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Nitrous Oxide Emission of a Tropical Peat Soil Grown with Pineapple at Saratok, Malaysia

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Abstract

Draining of peatland for agriculture could affect the release of nitrous oxide into the atmosphere. Presently, there is dearth of information on soil nitrous oxide emission from tropical peat soils cultivated with pineapples. Lysimeter and closed chamber methods were used to quantify nitrous oxide emission from root respiration, microbial respiration, and oxidative peat decomposition under controlled water table condition. Treatments evaluated were: peat soil grown with pineapple, uncultivated peat soils, and bare peat soil fumigated with chloroform. Cultivation of Moris pineapple on drained peat soils resulted in the higher release of nitrous oxide emission (15.7 t N_2O ha/yr), followed by fumigated peat soil with chloroform (14.3 t N_2O ha/yr), and uncultivated peat soil (10.2 t N_2O ha/yr). Soil nitrous oxide emission was affected by nitrate fertilization but emission was not affected by soil temperature nor soil moisture.

Keywords: greenhouse gases, land degradation, lysimeter, organic soils management, peatland, pineapple

1. Introduction

In Southeast Asia, there are approximately 27.1 million hectares of peat soil (Hoojier et al., 2010) out of which 2.6 million hectares of the peat soils are found in Malaysia (Ismail & Jamaludin, 2007). Draining of peat soils for agriculture is claimed to accelerate peat organic matter decomposition. Once peats are drained for agriculture, the tendency of nitrous oxide (N_2O) being emitted could be high. Nitrous oxide has been implicated in the global warming due to its ozone depleting nature (Jassal, Black, Roy, & Ethier, 2011; Chen, Mothapo, & Shi, 2014). The lifespan of N_2O is approximately 120 years compared to other greenhouse gases. The global warming potential of N_2O is 310 times greater than a molecule of carbon dioxide (CO_2) (Reth et al., 2008). Nitrous oxide is derived from both nitrification and denitrification (Maljanen, Martikkala, Koponen, Virkajärvi, & Martikainen, 2007; Jauhiainen et al., 2012). These processes are regulated by microbial activities. The microbial activities are also affected by soil nitrogen and nitrogen fertilization (International Atomic Energy Agency [IAEA], 1992; Saggar et al., 2013; Uchida, Von Rein, Akiyama, & Yagi, 2013). Nitrification occurs in aerobic condition for example, in drained and fertilized peat soils (van Beek, Pleijter, & Kuikman, 2010). This is because of decomposition of organic nitrogen which in turn accelerates soil mineralization (Jauhiainen et al., 2012). Nitrification increases inorganic nitrogen, and it is associated with the release of N_2O into the atmosphere. Anaerobic condition in peats favours N_2O emission through nitrifying bacteria which use nitrate for their metabolic processes. Nitrous oxide emission is reported to be regulated by soil moisture as the emission of this gas is high at intermediate soil moisture content (Kasimir-Klemedtsson et al., 1997). Furthermore, water table, fertilization, and availability of organic matter affect N_2O emission (Maljanen et al., 2007; van Beek et al., 2010; Jauhiainen et al., 2012).

In Malaysia, approximately 600, 000 hectares of peats are cultivated with oil palm (*Elaeis guineensis*), pineapple

(*Ananas comosus* (L.) Merr.), rubber (*Hevea brasiliensis*), and sago (*Metroxylon sagu*) (Ismail, 2008). Although attempts have been made to measure N_2O emission from cultivated tropical peats, such studies are limited to paddy (*Oryza sativa*) and rice-soybean fields (Inubushi, Furukawa, Hadi, Purnomo, & Tsuruta, 2003; Hadi et al., 2005). Presently, there is a scarcity of information on N_2O emission from pineapple cultivation on drained peat soils. This information is essential as 90% of pineapples are grown on peat soils of Malaysia (Raziah & Alam, 2010). To this end, it is imperative to determine N_2O emissions in pineapple cultivation on peat soils. Furthermore, pineapple is unique as it is classified as C3 and C4 plant or Crassulacean Acid Metabolism (CAM) plant (Mohammed Selamat, 1996; Ritchie & Bunthawin, 2010) which may well give a different trend of emission compared with crops such as oil palm which is widely planted on tropical peat soils. With the growing concern about the effects of greenhouse gases on the environmental quality coupled with the need to achieve sustainable agriculture, there is a need for direct N_2O measurement from cultivated peat soils to provide a basis for future emission factors under different land uses.

