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Full Length Research Paper

Enriched Rice Husk Biochar Ameliorant to Increase Crop Productivity on Typic Hapludults

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The application of rice huskbiochar enriched with farm yard manure (cattle dung) as ameliorant to soils have shown benefits for production such as maize (*Zea mays)*, shallot (*Allium cepa)*, and peanut *(Arachis hypogea)*, particularly through improving soil properties and crop productivity. However, studies examining the effects of enriched rice husk biochar on farms in upper land area of Karawang District not yet reported. This paper presents the results of research focused on the use of enriched rice husk biochar (enriched cattle dung manure) and rice husk only at the rate of 5ton.ha^{-1} and 10ton.ha^{-1}, in farmer fields as a soil amendment on upper hill silty-clay loam texture of Typic Hapludults in Karawang District. The study indicated that there were significant ($P<0.05$) positive effects in a certain silt-loam soil properties like soil pH, SOM and nutrient status, and crop production. Results of this study suggest that the practice of rice husk biochar application to soil at low rates must be enriched along with rice husk normally has immediate positive effects on the vegetative growth of crops, however, soil properties and overall crop yields may take a longer time to show improvement.

Keywords: rice huskbiochar, farm yard manure, soil ameliorant, crop production

INTRODUCTION

Biochar, is a by-product of the pyrolysis of biomass feedstocks as a carbon-rich amendment to improve soil biophysical and chemical quality (Njoku et al. 2016; Woolf 2008; Revell et al. 2012).It became a promising new technology in farming practices offering capacity to maintain and improve soil quality and nutrient cycling (Barrow, 2012).Soil fertility is an important factor to maintain the capacity of soil and to supply nutrients required by crops (Glaser et al. 2002).

Biochar is derived from organic materials such as wood, rice husk, leaves, grasses, crop residues and manure after heating in a closed container (temperature ranging 300 to 500 degrees Celsius) in an oxygen limited condition(Yu et al. 2013; Maia et al. 2011). Indonesia as a country of paddy field produces rice where is as the majority people consumption had also having understanding to its potential in producing rice husk.

Biochar is an emerging and potential additive for enabling increased production on degraded and low fertility acidic soils(Lehmann et al. 2006; Glaser et al. 2002).An increasing number of research studies have indicated that rice husk biochar is a potentially viable alternative to

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augment soil physical and chemical properties and productivity (Soderberg 2013; Atkinson et al. 2010).Incorporating rice husk biochar into soil leads to increased soil pH, nutrient availability, moisture absorption and carbon sequestration (Spokas 2013; Lal 2004) It is worthy to note that rice husk biochar is not a compost material, rather, it is a catalyst for soil microbial activity which enhances soil fertility and water holding capacity to increase crop growth and yields (Mekuria & Noble 2013; Ahmad et al. 2014). The quality of biochar depends on the type of feedstock, methods of preparation, and temperature and oxygen levels maintained during pyrolysis (Steinbeiss et al. 2009; Manyà 2012). Application of biochar to the soil can also contribute to climate change mitigation and adaptation by improving the management of waste materials, as well as, serving as a long-term sink for carbon. Yu et al. (2013) reported that, application of yellow pine-woody biochar in to loamy sand soils in North Carolina, USA, with a high percentage mixture of biochar resulted in notable increase in water holding capacity. Furthermore, (the use of biocharmay also help to mitigate global warming by reducing GHGs emissions from soil, mainly N_2O,while contributing to sustainable agriculture (Lal 2004; Case, 2012). Thus, the findings of numerous studies suggest that rice husk biochar could significantly mitigate climate change, enhance soil quality and increase crop production. However, the use of rice husk biochar in small holder agriculture in hill regions of Karawang District not been extensively documented.

The overall aim of this study was, therefore, to use rise husk biochar produced from rice field biomass and apply it to the soil on farmer fields to evaluate its effects on soil properties and crop production in hilly mountain farming system of Karawang District. Specifically, the objectives were: 1) To study the effects of rice husk biochar enriched with cattle manure as ameliorant application on soil quality indicators, and 2) to study crop growth of maize and soy bean grain product and yield enhancing effects of enriched rice husk biochar on farms.

MATERIALS AND METHODS

Site description and soil sampling:

The field trials were carried out in a silty loam of Typic Hapludults-Ultisols soil of Karawang District, Indonesia. The research trial plots were established on terraces where maize, onion, and peanut chosen due to the Department of Agriculture planning. Soils on the trial plots were mostly silty loam textured with high organic matter reflecting as a cultivated land in a dry-humid climate at high altitudes in Karawang.

Experimental design:

The experimental plot design used was a completely randomized design with each 10 m2 plot divided into two parts. First part was taken as control in which usual farmers practice without applying rice husk biochar which is soil only. The other part was treatment plot with 5 $ton.ha^{-1}$ of enriched rice husk biochar (ERHB),adding Farm Yard Manure (FYM-mixed of cattle dung and leaves) and10 $ton.ha^{-1}$ofrice husk (RH)only applied. There were a total of 10 plot fields refer to as replication, hence a total of 20 plots.

