Greenhouse gas emissions from legume and grass pastures prior to cropping.

David Lester[1], Rod O'Connor[2], Brian Johnson[2], David Lawrence[2] and Peter Grace[3]

[1] Department of Agriculture, Fisheries and Forestry Queensland, PO Box 2282, Toowoomba Qld 4350 Email david.lester@deedi.qld.gov.au
[2] Department of Agriculture, Fisheries and Forestry Queensland, PO Box 102, Toowoomba Qld 4350
[3] Institute of Sustainable Resources, Queensland University of Technology, Brisbane Qld 4000

Abstract

Mixed farming enterprises in southern Queensland have the option of using either short-term legume pasture phases or high analysis fertilisers to meet the nitrogen supply needs of the following grain crops. How safe the legume-fixed nitrogen is from gaseous loss after removing the pasture and at the initial stages of cropping remains an open question. The principal method of gaseous nitrogen loss is via the microbially mitigated process of denitrification. In preparation for grain sorghum cropping, pasture phases under two legumes (burgundy bean or lab-lab) or a grass (forage sorghum) were removed and the fluxes of the main greenhouse gases, nitrous oxide, methane, and carbon dioxide were measured. From August to December following 15 mm (or greater) rainfall events samples were collected in static chambers and analysed. In early November the previous forage sorghum phase was split into two section, one with and one without an application of 46 kg N/ha as urea. All pasture treatments (without urea) had very similar nitrous oxide emissions being generally < 15 µg N_2O-N/m^2/hr during the study period. However after urea application the nitrous oxide emissions were 10 to 100 fold greater. Saturated soil conditions following prolonged wet weather resulted in two methane emission spikes which are not commonly observed. Carbon dioxide flux had a seasonal increase from winter to summer, but increased soil nitrogen availability contributed to increased carbon dioxide flux with both legume and urea treatments higher than unfertilised forage sorghum from late spring onwards. Nitrogen fixed via pasture legume phases appears relatively safe from gaseous losses to the atmosphere via denitrification.

Key Words

nitrous oxide, carbon dioxide, methane, urea

Introduction

Mixed farming system (livestock and grain) producers can potentially source nitrogen for grain crop production from either high analysis fertilisers (most commonly urea) or using ley-pasture phases containing legumes or grasses. Ley pastures are emerging as one of the preferred practices for mixed farmers looking to adapt to any potential reduction in rainfall with climate change. Pastures are considered more reliable than grain production and ley grass/legume pastures may reduce the reliance of energy intensive nitrogenous fertilisers (Argent et al. 2012). Recent research in the grain production areas of southern Queensland has re-evaluated the potential of summer and winter forage legume species against traditional annual grazing grasses for use as short-term phases (Bell et al. 2012). Their research reports that burgundy bean (*Macroptillium bracteatum*) and lablab (*Lablab purpureus*) represented the most reliable forage legume options for production and profitability. However the extent of gaseous nitrogen loss after ending the pasture phase and changing to grain production remains unexplored in this region.

Nitrous oxide emission associated with denitrification, a microbially influenced soil process, is a relatively small, but significant loss pathway due to its potency as a greenhouse gas Nitrous oxide is also a useful indicator of potentially larger losses of nitrogen (as N_2). Denitrification requires an oxygen deficit under higher microbial activity and can occur primarily with water logging of soil reducing atmospheric gas exchange. Assessing the gaseous nitrogen losses following differing legume phases may provide producers with information about how much nitrate-nitrogen could be lost. Comparison could also be made against the current practice of applying fertiliser nitrogen.

After three summer seasons of burgundy bean, lablab or forage sorghum *(Sorghum spp. hybrids)* growth, pasture treatments were removed and grain production started. Carbon dioxide, methane and nitrous oxide emissions were monitored from August to December. To gain a measure of potential nitrogen fertiliser emissions, the forage sorghum plots were split to compare a fertiliser treatment against an untreated control.

Carbon dioxide flux increased with soil temperature from a low in August/September to higher levels in November and December. Average carbon dioxide flux also appeared higher from legume plots compared with forage sorghum suggesting a nitrogen supply limit to microbial activity. With the exception of two rainfall events methane flux was generally low. The methane emissions occurred in October and November after > 50 mm rainfall each with gravimetric soil moistures > 53% (g/g) suggesting a saturated soil moisture environment. Nitrous oxides fluxes from all pasture phases were generally ≤ 10 ug/ N_2O-N/m_2/hr and no apparent difference between them. However the urea application did generate larger nitrous oxide fluxes.

Methods

Between 2007 and 2010 ley-pasture phases of burgundy bean (BB), lablab (LL) and forage sorghum (FS-N) where grown on a grey Vertosol (Isbell 2002) east of Chinchilla on the property ‘Wychie’ (Bell et al. 2012). Full description of the site and experiment are reported in Bell *et al.* (2012). During autumn 2010 all treatments were killed using combinations of glyphosate (360 g a.i./L) and 2-4D amine (500 g a.i./L) in preparation for a return to cropping commencing with grain sorghum (*Sorghum bicolor*) in summer 2010-11.