Based on the above rationale, the general objective of this study was to quantify N_2O emissions from a drained tropical peat grown with pineapple. The first specific objective of the study was to partition N_2O emission from a cultivated peat into root respiration, microbial respiration, and oxidative peat decomposition. The second specific objective was to access the effects of soil temperature and soil moisture on soil N_2O emission. In this present study, it was hypothesized that peat soils cultivated with pineapple will cause higher loss of N_2O emission than from uncultivated peat soils. This hypothesis is based on the assumption that N_2O emission from cultivated peat is controlled by nitrification and denitrification, processes which are affected by fertilization with adequate availability of substrates for heterotrophic microbial metabolism.

Information obtained from quantifying the emission of N_2O from drained tropical peats cultivated with pineapples could be used to develop sustainable pineapple farm management procedures towards reducing greenhouse gas emission from agricultural activities.

2. Materials and Methods

2.1 Site Description

The study was carried out at the Malaysian Agricultural Research and Development Institute (MARDI) Peat Research Station at Saratok, Sarawak, Malaysia. The research station has a total area of 387 hectares located on a logged-over forest with a flat topography of 5 to 6 m above mean sea level. The peat soil is classified based on the Von Post Scale of H7 to H9 as decomposed dark brown to almost dark coloured sapric peat with a strong smell. The thickness of the peat soil ranges from 0.5 to 3.0 m. The mean temperature of the peat area ranges from 22.1 to 31.7°C. The relative humidity of the area ranges from 61 to 98%. The annual mean rainfall of the area is 3749 mm. In the wet season (November to January), the monthly rainfall is more than 400 mm whereas in the dry season particularly in July, the mean rainfall is 189 mm.

2.2 Soil Chemical and Physical Analysis

Peat samples were collected at a peat excavation site (0.5 hectares) located at the research station before setting up the lysimeter experiment. The experimental area was planted with Moris pineapple from 2004 to 2005, after which it was abandoned to fallow for six years. Soil sampling was performed at depths of 0-20 cm, 20-40 cm, and 40-60 cm systematically in 12 points located over a 20 m x 12.5 m grid. The soil samples were analyzed for pH, conductivity, ammonium-N, nitrate-N, organic carbon, total nitrogen, and cation exchange capacity. Soil pH and conductivity were measured based on 1:5 soil to water suspension (Ismail, Asing, & Zulkefli, 2007). Ammonium-N and nitrate-N were determined using the steam distillation method (Bremner & Keeney, 1966). Soil organic carbon was determined using the Walkley and Black method (Nelson & Sommers, 1982) whereas total nitrogen was determined using the Kjeldahl method (Bremner, 1960). Cation exchange capacity was determined using the Harada and Inoko method (Harada & Inoko, 1980). Bulk density was determined using the core method (Lim, 1991), and soil water holding capacity was determined using the method of Dugan, Verhoef, Robinson, and Saran (2010).

2.3 Characteristics of Lysimeter

Twelve cylindrical field lysimeters made from high density polyethylene, measuring 1.43 m in diameter and 1.5 m in height, were set-up in April 2012 to mimic the natural condition of drained tropical peats. The size of the lysimeters used in this study was designed to ensure satisfactory growth and development of pineapples for sixteen months. The twelve lysimeters were used for three peat soil treatments. The lysimeters were equipped with water spillage opening which was attached to clear tubes mounted on the outside of the vessel to regulate and monitor water level. Each lysimeter was filled with peat soil up to 120 cm depth. Water loss from the soil

was replenished by showering each lysimeter with 34.5 litres of rainwater. The amount of rainwater applied was based on the volume of the fabricated lysimeter and the mean annual rainfall at Saratok, Malaysia. The lysimeters with the peat soil were left in the open for five months to ensure that the peat soil had settled before beginning this study. The length of this initial phase was based on weekly determination of the peat soil's subsidence. The equilibrium state was achieved in September 2012 before carrying out the N_2O measurement. Throughout the study, the water table of the peat was maintained at 50 to 60 cm from the soil surface.

