Timing of P application for corn and soybean production

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Summary Points

- Both Bray-P1 and Olsen soil P in June was impacted consistently by P application rate and timing. Soil test P was greater in June following spring P application as indicated by significant P timing main effects and significant rate by timing interaction.
- Corn leaf P concentration were consistently impacted by P application rate and seldom impacted by timing.
- Soybean trifoliate P concentration was not impacted by P application rate or timing.
- Corn and soybean yield were impacted by P application rate at 2 of 3 corn and 2 of 3 soybean locations. Grain yield was increased when up to 60 lb P_2O_5 were applied.
- Phosphorus application timing did not affect soybean grain yield. Corn grain yield was greater with spring P application at both locations where P rate affected grain yield.
- There was a significant rate by timing interaction affecting grain yield at Morris. Corn grain yield was similar at Morris when 90 lbs P_2O_5 were applied in Fall versus 60 lb P_2O_5 in spring.
- Grain P concentration and P removed in the harvested grain were inconsistently impacted by P application rate and timing.
- Soybean grain quality (protein and oil concentration) were no consistently impacted by P application rate and timing.

Introduction

Phosphorus is a plant nutrient which, if deficient, can significantly limit crop growth and development. Phosphorus is considered a primary macronutrient. Primary macronutrients are elements that are essential for plant growth which more commonly require fertilizers to be applied to satisfy crop requirements. Orthophosphate is the form of phosphorus taken up by plants. The concentration of orthophosphate in the soil solution is low as orthophosphate is highly reactive with metal elements. Iron, aluminum, and calcium all can react with orthophosphate creating compounds varying in solubility. The ion which reacts with orthophosphate depends greatly on the pH of the soil.

Soils in major cropping regions in Minnesota predominantly formed under calcareous parent materials. Carbonates deposited in the material left following glaciation are still present near the soil surface in areas of the state. These soils with greater carbonate and calcium contents present challenges when managing phosphorus as it is difficult to increase available soil test phosphorus of calcareous soils. Soils with high calcium contents can fix phosphorus. Fixation is a process where orthophosphate reacts with calcium forming compounds like di- and tri-calcium phosphate. While fixed phosphorus is not technically lost from the soil it is rendered unavailable for plant uptake.

The relative rate of phosphorus fixation is not known in soils. Short term P sorption tests can be run to determine the amount of P which a soil will sorb, which can be substantial for some calcareous soils. Management of fertilizer P is common in the fall which gives more time for P to react and potentially bind phosphorus. Studies have been conducted focused on timing of P application but many were conducted in soils with a neutral to slightly alkaline pH which did not contain appreciable amounts of calcium carbonate.

In a previous study funded by AFREC, on-farm strip trials established to determine corn and soybean response to a single rate of phosphorous fertilizer showed that a high rate of P applied one year can have multiple years' benefits for crops in a two-year rotation. The exception was one location with a calcium carbonate equivalency of 20% where there was a yield benefit to P applied both years for a two-year corn-soybean rotation and P applied the previous year had not impact on the crop grown. Fall application provides more flexibility for farmers but there are questions as to whether spring is better under some circumstances.

Objective

The objective of this study is to establish whether there is a difference between fall and spring application of P fertilizer for corn or soybean production and whether potential differences may be tied to calcium carbonate content of the soil.

Materials and Methods

Table 1. Soil series information, planted crop at each location, and initial potassium soil test data from phosphorus studies conducted in 2019. Soil test data was collected in the Fall at trial establishment from each main plot.

			Soil Test P		Soil Test†			
Year	Location	Crop	Bray-P1	Olsen	K	pH	CCE	Soil Series
				ppm			%	
2019	Crookston	Corn	3	6	258	8.0	13.8	Colvin-Perella
	Lamberton	Corn	11	5	147	5.3	0.2	Normania
	Morris	Corn	12	7	253	7.4	0.9	Flom-Aazhahl-Hamerly
	Benson	Soybean	28	23	135	7.9	2.2	Arveson
	Morris	Soybean	5	3	245	7.4	0.7	Flom-Aazhahl-Hamerly
	Stewart	Soybean	2	10	183	7.7	16.2	Harps

† K, Soil test potassium (K-ammonium acetate); CCE, calcium carbonate equivalency.
‡Soil Texture: ClL, clay loam; FSL, fine sandy loam; L, loam; SCL, silty clay loam; SilL, silt loam.

