The Role of Carbon Sources in Immobilizing Phosphorus in Floodplain Soils
Office of Undergraduate Research Summer Undergraduate Research Grant 2018 Final Summary

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My research interest: Understanding the mechanisms behinds floodplain soil acting as a potential buffer reducing phosphorus loss into to the aqueous ecosystems.

Abstract

The nonpoint source of phosphorus (P) runoff and leaching from agricultural fertilization is accelerating the growth of eutrophication in aqueous ecosystems. Floodplains play a vital role in buffering P loss from soils to the waterbodies. Our objective is to investigate the ability of floodplain soils to buffer agricultural P losses through P immobilization under the influences of carbon/phosphorus ratio of native plant residues and various organic P species. The ability of floodplain soils to retain P was assessed by measuring the microbial P, inorganic P, phosphatase activity, and total P using biogeochemical experiments throughout the 60-day incubation. The degree of P immobilization was the greatest when the soils amended with native plant residues having a C: P ratio over 300. The degree of P immobilization was also greater in soils amended with RNA and phospholipids. Overall, the quantitative relationship between organic P and inorganic P implies cycles of net mineralization and immobilization.

I. Introduction

Phosphorus is an essential nutrient required for plant growth. Natural P concentrations are low in the soil, where P mostly exists in forms unavailable for plant uptake (Mallarino and Bundy, 2005). As a consequence, fertilizer P is widely applied, often in excess. Once P exceeds the retention capacity of the soil, it is susceptible to leaching and runoff. Consequently, P is transported to aqueous environments, where it contributes to eutrophication, hypoxia, and other water quality problems (Daniel et al., 1998). Thus, minimizing P loss is critical to improving water quality.

Floodplain soils intercept agricultural runoff and potentially buffer P loss through microbial immobilization (Noe et al., 2013). Immobilization transforms inorganic P to organic P, reducing its potential to be lost from the soil. The mechanism behind immobilization is influenced by the carbon(C): P ratio of plant residue (Achat et al., 2012). Microbes use C as an energy source and require P to carry out metabolic processes. The greater the energy (C), the more P microbes can immobilize (Zhang et al., 2018). However, they require a minimum amount of C to carry out this process. The widely accepted threshold for immobilization is a C:P ratio of 300:1 or higher (Dalal, 1977). Conversely, mineralization, or the conversion of organic P to inorganic P, generally occurs when the C:P ratio of plant residue is 200:1 or below.

To better understand the processes of P immobilization and mineralization in floodplain soils, we raised three research questions: (1) How do C sources (i.e., native tree leaves) with different C:P ratios affect soil P transformations? (2) How do various organic P species influence soil P cycling? (3) How can P retention in floodplain soils be increased? We hypothesize that plant residue with higher C:P ratios promote greater immobilization. The results of this research could be applied to the design of riparian buffers and increase their P retention capacity.

II. Tasks & Responsibilities

This summer, I assisted with field sampling and laboratory incubation experiments. We applied three different native tree leaves (i.e., hackberry, sugar maple, and silver maple) and three different organic P species (i.e., RNA, phosphatidylcholine, and phytic acid) to floodplain soil collected from Robert Allerton Park in Monticello, IL. The treatment soil groups and a control group then incubated for 60 days at 25°C and field capacity moisture. Aliquots of soil were removed on days 0, 10, 20, 30, 40, 50, and 60. Throughout the incubation, we conducted a range of experiments measuring soil total P, organic P, inorganic P (Bowman, 1989), phosphatase activity (Tabatabai and Bremner, 1969), microbial biomass P (Brookes et al., 19), exchangeable P (Arambarri and Talibudeen, 1959), and microbial C (Jenkinson and Powlson, 1976). We sought to evaluate the degree of P mineralization and immobilization occurring as a result of the treatments.

