Research article

Biochar Amendment to Different Paddy Soils on CH_4 Production, Labile Organic Carbon, pH and Electrical Conductivity Dynamics: Incubation Experiment

CHHIN PHY
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

KETSUDA DEJBHIMON
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

DAUNGSAMON TULAPHITAK
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

PHRUEKSA LAWONGSA
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

MATSA KEOPHILA
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

NIPA THAMMASOM
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

PATCHAREE SAENJAN*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: patsae1@kku.ac.th

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Abstract Today biochar research in agriculture is worldwide interested to mitigate greenhouse gas emission. Application of biochar in anoxic condition to different textured paddy soils was proposed to study. We gave hypothesis that biochar rates in paddy soils will correlate to the changing of CH_4 production, soil labile organic carbon (LOC), pH and electrical conductivity (EC), and their interactions. Biochar amendment rates, 6.25, 12.50, 18.75 and 25 t ha^{-1} were anaerobically incubated in loamy, clayey and loamy sand soils for 28 days. At the end of incubation, biochar amended loamy soils gave the highest cumulative CH_4 production followed by clayey and loamy sand soils. CH_4 production was enhanced by biochar amendment in loamy and clayey, but suppressed in loamy sand. The highest cumulative CH_4, 47.03 mg CH_4-C kg^{-1}, was produced from loamy soil with 12.50 t ha^{-1} of biochar. The highest LOC was in clayey soil followed by loam and loamy sand in all rates of biochar amendment. Biochar had tendency to enhance soil pH in loam, but not in clay and loamy sand. In addition, highest EC was in clay, especially with 25 t ha^{-1} of biochar amendment, followed by loam and loamy sand. Through the whole of incubation, biocahar amendment rates significantly negative correlated to CH_4 production rates in all soil textures. The positive correlations between LOC and biochar rates were found in clayey and loamy sand soils, while the former was highly significant. However, fluctuated correlations were manifested in loamy soil. Furthermore, in loamy sand, the stronger correlation between biochar rates, and both pH and EC, compared to loamy and clayey soils. Biochar amendments suppressed CH_4 production in loamy sand, but enhanced in loamy and clayey soil under anaerobic incubation. Further studies on biochar feasibility should be trialed in paddy-field condition.

Keywords organic material, soil organic carbon, greenhouse gas

INTRODUCTION

Rice paddy is an important distribution channel of anthropogenic greenhouse gas (GHG) emission, which impacts to global warming or climate change aspects. CH_4 production and emission from soil is derived from C mineralization, and widely documented with relation to the effect of soil temperature, moisture, pH, Eh and plant cultivars (Zheng et al., 2007). In addition, soil labile organic matter fractions are very important in vulnerable to transform and play crucial roles for C and nutrient cycling, and perform a major role for source and sink of GHG change such as CO_2 and CH_4 (Tian et al., 2013).

Biochar is a carbon rich by-product derived from thermal decomposition of organic matter under pyrolysis system with low oxygen concentration promoted the potential for improving soil properties (Denyes et al., 2012). Today biochar research in agriculture is worldwide interested to mitigate GHG emission such as CH_4, or CO_2 to environment. Therefore, this incubation experiment is established in a laboratory in order to identify the effectiveness of biochar amendment rates on soil parameters and their interaction in different soil textures.

OBJECTIVE

To investigate CH_4 formation, labile organic carbon (LOC), pH and EC dynamic characteristics from application of different rates of biochar and their interactions in anoxic condition within loamy, clayey and loamy sand paddy soils**.**

METHODOLOGY

Treatments, soils and incubation: The experiment was laid out in completely randomized design (CRD) in triplicate, incorporated with 0, 6.25, 12.50, 18.75 and 25 t ha^{-1} of biochar with 7.98 and 0.94 dS m^{-1} of pH and EC respectively. Biochar derived from a 5 years old eucalyptus wood, combusted at conventional kiln by 350 ^{o}C. The loamy, clayey and loamy sand soils were sampled from 0-15 cm depth in a paddy field in northeast of Thailand. More details of chemical and physical properties of soils and biochar were shown in Table1. The soil was air dried, grinded and passed through a 2 mm. sieve. Enough amount of soil sample was pre-submerged in deionized water for one week. Prior to the soil incubation, moisture content of the muddy soil was determined.

