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Horizontal and vertical emissions of methane from peat soils

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ABSTRACT

Methane emission depends on the rates of methane production, consumption and ability of soil and plants to transport the gas to the soil surface and also within soil particles. The objective of this study was to determine CH_4 fluxes horizontally and vertically from the floor and wall of the pit of a tropical peat soil. The horizontal emissions in the dry and wet seasons were 2.96 t CH_4 $ha^{-1}yr^{-1}$ and 4.27 t CH_4 $ha^{-1}yr^{-1}$, respectively and the vertical emissions were 0.36 t CH_4 $ha^{-1}yr^{-1}$ and 0.51 t CH_4 $ha^{-1}yr^{-1}$, respectively. The total amount of the horizontal and vertical emissions in the dry and wet seasons were 3.32 t CH_4 $ha^{-1}yr^{-1}$ and 4.78 t CH_4 $ha^{-1}yr^{-1}$, respectively. Horizontal emission was higher in the wet season due to an increase in the water table which resulted in an increase of CH_4 emission. Thus, there is a need for direct CH_4 measurement from cultivated peat soils to ensure that CH_4 emission is neither underestimated nor overestimated.

Introduction

Peat soils are important natural resources. Peat soils have been cleared, developed, and cultivated for large scale plantations due to their positive contribution to Malaysia's economic growth in agricultural sector. Globally, agriculture is considered to be responsible for about two-thirds of the anthropogenic sources of greenhouse gas emissions (Melling *et al*., 2005). Agriculture, forestry, and peat extraction for fuel and horticultural purposes are major causes of peatland disturbance because when peats are disturbed, the alteration in their hydrology results in the peat's oxidation which alters the greenhouse gases balance (Maria, 2008). Concerns on the role of peatlands as a main carbon sequester started because greenhouse gases (GHGs) emission contributes to global warming (Daud, 2009). Cultivation of different crops has varying impacts on the environment (Azqueta and Sotelsek, 2007). Cultivation of pineapples on peat soils has now become profitable and popular in Malaysia. Malaysia is known to be the only country in the world that uniquely and largely cultivates pineapples on peat soils. This practice has been in existence for nearly a century. However, concerns by NGOs has been expressed that increasing cultivation of pineapples on peat soils lead to increase in the emissions of harmful greenhouse gas such as methane (CH_4). Previous study on drained peat soil cultivated with pineapple done by Ahmed and Liza (2014) showed that 0.35% CH_4 were emitted. Currently, there is lack of information on soil CH_4 emissions horizontally and vertically from pineapple cultivation on drained tropical peatlands.

The objective of this study was to quantify horizontal and vertical CH_4 emissions on a drained tropical peatlands cultivated with pineapple.

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Materials and Methods

Site description

The study was carried out at Malaysia Agricultural Research and Development Institute (MARDI) Peat Research Station Saratok, Sarawak, Malaysia. MARDI, Saratok has a total area of 387 hectares and located on a logged-over forest with flat topography of 5 m to 6 m above mean sea level (Ahmed and Liza, 2015). Based on the von Post Scale, the peat soils is classified under H7 to H9; well decomposed sapric peat with a strong smell and thickness ranges 0.5 m to 3.0 m (Ahmed and Liza, 2015). The mean temperature of the peat area ranges from 22.1 to 31.7 °C with relative humidity ranging from 61 to 98% (Ahmed and Liza, 2015). The annual mean rainfall of the area is 3749 mm; where in the wet season, the monthly rainfall is more than 400 mm whereas in the dry season is 200.7 mm (Ahmed and Liza, 2015).

Greenhouse gases emission measurements

Methane emission measurements were carried out at 0-5 cm and 5-10 cm peat soil depths, respectively. Measurements of the CH_4 emission were carried out in 10 m x 10 m drained peat soil plots cultivated with pineapple. Methane flux sampling was carried out for 24 hours at every 6 hours interval (between 0600 hr to 0600 hr) and were monitored once throughout the dry (July 2015) and wet (December 2015) period.

