Improving Phosphorus Management for Soybean: Integrating Cover Crops and Fertilizer Placement and Time

Progress of Work

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ABSTRACT

The soybean crop provides one of the best opportunities to include a cool season cover crop (CC) ahead of planting. This study aims to maximize the soybean crop's phosphorus (P) use efficiency by using CC planting as a window of opportunity for better P fertilizer placement and timing. Specifically, combining P fertilizer with cereal CC seeds will place the fertilizer below the soil surface and combine two operations (CC planting and fertilizer application) in one pass. Other benefits include eliminating the environmental risk of P fertilizer runoff and potentially creating a synergistic benefit of the CC and fertilizer combination on P availability to the soybean crop. The overall objective of this study was to improve phosphorus management for soybean production in Kansas, increasing yields using improved diagnostic tools and fertilization strategies and leveraging opportunities for application placement with a CC in the rotation. Nine sites were established, with five locations under supplemental irrigation and four rainfed locations. Phosphorus treatments included a control with no P application and three P rates of 45, 90, and 135 Kg P2O5/ha, using mono-ammonium phosphate (MAP). CC treatments included oat and triticale with no P application and with P application of 45 Kg P2O5/ha. CC samples were collected before soybean planting to measure biomass and P uptake. Soybean whole plant samples were collected at the V3-V4 stage for P Uptake analysis. At harvest, grain yield was recorded for each plot. The results obtained with this research showed that there was no significant response to CC treatments in locations that are non-responsive to P fertilization. In responsive locations to P fertilization, there was a penalty in soybean growth and yields when adding CC to the system. Excessive CC biomass seems to negatively affect soybean growth and yield, highlighting the need for timely termination of the CC.

INTRODUCTION

Phosphorus is an essential nutrient for plant development and can be scarce in some ecosystems, in addition to being an important cost for agricultural production and being a non-renewable resource. Phosphorus management can alter plant use efficiency, just as tillage and fertilizer placement can alter nutrient availability and stratification in the soil (Mallarino and Borges 2006).

The creation of many agricultural best management practices have been proposed to reduce fertilizer P losses, and their implementation is important since most fertilizer recommendation systems for agricultural crops were developed based on maximizing yields and not on avoiding possible environmental impacts (Withers et al. 2014).

Keeping the soil exposed, in the period without crops growing, can cause soil disaggregation by the impact of rain, and consequently runoff of soil and nutrients by water or even losses by wind (Havlin et al. 2005). Cover crops have been encouraged to be used before crops such as corn and soybeans, seeking the principles of a more conservationist agriculture. Cover crops can decrease sediment losses as they cover the soil surface during the time when there are no crops growing in the field, reducing the energy of raindrops and the speed of water runoff, increasing water infiltration into the soil and avoiding nutrient losses (Blanco-Canqui et al. 2011).

The soybean crop provides one of the best opportunities to include a cool season cover crop before planting. Combining P fertilizer with cereal cover crop seeds will place the fertilizer below the soil surface and combine two operations (cover crop planting and fertilizer application). This study aims to maximize phosphorus use efficiency by the soybean crop by using cover crop planting as a window of opportunity for better P fertilizer placement and timing. The hypothesis of this study was that, in locations responsive to P application (low P levels in the soil), CC would be beneficial for soybeans as it would act as a slow-release source of P into the soil.

MATERIALS AND METHODS

This study was conducted in 2022 and 2023 at nine locations across Kansas. Among the nine locations, five were established under supplemental irrigation and four rainfed locations. Before fertilizer application, soil samples were collected at a depth of 0 to 15 centimeters using a hand probe. The average soil test P (Mehlich 3 and Bray 1), pH, and organic matter (OM) are presented in Table 1.

Phosphorus treatments included a control with no P application and three P rates of 45, 90, and 135 Kg P2O5/ha, using mono-ammonium phosphate (MAP). CC treatments included triticale (planted in fall) and oat (planted in spring) with no P application and with P application of 45 Kg P2O5/ha. P rates and CC were arranged in a factorial combination of treatments.

Table 1: Average soil test P, pH, and organic matter (OM) by location.

