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Fertilizer Management Effects On Phosphorus Concentrations in Runoff from No-Till Corn and Soybean

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ABSTRACT

Elevated P concentrations in runoff water from agricultural fields can induce algal blooms, eutrophication, and associated water quality degradation. Fertilizer management, such as timing and placement of P fertilizers, can influence the P concentration in runoff water, but additional information is needed from field-scale experiments to determine effects of fertilizer management systems on P loss. The objective of this study was to determine the effects of fall broadcast and spring injected fertilizer management systems on P concentrations in runoff water from a no-till corn-soybean cropping system. Natural runoff was monitored from 18 1.2-ac watersheds managed in a no-till corn-soybean cropping system at the Kansas Agricultural Watershed (KAW) field laboratory during the 2015/16 and 2016/17 water years. Treatments were applied in a 3x2 factorial with three levels of P fertilizer management (no P, fall broadcast P, spring injected P; CN, FB, and SI respectively) and two levels of cover crop (no cover and with cover). Flow-weighted composite water samples were collected from each runoff event and analyzed for total P, dissolved reactive P, and particulate P concentrations. Spring injected fertilizer management reduced dissolved P and total P concentrations by 70% and 40% respectively during the months prior to SI fertilizer application. Following SI fertilizer application, the dissolved P and total P concentrations in runoff from SI and FB treatments were relatively similar up until FB fertilizer application. Runoff from the CN treatment had the lowest dissolved P and total P concentrations. Results from this study indicate that subsurface P fertilizer application remains the best fertilizer management option for minimizing P concentrations in agricultural runoff.

INTRODUCTION

Minimizing phosphorus (P) loss from agricultural lands is essential to developing sustainable agricultural systems. Phosphorus is an essential nutrient for plant production as well as being critical for human and animal health. However, P inputs to surface waters promote algae growth, eutrophication, and harmful algal blooms. These water quality problems can decrease dissolved oxygen, release toxic compounds, trigger fish kills, and increase drinking water treatment costs (Correll, 1998; Hudnell, 2010; Paerl, 2008).

The timing and placement of P fertilizer, which can be used to reduce P loss from agriculture, are critical components of 4R nutrient management (selecting the Right source, Right rate, Right time, and Right place. Several studies have found that subsurface placement of P fertilizer reduces P loss in runoff water compared to surface broadcast fertilizer (Baker and Laflen, 1982; Mostaghimi et al., 1988; Kimmell et al., 2001; Zeimen et al., 2006). These studies all compare changes in placement at the same time, generally in the spring prior to planting. The timing of fertilizer application relative to intense rainfall and runoff has a strong influence on P loss from surface-applied fertilizers. Therefore, the general recommendation is to plan surface P fertilizer applications for times of the year when rainfall, and hence runoff, is not likely. For much of the Great Plains, the time of highest likelihood for runoff is in the spring and the lowest chance for runoff is in late fall. Therefore, surface broadcast P applications should be made during the fall.

The objective of this study was to determine the effects of fall broadcast and spring injected fertilizer management systems on P concentrations in runoff water from a no-till corn-soybean cropping system.

MATERIALS AND METHODS

The experiment was conducted at the Kansas Agricultural Watersheds (KAW) field laboratory located near Manhattan, KS. The KAW field lab consists of 18 watersheds, with average area of 1.2-ac, equipped with 1.5-ft H-flumes and ISCO 6700 series automated water samplers to monitor edge-of-field runoff. The soils are mapped as eroded Smolan silty clay loams with 3 to 7% slopes. The treatment structure is a 3·2 factorial with three levels of P fertilizer management (control, fall broadcast, and spring injected; CN, FB, and SI respectively) each with two levels of cover crop (no cover crop and with cover crop) arranged in a randomized complete block design with three replicates. The site was under conventional till management until the study was initiated in November 2014 and planted to corn in April 2015. Because the first water year (October 2014 to September 2015 was a transition from conventional till to no-till, we present results from only the second and third years of the study (2015/16 and 2016/17 water years).

