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A Comparative Study of Pelleted Broiler Litter Biochar Derived from Lab-Scale Pyrolysis Reactor with that Resulted from 200-Liter-Oil Drum Kiln to Ameliorate the Relations between Physicochemical Properties of Soil with Lower Organic Matter Soil and Soybean Yield

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Abstract

Biochars can be used as soil amendments for improving soil properties and crop yield. In this study, a pot experiment was conducted to compare the efficiency of pelleted broiler litter biochar (PBLB) derived from a lab-scale pyrolysis reactor (PBLBL) with that resulted from 200-liter-oil drum kiln (PBLBO). The biochar generated from each reactor was applied to the pot that contained lower organics materials, sandy soil, and grown soybeans cv.Chiangmai-60 (*Glycine max* [L.] Merr.) at the application rates of 5.00, 10.0, 15.0, and 20.0 t ha^{-1}. The results showed that both types of pyrolysis reactors (PBLBL and PBLBO), at every application rate, significantly improved the physicochemical properties of soil and increased the growth and yield of soybean; their comparison with a control treatment of soybeans is $p < 0.05$. At the application rate of 15.0 t ha^{-1} the PBLBL showed the highest soybean yield. The application of PBLBL and PBLBO significantly led to increased pH, soil organic matter, C:N ration, N, P, K, Ca, Mg and CEC.

Keywords: Biochar; low organic soil; pelleted broiler litter; pyrolysis; soil ameliorate.

1. Introduction

In recent years, biochar has been reported to boost soil fertility and improve soil quality such as raising soil pH, increasing moisture holding capacity, attracting more beneficial fungi and microbes, improving cation exchange capacity, and retaining nutrients in soil (Lehmann *et al*., 2006). Biochar is considered much more effective than other organic matter in retaining and making nutrients available to plants (Zheng *et al*., 2010). Its surface area and complex pore structure made by pyrolysis process are hospitable to bacteria and fungi needed by plants to absorb nutrients from the soil (Zheng *et al*., 2010). These characteristics make biochar an exceptional soil amendment for use in sustainable agriculture (Verheijen *et al*., 2010).

Biochar can be created from various kinds of materials such as plant material, animal litter such as poultry litter which, in Thailand, is the most common and easily available; char made from poultry litter provides useful properties for soil improvement and plant growth. Broiler littler contains high plant nutrition values especially nitrogen, phosphorus, and potassium for soil improvement and crop growth as well as promoting yield. A direct application of fresh broiler litter to crop production for immediate consumption can be harmful to health due to the contamination of pathogens, parasites, fungi, and heavy metal (Suppadit *et al*., 2003). In Thailand pelleting of broiler litter has been utilized to deal with litter management and, thus, reducing negative environmental impact (Suppadit, 2000). However, during a pelleting of broiler litter process some components may be denatured by the pressure and heat, and continued to release ammonium during storage time. In addition to pelleting process, biochar created from poultry litter tends to have more beneficial effects on soil quality and crop production than that produced from herbaceous, and biomass material (Chan *et al*., 2008). In most of literatures, biochar is derived from a lab-scale pyrolysis reactor which is complicated and inconvenient for rural and local people. For this reason this study proposed a 200-liter-oil drum kiln, which has been used for charcoal making in rural sectors of Thailand to reproduce biochar used in ameliorating lower organic matter soil; it was done by determining and comparing the efficiency of both kinds of biochar derived from two types of pyrolysis reactors in soybean planting. The experiment then evaluated the productive performance of soybeans in relation to the soil's physicochemical properties after amended with these two different types of biochar.

2. Materials and Methods

2.1. Soils

The soil used in this study was a series of Ongkarak soil which was classified as sandy soil containing 94.0% sand, 3.50% silt, and 2.50% clay. Soil samples were collected from the Tumbon Promanee areas, Mueng district, Nakhon Nayok province in Thailand. The selected soil samples were thoroughly mixed, air-dried, and passed through a 2.00 mm sieve prior to laboratory analysis. The physical and chemical characteristics of the soils were analyzed at the Land Development Department 1st Region, Pathum Thani province in Thailand. Table 1 shows the chemical characteristics, trace element, and heavy metals in the sandy soils before the experiment.

2.2. Preparation of feedstock

The broiler litter used in this experiment was taken from Siriwan Company Limited's network broiler chicken (*Gallus gallusdomesticas*) from Saraburi province in Thailand. Broilers were fed in closed houses with the evaporative cooling systems that measured 20.0 m wide × 50.0 m long with a stocking density of 17.5 chicken m^{-2}. Before starting the feeding broilers, the concrete floors were covered with rice hulls that were widely used in chicken farms in Thailand. At the end of the broiler production cycle (50 days) the broiler litter was removed and packed to plastic bags. Then, the broiler litters was brought into the pelleting process following the methods described by Suppadit and Panomsri (2010).

