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Carbon and Phosphorus Mineralization from Soils Amended With Cow Dung or Rice Husk Ash

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Abstract: Decomposition of agricultural waste liberates organically-bound nutrient to inorganic form for increased soil fertility and crop productivity. The present investigation delineates carbon and phosphorus mineralization from sandy and clay soils of Peninsular Malaysia amended with cow dung or rice husk ash. Laboratory incubation was conducted for 60 days and a replicate sample of the either soils were incorporated with cow dung or rice husk ash at equivalent rate of 10 t ha^{-1} under dark condition at 23^{o}C temperature and field capacity moisture content. The samples containing neither cow dung nor rice husk ash from both soils were included as controls. At fixed intervals, the amount of carbon and phosphorus mineralized from both treatments was determined using standard analytical methods. Temporal increase in carbon mineralization was observed in both the control and amended soils. Sandy soil amended with cow dung or rice husk ash had higher carbon evolution than control while the reverse was obtained from the clay soil. The cumulative carbon evolved from the sandy soil was 82.159, 88.175 and 91.750 µg g^{-1} for control and soil amended with cow dung and rice husk ash respectively while the respective values for these treatments from the clay soil were 112.336, 96.755 and 90.197 µg g^{-1}. When the means of carbon evolution from the two soils were compared, clay soil had higher evolution (19.952 µg g^{-1}) compared to sandy (17.477 µg g^{-1}). Incorporating cow dung or rice husk showed higher extractable phosphorus from both soils compared to control. There was three phases in both carbon and phosphorus mineralization pattern; initial flush, followed by a declined then a phase of slow increase. Sandy soil had higher mean values (29.571 µg g^{-1}) of extractable phosphorus than clay (8. 601 µg g^{-1}) and this was attributed to acidic nature of clay soil resulting into phosphorus precipitation and adsorption by soil clay and oxides of Fe and Al. The present result showed decomposition potential of cow dung and rice husk ash in these soils.

Keywords: Carbon, Phosphorus, Mineralization, Cow dung, Rice husk ash, Soil.

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1. Introduction

Climate greatly contributes to an inherent low fertility of many tropical soils. Intensive crop cultivation, continuous livestock grazing and erosion are causing significant loss of organic matter and nutrient depletion (Dossa et al., 2009). Low fertility constraints have negative impacts on livelihood of farmers due to consequent soil degradation and poor crop yield. It amelioration is achieve through additional input of fertilizers. Due to high cost of inorganic fertilizer, the resource-poor farmers rely on organic input for sustain soil fertility (Mafongoya et al., 2000). Organic waste utilization as soil amendments is an important management practice with driving benefit for soil fertility and environmental management (Ahmad et al., 2016; Benbi and Yadav, 2015; Oku et al., 2015). Its benefit includes increase in nutrient availability for plant growth, improvement of soil structure and microbial function. Agricultural waste contains substantial amount of essential nutrient in their organic form and their availability in soils is related to their conversion to inorganic forms (Mamo et al., 1999). Decomposition process which liberates organically–bound nutrient to an inorganic forms is associated with CO_2 released (Mafongoya et al., 2000). A number of organic materials such as manure, sewage sludge, crop residues, compost and municipal waste are being incorporated into the soil as a source of nutrient and for improving soil quality (Rasmussen and Collins, 1991; Six et al., 2002). Cow dung (CD) is one of the agricultural waste abundantly found in Malaysia and was reported to have high content of carbon (C), nitrogen (N), phosphorus (P) and other nutrient (Yoshitake et al., 2014). It decomposition therefore can increase soil nutrient and humus which helps in increasing aggregate stability for enhanced aeration and water retention. Application of cow dung was reported to increased soil electrical conductivity, inorganic P, total P and basic cations (Aarons et al., 2004). Dhital et al., (2010) reported 28.2 and 25.6 g C m^{-1} as C input returned to soil for the year 2007 and 2008 respectively due to cow dung decomposition. Cow dung therefore, plays an important role in ecosystem C balance.

Due to aromatic structure of black C containing materials, they serve as a source of the most stable form of C in soil (Masulili et al., 2010; Harris et al., 2013; Rasul et al., 2016; Mehmood et al., 2017). These materials were also shown to stimulate native organic matter mineralization (Wardle et al., 2008) due to their long-term C sink thus, enhances soil microbial activities. Rice husk ash (RHA) is one of the black C containing materials which is a product of low temperature combustion of rice husk hence contains fraction of aliphatic C that can easily be mineralize by soil microorganisms (Bruun et al., 2008; Smith et al., 2010). Rice husk ash was shown to increase soil pH, C and available nutrient for crop growth (Masulili et al., 2010). The ability of rice husk ash in increasing soil pH is an added advantage as it can be a substitute of liming materials for reducing cost especially in small farm holdings. Application of rice husk ash decreased soil bulk density but increased porosity and water holding capacity of an Ultisols (Njoku and Mbah, 2012). Also, the authors reported an increase in soil pH, organic C, exchangeable bases and CEC in rice husk ash amended soil compared to control.

