Effects of Cover Crops and Phosphorus Fertilizer Management on Soil Health Parameters in a No-Till Corn-Soybean Cropping System in Riley County, Kansas

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Summary

This study was implemented to examine the effects of cover crops and mineral phosphorus (P) fertilizer application on water quality and soil health parameters. The experiment was established in 2014, at the Kansas Agricultural Watershed (KAW) field research facility, Ashland Bottoms Research Farm, Kansas State University, Manhattan, KS. The experiment was a 2 × 3 factorial design with two cover crop treatments (with and without) and three phosphorus fertilizer treatments (none, spring injected P, and fall broadcast P). Measures of nutrient demand (enzyme activity), microbial metabolic activity (soil respiration), and labile carbon (potassium permanganate oxidized carbon) were taken to assess the treatment effects on the nutrient status and relative microbial activity of the soil ecosystem. Results from spring 2018 showed a cover crop main effect for five enzymes (acid and alkaline phosphatase, phosphodiesterase, β-glucosidase, and β-glucosaminidase), soil respiration, and active carbon (C). The main fertilizer effect was in potential β-glucosaminidase activity ($P = 0.02$). There was an interaction effect between phosphorus fertilizer and cover crop for the enzyme arylsufatase.

Introduction

Research has demonstrated improved soil structure, increased water holding capacity, and increased soil organic matter as a result of improved soil health (National Research Council, 2010). Cover crops have been shown to increase soil health (National Research Council, 2010), and have improved soil organic C and aggregation within no-till systems (Blanco-Canqui et al., 2011); however, it is not clear how effective these practices will be for soil health in a no-till system or if there will be any interaction with P fertilizer timing and placement. The effects of the treatments on soil health parameters, such as microbial activity, potential enzyme activity, and labile C pools at a field scale, will add to our understanding of these management options in the context of a common no-till cropping system. Ultimately these results will be used to aid producers with management decisions that will increase the sustainability of their farm enterprise.

Procedures

The experimental site is located at the Kansas Agricultural Watershed (KAW) Field Laboratory, approximately 5.5 miles south west of Manhattan, KS. It consists of an upland agricultural field that is terraced into 18 watershed units that are approximately 1.2–1.6 acres each. The site has a slope of 6–8% on primarily Smolan silty clay loam. The site has been in a continuous no-till, corn-soybean rotation since its establishment in 2014. This experiment is organized in a 2 × 3 factorial treatment design with three replications in a random block design. The cover crop factor has two levels, cover crop (CC) or no cover crop (NCC), and the fertilizer factor has three types of phosphorus fertilizer application, no fertilizer (NF), spring injected (SI), and fall surface broadcast (FB).

Cover crops have been planted annually since 2015 and have included: winter wheat before soybean in 2016, triticale and rapeseed before corn in 2017, and before soybean in 2018. Each year, the same amount of P was applied in both the spring injected and fall broadcast applications. The fall broadcast treatment was applied as diammonium phosphate (DAP) at 120 lb P/a (55 lb P_2O_5/a), and spring injected application was applied as ammonium polyphosphate at 14 gal/a (55 lb P_2O_5/a). Nitrogen (N) fertilizer, 28% urea ammonium nitrate, was injected below the surface at a uniform rate of 130 lb N/a for all plots.

In spring 2018, composite soil samples were collected from 0–2 in., after cover crop termination but prior to spring injected fertilizer P application. These samples were immediately stored at 40°F and analyzed promptly. Samples were assayed for enzyme activity, soil respiration, and active C (Table 1).

Results

The cover crops main effect was significant in all of the assays. Only arylsulfatase showed any interaction with fertilizer treatments (Figure 1). The only main fertilizer effect was documented in β-glucosaminidase activity ($P = 0.02$), an enzyme associated with the decomposition of recalcitrant C compounds in organic residues. β-glucosaminidase activity was increased by 21% in the FB treatment compared to NP but was not different compared to the SI treatment. Cover crops increased the potential enzyme activity, active C, and microbial metabolic activity (as measured by CO_2 respired) compared to the no cover crop treatment (Table 2).

Discussion

Enzymes are excreted by microorganisms and plants to catalyze the decomposition of organic matter (Madigan et al., 2018). Enzymes are excreted in response to nutrient demands of the biota and nutrient availability in the soil. This enzyme function by organisms has been described as "foraging behavior" (Madigan et al., 2018). In this snapshot of soil nutrient dynamics following the termination of the cover crop, cover crops increased the amount of enzyme activity compared to no cover crops. An increase in soil microbial respiration supported the increase in enzyme activity, suggesting a more active and possibly larger microbial community under cover crops. In conjunction with these measures, the active carbon measure indicates a readily available form of C for microbial uptake. This is important, as C is frequently the limiting growth factor for microbial communities (Spohn and Kuzyakov, 2013).

