Influence of nitrogen fertilizer and compost mix application on greenhouse gas emissions from humid subtropical soils.

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Abstract
The application of organic amendments (OA) is a strategy to improve soil fertility and offset the high cost of mineral fertilizers used in agricultural systems. However, information on the interaction of OAs with synthetic fertilizers and the resulting greenhouse gas emissions from these combinations are not well understood for different soil types. A 36 day laboratory incubation experiment (3 compost x 3 N rates) was conducted to quantify soil N_2O emissions along with CO_2 and mineral N from subtropical soils in Gatton, Australia. Nitrous oxide emissions decreased by 68% and 57% in 60N and 120N treatments respectively with the increase in compost applications rates up to 30 t/ha and 60 t/ha. Adding 60 t/ha compost and 120 kg N/ha is considered as the optimum fertilizer rate to minimize N_2O and CO_2 emissions from a sub-tropical Vertosol and potentially conserving soil physical, chemical and biological properties for a sustainable crop growth.

Key words: organic amendments, nitrous oxide, carbon dioxide, ammonium, nitrate

Introduction
Agricultural soils are a key anthropogenic source of N_2O contributing 50% of the global human-derived N_2O emissions (Syakila & Kroeze, 2011). The Food and Agriculture Organization projected a 35–60% increase in global agricultural N_2O emissions towards 2030 due to the increased synthetic and manure N inputs. Emissions are expected to be doubled by 2050 (Davidson et al., 2014). Various experiments on N_2O emissions from agricultural soils have demonstrated a strong positive correlation between the application of N fertilisation and N_2O emissions (Shcherbak, Millar, & Robertson, 2014). The application of organic amendments (OA) has been proposed as an effective option to improve soil fertility while reducing environmental pollution (Baggs et al., 2000).

Organic amendments not only act as a source of nutrients, but also affect microbial activity (Ge et al., 2009) and the soil organic pool, which is known to regulate the rate of N_2O production (Majumder et al., 2008). The application of compost to soils and its impact on N_2O emissions can be viewed in two different ways. Compost reduces N_2O emissions by promoting soil N immobilization, reducing the mineral N substrates available for nitrification and denitrification. In contrast, the application of compost will potentially increase N_2O emission by increasing dissolved organic carbon –DOC (Wright et al., 2008) which stimulates soil microbial activity (Zhu-Barker et al., 2015).

Although the agronomic benefits of OA's have been the focus of numerous studies (Manna et al., 2005; Thangarajan et al., 2013) there is little complementary information on the interaction of OAs with synthetic fertilizers and the subsequent contribution to GHG emissions. We hypothesize that the mineralisation of organic compounds in compost in concert with N fertilisation will reduce N_2O emissions from the soil under controlled environment conditions. The purpose of this short term study was to expand understanding of integrated processes which regulate N_2O and CO_2 production due to the interaction of green waste compost and N fertilizer along with the soil mineral N variations related to N_2O emissions under controlled environmental conditions. Such information will aid in the development of management strategies to reduce GHG emissions from agricultural soils with the goal of mitigating future global warming.

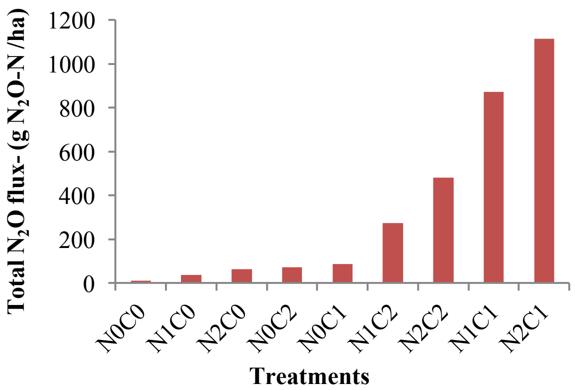
Methods
A Vertosol was sampled from Gatton, Australia (27.56°S and 152.27° E) and incubated at 25°C with 9 treatments (3 rates of green waste compost - GWC × 3 rates of N fertilizer) with four replicates (36 samples). Three sets of 36 sample combinations (108 samples) were used to allow for destructive sampling during the

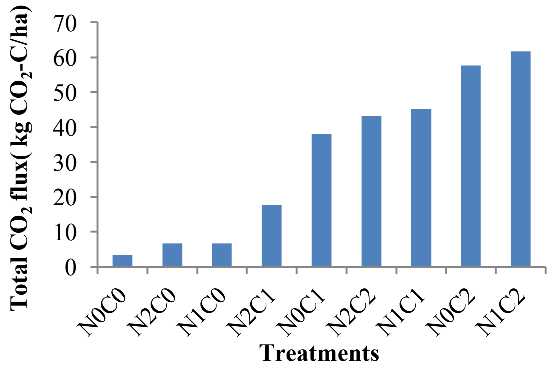
incubation. The incubation experiment examined N_2O and CO_2 emissions from the soil and changes in exchangeable ammonium (NH_4^+-N) and nitrate (NO_3^- -N) in response to these additions.

