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EFFECT OF N FERTILIZATION ON N_2O EMISSION FROM A TROPICAL PEAT SOIL: A LABORATORY INCUBATION STUDY

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SUMMARY

The objective of this study was to examine the effects of nitrogen (N) from two different fertilizers (ammonium sulphate and urea) on nitrous oxide (N_2O) emission from tropical peat soil. A 28-day laboratory incubation study was carried out to investigate the dynamics of N_2O production with N_2O fluxes measured by the linear regression of emissions over the incubation period. In general, N_2O flux decreased from Day 1 till the end of the incubation period for soil treated with ammonium sulphate. Preliminary results showed that the ammonium sulphate treatment produced higher N_2O emissions than the urea treatment or the control. The results might be attributable to the low nitrification rate of ammonium sulphate in peat soils, resulting in an accumulation of NH_4^+, which could enhance denitrification in anoxic conditions.

KEY WORDS: Nitrous oxide, tropical peat soil, ammonium sulphate, urea

INTRODUCTION

Much attention has been focused on the relationship between the application of nitrogen fertilizer to agricultural systems and nitrous oxide (N_2O) fluxes in the last two decades. Intensification of agriculture in developing countries includes the increased use of irrigation and fertilization. This is likely to increase the emission of nitrous oxide. Tropical peatland with high nitrogen content, when used for the expansion of agriculture, has been assumed to be a significant source of anthropogenic N_2O (Li *et al*., 1994). An increase in the amount of nitrogen applied has been associated with an increase in gaseous emission, which is linked to a 'hole in a pipe' model (Firestone and Davidson, 1989), where greater flow through the pipe will result in greater leakage through the hole. However, the magnitude of N_2O emission is also controlled by several other factors such as soil conditions e.g. available carbon, inorganic nitrogen, aeration, porosity and aggregate structure (Smith *et al*., 1998; Pihlatie *et al*., 2004). Furthermore, management practices such as the application of N-containing fertilizer (type, timing and application method), type of crop, tillage and residue management will also influence N_2O emission (Kledmedtsson *et al*., 1997; Ma *et al*., 2010).

Nitrous oxide is naturally produced in soils through the microbial activities of nitrification and denitrification. During nitrification ammonium (NH_4^+) is converted to nitrite (NO_2^-) by ammonia oxidizing bacteria (AOB) and then to nitrate (NO_3^-) by nitrite oxidizing bacteria (NOB). N_2O is emitted as a by-product during the nitrification process. Nitrification is limited by low oxygen and low pH levels (Daum and Schenk, 1998). However, some studies have

identified nitrifiers that adapts to acid condition (De Boer and Kowalchuk, 2001). Denitrification involves the reduction of nitrate (NO_3^-) to N_2O and dinitrogen (N_2) under increasingly anoxic conditions. Denitrification is limited by the availability of carbon and nitrate (Linn and Doran 1984; Bijay-Singh *et al*., 1988). However, it has been found to be less significant in peat soil due to the high organic carbon content of peat (Li *et al*., 1994).

The effect of N fertilization and fertilizer type on N_2O emission has been widely reviewed in recent years. Eichner (1990) reported that nitrous oxide emission was influenced by the type of fertilizer used (N applied as anhydrous ammonia resulted in a larger emission than N applied as either ammonium or nitrate). However, Bouwman (1990) concluded that the emissions were not related to fertilizer type, due to lack of consistency in study periods and methods. The role of nitrogen fertilizer and nitrogen type in the production of N_2O from tropical peat is still not fully understood. To date, only a few investigations of N_2O emission have been made on tropical peatland (Hadi *et al*., 2000; Inubushi *et al*., 2003; Takakai *et al*. 2006; Melling *et al*., 2007). Therefore, a laboratory incubation study was conducted to examine the effect of N from two different fertilizers on N_2O emission.

MATERIAL AND METHODS

Peat soil samples

The peat soil samples were collected from a partially drained mixed peat swamp forest in Sibu, Sarawak, Malaysia (2°12'N, 111°51'E).