Among all the experiments, I was most involved in the measurement of inorganic and total P. The inorganic P was extracted from the soil with a strong acid and then a weak base (Bowman, 1989). Molybdenum blue colorimetry was then used to analyze the amount of inorganic P present in the soil extracts (Murphy and Riley, 1962). The total P (organic and inorganic P) was determined colorimetrically following digestion, where the inorganic P extract was heated with an oxidizer ($K_2S_2O_8$) and a strong acid (Bowman, 1989). My other primary tasks included, but were not restricted to, (1) weighing soil, (2) measuring the density of soil extracts, (3) recording experimental results, (4) acid-washing dishes, (5) labeling, and (6) making reagents. In addition, I was responsible for following laboratory safety protocol.

III. Results and Discussion

During the 60-day incubation, we saw a general trend of greater immobilization in the sugar maple and silver maple treatments compared to the control (Fig 1). Both sugar maple (1012:1) and silver maple leaf residue (976:1) have C: P ratios higher than the threshold (300:1) of net immobilization. Our results were consistent with the hypothesis that a higher C: P ratio promotes immobilization. While the hackberry treatment (268:1) has a C: P ratio between the immobilization threshold of 300:1 and the mineralization threshold of 200:1, the soil that received the hackberry treatment generally underwent less immobilization than the other two treatments. Based on these results, we conclude that the C: P ratio is a critical factor affecting the degree of immobilization in the leaf treatments.

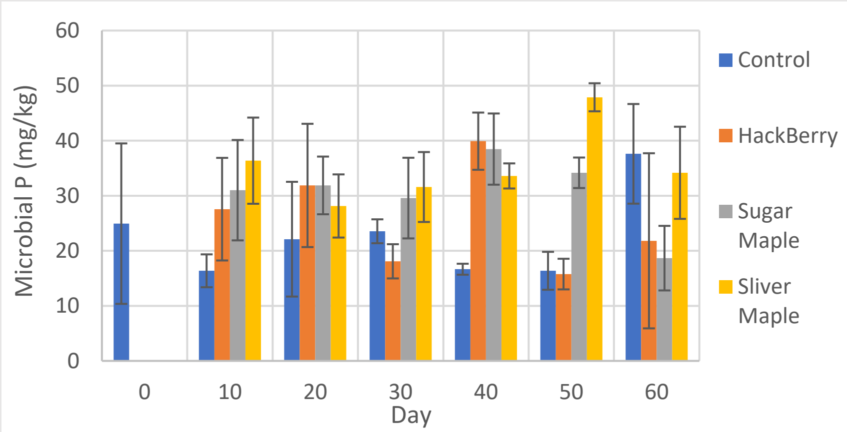

Figure 1. *The amount of soil microbial P (immobilized P) in the leaf treatments during the 60-day incubation*

Immobilization not only transforms inorganic P into microbial P but also promotes the accumulation of organic P (Qualls and Richardson, 2000). A decrease in the percent of inorganic P indicates net immobilization. The overall percentage of inorganic P was generally lower in the sugar maple and silver maple treatments (Fig 2), which corroborates the result that a greater degree of immobilization occurred in these two soil treatments. Similarly, less immobilization (and more mineralization) occurred in the soil with hackberry treatment, which tended to have a higher inorganic P content.

In the natural environment, various organic P species exist in the soil and influence P transformations (Noack et al., 2012). Some organic P species are more susceptible to degradation and, subsequently, immobilization. More immobilization occurred in the soil that received RNA and phosphatidylcholine treatment (Fig 3 & Fig 4). In contrast, soil treated with phytic acid had much lesser immobilization compared to the control and other two treatments.

