DMPP reduced nitrous oxide emissions, but did not improve grain yield

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Abstract

Nitrogen inhibitors have been used to reduce nitrous oxide (N_2O) emission and increase nitrogen use efficiency in many agricultural systems. However, its agronomic benefits, such as the improvement of grain yield, is uncertain. A four-year experiment with a wheat–canola–pulse–wheat crop sequence was established at Wagga Wagga, NSW in 2012. Nitrification inhibitor (3,4-dimethylpyrazole phosphate, DMPP) and urease inhibitor [N-(n-butyl) thiophosphoric triamide, NBPT] were applied as coated urea products (ENTEC and Green Urea, respectively) to wheat and canola crops over two growing seasons in 2012 and 2013. The objectives were *a*) to investigate whether the use of ENTEC and Green Urea can reduce N_2O emissions and increase grain yield; and *b*) to conduct a gross margin analysis to assess the economic benefit by using ENTEC and Green Urea. Results showed that DMPP reduced N_2O emission by 34% on the wheat crop in 2012 and 62% on the canola crop in 2013. There were no yield benefits from either ENTEC or Green Urea in any season. As a result, there was no economic benefit to use N inhibitors in dryland cropping system in southern NSW due to their higher input cost.

Keywords

Greenhouse gas emission, crop rotation, gross margin, wheat, canola.

Introduction

Most nitrogen (N) fertiliser is either applied in the form of ammonium (NH_4^+) or rapidly converted to NH_4^+ after its application (e.g. urea). Usually NH_4^+ converts quickly into nitrate (NO_3^-), a more mobile N formed by the process of nitrification with a bypass product of nitrous oxide (N_2O). The NO_3^- is then subjected to possible losses by leaching and gaseous emissions through denitrification. Nitrification inhibitors, such as 3,4-dimethylpyrazole phosphate (DMPP), have been reported to decrease nitrous oxide (N_2O) emissions substantially in sub-tropical cropping systems (De Antoni Migliorati et al. 2016; Scheer et al. 2016) and reduce the emission factor by up to 70% (Gilsanz et al. 2016). However, the majority of the research with DMPP has failed to demonstrate positive yield benefits or improved fertiliser use efficiency. Urease inhibitors, such as N-(n-butyl) thiophosphoric triamide (NBPT), are applied to slow the conversion of urea to NH_4^+ and therefore minimise losses of N via ammonia (NH_3) volatilisation (Watson et al. 1994).

A 4-year experiment with a wheat–canola–grain legume–wheat crop sequence was established at Wagga Wagga, NSW in 2012. The soil was a Red Kandosol (Isbell 1996). Both nitrification inhibitor (ENTEC, urea coated with DMPP, Incitec Pivot Fertilisers) and urease inhibitor (Green Urea, urea coated with NBPT, Incitec Pivot Fertilisers) were used in this experiment. The objectives were *a*) to investigate whether use of ENTEC and Green Urea can reduce N_2O emissions and increase grain yield; and *b*) to conduct a gross margin analysis to assess the economic benefit by using ENTEC and Green Urea.

Methods

The experimental design was a randomised split-plot design with tillage (tilled vs. no-till) for the whole plot and N rates (0, 20, 50 and 100 kg N/ha) as subplots. In 2012, ENTEC and Green Urea in contrast with normal urea were top-dressed separately at tillering stage on wheat crops at 100 kg N/ha on 7 August 2012. No N inhibitors were applied on the nil N treatment. In 2013, only ENTEC was used, but with four N rates (0, 25, 50 and 100 kg N/ha) when canola was at the 4-5 leaf stage (31 July 2013). For the nil N treatment, single super phosphate was used as the carrier of DMPP, applied on 20 May 2013. In both years, single super phosphate was applied at 15 kg P/ha as a basal application to all plots at sowing. Fluxes of N_2O were measured using manual chambers on 16 occasions over 219 days after N inhibitors were applied in August 2012 until March 2013 on the wheat crops, and 32 occasions over 296 days after canola sowing in May 2013 until April 2014. Chambers were 0.25-m-diameter PVC cylinders positioned between crop rows, then pushed into the ground to a depth of 0.1 m, leaving 0.2 m above the soil surface. At the time of sampling, a lid fitted with a rubber O-ring was placed on the top of each chamber. Gas samples were taken using pre-evacuated, 12-mL glass Exetainer (Labco, Lampeter, UK) vials at 0, 30 and 60 min post-closure. We collected 25 mL chamber air through a rubber septum in the chamber lid. All samples were later analysed using a laboratory gas chromatograph with an electron-capture detector for N_2O measurement. Cumulative N_2O emitted during the experiment was calculated by multiplying the average daily flux rate of consecutive samples by the number of days between those consecutive sample collections. However, where consecutive samples were collected at more than 3 days apart, the intervening daily fluxes were calculated using the equation of $y = 82.725x^{-0.728}$, where y is the estimated N_2O emission and x is the day after significant rainfall events. The equation was developed using auto-chambers data at the same site ($R^2 = 0.94$, $P < 0.01$, $x \leq 2$). N_2O sampling was taken for two significant rainfall events in late December 2012 and late January 2013. The N_2O emissions following these events were estimated based on the N_2O measurement after a rainfall event at the similar intensity occurring on 1 March 2013.