Field trials were established in farmer fields and at ag experiment stations in Minnesota (Table 1). Locations were targeted to test Low by either the Bray-P1 or Olsen tests (< 10 ppm Bray-P1 or <8 ppm Olsen P). Sites with a calcium carbonate equivalency of >5% CCE were given preference due to a greater capacity for P fixation but the exact CCE was not known until after trial establishment.

A split plot design was used where main plots consisted of four P rates and sub-plots consisted of timing (Fall or Spring). The four P rates were 0, 30, 60, and 90 lbs P_2O_5 per acre applied as MAP (11-52-0). All treatments were replicated four times. Nitrogen supplied with MAP was balanced with AMS. Gypsum was used to balance sulfur applied by AMS such that all plots received similar rates of N and S when P treatments are applied. Calcium supplied by gypsum was not expected to impact corn or soybean yield due to excessive levels of calcium already in the soil.

Corn and soybean will be the two crops utilized for this study. Additional crop species are not used as corn and soybean should provide sufficient information on potential differences in responses based on fertilizer timing which can be translated to additional crops. A total of three trials were established for each crop each year (6 trials total per year).

Soil samples (0-6") were collected from each main block prior to fall treatment application, were air dried, ground, and analyzed for P by Bray-P1, Olsen, and Mehlich-3 P tests. Samples were additionally analyzed for calcium carbonate equivalency (modified pressure calcimeter method) and pH (1:1 soil:water). Additional 0-6" soil samples were collected in June from all plots to assess change in Bray-P1 and Olsen soil test P after treatment application.

Table 2. Summary of cultural practices for studies conducted in 2019. Soil test data was collected in the Fall at trial establishment from each main plot.

				Date of		
Year	Location	Crop	Cultivar†	Fall Fert.‡	Spring Fert.	Planting
2019	Crookston	Corn	P 7632	2-Nov.	9-May	15-May
	Lamberton	Corn	P 0157	15-Nov.	17-May	17-May
	Morris	Corn	DK 4480	9-Nov.	25-Apr.	14-May
	Benson	Soybean	DG 11LL48	9-Nov.	6-May	7-Jun
	Morris	Soybean	C 0716	9-Nov.	25-Apr.	17-May
	Stewart	Soybean	NS 6162	17-Oct.	6-May	13-May

†C, Cropland; DG, Dyna-gro; DK, Dekalb; NS, North Star; P, Pioneer.

‡ Fall fertilizer (fert.) was applied the fall the previous year in which the study was harvested.

Leaf samples were collected from each corn plot at V8-V10 (uppermost fully developed leaf) and R1 (leaf opposite and below the ear), and for soybean at the R1-R2 growth stage (uppermost fully developed trifoliate). All soybean plots will be harvested with a small plot combine. Corn will either be harvested with a plot combine or by hand. Soybean grain yield is reported at 13% moisture and corn grain yield is reported at 15.5%. Grain samples were collected from each location and analyzed for total P concentration for both crops while soybean was analyzed for protein and oil concentration in grain by NIR.

Results and Discussion

Location data are summarized in Table 1. Sites were selected to have low initial soil test P (STP) and measurable carbonate levels. The exception to this was Lamberton which was included due to a very acidic pH which is a good comparison to the remaining sites to determine the impact of free iron and aluminum on the retention of soil test P. The only location which tested above the medium STP class was Benson. To establish the location we targeted high pH zones which have a tendency to have low soil P, but that was not the case for Benson. The remaining sites were all within targeted parameters. Calcium carbonate equivalency (CCE) was highest at Crookston and Stewart. At the remaining four locations there was measurable CCE (except for Lamberton) but the levels were lower than anticipated.

