PHOSPHORUS FERTILIZER MANAGEMENT: IMPLICATIONS ON CROP YIELDS AND SOIL P BUDGETS

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ABSTRACT

Recent volatility in fertilizer prices, declining commodity values, and increasing water quality concerns have intensified scrutiny around phosphorus (P) management decisions in Ohio. In response, we initiated a field trial to evaluate crop yield response and soil phosphorus budgets under various P application strategies within a corn–soybean rotation during the 2024 and 2025 growing seasons. The study investigated two P application timings (fall and spring), two fertilizer sources (triple superphosphate and diammonium phosphate), and five application rates (0, 30, 60, 90, and 120 lb P_2O_5/acre), with each treatment replicated four times. Soil samples were collected in fall 2023, 2024, and 2025 to determine Mehlich-3 extractable P. Corn and soybean yields were measured using a plot combine. In addition, corn tissue samples were analyzed to assess P uptake under different management scenarios. Results from 2024 indicate that fall-applied P significantly increased corn tissue P concentrations at the V4 growth stage compared to both the control and spring-applied P treatments. At the VT stage, spring-applied P and DAP treatments showed lower tissue P concentrations relative to other treatments. Despite these differences in tissue P content, corn yields were not significantly affected by P timing, source, or rate. However, P application rate had a significant impact on the soil P budget in 2024. Treatments receiving 0, 30, and 60 lb P_2O_5/acre resulted in negative P budgets. Soil P data collected in fall 2025 showed no influence of P rate. Like corn yield, soybean yield was similar across the treatments. Overall, these findings suggest that while P management practices can influence soil P budgets and plant P uptake, yield responses are minimal. These results highlight the need to further explore factors such as sub-surface soil P reserves and contributions from other P pools in meeting crop nutrient demands.

INTRODUCTION

Recent volatility in fertilizer prices, declining commodity values, and increasing water quality concerns have intensified scrutiny around phosphorus (P) management decisions in Ohio. Phosphorus management guidelines in Ohio are based on the Tri-State Fertilizer Recommendations (Culman et al.,2020), which uses soil test P level and crop removal rate to calculate P amount for the crops. While these recommendations are effective, limited guidance is present around how P rate could change based on the fertilizer source and application timings.

Different phosphorus fertilizer sources, rates, and application timings can have implications on crop yields and environment. Barcos (2007) and Nakayama et al (2024) showed no crop response to P applied in fall versus spring in Iowa and Illinios, respectively. However, fall P application has been observed to increase water quality concerns by increasing the dissolved reactive phosphorus by 33% and total P by 19%

compared to spring injected P scenarios. Similarly, while Diammonium Phosphate (DAP) and Triple Superphosphate (TSP) has been reported to produce similar crop yields, there is potential that nitrogen input from DAP can increase nitrate leaching to water bodies (Nakayama et al. 2024). Furthermore, rate of P application can alter the soil P budgets with minimal effect on crop yields (Rakkar et al. 2024). Therefore, it is important to evaluate the significance of soil P management strategies on soil and crop yields to further improve P recommendations while maintaining the environmental quality. Our objective of this study was to evaluate the crop and soil response to two different P sources (DAP and TSP), two application timings (Fall and Spring) and five different P fertilizer rates. We hypothesized that crop yields will improve with P application with potentially more benefit on crops from Spring applied P than Fall while minimal differences will be observed on soil and crops based on the P source.

MATERIAL AND METHODS

An experiment was established in 2023 at Wooster Research and Development center in Ohio (40.75944444, -81.90111111). Baseline soil sample analysis showed 22 ppm soil P, silt loam texture, 2.1% organic matter and pH of 6.9. The previous crop at the site was wheat and followed corn-soybean rotation during the study period (2024-2025). The study had 17 fertilizer treatments: two P sources (DAP and TSP); two P application timings (Fall and Spring) and five P application rates (0, 30, 60, 90, and 120 lb P_2O_5/acre) arranged in a factorial randomized complete block design with four replications. Plot width was 10 ft by 40 ft. The fall treatments were broadcasted on Feb 1, 2024 while spring applications occurred on May 7, 2024. Corn was planted with 30-inch row spacing on May, 2024. Other agronomic inputs such as herbicide and fertilizers were uniform across the study area. For 2025, no P fertilizer was applied to track the legacy of 2024 P application treatments. The crop for 2025 was soybean.