Results and discussion

In general, N_2O emission peaks followed the rainfall pattern regardless of N fertiliser treatment in both years on both crops (Figures 1 and 2). In 2012, the cumulative N_2O emission for the wheat crop was nearly doubled in the treatment with 100 kg N/ha of normal urea applied compared with nil N treatment (Figure 1b). There were significant differences in N_2O emission between N types (Figure 1c). The treatment with ENTEC applied reduced N_2O emission by 34% compared to that with normal urea applied. This reduction was much lower than those reported from sub-tropic cropping systems where annual N_2O losses were reduced by over 70% (De Antoni Migliorati et al. 2016; Scheer et al. 2016; Schwenke et al. 2016), probably due to much lower rainfall in this dry environment (344 and 446 mm in 2012 and 2013, respectively). There was no difference in N_2O emission between treatments with Green Urea and normal urea, indicating Green Urea was not as effective as ENTEC in reducing N_2O emission.

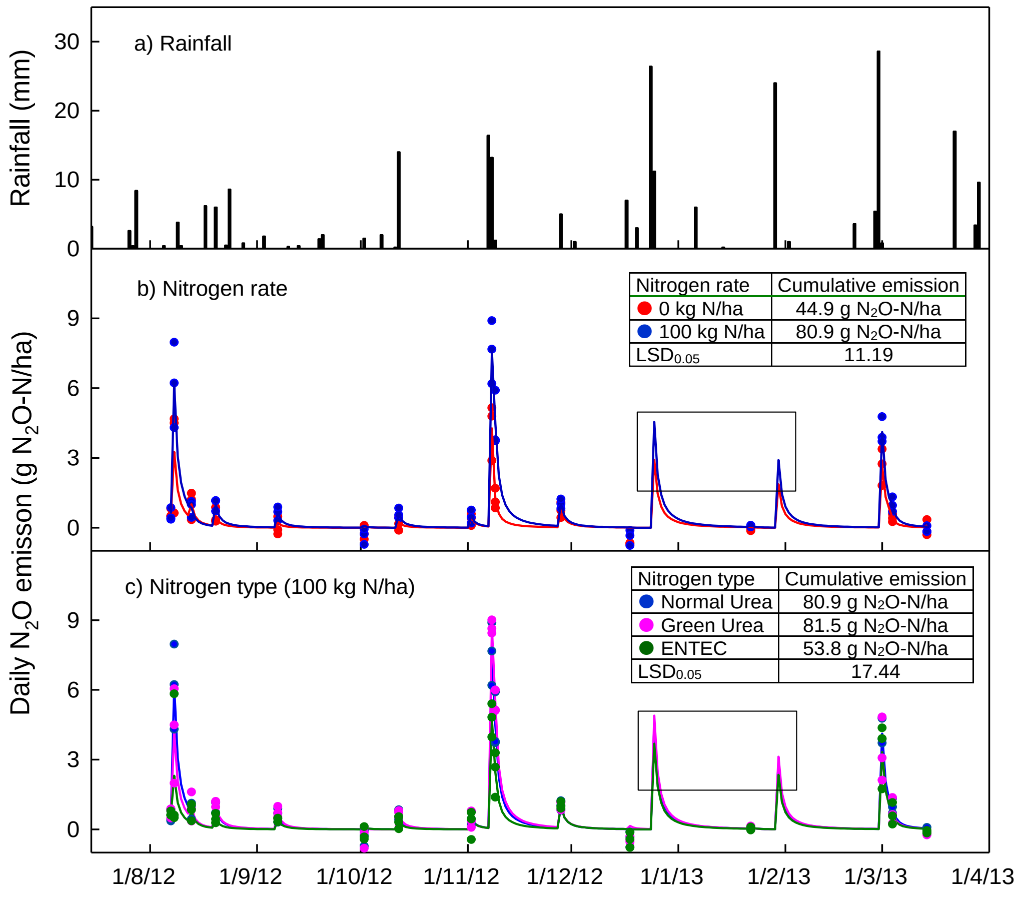

Figure 1. (a) Rainfall (mm), b) daily N_2O emission (g N_2O-N/ha) under different nitrogen rates and *c*) different nitrogen types. The coloured circles represented actual observations under different treatments and corresponding lines are calculated daily flux. The peaks in the box in (b) and (c) were estimated from the N_2O measurement on 1 March 2013. The inserted tables in (b) and (c) are cumulative N_2O (g N_2O-N/ha) emitted over 219 days from 7 August 2012 to 14 March 2013.

In 2013, the data collected from manual chambers with ENTEC applied showed that there was no significant difference in N_2O emission between different N rates (Table 1). However, the cumulative N_2O emission from the manual chambers was significantly less than those from the auto-chambers with normal urea applied (Li et al. 2016). For example, ENTEC reduced the amount of N_2O losses by 62% when 100 kg N/ha was applied. This is consistent with the 40–60% abatement rates reported in field experiments and incubation studies (Chen et al. 2010; Suter et al. 2010; Liu et al. 2013; De Antoni Migliorati et al. 2014).