Table 2 and 3 summarizes main effects and main effect interactions for the ANOVA for the measured variables for the corn and soybean trials, respectively. Tables 4 and 5 summarize the phosphorous (P) rate and timing main effects for corn and soybean, respectively. Interactions were generally not significant and the interaction data are not summarized for the majority of the measured variables. A lack of a significant interaction is an indication that there is no impact of P timing on fertilizer use by either crop. Exceptions however will be noted.

Soil samples were collected in June in order to assess potential loss of P availability following the fall application. In general, main effect significance was similar when P was analyzed by either the Bray P1 or Olsen P tests. The two exceptions were the corn location at Crookston and soybean location at Benson where the high level of carbonates neutralized the Bray solution and resulted in Very Low soil P tests which did not change with application rate. Benson was the only location where neither main effect was significant which could be due to greater variability in soil P due to the higher initial P soil tests. For Lamberton and both Morris sites, both main effects were significant for both soil tests while both main effects were also significant for the Olsen P test only at Crookston and Stewart. Since most sites were high pH where the Olsen P test is typically used, the Data in Figures 3 and 4 will be discussed for the corn and soybean locations, respectively.

The interaction between P source and rate was significant for the change in Olsen soil test P at the Morris corn and soybean locations. This indicates a difference in slope in the relationship between soil test P change and P application rate for the fall and spring applications. In all cases, Olsen soil test P was greater in June following spring application which is not surprising considering the greater time the P had to react with the soil from the fall application. From the relationships in Figures 3 and 4 it is surprising that more of the interactions were not significant. However, since most of the timing main effects were significant we have strong evidence that P is being tied up following fall application including at Lamberton which had an acidic pH. Sites like the soybean trial at Morris exhibited very little change in soil test P when up to 60 lbs P_2O_5 were applied.

Corn data are summarized in Table 5. Phosphorus application rate more consistently impacted measured variable compared to P application timing. Corn leaf P at V10 and R1 were generally increased linearly at most locations with the exception of R1 leaf P at Morris which was no affected by P application. The only timing effect occurred for R1 leaf P concentration which was greater for the fall application but the difference was negligible. Expected concentration of P in corn leaves at R1 is between 0.2 and 0.4 %. All locations tested within that range with the lowest concentrations of P combing back at 0.23 %.

Corn grain harvest moisture was inconsistently affected by P application. Yield, however, was increased by P application at Lamberton and was impacted by timing at two locations, Lamberton and Morris. Corn grain yield favored spring application at both locations which were significant. The P rate by timing interaction was also significant at Morris indicating a significant impact of P rate that varied based on timing. The interaction is not shown in figures but the analysis of data showed no yield difference between timing at the 0 and 90 lb application rates while spring application resulted in greater yield when 30 or 60 lbs P_2O_5 were applied. A regression was not run on the data but the ANOVA would indicate that application of 90 lbs would result in similar yield and that a small reduction in P could be taken if the P were applied at a rate greater than 60 lbs P_2O_5. The lack of a response to P at Crookston was likely due to high levels of Goss' Wilt which reduced yield potential in the trial. Overall yield potential was significantly lower at Crookston compared to the remaining sites. Corn grain P concentration and P removed in the harvested grain were also inconsistently impacted by P rate and timing effects.

Soybean data are summarized in Table 6. Phosphorus rate and timing did not affect the concentration in the uppermost fully developed trifoliate at R1. In addition, P concentration in the harvested grain, soybean protein and oil concentration were inconsistently impacted by treatments.

Soybean grain yield was affected by P rate at Morris and Stewart and was not impacted by timing. Soybean yield was increased when up to 60 lbs P_2O_5 were applied at both locations. Removal of P in the harvested grain was increased by P application rate at all three locations, even Benson where yield was not affected which is in contrast to corn where P removal was seldom impacted. Yield increase to P was greater at Morris where yield was nearly doubled with the 60 lb P_2O_5 application rate compare to the control, and grain yield was increased 2 bu/ac at Stewart.

Year 1 Conclusions

Data from year 1 shows that timing of P application may be more important for corn compared to soybean. Addition years' data will help confirm whether there is a clear impact of timing over a number of growing seasons. Soil test in June did vary based on when the P fertilizer was applied. However, there was no relationship between June STP and yield potential of corn or soybean.