2.4 Peat Soil N_2O Emission Treatments

The treatments involved in this lysimeter experiment were peat soil grown with pineapple (A), uncultivated peat soil (B), and bare peat soil treated with chloroform (C). Each treatment had four replications. The treatments were arranged in completely randomized design. Treatment A represents the total amount of N_2O emitted from root respiration, microbial respiration, and peat decomposition. Three Moris pineapple suckers were planted in the lysimeters at a distance of 30 cm. The pineapples were managed based on standard agronomic practices for pineapple cultivation on peats (Mohammed Selamat & Abdul Rahman, 1996). Treatment B represents N_2O emitted by microbial respiration and peat decomposition. Weed sprouting on the soil surface was controlled when necessary. Treatment C represents N_2O emitted by oxidative peat decomposition. For this treatment, concentrated chloroform was applied evenly on the peat soil surface to eliminate microbial respiration, and 64.6 litres of concentrated chloroform was used. This volume was based on the peat soil's water holding capacity. After the chloroform application, the soil was covered with cling film and canvas followed by securing it with heavy duty tape and aluminium seal lock to produce a vacuum-like condition in the lysimeters to minimize chloroform volatilization. The soil microbial population before and after the chloroform application was determined using the culture method. With this method, bacteria, fungi, and actinomycetes were enumerated as colony forming units (CFU) per gram of fresh soil on nutrient agar, Rose Bengal, and actinomycetes isolation agar, respectively (Suhaimi, Emmyrafedziawati, Umi Kalsom, Sahilah & Ismail, 2007). The chloroform was used to fumigate the peat soil one week before the soil N_2O measurement was commenced (optimum time interval achieved for the biocidal effect on soil microorganisms).

2.5 Soil N_2O Emission Measurements

Nitrous oxide emissions from the field lysimeters were measured using the closed chamber method (IAEA, 1992). Extracted gas samples from the chamber were analyzed for N_2O using gas chromatography (Agilent 7890A). The N_2O results were based on the measured N_2O from treatments A, B, and C in the wet and dry seasons. The values were averaged and converted into units of t/ha/yr. The gas flux was calculated from the increase in the chamber concentration over time using the chamber volume and soil area covered, using the following equation (IAEA, 1992; Widen & Lindroth, 2003; Zulkefli, Lim Kim Choo, & Ismail, 2010):

$$Flux = [d(N_2O)/dt] \times PV/ART \quad (1)$$

where $d(N_2O)/dt$ is the evolution rate of N_2O within the chamber headspace at a given time after putting the chamber into the soil, P is the atmospheric pressure, V is the volume headspace gas within the chamber, A is the area of soil enclosed by the chamber, R is the gas constant, and T is the air temperature.

The gas flux was measured in the early morning (2.40 a.m. to 5.55 a.m.), morning (7.15 a.m. to 10.30 a.m.), mid-morning to afternoon (10.35 a.m. to 1.50 p.m.), afternoon (1.55 p.m. to 5.10 p.m.), evening (8.00 p.m. to 11.15 p.m.), and night (11.20 p.m. to 2.35 a.m.). The flux measurements were carried out in September 2012, November 2012, and January 2013 to represent the concentrations of N_2O in the wet season whereas April 2013 and July 2013 flux measurements represent the concentrations of N_2O in the dry season. Soil temperature and moisture were measured using Eijkelkamp IP68 and ML3 sensors, respectively. Rainfall, temperature, and air humidity data were also recorded using a portable weather station (WatchDog 2900) installed at the experimental site.

Carbon dioxide (CO_2) and methane (CH_4) emissions from peat soils cultivated with pineapple were also quantified. However, results for CO_2 and CH_4 emissions were not reported in this paper.

2.6 Statistical Analysis

Treatment effects were tested using analysis of variance (ANOVA) whereas means of treatments were compared using Duncan's New Multiple Range Test at $p \leq 0.05$. The relationships between N_2O emission, soil temperature, and soil moisture were analyzed using Pearson correlation analysis. The statistical software used for these statistical analyses was the Statistical Analysis System (SAS) Version 9.1.