2.3. Preparation of biochar

To effect the combustion process of the biochar's chemical and physical characteristics the combustion of PBL was conducted under a lab-scale pyrolysis reactor and 200-liter-oil drum kiln. In order to generate biochar (PBLBO) using a 200-liter-oil drum kiln, the oil drum kiln was designed for a low-cost charchoal burning tank by cutting of the top tight seal of tank. The kiln was laid down horizontally for a PBL burning process (Appropriated Technology Association, 2003). Ten kilograms of PBL were loaded into the kiln, pre-heated at 55.0ºC - 60.0ºC, and its temperature gradually increased to 150ºC in order to drive the cool air into the tank and dehydrate the sample until the smoke turned to white color. Then the wood fuel was continually supplied to the kiln till the temperature rose up to 500ºC at which it was maintained for 5.00 hours. For the lab-scale of slow pyrolysis, the experiment was conducted at Land Development 1st Region, Pathum Thani province in Thailand. Ten kilograms of PBL were used to generate biochar (PBLBL) at the 500ºC pyrolysis temperature for 5.00 hours based on the recommendation of Lehmann (2007) and Uzoma *et al*. (2011). After the pyrolysis process, the reactor was cooled down at room temperature and biochar was collected. PBL was run 4 times in each reactor to generate PBLBL and PBLBO which were randomly sampled for use in physical and chemical properties analysis.

Table 1. Chemical characteristics of soil, pelleted broiler litter (PBL), pelleted broiler litter biochar produced by lab-scale pyrolysis reactor (PBLBL) and pelleted broiler litter biochar produced by 200-liter-oil-drum kiln (PBLBO)

Parameter	Soil	PBL	PBLBL	PBLBO
Moisture content	4.00	5.99	5.80	5.25
pH	4.50	6.00	9.40	9.90
EC (dS/m)	0.090	0.0787	0.102	0.109
OM (%)	1.07	3.97	3.30	3.37
N (%)	0.083	3.52	2.97	2.86
P (mg kg^{-1})	3.00	2.53	4.25	5.33
K (mg kg^{-1})	35.0	271	507	526
Ca (mg kg^{-1})	135	237	527	738
Mg (mg kg^{-1})	24.0	122	227	217
C/N Ratio	7.00	11.0	9.00	8.00
CEC (me/100g)	2.87	10.3	17.6	18.2
Heavy metal				
Cadmium (mg kg^{-1})	nd	nd	nd	nd
Mercury (mg kg^{-1})	nd	nd	nd	nd
Lead (mg kg^{-1})	nd	nd	nd	nd

nd = not detected (< 0.0001 ppm)

2.4. Location and greenhouse

The study was conducted at the plastic house at the Chulachomklao Royal Military Academy in Mueng district, Nakhon Nayok province in Thailand from November 2011 to March 2012. The temperatures during the trial period ranged from 23.0 to 33.0ºC. The trials were performed in a greenhouse that measured 6.00 m wide × 8.00 m long × 2.00 m high (96.0 m^3) under a clear plastic roof. Corrugated iron and blue netting were used as a borders around the plastic house. The black plastic pots of size 28.0 cm wide × 22.5 cm high (616 cm^3) were used to plant soybeans.

2.5. Pot experiments and data collection

This study was conducted at the plastic house with natural light and temperature settings. The temperatures during the experiment ranged from 23.0 to 33.0ºC. The experimental design used in the study was a randomized block design with four replications. Two kinds of pyrolysis (PBLBL and PBLBO) reactors, and five levels of biochar application rates (0, 5.00, 10.0, 15.0 and 20.0 t ha^{-1}) were used. The soils were mixed with biochar by applying a rotating soil mixer. For each rate of PBLBL and PBLBO, ten kilograms of mixed soil were filled into 25.4 cm plastic pots. After that, four seeds of soybeans cv. Chiangmai 60 (CM. 60) which were inoculated with Rhizobium spp. soil directly into each treatments were planted inside the pots. The potted plants were watered based on field capacity until the R7 stage (beginning maturity). The entire plot areas were weeded by hand. An aqueous solution of tobacco leaf extract was sprayed as needed for insect control. The growth and yield of soybean were recorded as follows; planting date, stage of emergence, number of nodes, stem height, leaf area, stem weight, yield (4 plants pot^{-1} × seeds pod^{-1} × 1 seed weight), number of pods $plant^{-1}$, number of seeds pod^{-1} and dry weight of 100 seeds. For the leaf area measurement, the full expanded leaves of soybean in each treatment were measured using a leaf area meter LI-3100A (LI-COR Biosciences). At any growth stage of soybean, a single stem plant of each treatment was harvested and dried with a hot air oven at 70.0ºC for 48.0 hours or until a constant weight was reached before weighing to determine its dry weight.

