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MULTI-YEAR APPLICATION OF DAIRY SLURRY ON GRASSLAND: EFFECTS ON CROP, SOIL BIOTA, SOIL NUTRIENTS, AND N_2O EMISSION

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Abstract

The long-term effects of using manure as the principal nutrient source in intensive crop production systems are not well known. This paper reports on the effects of multi-year application of fertilizer or dairy slurry on a tall fescue (*Festuca arundinacea* Schreb.) sward. Slurry sustained greater grass yield than chemical fertilizer. Unlike fertilizer, slurry supplied 70 to 120 kg N/ha one year after application but little after one year; 4-years of manure applications built up the stable organic matter pool in the soil. Manure-N was less prone to leaching but more prone to N_2O emissions than fertilizer-N. Manured soils had considerably more biological activity than fertilized soils. High rates of manure application increased soil P.

Kewords: Tall fescue, manure, nitrogen, carbon, phosphorus, microbes, invertebrates.

Introduction

The Fraser Valley in British Columbia has many high-input dairy farms that produce large quantities of liquid manure. Liquid manure can be used as the sole source of nutrients for forage grass without loss of production (Bittman et al., 1999). For the same immediate crop response as fertilizer N, manure has to be applied at equivalent rates of inorganic N. Although addition of organic C and N is known to enrich soil, alter soil biota and increase potential mineralization or immobilization, the long-term effects of using manure as the principal nutrient source in intensive production systems are not well known. Previous work has shown surprisingly large differences in N supplying capacity among apparently similar grassland soils and that these soils also have substantial capacity to immobilize mineral N (Bittman and Kowalenko, 1998). Accurate predictions of nutrient requirement are important because farmers must produce the maximum amount of crop while preventing nutrient loss to the environment. This paper reports on the effects (in 1998) of applying fertilizer or dairy slurry for several years on a perennial grass sward with respect to crop yield and persistence, soil nutrients, populations of soil microbes and invertebrates, and N_2O emission.

Material and Methods

The study, initiated in 1994, occupied 120 x 150m of permanent tall fescue on a medium texture alluvial soil at Agassiz, BC. The basic experiment had 10 treatments (shown below) and 4 replicates arranged as a randomized complete block. The 'low' and 'high' rates were nominally 50 and 100 kg ha^{-1} of inorganic-N applied for each harvest (4X per year) as NH_4NO_3 with other minerals as needed (F) or liquid dairy manure with sawdust bedding (M). Each plot was 3x150m; the manure was applied with a 3-m wide 'drag-shoe' applicator. Manure in 1998 averaged 91.7% water, 13.4:1 C:N, 6.7 pH and, on wet basis, 0.16% NH4-N, 0.31% total-N, 4.1% C. Manure applications started in different years so the treatments involved different lengths of time that fertilizer or manure was applied.

Treatment	1994	1995	1996	1997	1998
Control	0	0	0	0	0
Fertilizer (high and low)	F	F	F	F	F
Manure1 (high and low)	F	F	F	M	M
Manure2 (high and low)	F	F	M	M	M
Manure4 (high and low)	M	M	M	M	M
Fert/Man[1](high)	FM[1]	FM	FM	FM	FM

[1] Fertilizer and manure alternated each application.

The cumulative effects of the 1994-97 treatments were also evaluated in 1998 by superimposing (i) no nutrients, (ii) manure at high-N on a portion of the original treatments.

The crop was harvested and sampled annually in May, July, August, and Sept.-Oct. Plant-N concentration was determined by dry ashing (LECO FP428). Grass ground-cover was determined in March with a line transect. Soil samples (0-0.15, 0.15-0.30 and 0.30-0.60m depths) were taken at each harvest; NO_3 and NH_4 were extracted with KCl and analyzed with a FIA. Other soil nutrients were analyzed by ICP on “Kelowna” extracts. Total soil C and N were determined by dry ashing (LECO CNS2000). Soil bacteria, protozoa and bacteriophagous nematodes were counted in 0-0.3m soil samples taken 1 and 3 weeks after manure application. Soil solution was collected with suction lysimeters (0.6 and 0.9m depth) after rainfall events from March 1, 1998 to Feb. 28, 1999 and NO_3-N-concentrations determined with FIA. N_2O was measured by gas chromatography in samples from 0.7x0.7 m vented chambers taken twice per week for 4 weeks after treatments were applied. Carabid ground beetles were sampled using pitfall traps for 1-week periods every month from April-October. Earthworms were collected from the soil surface of two replicates in early April, 1999 after pouring a solution of cured hot mustard (53g/7L water) on 50x50 cm quadrats.

Results and Discussion

At similar rates of applied mineral-N, the manured plots yielded more than fertilized plots (Table 1). At similar rates of applied total-N, high-F plots yielded the same but took up more N than the low-M treatments. Yield increased with years of manure application at the low- but not the high-N rate. High-M reduced grass cover relative to low-N rates. Decline in manured swards in this trial was not due to wheel traffic as is often suspected on farms.