Knowledge of nutrients mineralization helps in assessing the contribution of organic material in increasing soil nutrient content. Carbon mineralization is studied through CO_2 measurement while for other element especially P several compounds solutions are used for the extraction of its different forms from soils. Soil properties affect the rate of nutrient mineralization hence availability. This necessitate for continuous research on nutrient mineralization pattern of these organic materials. The present study therefore, aimed at investigating C and P mineralization from sandy and clay soils amended with cow dung or rice husk ash.

2. Materials and Methods

2.1 Sampling

The Benta soil series was collected from Sementa Hulu (Lat 3.841663 0N Long 101.947251 0E), Raub district Pahang, Malaysia. This soil was texturally classified as sandy and Alfisols according USDA soil classification (Saleh, 1997). The Munchong soil series was texturally classified as clay and Oxisols by Paramananthan, (2000), and it was collected from the experimental farm (Lat 2.986460 0N Long 10.173313 0E), Faculty of Agriculture, University Putra, Malaysia. Surface soils (0-20cm) were sampled from different locations in the sample areas and later bulked to one sample. The selected properties of both soil are shown in Table 1. Cow dung was collected from the animal section of the experimental farm, Faculty of Agriculture, University Putra Malaysia while rice husk ash was obtained from Sungai Besar Berhad Selangor-Malaysia. All the samples were properly air dried sieved and stored in a clean container before the study.

2.2 Laboratory incubation study

Two hundred and fifty grams of either Munchong or Benta were weighed into plastic container (11 × 9 cm). The Benta soil was added with 1.15g of either CD or RHA while Munchong received 1g of either CD or RHA to give equivalent rate of 10 t ha^{-1}. The soils without CD or RHA were included as controls. The soils with added residues were mixed by repeated stirring with a stainless steel rod for homogenization.

Table 1 Characteristics of the soils used in the incubation study

Parameter	Benta	Munchong
Sand (%)	74.17	17.50
Silt (%)	5.83	9.17
Clay (%)	20.00	73.33
Soil type	**sandy**	**clay**
Db (g cm^{-3})	1.45	1.38
pH	6.73	3.66
SOM (%)	5.23	10.57
C (%)	1.67	2.12
N (%)	0.16	0.18
P mg kg^{-1}	6.95	73.66
CEC ($cmol_{(+)}$ kg^{-1})	12.67	11.91

All the soils were moistened to field capacity and a plastic vial containing 20 ml of 0.05M NaOH solution was placed into the containers to trap CO_2-C, and subsequently capped with tight-fitting lids.

All the containers were arranged in completely randomized design with three replicate on the laboratory bench at temperature of 23°C under dark condition. The solution of 0.05M NaOH was being removed at 4, 8, 20, 35 and 60 days interval for CO2-C determination and the new one was being replaced immediately. Similarly 2 g of soil was taken at 10, 35 and 60 days interval for the determination of extractable P. The moisture content was kept at field capacity by weighing the containers weekly and adding water where necessary. The lids of the containers were uncapped regularly to ensure oxygen supply. The soils were also stirred and rehomogenized at time interval to simulate the regular soil disturbance in the field. These practices bring about soil churning and homogenization, which are likely to have impact on mineralization and nutrient release from organic residues in the field (Agbenin, et al., 2008).

2.3 Analysis

The 0.05M NaOH solution removed at the fixed interval was added with 5 ml 0.5M BaCl2 to precipitate the C (Alef, 1995). This followed by addition of some drop of phenolphthalein indicator and the mixture was back titrated with 0.05M HCl to the end point. The CO_2-C was calculated using the equation below:

$$CO_2 - C = \frac{(Vo - V)\ x\ \ 1.1}{dwt}$$

Where vo: volume of the HCl for blank (ml); v: volume of the HCl for sample (ml); dwt: weight of the soil (g)

The P was analyzed according to Bray and Kurtz 2 method (Keeney et al., 1982). Briefly, the 2 g weighed soil inside the centrifuge tube was added with 14 ml extracting solution (0.03N NH4F + 0.1N HCl). The sample mixture was wrist inverted for 45 second then filtered through Whatman no. 42 filter paper. The contents of P was then determined using Lachat Instruments QuickChem 8000 series FIA+ System auto analyzer.