Compost samples were thoroughly mixed with 175 g of clay loam soil. The mixture was packed into a 15 cm high PVC cylindrical pipe (cores) with 5.05 cm inner diameter and incubated in sealed 1 L glass jars. Approximately 6 – 12 g of compost was mixed with each core according to the rate of compost application. Soil was pre-incubated for 7 days before adding N fertilizer in the form of ammonium sulphate- $(NH_4)_2SO_4$. After pre-incubation, soil moisture levels were adjusted to 60% in all treatments and constant soil moisture conditions maintained throughout the period.

Flux rates of N_2O and CO_2 were determined at 1, 3, 7, 14, 21, 28, 29, 32 and 36 days after starting the incubation. From the incubation jars, 20 mL headspace samples were removed on each occasion using a syringe and stored in 12 mL evacuated vials (Exetainer, Labco, UK). Jars were opened after each gas sampling and gas concentrations allowed to return to ambient conditions prior to closure. Gas samples were analysed for N_2O and CO_2 on a Shimadzu GC-2014 gas chromatograph. To evaluate changes in the mineral N content, soils were destructively sampled at 7, 28 and 36 days after the addition of the $(NH_4)_2SO_4$. Both NH_4^+-N and NO_3^- -N were measured using an AQ2+ SEAL Analytical WI, USA. After 28 days, all remaining soil cores were saturated to simulate a heavy rain event and N_2O and CO_2 were measured.

Results





Figures 1 and 2. Influence of synthetic and organic fertilization rates on cumulative N_2O and CO_2 emissions over a 36 day incubation from a Vertosol (Gatton, Australia)

The highest total N_2O flux of 1116 g N_2O-N/ha was recorded in the N2C1 treatment (120 kg N/ha and 30 t compost/ha) compared to the lowest emission (11 g N_2O-N/ha) in the C0N0 treatment (Figure 1). Compared to the N_2O flux from the control (N0C0) a statistically significant differences ($p<0.05$) were found in the N1C1, N2C1 and N2C2 treatments. Nitrous oxide emissions from the C1 treatment (30 t compost/ha) were higher than the emissions from C2 treatments (60 t compost/ha) for the different N application rates. Increasing the compost load reduced the N_2O emission (by 57% and 68% in N2 and N1 treatments respectively) by promoting N immobilization. Without the compost treatments, an increase in N fertilizer levels alone did not significantly affect the N_2O emissions in treatments N1C0 and N2C0.

When considering total CO_2 emissions over 36 days from the nine treatments, an increase in compost application (from C0 to C2) resulted in higher CO_2 emissions for all three N levels. In the absence of N fertilizer, the increase in compost levels from C0 to C2 showed a significant increase in CO_2 emissions (3.4 to 57.7 kg CO_2-C/ha) (Figure 2). The N1C2 (60 kg N/ha and 60 t compost/ha) treatment showed the highest CO_2 emissions (61.7 CO_2-C/ha) from all treatments. An increase in N application up to 120 kg N/ha (N2) with 3 compost levels showed a decline in CO_2 emissions compared to the treatments with zero N and 3 levels of compost. A statistically significant difference ($p<0.05$) was found in all treatments where compost had been added when compared to the control (N0C0).

After addition of water on day 28, daily N_2O emissions were declined in all N levels of three C levels tested above by 27% to 45%. During the first seven days after water addition, N_2O emissions showed a slight increase up to 12 g N_2O-N/ha/day. Daily CO_2 emissions followed a similar pattern and reduced daily emissions by 63% to 81%.

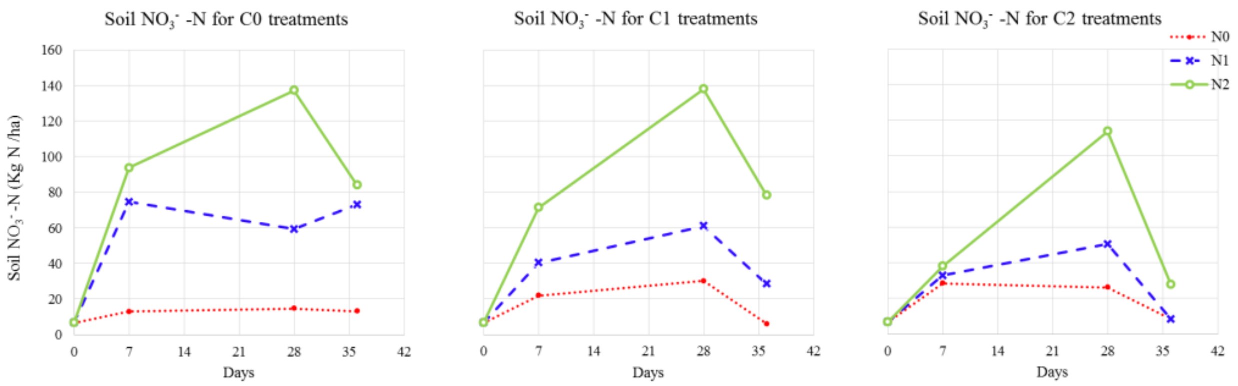


Figure 3: Variation in soil nitrate concentration of a Vertosol during incubation with or without compost treatments and N fertilizer.