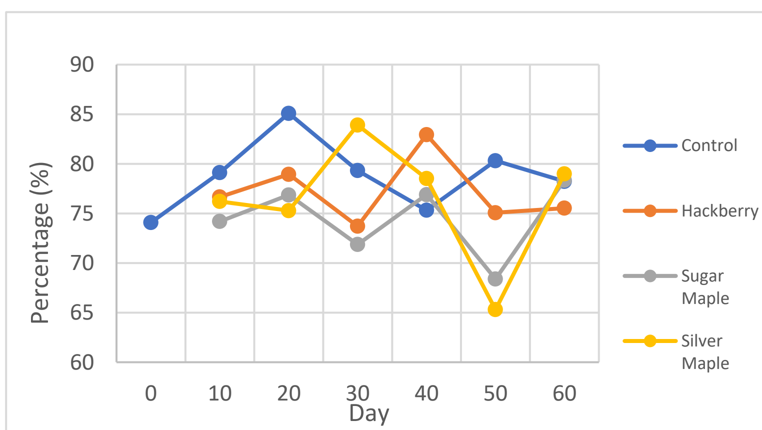

Figure 2. *The percent of soil inorganic P during the 60-day incubation in the leaf treatments*

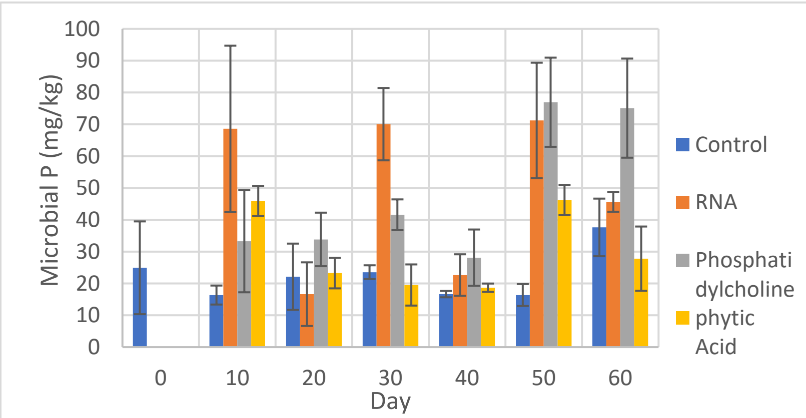

Figure 3. *The amount of soil microbial P (immobilized P) in the organic P treatments over the 60-day incubation*

The reason for such a significant difference in the degree of immobilization among the treatments is due to the behavior of the organic P species in the soil. Phytic acid is known for its high sorption capacity that allows it to be tightly retained by soil minerals (Turner et al., 2002). This property prevents phytic acid from being degraded, and thus, makes it harder for the microbes to break down phytic acid and use it as a P source.

Despite the differences in the degree of immobilization, the transformations of the various organic P species follow similar trends (Fig 4). The trend implies cycles of net mineralization and immobilization. This is evidenced by the percent of inorganic P, which follows a pattern of periodical increase and decrease over the course of incubation. For instance, at day 40, the inorganic P content reached the lowest point for all treatments, signaling net immobilization at this point. Future research could focus on investigating the sequence of P transformations for each organic P species.

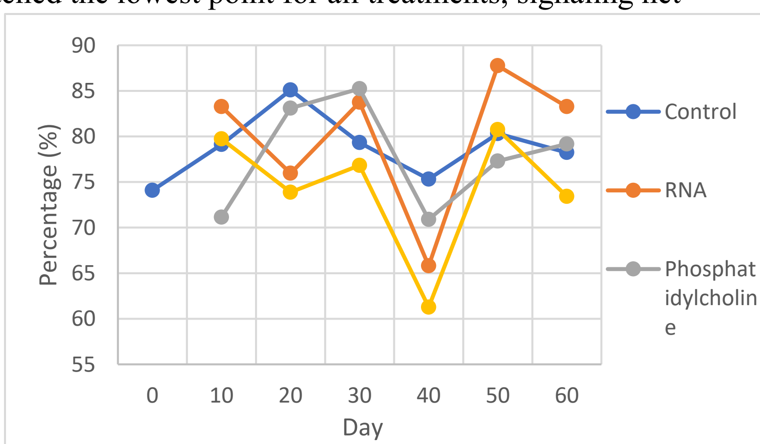

Figure 4. *The percent of soil inorganic P during the 60-day incubation in the organic P treatment*

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