A winter wheat cover crop was seeded in cover crop treatments with a no-till drill on 22 September, 2015 following corn harvest. Diammonium phosphate was applied to FB treatments with a tractor-mounted drop spreader on 12 November, 2015 at 54 lb P_2O_5 ac^{-1}. Cover crop was terminated with herbicide on 6 May, 2016 and soybean was planted with a no-till planter on 6 June, 2016. All SI treatments received 56 lb P_2O_5 ac^{-1} as ammonium poly-phosphate in a 2x2 placement at planting. The CN treatment did not receive P fertilizer.

A triticale and rapeseed mix cover crop was seeded in cover crop treatments with a no-till drill on 16 October, 2016 immediately following soybean harvest. Diammonium phosphate was applied to FB treatments with a tractor-mounted drop spreader on December 2, 2016 at 56 lb P_2O_5 ac^{-1}. Corn was planted with a no-till planter on 24 April, 2017 and cover crops were terminated with herbicide within two days following corn planting. All SI treatments received 53 lb P_2O_5 ac^{-1} as ammonium poly-phosphate in a 2x2 placement at planting. Nitrogen was balanced between all treatments at 155 lb N ac^{-1} with UAN applied with a disk-coulter injection unit within 3 days following planting. An additional 40 lb N ac^{-1} was applied to all treatments on 12 June, 2017 (V8) with streamers. Although the target P application rates were the same for both FB and SI treatments, limitations in equipment calibration and operation caused slight differences in actual application rates between treatments as indicated above.

Water depth within the flumes was continuously monitored throughout the study with ISCO 730 series bubbler units. Event-based flow-weighted composite water samples were collected for each runoff event throughout the study, with one sub-sample collected for every 0.04 inches of runoff. Water samples were removed from the field within 24 hours after the end of the precipitation event and analyzed for total suspended sediment, total P, and dissolved P. Particulate P was determined as total P minus dissolved P.

Events with mean runoff less than 0.06 and 0.08 inches for the 2015/16 and 2016/17 water years respectively had an excessively high quantity of missing water samples and were therefore excluded from statistical analysis. Runoff and concentration data were transformed prior to statistical analysis with either log or square-root transformations as appropriate to satisfy the assumptions of normality of residuals. Statistical analysis was computed with SAS proc glimmix and the least square means were back-transformed for presentation in results. Data for this study were averaged across cover crop treatments because interactions between cover crop and fertilizer management were rarely significant.

RESULTS AND DISCUSSION

Total P concentrations were greater in runoff leaving the FB fertilized treatment compared to the SI treatment prior to soybean planting in the 2015/16 water year (**Figure 1**). During this same time period, P concentrations in runoff from SI and CN treatments were similar for seven of the eight events. The total P concentration in runoff from the SI treatment increased significantly following the planting operation in June (i.e., the time of P application). Thereafter, the total P concentration in runoff water from the SI treatment was greater than or equal to that from the FB treatment. This trend continued into the 2016/17 water year until fertilizer was applied to the FB treatment in November 2016 (Figure 1). Total P concentrations in runoff from the FB treatment were greater than other treatments from November 2016 through mid April 2017. Following fertilizer application to the SI treatment on 20 April, 2017, the total P concentration in runoff water from the SI increased to nearly the same as from the FB treatment and remained similar to that of the FB treatment for the remainder of the year.