Table 3. ANOVA summary for measured variables (phosphorus rate and timing) for the three corn trials conducted in 2019.

Main Effect	Bray P Change	Olsen P Change	V10 Leaf	R1 Leaf P	Grain Moisture	Grain Yield	Grain %P	Grain P Removal
		-------------------------	-------------------------	-----*P*>F-----	-------------------------	-------------------------		
				Crookston				
P rate	0.42	**	*	***	0.56	0.45	*	0.44
Timing	0.22	*	0.15	0.07	0.11	0.68	0.34	0.94
P rt. x Time	0.49	0.23	0.89	0.63	0.52	0.90	0.18	0.29
				Lamberton				
P rate	*	*	***	**	**	*	*	0.10
Timing	0.10	0.07	0.36	0.57	0.46	0.08	0.37	0.14
P rt. x Time	0.64	0.58	0.71	0.59	0.07	0.42	0.09	0.07
				Morris				
P rate	***	**	0.09	0.28	0.19	0.39	0.88	0.72
Timing	**	**	0.23	0.63	**	*	0.38	*
P rt. x Time	0.17	*	0.63	0.31	0.71	**	0.68	0.18

Table 4. ANOVA summary for measured variables (phosphorus rate and timing) for the three soybean trials conducted in 2019.

Main Effect	Bray P Change	Olsen P Change	R1 Leaf P	Grain Yield	Grain %P	Grain P Removal	Grain Protein	Grain Oil
		----------	----------	-----*P*>F-----	----------	----------		
				Benson				
P rate	0.27	0.20	0.15	0.31	0.36	0.10	0.82	0.16
Timing	0.33	0.89	1.00	0.74	0.11	0.28	0.26	0.71
P rt. x Time	0.78	0.44	0.95	0.08	0.98	0.40	0.73	0.68
				Morris				
P rate	***	***	0.29	**	***	*	*	0.19
Timing	**	**	0.74	0.81	*	0.90	0.10	0.29
P rt. x Time	**	**	0.40	0.11	0.55	0.71	0.91	0.77
				Stewart				
P rate	0.98	**	0.91	*	0.13	0.08	0.13	*
Timing	0.64	**	0.67	0.78	0.25	0.31	0.07	0.74
P rt. x Time	0.09	0.25	0.48	0.18	0.80	0.35	*	0.53

Table 5. Summary of treatment main effects for three corn locations where P fertilizer rates were applied in Fall or spring ahead of the 2019 cropping season. Treatments are considered significantly different at $P \leq 0.10$. Numbers followed by the same letter for individual site treatment main effects are not significantly different.

	P application rate (lb P_2O_5 ac^{-1})				Application Time	
Location	0	30	60	90	Fall	Spring
	------ V10 Upper Leaf %P ------					
Crookston	0.31b	0.32b	0.35a	0.34a	0.33	0.32
Lamberton	0.25c	0.30b	0.30b	0.32a	0.29	0.29
Morris	0.23a	0.24ab	0.25ab	0.27a	0.26	0.25
	------ R1 Leaf %P ------					
Crookston	0.23b	0.24b	0.28a	0.28a	0.26a	0.25b
Lamberton	0.23c	0.25bc	0.26b	0.28a	0.25	0.25
Morris	0.24	0.25	0.25	0.26	0.25	0.25
	------ Moisture in harvested grain % ------					
Crookston	26.0	25.4	26.1	24.6	25.1	26.0
Lamberton	20.2a	19.4b	19.3b	19.1b	19.6	19.4
Morris	19.3	19.7	19.5	19.8	19.3b	19.8a
	------ Corn grain yield at 15.5% bushels per acre ------					
Crookston	133	120	129	143	132	130
Lamberton	175b	192a	200a	194a	187b	193a
Morris	233	223	235	233	225b	238a
	------ Corn Grain %P ------					
Crookston	0.24b	0.24b	0.27a	0.27a	0.25	0.26
Lamberton	0.17b	0.18b	0.19ab	0.21a	0.18	0.19
Morris	0.19	0.18	0.19	0.18	0.18	0.19
	------ P Removed in Corn Grain (lb P_2O_5/ac) ------					
Crookston	34	33	36	38	35	35
Lamberton	34b	37ab	40a	42a	37	39
Morris	48	43	48	46	44b	48a

Table 6. Summary of treatment main effects for three soybean locations where P fertilizer rates were applied in Fall or spring ahead of the 2019 cropping season. Treatments are considered significantly different at $P \leq 0.10$. Numbers followed by the same letter for individual site treatment main effects are not significantly different.

