CO_2 Evolution and Phosphorus availability in Sandy Loam Soil as Influenced by Levels of Poultry Litter and Peanut Hull Char Mixture

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Abstract –*Soil management practices like increasing soil organic carbon content by application of organic material like biochar and improving soil biodiversity can play an important role in sequestering C in soil. Twenty eightdays of incubation experiment was conducted to determine the effects of biochar on CO_2 evolution andsoil chemical properties of sandy loam soil. There were 7 treatments (T_1 = Control, T_2 = 50 g PLC kg^{-1} soil, T_3 = 50 g PHC kg^{-1} soil, T_4 = 40 g PLC + 10 g PHC kg^{-1} soil, T_5 = 30 g PLC + 20 g PHC kg^{-1} soil, T_6 = 20 g PLC + 30 g PHC kg^{-1} soil and T_7 = 10 g PLC + 40 g PHC kg^{-1} soil which were laid out in RCBD with three replications.*

The results showed that application of biochar enhances microbial respiration but there were no significant differences between the treatments ($P < 0.05$) on the CO_2 evolved in sandy loam soil for about 28 days of incubation experiment. Some chemical properties of sandy loam soil after the incubation experiment such as soil pH, % organic carbon and extractable P were significantly increased by the application of different proportions of biochar ($P < 0.05$). However, the addition of different proportions of biochar (T4, T5, T6, and T7) and biochar alone (T2, T3) resulted in lower soil pH than the control (T1) due to the production of NH_4^+, CO_2 and organic acids during microbial metabolism. The result of the experiment revealed that addition of 30g PLC Kg^{-1} soil + 20g PHC Kg^{-1} soil could enhance microbial respiration and promote nutrient availability in sandy loam soil.

Keywords –*CO_2 evolution, Phosphorus, sandy soil, biochar*

INTRODUCTION

Climate change is one of the most important challenges we are facing today. IPCC [1] reported that increases in global temperature have now been unequivocally proven and are occurring with an unprecedented rate. The growing global concern includes the threats of nutrient depleted soils associated with food insecurity, global warming and the urgent demand for renewable energy alternatives. Despite of the issue on global warming, it should be of utmost importance to develop new methods using renewable resources addresses to climate change mitigation. Although several options have been proposed for contending with this issue, but no single solution has been found. Thus, technology must be proposed to offer an integrated approach in contribution to the solution of global challenges and draws attention on the problems associated in sandy soils.

Sandy soils are coarse textured with very low organic matter content, low water and nutrient holding capacity, having nutrient deficiencies, less microbial activity, poor structural stability, and high infiltration rate that would limit its productivity. The storage capacity for carbon of sandy soils is typically less than 1% because of the low potential to protect carbon from microbial activity [2]. Due to its fertility related problems, management of sandy soils requires practices that maintain and improve soil physico-chemical properties while sustaining optimum crop yield over time.

Soil fertility can be maintained and improved by using either organic manure or inorganic fertilizers [3], [4]. Unfortunately, sandy soil improvement by application of chemical fertilizers is often unaffordable for poor farmers; therefore, they are forced to depend on the organic manures as a nutrient source [5]. However, effectiveness of organic materials in reclaiming and improving the fertility and productivity of sandy soils varies also with quality and quantity of organic material applied and the advantages of organic manure amendments are generally short-lived in a sandy soil because of the rapid decomposition of soil organic matter under high temperature and aeration [6]. In connection, Philippines have abundant biomass resources generated from extensive agriculture, forestry industries and livestock such as fuel wood, bagasse, coconut residues, ricehull, peanut hull, municipal solid waste and animal waste especially poultry litter which has been widely used as fertilizer. In the study of Camba et al. [7] as cited by Sarong [8] they also stated that Philippines has a broiler litter which is estimated to reach 1.18 million metric tons yearly. With this over supply amount of organic wastes, it is indeed a real problem in proper wastes disposal in the country. However, contaminant problems (e.g. residual hormones, antibiotics, pesticides, and pathogens) are associated with the application of uncharred poultry litter [9].