3. Results

3.1 Peat Physical and Chemical Properties

Results of peat soil properties were compared with the previously reported ranges (Table 1) for tropical peats in Southeast Asia (Andriesse, 1988) and Malaysia (Andriesse, 1988; Malaysian Agricultural Research and Development Institute [MARDI], 1996; Murtedza, Padmanabhan, Mei, & Siong, 2002).

The bulk density of the peat soil at 10 cm ranged from 0.09 to 0.18 g/cm^3 whereas water holding capacity of the peat soil was 40.2%. Soil moisture increased with increasing depth.

Values of pH, conductivity, CEC, total organic carbon, and total nitrogen of the peat soil are within the reported range (Andriesse, 1988; MARDI, 1996; Murtedza et al., 2002; STRAPEAT, Universiti Malaysia Sarawak [UNIMAS], & National Resource and Environment Board [NREB], 2004). The soil chemical properties showed no significant difference with depth except for total nitrogen, ammonium-N, and nitrate-N. The total nitrogen ranged from 1.1 to 1.3%. Ammonium-N ranged from 94.8 to 138.5 mg/L whereas nitrate-N ranged from 48.8 to 72.0 mg/L at the three soil depths.

Table 1. Physical and chemical properties of a drained peat soil sampled at different depths

Variable	Mean (0 to 10 cm)	Results per soil depth (cm)			Reported range
		0 to 20 cm	20 to 40 cm	40 to 60 cm	
		Physical properties			
Bulk density (g/cm^3)	0.14				0.09 – 0.12 (Andriesse, 1988)
Water holding capacity (%)	40.2				275 – 322 (Andriesse, 1988)
Moisture (%)		80.9^c	84.9^b	88.8^a	90 – 95 (Murtedza et al., 2002)
		Chemical properties			
pH		3.8^a ± 0.1	3.9^a ± 0.1	3.9^a ± 0.1	3.0 – 4.5 (Andriesse, 1988)
Conductivity (µS/cm)		178.5^a±4.6	175.4^a±4.3	172.7^a±2.4	< 200 (MARDI, 1996)
Cation exchange capacity (cmol$_{(+)}$/kg)		146.4^a±20.1	137.6^a ± 13.7	175.6^a ±34.9	200 (Andriesse, 1988) 145 (MARDI, 1996)
Total organic carbon (%)		40.0^a±0.8	39.8^a ± 1.4	36.5^a ± 1.1	12 – 60 (Andriesse, 1988) 20.4 – 38.4 (STRAPEAT et al., 2004)
Total nitrogen (%)		1.33^a±0.03	1.18^b ± 0.04	1.12^b±0.03	1.10 – 1.67 (Murtedza et al., 2002)
Ammonium-Nitrogen (mg/L)		138.5^a±16.2	100.0^b ± 4.2	94.8^b ± 7.7	n.a.
Nitrate-Nitrogen (mg/L)		72.0^a±5.4	48.8^b ± 6.3	65.8^{ab} ± 3.0	n.a.

Values (mean ± standard error) with different letter across the column are significantly different at $p \leq 0.05$.
n.a. = not available

3.2 Soil N_2O Emission

Nitrous oxide emissions under treatments A, B, and C varied in the wet and dry seasons (Figure 1). In the wet season, the N_2O emission was in the order of 15.9 t N_2O ha/yr for treatment C, followed by 13.7 t N_2O ha/yr for treatment A, and 10.7 t N_2O ha/yr for treatment B. However, in the dry season, the N_2O emission was in the order of 17.6 t N_2O ha/yr for treatment A, followed by 12.6 t N_2O ha/yr for treatment C, and 9.6 t N_2O ha/yr for treatment B.