2.6. Chemical analysis

At the end of the pot experiments, the stems and seeds of soybeans including soil samples were harvested and analyzed for their chemical properties at the laboratories of Land Development 1st Region, Pathum Thani province in Thailand. The soil from each pot was air-dried at 36.0ºC until it reached a constant weight; then it was crushed gently to pass through a 4.00 mm sieve to be separated from plant debris following Suppadit *et al*. (2012). The EC and pH in PBLBL and PBLBO and soil samples, before and after the experiment, were determined in a soil: water extracts ratio (1:10 w/v) using conductivity meter (electrical conductivity method) and pH meter respectively according to procedures of Peverill *et al*. (1999). The cation exchange capacity (CEC) was measured using NH^{4+} replacement method following the procedures of Schollenberger and Simon (1945); then the < 4.00 mm soil samples were analyzed for their moisture, organic matter (OM), C/N ratio and extractable N, P, K, Ca, and Mg. The organic matter was analyzed following the method of Walkley and Black (1934) and the total N by the method of Kjeldahl. The available phosphorus was analyzed using Bray II extraction solution; the amount of P was determined by Spectrophotometer. The amount of K, Ca^{2+} and Mg^{2+} were extracted by 1 N NH_4OAc, and pH 7; the extract solution was then analyzed using Spectrophotometer.

2.7. Plant tissue analysis

The stems and seeds of soybeans were oven dried at 70.0ºC for 48.0 hrs. The protein and lipid in the seeds were measured using the Kjeldahl method with a Kjel-Foss Automatic (Model 16210) and the Soxhlet extraction method according to the procedures described in the Land Development Department (2004) manual. The heavy metals in the PBLBL, PBLBO and soils were measured using the inductively coupled plasma atomic emission method with an inductively coupled plasma emission spectrophotometer according to the procedures of AOAC (1970; 1980).

2.8. Data analysis

The Statistical Analysis System (SAS version 6.12) softwares were used to analyze the data obtained in this study. Duncan's New Multiple Range Test (DNMRT) was used to determine the means differences among treatments at a significance level of $p < 0.05$.

3. Results and Discussion

3.1. Growth and yield of soybean

Soybeans treated with PBLBL and PBLBO, for all application rates, had higher stem lengths, numbers of nodes, leaf areas, and dried stem weight than those under control treatment. The application of a combination of biochar derived from the two types of reactors

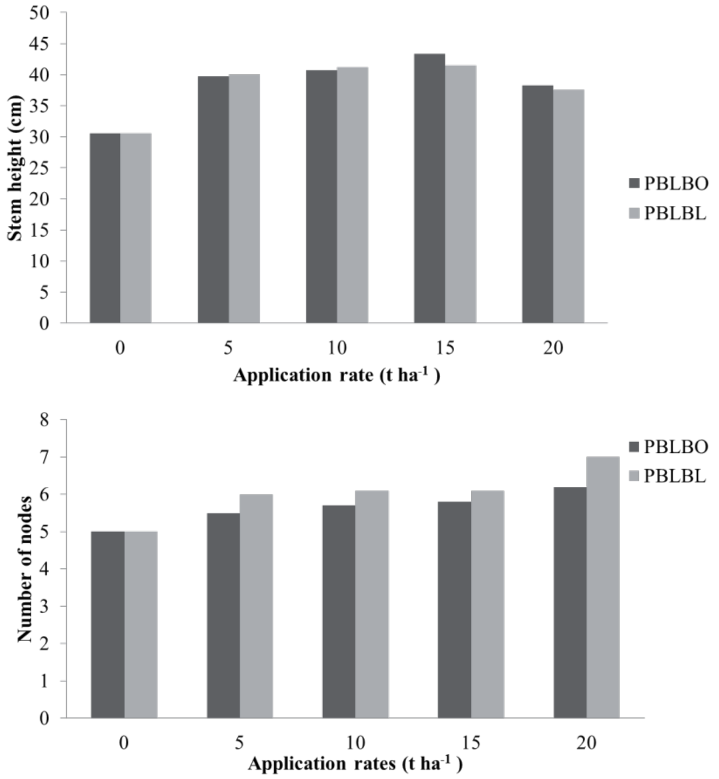

Figure 1. Effects pelleted broiler litter biochar (PBLB) derived from lab-scale pyrolysis reactor (PBLBL) and PBLB derived from 200-liter-oil-drum kiln (PBLBO) on plant height (above) and number of nodes plant^{-1} (below) of soybeans cv. Chiang Mai 60.

(PBLBL and PBLBO) with an application rate of 20.0 t ha^{-1} produced the shortest stem lengths (Fig. 1). For application rate, the stem length of soybeans treated with the PBLBO was slightly higher than that of soybeans fed with the biochar resulted from PBLBL.

At the end of the experiment the number of nodes plant^{-1} as influenced by biochar derived from lab-scale pyrolysis reactor and 200-liter-oil drum reactors, at all application rates, were higher than those of the soybeans under control treatment. An application of the PBLBL at 20.0 t ha^{-1} produced the highest number of nodes plant^{-1} (7.00 nodes plant^{-1}). The number of nodes plant^{-1} of soybeans with the application rates at 5.00, 10.0 and 15.0 t ha^{-1} of PBLBL (6.00, 6.10 and 6.10 node plant^{-1}) was higher than that of soybeans treated with PBLBO application (5.50, 5.70 and 5.80 node plant^{-1}) (Fig. 1). The least number of nodes plant^{-1} was recorded among the soybeans under control treatment.