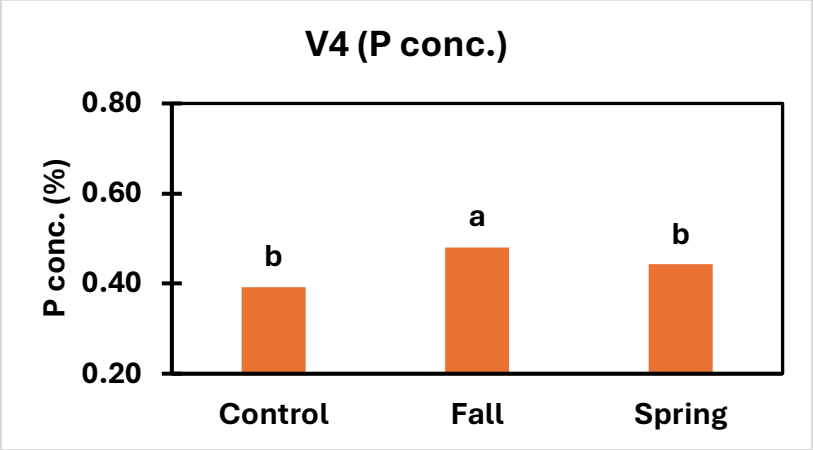
Soil samples were collected from each plot in fall of 2023 (baseline), 2024, and 2025 from 0 to 6 inches. The samples were air-dried, ground, and analyzed for available P using Mehlich-3 extraction procedure (NCERA-13, 2015). Soil budget was calculated by subtracting Baseline soil P and fall P values of 2024 and 2025 season. Leaf tissue samples were collected at V4-V5 stage and VT stage to determine the P content in corn plants. At harvest, grain yield data was collected by harvesting the two center rows of corn plots and center six rows of soybean plots. Grain yield is reported at 15.5% moisture content for corn and 13% for soybeans.

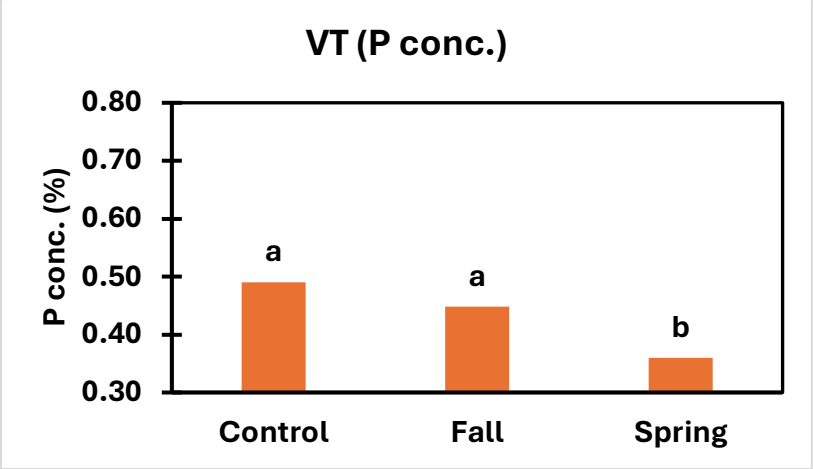
A three-way analysis of variance was conducted by year using R 4.5.1 version to determine the effect of P source, timing and rate on soil P budget, %P tissue content, and crop yields. The significance level was set at $P \leq 0.05$ for all statistical analysis.

RESULTS AND DISCUSSION

In 2024, phosphorus fertilizer treatments affected %P in corn tissue at V4 and VT stage (Table 1; Fig. 1). At V4, %P in corn was significantly higher in fall treated plots compared to spring and control treatments. At VT, the %P in corn was significantly lower in spring treatments compared to the control and fall treatments. During VT, source of P also affected %P, with DAP treatments showing the least %P in corn tissue. Despite

differences in %P during the growing season, corn yield was similar across all the treatments. Similar to 2024 yield outcomes, soybean yield in 2025 was similar across the treatments.





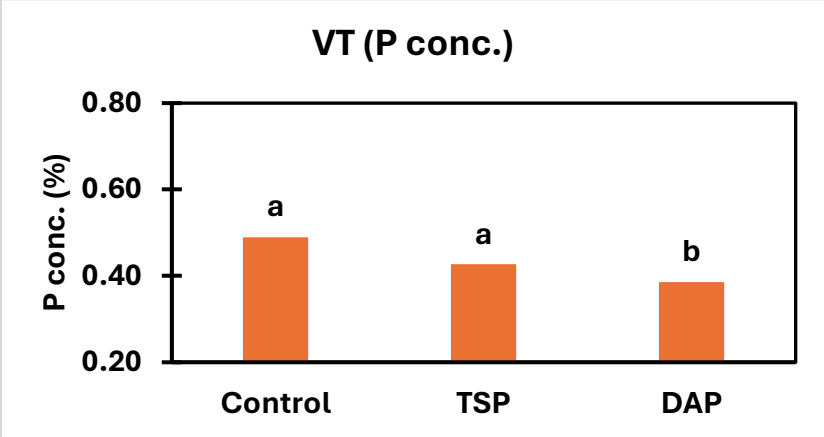


Fig. 1. Phosphorus concentration (%) in corn tissue during V4 and VT stage in 2024 at Wooster, OH.

