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Cumulative Contributions of Various Forms of Swine Manure to Soil Test Phosphorus in a Clay Loam soil under Long-Term Corn-Soybean Rotation

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Introduction

- Intensified animal production and N-based manure application have resulted in elevated levels of soil phosphorus (P), which may cause increases in P loss to water resources.
- P-based application of manures has been proposed to eliminate excessive P addition.
- In addition, P forms and their distributions in manures may differ, depending on the form (*i.e.*, liquid, solid, and composted) of manure, even if within the same type (*i.e.*, swine, poultry, etc.).
- Soil test P (STP) has been widely used to indicate availability of P to crops and loss vulnerability to water resource.
- Little information is available on contributions of various forms of swine manure to STP, especially on a long-term cumulative base, and their standardized measurements.

Objectives

- To qualify and quantify the long-term cumulative changes in STP as related to various forms of swine manure and chemical fertilizer addition under corn-soybean rotation in a clay loam soil in Ontario, Canada.
- To determine swine manure P source coefficients (PSCs).

Materials and Methods

- Soil: Brookston clay loam, GPCRC, Agriculture and Agri-Food Canada, Harrow, ON.
- Experiment duration: 8 years, 2004-2011
- Soil sampling: each fall at 0-15, 15-30, 30-50 and 50-70 cm depths
- Soil test P determination: Olsen procedure

Fig.1. Application of liquid (left) and solid or composted swine manure (right).

Materials and Methods

- Experimental design:
  - Randomized complete block design, with 3 reps
  - Cropping system: corn-soybean rotation
  - Treatments: liquid swine manure (LM), solid swine manure (SM), composted swine manure (MC), chemical fertilizer P (as TSP), and zero-P
  - For all treatments, except for zero-P in which no fertilizer P was added, were applied to the corn phase only at 100 kg P ha^{-1} (Fig. 1), with N and K adjusted to 200 kg ha^{-1} available N and 100 kg K ha^{-1}
  - Plot size: 12m × 25m each
- PSCs calculation:
  - PSC=(STP mass + crop P uptake)$_{manure}$/(STP mass + crop P uptake)$_{chemical\ fertilizer\ P}$
  - STP$_{Olsen}$ and crop P uptake were cumulative values after 8 years

Results

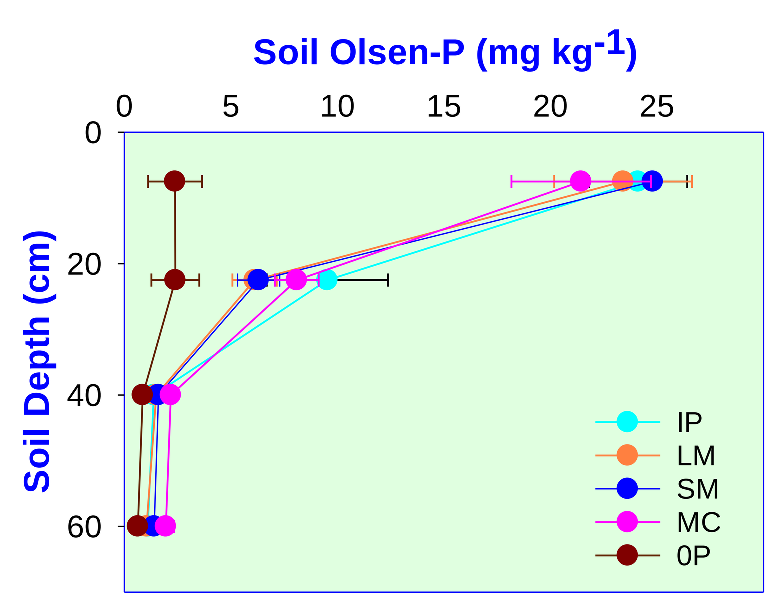

Fig.2. Post-harvest soil test P (Olsen) in 0-70cm profile as related to additions of inorganic fertilizer (IP) and liquid (LM), solid (SM), and composted (MC) swine manure, in comparison with zero-P addition (0P), under corn-soybean rotation after 8 years, in a Brookston clay loam soil, Ontario, Canada

Post harvest soil profile in soil test P (STP) (Fig. 2)

- After 8 years, compared with zero-P, P addition from any of the sources increased the levels of STP in the 0-30 cm depth, below which STP remained unchanged.

