Crop Availability of Phosphorus Recovered as Struvite from Corn Processing for Bioenergy in Corn-Soybean Rotations

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Introduction

There is strong interest on recovering nutrients from the stream of industrial processing of crop biomass for bioenergy so that they can be efficiently utilized as fertilizer materials. Phosphorus can be recovered as struvite [$NH_4Mg(PO_4).6H_2O$] from the aqueous stream. A low P water-solubility in struvite and previous research with the pure mineral or struvite precipitated from liquid animal manure suggest a slow-release of P. However, a recent greenhouse study in Iowa (M.A. Tabatabai, unpublished) found similar P crop-availability of superphosphate (0-46-0) and struvite for ryegrass.

Objectives

The objective of this study was to evaluate in the field the P availability for corn and soybean of P recovered as struvite from the aqueous stream of corn fiber processing for bioenergy.

Materials and Methods

Field plot trials were established at three locations with different soils and properties (Table 1). Initial soil-test P (STP) was Very Low to Low (8 to 12 mg kg^{-1} Bray-1) and pH was 5.5 to 6.5 (15-cm depth). Each trial was evaluated for 2 years with corn the first year and soybean the second.

The treatments were struvite and triple superphosphate (TSP) each applied at seven rates (0 to 120 kg total P ha^{-1}), which were arranged in a randomized complete-block design with three to four replications. Both sources were granulated. The struvite was the same used in the Iowa greenhouse study mentioned previously. It had 47 g kg^{-1} moisture, 117 g kg^{-1} total P, 6.0 g kg^{-1} water-soluble P, 72 g kg^{-1} P soluble in 2% citric acid, and pH 6.9. Both sources were broadcast and incorporated into the soil by disking before planting corn. Non-limiting rates of N, K, S, and Mg were uniformly applied across all plots the first year.

In the first year (corn) measurements were aboveground plant dry weight (DW), P concentration, and P uptake at the V6 growth stage, grain yield, grain P concentration, grain P removal, and post-harvest soil-test P by the Bray-1, Mehlich-3, and Olsen tests. In the second year (soybean) no measurements were made for the V6 growth stage but others were similar to the first year. Soybean at the O'Brien site was lost due to excess rainfall.

Table 1. Site information for three field experiments†

County	Boone	Floyd	O'Brien
Soil classification	Webster Typic Endoaquolls	Floyd Typic Endoaquolls	Marcus Aquic Hapludolls
Bray-1 P, mg kg^{-1}	8.1	10.6	12
Soil-test P class	Very low	Low	Low
Texture	Silt Loam	Loam	Silty Clay
Clay, %	22	20	42
Silt, %	56	38	50
Sand, %	21	41	7
pH	5.9	5.5	6.5
Org. matter, g kg^{-1}	46	33	50
Ca, mg kg^{-1}	3597	1696	3770
Mg, mg kg^{-1}	589	244	827

† Soil properties for a 15-cm sampling depth.

Fig. 1. Corn grain yield and P removal across Floyd and O'Brien sites.

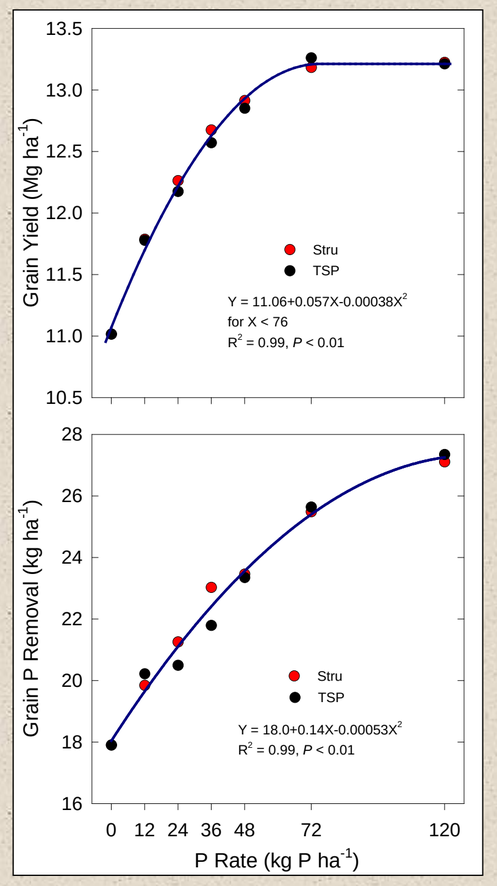


Fig. 2. Corn DW and P uptake at the V6 stage across Floyd and O'Brien sites.