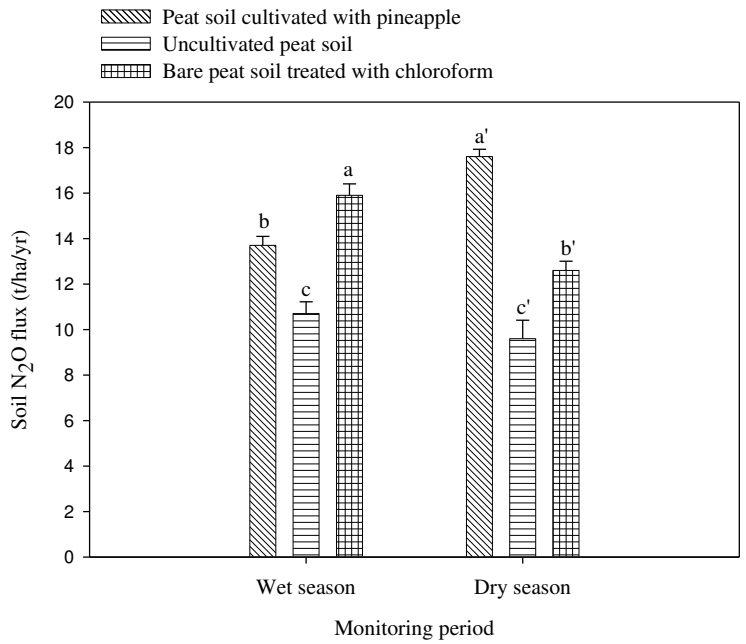

Figure 1. Soil N_2O emission (wet and dry seasons) from peat soil cultivated with pineapple, uncultivated peat, and chloroform fumigated peat soil. (Error bars represent standard error and soil mean fluxes with different letters are significantly different at $p \leq 0.05$)

The N_2O emission was also affected by time of sampling (Figure 2). In the wet season, the N_2O emissions in the early morning, evening, and night were significantly higher compared with the N_2O emissions in the morning, mid-morning to afternoon, and afternoon. In the dry season, the N_2O emission peaked in the afternoon and evening but the N_2O emissions in the early morning, morning, mid-morning to afternoon, and night were lower.

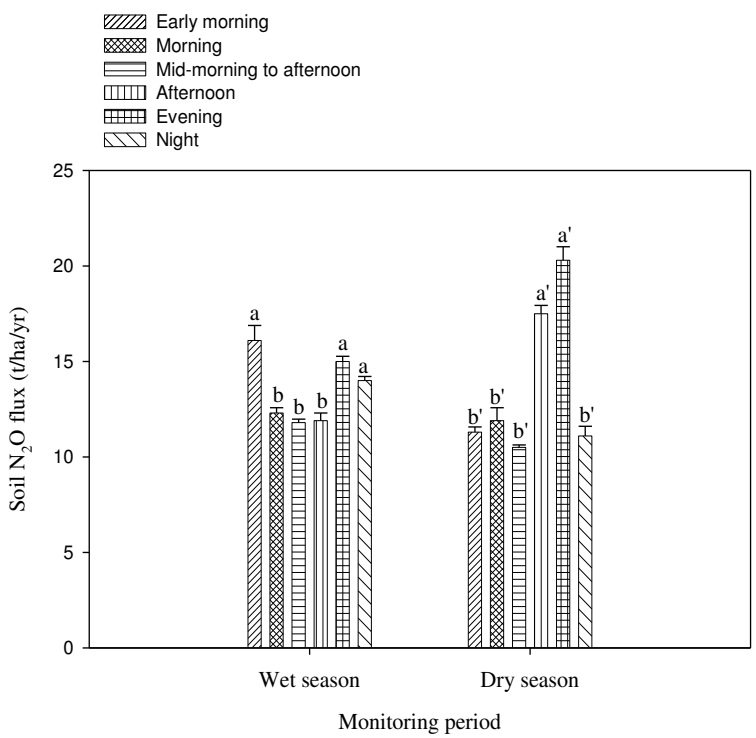

Figure 2. Soil N_2O emission (at different times of the day and different seasons) from drained tropical peat. (Error bars represent standard error and soil mean fluxes with different letters are significantly different at ≤ 0.05)

