MITIGATING PHOSPHORUS MOVEMENT FROM AGRICULTURAL FIELDS

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Abstract

Agriculture is often cited as the primary factor for the high P loads polluting Lake Erie and Ohio's watersheds, but the contributions of agriculture as a system, a combination of tillage, best management practice (BMP) and fertilizer source rather than an industry is unknown. This study supplied either commercial fertilizer or poultry litter to tilled or no-till production systems with their corresponding BMPs of incorporation and cover crops, respectively, to determine the P lost via surface runoff. At two locations in the Maumee Watershed of Lake Erie, simulated rainfall was used to generate runoff following implementation of the above systems. One site had been under no-till for at least 20 years and the other had not. At both sites, incorporation of the commercial fertilizer reduced dissolved P compared to the commercial fertilizer left on the soil surface. The surface application of commercial fertilizer in the no-till plots resulted in similar runoff P concentrations with or without a cover crop at both locations. The application of poultry litter was not significantly different than the control for both tillage systems at one location, but was at the other location. This may be attributed to a combination of site differences and the nutrient solubility differences. Some degree of incorporation will likely decreasing dissolved P loading associated with runoff from either fertilizer source especially commercial fertilizer.

Introduction

There are two sources of P of concern to the water quality of streams and lakes. Total P is a measure of both the soluble and insoluble P, the latter mostly attached to sediment; dissolved P only measures the soluble fraction. Dissolved P is of concern because it is readily available in freshwater systems, whereas insoluble P attached to sediment needs to become desorbed before it can be utilized.

In the early 1980s, conservation tillage methods were receiving attention as best management practices to reduce agricultural pollutants in runoff as these practices had been shown to reduce total phosphorus (TP) loading through the reduction of sediment transport (Mueller, Wendt and Daniel, 1984). However, other researchers stated a corresponding reduction in soluble nutrients in the runoff was not likely unless there was also an improvement in fertilizer application methods (Baker and Laflen, 1982). Indeed, studies indicated a greater loss of soluble P under no-till, despite a decrease in soil loss and an increase in crop residue (McDowell and McGregor, 1894).

In the mid-1990s, following nearly two decades of decline, excess P again began appearing in Lake Erie and the corresponding watershed causing excess algae growth and subsequently reducing the availability of dissolved oxygen (Ohio EPA Lake Erie Phosphorus Task Force, 2009). Growth of most blue-green algae into massive blooms is limited by P in freshwater systems due to the algae's ability to utilize nitrogen from the atmosphere, which most plants are unable to do (Pote, et al., 1996).

This study evaluated surface runoff from a tilled and no-till field for dissolved and total P following either commercial fertilizer (diammonium phosphate) or animal manure (poultry litter) application. In both the tilled and no-till production system, there was a control where no fertilizer was applied, surface application and the implementation of a best management practice (BMP). For the tilled system, the BMP was to incorporate the fertilizer and for the no-till system, a cover crop was the BMP. The objective was to compare the runoff losses of P based on nutrient source and BMP in each tillage system.

Methods

Two experimental locations were established within the Maumee Watershed of the Lake Erie Basin in Northwest Ohio. One experiment was established near Custar, Ohio in Wood County on a Hoytville clay loam soil (fine, illitic, mesic Mollis Epiaqualf). The other experiment was established near Wauseon, Ohio in Fulton County on a Blount loam (fine, illitic, mesic Aeric Epiaqualf). Each experimental site had a minimum slope of 2% to ensure runoff would occur.
Each experimental location utilized a split-plot design in a randomized complete block design with three replications. The main plot factor was tillage/best management practice (BMP) (tillage with nutrient incorporation, tillage without nutrient incorporation, no-till with a cover crop, and no-till without a cover crop) and the subplot factor was nutrient source (control, diammonium phosphate (DAP), and poultry litter). Each plot was 10 ft x 10 ft, and the runoff area was 7 ft x 7 ft. The no-till without cover crop plot was mowed to remove living biomass and wheat straw was applied to provide a residue surface. Tillage was accomplished with a roto-tiller (due to the small plot size) at each experimental location to a depth of approximately 4-6 inches. Commercial fertilizer (DAP) and poultry litter were applied at rates of 92 lb P_2O_5 per acre. Nutrient materials were spread by hand.

At two different depths (0-2" and 0-8"), 10 soils samples were collected to constitute a composite sample from every plot prior to plot establishment. Samples were submitted to the Ohio State University Chemical Laboratory in Columbus for Mehlich III, Bray-Kurtz P-1, and water extraction for phosphorus (Table 1).

