EFFECT OF MULTI-YEAR SURFACE-BANDING OF DAIRY SLURRY ON GRASS

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ABSTRACT

Applying liquid manure by surface banding increases short-term yield compared to broadcasting probably by reducing NH_3 loss. However, the response to surface-banding slurry manure on grass N after several years of application has not been reported. This study compared the effects of commercial fertilizer with drag-shoe applied dairy slurry on yield, N uptake and soil parameters of a tall fescue (*Festuca arundinacea*) sward in years 7-8 of a trial in south-coastal British Columbia, Canada. At equivalent rates of mineral-N, annual grass yield (average of 200 and 2001) was 2-3 Mg ha^{-1} greater with manure than fertilizer whereas at equivalent rate of total-N (400 kg ha^{-1}) annual yield was 1.3 mg ha^{-1}greater with fertilizer. N-uptake was 6 and 11 kg ha^{-1} greater from manure than from fertilizer at 200 and 400 kg mineral-N ha^{-1}, respectively, suggesting a relatively small benefit from historical applications of N. Apparent N recovery for both fertilizer and manure was about 80 and 70% at 200 and 400 kg mineral-N ha^{-1}, respectively. Alternating manure/fertilizer (400 kg TAN ha^{-1}) produced high yield and N-uptake with less applied total-N than manure alone. There was 230, 309 and 519 kg ha^{-1} of unrecovered applied N annually (average of 2000 and 2001) for the low manure, alternating and high manure applications, respectively. High manure plots had significant higher total soil N (approximately 1000 kg ha^{-1}) and available soil P and K, but there was less fall soil NO_3 with manure than with fertilizer. The study indicates that high yields of tall fescue can be maintained by banding slurry manure with or without mineral fertilizer at annual total-N rates of 400 - 600 kg ha^{-1} with little risk of ground water contamination but significant amounts of applied N are lost from the system.

INTRODUCTION

The goal of using slurry manure efficiently is to utilize its nutrients for crops and replace manufactured fertilizer without contaminating the environment. There is interest in applying slurry on perennial forages because these crops often take up more nutrients than annual crops and allow several applications per year. Also, because forages provide year-round ground cover and typically have deep roots, the manure poses less risk of run-off and leaching. Surface broadcasting is a rapid and inexpensive method for applying slurry but may damage the crop (Christie, 1987) and contaminate herbage with microbes (Davies et al., 1996), and produces inconsistent crop response (Bittman et al., 1999). Surface banding of slurry on grass, now widely practiced in western Europe, provides more consistent yield response than broadcasting (Bittman et al., 1999) probably by reducing NH_3 volatilization through more slurry contact with soil and less with residues and standing crop (Sommer and Hutchings, 2001). Previous multi-year studies on broadcast application of dairy slurry to grass have shown similar or lower yield and N recovery, and reduced longevity of perennial grasses, relative to commercial fertilizer based on equivalent mineral-N (Christie, 1987; Siman et al., 1987). While surface banded dairy slurry can replace fertilizer on grass in the short term (Bittman et al., 1999), but the effects after several years of this practice on crop response, nutrient use and grass persistence has not been reported. The objective of this study was to compare the effects on tall fescue (*Festuca arundinacea* Schreb.) of commercial fertilizer with drag-shoe applied dairy slurry with respect to yield, N-uptake and environmental impact in years 7 and 8 of a long-term trial in coastal British Columbia, Canada.

