Soil nitrous oxide emissions under dryland N-fertilised canola and N_2-fixing chickpea in the northern grains region, Australia

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Abstract
Nitrous oxide (N_2O) emissions from cropping soils contribute to increasing atmospheric N_2O. Planning to reduce emissions requires real-world measurements. Crop production systems that partially rely on nitrogen (N) fixed by legumes may emit less N_2O than systems that are totally dependent on fertiliser N inputs. We measured N_2O emissions from a dryland vertosol in northwest NSW, Australia during the growth of N-fertilised canola (*Brassica napus*) and N_2-fixing chickpea (*Cicer arietinum*). At sowing, canola received 80 kg N/ha as urea, and chickpea was inoculated with effective rhizobia. Emissions of N_2O were monitored seven times per day using an automated system of chambers connected to a gas chromatograph. Daily N_2O emissions ranged from -1.7 to 39.6 g N_2O-N/ha/day in canola plots and -1.6 to 12.5 g N_2O-N/ha/day for chickpea. During crop growth, the N-fertilised canola plots emitted a total of 293 g N_2O-N/ha, equivalent to 0.37% of the urea N applied. Chickpea plots emitted 29 g N_2O-N/ha. The canola plots emitted a further 241 g N_2O-N/ha in the first months of the post-crop fallow, mostly during a short period of high rainfall, compared with 58 g N_2O-N/ha for chickpea. We hypothesise that the canola residue may have mineralised N earlier than chickpeas.

Key Words
Nitrous oxide, nitrogen, urea, canola, chickpea.

Introduction

Cropping soils are an important anthropogenic source of nitrous oxide (N_2O), a greenhouse gas with 298 times the global warming potential of carbon dioxide. The soil-emitted N_2O originates from the processes of nitrification (oxidation of ammonium to nitrite then nitrate) and denitrification (reduction of nitrate or nitrite to N_2O and N_2). As both processes are biologically driven, soil moisture and aeration are key factors in emissions, along with availability of inorganic nitrogen (N) and organic carbon (C) substrate. In the north-eastern Australian dryland cropping region, inorganic N requirements of cereal crops are mainly supplied by inorganic fertilisers and soil organic matter mineralisation, with low reliance on N_2-fixing legume crops or pastures.

Partial substitution of fertiliser N inputs with biologically-fixed legume N should reduce N_2O emissions through (a) reduced reliance on fertiliser N, whose manufacture alone produces 1.5-2.2 kg CO_2-equivalent emissions for every kg N fertiliser produced (Wood and Cowie 2004), and (b) reduced availability of soil mineral N for loss through moderated release during crop residue decomposition. N_2O emissions factors for non-irrigated cropping in Australia have been reduced from the IPCC default of 1.25% of fertiliser N applied down to 0.3%, but the lack of local data for emissions from legume-derived N has meant that 1.25% still applies (DCC 2009). Elsewhere, Rochette and Janzen (2005) reviewed published data on N_2O emissions from a range of legume crops; with averages of 1.0 kg N/ha for annual crops, 1.8 kg N/ha for pure forage crops and 0.4 kg N/ha for grass legume mixes. These averages were only slightly above background soil emissions. Detailed phenological studies with soybean demonstrate that N_2O emissions associated with a legume crop are insubstantial until the plant has matured and senesced plant parts begin to decompose (Ciampitti *et al*. 2008). Therefore, it is not the growth of the legume plant and its biological fixation of N from the air, *per se*, that is responsible for N_2O emissions, but rather it is the release of mineral N into the soil from decomposing leguminous residues, including roots and nodules. Dalal *et al*. (2003) stated that the extent of N_2O emissions during and following a pulse crop in the Australian cereal-growing region was unknown. There has been little published work in Australia since this document, so the situation remains unchanged. As a result, the comparison of soil N_2O emissions from fertiliser N and legume-derived N in crop production systems is the focus of our research on a vertosol (cracking clay) soil near Tamworth in the northern grains region of north-eastern Australia.

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Methods

Field trial

The experiment was located on a black vertosol at the Tamworth Agricultural Institute, near Tamworth, NSW, Australia. This alkaline, cracking medium clay soil is typical of the majority of the soil used for dryland cropping in the northern grains region of eastern Australia. The crop rotation trial was established in standing wheat stubble in June 2009, and was designed as a three year experiment using a randomized complete block design consisting 6 treatments and 4 replicates. Plots were 12 m length and 6 m width. Rainfall at the site was measured using a rain gauge equipped with tipping bucket and data logger.

