Manure composting and tillage effects on phosphorus levels in runoff in a corn silage system

María R. Yagüe[1], Carrie A.M. Laboski[2], and Todd W. Andraski[2].

[1]Soils and Irrigation Department (UA CSIC), Agrifood Research and Technological Center of Aragon, Zaragoza, Montañana 930, 50059 Zaragoza, Spain.

[2] Department of Soil Science, University of Wisconsin-Madison, 1525 Observatory Drive,Madison, WI, USA.

Abstract

Composted and semi-solid dairy cow (Bos taurus) manure can be an excellent source of nutrients and organic matter when added to soils, but can also increase phosphorus (P) runoff losses. We conducted a rainfall simulation study to determine the effects of spring applied dairy cow manure (no manure, in-barn composted, and raw instead of pit) with and without incorporation (CP, chisel plow; NT, no-till) on sediment and P in runoff. Runoff was collected from a 0.83 m² area 60-min. following the onset of rainfall simulation (76 mm h⁻¹) in June (spring) and Oct. (fall) in a corn (Zea mays L.) silage system. Runoff dissolved reactive P (DRP) and dissolved organic P (DOP) concentrations were positively correlated with manure P rate and were higher in NT compared with CP. Conversely, sediment and particulate P (PP) concentrations in runoff were inversely correlated with manure P rate and were higher in CP compared with NT. Runoff volume where no manure was applied was higher in NT than in CP in spring, but similar in fall. However, the addition of manure reduced runoff volumes by an average of 82% in NT and 42% in CP. This reduction in runoff volume where manure was applied resulted in similar or lower DRP, DOP, and PP loads compared to where no manure was applied.

Introduction

Phosphorus has been identified as the most limiting nutrient in freshwater environments (Correll, 1998) contributing to water eutrophication. The Environmental Protection Agency (US EPA, 1996) has identified eutrophication as the main cause of impaired surface water quality. Runoff water and eroded sediment from fertile landscapes are major contributors of P to lakes and streams.

Manure application can be an important factor influencing runoff P loss immediately following application. However, addition of manure can increase soil organic matter levels thus influencing soil porosity, aggregate stability, and factors that effect runoff and erosion potential (Gilley and Risses, 2000). For this reason, manure additions to cropland can reduce total P losses in runoff on well-drained soils due to increased infiltration and reduced soil erosion (Andraski et al., 2003). Wisconsin currently has 1.25 million head of dairy cattle (Wisconsin Agconnection, 2008). Land application of manure to cropland is generally the only current practical management option for livestock producers.

Objective

- The objective of this study was to determine the effect of spring-applied dairy manure (none, composted, raw instead of pit) with and without incorporation (no-till and chisel plow) on the concentration and loads of several forms of P in spring (June) and fall (October) runoff.

Materials and Methods

Experimental Design:

- Study was conduced at University of Wisconsin Agricultural Research Station at Arlington, on a well-drained Ringwood silt loam soil.
- A randomized complete block design in a split-plot arrangement with four replicates.
- The main plot treatment was tillage immediately following manure application: chisel plow (CP) and no-till (NT).
- The subplot was dairy manure source: none, in barn composted, and raw instead of pit.

Materials and Methods (cont.)

Experimental Design:

- Rainfall simulation using a mobile, multiple intensity rainfall simulator and an application rate of 75 mm h⁻¹ as described by Andraski et al., (2003).
- Rainfall simulations were performed in early June following corn planting and late October.

Measurements runoff:

- Total volume runoff was measured in 60 min runoff simulation (Figure 1 and 2).
- Sediment concentration in runoff was determined by weighing before and after drying at 105ºC.
- The total dissolved phosphorus (TDP) and total phosphorus (TP) was determined by EPA 365.5 (USEPA, 1993).
- The dissolved reactive phosphorus (DRP) runoff samples were analyzed using the ascorbic acid method (Murphy and Riley, 1962).
- The particulate P (PP) concentration in runoff was calculated as the difference between TP and TDP.

Measurement manure:

- Total solids, TP, and water extractable P (WEP) with an extraction ratio (manure:water) of 1:100 and 1:1000.

