Biochar Effects on Phosphorus Pools in Three Soils from Minnesota

Paulo Pagliari[1], Heidi Waldrip[2], Jeff Strock[1], Ashley Roiger[1]

[1]University of Minnesota, Lamberton, MN; [2]USDA-ARS Conservation and Production Research Laboratory, Bushland, TX

Introduction

The increasing search for renewable sources of energy has led to development of several new techniques for energy production, including pyrolysis of organic compounds (e.g., corn stover, grass biomass, animal manure, wood shavings and others). During the pyrolysis process, biochar is created as a co-product. To date, the most beneficial use of biochar has been related to carbon (C) sequestration, as biochar C appears to be relatively resistant to microbial degradation in soil.

Although biochar can contain significant amounts of phosphorus (P), there is limited understanding of effects of biochar application on soil phosphorus (P) forms (e.g., organic and inorganic P) and solubility/plant availability (e.g., labile, moderately stable, and recalcitrant P) in agricultural soils.

Objectives

1- Use sequential extraction and phosphatase hydrolysis to assess changes in soil P forms in three Minnesota soils after application of biochar and other organic amendments.

2- Investigate the interaction of biochar effects and plant growth on soil P forms and availability.

Materials and Methods

- In a greenhouse study, turkey manure incinerated ash (TMA), switch grass biochar (SWITCH), corn stover biochar (CS); and triple super phosphate (TSP) were added to soils at P rates of 0, 50, 100, 150 kg P ha^{-1} and then either corn (*Zea mays*) or wheat (*Tritium aestivum*) were grown for 56 days.
- The soils used were a Barnes loam, Canisteo clay loam, and Hubbard loamy sand with initial soil test P (STP) concentrations of 5, 8, and 12 ppm (Bray-1) and 3, 3, and 2 ppm (Olsen), respectively.
- After 56 days of plant growth, soil samples were collected and P sequentially extracted in water (H_2O), 0.5 M sodium bicarbonate ($NaHCO_3$), and 0.1 M sodium hydroxide (NaOH) (Waldrip-Dail et al., 2009).
- Enzyme hydrolysis of soil extracts was performed according to He and Honeycutt (2001) using acid phosphomonoesterase type I from wheat germ (E.C. 3.1.3.2), type IV-S from potato (E.C. 3.1.3.2), and nuclease P1 from *Penicillium citrinum* (E.C. 3.1.30.1).
- The experimental design included four replications per treatment.