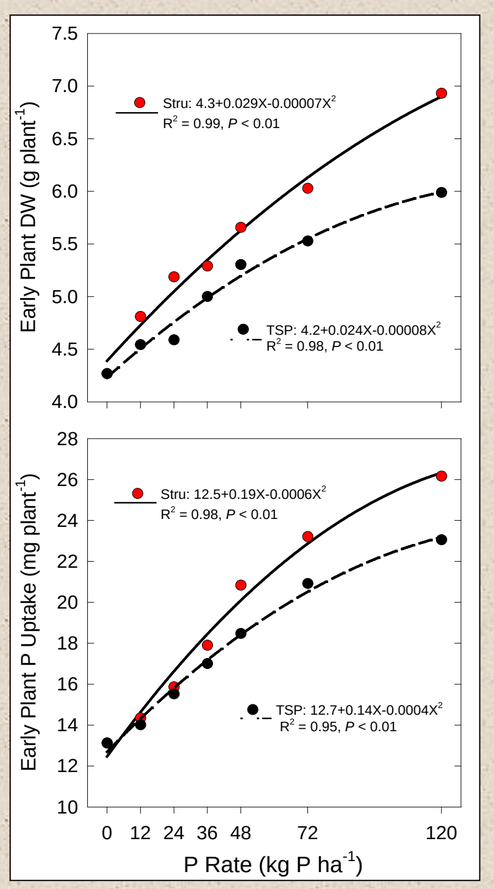


Fig. 3. Corn grain yield and P removal at the Boone site.

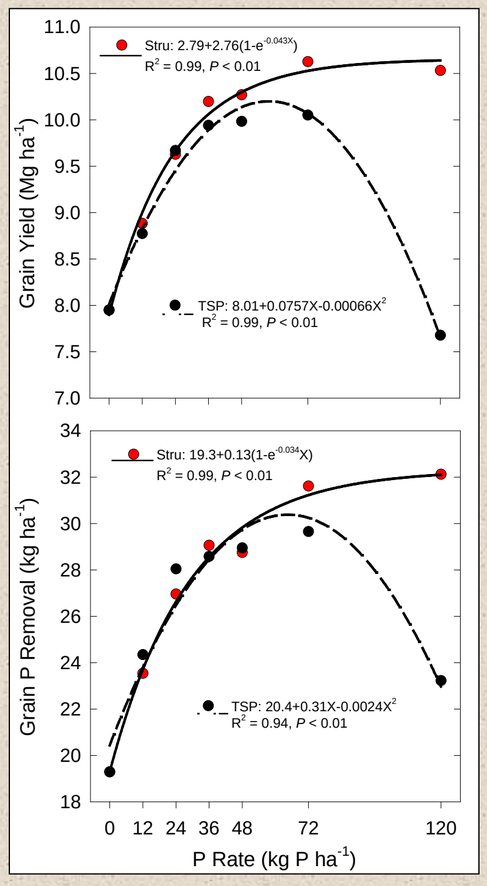


Fig. 4. Corn DW and P uptake at the V6 stage at the Boone site.

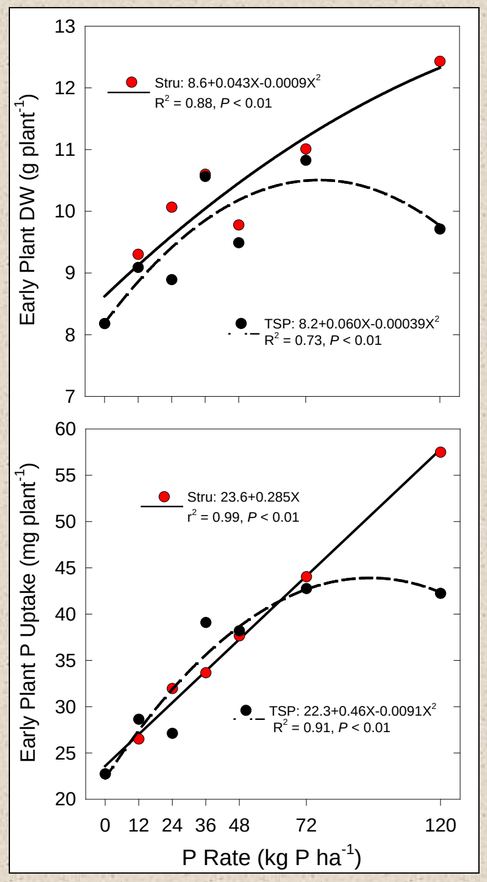


Fig. 5. Soybean grain yield and P removal across Boone and Floyd sites.