Harvest:

- The whole corn (Pioneer 37Y14) plants were weighed and chopped.
- Subsampled for subsequent whole plant dry matter and TP determination (Jones and Case, 1990).

Statistical Analysis:

- An analysis of variance using PROC GLM and regression analysis using PROC REG and PROC NLIN.
- Significant differences treatment means were evaluated using Duncan's multiple range (p< 0.10).
- Using program SAS Institute (2002).

Figure 1. *A welded frame surrounded with a wind sreen, a top-mounted water nozzle, an electric brake-clutch, and two return pans for excess source water return via a small transfer pump.*

Figure 2. *A wagon containing a mounted generator, source-water tank, two retractable hose reels for supply and return, water pump, vacuum pump, and a runoff collection tank.*

Table 1. Total solids, total P, and water-extractable P (WEP) concentrations and spring application rates for composted and pit dairy manure at Arlington, WI, 2008.

Analysis	Manure			
	Composted	Pit	Composted	Pit
	--- concentration, g kg^{-1} ----		---------- kg ha^{-1} ----------	
Total solids	280 ± 7	210 ± 17	13539 ± 340	16906 ± 1381
Total P	3.48 ± 0.10	5.56 ± 0.86	47 ± 1	95 ± 21
WEP 1:100	0.50 ± 0.05	1.20 ± 0.23	7 ± 0.4	20 ± 4
WEP 1:1000	0.97 ± 0.06	1.71 ± 0.18	13 ± 1	29 ± 2

Results

Surface residue, runoff volume and sediments

- The increased surface residue/organic matter provided by the addition of manure resulted in significantly lower runoff volumes and sediment loads in NT and CP in June and October (Table 2). Where manure was applied, runoff volume and sediment load was similar among tillage systems in June, but significantly lower in NT compared with CP in fall.
- Where no manure was applied, runoff volume and sediment load was not significantly different between NT and CP in October, but lower in CP in June due to less soil surface crusting resulting in greater infiltration.
- Surface residue levels ranged from 25% without manure to 57-70% with manure in NT. In CP, surface residue levels ranged from 13% without manure to 21-29% with manure.

Yield and crop P uptake

- No significant effect of manure source or tillage on corn biomass yield (ave. 24.8 Mg ha^{-1}).
- Initial soil P content (ave. 77 ± 22 mg P kg^{-1} by Bray P1) was sufficient to provide entire plant P requirements.

Table 2. Tillage and dairy manure sources effects on surface residue, runoff, dissolved reactive P (DRP), dissolved organic P (DOP), particulate P (PP), and total P (TP) loads in runoff in June and October 2008 at Arlington, WI.

Month	Tillage†	Source	Surface residue	Runoff	Sediment	P fraction in runoff			
			%	mm	kg ha^{-1}	DRP	DOP	PP	TP
						---------- load, g P ha^{-1} ----------			
June	NT	None	26b	39a	2166 a ‡	70	50	1265 a	1384 a
		Composted	67a	6c	162 c	76	27	89 c	192 b
		Pit	70a	3c	68 c	58	27	39 c	124 b
	CP	None	13c	12b	475 b	14	10	329 b	353 b
		Composted	29b	7c	359 bc	12	8	179 bc	199 b
		Pit	29b	6c	179 bc	17	12	120 bc	149 b
Tillage (T)			<0.01	0.04	0.02	0.08	0.08	0.04	0.05
Source (S)			<0.01	<0.01	<0.01	0.95	0.24	<0.01	<0.01
T x S			<0.01	<0.01	<0.01	0.86	0.23	<0.01	<0.01
CV, %			14	28	43	102	64	54	49
October	NT	None	25b	61a	2342 a	66	69 a	1272 ab	1406 a
		Composted	57a	17d	366 d	47	26 cd	200 d	273 c
		Pit	58a	10d	216 d	45	13 d	108 d	166 c
	CP	None	13c	52a	2279 a	73	60 a	1379 a	1513 a
		Composted	21bc	37b	1809 b	69	52 ab	1092 b	1213 a
		Pit	25b	28c	1063 c	73	42 bc	733 c	847 b
Tillage (T)			<0.01	0.17	<0.01	0.15	0.07	<0.01	<0.01
Source (S)			<0.01	<0.01	<0.01	0.62	<0.01	<0.01	<0.01
T x S			<0.01	<0.01	<0.01	0.73	0.04	0.02	0.02
CV, %			22	17	24	41	32	30	29

† NT, no-till; CP, chisel-plow.
‡ Values within each column followed by the same letter are not significantly different at the 0.10 probability level where the tillage x source interaction was significant.