MATERIALS AND METHODS

The experiment was initiated in 1994 on a stand of tall fescue established in 1993 on silty to sandy loam soil of the Monroe series in coastal British Columbia. Dairy slurry was obtained from local high-input dairy farms in which wood shavings are used for bedding. The dairy slurry averaged 92% water, 13:1 C:N and 6.7 pH, and on wet basis (g kg^{-1}), 1.6 NH_4-N, 3.1 total-N, 41 C and 5 P. Manure was surface-banded (23 cm spacing) with a 3-m wide sleigh-foot or drag-shoe slurry applicator mounted behind a 4,000 L tank (Bittman et al. 1999). Six treatments are reported in this paper: unfertilized control, two dairy slurry treatments applied at nominal rates of 50 and 100 kg ha^{-1} of total ammoniacal-N (TAN); two fertilizer (NH_4NO_3) treatments applied at the same N rates, and a treatment with alternating manure and fertilizer each at 100 kg mineral-N ha^{-1}. Nutrients were applied each year in early spring and after each but the final harvest. Other nutrients were applied to fertilized plots in spring as indicated by soil test. Plots were harvested and fertilized twice in 1994, 3 times in 1995 and four times in all subsequent years. Herbage samples were oven dried at 55^{o}C, ground and analyzed for N by dry ash technique. Recovery of applied N is defined as herbage removal from treated plots minus removal from control plots. The Non -Recovery Index was calculated as: unrecovered N (applied-N minus recovered-N) divided by yield expressed as percent. Plant cover was quantified by point intercept along a 50-m transect in July, 2002. Soil samples were collected at 0-15, 15-30 and 30-60 cm depths on Oct., 2000, air-dried, extracted with KCl (NO_3) or Kelowna extract (P and K), and analyzed by FIA (NO_3) or ICP (P and K). Total soil N and C in 0-15 cm (sampled in 2002) was determined by dry ash method.

RESULTS AND DISCUSSION

At equivalent rates of mineral-N (200 and 400 kg ha^{-1}), grass yields (mean of 2000 and 2001) were about 2-3 Mg ha^{-1} greater with manure than fertilizer (Table 1). This result was in contrast to previous reports on the effects of short-term surface banding (Bittman et al., 1999) and long-term broadcasting (Christie, 1987), where yield response to fertilizer and dairy

slurry was similar at equivalent rates of mineral-N. At equivalent rate of total N (400 kg ha^{-1}), yields of fertilized plots were 1.3 Mg kg^{-1} a greater than manured plots. To obtain the same yield as with 400 kg ha^{-1} of fertilizer would require slurry application at annual rates of about 520 kg total-N ha^{-1}. Adding fertilizer (200 kg N ha^{-1}) to manure (400 kg total-N ha^{-1}) ('alternating' treatment) increased yield over manure alone by 2.6 Mg kg^{-1}. Doubling manure rates from 400 to 800 total-N ha^{-1} increased grass yield from 12.1 to 15.0 Mg ha^{-1}. Despite this high yield, the high manure rate had decreased ground cover of the tall fescue stand to about 59.5% compared to 75-80% for other fertilizer or manure plots (Table1). The sparser fescue stands were not invaded by other species so there was more bare ground around plants so that individual plants probably grew larger. Previously, Christie (1987) reported that high rates of broadcast dairy slurry diminished the proportion of perennial ryegrass, increasing that of *Agrostis stolonifera* L, with no loss in yield. Christie (1987) attributed the loss of ryegrass to a manure crust on the soil surface impeding early regrowth. Since the banded manure did not cover most of the soil, the loss of stand in our trials may have been due to NH_4 toxicity or to self-thinning by the plants which grew tall and competed for light and water.

***Table 1**. Effects of commercial fertilizer and banded dairy slurry at different N application rates on yield, N-uptake and N concentration of tall fescue (average 2000 and 2001), grass ground cover (July 2002), and soil N and C (Oct. 2002) in a long-term trial initiated in 1994 in south coastal British Columbia.*

			Herbage					Soil (0-15 cm)	
	Min.-N	Total-N	Yield	N-Uptake	N-Concent.	Non-Recov. Index[z]	Grass Cover	Total N	Total C
	---kg ha^{-1}--		Mg ha^{-1}	kg ha^{-1}	g kg^{-1}	kg/Mg^{-1}	%	----g kg^{-1}----	
Control	0	0	5.5e[y]	92d	17.0d	--	71.5	2.8c	37c
Fertilizer	200	200	11.4d	256c	22.0c	3.2	82.0	2.8c	38c
	400	400	13.4b	362b	27.0a	9.7	75.0	3.0bc	40bc
Manure	200	400	12.1c	262c	22.0c	19.0	80.5	3.1b	43b
	400	800	15.0a	373ab	25.0b	34.6	59.5	3.5c	48a
Alternating	400	600	14.7a	388a	26.0a	20.7	77.5	--	--

[z] Non-Recovery Index for N calculated as: (Total-N applied - N-uptake)/Yield
[y] Values in column not followed by same letter are different at P<0.05 (LSD)