Canola (*Brassica napus*) and chickpea (*Cicer arietenum*) were sown in 50 cm rows with a zero-tillage planter on the 19th June 2009. Urea (80 kg N/ha) was banded at sowing, just below the soil surface mid-row between every alternative canola row. Canola was harvested by small plot header on the 23rd November, and chickpea on the 26th November. All crop residues from each plot were returned to and spread across the surface of those plots. Aboveground residues from plants grown within the measurement chambers were returned to the chambers after the grain was removed and held in place by netting during the fallow. There was no cultivation of the plots. Weeds were controlled with herbicides and hand-weeding.

Nitrous oxide measurements

We used an automated greenhouse gas measuring system (Breuer *et al*. 2000) to measure N_2O emissions from 3 replicates of 2 treatments (N-fertilised canola and unfertilised chickpea) within the rotation trial. The system consisted of one 50 cm x 50 cm polycarbonate chamber located on each plot, clamped to a stainless steel base inserted 10 cm into the soil. Three bases were located in each treatment plot and chambers moved to a new position periodically to minimise any negative effects on soil properties or plant growth. We increased the height of the chamber using extensions to match the crop's height during the growing season. For chickpea, the chambers were placed from mid-row to mid-row, while for canola, the chambers were placed to cover both the plant row and the mid-row urea fertiliser band. In every 192 minute cycle, the lids of all chambers shut for the first 90 minutes, then re-opened for the remaining 102 minutes. During the 90 minute closed chamber period, the air in each chamber was sampled sequentially four times and N_2O measured using a gas chromatograph equipped with an electron capture detector. N_2O emissions were calculated from the slope of the linear increase in N_2O concentration during the closed chamber period, then corrected for chamber air temperature, air pressure and chamber volume.

Results

Figure 1 depicts the daily emission of N_2O from soil under N-fertilised canola and unfertilised chickpea through the period of crop growth from mid June till harvest in late November 2009, then two months into the summer fallow period until late January 2010. Daily N_2O emissions ranged from -1.7 to 39.6 g N_2O-N/ha/day in the canola plots and -1.6 to 12.5 g N_2O-N/ha/day for chickpea. The higher results were recorded for both crops during a week of rainfall from 26th December 2009 that totalled 134 mm. Most daily emissions however were low, with the canola soil emitted more than the chickpea soil, which was often below detection. Both the range in our results and the low averages were of the same order as other soil N_2O emissions measured under dryland wheat crops (Barker-Reid *et al.* 2005, Galbally *et al.* 2005, Barton *et al*. 2008, Officer *et al.* 2008).

In the 157 days from sowing until harvest, soil under N-fertilised canola emitted a total of 293 g N_2O-N/ha. Much of this occurred in the first two months after N application in conjunction with rainfall events that would have stimulated soil nitrification after the urea had hydrolysed to ammonium. Emissions from canola plots equated to 0.37% of the N applied as urea at sowing, although we did not correct for background, i.e. nil fertiliser N. Over the same period the soil under chickpeas emitted only 28.5 g N_2O-N/ha. If we consider this as the background N_2O emission then the emission factor for N fertiliser under canola during crop growth was 0.33% of that applied. This is close to the Australian emission factor used for accounting emissions from non-irrigated crops (DCC 2009), and therefore of similar magnitude to previous research done on soil under cereals (Barker-Reid *et al*. 2005, Galbally *et al*. 2005). Rainfall during the cropping period totalled 179 mm, which is approximately half the longterm average at Tamworth. Despite this, crop growth was reasonable with canola yielding 1.7 t grain/ha and chickpea 1.3 t grain/ha, although chickpea yields were substantially depressed by insect damage at grain-filling.

