Soil Phosphorus Losses in Surface Runoff and Tile Drainage as Related to P-Based Addition of Various Forms of Cattle Manure and Chemical Fertilizer


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Introduction

- Nitrogen-based manure application results in phosphorus (P) build-up in soils, due to the smaller N:P ratios in manures than those required by crops. Elevated levels of P in soils can cause increased P loss into surface water resource.
- Forms and contents of P in manure vary, depending on the type (i.e. swine, cattle, etc.) and form (i.e. liquid, solid), and thus the vulnerability to loss can differ.
- In the current Ontario P Site Index, of manure P 40% in the year of application and 80% in the following years are defaulted as available, regardless of types and forms.
- Manure P source coefficients are essentially required, if risk assessment of manure and soil P is to precisely reflect the reality of field conditions after application and if soil and manure P is to be efficiently managed to minimize losses to water resource, while satisfying crop needs for maximum production.

Objectives

- To evaluate whether liquid and solid cattle manures are different in the effects on soil P loss in both surface and sub-surface runoff in a clay loam soil of Ontario, Canada, under corn-soybean rotation, in comparison with chemical fertilizer
- To determine the cattle manure P source coefficients

Materials and methods

- Soil: Brookston clay loam (38% clay), GPCR, Agriculture and Agri-Food Canada, Harrow, ON, Canada
- Experiment duration: 4 years, 2008-2012
- Experimental design
  - Liquid (LCM) and solid (SCM) cattle manure and chemical fertilizer (CF), as TSP, each of them added at 50 kg P ha⁻¹
  - Fertilizers N and K added to the CF treatment at or topped up in the cattle manure treatments to 200 kg N ha⁻¹ and 100 kg K ha⁻¹, respectively
  - All nutrients added to the corn phase of a corn-soybean rotation
  - Reps: 2; Plot size: 0.1 ha each
- Surface & Sub-surface (tile drainage) runoff water monitoring, sampling and P determination
  - Flow volume monitoring and water sampling:
    - Continuous & year-round using auto-monitoring and sampling systems (Fig. 1)
  - Water samples collected with every 1000 L during growing season & every 3500 L during non-growing season
  - Water P analysis: dissolved reactive P (DRP), dissolved un-reactive P (not reported here), particulate P (PP), & total P
- Manure P source coefficient (PSC) calculation
  - PSC = 100*(soil P loss in manure treatment/soil P loss in chemical fertilizer P treatment)

Results

Surface runoff flow volume (Fig. 1A)

Compared with CF (188mm), LCM (164mm) decreased, while SCM (322mm) increased, the mean value of annual runoff volume.

Table 1. Four-year means of annual flow volume (AFV, mm), annual P loss (AFL, g ha⁻¹ yr⁻¹), and % of AFL in either surface or sub-surface runoff water discharge over total soil P loss (i.e., the sum of surface and sub-surface) (% SPL) as related to addition of chemical fertilizer (CF) and liquid (LCM) and solid (SCM) cattle manure in a clay loam soil, ON, Canada

<table>
<thead>
<tr>
<th>Pathway</th>
<th>P source</th>
<th>AFV</th>
<th>DRP</th>
<th>PP</th>
<th>TP</th>
<th>DRP</th>
<th>PP</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>CF</td>
<td>187.6</td>
<td>491</td>
<td>1455</td>
<td>1972</td>
<td>34.4</td>
<td>38.2</td>
<td>37.0</td>
</tr>
<tr>
<td></td>
<td>LCM</td>
<td>163.7</td>
<td>368</td>
<td>1799</td>
<td>2194</td>
<td>34.7</td>
<td>54.1</td>
<td>48.9</td>
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<tr>
<td></td>
<td>SCM</td>
<td>322.3</td>
<td>1214</td>
<td>1256</td>
<td>2573</td>
<td>57.7</td>
<td>64.9</td>
<td>61.3</td>
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<tr>
<td>Sub-surface (tile)</td>
<td>CF</td>
<td>482.8</td>
<td>934</td>
<td>2351</td>
<td>3360</td>
<td>65.5</td>
<td>61.8</td>
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</tr>
<tr>
<td></td>
<td>LCM</td>
<td>426.7</td>
<td>693</td>
<td>1525</td>
<td>2291</td>
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<td>45.9</td>
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<tr>
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<td>SCM</td>
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<td>888</td>
<td>679</td>
<td>1623</td>
<td>42.3</td>
<td>35.1</td>
<td>38.7</td>
</tr>
</tbody>
</table>

Conclusions

- Compared with CF, P added in LCM at the same rate decreased soil DRP, PP and TP losses;
- P added in SCM also decreased PP and TP losses, although it increased DRP loss.
- Sub-surface runoff was a major pathway for soil P loss.
- PSCs varied with the form of cattle manure and the form of P in field discharge water.
- PSCs for LCM were 74%, if based on DRP loss, and 84%, if based TP loss.
- PSCs for SCM were 147%, if based on DRP loss, and 79%, if based on TP loss.

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