2.4 Statistical analysis

All the data was subjected to analysis of variance (ANOVA) using SAS 9.4 statistical software. The treatment means were separated using least significant difference (LSD) and the significant means were grouped using student Tukey range test.

3. Results and Discussion

3.1 Carbon mineralization

Application of CD or RHA had no significant ($p > 0.05$) increase in CO_2-C evolution in Benta soil however, Munchong soil with neither CD nor RHA was significantly ($p < 0.05$) higher in CO_2-C evolution compared to that with CD or RHA. Table 2 shows the mean values of CO2-C evolved from both soil due to treatments effect. The control Munchong had higher CO_2-C evolution (22.467 µg g^{-1}) compared to that added with CD (19.351 µg g^{-1}) or RHA (18.039 µg g^{-1}). This can be attributed to inhibition of microbial activities due to some changes in the soil environment and adsorptive protection of native organic matter as a result of CD or RHA application. Decomposition of added organic residues and soil organic matter mineralization are the major pathways of C cycling in soils (Wang et al., 2015). Addition of organic residues can therefore, be a source or sink of soil C having serve as substrate for soil microorganisms and priming effect on soil organic matter mineralization. This priming effect can be positive when an organic input accelerates mineralization through increase in extracellular enzymes production, nutrient addition, improvement of soil structure for aeration and moisture retention (Kuzyakov et al., 2000). On the other hand, addition of organic residues can instigate negative priming effect on mineralization through N immobilization and adsorptive protection of soil organic matter (Zimmerman et al., 2011). Similarly fine soil textured was reported to physically protect organic matter decomposition through adsorption by soil clay surfaces (Van Veen and Kuikman, 1990; Qayyum et al., 2014; Jien et al., 2015).

The present study therefore suggest that, soil disturbance due to drying, grinding and rewetting coupled with CD or RHA incorporation changed the structure of this soil which led to formation of new aggregates. Considering the higher clay content of this soil, the new formed aggregates adsorbed the added organic residues and wrapped them thereby preventing them from rapid decomposition by microorganisms.

Our result shows that CO_2-C evolution due to CD amendment to the Munchong soil was statistically similar with RHA, even though result of their analysis (data not shown) revealed that CD had higher C content and lower C:N ratio than RHA. This can be attributed to short time period of the incubation in which the microbial attack on these residues led to loss of only readily decomposable substrate and leaving more resistant substances for further decomposition (Stevenson, 1994).

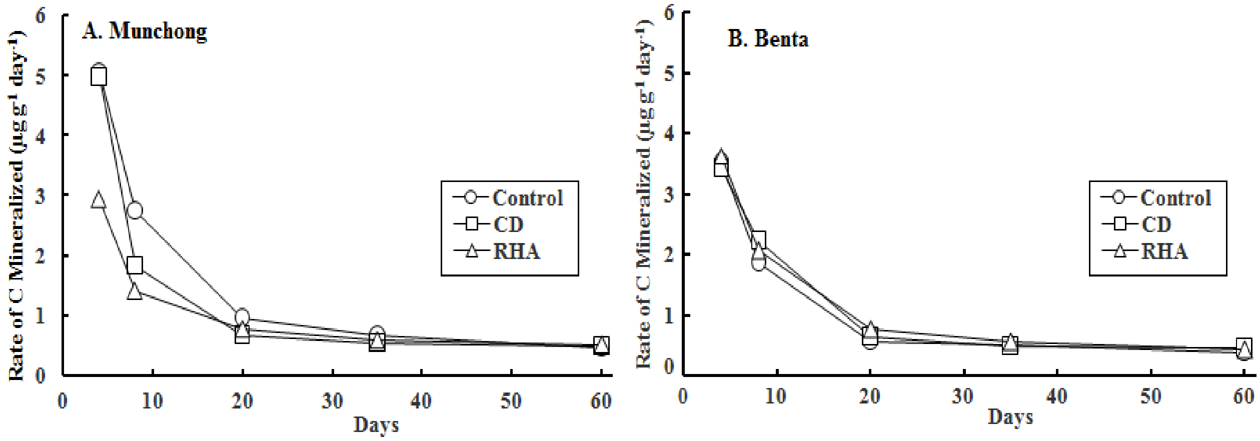

Figure 1 Rate of CO_2-C mineralization of the studied soils

Combustion process of RHA production altered chemical composition of parent rice husk which led to oxidation of volatile C compound leaving only stable and recalcitrant compounds. However, Zimmerman et al. (2011) reported that, low temperature produced biomass are least partially biotical and chemically reactive thus, tends to show rapid C mineralization.