A weight of muddy soil used in this incubation trial was equivalent to 5 g of dried soil, was placed in a 60 ml serum bottle. The soil-biochar mixture with 15 ml of deionized water was shaken by using vortex shaker in order to expel any gas bubbles in soil slurry, and flushed the head space in the bottles by ejecting N_2 (99.99%) gas with 1 bar pressure for 1 minute, the bottle was closed immediately with butyl rubber stopper and aluminum crimp top seal. They were wrapped up with aluminum foil for protecting the light radiation.

Table 1 Basic chemical and physical properties of soils and biochar

Soils/biochar	Sand (%)	Silt (%)	Clay (%)	BD (g cm^{-3})	SOC (%)	LOC (g-C kg^{-1})	TN (%)	C:N ratio
Clay	2.53	17.31	80.26	1.44	1.75	1.70	0.16	10.94
Loam	50.00	36.70	13.30	1.45	0.79	0.50	0.07	11.29
Loamy sand	84.14	11.95	3.91	1.80	0.12	0.10	0.02	6.00
Biochar	-	-	-	-	38.60	13.30	0.50	77.20

Gas samplings and soils analyses: Gas samplings were performed every week for 4 weeks. Before the actual gas samplings, the incubated samples were flushed with N_2 (99.99%) for 1 minute, sealed tight as mentioned previously and incubated again for 24 hours. One ml gas sample was taken from the head space of incubation bottle using an air-tight syringe. The concentration of CH_4 in the gas samples was analyzed with gas chromatograph (GC), Shimadzu GC2014, detector temperature 200 ^{o}C (FID), injection port 150 ^{o}C, oven 180 ^{o}C, stainless steel column 2 m length packed with unibead C. Carrier gas is He and retention time is 2.25 minutes. To calculate the CH_4 production was mentioned by Ro et al., (2011). Labile organic carbon (LOC) was analyzed by permanganate-oxidation method (Moody and Cong, 2008). The actual soil pH and EC were measured by pH and EC meters, respectively.

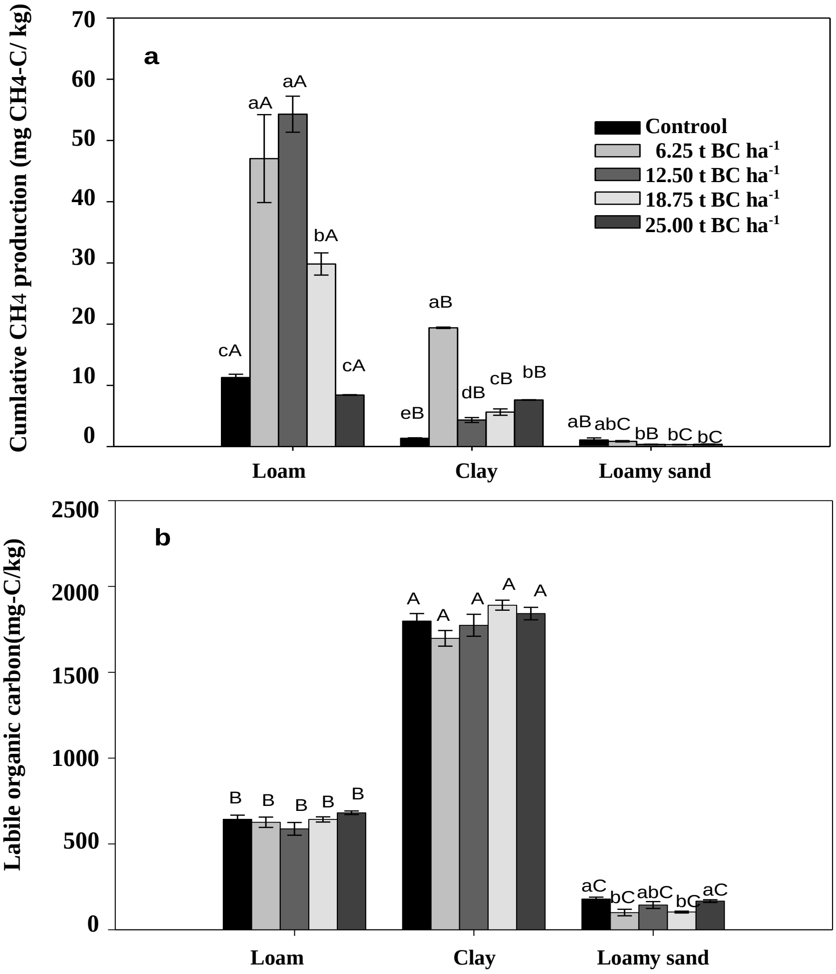
Statistical Analysis: The data collected was analyzed statistically using Analysis of Variance (ANOVA) technique and treatment means were compared by using Duncan's Multiple Range Test (DMRT) with SAS statistical program.