On both wheat and canola crops, there was no difference in grain yield between normal urea and urea coated with either DMPP or NBPT in both years (data not shown), which is consistent with many other studies (Weiske et al. 2001; De Antoni Migliorati et al. 2016; Lester et al. 2016), despite the significant abatement of N_2O emissions that were observed with DMPP. This is probably no surprise as the N saved from reduction of N_2O emission due to use of N inhibitors (34-62% reduction in this study) is about 0.1% (0.1 kg N/ha) if we use the current emission factor (0.2%, ANGA 2015) for all non-irrigated N-fertilised crops in Australia. Such a small amount of N could not significantly increase grain yield or protein. As a result, the gross margin on treatments with N inhibitors were always lower than those with normal urea due to higher variable costs of using the inhibitors (Table 2).

In conclusion, N inhibitors significantly reduced nitrous oxide emissions, but did not increase grain yield. There was no economic benefit to use N inhibitors in dryland cropping system in southern NSW.

Table 1. Cumulative N_2O emission with auto-chambers (normal urea applied) and manual chambers (ENTEC applied) over 296 days from 23 May 2013 to 22 April 2014.

Nitrogen rate (kg N/ha)	Cumulative emission (g N_2O-N/ha)		
	Auto-chambers	Manual-chambers	$LSD_{0.05}$
0	172.0	79.6	34.63
100	216.2	81.2	79.50
	ANOVA (split-plot model)		
Tillage effect	n.s.	n.s.	
N rate effect	P = 0.075	n.s.	
Tillage × N rate	n.s.	n.s.	

n.s., not significant; - not applicable

Table 2. Gross margin analysis for wheat in 2012 and canola in 2013.

N type	N rate (kg N/ha)	Grain yield (t/ha)	Income ($/ha)	Variable costs ($/ha)	Gross margin ($/ha)
			Wheat		
Normal urea	0	3.9	866	354	512
	25	4.1	933	387	546
	50	4.0	891	416	475
	100	3.7	841	475	366
Green urea	100	3.7	837	486	351
ENTEC	100	3.7	828	507	320
			Canola		
Urea	0	1.6	716	346	370
	25	1.7	775	380	395
	50	1.9	840	413	426
	100	1.8	792	472	320
ENTEC	0	1.7	749	348	401
	25	1.8	796	389	407
	50	1.7	789	427	362
	100	1.9	837	507	330

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