Incorporating CD or RHA increase CO_2-C evolution from the Benta soils, even though the difference compared to control was not significant possibly because of the short period of the study. However, it can be postulated that, long term incubation of these added residues will result into increase C mineralization. Decomposition of organic residues provides energy to organisms and nutrient for uptake by both microorganisms and plants (Van Veen and Kuikman, 1990), it also add soil humic and fulvic acid which helps in stabilizing soil aggregate for improving soil structure in water and nutrient retention.

Result of CO_2-C evolution rate from controls and soils treated with CD or RHA during the 60 days of incubation is shown in Figure 1. The rate of decomposition from both soils was high (≥ 70%) at the initial 10 days, then continuously decreased up to the end of incubation period. The rate of CO_2-C mineralization in Munchong soil was high from control compared to the soil treated with CD or RHA. In contrast, Benta soils treated with RHA was high in CO_2-C mineralization rate which followed by that treated with CD then control. Rate of C mineralization during incubation period may not reflect the actual rate occurring in the field due to physical alteration of soils and the selected residues, control temperature and moisture, restriction of soil microbial community (Dossa et al., 2009) associated with laboratory incubation study. However, the result obtained provides useful information in relating decomposition potential of a residue planned to be used as soil amendment. There was a significant ($p < 0.05$) difference on CO_2-C evolution between time intervals measured during the incubation period from both soils.

As shown in Table 3, the CO_2-C evolved during the incubation period considerably varied between the treatments from both soils. The values range of 11.733 µg g^{-1} to 31.020 µg g^{-1} was obtained from Munchong soil while Benta soil had 11.362 µg g^{-1} to 27.317 µg g^{-1}. Out of the total CO_2-C evolved from control Munchong, 18 and 20% evolved at 4 and 8 days of incubation respectively, while the respective amount evolved at 20, 35 and 60 days represent 17, 21 and 24%. The Munchong soil amended with CD had 21% CO_2-C evolution at 4 days then, amount evolved at 8, 20, 35 and 60 days represent 15, 14, 20 and 30% respectively.

Table 2 Mean values of cumulative CO_2-C released from control and the soils amended with cow dung or rice husk ash

Treatments	**Soils**	
	Munchong (µg g^{-1})	**Benta (µg g^{-1})**
Control	22.467^a ± 4.49	16.432 ± 4.76
Cow dung	19.351^b ± 6.52	17.635 ± 5.80
Rice husk ash	18.039^b ± 7.88	18.350 ± 5.82

Means with the same letter are not statistically significant (n=15, ± S.D)

Table 3 Net CO_2-C mineralized from control and treated soils at fixed intervals of the incubation period

Days	Munchong ($\mu g\ g^{-1}$)			Benta ($\mu g\ g^{-1}$)		
	Control	CD	RHA	Control	CD	RHA
4	20.240^{ab}	19.947^{b}	11.733^{c}	14.080^{c}	13.640^{bc}	14.520^{b}
8	22.00^{ab}	14.667^{bc}	11.293^{c}	14.813^{bc}	17.707^{b}	16.573^{b}
20	19.328^{b}	13.426^{c}	15.492^{c}	11.362^{c}	12.690^{c}	15.199^{b}
35	23.459^{ab}	19.327^{bc}	20.656^{b}	18.150^{b}	16.822^{bc}	19.478^{ab}
60	27.310^{a}	29.388^{a}	31.020^{a}	23.754^{a}	27.317^{a}	25.981^{a}

Means with the same letter are not statistically significant.

Munchong soil amended with RHA had 13% CO_2-C evolution at 4 and 8 days each, while the amount evolved at 20, 35 and 60 days represent 17, 23 and 34% respectively. Similarly, the percent CO_2-C evolution from control sample of Benta was 17% at 4 days, 18% at 8 days and 14% at 20 days. Meanwhile the amount evolved at 35 and 60 days represent 22 and 29% respectively. The Benta soil amended with CD had 12% CO_2-C evolution at 4 days while the amount evolved at 8, 20, 35 and 60 days represent 20, 14, 19 and 31% respectively. The percent amount of CO_2-C evolution from Benta soil amended with RHA was 16, 18 and 17% at 4, 8 and 20 days respectively, while 21 and 28% are the respective percent evolved at 35 and 60 days. Organic matter decomposition is carried out by microorganism and extracellular enzymes in the soils (Schmidt et al., 2011; Lehmann and Kleber, 2015). Its rate and subsequent nutrient release is control by prevailing environmental factors necessary for growth and development of these organisms, these includes temperature, pH, moisture content and to great extent the nature and composition of the added organic materials (Dao and Schwartz, 2010; Davdson and Janssens, 2006; Plante and Conact, 2014; Six et al., 2002).

