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The effect of increasing nitrogen fertiliser on emission of nitrous oxide when growing sorghum on Vertosols

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Introduction

Nitrous oxide (N_2O) is a greenhouse warming gas that is accumulating in the atmosphere. N_2O is produced naturally in the soil by the biological processes of nitrification and denitrification, but adding nitrogen (N) as fertiliser, manure or legume crop residues increases N_2O emissions above natural levels. Nitrification is where ammonium (from urea, ammonium sulfate, anhydrous ammonia) is converted to nitrate in aerobic soils, with a little N_2O lost as well. Denitrification occurs in anaerobic (oxygen depleted) soils, as occurs when soils are waterlogged, and converts nitrate into the gases nitric oxide (NO), nitrous oxide (N_2O) and di-nitrogen (N_2). Most of the N lost during denitrification is N_2 which does not affect global warming but does constitute a significant loss of applied N from the paddock.

Previous research at Tamworth has shown that N_2O emissions can be relatively high from N fertiliser applied to summer sorghum, so strategies are needed for mitigation in this sector. One such strategy is to better match the crop's N demand with N supplied by fertiliser, as excess N may lead to disproportionately high losses as N_2O. In the 2012–13 summer, we had two field trials comparing N_2O emissions emanating from cracking clay soils (Vertosols) fertilised at various N rates for grain sorghum production.

Site details

Main trial (auto chambers)

Location: **Tamworth Agricultural Institute**

Co-operator: **NSW DPI**

On-farm trial (manual chambers)

Location: **Quirindi**

Co-operator: **Ian Carter**

Treatments

Tamworth trial	Quirindi trial
N rates – 0, 20, 40, 80, 120, 160, 200 kg N/ha (side-banded as urea at planting)	N rates – 0, 40, 80, 120, 160, 200, 240 kg N/ha (side-banded as urea at planting)
Variety – MR Bazley Row spacing – 75 cm Sown – 23rd October 2012 Harvested – 22nd March 2013	Variety – MR Bazley Row spacing – 75 cm Sown – 8th December 2012 Harvested – 3rd May 2013
Auto gas emissions chambers on 0, 40, 120 and 200 kg N/ha treatments. Sampled 8 times/day for whole year from planting.	Manual gas emissions chambers on all N rate treatments. Sampled every 1–14 days, depending on rain, from sowing till harvest.

Key findings

Sorghum grain yield increased with nitrogen (N) fertiliser rate up to 120 kg N/ha at two trials on N-deficient Vertosols (cracking clay soils). Higher N rates only increased grain protein not yield.

Intense rainfall on the heavy clay soil type at the Quirindi site led to prolonged waterlogging and denitrification (N loss from the soil as N gases, including nitrous oxide (N_2O)). The loss of N led to reduced grain yield and protein.

At both sites more N_2O was emitted from the soil as N fertiliser rate increased. At the Tamworth site, 0.79% of the N applied as fertiliser was emitted as N_2O. At the Quirindi site, the proportion of N emitted as N_2O also increased with N rate, from 1.43% up to 3.3% at the highest N rate.

N supply for sorghum (soil N + fertiliser N) should be matched to potential grain yield to minimise N_2O production.