At present, environmental concerns are to install waste management systems that will address to waste disposal problem. Thus, wastes generated from poultry and livestock farms are being converted into black carbon manufactured through pyrolysis of biomass that has become known as 'biochar' [10].Hence, conversion of raw poultry litter to char can be an alternative management strategy in utilizing these resources as soil ameliorant. Glover [11] reported also that the thermal processing of wastes into biochar has been identified as an opportunity to destroy contaminants making beneficial land application possible. Demirbas et al. [12] added that this technology is seen more as a pollution mitigation device with an energy generation component rather than a merge energy system and charring of agricultural waste products such as nut shells and rice hulls for energy production may be advantageous compared to disposal as waste by some other means.

Since one of the alternative practice would be the use of more stable compounds such as biochar[13] instead of the ordinary degradable organic manures to counteract soil fertility issues, global warming and waste disposal problems. Several studies acknowledge the effect of biochar in improving soil properties, minimizing nutrient leaching and promoting nutrient availability in less productive soils.Biochar is the carbon-rich product obtained when biomass is heated in a closed container with little or no available air through a process called pyrolysis. It is a mixture of char and ash, but it is mainly (70 - 95%) carbon [14]. It contains high concentrations of carbon that can be rather recalcitrant to decomposition, so it may stably sequester carbon [6]. It is also a porous material with high surface area Liang et al. [15] thus it can significantly affect soil moisture and nutrient dynamics [6],[16]. It can also increase soil aeration Laird [17] and reduce soil emissions of N_2O, a greenhouse gas [18], [19]. Generally, biochar can be a simple yet powerful tool to combat climate change and much speculation concerns the effects of biochar on microbial activity in soil [20]. In the study of Theis et al. [21], they stated that biochar can provide suitable habitat for microorganisms because of its high internal surface area and its ability to absorb soluble organic matter, gases and inorganic nutrients. Similarly, some studies also reported increased in microbial activity in soils enriched in biochar [19], [22]. Some indications also exist that soils rich in bio-char enhances microbial community composition, species richness, and diversity change with greater concentrations [23], [21].However, biochar is not easily degraded by soil microbes [6] which favor the use of this material for the sandy soils.

In terms on soil fertility issues, there are several studies reported that biocharwhen applied to sandy soil, can improve soil water holding capacity [24]. In similar way, it can improve soil strength and water- holding capacity of sandy soil ([10], [25]. All those positive influences make biochar an ideal amendment for the coarse textured soils. Although a positive effect of biochar amendments on crop yields and soil characteristics was already known to ancient cultures [13], to date little is known about the effects of biochar addition on soil microorganisms activity and consequently on the soil carbon balance. Poultry litter and peanut hull char as source of carbon material in the experiment have shown some scientific evidences that poultry litter biochar has the highest significant increase in Mehlich1 extractable P and sodium (Na) concentrations after application to loamy sand [26] and application also of peanut hull biochar to loamy sand was superior in supplying nutrients compared with pine chip biochar[27].

In Agriculture, there are less study giving enough information on the effect of poultry litter and peanut hull char mixture on microorganisms, thus, a better understanding of its influence to soil microbial population is needed and relatively little information is available on the agricultural and ecological value of combination of biochar from animal manure and plant biomass. Biochar from animal manure feedstock often have higher nutrient content than from plant biomass [28], [9]. Combined application of poultry litter and peanut hull char may result in greater positive changes in microbial activity and fertility of sandy soils. Evaluation on microbial population can be achieved through microbial respiration, in which CO_2 evolution will be determined. Since the study focusing on the influence of biochar to microorganisms, it is hypothesized that application of biochar could enhance microbial respiration while promoting nutrient availability in sandy soil.

OBJECTIVES OF THE STUDY

To determine the appropriate proportion of poultry litter and peanut hull char mixture in enhancing microbial respiration and improving some chemical properties on sandy loam soil.

