Strategies to reduce nitrous oxide emissions from nitrogen fertiliser applied to dryland sorghum. Part 2. Nitrous oxide emissions

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Key findings

Fertiliser nitrogen (N) rates tailored to suit paddock history/ soil mineral N levels optimised N_2O emissions.

At Tamworth, withholding N fertiliser on a high mineral N soil reduced N_2O emissions, but did not optimise grain yield.

At Breeza, most strategies of urea + nitrification inhibitor, polymer-coated urea and split N application substantially reduced N_2O emissions. Most alternatives produced similar grain yields to the current practice of urea all applied at sowing, so the N_2O emissions intensity per tonne of grain produced was also reduced.

A 1:3 blend of urea + polymer-coated urea all applied at sowing, increased N_2O emissions compared with the urea all at sowing treatment. The treatment also reduced grain yield, so potential slow-release treatments need to be carefully evaluated from both an N_2O emissions and grain production point of view.

Introduction

This paper reports the nitrous oxide (N_2O) emission results from the 2014–15 grain sorghum trials, which aimed to optimise both nitrogen (N) rate and fertiliser N release to benefit crop production and reduce N_2O emissions. The concentration of N_2O, a potent greenhouse warming gas, in the atmosphere is increasing, largely as a consequence of increased N inputs into the soil through N fertiliser, legume N_2-fixation and manures. Once in the soil, all sources of N are subject to the biologically-driven soil processes of nitrification and denitrification, with soil water content determining the timing and amount of N_2O emitted. Emissions are typically characterised by an emissions factor (EF) – the proportion of added N emitted as N_2O.

Modern agriculture requires substantial N inputs for sustainable production, so a balance must be found between optimising grain yields and also minimising N_2O emissions while producing these yields. Simply aiming to minimise N_2O emissions with no regard to continued profitable grain production can result in strategies that are unlikely to be adopted by grain growers. An integrative measure of both emissions and productivity is the emissions intensity (EI), which calculates the quantity of N_2O emitted in relation to grain yield produced per hectare.

Trial results from previous years of this project have established that optimising the N-fertiliser rate for optimum grain yield is crucial for minimising N_2O, as N applied in excess of crop uptake can lead to exponentially increasing rates of N_2O loss (2012–13). In 2013–14, we found that applying urea with a nitrification inhibitor can lead to large reductions in N_2O emissions, as can delaying applying urea until the period of rapid crop N uptake (7-leaf stage or booting).

In 2014–15, the trial at the Tamworth site tailored the N fertiliser applied to the amount present in the soil at sowing to assess the reduction in N_2O emissions. Different previous crop histories in 2013–14 (sorghum or soybean) led to different N fertiliser rates for sorghum in 2014–15. We also had a nil-N fertiliser rate treatment on each of these previous histories as a background for the N_2O emission factor calculations. At Breeza, the treatments focused on comparing alternative slow-release fertilisers, fertiliser blends, and split application strategies. Products used were urea, Entec® (urea + nitrification inhibitor), and polymer-coated urea. These products were all applied either individually or in various blends together at sowing at a total N rate of 90 kg N/ha. We also applied these products individually at 30 kg N/ha at sowing followed by 60 kg N/ha at the 7-leaf stage as either straight urea or urea + NV® (urease inhibitor). Results presented for both sites relate to N_2O emissions between sowing and harvest.

Site details

2014–15

Location:	**Tamworth**
Co-operator:	**NSW Department of Primary Industries (Tamworth Agricultural Institute)**
Agronomy:	**MR Bazley sown in 75 cm rows on 28 October 2014, harvested on 6 March 2015**
In-crop rainfall:	**422 mm**
Location:	**Breeza**
Co-operator:	**NSW Department of Primary Industries (Liverpool Plains Field Station)**

Agronomy:	**MR Bazley sown on 100 cm rows on 11 November 2014, harvested 20 March 2015**
In-crop rainfall:	**264 mm**