The leaf areas of soybeans at the growth stages of R1, R3, R5, and R7 increased significantly *($p < 0.05$)* for all treatments. The soybeans under control treatment had the lowest leaf areas for all growing stages. An application of PBLBO at 15.0 t ha^{-1} produced the highest leaf areas at the R5 and R7 of growth stages. With the exception of the application of PBLBO at 15.0 t ha^{-1}, the leaf areas of soybeans treated with PBLBO at the growth stage of R7 were higher than those other treatments (Fig. 2).

The dried stem weight of soybean was significantly influenced by biochar derived from both of PBLBL and PBLBO, for all application rates, except for an application of PBLBO at 5.00 t ha^{-1}. With the exception of an application of PBLBO at 5.00 t ha^{-1} and control treatment, the dried stem weight of soybeans increased gradually till reaching the peak of growth stage at R6; after that the dried stem weight of soybean decreased rapidly. Both applications of PBLBL and PBLBO at 15.0 t ha^{-1} produced the higher stem dried weight of soybeans. The highest dried weight of soybeans was found in the treatment of PBLBL at 15.0 t ha^{-1} (Fig. 3).

All yield constituents in terms of number of pods plant^{-1}, number of seeds pods^{-1}, and 100 dried seed weight were showed significant interaction results *($p < 0.05$)* (Table 2.). The interaction between PBLBL mixing rate 15.0 t ha^{-1} showed the highest yield at 10.0 g pot^{-1} following with PBLBO at the same mixing rate (8.78 g),and the lowest was the soybeans in the controlled group (2.00 g). The pods plant^{-1}, seeds pods^{-1}, and 100 dried seeds weight also showed the similar trends like the yield pots^{-1} (Table 2.). According to Uzoma *et al*. (2011) the study using cow manure biochar for maize planting in sandy soil revealed that a biochar mixing rate 15.0 t ha^{-1} had maize grain yield up to 150 % greater than that resulted from applying the highest mixing rate of 20.0 t ha^{-1}. Also according to Suppadit *et al*. (2012) using quail litter biochar (QLB)

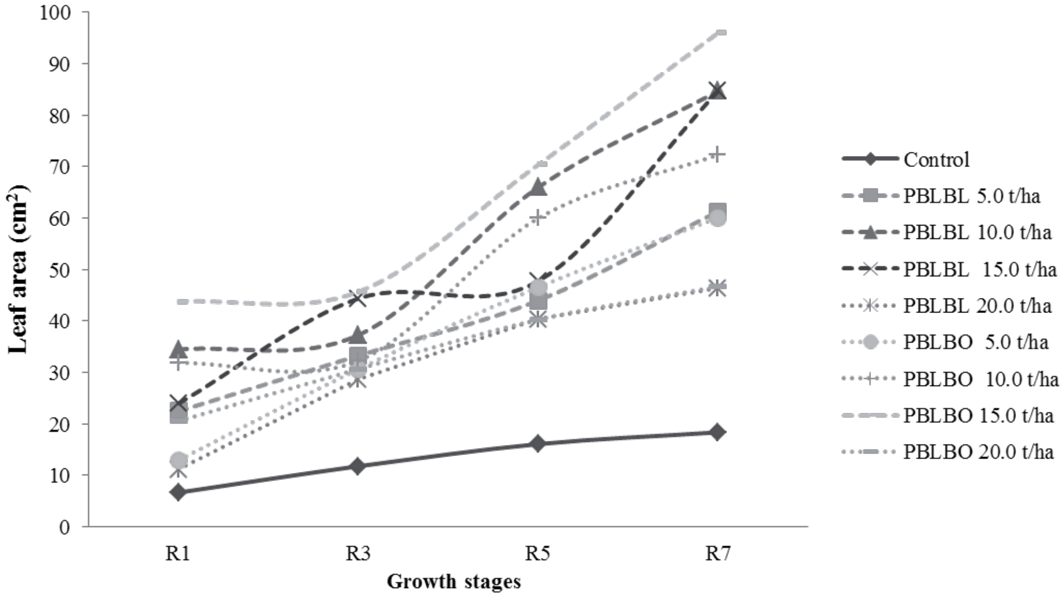

Figure 2. Effects of pelleted broiler litter biochar (PBLB) derived from lab-scale pyrolysis reactor (PBLBL) and PBLB derived from 200-liter-oil-drum kiln (PBLBO) on leaf area of at different growth stage (R1-R7) planted in lower organic and sandy soil treated with PBLBL and PBLBO at various levels.

