower rates demonstrated that P availability was similar for both sources. We cannot explain lower plant dry weights for the two highest TSP rates.

Grain yield responses. Figure 2 shows grain yield results for the four years of the study. There were large grain yield increases from application of both sources in the first year and also large residual effects on yield the other years. In the first year there were no differences between the P sources, and corn yield was maximized (221 bu/acre) by 98 lb P₂O₅/acre. Therefore, there was no difference in P availability between the sources. The TSP highest rates produced yield as high as struvite in spite of apparent early growth decreases with these rates.

In the second year (Figure 2), there was a large residual effect on soybean grain yield of P applied before the first year, and there were no differences between the P sources. Yield was maximized (72 bu/acre) by 132 lb P₂O₅/acre. A higher rate applied the previous year was needed to maximize yield because of P removal with harvest of the previous corn crop.

In the third year (Figure 2) the residual effect

of the highest struvite P application rate increased corn yield slightly more than the highest TSP rate. This difference is not reasonable because such a result was not observed the previous two years and the following year. Figure 2 shows that the soybean response in the fourth year was linear up to the highest P rate applied three years before, and that there was no difference between the P sources for any rate. Perhaps random variability or experimental error explains the difference found in the third year.

Soil-Test Phosphorus. Figure 3 shows post-harvest STP for the first three years of the study. The P application the first year of the study increased soil-test P significantly, and the increases were similar for both P sources. The STP increase was slightly curvilinear in all three years, which indicated that one lb of P applied increased soil-test P slightly more as the application rate increased. This is the expected result of a higher impact of P removal for the lower P rates. On average, the highest STP level was 47 ppm, which was an increase of 36 ppm over the initial level. The highest average STP level decreased to 30 and 20 ppm by the end of the second and third years, respectively.

Conclusions

The type of struvite used in the study had P availability similar to that of P fertilizer when P rates commonly in corn-soybean rotations were applied. If bioenergy production continues increasing in Iowa, this P byproduct would become a very cost-efficient P source for Iowa crops.

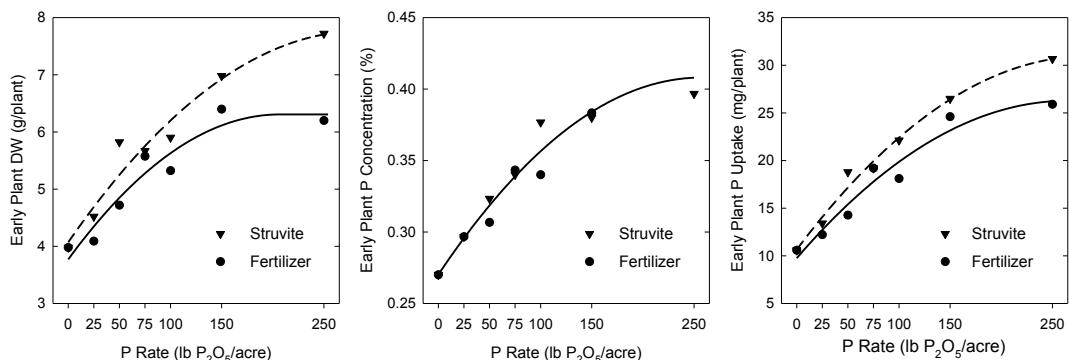


Figure 1. Effect of P applied as struvite or superphosphate on corn early plant growth (DW), P concentration, and P uptake at the V6 growth stage (the P treatments were applied before planting this crop).

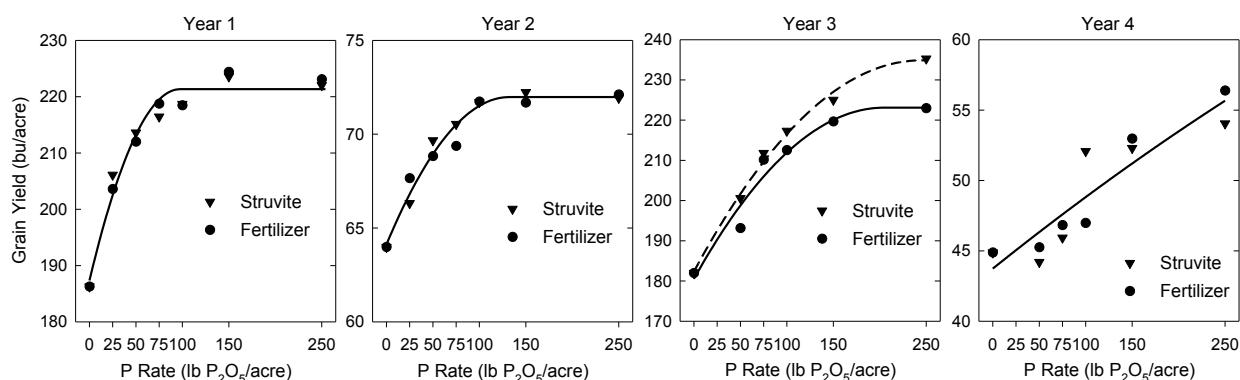


Figure 2. Effect of P applied as struvite or superphosphate on grain yield of four crops from 2009 until 2012 (P treatments were applied the first year only).

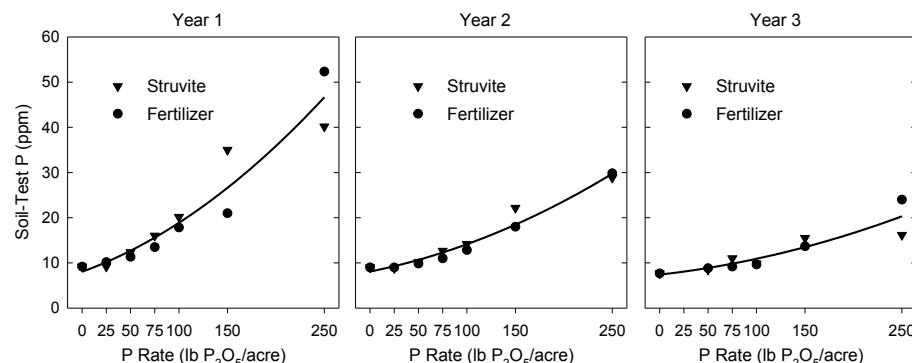


Figure 3. Effect of P applied as struvite or superphosphate on post-harvest soil-test P (Bray-1) of three crops from fall 2009 until fall 2011 (P treatments were applied the first year only).