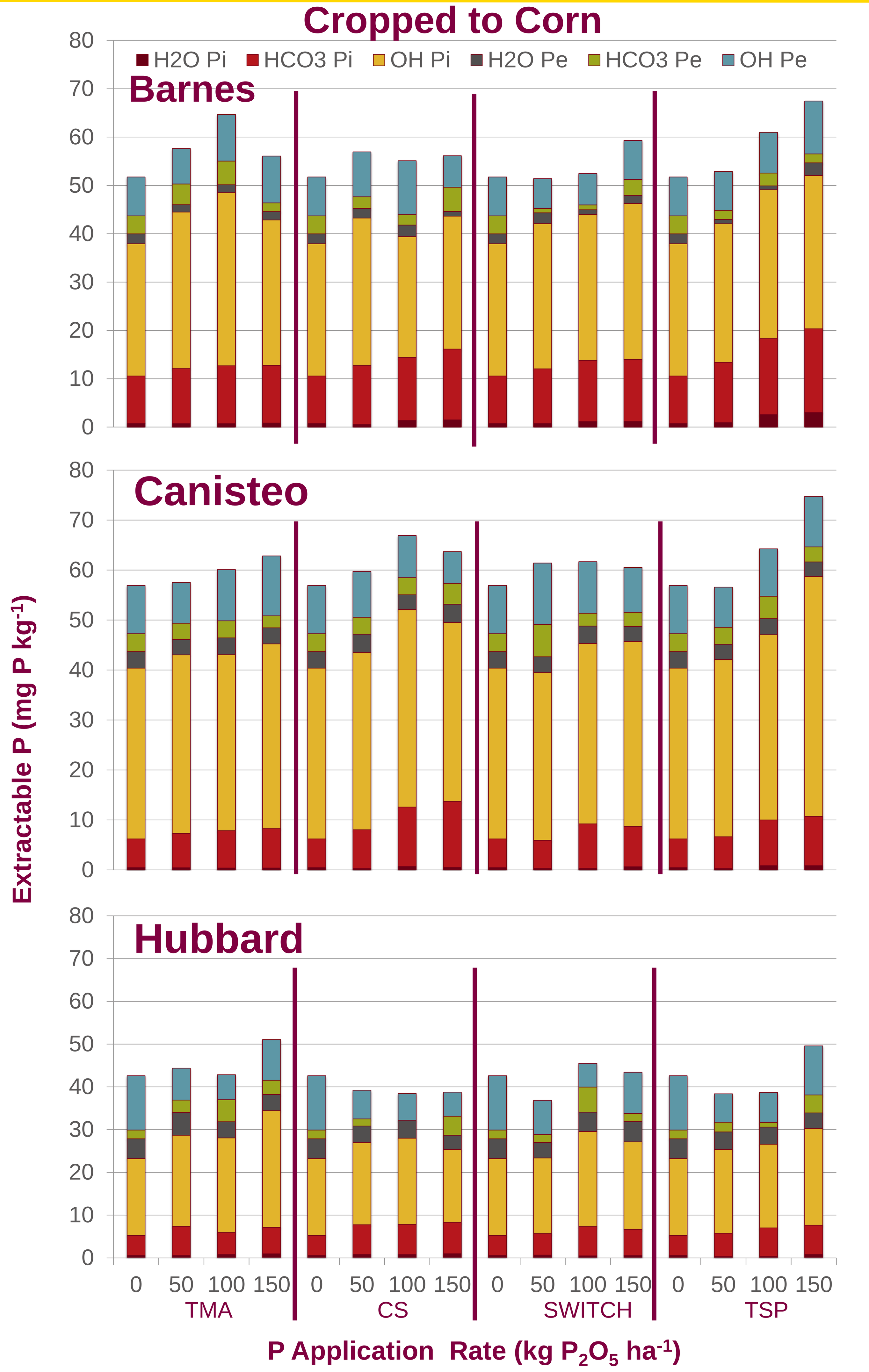

Figure 1. Average concentrations of inorganic P (P_i) and enzymatically hydrolysable P (P_e) in soil samples collected after 56 days of corn growth. Soils were extracted with water (H_2O), sodium bicarbonate (HCO_3), and sodium hydroxide (OH).