MATERIALS AND METHODS

Soil Collection and Preparation

Sandy loam soil was collected at 0 - 20 cm soil depth near from Calbiga-A river at the Department of Agronomy and Soil Science Shed House, Visayas State University. Immediately after collection, the soil was air-dried and liberated from stones, litters, and roots. After two to three days of air-drying, sieving was done using a 2-mm wire mesh to ensure uniformity of the soil in terms of aggregate size and weight. Thereafter, the soil was characterized with initial pH (water), % OC and extractable P. Soil pH was analyzed potentiometrically using 1:2.5 soil-water ratio (PCARR, 1980); % Organic C (OC) was determined using the heanes' method (Heanes, 2010) and Extractable P was extracted using the Olsen method (PCARR, 1980).

Poultry Litter and Peanut Hull Char Processing

Charring was done using a modified Top Lit Updraft Double Barrel processing [8]. Sub-samples of air-dried poultry litter and peanut hull was placed into a tin can measuring 35 cm in height x 20 cm diameter (the carbonization chamber) at about ¾ height of the can. The carbonization chamber was tightly covered and placed in a drum measuring 80 cm in height x 40 cm diameter (the combustion chamber) with three holes (measuring 5 cm diameter) at its lower side. Three small cans measuring 5.8 cm in height x 5.2 cm diameter was placed under the carbonization chamber to facilitate airflow. After the set-up of the poultry litter and combustion chamber, the combustion chamber was filled with rice hull and wood chips at 3:1 ratio which acted as the combustion fuel to achieve an even burn. After a few minutes, a tin lid with a chimney (measuring 62 cm height x 8 cm diameter) was placed on top center of the drum to achieve a sufficient draft for a clean burn. During the 4 hours period of charring, temperature of about (500 ^{0}C and above) was monitored every 10 minutes using a thermometer attached to the external wall of the combustion chamber. After the poultry litter and peanut hull converted into char, the combustion and carbonization chambers was allowed to cool overnight at room temperature (28^{0}C) and removed from the carbonization chamber; weighed and placed in a sealed polyethylene bags ready for chemical analysis and incubation set-up. After charring, both poultry litter char (PLC) and peanut hull char (PHC) was ground and passed through to a 2mm sieve. The sieved PLC and PHC was also analyzed for pH, % OC and extractable P following the same method mentioned above.

Soil and Biochar analysis

Table 1. Chemical properties of soil and biochar before incubation

Chemical properties	Soil	Poultry litter char	Peanut hull char
pHwater (1: 2.5)	6.04	10.61	10.52
Organic C (%)	3.2		
Phosphorus (mg kg^{-1})	3.87	123.16	36.14

Set-up and Design

The study was carried out at the Soil Microbiology Laboratory of the Department of Agronomy and Soil Science, Visayas State University. There were seven treatments with three replications and laid out in a Randomized Complete Block Design. A control treatment (without an amendment) was included. The treatments were as follows:

T_1 = no amendment

T_2 = 50g Poultry litter char kg^{-1} dry soil

T_3 = 50g Peanut hull char kg^{-1} dry soil

T_4 = 40g Poultry litter char kg^{-1} dry soil + 10g Peanut hull char kg^{-1} dry soil

T_5 = 30g Poultry litter char kg^{-1} dry soil + 20g Peanut hull char kg^{-1} dry soil

T_6 = 20g Poultry litter char kg^{-1} dry soil + 30g Peanut hull char kg^{-1} dry soil

T_7 = 10g Poultry litter char kg^{-1} dry soil + 40g Peanut hull char kg^{-1} dry soil