Treatments

Table 1. *Treatment details of the Tamworth and Breeza trials in 2014–15*

Tamworth		Breeza		
Name	Pre-crop, fertiliser	No.	N side-banded at sowing	N topdressed at booting
sorg_0_N	After sorghum, no N applied	1	0	0
sorg_+N	After sorghum, 120 kg N/ha urea side-banded at sowing	2	90 kg N/ha urea	0
soy_0_N	After soybean, no N applied.	3	90 kg N/ha Entec*	0
soy_+N	After soybean, 40 kg N/ha urea side-banded at sowing	4	90 kg N/ha polymer-urea**	0
sorg_split	After sorghum, 40 kg N/ha urea side banded at sowing + 80 kg N/ha topdressed as urea at booting.	5	30 kg N/ha urea + 60 kg N/ha Entec	0
		6	30 kg N/ha urea + 60 kg N/ha polymer-urea	0
		7	30 kg N/ha urea + 30 kg N/ha Entec + 30 kg N/ha polymer-urea	0
		8	30 kg N/ha urea	60 kg N/ha urea
		9	30 kg N/ha Entec	60 kg N/ha urea
		10	30 kg N/ha polymer-urea	60 kg N/ha urea
		11	30 kg N/ha urea	60 kg N/ha NV-urea***
		12	30 kg N/ha Entec	60 kg N/ha NV-urea
		13	30 kg N/ha polymer-urea	60 kg N/ha NV-urea

*Entec® is urea coated with the nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) [Incitec Pivot Fertilisers Ltd]

**Polymer-coated urea delays conversion of urea for up to 2 months

***NV®-urea is urea coated with the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT). [Incitec Pivot Fertilisers Ltd]

Results – Tamworth

- The N fertilised post-sorghum treatment emitted more N_2O than the nil-N fertilised post-sorghum plots (Table 1).
- There was no significant difference in cumulative N_2O emissions from the N fertilised versus the nil-N fertilised post-soybean plots, both of which were greater than the nil-N post-sorghum.
- Twice the long-term average rainfall was experienced at this site in December 2014, which was the third wettest December since 1959, with 175 mm rainfall recorded in December out of the 422 mm total over the growing season. In comparison, total rainfall during the previous two growing seasons at the Tamworth site was 322 mm (2012–13) and 226 mm (2013–14). Despite these wetter conditions, the cumulative loss of N_2O was less than that measured in the previous two summer seasons for a similar treatment (sorghum +100 kg N/ha), because of different timings and patterns of rainfall in relation to the N demands of the sorghum crop.
- Despite the high rainfall totals this season, the timing and intensity of the rainfall events was generally not sufficient to cause the degree of waterlogging experienced at the site in past seasons. Also, the soil profile in the current season was not fully wet at sowing, so it could accommodate further filling in-season compared with previous seasons, where the in-season rain fell on fully wet profiles that ponded more readily.
- N_2O emission factors for the post-sorghum and post-soybean N fertiliser were low (and not significantly different), indicating good synchrony between fertiliser N supply and crop N demand (Table 1).

Table 1. Grain yield and cumulative N_2O emissions summary for the Tamworth trial (2014–15)

Treatment	Grain yield (t/ha)	N_2O emission (g/ha)	N_2O emission factor (%)	Emissions intensity (g N_2O/t grain)	Emissions reduction (%)*
sorg_0_N	7.0 a	87 a	–	13 a	72 b
sorg_+N	10.3 c	309 c	0.19	30 b	*
soy_0_N	8.3 b	208 b	–	25 b	33 a
soy_+N	10.2 c	215 bc	0.02	21 ab	30 a
sorg_split	11.6 d	–	–	–	–
* Compared with N_2O emissions from 120 kg N/ha post-sorghum treatment.					