To compare gaseous emissions at the site, two 25 cm PVC static gas chambers per plot were installed in late July 2010 and gas monitoring commenced 4 August (Fig. 1). Subsequent sampling events were triggered by the site receiving at least 15 mm rainfall in the preceding 24-72 hour period. At the start of the sampling period (generally between 1000 and 1200 hours), a PVC cap with gas sampling port was placed on the chamber. At 0, 30 and 60 minutes approximately 20 mL of gas was extracted and placed into an evacuated 12 ml Exetainer® (Labco Limited). If free water was visible inside the chamber, no samples were collected. Conveyor matting was laid to facilitate moving between plots and improve access across the site during wet conditions (Fig. 1). Marine ply boards (150 x 60 cm) were laid from the matting to access the chambers themselves during sampling (not shown).

Gas sample analysis was conducted using gas chromatography and flux data for carbon dioxide, methane and nitrous oxide calculated as in Barton *et al.* (2008) where the emissions are the linear increase in concentration during the measurement period. If the Pearson’s correlation coefficient (r^2) for carbon dioxide flux was < 0.80, indicating microbial respiration was not occurring, all gas data was discarded. Soil temperature was measured using a digital thermometer inserted to 5cm at the time of sampling at each set of chambers and the site mean is reported here. Rainfall is as recorded at the Bureau of Meteorology Seven Oaks TM (No. 41020) station. A soil sample (0-10 cm) was collected from each treatment in one replicate at the first gas sampling of each sampling after a rainfall event. Samples for nitrate (7B1a) and ammonium (7C2a) analysis (Rayment and Lyons 2011) were dried at 40^{o}C and ground to < 2 mm while gravimetric moisture was determined at 105^{o}C for 48 hours.

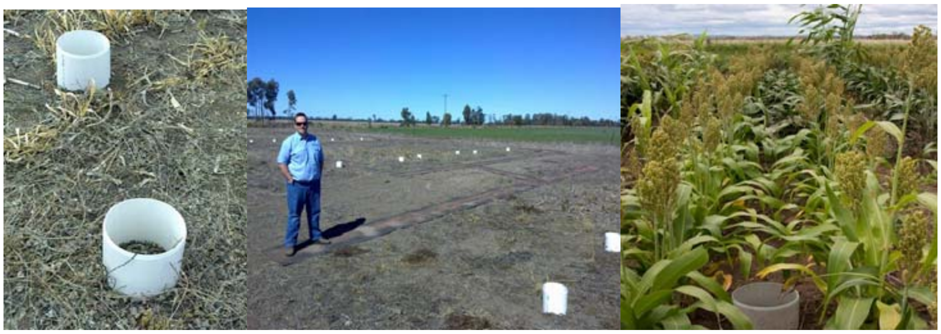

Figure 1. Static chambers in the fallow, conveyor matting for plot access and the sorghum crop to assess nitrous oxide, methane and carbon dioxide emissions in the cropping system.

Grain sorghum (*Sorghum bicolour* cv. Pacific Seeds MR Bazley) was sown at 40 000 seeds/ha on 75 cm row spacing over all treatments on 2 November 2010. Within the forage sorghum plots urea (46% N) was banded at 100 kg/ha (46 kg N/ha) between the sowing rows generating the FS+N treatments. An additional two chambers per plot were added with one placed over a fertiliser band, and one repositioned over the sown (non-urea) row. Nitrous oxide flux of the non-urea row was subtracted from the fertilised band data to give a net flux result.

Results

Carbon dioxide flux increasing with soil temperature as a seasonal response is consistent with reports at other sites relatively nearby (Wang et al. 2011). The 14-16°C soil temperatures in August and September averaged 20 mg/CO_2-C/m^2/hr across all treatments compared to 62 mg/CO_2-C/m^2/hr with the 20+°C from mid-October (Table 1). It is interesting to note the positive impact of nitrogen availability on carbon dioxide flux after this time. The burgundy bean, lablab and forage sorghum with N (as a group) treatments had an average flux of 65 mg/CO_2-C/m^2/hr compared to 40 mg/CO_2-C/m^2/hr for forage sorghum without N. Whether this effect is due to nitrogen either increasing the overall microbial biomass or the just the respiration rate is unknown.

Nitrous oxide flux mirrored carbon dioxide with respect to the influence of soil temperature (Table 1). Mean flux across burgundy bean, lablab or forage sorghum without N treatments prior to 11 October (< 20°C soil temp) was 3.08 µg N_2O-N/m^2/hr, while the mean from the 18 October sampling onwards (> 20°C soil temp) was 6.5 µg N_2O-N/m^2/hr. Nitrous oxide flux in legume and non-urea treated plots were similar with generally < 15 µg N_2O-N/m^2/hr, within the context of episodic sampling using static chambers. Islam et al. (1992) reported denitrification from various tillage, crop and pasture systems appeared related to the amount of freshly added carbon substrate available. More robust comparison of emissions could be achieved through continuous monitoring with automated systems, establishing if different emission patterns exist for legume-fixed nitrogen in this environment, and assessing soluble carbon pools within the treatments.

