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N- vs. P-based Manure Applications and Water Quality Impact

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Background

- Animal manures can be important source of nutrients to growing crops, but applications must be matched to crop uptake.
- Excess nutrients can be lost into environment through leaching and runoff, contributing to water quality decline.
- We are conducting a long-term field research project to assess potential impact on water quality of dairy manure spread at N- or P-based rates on three agronomic crops.

Objectives

- Develop and validate nutrient management strategies for reducing N and P losses from cropland to waters.
- Examine how N- and P-based dairy manure applications affect nitrate and P losses in leaching and runoff, monitor N and P dynamics in crop uptake and soil profile accumulation.

Field Experiment

- Initiated 1998 to study N and P balance in manured or fertilized annual and perennial agronomic crops.
- Alfalfa, silage corn and orchardgrass strips, plots 15 x 20 m, three replications of crop x treatment combinations. Crops rotated in Spring 2002, alfalfa → corn, corn → grass, grass → alfalfa.
- Nutrient application rates based on crop uptake, adjusted for nutrient availability in the manure.
- **Treatments:**

Control – no N or P added	**N-based manure** – added to meet crop N requirement
Fertilizer – N and K supplied by chemical fertilizers	**P-based manure** – added to meet crop P requirement, supplemental N fertilizer

- Measure concentration and mass of N and P in leachate below 1 m depth and in surface runoff.
- Monitor changes and distribution of N and P in soil profile and harvested crops.

- Dairy manure slurry applied with calibrated side delivery spreader. Applications made pre-planting to corn and in spring and following forage harvests to alfalfa and grass.

- Leachate collected by zero-tension pan and passive capillary wick lysimeters, runoff by paired surface runoff subplots.

Results

- 1998-99 and 2001-02 sampling year precipitation below 30-yr average of 105 cm.

- Cumulative monthly precipitation deficits reached 35 cm in 1999 and 54 cm in 2002 (Fig. 1).

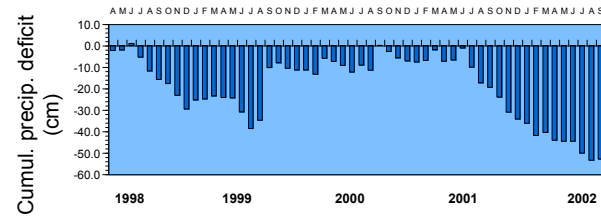


Fig. 1. 1998-2002 cumulative deficit from average precipitation.

Table 1. Four-year annual mean NO_3-N and total P losses in leachate, 1998-2002.

Crop	Treatment	Leachate conc. Nitrate-N (mg L^{-1})	Leachate conc. Total P (mg L^{-1})	Mass in lea. Nitrate-N (kg ha^{-1})	Mass in lea. Total P (kg ha^{-1})
Alfalfa	Control	7.8	0.06	30	0.25
	No Trt	12.0	0.08	42	0.28
	Manure-N	19.5	0.11	145	0.99
	Manure-P	14.6	0.08	85	0.48
Corn	Control	8.3	0.08	47	0.58
	Fertilizer	16.5	0.07	56	0.53
	Manure-N	11.5	0.09	68	0.57
	Manure-P	18.1	0.07	127	0.37
Orchard-grass	Control	9.7	0.09	28	0.36
	Fertilizer	9.4	0.06	64	0.78
	Manure-N	11.3	0.06	101	0.37
	Manure-P	10.6	0.10	50	0.34

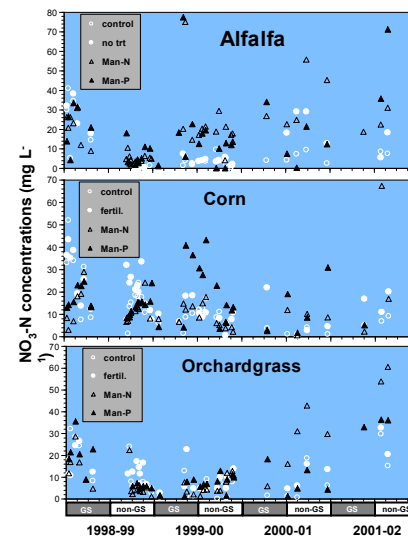


Fig. 2. Four yr time course of treatment mean leachate NO_3-N concentrations.