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Results – Breeza

- Cumulative N_2O emission from the standard urea-at-sowing treatment (T2) at this site was greater than that of the sorghum (120N) treatment at the Tamworth site, despite the drier conditions at Breeza.
- The addition of 33% urea/67% polymer-coated urea mixture all at sowing (T6) led to significantly greater N_2O emissions than the 100% urea-at-sowing treatment, particularly between mid-December 2014 and mid-January 2015 (data not shown). It appears that the delayed release of mineral N from the polymer-coated urea continued to supply mineral N during times conducive to emissive losses, whereas the mineral N release from straight urea occurred over a more concentrated period of in time. This treatment also yielded significantly less than the optimum yield, which indicated that disconnect occurred between fertiliser N supply into the soil and crop N uptake.
- N_2O emissions from 100% polymer at sowing (T4) were less than the 100% urea-at-sowing treatment (T2), but still greater than most other treatments (Table 2).
- There was still sufficient mineral N in the soil near the end of the season for a noticeable increase in emissions in response to rain in late February 2015 (data not shown), but the similarity of this emission response in all treatments, including the nil-N control, indicates that the mineral N was sourced from soil N mineralisation rather than from N fertiliser additions.
- The urea/polymer-coated mixture applied all at sowing (T6) increased N_2O emissions by 44% above that of 100% urea-at-sowing (T2), and therefore gave a higher emission factor (EF).
- All other treatments significantly reduced emissions compared with T2 and therefore lowered EF.
- 100% polymer-coated urea at sowing (T4) reduced emissions by 27% compared with urea-at-sowing (T2).
- Most other options led to reductions of over 50%, which were statistically similar to the amount of reduction measured in the nil-N treatment (T1).
- The reduction in emissions from the 100% Entec® at sowing (T3) was 64%, which is similar to previous trials with Entec in this project.
- There was a trend for both the split urea treatments (T8 and T11) to show greater N_2O losses than the splits using either Entec® (T9 and T12) or polymer-urea (T10 and T13).

Table 2. *Grain yield and cumulative N_2O emissions summary for the Breeza trial (2014–15)*

Treatment number	Grain yield (t/ha)	N_2O emission (g/ha)	N_2O emission factor (%)	Emissions intensity (g N_2O/t grain)	Emissions reduction (%)*
1	5.2 a	133 a	–	24 a	79 d
2	7.1 d	637 d	0.56 c	90 c	*
3	6.6 cd	228 ab	0.11 a	35 ab	64 cd
4	7.1 d	465 c	0.37 b	67 bc	27 b
5	6.6 bcd	220 ab	0.10 a	32 ab	66 cd
6	6.1 bc	915 e	0.87 d	163 d	–44 a
7	6.9 d	278 ab	0.16 a	40 ab	56 cd
8	6.7 cd	344 bc	0.23 ab	52 ab	46 bc
9	5.8 ab	207 ab	0.08 a	38 ab	68 cd
10	6.8 d	214 ab	0.09 a	31 ab	67 cd
11	6.8 d	311 bc	0.20 ab	46 ab	51 bc
12	6.7 cd	208 ab	0.08 a	31 ab	67 cd
13	6.9 d	230 ab	0.11 a	33 ab	64 cd

* Compared with N_2O emissions from 90 kg N/ha treatment (T2).

Summary

The Tamworth trial results demonstrate the importance of using knowledge about starting soil mineral N to select the optimum rate of N fertiliser applied, either through soil testing or through calculations based on previous crop information. Reducing the rate of application of N fertiliser to soil with greater mineral N at sowing led to a 30% reduction in N_2O emissions compared with soil that had low mineral N. Not adding any N fertiliser to the post-soybean soil also reduced N_2O emissions (by 72%), but did not optimise grain yields.

At Breeza, most N strategy treatments reduced N_2O emissions compared with the standard practice of 100% urea applied at sowing (T2), yet still maintaining grain yield. Most treatments also substantially reduced the emissions intensity index and are therefore potentially viable options for farmers to reduce N_2O emissions. However, the emissions intensity measurements do not take into account the additional costs of implementing these options, either through a higher product purchase price or additional field application costs. One of the treatments aimed at slower N release gave both increased N_2O emissions and sub-optimal yields, which provides a warning that N release from slow release strategies is not automatically beneficial to the environment or production, but needs to be tailored for both through future research.

Acknowledgements

This research was funded by NSW DPI and the Australian Government Department of Agriculture as part of the project DAN00129: NANORP Filling the Research Gap. Many thanks to Helen Squires, Mandy Holland, and Peter Sanson for assistance with field sampling and measurements, and the Tamworth cereal agronomy team for assistance with crop agronomy. Thanks also to Incitec Pivot Fertilisers Ltd for supplying Entec®, NV®, and the polymer-coated urea (not currently a commercial product).