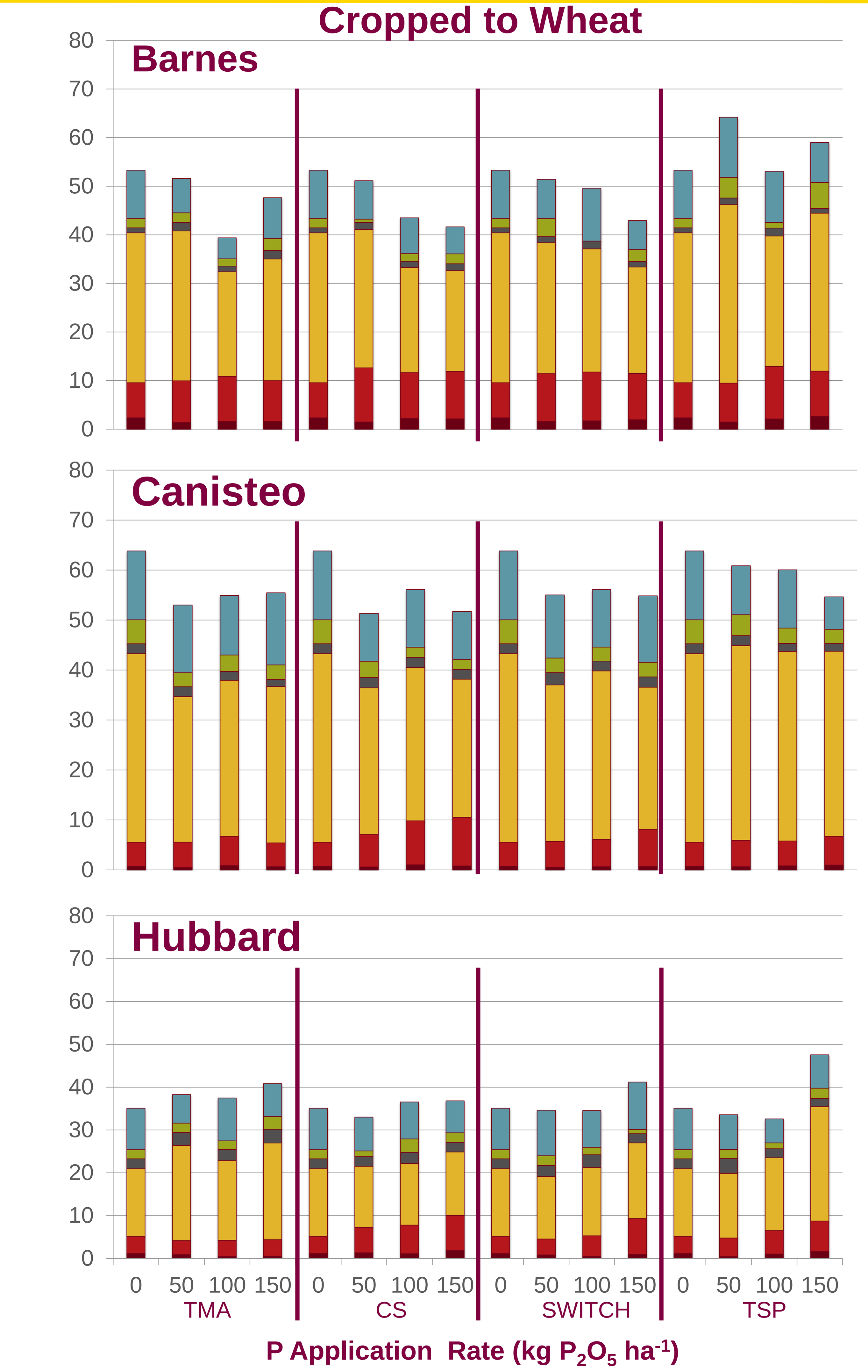

Figure 2. Average concentrations of inorganic P (P_i) and enzymatically hydrolysable P (P_e) in soil samples after 56 days of wheat growth. Soils were extracted with water (H_2O), sodium bicarbonate (HCO_3), and sodium hydroxide (OH).

Results and Discussion

- All sources of P tested affected the soil P pools; however, the effects varied by soil type and crop (***Figs. 1 and 2***).
- The same amount of total P was added for both crops (corn vs. wheat) and with all amendments (TMA, SWITCH, CS, and TSP); however, soils cropped to wheat contained lower levels of total P than with corn (***Figs. 1 and 2***).
- The majority of inorganic P (P_i) was extractable with NaOH (Al/Fe-associated P_i), followed by $NaHCO_3$ (moderately labile P_i) and H_2O-P_i (readily soluble P_i).
- Concentrations of P_i increased as a function of P application rate in soils cropped to corn. The P_i increased according to: TSP > TMA = CS = Switch. Increases in soil P_i in wheat-cropped soils were more incosistent than in corn-cropped soils (***Fig. 2***).
- On average, P_i increased by 17% in soils cropped with corn, and 0% in soils cropped with wheat.

Results and Discussion (cont.)

- Extractable enzyme hydrolysable organic P (P_e) decreased as the P rate increased, in contrast to P_i (***Figs. 1 and 2***).
- The decreases in P_e were more pronounced in the Canisteo (clay loam, Bray-1 P=8 ppm) (from 2 to 38% reduction) and Hubbard (loamy sand, Bray-1 P=12 ppm) (6 to 46% reduction) soils for both crops.
- Overall, P_e distribution was affected more by specific crop then P source or soil type:
  - with corn, soil P_e was classified as monoester-like P (47% of total P_e) > DNA-like P (30% of total P_e) > phytate-like P (23% of total P_e).
  - With wheat, soil P_e was classified as phytate-like P (45% of total P_e) > DNA-like P (30% of total P_e) > monoester-like P (25% of total P_e).

Conclusions

- The results of this research indicated that soil P forms in three agricultural soils with differing STP levels and physicochemical properties were not significantly different when any of the amendments were applied at the same P rate.
- The reduction in soil P_i after plant growth was greater with wheat than corn, perhaps to the fact that wheat achieved full maturity during the 56 days while corn was only grown to stage V5.
- Soils cropped with corn had higher levels of P_e in the form of phytate-like P than monoester-like P, compared with soils cropped with wheat. This difference in phytate-like P in the soils from the two cropping systems suggests a root-derived effect on P mineralization and/or microbial activity. Further studies should focus on differences in enzyme activity as a function of biochar application to soils under diverse cropping systems.

UNIVERSITY OF MINNESOTA | EXTENSION

References

He, Z., and C.W. Honeycutt. 2001. J. Environ. Qual. 30:1685–1692. doi:10.2134/jeq2001.3051685x

Waldrip-Dail H, Z. He, M.S. Erich, and C.W. Honeycutt. 2009. Soil Sci 174:195–201.