4. Discussion

4.1 Peat Physical and Chemical Properties

The bulk density of the peat soil is typical of a sapric peat. The bulk density was determined at 10 cm due to the saturated condition of the excavation site. The water holding capacity was below the reported range because its determination was based on oven-dry weight method (Andriesse, 1988). The increasing moisture content with increasing peat soil depth is related to the high water table at the excavation site during soil sampling. However, removal of trees and debris after land clearing may have accelerated oxidative peat decomposition and therefore soil moisture content is lower. The pH of the peat soil was low, suggesting a need for liming before being cultivated. The low conductivity of the peat soil indicates that the soil is not saline as the research station is drained by two large tidal rivers (Sebelak River and Nyabor River). The intrusion of salt water at the station is prevented by a tidal gate constructed at the main outlet leading to Nyabor River. The CEC of the peat soil is high because of lignin-derivates formed during decomposition. Ion exchange in peats is related to carboxyl and phenolic radicals of humic substances and hemicelluloses (Andriesse, 1988). The high organic carbon content is due to the botanical origin (woody) of the sapric peat (Andriesse, 1988; Murtedza et al., 2002). Total nitrogen, ammonium-N, and nitrate-N contents decreased with increasing soil depth (from 0-20 cm to 20-40 cm depths) because decomposition of peats generally decreases (low oxidation with increasing water content) down the soil profile (Andriesse, 1988). Furthermore, tropical peats are generally higher in lignin but lower in cellulose. Microbes decompose cellulose easily thus, leaving behind the resistant lignin as the peat decomposes thereby increasing nitrogen content.

4.2 Soil N_2O Emission

The variation in the N_2O emission under treatments A, B, and C is related to seasonal variation that is, in the wet (September 2012, November 2012, and January 2013) and dry (April and July 2013) season. The difference in the N_2O emission under treatment A in the wet and dry seasons could be ascribed to fertilization. This observation is consistent with the fertilizer application at 4.5 months old (September 2012) and 9 months old (January 2013) of the pineapple plants (Table 2). The fertilizers applied were foliar and compound fertilizers which had urea and ammonium sulfate that may have increased nitrate content in the soil. The nitrogen based fertilization may have contributed to N_2O emission through mineralization (Kasimir-Klemedtsson et al., 1997; Couwenberg, 2011; Jassal et al., 2011). Furthermore, the N_2O emission under treatment A may have also been influenced by root exudates at the rhizosphere. These root exudates are low in nitrate due to plant nitrogen uptake (Saggar et al., 2013) thereby contributing to a different rate of N_2O emission.

The N_2O emission under treatment B is related to the microbial structure in the peat soil and the low availability of adequate substrate as source of energy for nitrifying and denitrifying microorganisms. The N_2O emission under treatment C was affected by oxidative peat decomposition as the fumigant (chloroform) used inhibited microbial respiration. Decreasing N_2O emission under treatment C throughout the wet and dry seasons was because of chloroform fumigation which may have increased extractable ammonium (Jenkinson & Powlson, 1975) in the soil through decomposition of soil organic matter. The decomposition process led to the availability of suitable substrates for microbial metabolism. However, the biocidal effect of the chloroform inhibited microbial activities and thus leads to a lower N_2O emission from treatment C (Jenkinson & Powlson, 1975; Zelles et al., 1997). This observation is consistent with the data in Table 3 where the chloroform eliminated microbial respiration by inhibiting bacteria, fungi, and actinomycetes activities. Bacteria, fungi, and actinomycetes population before and after fumigation were statistically similar. Fungi were not detected in this present study. These observations are also in agreement with most findings, which demonstrate that chloroform can effectively kill (94% to 99%) microorganisms (Jenkinson & Powlson, 1975; Ingham & Horton, 1987; Dickens & Anderson, 1999). The effectiveness of the fumigation is supported by the decrease in the mean soil microbial biomass carbon (Table 3). However, it must be stressed that the lower population of soil microorganisms and reduction in soil microbial biomass carbon after chloroform fumigation were not reliable in demonstrating N_2O emission through the inhibition of microbial respiration. The present study failed to consider microbiology bioassays to verify the contribution of microbial respiration to N_2O emission. The insignificant difference in peat subsidence rates throughout the duration of this study regardless of treatments suggests that the chloroform used did not affect N_2O emission due to oxidative peat decomposition. This observation corroborates that of Toyota et al. (1996) who also found no significant effect of chloroform fumigation on soil bulk density and compaction.