Reference jars = 100 mL distilled water

Before amendment, air-dried 100 g soil (unamended) was placed in a glass jar measuring 8 cm diameter and 20 cm height and allowed to equilibrate at room temperature for 24 hr. After which, specified proportions of PLC and PHC was mixed well with pre-equilibrated soil. After addition, the soil moisture was adjusted 50% of its field capacity. After the organic materials were mixed with soil, a 50-mL beaker with 15mL 1N NaOH that serve as alkali trap was placed right away inside the glass jars positioned securely on the soil surface. The jars were covered with a lid to avoid CO_2 contamination from the outside atmosphere and wrapped with two layers carbon paper to block any light from passing through the transparent glass. Wrapping the jars with carbon paper was done to preclude the growth of photosynthetic microorganisms, such as algae. The samples were then incubated at room temperature (27-28^{0}C). A reference jar with only NaOH and distilled water was placed also under the same conditions to take into account the initial carbonization of NaOH. During the entire incubation period, the CO2 that evolved was measured weekly at 0, 7th, 14th, 21st, 28th day of incubation and subjected to titration method. At each sampling period, the alkali trap was taken out from the jar for determination of the amount of CO_2. Alkali solution was replaced with a freshly prepared NaOH at every examination period. Titration was also performed by collecting the beaker of 15ml 1N NaOH from each jar and transferring the liquid into a 125 ml Erlenmeyer flask. This was repeatedly done wherein one beaker was collected at a time and after each collection, then the jar was immediately covered. Using a volumetric pipette, 1 ml of 0.5 N BaCl2.2H2O was added into the Erlenmeyer flask to precipitate the carbonate in the alkali as insoluble Barium carbonate. Afterwards, 2-3 drops of phenolphthalein was added. If the solution displayed a pink color this is attributed to the unneutralized alkali still present which entailed titration with 1 N HCl. Titration was done gradually while swirling the flask at the same time until reaching the endpoint as indicated by the disappearance of the pink color. The initial and final readings of titration volume marked on the 25 ml burette were carefully recorded before and after titration. In instances when no color appeared, no titration was done.

At the end of four weeks incubation, unamended and biochar amended soil samples was removed from the jar, air-dried and analyzed for pH, % OC and extractable P using the methods described above bases for soil chemical properties.

Calculation of CO2 evolved

The respiration value (mg CO_2 100 g^{-1}) dry soil was computed using the formula:

Milligrams C or CO_2 = (B-V) NE

Where:

B =titration volume (ml) of HCl in the blank (without soil)
V =titration volume (ml) of HCl in the treatments with soil
N =Normality of the acid (0.97268)
E =equivalent weight of CO_2 which is 22

Data analysis

Statistical analysis was done using the Sirichai Statistic Version no. 6. The data collected was subjected to analysis of variance (ANOVA) at 5% significance level to determine whether there were differences on the CO2 evolved and on some chemical properties of sandy soil as affected by different proportion of poultry litter and peanut hull char mixture. Duncan's Multiple Range Test (DMRT) was used to determine which of the treatment means were significantly different from the other.

RESULTS AND DISCUSSION

Effects of Biochar Mixture on Microbial Respiration

Means for cumulative CO_2 evolved (mg 100 g^{-1} soil) throughout the 28 days of incubation experiment is presented in Table 2 and Figure 3. Results showed that microbial respiration rates did not differed between the treatments except control ($P< 0.05$). Using sandy loam soil, both biochar treatment combinations (PLC+PHC) in different proportions showed similar respiration rates. The highest respiration rate was measured in the treatment with poultry litter derived biochar alone (50g PLC kg^{-1} soil) T2, which was significantly higher ($P< 0.05$) than the treatment with combinations within the first 0 day up to last day of the incubation experiment (Table 2, Figure 3).

Table 2. Means of cumulative CO_2 evolved (mg 100 g^{-1} soil) throughout the 28 days of incubation experiment as affected by levels of poultry litter and peanut hull char mixture

Treatments	CO2 evolved (mg 100 g-1 soil
Control	16.91 b
50g PLC Kg^{-1} soil	97.80 a
50g PHC Kg^{-1} soil	87.10 a
40g PLC Kg^{-1} soil + 10g PHC Kg^{-1} soil	85.67 a
30g PLC Kg^{-1} soil + 20g PHC Kg^{-1} soil	96.37 a
20g PLC Kg^{-1} soil + 30g PHC Kg^{-1} soil	84.60 a
10g PLC Kg^{-1} soil + 40g PHC Kg^{-1} soil	86.88 a
LSD (5%)	15.61

Means not sharing letter in common differ significantly at 5% level by Duncan's multiple range test.