Figure 2 depicted the cumulative mineralized CO_2-C over time which shows a curvilinear relationship between the mineralized C and time of incubation thereby suggesting different pool of C releasing at different time and rate (Mohanty et al., 2013). The result also shows that, at any given time, the CO_2-C evolution from Munchong soil was greater for control over the CD or RHA amended soils while in Benta application of RHA shows high CO_2-C evolution from the fixed intervals than CD and control. The order of cumulative CO_2-C evolved at the end of incubation from Munchong soil was, control > CD > RHA while, that of Benta soil was RHA > CD > control.

The net CO_2-C evolution pattern from both soils was similar (Table 3) with high initial flush during the first 10 days which was attributed to depletion of easily mineralizable fraction, then a decline in evolution and a linear increase up to the end of incubation period. The high initial flush can be attributed to native soil organic matter solubility and microbial death due to drying, sieving and rewetting of these soils. The decreasing phase indicated the exhaustion of the easily mineralizable fraction or the beginning of decomposition of the added residues which might couple with low substrate supply and lesser microbial activity hence low CO_2-C evolution.

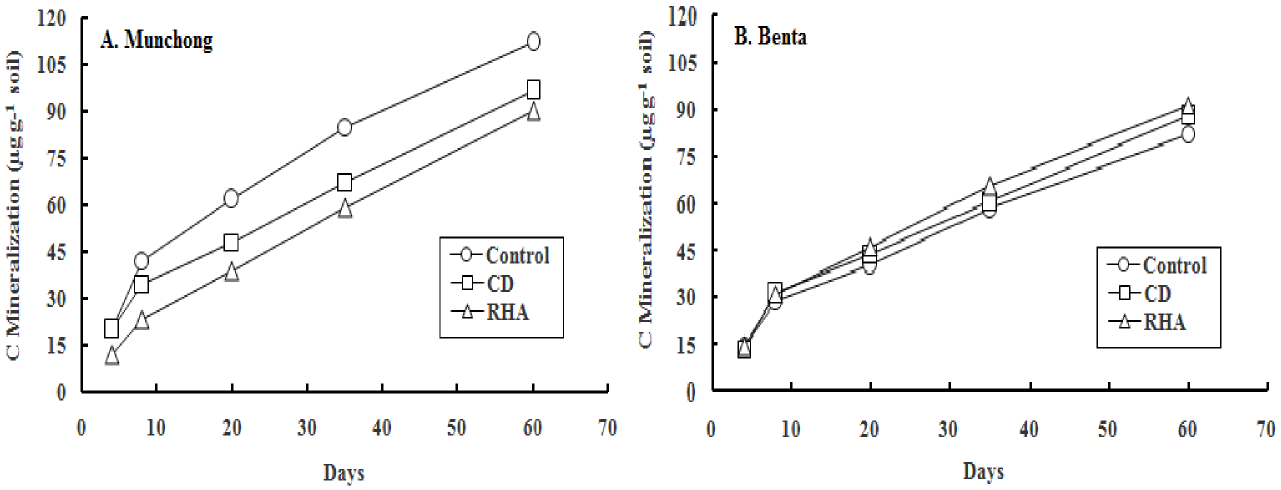

Figure 2 Cumulative CO_2-C mineralized from the studied soils

Table 4 Mean values of CO_2-C evolution from the two soils

Soils	CO_2-C evolved (µg g^{-1})
Munchong	$19.952^a \pm 5.41$
Benta	$17.472^b \pm 6.57$

Means with the same letter are not statistically significant (n=45, ± S.D).

However, the later linear increased can be ascribed to proceeding decomposition of the added residues and/or microbial attack on none-easily mineralizable C fraction of the soil organic matter. The present result agrees with Riffaldi et al. (1996) who reported a curvilinear relationship between cumulative C mineralized and time of incubation. As opposed to the pattern of CO_2-C evolution from Munchong, application of organic residues were shown to be greater in CO_2-C evolution compared to control at fixed intervals during incubation (Mamo et al., 1999; Iyamuremye et al., 2000; Dossa et al., 2009) however, the pattern obtained from Benta soils agrees with their result.

The drying, grinding and rewetting of soil attributed to the initial flush were reported to results into availability of simple sugars and starch (Bernhard-Reversat, 1999), humic substance solubility (Benbi and Yadav, 2015), microbial death and regrowth (Mishra et al., 2016) which are all associated with rapid CO2 release. Dossa et al. (2009) reported that, second and third phase of decomposition represent increasingly difficult-to-degrade and slowly biodegradable compounds. Sall et al. (2003) attributed the decline in CO_2-C evolution at the second phase not only to disappearance of simple sugars in the organic residues but also due to appearance of polyphenols which could inhibit microbial growth and organic matter decomposition. The present result therefore, give a hint in estimating C mineralization potential of the studied soils through monitoring CO_2 fluxes over time. It also offered an insight in assessing the decomposition pattern of the added residues.