Table 2. Fertilizer management for pineapple cultivation on a drained tropical peat soil

Months after planting	Activities	Fertilizer description	
		Type	Rate
1.5 months (05 June 2012)	First foliar fertilizer application	Mixture of copper sulfate (42 g), iron sulfate (21 g), zinc sulfate (42 g) and lime (640 g) dissolved in 18 litres of water.	50 mL per plant
3 months (19 July 2012)	First compound fertilizer application	A 100 kg of compound fertilizer is a mixture of 72 kg of ammonium sulfate, 1 kg of Christmas island rock phosphate (CIRP) and 27 kg of muriate potash (MP).	20 g per plant
4.5 months (03 September 2012)	Second foliar fertilizer application	Mixture of copper sulfate (42 g), iron sulfate (21 g), zinc sulfate (42 g), lime (640 g) and urea (640 g) dissolved in 18 litres of water.	100 mL per plant
6 months (18 October 2012)	Second compound fertilizer application	A 100 kg of compound fertilizer is a mixture of 72 kg of ammonium sulfate, 1 kg of Christmas island rock phosphate (CIRP) and 27 kg of muriate potash (MP).	20 g per plant
9 months (16 January 2013)	Third compound fertilizer application		

Table 3. Effect of fumigating drained peat soil with chloroform on microbial population and soil microbial biomass carbon

Monitoring cycle	Mean population (CFU/g fresh soil)			Mean soil microbial biomass carbon (µg C/g soil)
	Bacteria	Fungi	Actinomycetes	
Initial before chloroform application	5.65×10^{5a}	1.08×10^{3}	2.72×10^{3ab}	94.7^{a}
September 2012	3.86×10^{5a}	n.d.	3.93×10^{2bc}	29.6^{f}
November 2012	6.91×10^{5a}	n.d.	3.49×10^{3a}	73.4^{b}
January 2013	9.10×10^{3a}	n.d.	5.83×10^{2bc}	56.0^{d}
April 2013	5.43×10^{3a}	n.d.	1.11×10^{2c}	67.2^{c}
July 2013	1.38×10^{4a}	n.d.	9.30×10^{2bc}	46.0^{e}

Means with different letters within the same column are significantly different at $p \leq 0.05$

n.d.=not detected

Although the N_2O emission was affected by time of sampling, the overall data (wet and dry seasons) showed no correlation between N_2O emission and soil temperature (Table 4). This finding suggests that N_2O emission was not affected by soil temperature due to the moderate soil temperature fluctuation (0.2 and 1.6°C) of the tropics during N_2O measurement. The controlled water table in the lysimeters (controlled water table fluctuation between 50 and 60 cm from the soil surface) explains the insignificant correlation between N_2O emission and soil moisture.

Table 4. The relationship between soil N_2O emission, soil temperature, and soil moisture in dry and wet seasons

Variable	Soil temperature	Soil moisture
Soil N_2O emission	r = -0.0231	r = -0.0989
	p = 0.7315	p = 0.1399

Note: Top values represent Pearson's correlation coefficient (r) while bottom values represent probability level at 0.05 (n=360 for pooling data throughout wet and dry seasons).

In summary, peat soils drained for agriculture released 15.7 t N_2O ha/yr under pineapple cultivation, followed by bare peat soil treated with chloroform (14.3 t N_2O ha/yr), and uncultivated peat (10.2 t N_2O ha/yr). The higher N_2O emission under treatment A was because of fertilization which may have increased N_2O emission. Chloroform application which increased ammonium content in the soil explains the N_2O emission through nitrification and this is evident in the moderate N_2O emission from treatment C. The N_2O emission in this present study may have also been influenced by the heterogeneity of the soil organic matter and the diversity of microbial structure in peat (Ö. Berglund & K. Berglund, 2011; Saggar et al., 2013).

5. Conclusion

Soil N_2O emission was affected by nitrogen based fertilization for pineapple cultivation on peat and the availability of adequate substrate for microbial metabolism. Chloroform fumigation decreased soil N_2O emission through the inhibition of microbial respiration. The soil N_2O emissions were neither affected by soil temperature nor by soil moisture throughout the wet and dry seasons. Further research is needed to assess N_2O emission from cultivated peats as N_2O emission from drained peats seems to be influenced by nitrogen fertilization, diversity of microbial structure, and the heterogeneity of the soil organic matter.

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