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Yield and N recovery by grass species in response to long term applications of manure and mineral fertilizer in a cool maritime climate

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Introduction

Liquid manure is an important source of nutrients on many modern dairy farms. Nitrogen (N) use efficiency of slurry is usually less than chemical fertilizer, but the difference is less when tested in trials lasting at least 7 years than in short term trials (Schröder *et al.*, 2007). The efficiency of slurry manure N can be improved by minimizing loss of ammonia after application using low emission applicators. In grass stands where injection is impractical, mitigation methods often involve spreading the slurry in narrow bands directly on the soil surface. Losses of N as ammonia, nitrous oxide and leaching have been measured in many trials, but few have measured all three, while other N pathways such as runoff, denitrification to N_2, and immobilization into stable soil N often go unmeasured. An alternative approach to determine total losses is to calculate the N balance (losses=inputs-outputs), but long term trials are needed to allow recovery of legacy N from manure and to account for soil N changes. This 7-year study was set up on a long term study with seven previous years of nutrient applications, where the slurry was applied with a low-emission trailing shoe applicator. The objective of the study was to assess crop yield, N use efficiency and N recovery, and to infer N losses by three important forage grasses: perennial ryegrass (PRG, *Lolium perenne* L.), orchardgrass (OG, *Dactylis glomerata* L.) and tall fescue (TF, *Festuca arundinacea* Schreb.).

Materials and Methods

This study was located on a silty loam soil near Agassiz (49° N, 121° W), British Columbia, Canada. The region has moderate temperatures year round and abundant precipitation (1700 mm annual; 70% in Oct. to March). The nutrient treatments (dairy slurry and commercial fertilizer) were applied on established TF in a randomized complete block design starting in 1996 (Bittman *et al.*, 2007). Dairy slurry with wood chip bedding (59 g dry matter, 2.5 g total N and 1.31 g ammonium-N per kg fresh slurry) was obtained from high-producing commercial dairy operations. All nutrient treatments were applied in 4 equal doses annually (rates below) in late March and after the 1st, 2nd and 3rd of four harvests. The slurry was applied with a low-emission trailing shoe applicator. In 2003, the sward was terminated by ploughing and each plot was seeded with PRG, OG, or TF. The experimental design was split-split plot (4 blocks) with nutrients as subplots and grasses as sub-subplots (years were main plots). Annual manure rates in 2004-2010 averaged 384 (MLo) and 724 (MHi) kg total-N ha^{-1} with about half as ammoniacal N. Mineral fertilizer (NH_4NO_3) was applied at 200 (FLo) and 400 (FHi) kg N ha^{-1} with other nutrients (P, K, S, B, and Zn and lime) applied according to soil test. Total N rate of FHi was intended to match MLo (nominal 400 kg N ha^{-1}). There was also a control treatment (CTR) which received no fertilizer and a treatment with alternating FHi and MHi applications (M-F). Plots (1.5 x 7m plots) were harvested with a sickle bar harvester and fresh herbage samples were dried (60°C) and analyzed for N concentration by the dry ash method. We calculated:

- N Use Efficiency (NUE) (kg yield kg N^{-1}) = (kg yield – kg yield of control)/ kg applied N
- N uptake (kg N ha^{-1}) = yield x N concentration
- Apparent N Recovery (ANR) (%) = ((N uptake - N uptake by control)/N applied) *100
- Unadjusted N Recovery (%) = (N uptake/N applied) *100

Analysis of variance was done as a mixed model with replicates as random effect, and means separation was according to Fisher's protected LSD test.

Results and Discussion

Yield and NUE of grasses, across nutrients and years, were significantly different: TF> OG>PRG (not shown). High yield of TF was due to high first-cut yield while the low yield for PRG was due to poor summer growth. For TF, first cut contributed 45 and 37% of annual yield with manure and commercial fertilizer, respectively, and a similar pattern was observed for PRG and OG. This suggests that there was more N mineralized in early spring from previous applications of manure than commercial fertilizer. There was a significant interaction for annual yield between nutrients, species and years. OG and TF had similar yield across nutrient treatments in the first two years and, with commercial fertilizer, across all years (Fig.1). However, with manure, yield of TF increased over years more than OG. These results suggest that TF is more suited than OG to manure. Yield of PRG did not change appreciably over years and was consistently lower than the other species reflecting overall lower NUE. At the nominal application rate of 400 kg N ha^{-1}, NUE was greater for manure (MLo) than fertilizer (FHi) which may be due both to legacy N in the manure plots and to suboptimal rates of P, K, etc. in the commercial fertilizer plots since these nutrients were applied according to soil-test, not at rates that would ensure sufficiency. For all three species, greatest yield was achieved by alternating MHi and FHi) (M-F treatment)