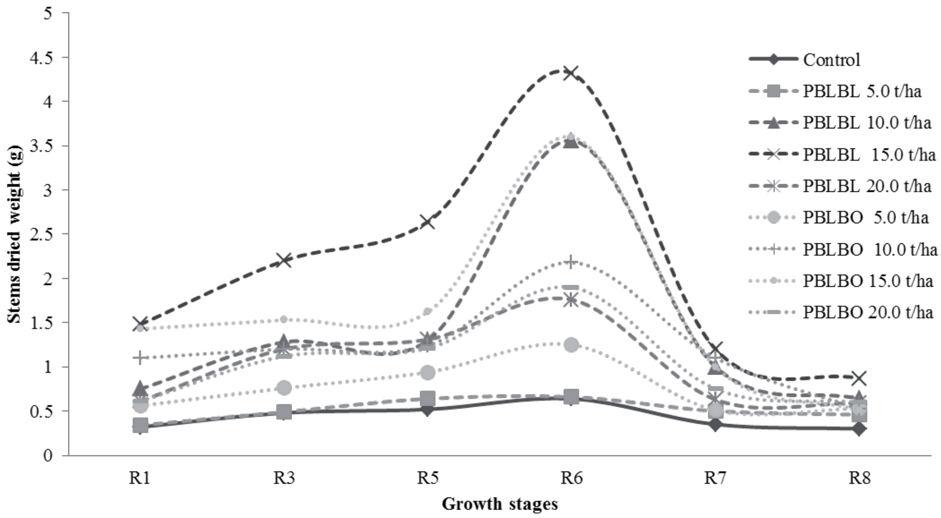

Figure 3. Effects of pelleted broiler litter biochar (PBLB) derived from lab-scale pyrolysis reactor (PBLBL) and PBLB derived from 200-liter-oil drum kiln (PBLBO), at different application rates, on dried stem weight at different growth stages.

Table 2. Effects of PBLB derived from PBLBL and PBLBO with four application rates on yield and nutrients in seed of soybeans cv. Chiangmai 60.

Items	Control	PBLBL (t ha^{-1})				PBLBO (t ha^{-1})			
		5.00	10.0	15.0	20.0	5.00	10.0	15.0	20.0
Yield components									
Yield (g pot^{-1})	2.00^{f}	7.20^{d}	8.80^{b}	10.0^{a}	7.20^{d}	4.00^{e}	7.60^{c}	8.78^{b}	7.20^{d}
Pods plant^{-1}	3.50^{i}	7.60^{g}	8.60^{b}	9.19^{a}	7.68^{f}	4.80^{h}	8.27^{d}	8.40^{c}	7.80^{e}
Seeds pod^{-1}	1.29^{d}	2.00^{c}	2.09^{b}	2.20^{a}	2.03^{bc}	1.98^{c}	2.09^{b}	2.09^{b}	2.00^{c}
100 dried seeds weight (g)	10.7^{g}	16.5^{e}	17.6^{c}	18.4^{a}	17.5^{cd}	15.8^{f}	17.6^{c}	18.2^{ab}	17.6^{c}
Seed' quality									
Protein (%)	35.1^{e}	35.9^{c}	36.0^{b}	36.1^{b}	36.6^{a}	35.5^{d}	36.0^{b}	36.1^{b}	36.5^{a}
Lipid (%)	18.1^{h}	19.2^{f}	19.6^{d}	19.9^{b}	19.9^{b}	19.1^{g}	19.5^{e}	19.7^{c}	20.0^{a}

Means in the same row with different letters are significantly different at $p < 0.05$.

at 94.3 g pot^{-1} showed the highest soybean yield than applying the maximum QLB rate at 123 g pot^{-1}. The higher yield resulted from the mixing rate 15.0 t ha^{-1} in comparison with the mixing rate 20.0 t ha^{-1} was perhaps mainly due to the fact that biochar is alkaline in nature, which may affect soil pH (Suppadit, 2012). That the application of PBLBO yielded soybeans with much higher EC than those treated with PBLBL may be due to the salinity affect to plant for nutrient uptake (Crowley and Arpaia, 2011).

3.2. Seed quality

The applications of biochar derived from PBLBL and PBLBO at all rates (5.00, 10.0, 15.0 and 20.0 t ha^{-1}) produced significantly higher yield pot^{-1}, pods plant^{-1}, seeds pod^{-1}, 100 dried seed weight and seed quality (% protein and % lipid) than control. The highest number of yield pot^{-1} (10.0 g pod^{-1}), pods plant^{-1} (9.19 pod plant^{-1}), seeds pod^{-1} (2.20 seeds pod^{-1}) and 100 dried seeds weight (18.4 g) produced by a combination of PBLBL at 15.0 t ha^{-1} of application rate, while the least number of yield components was produced by controlled pots. The influence of biochar derived from PBLBL and PBLBO on seed quality revealed that the highest amount of protein obtained from an application rate of 20.0 t ha^{-1}, while the highest amount of lipid was found in an application of biochar derived from PBLBO and applied to soybean at 20.0 t ha^{-1} (Table 2.). The increase of protein contents in seeds could be directly related to nitrogen uptake of plants (Winslow, 2011). Biochar also plays important roles in improving their nitrogen fertilizer uptake (Chan *et al*., 2007). Hunt *et al*. (2010) also reported that an application of biochar to plants in both tropical and temperate climates condition could increase plant growth, water retention, and microbial activity as well as reducing nutrient leaching.