Table 4 shows the mean values of CO_2-C evolution from the two soils. Munchong soil was significantly ($p < 0.05$) higher in C mineralized compared to Benta, and this can be attributed to differences in their properties most importantly organic matter content and nutrient elements. The result of soils analysis (Table 1) indicated high C, N, P and soil organic matter content in Munchong compared to Benta which therefore, suggested to be the reason for it higher C mineralization. Among other factors, soil properties affect decomposition of added organic input in soil and mineralization of soil organic matter (Navarro-Pedreno et al., 2014). Soil texture and pH were among the important soil properties affecting organic matter decomposition. Fine textured soil affects decomposition through adsorption of organic matter by inorganic clay surfaces and its entrapment in small aggregate thereby not accessible by microbes. Therefore in contrast to our present result, Huang and Chen, (2009) reported rapid C mineralization in a coarse-textured soil than in fine textured soil. However, earlier study by Scott et al. (1996) reported none effect of texture on litter decomposition from soils with different textural class. Meanwhile, Franzluebbers et al. (1996) observed an increased in soil microbial biomass C with increasing soil clay content with no relationship between mineralized C and texture. Similarly, contrary to our result, higher CO_2 evolution was reported in soil with pH 5.06 compared to that with pH of 3.87 (Kemmitt et al., 2006). Sewage sludge decomposition and C mineralization was also reported to be favored by high soil pH (Navarro-Pedreno et al., 2014).

3.2 Phosphorus mineralization

Incorporating CD or RHA significantly ($p < 0.05$) increased extractable P from both soils (Table 5). Application of CD had higher P mineralized from both soils which was at par with the soils amended with RHA while the control was the least but statistically similar with Munchong soil amended with RHA. Result of the chemical analysis (data no shown) indicated that CD contains more P than RHA thus, suggested to increase the amount of extractable P in soils compared RHA.

Table 5 Mean values of extracted P from control and the soils amended with cow dung or rice husk ash

Treatments	Site	
	Munchong (P µg g^{-1})	**Benta (P µg g^{-1})**
Control	$7.8356^b \pm 5.76$	$27.221^b \pm 10.93$
Cow dung	$9.4578^a \pm 4.56$	$30.959^a \pm 11.26$
Rice husk ash	$8.5111^{ab} \pm 5.16$	$30.534^a \pm 12.50$

Means with the same letter are not significantly different (n=9, ± S.D).

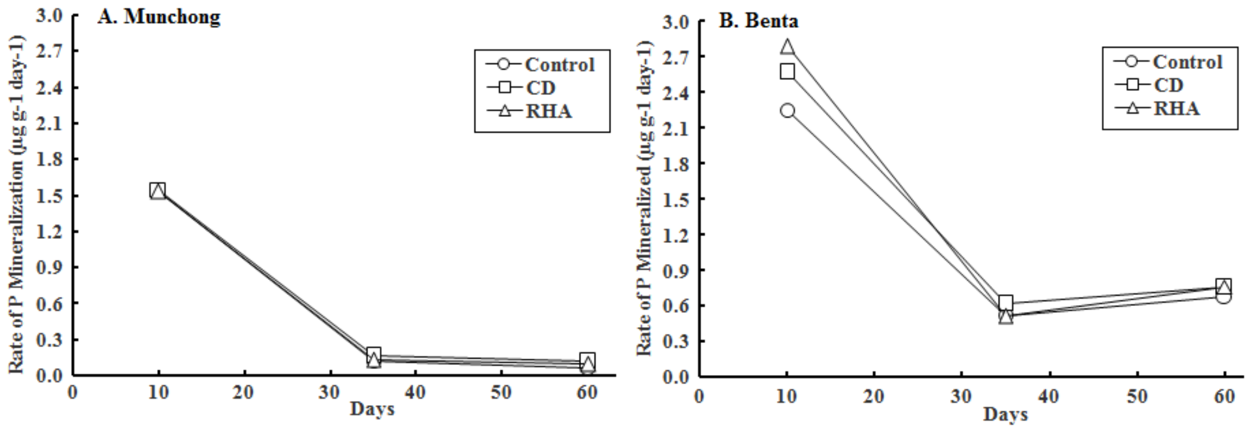

Figure 3 Rate of P mineralization from the studied soils

A common way of organic waste disposal is their incorporation into the soil and this increase soil fertility by improving soil properties, augmenting microbial activity and nutrient release (Whalen et al., 2001; Bhatt, 2017). The present result agrees with Dossa et al. (2009) that reported higher P mineralized in organic input amended soil compared to control. Incorporating organic residues to loamy sand, in southern Australia, increases all the P fractions except microbial biomass P (Alamgir et al., 2012). However, Barajas-Aceves and Dendooven, (2001) reported none significant difference between control and sludge amended soils in P mineralization during 70 days incubation period. The higher P mineralized due to application of these organic residues compared to control can be attributed to their soluble P content which was reported to easily mineralize upon applied into the soils (Kwabiah et al., 2003). This result therefore, suggested that application of CD or RHA helps in increasing P availability in the studied soils.