- Four yr nitrate-N concentrations in leachate from plots receiving manure or fertilizer N did not differ significantly by crop (Table 1), and generally exceeded the 10 mg L^{-1} drinking water standard.

- Leachate nitrate-N concentrations were highest from all crops in the months following tillage and project establishment in 1998, and following dry soil conditions during the growing seasons (Fig. 2).

- No significant relationship between rate of manure application and leachate total P (TP) concentration.

- Mass of TP lost in leachate averaged less than 1 kg ha yr^{-1}.

- For several manure treatments, P concs. in leachate were in range associated with eutrophication (0.10 mg TP L^{-1}).

- Initial data for nitrate-N concentration analysis of runoff in range similar to that in leachate (Table 2).

- Runoff total P concentrations substanially higher than in leachate for manure surface-applied to alfalfa (Table 2).

- Soil test P (STP, Mehlich-3 method) increased by up to 55 mg kg^{-1} over 4 yrs in surface 5 cm soil of plots receiving manure at N-based rates (Fig 3.).

Table 2. Preliminary NO_3-N and total P losses in runoff, 2003.

Crop	Treatment	Runoff conc. Nitrate-N (mg L^{-1})	Runoff conc. Total P (mg L^{-1})
Alfalfa	Control	2.0	0.7
	Manure-N	5.8	1.3
	Manure-P	4.2	2.3
Corn	Control	11.8	0.2
	Manure-N	---	---
	Manure-P	27.8	0.6

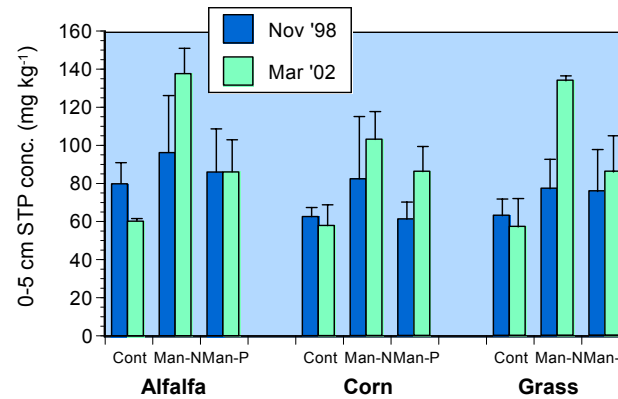


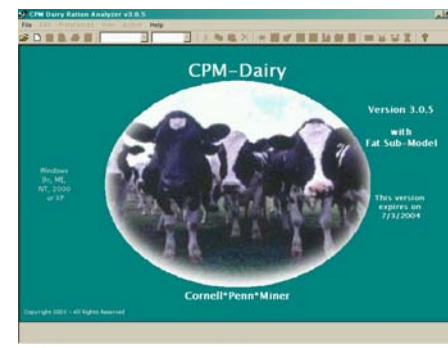
Fig. 3. STP conc. in surface 5 cm of soil after 4 yrs dairy manure application.

Education and Outreach

- Collaboration with scientists at Penn State Univ., Univ. of Delaware and Stroud Water Res. Center.

- Summaries of research provided to state nutrient management personnel, educational materials developed for public at Pennsylvania Farm Show.

- Data included in classroom teaching for Univ. of Pennsylvania veterinary students and incorporated into computer modeling with dairy ration formulation software CPM-Dairy.



Conclusions

- Nitrate in leachate generally above drinking water standard of 10 mg L^{-1}, lower from orchardgrass than corn or alfalfa.

- N-based manure applications to perennial crops had substantially more NO_3-N losses than P-based or fertilizer trts.

- Leachate P losses negligible in agronomic terms but may be in range causing concern over potential for eutrophication.

- Four yrs dairy manure applications at N-based rates increased soil test P in surface soil. Manure applied at P-based rates did not significantly increase STP levels.