Location	P application rate (lb P_2O_5 ac^{-1})				Application Time	
	0	30	60	90	Fall	Spring
	---------- R1 Trifoliate %P ----------					
Benson	0.37	0.38	0.40	0.42	0.39	0.39
Morris	0.42	0.35	0.44	0.45	0.41	0.42
Stewart	0.39	0.39	0.39	0.40	0.39	0.39
	---------- Soybean grain yield at 13% bushels per acre----------					
Benson	56.3	55.9	58.7	56.2	56.9	56.7
Morris	32.7c	39.3b	47.5a	43.0ab	40.8	40.4
Stewart	57.1c	58.2bc	59.8a	58.8ab	58.4	58.6
	---------- Soybean Grain %P ----------					
Benson	0.72	0.69	0.73	0.73	0.71	0.72
Morris	0.46b	0.47b	0.52a	0.54a	0.49b	0.51a
Stewart	0.56	0.57	0.58	0.60	0.57	0.58
	---------- P Removed in Soybean Grain (lb P_2O_5/ac)----------					
Benson	48ab	46b	51a	50a	48	49
Morris	16c	23b	27ab	28a	24	24
Stewart	38c	39bc	41ab	42a	40	41
	---------- Soybean Grain Protein % ----------					
Benson	45.7	45.7	45.8	45.9	45.9	45.7
Morris	45.1b	45.0b	45.8a	45.9a	45.3b	45.6a
Stewart	45.8	46.2	46.0	46.0	45.9b	46.1a
	---------- Soybean Grain Oil % ----------					
Benson	21.5	21.5	21.2	21.5	21.4	21.4
Morris	20.7	20.9	20.5	20.6	20.7	20.6
Stewart	22.8a	22.5b	22.4b	22.6b	22.6	22.6