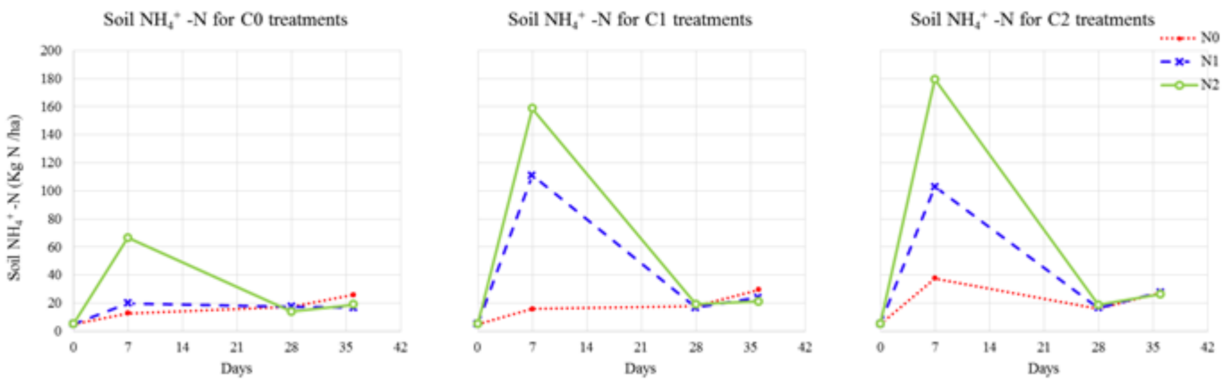


Figure 4: Variation in soil ammonium concentration of a Vertosol during incubation with or without compost treatments and N fertilizer.

After the application of compost and $(NH_4)_2SO_4$ in different combinations, both soil NO_3^- and NH_4^+ concentrations have increased above the control in all treatments during the first seven days after the fertilizer application. Higher NH_4^+-N content were found in N1C1, N2C1 and N2C2 treatments (treatments which contained High N and C levels (30 and 60 t/ha compost and 60 and 120 kg N /ha) (Figure 4). The N2C2 treatment had the highest soil NH_4^+ concentration (179.4 kg N/ha) at day 7 and in all treatments NH_4^+ levels had declined to 20 kg N/ha by day 28. When considering soil NO_3^- concentrations, a gradual increase were found up to 28 days (Figure 3) and plateaued after saturation approximately 20 kg N/ha. The highest NO_3^--N concentration (137.9 kg N/ha) was found in N2C1 treatment. After saturation of the soil cores on the day 28 of the incubation, soil NO_3^- concentration showed a rapid decline.

Discussion

The effect of compost on N_2O and CO_2 emissions

Application of compost together with N fertilizer had a significant effect on N_2O emissions (Figure 1) and is consistent with previous study of (Zhu et al., 2013). Increased compost application decreased N_2O emissions due to the immobilisation of N (by increasing soil organic C availability) and nitrification in the soils by addition of compost. The significantly elevated N_2O production was found due to ammonium oxidation (in aerobic conditions) and denitrification (in water logged conditions) occurred in the soil along with the compost application. The application of compost stimulated soil respiration and therefore O_2 consumption in soil enhanced N_2O emission from NH_4^+ based fertilizers (Contreras-Ramos et al., 2009). Increasing compost application rates enhanced CO_2 emissions from the soil, as previously observed in other studies of (Nguyen et al., 2014) and (de Urzedo et al., 2013) due to the supply of labile C.

The reduction in N_2O emissions after addition of water on day 28 is due to the suppression of the nitrification process in anaerobic conditions occurred in the cores usually above 60% of WFPS. The anaerobic conditions promoted denitrification (> 80% of WFPS) and N_2O production was reduced due to lack of O_2. Whilst di-nitrogen (N_2) was not measured we infer that under these conditions the main product would in fact be N_2.

Conclusion

The application of relatively high rates of compost (30 and 60 t/ha) with high N fertilizer rates (60 and 120 kg N/ha) to a sub-tropical Vertosol from Gatton (Australia) resulted in significant increases in CO_2 emissions but a reduction in N_2O emissions. Within the same N level, the increase in soil C inputs reduced the N_2O emissions due to the soil N immobilization. Considering these observations, a mixed application of compost with N fertilizer has potential to reduce N_2O emissions from sub-tropical clay soils. From this incubation experiment N2C2 treatment (60 t/ha compost and 120 kg N/ha) is the optimum compost and N fertilizer combination to reduce both N_2O and CO_2 emissions at the same time. Field research is warranted to test whether this combination of compost and N will reduce N_2O emissions intensity (N_2O/yield) and Global Warming Potential of this treatment.

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