Soil incubation methodology

Soil was collected at a depth of 0-15 cm, homogenized and stored at 4 °C prior to incubation. 80 g of soil was placed in each of 2 L polyethylene incubation bottles. Microbial activity was stimulated by a 4-day pre-incubation period at room temperature (23-25 °C).
Three treatments were investigated: no addition of fertilizer (control) (N0), addition of ammonium sulphate at a rate equivalent to 65 kg N ha^{-1} (AS) and addition of urea at a rate equivalent to 65 kg N ha^{-1} (U). Treatment was applied on Day 1. After treatment the samples were incubated at 23-25 °C at about 75% soil moisture content for 28 days (Days 1 – 28). All the bottles were covered with parafilm except during sampling, to allow air exchange. No ultra-pure water was added because water loss was found to be negligible. All treatments were replicated 3 times.

Nitrous oxide flux measurements

Samples for N_2O determination were taken on Days 1, 2, 3, 5, 6, 7, 14, 21, and 28. On each sampling day 20 ml gas samples were taken with a syringe before closure and 10 and 20 minutes after closure, and injected into 10 ml gas-tight vials (SVF-10, Nichiden, Japan). To avoid under pressure during gas sampling, an equilibrium bag was installed on the screw cap of each bottle. The N_2O concentrations in the gas samples were determined using a gas chromatograph equipped with an electron capture detector (Agilent, 7890N) maintained at 300 ˚C.

Soil sampling and analysis

Destructive sampling was carried out on Days 3, 7, 14, 21 and 28. The pH was determined from a moist soil:water ratio of 1:2.5 (v/v) using a Metrohm 744 pH meter (Metrohm, Switzerland) calibrated with pH 4 and pH 7 buffer solutions. Total soil C and N were analysed by dry combustion on a LECO TruMac CN analyzer (LECO Corp, USA) after drying at 60 ˚C. Soil nitrate and ammonium were extracted using a moist soil:water ratio of 1:5 (w/v) and analysed using ion chromatography (IC Metrohm, Switzerland). Soil water content was determined gravimetrically using a Thermogravimetric Analyzer (Leco, TGA 601) at 105 ˚C. Finally loss of ignition was determined by ashing the samples at 550 ˚C.

Statistics and calculations

Statistical analyses were performed using SAS 9.1 (Statistical Analysis Systems Institute Inc., 2009). Nitrous oxide production was estimated from linear regressions of the amounts of N_2O emitted against the 28-day incubation period. Net nitrification was calculated as nitrate accumulated on Day 28 minus nitrate content on Day 0.

RESULTS

Soil properties

Table 1. Physico-chemical properties of the soil under different treatments.

Properties	Control	Ammonium sulphate treatment	Urea treatment
Soil pH	3.6	3.2	4.4
Moisture content (%)	75.45	75.40	75.17
Loss of ignition (%)	96.22	95.89	95.93
Total C (%)	55.06	54.79	55.24
Total N (%)	2.07	2.28	2.28
C:N	26.56	24.00	24.24
NO_3^--N (mg kg^{-1})	642.10	439.52	908.73
NH_4^+-N (mg kg^{-1})	174.42	1541.58	667.94

N_2O emission

The increase in the N_2O concentration in the chamber headspace of the incubation bottles was found to be linear for the 20 minutes' closure period with maximum N_2O emission (569 µg N_2O-N $m^{-2}h^{-1}$) from the soil treated with ammonium sulphate. The next greatest N_2O emission (487 µg N_2O-N $m^{-2}h^{-1}$) was recorded from the control. N_2O emissions from the soil treated with urea showed lower values but similar trend to the soil treated with ammonium sulphate. Average N_2O emissions from the control (97 µg N_2O-N $m^{-2}h^{-1}$) and urea treatments (92 µg N_2O-N $m^{-2}h^{-1}$) was not significantly different but was lower than the ammonium sulphate treated soil (216 µg N_2O-N $m^{-2}h^{-1}$) (Fig. 1).