Site	Year	Soil test values			
		STP-M3	STP-B1	pH	OM
		- - - - mg kg^{-1} - - - -			g kg-1
1	2022	79	84	5.3	33
2	2022	17	19	5.7	27
3	2022	3	6	5.8	37
4	2023	10	18	6.5	16
* 5	2023	5	13	6.0	31
6	2023	9	14	7.1	22
* 7	2023	3	8	6.1	33
* 8	2023	7	14	5.9	25
9	2023	18	30	6.8	19

* Yield was not included for this analysis.

CC samples were collected before soybean planting to measure biomass and P uptake. Soybean whole plant samples were collected at the V3-4 growth stage to be analyzed for P uptake. The plant tissue samples were digested using nitric-perchloric acid digestion and analyzed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). At harvest, grain yield was recorded for each plot.

Data was analyzed by location and combined using lmer4 package in R 4.3.1, using RStudio (Version 2023.06.1+524), assuming block as a random factor in the model. When locations were combined, it was also considered as a random effect.

RESULTS AND DISCUSSION

The biomass of CC showed a significant difference comparing oat and triticale, with higher values when P fertilizer was applied (Figure 1). The difference between the CC was mainly due to the longer time given for triticale to grow, as it was planted in the fall of the year before soybean planting, while oat was planted in the spring.

Early-season phosphorus uptake (V3-V4) showed no significant difference between CC treatments with or without fertilizer P application I non-responsive locations (Figure 2 – Non-Responsive). In locations responsive to the application of P fertilizer (Figure 2 - Responsive), there was a penalty in P uptake when a CC was added, showing a tendency to reduce even further when the CC was triticale.

The CC undergoes a decomposition process that lasts several days, during which the nutrients they contain are gradually released into the soil. In scenarios where soil P availability is limited (Figure 2 – Responsive), delayed decomposition of cover crops can result in slower release of P. Consequently, this delay can negatively affect soybean crops, particularly during the early season, as the slow release of phosphorus from cover crop residues may not readily satisfy soybean nutrient demand. This delay can potentially interfere with the development of soybean plants and their P uptake (Varela et al. 2017).

In locations where the crop was non-responsive to P fertilization, the treatments with or without cover crops did not exhibit a significant difference in grain yield (Figure 3 – Non-Responsive). However, the scenario changes in areas with low P levels (Figure 3 – Responsive). The decomposition of cover crops may not occur timely or completely by the time the main crops need to uptake this nutrient for optimal growth, resulting in a penalty by using CC (Poudel et al. 2023). The disparity in grain yields in these cases can also be attributed to the disadvantage faced during the soybean early season, where nutrient demand is high but supply from cover crop decomposition was slow.

In summary, there was no significant response to CC treatments in non-responsive locations. In locations responsive to P fertilization, there was a penalty in soybean growth and yields when adding CC to the system, rejecting our hypothesis that CC treatments would act as a slow-release source of P into the soil for the next cash crop.

The situation where cover crops were at a disadvantage could also result from the dryer Kansas environment, which might have impacted the rate of decomposition and/or the availability of water to the main crop. However, in scenarios where no significant differences in grain yield were observed, employing CC may still present benefits as they can enhance soil health and protection, contributing to a better soil structure or playing as a weed suppressor.