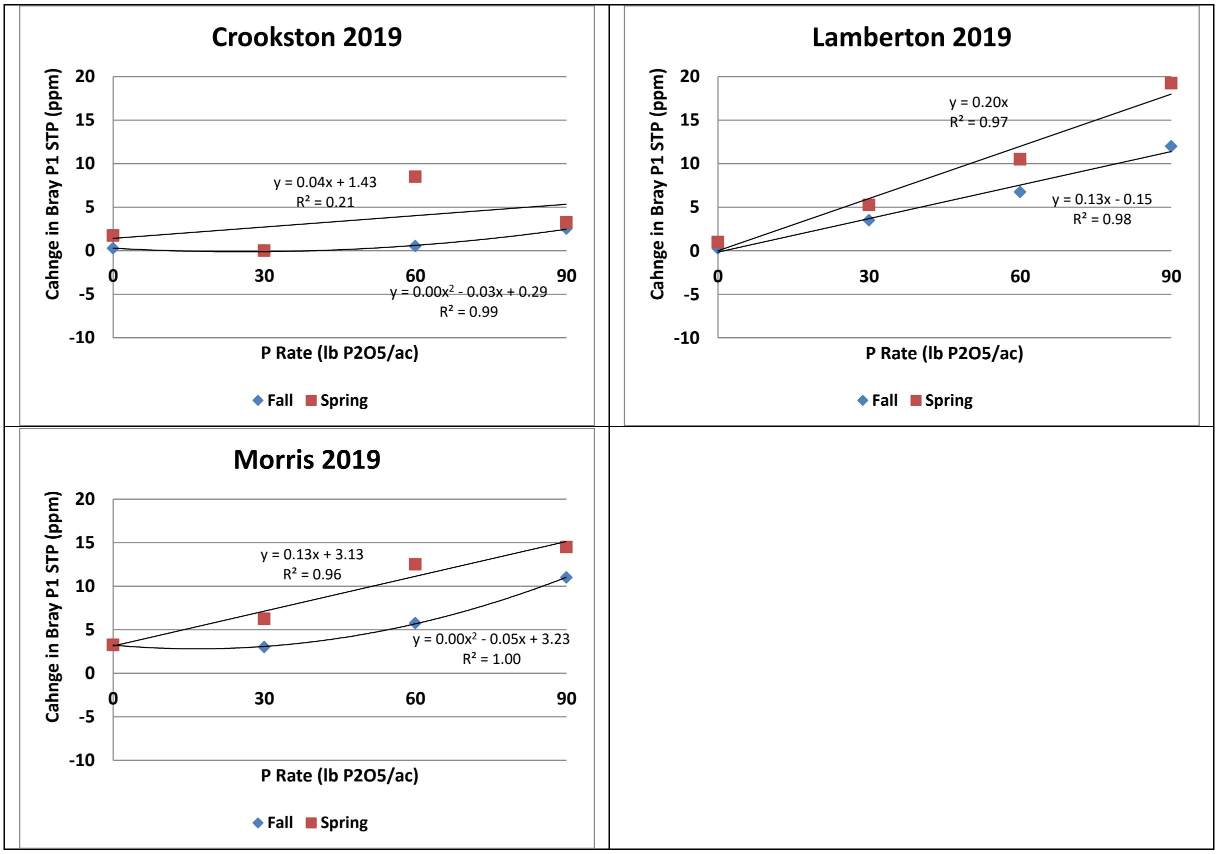

Figure 1. Summary of change in Bray-B1 P following P application ahead of corn in Fall or Spring 2019.