Figure 3 depicted rate of P mineralization during the incubation period from both soils. Munchong soil shows a continuous decline in rate over time with 12 times decrease from control at 35 days compared to the rate at 10 days and 2 times decrease at 60 days compared to the rate at 35 days. Munchong soil amended with CD had 9 times decrease in rate at 35 days compared to 10 days while the decrease was 1.5 times at 60 days compared to 35 days. There was 11 times decrease in P mineralization rate at 35 days compared to 10 days from Munchong soil amended with RHA and rate declined further with 1.4 times at 60 days compared to 35 days interval.

In contrast, P mineralization rate in Benta soil shows initial flush followed by a declining rate at 35 days interval and a slow increase in rate at 60 days of incubation. Benta soil amended with RHA shows higher initial rate followed by control then the soil amended with CD. The rate decreased to 4 times at 35 days compared to the rate at 10 days in both control and soil amended with CD while the rate decreased up to 5 times in RHA amended soil. Meanwhile, the P mineralization rate increased by 1 fold in both the control and soils amended with CD or RHA at 60 days of incubation.

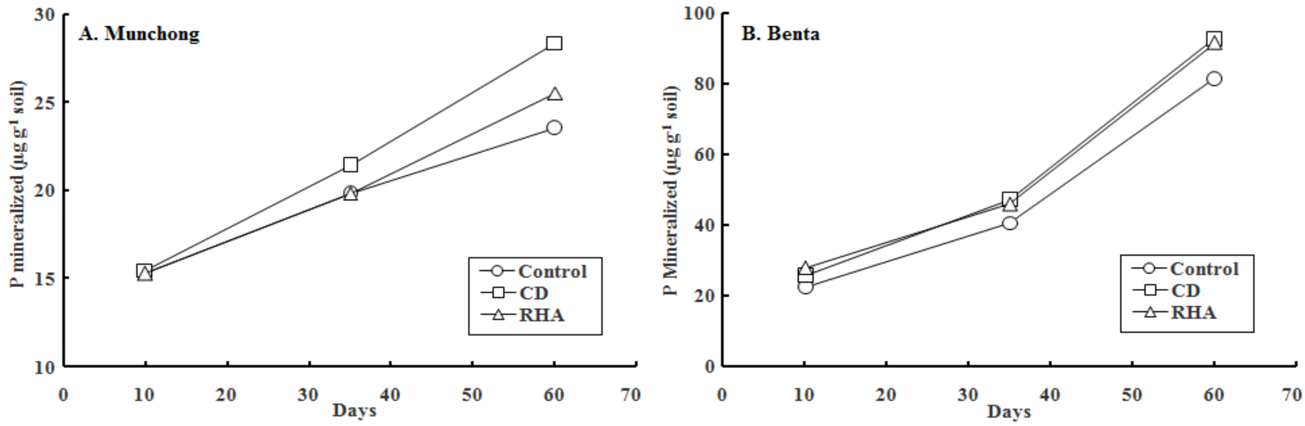

Figure 4 Cumulative P mineralized from the studied soils

Table 6 Net P mineralized from control and treated soils at fixed intervals of the incubation period

	Munchong (µg g^{-1})			Benta (µg g^{-1})		
Days	**Control**	**CD**	**RHA**	**Control**	**CD**	**RHA**
10	15.337^{a}	15.480^{a}	15.290^{a}	22.517^{bc}	25.683^{bc}	27.910^{b}
35	4.457^{bc}	5.923^{bc}	4.567^{bc}	18.110^{c}	21.607^{bc}	18.017^{c}
60	3.713^{c}	6.970^{b}	5.677^{bc}	41.037^{a}	45.587^{a}	45.677^{a}

Means with the same letter are not statistically significant.