Residual soil NO_3-N in Oct. was negligible in control and low-N plots but 40 and 120 kg/ha in high-M4 and high-F plots, respectively (Table 1). Soil-solution NO_3 was much greater in high-N than low-N plots and slightly higher in high-F than high-M4 plots. These findings are surprising because twice as much total-N had been applied on the manured than fertilized plots over 5 years, suggesting that more N was immobilized in manured than fertilized plots. Indeed, the 0-15 cm soil layer in the M4 treatments contained significantly more total-N and C compared to control and F treatments. Since residual soil NO_3 in Oct. is likely to leach over-winter, manure is less likely to cause leaching than fertilizer. Most N_2O was emitted in the 2-weeks after nutrient application, especially in summer. In the day after application, emissions averaged 5-60 and 15-400 ng N_2O-N/m^2/s for the low- and high-N treatments, respectively. Soil P was greater for high rates of manure than fertilizer or control treatments

Manure significantly increased populations of bacteria relative to fertilizer and control plots (Table 1). Manure also increased numbers of protozoa and bacteriophagous nematodes which mineralize N tied up in microbial biomass. There was also evidence of increased activity of several soil nutrient mineralizing enzymes in the heavily manured plots and a concomitant decrease in the heavily fertilized plots (data not shown). Of thirteen carabid species found, *Pterostichus melanarius* (Illiger) comprised 85% of the population, with numbers positively related to N-rate in the 4-year treatments (r^2= 0.45). This suggests that high levels of applied N provided long-term habitat enrichment that attracted the beetles or enhanced their reproduction. Earthworm numbers (and biomass) were collectively higher in manure treatments than in fertilizer treatments.

Where a 'no-nutrient' treatment was superimposed in 1998, yield and N-uptake of previous F plots were similar to controls (Table 2). In contrast, low-M plots yielded 4 t/ha and took up 75 kg/ha more N than controls, and high-M plots yielded over 5 t/ha and took up over 125 kg/ha more N than control. Amount of N supplied by previous manure treatments was similar for one year as four years, suggesting that most of the N came from the manure applied in the previous year. The manure-N remaining from two or more previous years appears stable. Where a high rate of manure was superimposed on the previous treatments, there was much more residual NO_3 on the previous high-M4 than the high-F treatment, suggesting that the source of N influences the quantity of soil NO_3 in autumn. For the 'no-nutrient' superimposed treatment, quantities of residual soil nitrate were small regardless of previous treatments.

In conclusion, this study showed that dairy slurry sustained greater yield of perennial grass than chemical fertilizer and that 4-years of manure applications built up the stable organic matter pool in the soil. Manure supplied 70 (low rate) to125 (high rate) kg N/ha the first year after one or more years of application. Manure-N was less prone to loss by leaching than fertilizer N. Manured soils had considerably more biological activity and N_2O emissions than fertilized soils. High rates of manure application increase soil P which suggests the need to remove some high-P solid fraction prior to spreading.

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Table 1 - Effect of fertilizer and manure applied at two rates for different numbers of years (see Materials and Methods) on crop, soil nutrients, soil microbes and soil invertebrates in 1998.

	--Crop Parameters--------			**--------------------------Soil Nutrients--------------------------**							**------Soil Microbes------**			**----Invertebrates----**	
	Grass Cover	Yield	N-Uptake	Residual nitrate (Oct.)	Apparent N-Uptake from Applied N	Soil P concentration (0-0.15m depth	Total soil C (0-0.15 m depth)	Total soil N (0-0.15m depth)	Nitrate in Soil Solution (0.6m)	Nitrate in Soil Solution (0.9m)	Bacteria (x10^{6})	Protozoa	Nematodes (bacteriophage)	Mean *P. melanarius*	Mean Earthworms
Treatment	**%**	**t/ha**	**kg/ha**	**kg/ha**	**kg/ha**	**g/kg**	**%**	**%**	**mg/kg**	**mg kg**	**cells/ g soil**	**cells/ mg soil**	**/100g soil**	**/trap**	**/quadrant**
Control	65	8.9	155	0	---	137	3.45	0.29	0.1	0.0	600	168	246	24.0	29.5
Low-N															
Fertilizer	72	14.1	297	0	142	133	3.21	0.27	0.2	0.1				29.5	25.0
Manure 1	76	15.0	295											51.5	37.5
Manure 2	72	15.3	319						0.2	0.3				32.5	36.5
Manure 4	73	16.1	338	2.2	117	156	3.82	0.31	0.9	0.3	763	263	1017	26.2	30.5
High-N															
Fertilizer	69	15.5	420	119.9	392	130	3.56	0.30	4.0	4.6	521	107	268	27.2	22.5
Manure 1	61	18.3	450						2.2	3.1				36.5	31.0
Manure 2	59	18.1	468						2.6	4.3				41.2	54.0
Manure 4	58	17.6	457	41.7	223	188	3.81	0.31			931	533	1092	38.0	41.5
Fert./Man [1]	63	17.9	481											33.8	37.5
LSD (0.05)	9	0.9	29	33.7		25	0.29	0.02	1.3	2.3	128	125	175	19.3	21.8

[1]Fertilizer and manure alternated for each harvest.

Table 2 - Yield N-uptake, and residual soil NO_3 (in Oct.) in a tall fescue sward as affected by 'no-nutrient' and 'high manure' treatments superimposed in 1998 on fertilizer and manure treatments applied 1994-97.

	---------No Nutrient in 1998---------			----High-N Manure in 1998----		
	Yield	N-Uptake	Residual NO_3 in soil	Yield	N-Uptake	Residual NO_3 in soil
Previous Treatment	t/ha	kg/ha	kg/ha	t/ha	kg/ha	kg/ha
Control	6.36	113	0.0	13.0	329	15.4
Low-N						
Fertilizer	6.75	123	0.0	13.1	327	14.6
Manure 1	10.11	189		14.6	370	
Manure 2	10.30	196		14.7	370	
Manure 4	10.13	186	0.1	14.2	365	35.6
High-N						
Fertilizer	6.93	129	0.0	12.3	326	25.7
Manure 1	11.90	229		14.6	381	
Manure 2	12.01	238		14.4	391	
Manure 4	11.72	241	6.4	13.6	359	108.3
Fert./Man.[1]	11.52	223		14.9	370	
LSD (0.05)	1.07	30	3.7	1.1	30	37.6

[1]Fertilizer and manure alternated for each harvest.