RESULTS AND DISCUSSION

Cumulative CH_4 production: Biochar amendment significantly enhanced cumulative CH_4 production accompanied with a large range (8.42 to 54.03 mg CH_4-C kg^{-1}) in loamy soil, and a moderate range (5.63 to 19.40 mg CH_4-C kg^{-1}) in clayey soil, when compared to its control without biochar Aemicalon, but it decreased CH_4 production with a very low range (0.31 to 0.86 mg CH_4-C kg^{-1}) in amended loamy sand soil (Fig. 1, a). Biochar amendment rates significantly negative correlated to CH_4 production rates in all soil textures (Table 2). A quadratic regression determination had identified that cumulative CH_4 production was influenced by LOC in loam, but not found in clay and loamy sand. While pH had impacts on cumulative CH_4 production in clayey and loamy sand, and EC had determined cumulative CH_4 production in all types of soil (data not shown). Zhang et al. (2012) had given a report that methane emission over the whole rice growing season was significantly increased by the rate of biochar amendment. Yu et al. (2012) also confirmed that under the high soil moisture, 85 and 100% water filled pore space, biochar enhanced methane emission. In contrast, Feng et al. (2012) indicated that biochar amendment in paddy soil decreased CH_4 emission as well as Liu et al. (2011) had proved that application of biochar reduced methane emissions from the paddy soil. These findings agreed to our results which CH_4 productions were enhanced in loamy and clayey soils, but decreased in loamy sand soil amended with biochar. Zhang et al. (2010) had emphasized that the degree of methane emission vary depending upon the type of soils, biochar application rates, soil moisture conditions, the fertilization, and water management regimes.

Labile organic carbon (LOC): The highest LOC was found in amended clayey soil, 1697.45 to 1890.71 mg-C kg^{-1}, followed by loamy soil, 587.46 to 681.20 mg-C kg^{-1}, and loamy sand, 99.93 to 178.99 mg-C kg^{-1}, respectively. The results found that biochar had no influence on LOC in loamy and clayey soils, but fluctuated among biochar rates in loamy sand (Fig. 1, b). The dynamic changes of LOC in loamy soil with 6.25, 12.50 and 18.75 t ha^{-1} of biochar were gradually increased from 0 to 21 DOI, but tended to go down at 28 DOI, contradictory to the LOC change in clayey soil, which was still keep increasing over the whole incubation. In addition, LOC changes in loamy sand soil were very low but fluctuated (data not shown). The positive correlations between LOC and biochar rates were found in clayey and loamy sand soils, while the former was highly significant (Table 2**)**. However, fluctuated correlations were manifested in loamy soil. Zhang et al. (2012) found that biochar amendment did not change LOC over the rice growing season.