Results

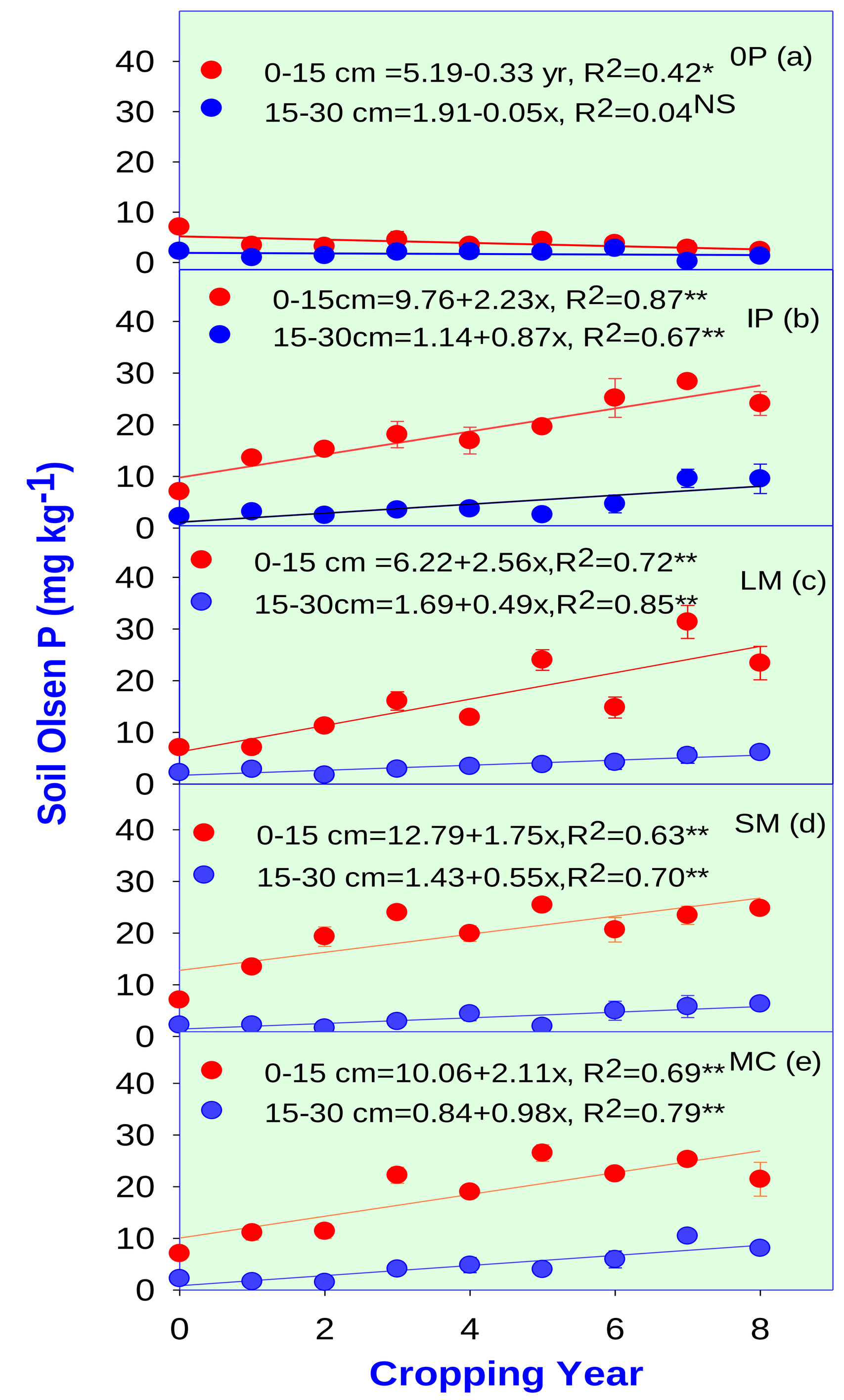

Fig.3. Changes in soil test P (Olsen P) with addition of chemical fertilizer and various forms of swine manure under corn-soybean rotation over 8 years. (a) 0P: zero-P; (b) IP: inorganic fertilizer P; (c) LM: liquid swine manure; (d) SM: solid swine manure; (e) MC: swine manure compost. * and ** significant at P≤ 0.05 and 0.01 levels, respectively. NS, not significant at P= 0.05 level.

Changes in STP over eight years

- For the zero-P treatment, STP content in the 0-15 cm depth decreased linearly with year of cropping, with every 34.6 kg P ha^{-1} crop removal required to decrease STP by 1.0 mg kg^{-1}, while the STP in the 15-30 cm depth remained unchanged (Fig. 3a).
- In contrast, for the fertilized treatments, levels of STP in both 0-15 and 15-30 cm depths increased with year of cropping, but the increasing rate varied, depending on the source of P (Fig. 3b-e).
- To increase STP in the 0-15cm layer by 1.0 mg P kg^{-1}, an amount of 19.5, 28.6, and 23.7 kg P ha^{-1} yr^{-1} was required for LM, SM, and MC, respectively, compared with 22.4 kg P ha^{-1} yr^{-1} for chemical fertilizer.

Results

- When the subsoil layer (15-30 cm) was included, an amount of 16.4, 21.7 and 16.2 kg P ha^{-1} yr^{-1} was required respectively from LM, SM, and MC to increase each mg P kg^{-1} STP, in comparison with 16.1 kg P ha^{-1} yr^{-1} from chemical fertilizer.
- By using a net P addition approach that subtracts the crop P removal from the total P applied, it was 11.8, 17.5 and 14.9 kg P ha^{-1} yr^{-1} required from LM, SM and MC, respectively, to increase each mg P kg^{-1} STP, in comparison with 14.7 kg P ha^{-1} yr^{-1} net addition of chemical fertilizer, in the surface soil layer.