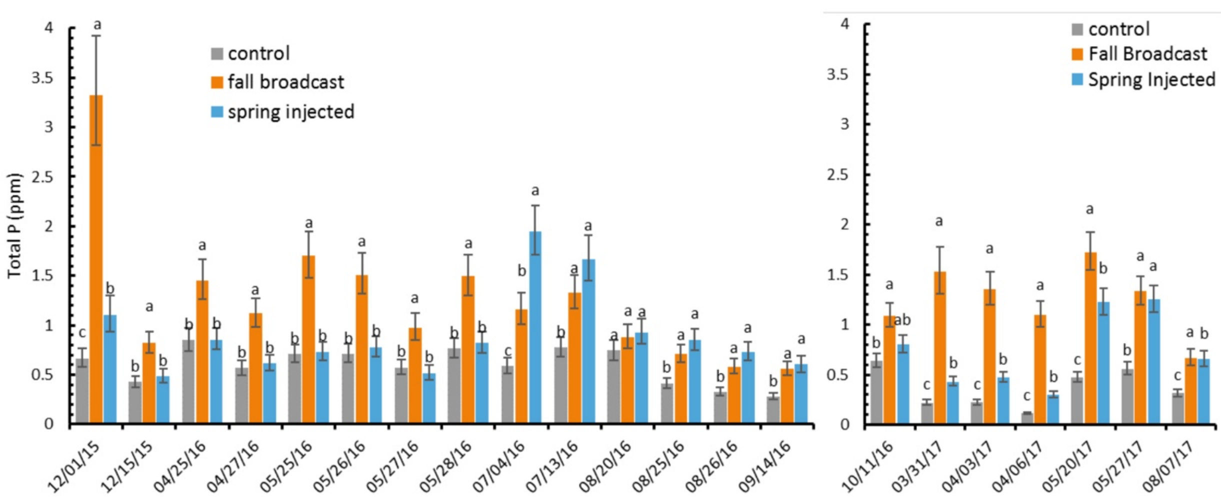

Figure 1. Total P concentration in runoff water as affected by P fertilizer management for the 2015/16 (left) and 2016/17 (right) water years. Letters above bars indicate significant differences within runoff event. Data are averaged across cover crop treatment.

Effects of fertilizer management on dissolved P concentrations in runoff were similar to what was observed for total P (**Figure 2**). However, treatment differences were typically greater. For example, prior to soybean planting in June 2016, the total P concentrations of runoff from the SI treatment were about 40% less than in runoff from the FB treatment whereas dissolved P concentrations in runoff from SI treatment were 70% less than from the FB treatment during the same time period.

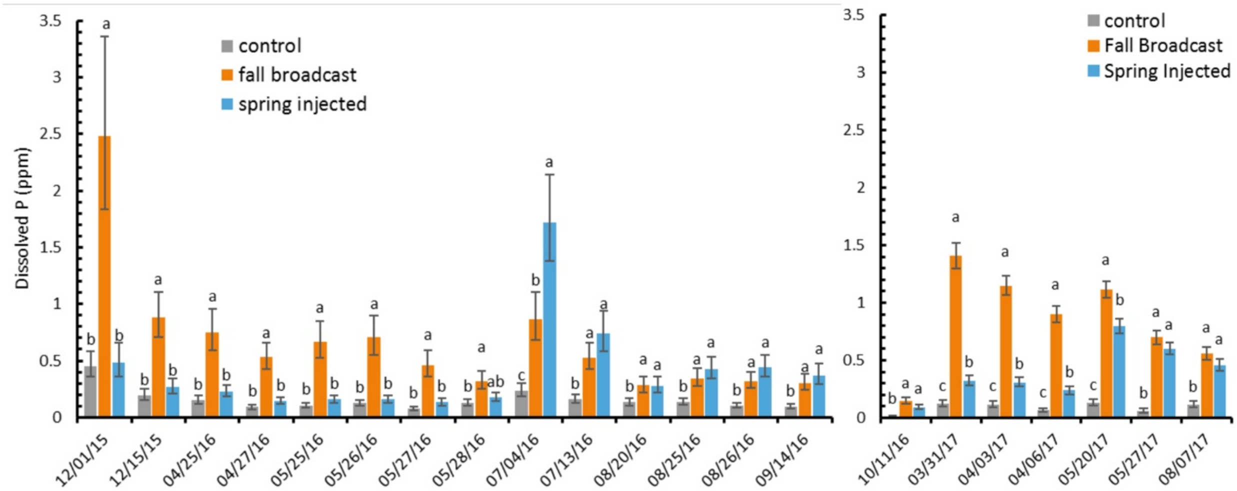

Figure 2. Dissolved P concentration in runoff water as affected by P fertilizer management for the 2015/16 (left) and 2016/17 (right) water years. . Letters above bars indicate significant differences within runoff event. Data are averaged across cover crop treatment.