The soil samples were taken before use of any material added, as soil only, in November, 2014 and after in September 2015 respectively. Soil samples were collected from 20 randomly selected plots. Each of the soil samples were collected from the topsoil (0-15 cm) and the sub-soil (15-30 cm) horizon to examine the soil nutrient levels and soil quality for lab analysis; soil samples were kept in closed plastic bags and transported to the Faculty laboratory. For laboratory analysis all samples were air dried ground and passed through a 2 mm sieve for soil physical and chemical analysis. The soil physical and chemical properties were determined using USDA standard methods: soil texture by the Bouyoucossoil hydrometer method, soil pH (1:1 soil: water mixture) using a digital pH meter and probe (McLean 1982), bulk density (BD) by core method, soil organic carbon (SOC) dry combustion (loss on igniton) method (Nelson and Sommers 1982), total nitrogen(TN) by Kjeldahl method (Bremner and Mulvaney 1982), available phosphorus(AP) by modified Olsen's method (Olsen and Sommers 1982), exchangeable potassium(EK) by ammonium acetate extraction followed by atomic absorption spectro-photometry and caution exchange capacity (CEC) by ammonia acetate extraction method.

Application of Rice Husk Biochar:

Enriched rice husk biochar (ERHB) was applied in the field trials at the rate of 5 ton and 10 ton rice husks (RH) only per hectare, respectively. Rice husks was produced locally from available feed stocks (waste of paddy production)at 300°C to 500°C under low pyrolysis process for 3-5 hours, whereas the enrichment material was made from cattle dung mixed with leaf-litter and weed biomass and animal bed materials which were composted in a pit near the farmstead. Rice husk biochar characterization was performed at the Soil Laboratory Dept. The characterization of rice husk biochar is in Table 1.

Statistical analysis:

Results obtained from measurement of soil properties and crop production were analyzed by use of Minitab 17

Table 1: Chemical properties of RHB

Parameters	Mean	Instrument employed
pH	11.13	Probe method (McLean, 1982)
Organic Matter (OM)%	53.58	Loss on Ignition (Nelson and Sommers 1982)
Total Nitrogen (ppm	1988	Kjeldhal method (Bremner & Mulvaney, 1982)
Available Phosphorus (ppm	7835	Dry ash (Olsen & Sommers, 1982)
Available Potassium (ppm)	1528	Ammonia Acetate followed by Atomic absorption Spectrometer(AAS) (Knudsen et al., 1982)

Table 2: Mean values (± std.dev.) of topsoil (0-15 cm) physical and chemical properties prior to plot establishment (soil), for ERHB treatment and for RH control.

Parameters	Soil data	ERHB	RH only
Ph	5.3 ± 0.6a	5.3 ± 0.3a	5.4± 0.9a
Soil Org. Matter (%)	10.9 ± 1.5a	11.6 ± 1.7a	11.6±2.2a
Total Nitrogen (ppm)	4526 ± 1089a	3647 ± 1422a	4272± 818a
Avail. Phosphorus (ppm)	516.0 ± 161.1a	312.0 ± 185.5b	207.7 ± 96.b
Exch. Potassium (ppm)	205.0 ± 67.0a	201.0 ± 72.6a	1699 ± 75.0a
Cat. Exch.Caps.(m.e/100gm)	51.0 ± 9.0a	41.5 ± 10.0b	47.7 ± 15.4a

Means in the same rows followed by same letters are not significantly different at p<0.05.

software. The inferential differences were determined significant at the rate 5% level of significance (p/0.05). Paired “t” test was employed for the determination of statistical significance for the measured parameters, namely, crop yield, soil pH, Soil Organic Matter (SOM), Total Nitrogen (TN), Available Phosphorus (AP), Exchange Potassium (EK) and Caution Exchangeable Capacity (CEC).

RESULTS

Soil properties

The mean values of soil physical and chemical properties of topsoil (0-15cm) and sub soil (15-30 cm) before any treatment applied (soil only), after ERHB and RH only amendment are as below in Tables 2 and 4.

Regarding the topsoil, AP increased significantly (P<0.05) in both RHB plots after application of ERHB and RH only in to the soil. In contrast CEC decreased significantly (P<0.05, Table 3) in ERHB plot compared to RH only plot. These trends were readily explained and may be due to sampling and analytical variability.

The topsoil of the ERHB amended treatment and only RH added plots showed EK was slightly higher in RH amended soils compare to only ERHB added soils with no statistical significance. Whereas, pH, SOM, TN were observed to be somewhat higher in the RH only control treatment (Table 3).

Regarding the subsoil, SOM, TN, EK increased significantly (P<0.05),whereas, in contrast CEC decreased significantly (p<0.05) after ERHB and RHB itself addition to the soil. Similarly AP increased slightly in both RHB amended soils but the difference was not statistically significantly (Table 5). In a similar manner, while

Table 3. Paired 't' test p-values and statistical significance for top soil (0-15 cm).