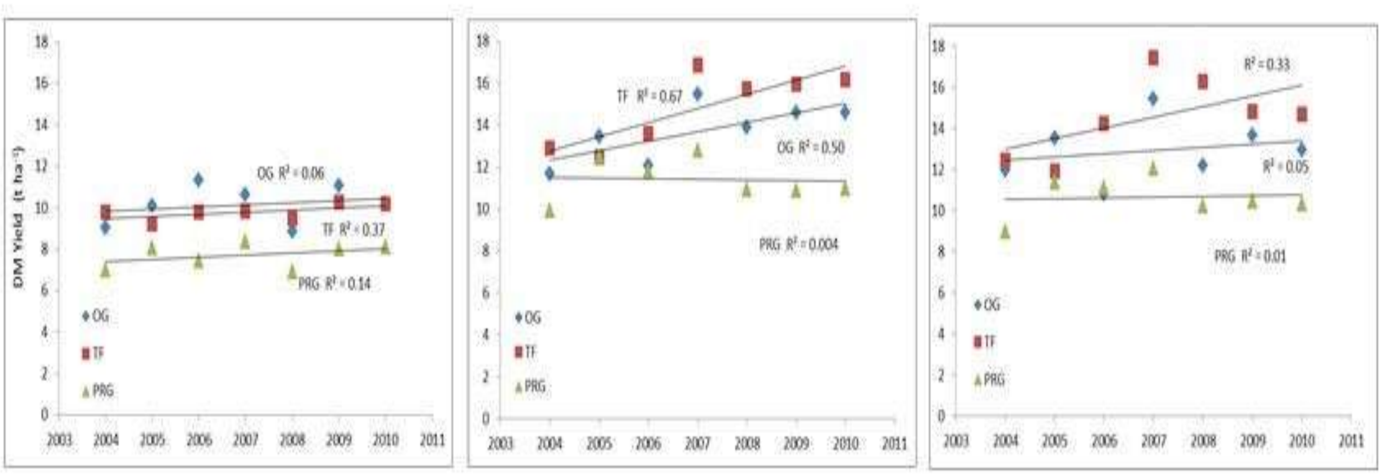

Fig1. Annual dry matter (DM) yield of orchardgrass (OG), tall fescue (TF) and perennial ryegrass (PRG) receiving commercial fertilizer at 200 kg N annually ha^{-1} (FLo, left), manure at nominally 800 kg N ha^{-1} (MHi, right), and alternating applications of MLo and FHi (M-F, middle).

In contrast to yield, N uptake at the nominal 400 kg N ha^{-1} rate was greater for commercial fertilizer (FHi) than for manure (MLo) applications (Table 1). The N fertilizer replacement value (NFRV) of manure was 89, 77, and 70% for TF, OG and PRG, respectively. As with yield, greatest N uptake was from the M-F treatment, even exceeding MHI which received 180 kg ha^{-1} more N. N uptake was significantly greater for OG than TF with fertilizer but uptake was greater for TF than OG with MHi treatment, suggesting that TF is better suited than OG for farms applying high rates of slurry N, and that on these farms less N would be lost from fields planted with TF than OG. Lower N uptake by PRG suggests that it is least suited for intensive dairy production systems in our region. Because it has relatively high content of digestible nutrients, PRG is often the preferred grass on dairy farms, especially those that do not produce high energy crops, but PRG fields would be relatively prone to N leaching. The least unrecovered N per kg of herbage produced was with the M-F treatment, across all species, suggesting it is the most sustainable N source (not shown).

Table 1. Annual N uptake by three grasses (2004-2010) on plots treated with dairy slurry, mineral fertilizer or both since 1996 in British Columbia,

	N rate	Orchardgrass		Tall fescue		Perennial ryegrass		***Mean***	
	----------	----------	----------	kg ha^{-1}	----------	----------	----------	----------	
Control	0	100	J	94	J	77	K	**90**	**f**
FLo	200	239	G	210	H	178	I	**209**	**e**
FHi	400	310	D	289	E	268	F	**289**	**c**
MLo	384	263	F	268	F	219	H	**250**	**d**
MHi	724	332	B	371	A	294	E	**332**	**b**
M-F	546	371	A	374	A	321	C	**355**	**a**
Mean		**269**	**a**	**267**	**a**	**226**	**b**		

Values not followed by the same uppercase letter are significantly different at P<0.05; Mean values in the column or row not followed by the same lower case letter are significantly different at P<0.05

Apparent N recovery at the nominal 400 kg ha^{-1} N rate, across grasses, was 50% for fertilizer (OG highest at 53%) and 40% for manure (TF highest at 44%). This calculation includes an adjustment for N uptake by control plots to account for N released from the soil. However, there was no evidence of reduction of soil N in these long term plots so the N recovery can be considered simply as: total crop N uptake/ total N applied. This 'unadjusted' N recovery is 72% (OG highest at 77%) and 63% (TF highest at 67%) for commercial fertilizer and manure, respectively. A correction for wet N deposition (~10 kg ha^{-1}) would reduce recovery values by about 2.5%. While the former calculation suggests that on average (across grasses) 50 and 60% of applied N was lost from fertilizer and manure, respectively, the latter calculation suggests losses of only 28 and 37%. Based on previous studies on banded slurry, about 13% of manure N would be lost by volatilization and we estimated that about 13% was stored in the soil (tall fescue), suggesting that about 11% of manure N was lost by leaching and denitrification.

Conclusion

This long term trial suggests that OG was more suited to applications of mineral fertilizer and TF to application of slurry manure. PRG which is valued for its nutritional quality yielded less and recovered less N than the other species and may be less suitable for dairy farms with access to high energy feed in this region. Highest yields and lowest N losses per yield were attained by TF receiving alternating applications of manure and commercial. More than 50% of N loss from manure was by ammonia volatilization.

References

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