The highest CO_2 evolved was obtained by application with poultry litter char alone (T2) and the lowest was measured by Treatment 1 (no amendment). Respiration rates showed a strongly increased trend within day 0 to day 7 of incubation and had leveled off immediately started at day 7 and continuously extend in decreased trend up to day 28 in all treatments except in T4 (Figure 3). The increasing trend in respiration rates within day 0 to day 7 indicates that addition of biochar mixture with different proportions provides potential nutrient or energy source for microbes upon decomposition of material. Although black C in general is presumably very stable, Shneour [29] reported a significant oxidation of graphite (the most stable form of black C) by microorganisms. Therefore, decomposition also of bio-chars can be expected. According to Sarong [8] maintenance of organic matter in sandy soils is often a problem and thus require a more stable C source, thus CPL (charred poultry litter) is better alternative source than UPL (uncharred poultry litter). The decreasing trend in respiration rates also indicates inactivity and death of microorganisms within day 7 up to day 28 of incubation experiment. In the case of T4in Figure 3, the respiration rates showed a constant evolution of CO_2 within day 14 to day 21 which probably due to some microorganisms who are still able to survive by feeding those dead microorganism until such time that there were no available food for survival which tend to have a decreased in respiration.

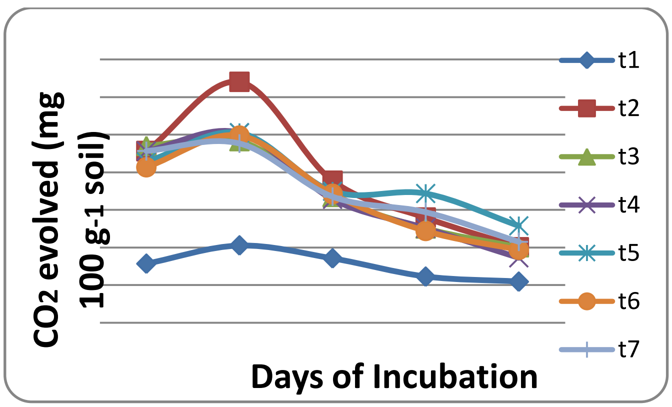

Figure 3. Cumulative CO_2 evolved (mg 100 g-1 soil) for the day 0, 7, 14, 21, and 28 days of incubation as affected by levels of poultry litter and peanut hull char mixture

Generally, the cumulative CO_2 produced throughout the 28 days of incubation was influenced by different proportions of poultry litter and peanut hull char but there were no significant differences between the treatments at 5% significance level. Application with biochar mixture during 28 days of incubation represented an irregular trend of cumulative CO_2 evolution as shown in Figure 3. This also illustrates that application of biochar with different proportions in sandy loam soil provides a convenient way of improving the soil organic matter and reduce C emissions as well.

Effects of Biochar mixture on some chemical properties

Chemical properties of sandy loam soil after 28-days of incubation such as pH, OC and extractable P are presented in Table 3. Results showed that there were significant increased in soil pH, organic carbon and extractable P in all treatments using sandy loam soil after the 28-days of incubation experiment. A similar linear increasing trend on soil pH, total N and extractable P was observed [8].