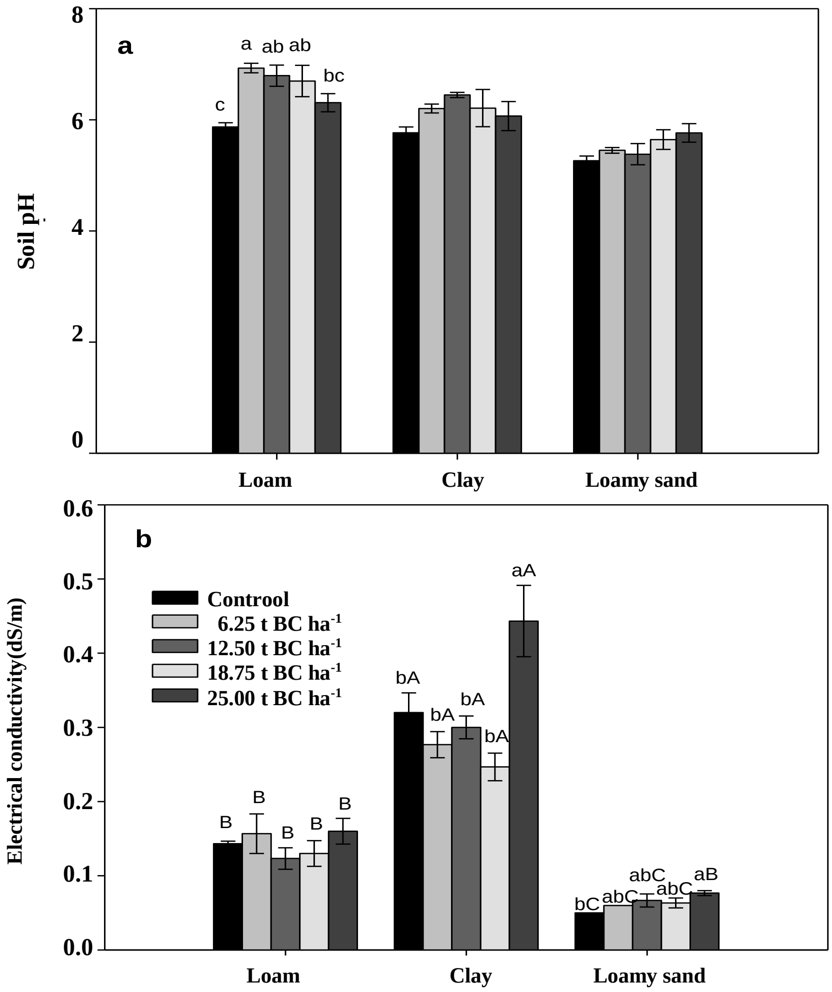
Potential of hydrogen (pH): The dynamic changes of pH in different soil textures showed the same patterns, which increased from the initials to the fluctuated peaks at 7, 14 and 21 DOI and thereafter had tendency to go down at the end of experiment. The highest initial pH indicated in loamy soil followed by clayey and loamy sand, but at the end of incubation we did not find any significant differences among those soil amendments. The pH values were range from 5.87 to 6.93, 5.77 to 6.45 and 5.26 to 5.76 for loamy, clayey and loamy sand respectively. Furthermore, we did not see the effects of biochar on soil pH in clayey and loamy sand soils, except for amended loamy soil which bichar had influenced to enhance soil pH (Fig. 2, a). Furthermore, in loamy sand, the stronger correlation between biochar rates and pH, compared to loamy and clayey soils (Table 2). Farrel et al. (2013) had proved that pH change in biochar amended soils were higher than control soil over the duration of incubation experiment because biochar was highly alkalinity. Lai et al. (2013) also claimed that the application of biochar increased the soil pH due to their alkalinity. Nigussie et al. (2012) also supported the findings above, i. l. biochar stimulated soil pH, and the result gave another reason that the high surface area and porous nature of biochar and the factor increases cation exchange capacity (CEC) of the soil and significantly positive correlate with pH. Ventura et al. (2012) reported that biochar amended soil 30 and 60 t ha^{-1} had no effect on soil pH from upland field experiment.