These results suggest cover crops increase the soil health benefits in no-till systems directly after the cover crop termination in the spring. It is difficult to predict whether these benefits will be conferred to the cash crop later in the season, have any beneficial effect on yield, or reduce dependence on chemical inputs. While soil health may be improved by cover crops, the marginal economic or environmental benefits are yet to be determined.

References

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Table 1. Methods used to measure soil health parameters

Measurement	Method reference
Acid and alkaline phosphatase	Tabatabai and Bremner, 1969; Eivazi and Tabatabai, 1977
Phosphodiesterase	Browman and Tabatabai, 1978
β-glucosidase	Eivazi and Tabatabai, 1988
β-glucosaminidase	Eivazi and Tabatabai, 1988; Parham and Deng, 2000
Arylsulfatase	Tabatabai and Bremner, 1970a
Active carbon - potassium permanganate oxidized carbon	Weil et al., 2003
Dissolved inorganic nitrogen	Jones and Willett, 2006
Soil respiration - potassium hydroxide trap	Zibilske, 1994

Table 2. Spring 2018 cover crop treatment main effects on soil health measurements from the Kansas Agricultural Watershed (KAW) Field Laboratory, Manhattan, KS

Soil health parameter	Units	Cover crop	No cover crop	% Change	*P*-value
Acid phosphatase	ug p-nitrophenol/ g dry soil hour	106.42	90.89	17%	0.0001
Alkaline phosphatase		33.24	22.83	46%	0.006
Phosphodiesterase		30.25	22.00	38%	0.0001
β-glucosidase		27.91	22.71	23%	0.001
β-glucosaminidase		4.78	2.55	87%	0.0001
Active carbon (C)	mg C/kg dry soil	328.34	268.88	22%	0.001
Soil respiration	mg CO_2 /kg dry soil	0.29	0.21	38%	0.02

The percent change was calculated: % change = [(cover crop – no cover crop)/no cover crop] × 100.

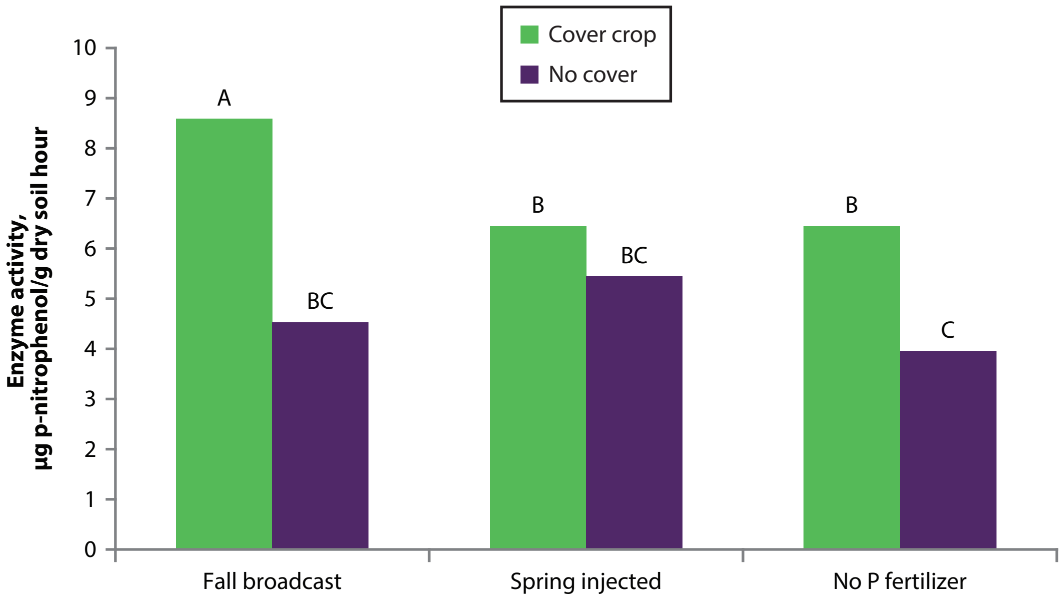

Figure 1. Spring 2018 cover crop treatment interaction with phosphorus (P) fertilizer application treatment on potential arylsulfatase enzyme activity from watersheds at the Kansas Agricultural Watershed (KAW) Field Laboratory, Manhattan, KS.