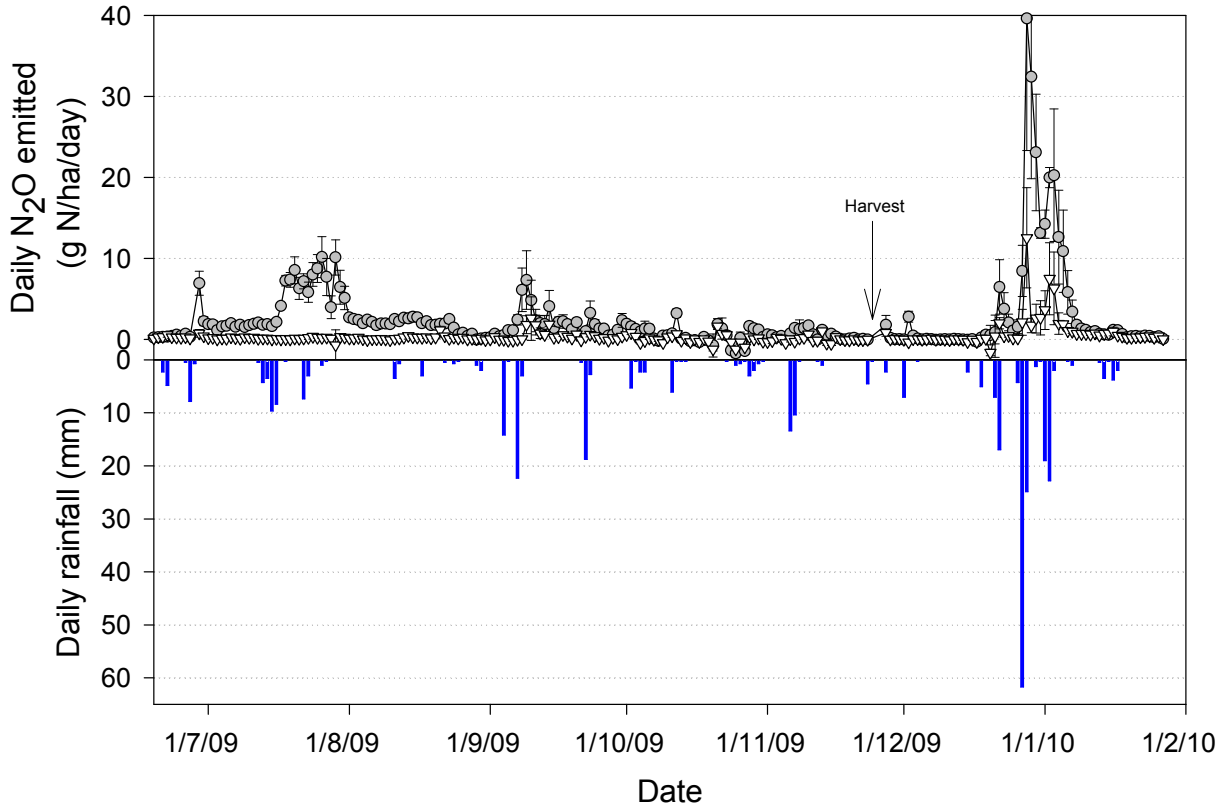

Figure 1. Daily emission of nitrous oxide emissions from soil under canola (circles) and chickpea (triangles) as influenced by date since urea fertiliser application (canola only) and daily rainfall (bottom graph). Data points are means of three replicates with standard errors of the means shown.

We expected that the N_2O emissions from the soil after canola would be minimal as the plant growth should have depleted the available soil N, but during the first two months of the summer fallow period, a further 241 g N_2O-N/ha was emitted from the soil after canola and another 57.6 g N_2O-N/ha were emitted from the soil after chickpea. Most of the fallow emissions occurred during a week of continued rainfall at the end of 2009. This is in concert with Barker-Reid *et al*. (2005) who found rainfall and mineral nitrogen status to be the main influence on N_2O fluxes, especially in conjunction with rainfall after extended hot, dry periods. Unprocessed data on crop residue N and soil mineral N concentrations post-harvest should shed further light on the suitability of conditions for denitrification, an uncommon event in dryland cropping for this region.

Conclusion

Soil emissions of N_2O during a dryland canola crop were of similar magnitude to those observed from soils growing wheat in other Australian cropping regions, and also with some N-rates on cotton grown in the same region (Galbally *et al.* 2005). Emissions coincided with significant rainfall events, particularly soon after N fertiliser application (before significant plant uptake) and also post-harvest, when presumably the decomposing canola residues had released inorganic N in the surface soil. Pending analyses of soil and crop residues should confirm this. Emissions of N_2O from soil during chickpea growth were practically undetectable for most of the growing season, as found by researchers in the northern hemisphere (Rochette and Janzen 2005). Post-harvest decomposition would have released some of the biologically-fixed N from the crop residues, but this may not have led to as much available N as in the soil after canola. Continued monitoring during the summer fallow and into the following winter cereal crop will establish whether the total subsequent N_2O emissions from the chickpea residues are still less than that from N-fertilised canola.

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