3.3. Effects of PBLBL and PBLBO on physicochemical properties in soil

The effects of PBLBL and PBLBO on physicochemical properties in soil are given in Table 3. The statistical analysis revealed a significant *($p < 0.05$)* increase in soil physicochemical properties due to an addition of PBLBL and PBLBO. The percent of moisture content in soil treated with both biochar increased dramatically according to the rates of application and higher than that of control treatment (Table 3). The soil treated with PBLBL, at all application rates, showed the higher amount of moisture content than that treated with PBLBO. The highest means values of soil moisture contents were observed in the soil treated with PBLBL with an application rate of 20.0 t ha^{-1}. The soil used in this study is sandy soil with low ability of water retention. Using the biochar derived from PBL, PBLBL and PBLBO could increase water holding ability in soil. It was expected that the biochar derived from pelleted broiler litter had a greater impact in increasing water retention in sandy soil. Revell (2012) reported that an addition of poultry litter biochar to sandy and silt loam soil in a lettuce germination study increased linearly water holding ability about 15.0% and 40.0% of each soil respectively. Brockhoff *et al.* (2010) also showed that an addition of biochar of 25.0% by volume increased water holding capacity (WHC) of pure sand by as much as 370%. The study of Kammann *et al.* (2011) showed that an application of biochar at the rate up to 100 mg ha^{-1} to sandy soils improved drought tolerance and water use efficiency in *Chenopodium quinoa* relative to an untreated control. Woolf *et al.* (2010) confirmed that biochar is a useful tool for increasing of available moisture in sandy soil. Moreover, PBLBL and PBLBO are porous materials with a high surface areas (Liang *et al*., 2006) and mainly consist of micro-pores (Verheijen *et al.*, 2010). This can lead to an increase in water retention in soil at root zone. Therefore, PBLBL and PBLBO can function as improvers to keep the soil moist and nutrients more available for growing and improving crops productivity (Steinbeiss *et al*., 2009).

The application of PBLBL and PBLBO on sandy soil for growing soybeans in this study significantly *($p < 0.05$)* increased the means values of pH and EC (Table 3). The pH levels were expected to rise with the addition of biochar derived from PBLBL (pH 9.40) and that from PBLBO (pH 9.90). The highest means values of pH and EC were observed in soil treated with PBLBL and PBLBO at the rate of 20.0 t ha^{-1}. The result was consistent with Singh *et al*. (2011) which it was found that adding of empty fruit bunches (EFB) with pH 8.00 to the soil obviously elevated it. In addition, Basri *et al*. (2013) indicated that the soil pH treated with biochar was increased from 5.20 to 6.20. Biochar have neutral to basic pH and researches explored an elevation in soil pH after biochar applications when initial pH was low. Adding biochar is not only an attractive approache to reduce environmental pollution these days, but also has an ability to reduce nutrient leaching, improve crop yield, and lead to a sustainable management of fertilizer (Glaser *et al*., 2001). Plant or animal litter can be sources of organic materials to be turned into biochar which was highly considered as a carbon sequester, soil conditioner, and retainer of ammonium to reduce nitrous oxide emission (Clough and Condron, 2011; Singh *et al*., 2011). The soil analysis after soybean harvest showed that the organic matter level of soil treated with PBLBL and PBLBO at any

Table 3. Effects of addition of PBLBL and PBLBO mixed for growing soybeans cv. Chiangmai-60 on soil physicochemical properties

Items		PBLBL (t ha^{-1})				PBLBO (t ha^{-1})			
	Control	5.00	10.0	15.0	20.0	5.00	10.0	15.0	20.0
Moisture content (%)	4.48^{e}	5.27^{c}	5.30^{c}	6.00^{b}	6.93^{a}	4.92^{d}	4.92^{d}	5.35^{c}	6.00^{b}
pH	4.00^{f}	4.85^{c}	5.05^{b}	5.40^{a}	5.45^{a}	4.40^{e}	4.60^{d}	5.00^{bc}	5.30^{a}
EC (dS/m)	0.0898^{c}	0.0514^{f}	0.0732^{e}	0.0910^{c}	0.130^{b}	0.0732^{e}	0.0811^{d}	0.0918^{c}	0.152^{a}
OM (%)	1.05^{e}	1.35^{c}	1.36^{c}	1.38^{bc}	1.40^{b}	1.29^{d}	1.37^{bc}	1.49^{a}	1.40^{b}
N (%)	0.0830^{c}	0.0978^{b}	0.0983^{b}	0.0990^{b}	0.123^{a}	0.0980^{b}	0.0980^{b}	0.0998^{b}	0.120^{a}
P (mg kg^{-1})	3.00^{g}	10.0^{f}	28.0^{d}	38.0^{c}	37.0^{c}	22.0^{e}	23.0^{e}	55.0^{b}	104^{a}
K (mg kg^{-1})	35.0^{h}	96.0^{g}	167^{e}	227^{c}	256^{b}	95.8^{g}	149^{f}	220^{d}	267^{a}
Ca (mg kg^{-1})	135^{h}	149^{f}	208^{c}	209^{c}	236^{b}	145^{g}	165^{e}	169^{d}	256^{a}
Mg (mg kg^{-1})	24.0^{i}	37.5^{h}	56.5^{e}	75.5^{c}	80.5^{b}	38.5^{g}	55.5^{f}	71.5^{d}	94.5^{a}
C : N ratio	6.50^{g}	7.00^{f}	8.07^{d}	8.41^{bc}	8.65^{b}	7.37^{e}	8.12^{cd}	8.51^{b}	9.07^{a}
CEC (me/100g)	2.72^{g}	2.72^{g}	2.82^{f}	3.00^{d}	3.11^{c}	2.82^{f}	2.89^{e}	3.46^{b}	3.68^{a}

Means in the same row with different letters are significantly different at $p < 0.05$.

rate was higher than that of control treatment. This indicated that the biochar derived from PBLBL and PBLBO acted as original organic matter material when added to soil. The PBLBL and PBLBO themselves have high organic matter.