The rate of P mineralization from Munchong shows similar pattern with that of C thus, continuous decline over time but this was not the case for Benta soil as it shows initial flush which declined at 35 days then increased at 60 days interval. Mafongoya et al., (2000) studied P mineralization from sandy loam soil amended with goat manure and reported P mineralized up to 14 days after incubation then, a temporary immobilization at 28 days which was followed by net P mineralization. The initial flush can be attributed to solubility of native soil organic matter and water soluble P content in the organic residues while the declining phase suggests the exhaustion of these available substrate or is a period where immobilization rate was similar to mineralization (Grierson et al., 1998). The last phase of increasing P mineralization was attributed to active microbial activity and P release. This increase was slow in Munchong compared to Benta which might be due to acidic nature of the former thus, an evident of P fixation by soil clay and oxides of Fe and Al.

Phosphorus mineralization significantly ($p < 0.05$) differed between the days interval during the incubation period from both soils. Munchong soil had P content of 15.337, 4.457 and 3.713 µg g^{-1} for 10, 35 and 60 days respectively representing 65, 19 and 16 % of its total P extracted (Table 6).

Application of CD to this soils resulted into P content of 15.480, 5.923 and 6.970 µg g^{-1} for 10, 35 and 60 days interval respectively representing 55, 21 and 25 % of the total P extracted from this treatment. Munchong soil amended with RHA had P content of 15.290, 4.567 and 5.677 µg g^{-1} for 10, 35 and 60 days respectively representing 60, 18 and 22% of the total P extracted from this treatment. Similarly, control sample of Benta soil had P content of 22, 18 and 41 µg g^{-1} for respective day's interval of 10, 35 and 60 representing 28, 22 and 50% of its total P extracted. Benta soil amended with CD had P content of 25.683, 21.607 and 45.587 µg g^{-1} for 10, 35 and 60 days interval respectively which represent 28, 23 and 49% of the total P extracted from this treatment.

Benta soil amended with RHA had P content of 27.910, 18.017 and 45.677 µg g^{-1} for 10, 35 and 60 days interval respectively which represent 30, 20 and 50% of the total P extracted from this treatment. Addition of organic residues contributes to the P availability in soil through microbial activity and solubilization of adsorbed inorganic P (Alamgir et al., 2012; Guppy et al., 2005). There are various mechanism influencing P availability due to application of organic matter in soil as reported by Guppy et al. (2005) and they include P release from the residues, exchange of sorbed P with organic acid anions produced during decomposition, metal complexation, increasing micro-aggregation which will lead to reduced soil surface area and decreasing potential P sorption site, and increase in soil pH which would result in more negative charge surfaces and increasing P solubility.

As shown in Figure 4, cumulative P mineralized had linear relationship with time from both soils with application of CD showing high P content followed by RHA amendment then control. This was also the case for P content at fixed intervals except from Benta soil amended with RHA which shows high P than CD incorporation. Phosphorus mineralization depends on solubilization of different P pools in soil and this is control by soil properties especially its pH, microbial activity and chemical composition of the added organic residues. Microorganisms solubilize organic P into inorganic forms through production of organic acid which hasten decomposition and /or solubilization process and P release (Montgomery et al., 2005; Mohammed et al., 2014).

Table 7 shows the mean values of P mineralization from the two soils. Munchong soil was significantly ($p < 0.05$) lower in P mineralized compared to Benta. This was attributed higher P solubilization of Benta due to its low clay content and high pH. The P mineralization in acid soil is constrained by sorption and precipitation reactions (Iyamuremye et al., 2000) due to its low pH, Fe and Al oxides contents.

Table 7 Extracted P from the two soils

Treatment	P mineralized (µg g^{-1})
Munchong	$8.601^{b} \pm 5.02$
Benta	$29.571^{a} \pm 11.26$

Means with the same letter are not significantly different (n=27 ± S.D).

The oxides and hydroxides of Fe and Al are positively charged minerals with strong sorption affinity for P (Gimsing et al., 2007) thus, in acid soil, P precipitate and forms Fe or Al phosphate (Alamgir et al., 2012).

4. Conclusion

The present study showed increased in C and P mineralization over time from both the control and soils amended with CD or RHA. Benta soil amended with CD or RHA had higher CO_2-C evolution than control while the reverse was obtained from the Munchong soils. The Munchong had higher CO_2-C evolution than Benta which was attributed to its contents of native organic matter. Incorporating CD or RHA showed higher extractable P from both soils compared to control. There were three phases in both C and P mineralization pattern; initial flush, followed by a declined phase, then a net increase. The values of extractable P were higher in Benta soils compared to Munchong which was attributed to acidic nature of Munchong resulting into P adsorption by soil clay and oxide minerals.

Author Contribution: AW Samsuri: initiated and designed the research; J Garba: Performed the experiment and wrote the manuscripts; SA Hamdani and R Othman assisted in performing the experiment. All the authors discussed the result and assisted in manuscript preparation.

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