Results (cont.)

Phosphorus runoff load

Dissolved reactive P (DRP)

- The addition of manure had no significant effect on DRP load in June or October (Table 2). Dissolved reactive P loads were significantly (P>0.1) greater in NT (68 g P ha^{-1}) compared with CP (14 g P ha^{-1}) in June, but not in October regardless of manure source (62 g P ha^{-1}).

Dissolved organic P (DOP)

- In June manure had no significant effect on DOP load, but DOP loads were significantly lower in CP (10 g P ha^{-1}) compared with NT (35 g P ha^{-1}) (Table 2). In October, DOP loads were lowest where manure was applied to NT (20 g P ha^{-1}), intermediate where manure was applied to CP (47 g P ha^{-1}), and highest where no manure was applied regardless of tillage system (63 g P ha^{-1}).

Particulate P (PP)

- Where no manure was applied, PP loads were significantly higher in NT (1265 g P ha^{-1}) compared with CP (329 g P ha^{-1}) in June, but similar (1272 and 1379 g P ha^{-1}) in October (Table 2). The addition of manure resulted in significantly lower PP load in NT compared with CP in June and October. Where manure was applied, PP loads averaged 64 g P ha^{-1} in NT and 150 g P ha^{-1} in CP in June, and to 154 g P ha^{-1} in NT and 913 g P ha^{-1} in CP in October.

Total P (TP)

- In June, significantly higher TP loads were measured in NT without manure (1384 g P ha^{-1}) compared with the remaining treatments (124 to 353 g P ha^{-1}) which were not significantly different. In October, TP loads were highest in NT and CP without manure and CP with composted manure (average 1377 g P ha^{-1}), intermediate in CP with raw instead of pit manure (847 g P ha^{-1}), and lowest in NT with manure (average 220 g P ha^{-1}).

Soil test phosphorus (STP) levels

- Soil test P was usually evenly distributed throughout the plow layer (0-15 cm) in CP but stratified where manure was applied in NT.

Discussion Points

- DRP loads in runoff were unaffected by addition of manure (due increased infiltration) in June and October.
- DRP loads were reduced by tillage (CP) in June, but not four months later (October).
- The temporary effect of soil tillage on reducing DRP and DOP losses in runoff may promote greater runoff P losses later in the season due to the combination of reduced surface residue (corn and/or manure) and increased surface sealing in CP compared with NT. This occurred in our study where DOP, PP, and TP loads were significantly higher in CP compared with NT in October where manure was applied.

References

- Andraski, T.W., L.C. Bundy, and K.C. Kilian. 2003. *J. Environ. Qual.* 32:1782-1789.
- Correll, D.L. 1998. *J. Environ. Qual.* 27:261-266.
- Gilley J.E., L.M Risses, 2000. *Trans of ASAE* 43(6):1583-1588.
- Murphy, J., J.P. Riley. 1962. *Anal. Chem.* 27:31-36.
- USEPA. 1993. Method 365.5. Washington, D.C.
- US EPA. 1996. United States Environmental Protection Service. *EPA 841-R-96-002.* Washington., D.C
- SAS Institute 2002. User's guide. SAS version 8.1. SAS Inst., Cary NC.
- Wisconsin Agconnection, 2008. In: www.wisconsinagconnection.com/story-state.php?id=1390&yr=2008.

Acknowledgements

The author would like to acknowledge the Department of Soil Science, University of Wisconsin-Madison who made possible stage-research. The authors would like to thank the UW-Madison Graduate School for funding.