Despite much higher yields, N-uptake was, unexpectedly, just 6 and 11 kg ha^{-1} greater from manure than from fertilizer at 200 and 400 kg mineral-N ha^{-1} application rates, respectively (Table 1). In fact, at the total-N application rate of 400 kg ha^{-1} yield was 10% lower whereas N-uptake was 27% (100 kg N ha^{-1}) lower from manure than from fertilizer. The low uptake was due to 19% (27 vs. 22 g kg^{-1}) lower N concentration in the herbage grown with manure (herbage NO_3 concentrations was not determined.). These results suggest a yield benefit but a relatively small N contribution from historic applications (and organic fraction) of manure. Adding 200 kg N fertilizer ha^{-1} to the low manure rate (alternating treatment) increased N concentration by 4 g kg^{-1} and N uptake by 126 kg ha^{-1}, an uptake efficiency of 63% which is higher than the uptake efficiency (53%) of fertilizer N increment from 200 to 400 kg ha^{-1}. The amount of applied mineral-N not recovered in the harvested herbage was about 30 kg ha^{-1} for the 200 kg ha^{-1} application rate and 105-130 for the 400 kg ha^{-1} application rate, regardless of N source. But based on total-N applied, there were 230, 309 and 519 kg ha^{-1} of unrecovered N for the low manure, alternating and high manure applications, respectively. The ratio of unrecovered total applied N relative to herbage yield (Non-Recovery Index in Table 1) was higher for manured than fertilized plots, but was similar for the low-manure and the low-manure plus fertilizer (alternating) treatments. The Non-Recovery Index was at least 3-fold lower for first cut than for annual production (not shown).

With the large amounts of unrecovered N in manure treatments, there would be an expectation of high soil NO_3 concentration at the end of the season. However, residual (in Oct.) soil NO_3-N was under 10 mg kg^{-1} at all depths for both the low fertilizer and low manure treatments, despite 230 kg ha^{-1} of unrecovered N for the latter. In fact, there was more residual NO_3-N (24.5, 16.5 and 5.5 mg kg^{-1} for the 0-15, 15-30 and 30-60 cm depth, respectively) in the high fertilizer plots with only 130 kg ha^{-1} of unrecovered N than in the high manure plots with 519 kg ha^{-1} unrecovered N (15.5, 9.8 and 5.5 mg kg^{-1} for the three depths, respectively). Even with surface banding, about 30% of applied manure TAN was likely lost in the days following application (Lorenz and Steffens, 1996). Other reports on this trial have shown greater microbial (bacteria and nematodes) and invertebrate populations in manured than in fertilized plots, which may help to explain both depletion and immobilization of N (Forge et al., in press; Bittman et al., in press; Raworth et al. 2004). Higher nitrous oxide emissions (Bittman, unpublished) suggest higher denitrification rates on manured than on fertilized plots which may be a further contributing to unrecovered N. Increase in total soil N from the high manure treatment (Table1) may account for sequestering of about 1000 kg N ha^{-1} between 1994 and 2002; much lower amounts were stored in the other treatments. It is not known how much more manure-N can be conserved in the soil or at what point equilibrium will be reached.

At the low manure rate there is no accumulation of available P or K in the soil (not shown). At the high manure rate, concentrations of both available P and K are accumulating which further suggests that this rate of application is excessive. Adding fertilizer reduced K accumulation below that of the low manure rate probably by increasing yield and K uptake.

CONCLUSION

This study shows greater yield response to banded dairy slurry than previously reported in short-term banding trials or long-term broadcasting trials. The relatively low N concentration and uptake from slurry compared to fertilizer suggests that historic N applications and current organic N applications had relatively little impact on N uptake. Augmentation of manure with mineral N may be needed for adequate levels of protein. Very little crop loss, residual soil NO_3 levels or accumulation of P and K occurred at the low slurry application rate. Some unrecovered manure-N was probably lost as gaseous NH_3, N_2 and N_2O while some was immobilized by microbes and sequestered in the soil organic matter. It is not known weather the soil organic matter has reached equilibrium. The study indicates that high yields of tall fescue can be maintained by banding slurry manure with or without mineral fertilizer at annual total-N rates of 400 - 600 kg ha^{-1} with little risk of ground water contamination, but significant amounts of applied N are nonetheless lost from the system. Research is needed to learn how to further improve the long-term efficiency and sustainability of using manure as the main source of nutrients for perennial grass swards.

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