Soil CH_4 horizontal emission measurements

The horizontal movement of CH_4 emissions from the peat soil surface was measured using the closed chamber method (Norman *et al*., 1997; Crill *et al*., 1988). The fabricated I-shaped chamber was gently pressed vertically on the surface of the soil pit at of 3-5 cm depth. The chamber was equilibrated for 30 minutes. The headspace samples of 20 mL were extracted from the chamber every minute for 6 minutes starting at 1 minute using a 50 mL syringe. The extracted gas was then transferred to 20 mL vacuum headspace vials using a disposable syringe needle. Methane concentration was measured using a Gas Chromatography (GC- Agilent 7890A) equipped with a thermal conductivity detector (TCD) (Ahmed and Liza, 2015).

Soil CH_4 vertical emission measurements

The vertical CH_4 movement was measured at 5 cm depth interval (0-5 cm, 5-10 cm), from the surface to 10 cm above water table (saturated zone). The L-shaped chamber was installed horizontally to the wall of the peat soil at 20 cm. The end of the chamber was covered and sealed with steel cap and parafilm, respectively. For each depth, peat soil was manually removed to a suitable working size pit. The open cylinder was left standing for approximately 30 minutes to establish an equilibrium state.

Methane flux calculation

The CH_4 sampling and measurement was carried out for 24 hours at every 6 hours (between 0600 hr to 0600 hr). The gas flux was measured in early morning I (0600-0700), afternoon (1200-1300), evening (1800-1900), midnight (2400-0100), and early morning II (0600-0700) to obtain a 24 hours GHG emission. The gas sampling was carried out once a month from July 2015 to August 2015 for dry season; September and December 2015 for wet season. Thus, the total numbers of gas sampling are 4 times in 4 months. The results were based on the measurement of CH_4 from the five durations using two methods (I-chamber and L-chamber) in the dry and wet seasons. The values of CH_4 emitted were averaged and converted into units of t ha^{-1} yr^{-1}. The CH_4 fluxes were then calculated using the following equation (Zulkefli *et al*., 2010; Widen and Lindroth, 2003; IAEA, 1992).

$$\text{Flux}= [(CO_2/CH_4)\ dt]\ X\ PV\ ART'$$

where $(CO_2/CH_4)/(dt)$ is the evolution rate of CO_2/CH_4 within the chamber headspace at a given time after which the chamber were placed 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.

Statistical analysis

Analysis of variance (ANOVA) was used to detect treatment effects whereas treatments means were compared using Duncan's New Multiple Range Test (DNMRT) at $P \leq 0.05$. The statistical software used for this analysis was Statistical Analysis System (SAS) version 9.3.

Results and Discussion

Methane emission was significantly affected by season (Figure 1). The seasonal variation in CH_4 flux was higher in the wet seasons due to rainfall which might have increased the water table of the peat soil. According to Farmer *et al*. (2011), during wet season, CH_4 is emitted in the form of bubbles which are transported by molecular diffusion through the aerobic layer of the peat. Soil CH_4 emission was not significantly different regardless of sampling period (Figure 1). Methane emission in the morning (1.02 t ha^{-1} yr^{-1}) was the highest during the wet season followed by early morning (0.99 t $ha^{-1}yr^{-1}$). The lowest CH_4 emission occurred at noon (0.72 t $ha^{-1}yr^{-1}$). However, in the dry season, CH_4 emission in the early morning (0.68 t ha^{-1} yr^{-1}) was highest in the dry season followed by at noon (0.64 t $ha^{-1}yr^{-1}$). The lowest CH_4 emissions occurred in the morning (0.51 t $ha^{-1}yr^{-1}$). The differences in the day and night temperature of the experimental site in the dry and wet seasons might have also inhibited the photosynthetic activity of the *Ananas comosus* (L.) Merr. plants.