Fertilizer management did not impact particulate P concentrations in runoff to the same extent that it impacted total P and dissolved P concentrations. Particulate P concentrations in runoff from the CN treatment were significantly less than the other treatments in only five of the 21 runoff events (12/01/15, 05/25/16, 03/31/17, 04/03/17, and 04/06/17; **Figure 3**).

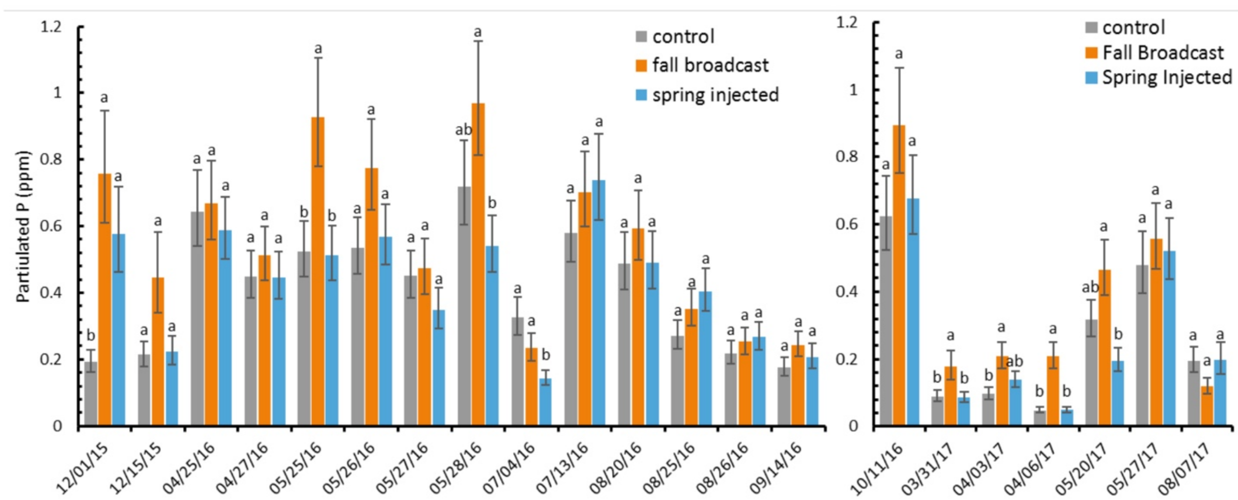

Figure 3. Particulate P concentration in runoff water as affected by P fertilizer management for the 2015/16 (left) and 2016/17 (right) water years. . Letters above bars indicate significant differences within runoff event. Data are averaged across cover crop treatment.

The primary effects of fertilizer application and fertilizer management were to increase dissolved P concentration in runoff events following the application of fertilizer. Fall broadcast fertilizer application tended to increase the dissolved P concentration in runoff more than the SI application and the effects tended to persist for a longer duration. Following SI fertilizer application there were fewer differences between P concentrations in runoff from the FB and SI treatments.

Conclusions

These results indicate that spring subsurface placement of P fertilizer maintains lower dissolved P concentrations in runoff water compared to fall broadcast fertilizer application, which led to lower total P concentrations in runoff water. Therefore, subsurface P placement remains the best management practice for reducing P loss from agricultural fields, even if broadcast applications are made at times when runoff is reduced. This study will continue through one more rotation cycle to confirm trends observed thus far.

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