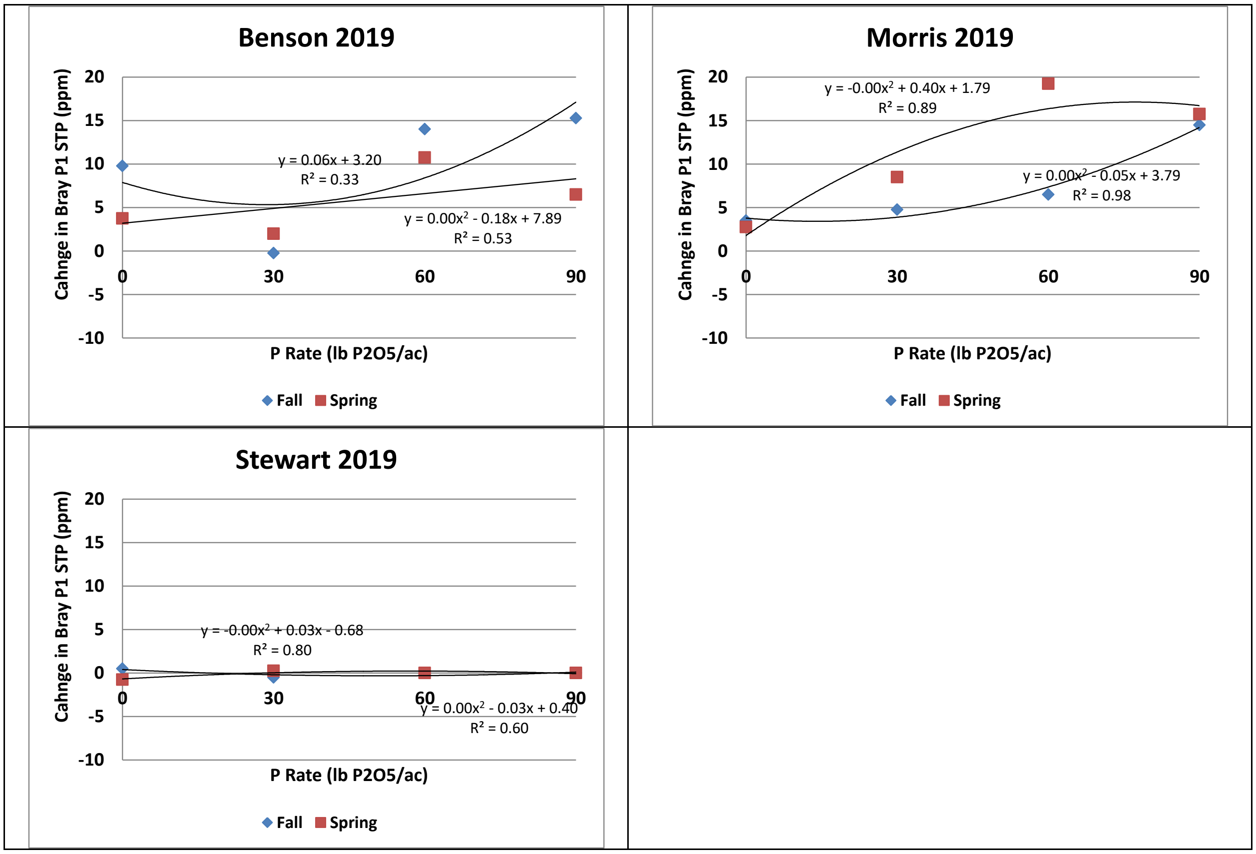

Figure 2. Summary of change in Bray-B1 P following P application ahead of soybean in Fall or Spring 2019.

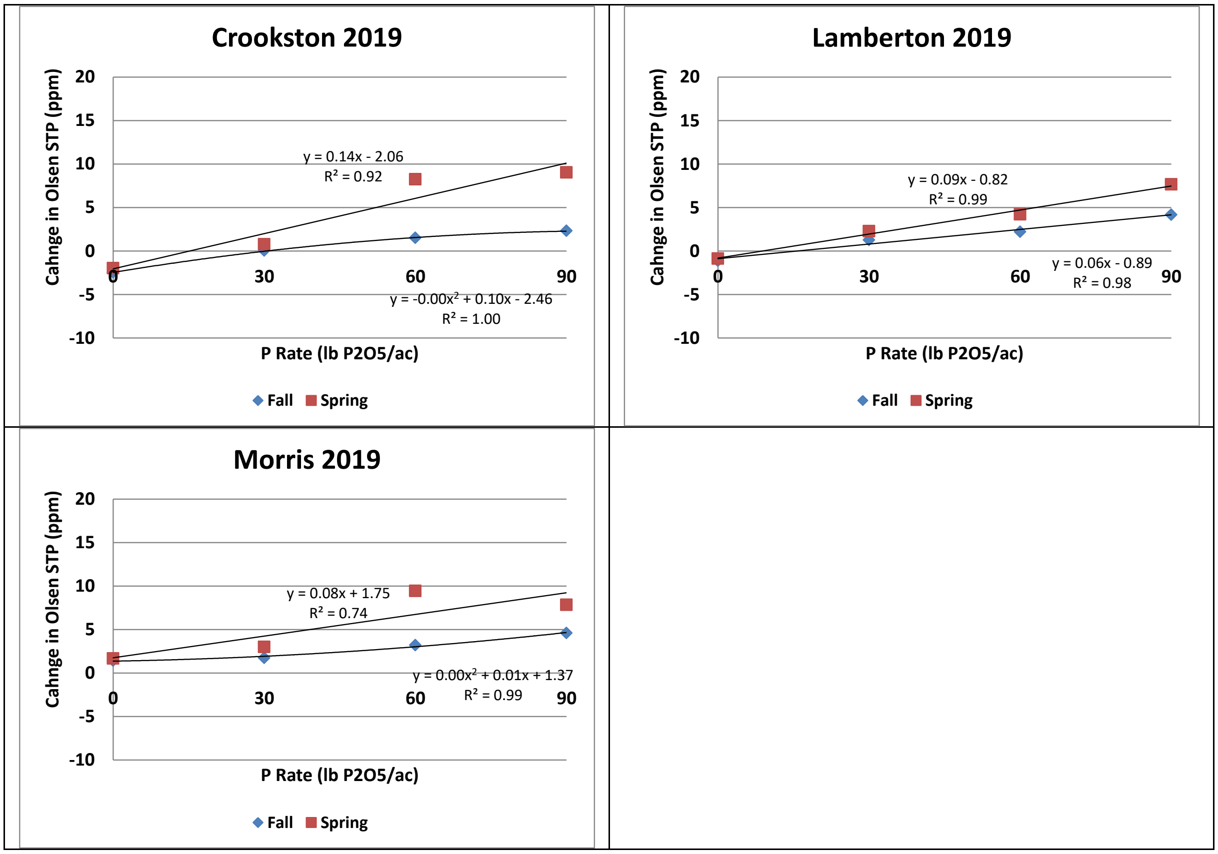

Figure 3. Summary of change in Olsen P following P application ahead of corn in Fall or Spring 2019.