After the nutrient treatments were applied and the soil samples collected, metal borders were installed around each plot. At the downslope end of each plot a piece of 4" PVC pipe was installed to carry the runoff water to a temporary storage basin. A rainfall simulator (Miller, 1987; Humphry et al., 2002) was used to simulate a 2.4 in/hr rainfall event to induce surface runoff. Once surface runoff started, runoff water was collected for 30 min. Total runoff volume was measured, and a single homogenized water sample (250 mL) was collected from the runoff water. A subsample (>15 mL) of the runoff water sample was filtered immediately through a 0.45 µm syringe filter to remove any particulate matter. The unfiltered water sample was acidified with a single drop of concentrated nitric acid. All water samples were immediately stored at <4°C, and remained in cold storage until analysis.

Table 1. Initial Bray P-1, Mehlich III, and water extractable phosphorus levels at the 2 and 8 inch depths for plots at both experimental locations.

		Bray P-1		WEP†		Mehlich III	
Location	Tillage/BMP	2"	8"	2"	8"	2"	8"
		------------------------mg/kg------------------------					
Northwest	Till with incorporation	45.7	13.1	28.5	3.5	65.9	17.3
	Till without incorporation	38.7	11.5	26.2	3.8	58.5	16.3
	No-till with cover crop	45.8	13.1	30.4	4.2	72.1	19.0
	No-till without cover crop	51.3	12.1	34.1	3.9	72.7	24.0
Wauseon	Till with incorporation	7.6	4.9	3.3	2.1	13.1	9.7
	Till without incorporation	8.2	8.2	3.6	2.2	15.7	12.4
	No-till with cover crop	4.9	3.8	2.9	1.8	9.8	8.6
	No-till without cover crop	7.3	3.1	2.8	1.7	13.9	8.1

† - WEP – water extractable P

The filtered runoff water sample was analyzed using Inductively Coupled Argon Plasma-Atomic Emission Spectrometry (ICP-AES) to determine dissolved P concentration. The unfiltered sample was analyzed for total P using a persulfate digestion followed by ICP-AES analysis. Dissolved P load and total P load was calculated by multiplying the concentration of the two different fractions by the total runoff volume collected.

A GLIMMIX model was used in SAS to evaluate main and simple effects (SAS, 2003). Tillage/BMP and nutrient source were considered fixed while rep was considered a random effect within the model. Means comparisons were made between main and simple effects using a diff statement at a probability level of 0.05.

Results and Discussion

Custar (November 2009)

No rain fell between plot establishment and the initiation of the rainfall simulator runs. These are the ideal weather conditions as then the runoff data collected is truly representative of a significant rainfall event following fertilizer application. Temperatures in the top 2" of soil were above 32°F for the duration of the project, thus eliminating the concern of frozen soil conditions. Initial soil P test levels were not high for the 0-8" sampling depth, but the 0-2" levels were higher (Table 1). This was a clear indication that this location had not experienced any tillage in at least the last 20 years.

Due to the presence of interactions between tillage/BMP and nutrient source at this location for dissolved P concentration and total P concentration, main effects will not be discussed. Dissolved P concentrations for the control plots were similar for till and no-till with and without the identified BMP (Table 2). Thus tillage/BMP did not impact dissolved P transport in the absence of a nutrient application.

Application of phosphorus as DAP resulted in increased dissolved P concentrations above the control for all tillage/BMP factors, with the exception of incorporation with tillage, by a magnitude of at least 5x. (Table 2). Interestingly, application of poultry litter did not significantly increase dissolved P concentration above the control for any of the tillage/BMP factors evaluated. Incorporation of DAP with tillage was the most effective BMP evaluated in our study to decrease dissolved P concentration as it resulted in a decrease of at least 55%. Inclusion of a cover crop as a biological trap for supplemental P did not affect dissolved P concentration as both no-till treatments (without a cover crop and with a cover crop) had concentrations of 9.5 and 12.0 mg/L, respectively.

Table 2. Effect of tillage treatment and phosphorus source on dissolved and total phosphorus concentrations from the study conducted at the Northwest Research Station in November 2009.

Tillage/BMP	Nutrient source*	Dissolved P*	Total P*
		--------------mg/L------------	
Till with incorporation	Control	0.6 de	1.0 bc
	DAP§	5.0 b	5.9 a
	Poultry litter	1.2 cd	1.9 b
Till without incorporation	Control	0.8 cde	1.4 bc
	DAP§	13.5 a	13.0 a
	Poultry litter	1.1 cd	1.1 b
No-till with cover crop	Control	0.3 e	0.5 c
	DAP§	12.0 a	10.9 a
	Poultry litter	1.0 cd	2.1 b
No-till without cover crop	Control	0.8 cd	1.0 b
	DAP§	9.5 ab	9.5 a
	Poultry litter	1.8 c	2.4 b