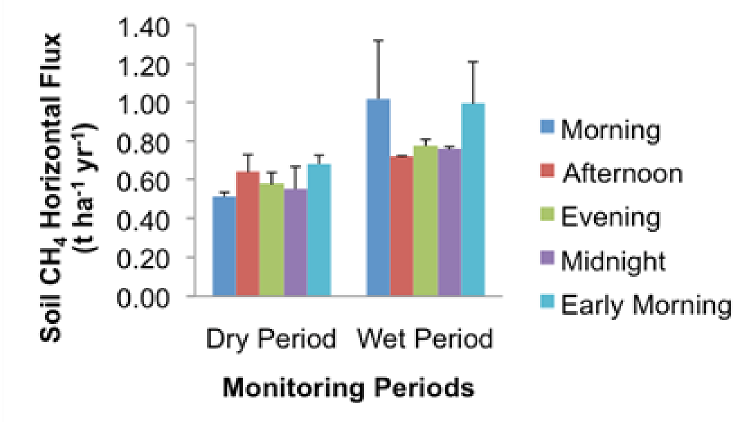

Fig. 1 Horizontal emission of methane from peat soil cultivated with pineapple at different sampling periods (Error bars represent standard error).

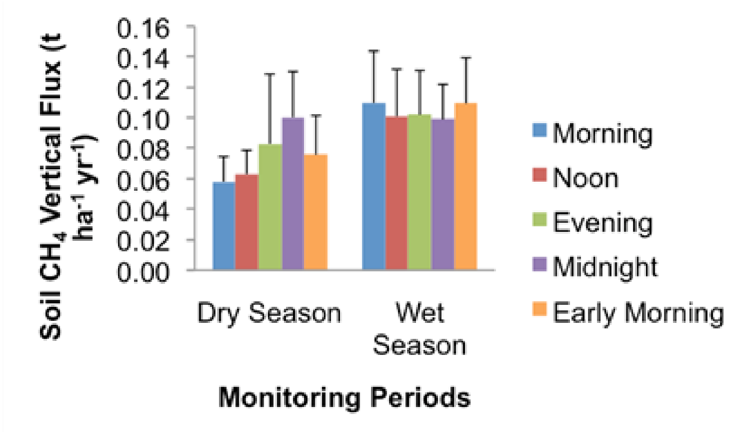

Fig. 2 Vertical emission of methane from peat soil cultivated with pineapple at different sampling periods (Error bars represent standard error).

Furthermore, the root respiration and decomposition of the pineapple plants might have contributed to the emission of CH_4 in the wet season (Ahmed and Liza, 2015). In the dry and wet seasons, there was distinct seasonal variation in the vertical emission of *CH_4* (Figure 2). Vertical emission of CH_4 was higher in the wet season due to the water table level of the peat soil. In the wet season, higher *CH_4* emission occurred because of favourable conditions essential for methanogenesis which increases oxidation of CH_4 (Melling *et al*., 2005). The *CH_4* emission is also related to the microbial population and the availability of adequate substrate for microbial metabolism, but not for plant root activities (Kechavarzi *et al*., 2010; Kuzyakov, 2006). According to Melling *et al*., (2005), a thick aerobic layer with higher temperature increases CH_4 oxidation thus, resulting in higher CH_4 uptake as shown in CH_4 emission during the wet season (Figure 2). The CH_4 emissions were statistically similar across all the five sampling periods however, there was higher CH_4 emission in the early morning (2.73 t ha^{-1}yr^{-1}) during wet season followed by at noon (2.59 t ha^{-1}yr^{-1}) and morning (2.06 t ha^{-1}yr^{-1}) in that order. The CH_4 emitted regardless of time of sampling was not significantly different (Figure 2).

Conclusion

In tropical peat soils cultivated with pineapples, horizontal emission of *CH_4* is higher than vertical emission. However, to avoid underestimation of *CH_4* emission from pineapples cultivation on tropical peats, both horizontal and vertical emissions of this gas must be considered regardless of season.

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