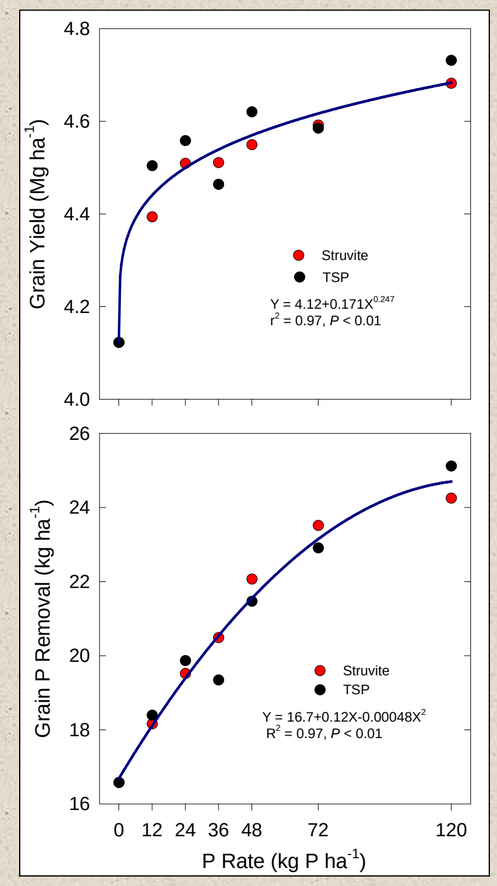
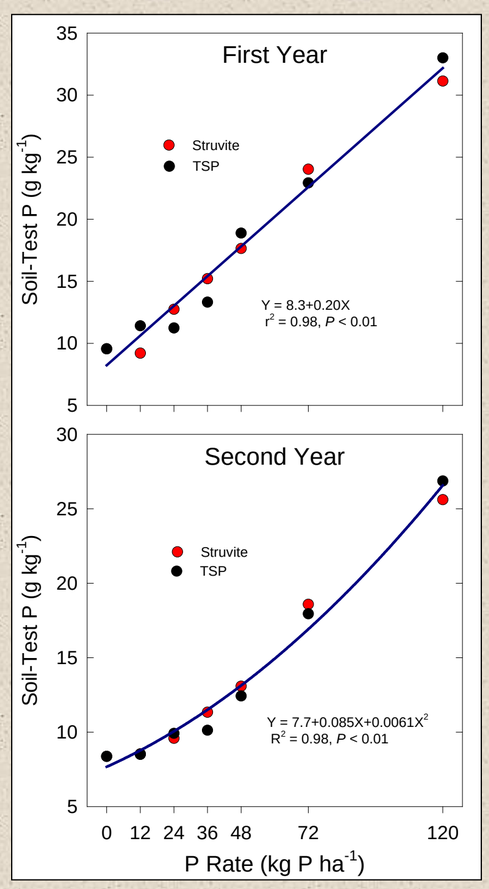


Fig. 6. Mean post-harvest soil P for the first (corn) and second (soybean) years.



Results

1st-year corn responses.

There were large grain yield and early plant growth increases from applied P for both sources, which is consistent with the initially low soil P levels at the three sites.

Both yield levels and corn responses to P were similar at the Floyd and O'Brien sites, so means across both sites are shown. There was no yield or P removal difference between P sources (Fig. 1). On average, 76 kg P ha^{-1} maximized grain yield, and the highest rate applied maximized P removal. Both P sources increased early corn plant DW and P uptake curvilinearly up to the highest rate applied (Fig. 2). However, for all rates struvite was more efficient than TSP at increasing plant DW and P uptake.

At Boone, the P sources did not differ for grain yield or P removal up to the 48-kg P rate (Fig. 3). However, the 72-kg P rate as TSP increased both yield and P removal less than struvite did, and the highest TSP rate sharply decreased grain yield and P removal compared with lower rates (Fig. 3). For early corn DW and P uptake (Fig. 4), the P sources did not differ up to the 72-kg P rate but the highest TSP rate decreased both measurements.

The observed corn early growth, P uptake, and grain yield decreases from the highest TSP rate at Boone was surprising. We believe the very high rate of water-soluble P applied with TSP induced a deficiency of some other nutrient.

We can't explain with certainty the higher efficiency of struvite than TSP at increasing early corn growth and P uptake at Floyd and O' Brien sites (Fig. 2).

2nd-year soybean responses.

There were large and approximately similar P residual effects on soybean grain yield and P removal at both successfully harvested trials (Floyd and O'Brien sites), so Fig. 5 shows means across both sites. There were no difference between the P sources.

Soil-test P responses.

The post-harvest soil P levels (Fig. 6) showed large increases from applied P but no differences between the sources in any year.

Conclusions

Phosphorus recovered as struvite from the aqueous stream of corn fiber processing for bioenergy had crop availability similar to inorganic fertilizer. This result is relevant for production agriculture, since large amounts of struvite could be available in the future as bioenergy production from corn increases.