Soil pH describes the acidity and alkalinity of the soil. Sandy loam soil has initial pH of 6.04 (Table 1), after the 28-days of incubation experiment showed a positive increased of soil pH in all treatments with a range of 7.24 to 7.71(Table 3). Application also of biochar with different proportions showed a significant increased in soil pH. Van Zwieten et al. [30] and Chan et al. [28] also observed an increase in soil pH after the application of biochar. In addition, other studies showed that there was a significant positive linear relationship between biochar rate and soil pH [31]. The highest pH after incubation was measured in T1 (no amendment at all) in compared to other treatment with biochar proportion and the lowest soil pH obtained by the application of poultry litter char alone (T2). Some expectations in different studies are the positive increase of soil pH after organic material application superior to unammended soil. Since, hydrogen ion activity (pH) of soil would contribute on the growth and proliferation of soil microbes. The result explains that the production of NH_4^+, CO_2 and organic acids during microbial metabolism may contribute to the decrease in soil pH instead of increasing the soil pH superior to the control treatment. This is attributed to adverse effect of pH favorable and biochar application on soil microbial activity, which contributes to high respiration rate during the day 7 of incubation experiment and consequently high CO_2 evolution. However, soil pH beyond 7.0 adversely affected CO_2 emission.

Results also showed that application of different proportions of biochar significantly increases ($P<0.05$) the total organic carbon concentration (OC) after the incubation experiment especially in T5 (30g PLC Kg^{-1} soil + 20g PHC Kg^{-1} soil) (Table 3). In an acid sandy soil, direct effects of application of poultry litter char at rates 10, 20, 30 and 40 g kg^{-1} soil resulted in significant linear increase in SOC at 20 days after application (Sarong, 2012). The highest organic carbon content was measured on the treatments applied with peanut hull char alone (T3) and those treatments containing high percentage of peanut hull char in biochar proportions and the lowest was obtained by T2 (poultry litter char alone). The results could be due to the explanation that the biochar derived from a plant material contains greater amount of carbon content than from animal wastes.

In the presence of biochar with different proportions, soil soluble P increased significantly ($P<0.05$) in all treatments after 28days of incubation experiment especially T5 (Table 3). The highest P content was obtained by the application of poultry litter char alone (T2) which could be attributed to the P contained in poultry litter char. In similar study, Uzoma et al. [31] reported that in the presence of biochar, soil soluble P increased significantly due to the high P content present in cow manure biochar. Revell et al. [32] added that addition of poultry litter biochar with pH 9.3 increased the pH of sandy loam and a silt loam and observed great increased in Mehlich1 and Olsen Total phosphorus (P) of about 43 g kg^{-1}.

Table 3. Means of soil pH $_{H2O}$, organic carbon and extractable P after 28 days of incubation as affected by levels of poultry litter and peanut hull char mixture

Treatments	pH H_2O (1-2.5)	Organic carbon (%)	Extractable P (mg kg^{-1})
Control	7.70a	3.80d	4.67f
50g PLC Kg^{-1} soil	7.24c	5.53c	59.09a
50g PHC Kg^{-1} soil	7.71a	7.09ab	18.70b
40g PLC Kg^{-1} soil + 10g PHC Kg^{-1} soil	7.31bc	6.41b	15.61c
30g PLC Kg^{-1} soil + 20g PHC Kg^{-1} soil	7.69a	7.57a	12.17d
20g PLC Kg^{-1} soil + 30g PHC Kg^{-1} soil	7.61ab	6.89ab	10.28d
10g PLC Kg^{-1} soil + 40g PHC Kg^{-1} soil	7.68a	6.70ab	6.95e
LSD (5%)	0.3	0.83	1.95

Means not sharing letter in common differ significantly at 5% level by Duncan's multiple range test.

CONCLUSION AND RECOMMENDATION

It could be concluded in the study that the proportions of biochar have no significant differences in enhancing the CO_2 evolved using sandy loam soil. However, application of different proportions of biochar promoted nutrient availability in sandy loam soil such as soil pH, % organic carbon and extractable P. Generally, T5 = 30g PLC Kg^{-1} soil + 20g PHC Kg^{-1}soil is the appropriate proportion of biochar in enhancing microbial respiration and promoting nutrient availability of sandy loam soil.

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