- When taking crop P removal and the increases of STP in both surface and sub-surface soil layers into account, it required only 10, 13.9 and 10.5 kg P ha^{-1} for LM, SM, and MC, respectively, to increase 1 mg P kg^{-1} STP, compared with 10.8 kg P ha^{-1} yr^{-1} for chemical fertilizer.

Table 1. Cumulative values of soil test P (STP) and total crop P uptake as related to application of inorganic fertilizer P (IP) and various forms of swine manure (LM: liquid; SM: solid; MC: liquid manure compost) and calculated manure P source coefficients (PSC) after 8-year corn-soybean rotation in a clay loam soil, Ontario, Canada.

P Source	STP (kg P ha^{-1})		Total P uptake (kg P ha^{-1})	PSCs	
	0-15cm	15-30cm		0-15cm	0-30cm
IP	62	20	165	/	/
LM	62	14	174	1.04	1.01
SM	55	14	167	0.98	0.96
MC	59	21	151	0.93	0.94

P Source coefficients (PSCs) (Table 1):

- PSCs were 1.04, 0.98 and 0.93 when considering the 0-15cm soil depth, and 1.01, 0.96, and 0.93 when considering the 0-30cm depth for LM, SM, and MC, respectively.

Conclusions

- Crop production without P addition reduced the levels of STP, with 34.6 kg P ha^{-1} yr^{-1} crop removal required to decrease STP by 1.0 mg kg^{-1}.
- The effect of added P on the increase of STP followed the order of IP > MC > LM > SM.
- Swine manure PSCs varied slightly with its forms, but all were similar to fertilizer P with long-term P-based application.

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