The nitrogen level in soil, for all kinds of biochar derived and application rates, increased 0.740% to 2.00% rates. The highest increase of nitrogen level in soil after soybean harvest was the applications of biochar derived from both PBLBL and PBLBO at 20.0 t ha^{-1}, 0.123% and 0.120%, respectively. The P, K, Ca, Mg, C:N ratio, and CEC level in soil increased significantly at all application rates of any kinds of biochar. The potassium and phosphorus levels were significantly increased two to seven folds and three to twelve folds, respectively. For all applications the rates of PBLBL and PBLBO significantly increased in the C:N ratio and increase gradually with the increase of application rates. Biochar is characterized by C:N ratios with the enrichment sources of carbon. The C:N ratio of organic soil amendment could be affected directly whether to N mobilize or immobilize particularly when the C:N ratio was higher than 20:1, a generic interpretation indicated that N will be immobilized and became unavailable to plants (Havlin *et al*., 2005). According to result in this study, the C:N value in all treatments were lower than 20, which suggested that any application rated of both biochar used in the study can be used as organic soil amendment.

4. Conclusion

Converting poultry litter into biochar using a 200-liter-oil drum kiln provides a low cost method to generate a value-added product in rural sectors of Thailand. This study clearly showed that PBLBO biochar which is derived from the low cost biochar-making tank produced the higher chemical and physical properties than that of PBL and PBLBL. When PBLBO biochar was added to sandy soil for growing soybeans cv. Chiangmai-60 it was found that, irrespective addition of either PBLBO or PBLBL, it improved the physicochemical properties of soil, the growth, and yield of soybeans despite of application rates. This suggested that the addition of PBLBO and PBLBL into the soil can promote the growth and yield of soybeans cv. Chiangmai-60 as well as improving the chemical and physical properties of soil. Even though, PBLBL showed potentials in promoting plant growth and yield including improvement of soil properties the making biochar by this method is costly. Therefore, the PBLBO method seem to be the most suitable biochar reactor for farmers because it was a simple and low cost way to reproduced biochar in remote areas; the farmers should be encouraged to generate biochar and apply it to their crops.

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References

Agboola AA. Organic matter and soil fertility management in the humid tropics of Africa. IBSRAM Proceedings (Thailand) 1990; 10: 231-44.

AOAC. Official methods of analysis. Association of Official Analytical Chemists (AOAC). 11th ed. Washington, DC, USA. 1970; 1015.

AOAC. Official methods of analysis. Association of Official Analytical Chemists (AOAC). 13th ed. Washington, DC, USA. 1980; 1018.

Appropriated Technology Association. Manual for 200-liter Charcoal Kilns. Nakhon Rachasima, Thailand, 2003.

Basri MHA, Junejo N, Abdu A, Hamid HA, Kusno MA. Elevation and variability of acidic sandy soil pH: amended with conditioner, activator, organic and inorganic fertilizers. African Journal of Agricultural Research 2013; 8: 4020-24.

Brockhoff SR, Christians NE, Killorn RJ, Horton R, Davis DD. Physical and mineral-nutrition properties of sand-based turfgrass root zones amended with biochar. Agronomy Journal 2010; 102: 1627-31.

Chan KY, Van Zweiten L, Meszaros I, Downie A, Joseph S. Agronomic values of green wasted biochar as a soil amendment. Soil Research 2007; 45: 629-34.

Chan KY, Van Zweiten L, Meszaros I, Downie A, Joseph S. Using poultry litter biochars as a soil amendments. Soil Research 2008; 46: 437-44.

Clough TJ, Condron LM. Biochar and the nitrogen cycle: Introduction. Journal of Environmental Quality 2011; 39: 1218-23.

Clowley D, Arpaia MU. Salinity-chloride interactions effects on yield [monograph on the Internet]. California: Production Research Report Commission, California Avocado Commission, Salinity Management; 2011 [cited 2013 Sep 3]. Available from: http://www.californiaavocadogrowers.com/sites/default/files/documents/Salinity-Chloride-interactions-effects-on-yields-Crowley-Arpaia-Year-End-Report-2011.pdf.

FAO, Food and Agriculture Organization of the United Nations. ResourcedSTAT-Fertilizer [homepage on the Internet]. 2009 [cited 2013 Sep 3]. Available from: http://faostat.fao.org/site/575/DesktopDefault.aspx?PageID=575.

Glaser B, Haumier L, Guggnenberger G, Zech W. The 'Terra Preta' phenomenon: A model for sustainable agriculture in the humid tropics. Naturwissenschafen 2001; 88: 37-41.