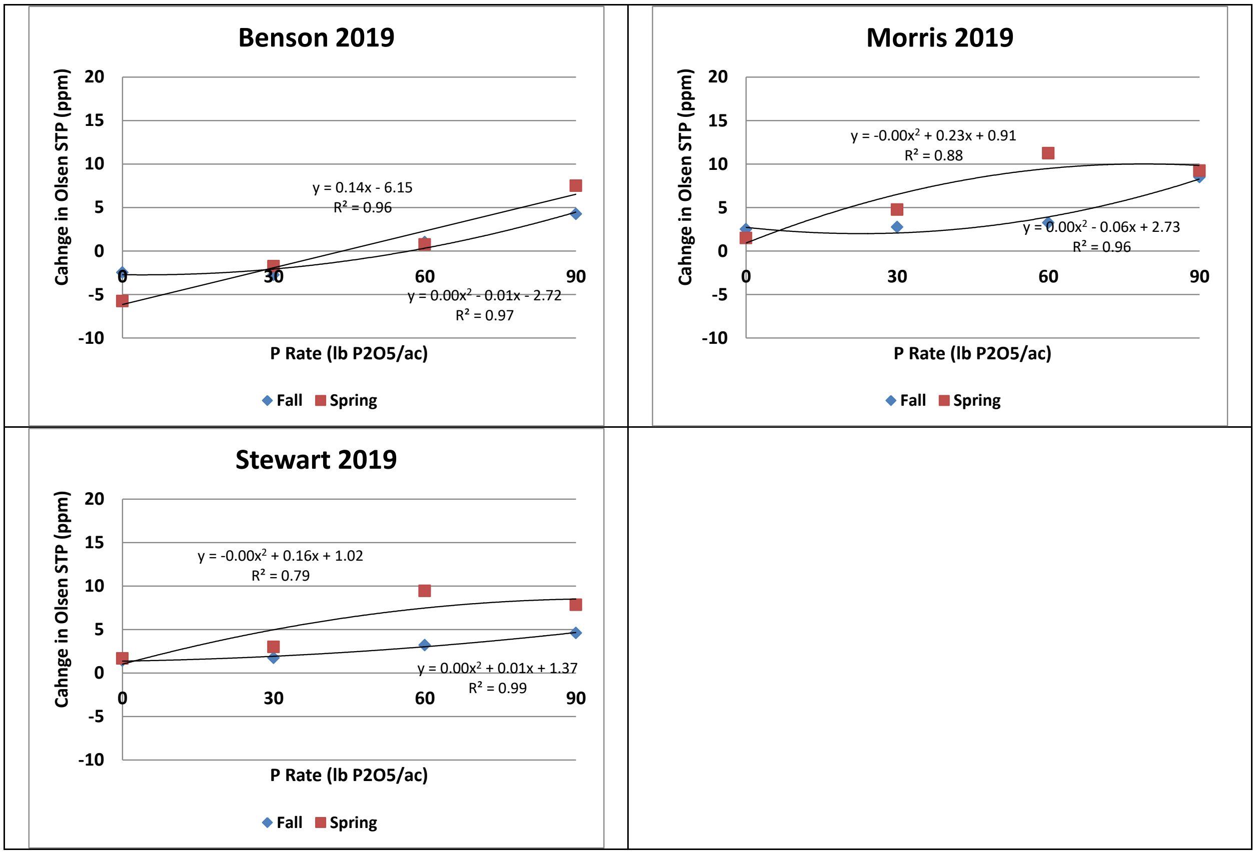

Figure 4. Summary of change in Olsen P following P application ahead of soybean in Fall or Spring 2019.