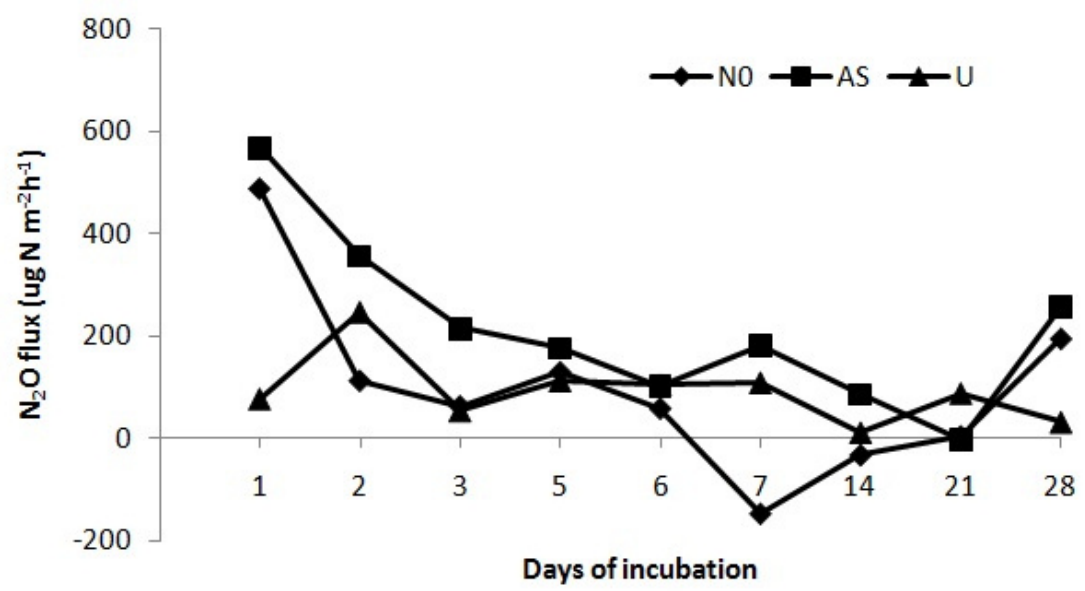

Fig. 1. N_2O emissions from the three treatments (N0 = no N fertilizer; AS = ammonium sulphate applied at a rate of 65 kg ha^{-1}; U = urea applied the same rate) over the 28-day incubation period.

NO_3^- and NH_4^+ concentration

The nitrate-N (NO_3^--N) concentrations of soil under the three treatments over the incubation period are shown in Fig. 2a. Although differences in the soil NO_3^--N concentration are significant between different treatments, the curves follow the same pattern where soil NO_3^--N concentrations increased during the first seven days of incubation and gradually decreased after that period. As for the urea treatment, the concentration decreased sharply after Day 14 and increased again after Day 21.

In the ammonium sulphate-treated soil, ammonium-N (NH_4^+-N) concentration increased continuously after fertilizer application until Day 7 and then gradually decreased towards the end of the incubation period, resulting in a final concentration of 1498 mg kg^{-1}. Increases in NH_4^+-N concentration in the urea-treated soil were considerably lower than ammonium sulphate-treated soil. As expected, the control (with no additional N) showed the lowest soil NH_4^+-N concentration (Fig 2b).