Different letters showed significantly different at p<0.01, vertical bars represent SE-mean. The lowercase used to compare between the treatments within each soil type and the uppercase used to compare the same treatments among the three soil types

Fig. 1 Cumulative CH_4 production (a) and LOC at 28 DOI (b) from anoxic incubated soils an affected by different rates of biochar application.

Electrical conductivity (EC): The highest initial EC was in loamy soil (0.34 to 0.40 dS m^{-1}) followed by clay (0.20 to 0.32 dS m^{-1}) and loamy sand (0.02 to 0.08 dS m^{-1}), respectively, but at the end of experiment we found that the highest EC was in clayey soil (0.25 to 0.44 dS m^{-1}) followed by loamy (0.12 to 0.16 dS m^{-1}) and loamy sand (0.05 to 0.08 dS m^{-1}) soils, respectively. Fig. 2, b showed that biochar amendments had no potentials on soil EC in loamy soil, except for 25 t ha^{-1} of biochar amendment in clayey and loamy sand respectively, which promoted soil EC, compared to the control. In addition, in loamy sand, the stronger correlation between biochar rates and EC was evident, compared to loamy and clayey soils (Table 2).



Different letters showed significantly different at p<0.01, vertical bars represent SE-mean. The lowercase used to compare between the treatments within each soil type and the uppercase used to compare the same treatments among the three soil types

Fig. 2 Soil pH (a) and EC (b) at 28 DOI from anoxic incubated soils an affected by different rates of biochar application

Table 2 Pearson correlation coefficients (r) relating biochar rates to CH_4 production rate, LOC, pH and EC

Soil parameter	DOI	Loamy soil	Clayey soil	Loamy sand soil
CH_4 (mg CH_4-C $kg^{-1}d^{-1}$)	7	-0.80**	0.80**	-0.51
	14	-0.82**	-0.82**	-0.52
	21	-0.86**	-0.81**	-0.60*
	28	-0.85**	-0.88**	-0.69*
LOC (mg kg^{-1})	7	0.75**	0.73**	0.51
	14	-0.66*	0.69*	0.41
	21	-0.29	0.57	0.68*
	28	0.50	0.63*	0.51
pH	7	0.39	0.77**	0.85**
	14	0.19	0.58*	0.96***
	21	-0.32	0.15	0.16
	28	-0.61*	-0.22	0.50
EC (dS m^{-1})	7	-0.04	0.54	0.91***
	14	0.17	-0.22	0.86**
	21	-0.56	0.19	0.79**
	28	-0.05	0.58*	0.51

Ventura et al. (2012) indicated that biochar application significantly increases soil EC and it was a direct relationship between biochar rate and EC. The higher rate of biochar application results in higher EC. Nigussie et al. (2012) had emphasized that biochar amended soils enhanced EC in chromium polluted soil because biochar attributed to ash accretions as ash residue which was dominated by carbonates of alkali and alkaline earth metals, variable amounts of silica, heavy metals, sesquioxides, phosphates and small amounts of organic and inorganic N. In addition, Farrel et al. (2013) proved that biochar had highly EC, which tend to promote soil EC.

CONCLUSION

Biochar amendment had varied effect on CH_4 production in different soil textures under anaerobic incubation. Biochar enhanced CH_4 production in loam and clay, but decreased in loamy sand. Simultaneously, biochar amendment had no potential to change LOC in every soil. While, biochar had influenced to stimulate soil pH in loam, but not found any effectiveness in other two soils. In addition, EC changes were tending to increase by biochar in clay and loamy sand. The correlation was found between biochar rates and soil parameters in each soil texture and interaction between LOC, pH, EC, and CH_4 production. In order to minimize biochar production from tree feedstock, the future research should generate biochar from crop residues (rice straw, rice hull, grass etc.), or agricultural industrial wastes.

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