Table 1. Analysis of variance (p-values) to detect the impact of P source, P timing, and P rate on %P at V4 and VT stage, corn and soybean yields, and soil P budget.

	2024				2025	
Factor	**V4**	**VT**	**Corn Yield**	**Change in fall soil P**	**Soy Yield**	**Change in fall soil P**
P_source	0.07	**0.01**	0.07	0.07	0.91	**0.03**
P2O5_Rate_lb_ac	0.83	0.58	0.28	**0.03**	0.33	0.38
Application_Timing	**0.01**	**0.00**	0.24	0.56	0.77	0.10
P_source:P2O5_Rate_lb_ac	0.06	0.53	0.35	0.61	0.11	0.59
P_source:Application_Timing	0.33	0.24	0.07	0.26	0.17	0.92
P2O5_Rate_lb_ac:Application_Timing	0.20	0.70	0.54	0.50	0.96	0.53
P_source:P2O5_Rate_lb_ac:Application_Timing	0.22	0.77	0.27	0.36	0.79	0.76

Phosphorus treatments significantly affected the soil P budget measured by subtracting P values at the end of each season from baseline P values (Fig 2). In 2024, P rate significantly changed the soil P reserve. The control, 30 and 60 lb P rate showed negative P budgets whereas P values were similar to baseline in other treatments. Statistically significant soil P reduction was observed in control compared to 90-and 120-lb P rates. In contrast, in 2025, P rates had no influence on the soil P measured at the end of soybean growing season compared to baseline soil P. However, P sources showed significant effect on soil P budget with TSP showing the least change in P reserve.

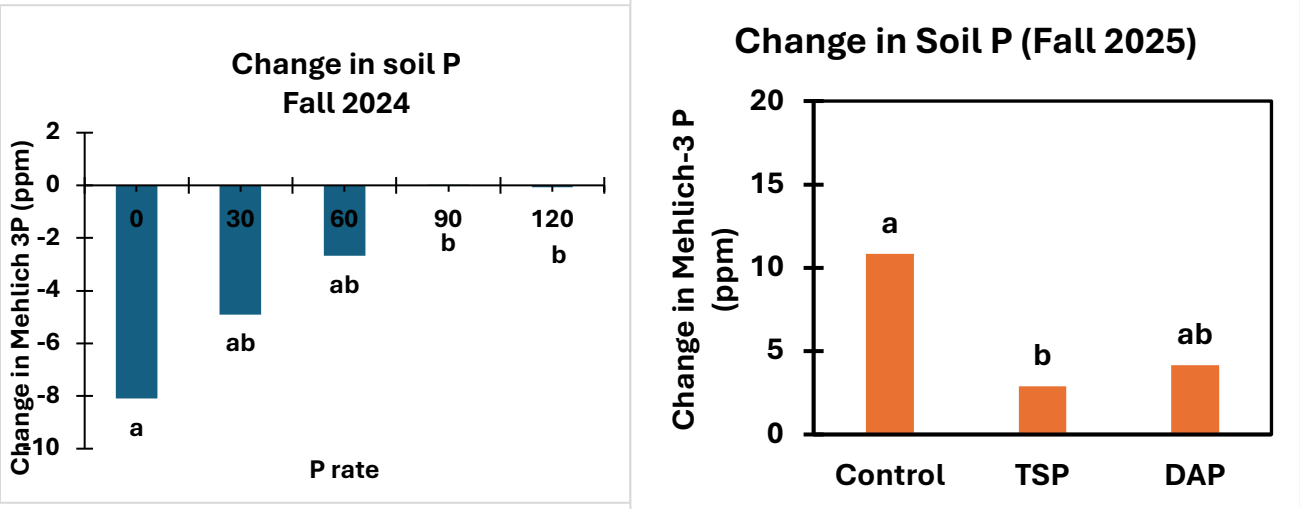


Fig 2. Changes in soil P (End of growing season P -baseline P) as impacted by P source, rate, and timings in 2024-2025 at Wooster, OH.

Overall, these findings suggest that while P management practices can influence soil P budgets and plant P uptake, yield responses in Ohio are minimal, especially when soil P is above the critical level of 20 ppm.

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