Results

- There was a strong plant growth response to N fertiliser at both trial sites as shown by biomass cuts taken at flowering (Figure 1). At Tamworth there was very little initial soil mineral N so the sorghum in the nil N rate plots was visibly N deficient and yielded poorly, around 2.3 t/ha (Fig 1b). Top yields were achieved at N rates of 120 kg N/ha and above (around 6.6 t/ha). N rates greater than 120 kg/ha produced no further increase in grain yield, but did continue to increase grain protein (from around 7.5% to 10%) (Figure 1c).
- The Quirindi site was not as low in initial soil mineral N as the Tamworth site and produced a similar amount of biomass by the flowering stage of crop development (Figure 1a). However, grain yields and proteins at the Quirindi site were much lower than at the Tamworth site. This was because much of the N applied in fertiliser was lost from the soil through denitrification in January–February 2013. Earlier dry conditions in the trial meant that the growing crop had used very little of the fertiliser N by the end of January when heavy rains waterlogged the soil resulting in denitrification.
- N_2O emissions were greater from the higher N treatments throughout the early growing season in response to rainfall (Figure 2). The highest N_2O concentrations were associated with the manual chamber measurements made in late January 2013, when 145 mm of rain had fallen over the previous 5 days (95 mm on the last day). The highest N_2O emissions came from the treatments with the highest N fertiliser applied.
- Total N_2O losses at the Quirindi site were three times higher than those measured at the Tamworth site as the rainfall at the former was much greater in total, fell with a greater intensity, and fell at an early crop growth stage (before it had used much of the supplied N). The soil at Quirindi was also heavier texture (80% clay) compared to that at the Tamworth trial site (44% clay). Heavier clay soils are more slowly drained and therefore remain oxygen depleted for longer.
- The N fertiliser emission factor (% of applied N lost as N_2O) increased with increasing fertiliser N rate at Quirindi (from 1.45–3.3%), but remained around 0.79% at Tamworth for the three N rates tested.

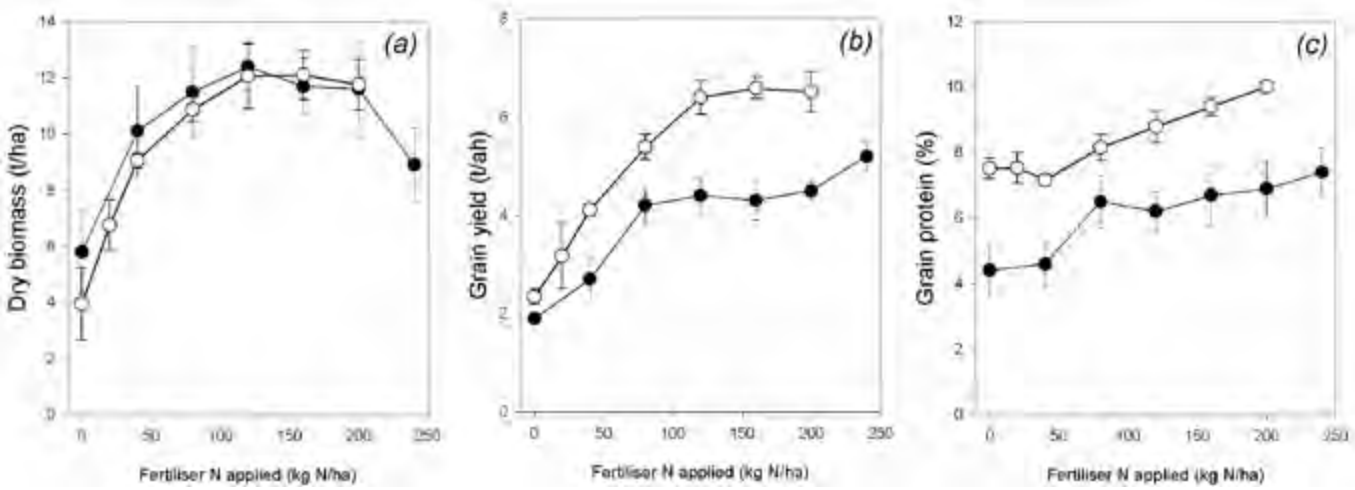

Figure 1. *Effect of nitrogen fertiliser rate on (a) plant biomass at flowering, (b) grain yield, and (c) grain protein at Tamworth (white circles) and Quirindi (black circles). Yield and protein are corrected to 12% moisture.*