Urea application (FS+N) resulted in much larger nitrous oxide fluxes up to 485 µg N_2O-N/m^2/hr compared to the legume and non-urea plots (Table 1). Soil nitrate nitrogen concentrations in these FS+N bands ranged from 3-12 mg/kg, whilst those in the BB, LL and FS-N treatments were 1-9 mg/kg. The low soil nitrate concentration in the urea FS+N does not appear to explain the observed nitrous oxide flux. Possibilities for the lower nitrate concentration could be the movement of nitrate from the fertiliser band to below the soil sampling depth (10 cm) as suggested by Avalakki et al. (1995) during 15N denitrification studies, or the lower sampling intensity associated with using only one replicate.

Mean methane flux spiked on two sampling events with 33 µg CH_4-C/m^2/hr on 11 October where gravimetric soil moisture was 59% (g/g) and 98 µg/CH_4-C/m^2/hr on 19 November with 53% (g/g). Soil moisture characterisation at this site (L. Bell *pers comm.*) and at nearby sites of similar soil type suggests an indicative soil saturation at 44% (g/g) (Dalgliesh and Foale 1998). Excluding these events, the mean methane flux was -0.74 µg/CH_4-C/m^2/hr, confirming uptake of methane under aerobic soil conditions. The issue of spatial variability was particularly evident on the 19 November event with two (of three) replicates having fluxes of 160±7.2 µg/CH_4-C/m^2/hr whilst the remaining replicate was -3.4±8.8 µg/CH_4-C/m^2/hr.

Conclusion

Initial comparisons with static chambers on nitrous oxide flux between two legume ley-pastures and a forage sorghum treatment suggest little difference in nitrogen loss. Urea fertiliser applications generate higher nitrous oxide releases. This is very encouraging for farmers considering legume leys for a 'low input/energy' and organic way of adding nitrogen to the farming system. However, automated gas collection methods will be required to compare the full seasonal emissions of these legume leys to the traditional use of fertilisers. Under saturated field conditions, methane emissions can occur.

Table 1. Rainfall, soil gravimetric moisture, soil temperature, carbon dioxide and nitrous oxide fluxes from soils under burgundy bean (BB), lablab (LL) or forage sorghum (FS) pasture treatments without (FS-N) or with urea (FS+N) application at "Wychie", near Chinchilla Qld. Dates indicate the sampling times following >15mm rainfall.

				CO_2 flux (mg/C/m^2/hr)				N_2O flux (µg/N/m^2/hr)			
Date	Rainfall (mm)	Soil H_2O (%)	Soil Temp (°C)	BB	LL	FS -N	FS +N	BB	LL	FS -N	FS +N*
4/08/2010	0	27	14.3	13.91	19.20	16.13		0.43	1.20	0	

11/08/2010	34	40	16.6	33.61	27.62	23.41		0	0.14	0	
12/08/2010		35	14.2	11.66	26.63	22.07		0	0	0	
13/08/2010		33	14.2	16.76	21.92	18.15		5.43	8.54	5.75	
24/08/2010	44	42	16.4	18.79	12.06	19.15		2.16	2.13	0	
25/08/2010		41	15.3	13.88	8.80	12.70		1.69	1.74	0	
6/09/2010	37	51	19.3	25.13	13.63	23.25		6.11	16.05	2.33	
7/09/2010		40	20.2	34.70	22.79	32.71		5.99	8.04	4.05	
20/09/2010	19	46	17.3	26.40	10.29	18.63		3.69	2.48	5.24	
11/10/2010	58	59	22.6	33.13	8.10	11.44		-	-	-	
18/10/2010	15	44	21.9	61.65	35.32	39.20		3.60	0.57	4.56	
5/11/2010	0	16	27.2	44.69	78.44	34.07	49.63	4.17	15.10	1.59	0
18/11/2010	38	69	23.2	65.33	75.72	36.01	57.60	12.99	13.69	1.84	41
19/11/2010	64	53	27.5	73.52	105.61	45.91	85.68	8.59	-	12.62	163
21/11/2010		47	21.3	45.54	57.31	39.58	53.21	5.79	15.79	9.14	182
2/12/2010	17	41	24.5	46.43	53.84	37.44	53.32	4.87	6.83	3.42	136
9/12/2010	62	47	25.3	61.21	77.99	39.96	54.72	7.27	10.24	4.50	485
22/12/2010	75	52	25.9	70.33	99.92	44.26	71.77	0	0	0	37
Mean				38.70	41.96	28.56	60.85	4.28	6.41	3.24	158

* = result is flux of fertilised row – adjacent non-fertilised row

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