Hamer U, Marschner B, Brodowski S, Amelung W. Interactive priming of black carbon and glucose mineralization. Organic Geochemistry 2004; 35: 823-30.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL. Soil fertility and fertilizers: An introduction to nutrient management. 7th ed. Pearson Education, New Jersey, USA. 2005; 515.

Hunt J, DuPonte M, Sato D, Kawabata A. The basics of biochar: a natural soil amendment. Soil and Crop Management [Internet]. 2010 [cited 2013 Sep 3]; SCM30: 1-6. Available from: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-30.pdf.

Johnson RA, Bhattacharyya GK. Statistics Principles and Methods. 4th ed. John Wiley & Sons Inc., New York, USA. 2001; 236.

Kammann CI, Linsel S, Gobling JW, Koyro H. Influence of biochar on drought tolerance of Chenopodium quinoa Willd and on soil-plant relations. Plant and Soil 2011; 354: 195-210.

Land Development Department. Plant, fertilizer, water and soil analysis manual. Ministry of Agriculture and Cooperatives, Bangkok, Thailand. 2004; 184.

Lehmann J. A handful of carbon. Nature 2007; 447: 143-44.

Lehmann J, Gaunt J, Randon M. Bio-char sequestration in terrestrial ecosystem - a review. Mitigation and Adaptation Strategies for Global Change 2006; 11(2): 403-27.

Lehmann J, Joseph S. Biochar for environmental management. Science and Technology. Earthscan, London, 2009; 405.

Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad JO, Thies J, Luizao FJ, Peterson J, Neves EG. Black carbon increases cation exchange capacity in soils. Soil Science Society of America Journal 2006; 70: 1719-30.

Peverill KI, Sparrow LA, Reuter DJ. Soil analysis and interpretation manual. CSIRO Publishing, Melbourne, Australia. 1999; 369.

Revell KT, Maguire RO, Agblevor FA. Influence of poultry litter biochar on soil properties and plant growth. Soil Science 2012; 177: 402-08.

SAS Institute. SAS user's guide: statistics. 4th ed. SAS Institute, Cary, North Carolina, USA.1996; 956.

Schollenberger CJ, Simon RH. Determination of exchange capacity and exchangeable bases in soil ammonium acetate method. Soil Science 1945; 59: 13-24.

Singh BP, Hatton BJ, Singh B, Cowie AL, Kathuria A. Influence of biochars on nitrous oxide emission and nitrogen leaching from two contrasting soils. Journal of Environmental Quality 2011; 39: 1224-35.

Steinbeiss S, Gleixner G, Antonietti M. Effect of biochar amendment on soil carbon balance and soil microbial activity. Soil Biology and Biochemistry 2009; 41: 1301-10.

Suppadit T. Poultry waste pelleting: villager technology. Livestock Production Journal 2000; 18: 51-54.

Suppadit T. Environmental health management. The Graduate Program in Environmental Management, Center of Graduates Studies Development, National Institute of Development Administration, Bangkok, Thailand. 2003; 240.

Suppadit T. Effects of pelleting process on fertilizing values of broiler litter. Journal ISSAAS 2009; 6 (2): 136-46.

Suppadit T, Phumkokrak N, Poungsuk P. The effect of using quail litter biochar on soybean (Glycine max[L.] Merr.) production. Chilean Journal of Agricultural Research 2012; 72 (2): 244-51.

Suppadit T, Panomsri S. Broiler litter pelleting using Siriwan model machine. Journal of Agricultural Technology 2010; 6 (3): 439-48.

Ultra VU, Javier E. Influence of long term organic fertilization on the soil microbial community functional structure and enzyme activities in paddy soil [monograph on the Internet]. 2012. [cited 2013 Sep 3]. Available from: http://www.afaci.org/file/anboard2/2012%20%20Philippine%20paddy.pdf.

Uzoma KC, Inoue M, Fujimaki H, Zahoor A, Nishihara E. Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use and Management 2011; 27: 1-8.

Verheijen FGA, Jeffery S, Bastos AC, van der Velde M, Diafas I. Biochar application to soils - a critical scientific review of effects on soil properties, processes and functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg 2010; 149 p.

Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science 1934; 37: 29-38.

Winslow T. Agri-Analyse Inc., Sherbrooke, Québec. Quoted in Husk B, Major J. Biochar commercial agriculture field trial in Québec, Canada-Year Three: effects of biochar on forage plant biomass quantity, quality and milk production. [Internet]. 2011 [cited 2013 Sep 3]. Available from: http://www.blue-leaf.ca/main-en/files/Blue Leaf Biochar Forage Field Trial-Year3 Report.pdf.

Woolf D, Amonette JE, Street-Perrott FA, Lehmann J, Joseph S. Sustainable biochar to mitigate global climate change. Nature Communications 2010; August: 1-9. (Doi: 10.1038/ncomms1053)

Zheng W, Shama BK, Rajagopalan N. Using biochar as a soil amendment for sustainable agriculture. Illinois Department of Agriculture Sustainable Agriculture Grant's Research Series 2010; 1-42.

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