*means followed by the same letter are not different at a 0.05 alpha level using a diff statement in PROC GLIMMIX

§ diammonium phosphate

Total P concentrations for the control plots were similar for till and no-till with and without the identified BMP (Table 2) indicating that total P was not impacted by the tillage or BMP in the absence of a nutrient application. Application of phosphorus as DAP resulted in total P concentrations that increased by a minimum of 5.9x over the corresponding controls for all tillage/BMP factors. Incorporating DAP with tillage decreased total P concentration by a minimum of 43% compared to the other surface application approaches. Inclusion of a cover crop in the no-till treatment did not impact total P concentration compared to the no-till plot without a cover crop when DAP was applied (9.5 and 10.9 mg/L, respectively). Application of poultry litter as the P source did not increase total P concentrations above the control when the plot was tilled (Table 2). Total P concentration was increased above the corresponding controls when no-tillage was done.

Wauseon (May-June 2010)

In contrast to the research near Custar, a series of thunderstorms passed over the location between plot establishment and initiation of simulated rainfall events resulting in approximately an inch of rainfall over a 24-hr period. Another field with adequate slope could not be identified, so the experiment was carried out.

The result of the natural rainfall is much lower dissolved P and total P concentrations and subsequent total loads during the experiment. Runoff volumes tended to be higher at this experimental location, most likely due to wetter soil conditions at the time of rainfall simulation. Increased runoff volumes may have also caused P concentrations to be lower due to a dilution effect; however, initial soil test levels were low, and little stratification was evident (Table 1).

Due to the absence of interactions between tillage/BMP and nutrient source at this location for dissolved P concentration and total P concentration, main effects will be discussed. Dissolved P concentration in the runoff was higher in the no-till treatments with or without a cover crop, and the average increase in dissolved P concentration was 445% (Table 3). Thus, tillage (either before or after nutrient application) resulted in decreased dissolved P concentrations. Dissolved P concentration was increased above the corresponding control by application of either DAP or poultry litter (Table 4). Total P concentration was similar for all tillage/BMP factors. Therefore, the tilled treatments experienced more particulate P transport than the no-till treatments (Table 3). Total P concentration was also increased by application of either DAP or poultry litter (Table 4).

Table 3. Main effect of tillage/BMP on dissolved and total phosphorus concentration, and runoff volume from the study conducted on a producer's field in Fulton County near Wauseon, OH in June 2010.

Tillage/BMP	Dissolved P*	Total P*	Runoff volume
	-----------------mg/L-----------		----------L---------
Till with incorporation	0.1 b	1.2 ab	140
Till without incorporation	0.1 b	1.7 b	115
No-till with cover crop	0.4 a	0.8 a	112
No-till without cover crop	0.7 a	1.2 ab	100

*means followed by the same letter are not different at a 0.05 alpha level using a diff statement in PROC GLIMMIX

Table 4. Main effect of nutrient source on dissolved and total phosphorus concentration, and runoff volume from the study conducted on a producer's field in Fulton County near Wauseon, OH in June 2010.

Nutrient source	Dissolved P*	Total P*	Runoff volume
	----------------mg/L-----------		----------L---------
Control	0.1 b	0.7 b	124
Diammonium phosphate	0.5 a	1.5 a	114
Poultry litter	0.5 a	1.6 a	112

*means followed by the same letter are not different at a 0.05 alpha level using a diff statement in PROC GLIMMIX

Conclusions

Despite the dramatic differences in weather conditions experienced between plot establishment and initiation of rainfall simulator runs, similar conclusions can be drawn with regard to the performance of the proposed BMPs evaluated. Incorporation of DAP with tillage resulted in decreased dissolved P concentrations in runoff water compared to DAP left on the soil surface.

Surface application of DAP on a no-till field with a cover crop does not appear to reduce the export of dissolved P. Surface nutrient applications on no-till soils (with or without a cover crop) apparently do not allow adequate time for the dissolved fertilizer P to infiltrate the soil where it can be held. The presence of an actively growing crop, while conceptually would allow for greater potential uptake of nutrients, has little influence on surface nutrient loss if the nutrients are unable to move into the soil.

Total P concentration was decreased by incorporation with tillage at Custar but not at the Wauseon location. Thus, the Custar study had very little sediment in the runoff while the on-farm site obviously had higher particulate P loss associated with tillage. The Wauseon location is indicative of the trade-off made when tillage is utilized as a management tool to decrease dissolved P transport.

The two phosphorus sources performed similarly at the Wauseon location as application of either material resulted in increased dissolved P loss. This was not observed at the Custar location. This may be attributed to differences in solubility of the materials, as DAP is more soluble than poultry litter. The differences in the two study locations may also be attributed to the rainfall event that occurred at Wauseon before initiation of simulator runs.

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