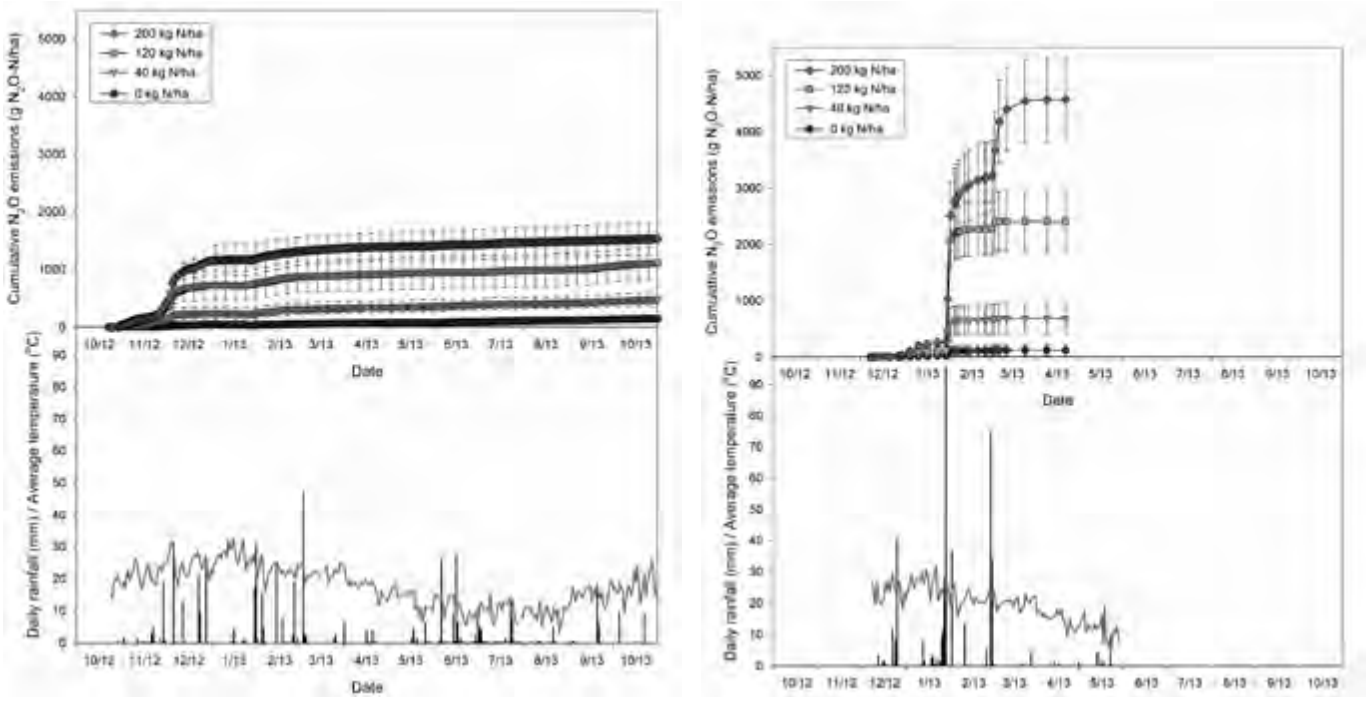

Figure 2. *Cumulative N_2O emissions from different N fertiliser rate treatments at Tamworth (left) and Quirindi (right) trial sites, along with the daily rainfall and daily average temperature at each site (below). Measurements at Tamworth were for 12 months, while those at Quirindi covered from sowing until harvest.*

Summary

Applications of N fertiliser above 120 kg N/ha to two sorghum crops grown on Vertosols produced no additional grain yield. While some of the extra N was accumulated into additional grain protein, much of the unused nitrate N in the Quirindi soil was lost by denitrification when the soil became waterlogged which reduced grain yield and protein at that site. Some of the denitrified N was lost as N_2O which has important environmental consequences. At both the Tamworth and Quirindi sorghum trials, total soil N_2O emissions increased with increasing N fertiliser application rate. At Tamworth, the losses as a proportion of N applied were much the same regardless of N rate, whereas increasing N fertiliser rate at Quirindi led to a higher proportional loss of N_2O in much more waterlogged conditions. N supply for sorghum (soil N + fertiliser N) should be matched to potential grain yield to minimise N_2O emissions.

Acknowledgements

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