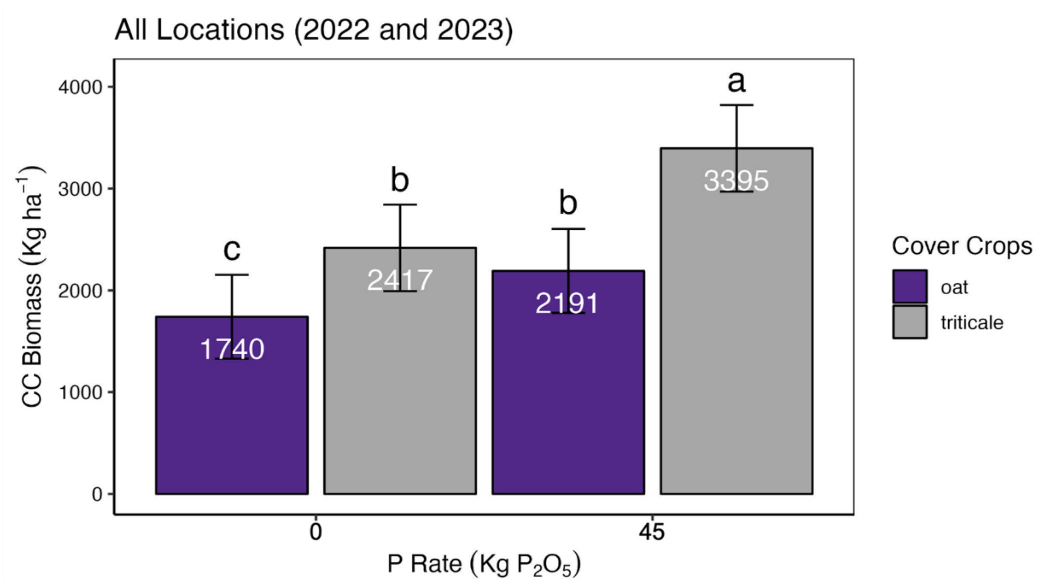

Figure 1: Cover crop biomass (Kg ha-1) as affected by different P rates and cover crop species across 9 locations.

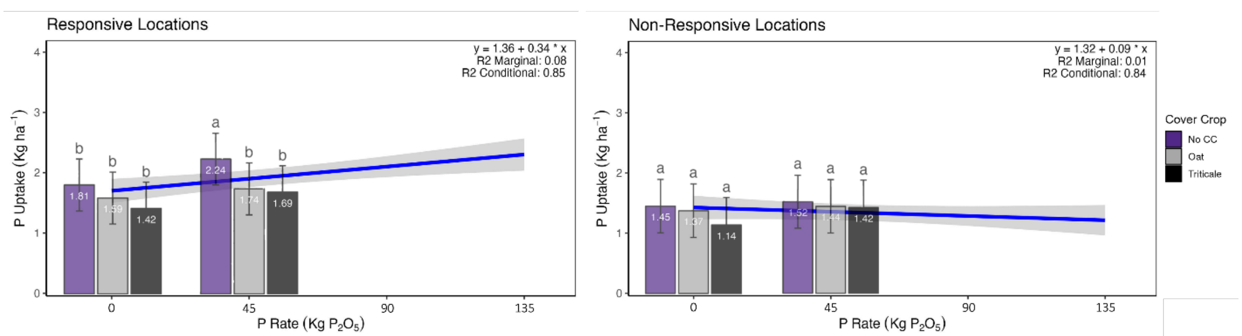

Figure 2: Phosphorus uptake (Kg ha-1) as affected by different P rates (regression line) and Phosphorus uptake (Kg ha-1) as affected by different P rates and cover crop species (bars) in <u>responsive</u> and <u>non-responsive</u> locations to P fertilizer.

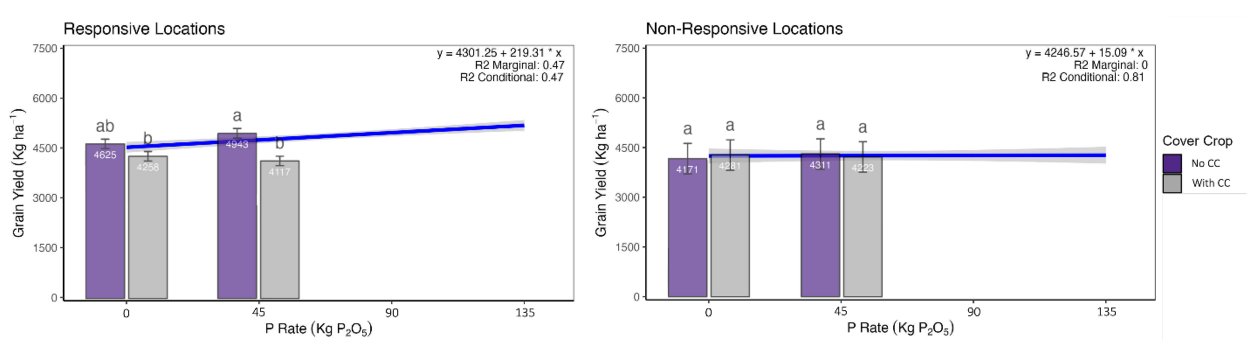

Figure 3: Grain yield (Kg ha-1) as affected by different P rates (regression line) and grain yield (Kg ha-1) as affected by different P rates and cover crop species (bars) in <u>responsive</u> and <u>non-responsive</u> locations to P fertilizer.

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