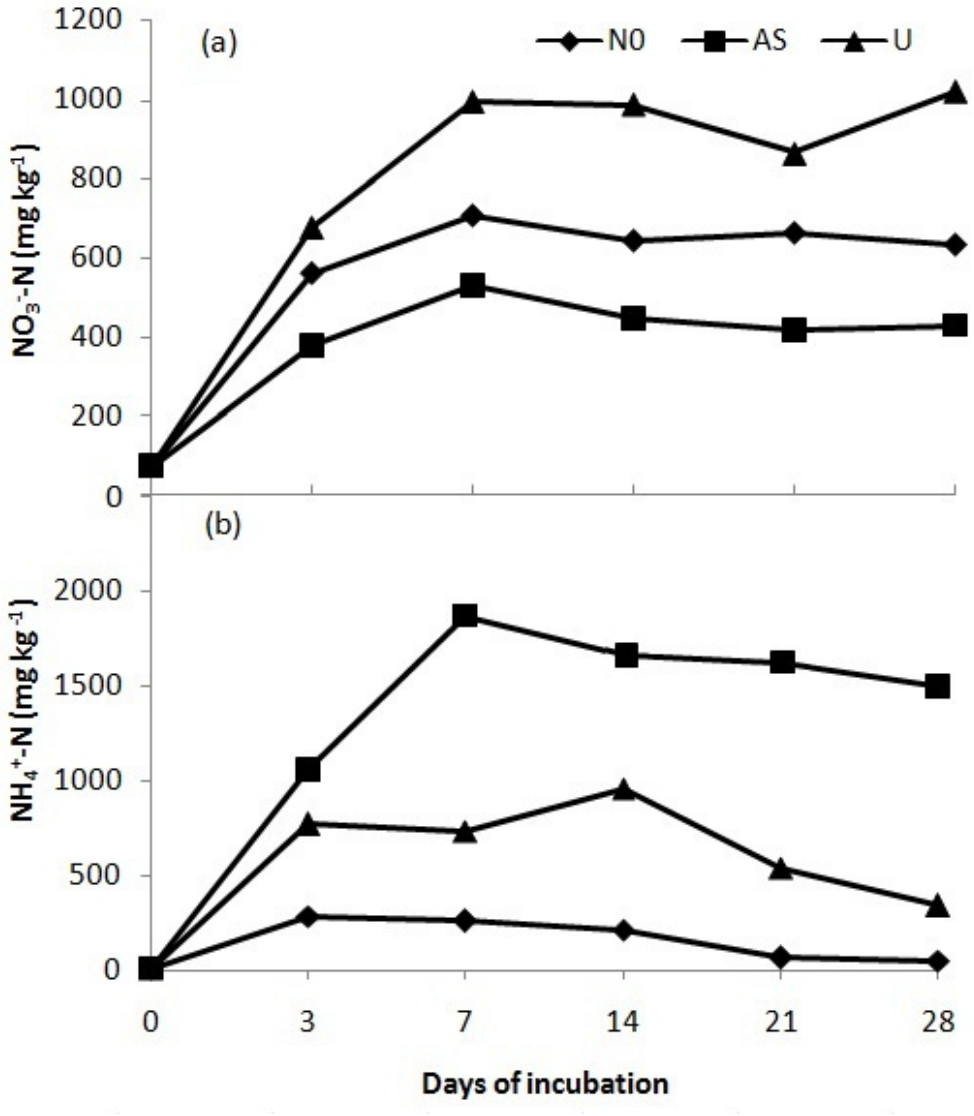

Fig. 2. Changes in soil (a) NO_3^--N and (b) NH_4^+-N concentration in the control (N0), ammonium sulphate (AS) and urea (U) treatment over time.

DISCUSSION AND CONCLUSION

The peat soil used in this experiment exhibited a high moisture content (75%). At a water-filled pore space value greater than 75%, denitrification becomes the dominant process and the rate of N_2O emission could increase dramatically (Skiba *et al*., 1992) provided other factors are not limiting. Maljanen *et al*. (2003) found that under high water content, N mineralization and nitrification were restricted and resulted in low nitrate available for denitrification. This might be the case for ammonium sulphate-treated soils where the nitrification rate was the slowest among the treatments. In addition, the pH of the ammonium sulphate-treated soil was 3.2 compared to 3.6 for the control. The acidic conditions will further slow down the nitrification rate and inhibit N_2O reductase, which yields more N_2O than N_2 under anoxic conditions (Thomsen *et al*., 1994). Besides, under relatively anaerobic condition, the excess NH_4^+ in ammonium sulphate treatment would be reduced to N_2O.

The increased N_2O emission in urea-treated soil occurred after only one day of treatment, indicating a lag period for the hydrolysis of urea into NH_4^+. Also, the net nitrification in the urea-treated soil was higher than that in the ammonium sulphate-treated soil. This might be attributed to the hydrolysis of urea, which temporary increased soil pH (Regina *et al*., 1998) resulting in enhanced nitrification (Pihlatie *et al*., 2004). However, it was demonstrated that the mean N_2O emission from urea-treated soil and the control were not significantly different even though the pH of urea-treated soil was higher than that of the control. High nitrate content of the control may have enhanced the background emission through denitrification. These findings on the effect of different N fertilizers on N_2O emission from tropical peat soil are only preliminary. Further studies are needed to confirm the findings.

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