Parameters	**ERHB**(P value)	**Significant**	**RH only** (P value)	**Significant**
Ph	0.642	Ns	0.713	Ns
Soil Org. Matter (%)	0.998	Ns	0.207	Ns
Total Nitrogen (ppm)	0.119	Ns	0.192	Ns
Avail. Phosphorus (ppm)	0.002	**	0.000	**
Exch. Potassium (ppm)	0.291	Ns	0.291	Ns
Cat. Exch.Caps.(m.e/100gm)	0.008	**	0.538	Ns

**significant at P<0.05; ** highly significant at P<0.01; ns = non significance*

Table 4: Mean values (± std. dev.) of subsoil (15- 30 cm) properties prior to plot establishment (soil), for ERHB treatment and RH only plots.

Parameters	**Soil data**	**ERHB**	**RH only**
pH	5.2 ± 0.37a	5.2 ± 0.27a	5.4 ± 1.0a
Soil Org. Matter (%)	9.4 ± 2.4a	11.2 ± 1.2b	11.0 ± 1.5b
Total Nitrogen (ppm)	4165 ± 788a	3310 ± 1352b	4032 ± 493a
Avail. Phosphorus (ppm)	363.0 ± 154.7a	282.0 ± 177.6a	160.0 ± 12.0.b
Exch. Potassium (ppm)	111.4 ± 48.0a	177.5 ± 47.b	157.0 ± 57.0b
Cat. Exch.Caps.(m.e/100gm)	49.0 ± 8.0a	43.7 ± 8.0b	400. ± 9.0b

Means in the same rows followed by same letters are not significantly different at p<0.05

comparing the subsoil of the ERHB treatment and only RH added plots; pH and AP (not significantly), SOM, TN and EK (significant at P<0.05) were higher in the ERHB and RH amended soil. Whereas, parameters such as AP,EK (significantly different at P<0.05), and pH and TN (not significantly different) were higher in soil of the RH only treatment (Table 5).

3.2 Influence of Enriched Rice Husk Biochar (ERHB) and Rice Husk (RH) on crop yields

Crop yield planted within the hill farming system, were observed to be significantly (p<0.05) higher in both ERHB amended soils compared to only RH added soils (Table 6). Clearly, maize showed the greatest differences in yields due to ERHB addition (77% higher) over RH only treatment. However, the vegetative growth and yields of the high value soy bean were also markedly higher in the ERHB amended plots (by 66%) compared to RH only plots.

DISCUSSION

Soil properties in relation to soil depth

As seen from the soil data (Tables 2 and Tables 4) it is an apparent that the top soil (0-15cm) and sub-soil (15-30 cm) in this field experiment were of a fertile silt loamy soil with chemical properties generally in the medium range for crop production. As seen from the results, most of the measured parameters were not significantly different between ERHB ameliorant soils and those with only RH added. This was likely due to the fact that the soil was already of good quality with high SOM status. Higher AP levels of the ERHB ameliorant soils could be due to improved

Table 5. Paired't' test p-values and statistical significance for physical and chemical properties of sub-soil (15-30 cm).

Parameters	**ERHB**(P value)	**Significant**	**RHonly** (P value)	**Significant**
pH	0.681	Ns	0.286	Ns
Soil Org. Matter (%)	0.011	*	0.013	*
Total Nitrogen (ppm)	0.074	*	0.554	Ns
Avail. Phosphorus (ppm)	0.203	Ns	0.001	**
Exch. Potassium (ppm)	0.004	**	0.043	*
Cat. Exch.Caps.(m.e/100gm)	0.043	*	0.002	** *

**significant at P<0.05; ** highly significant at P<0.01; ns = non significance*

Table 6: Mean values (± std. dev.) of crop yield (t/ha)for ERHB treatment and RH only along with paired 't' test p-values and statistical significance.

Crop	**ERHB**	**RH only**	**P value**	**Significance**
Maize	1.3 ± 0.4	0.3 ± 0.1	0.001	**
Onion	5.0 ± 4.0	3.0 ± 2.1	0.066	*
Peanut	3.04 ± 2.4	2.0 ± 1.4	0.039	*

**Means are significantly different at P=0.05; **Means are significant at P=0.01*

availability of phosphorous as a result of RH addition (Asai et al. 2009). Lower values of CEC in these plots despite high SOM compared to the RH only control, were however, not easily explained. Generally, the CEC of soil is a function of the clay type and content and would not expect to change significantly with addition of RH. In both top soil and sub soil, increase in pH was observed in the ERHB ameliorant soil compared to the soil data values and the RHB only control treatment. This was evidently due to the alkaline nature of RH (Barrow 2012), which, upon addition to the soil could have contributed towards reducing the acidic level of soil.

Nonetheless, the increase was, expectantly, not significant in the sub soil, which was due to the application of low rates of RH and is incorporation with tillage only within the top 15-20cm of soil. Moreover, addition of the organic manure could have resulted in nitrification which releases protons to the soil. In contrast, there was a significant decrease in CEC availability in RH amended top soil and sub soil. Here, the RH might have become intimately associated with SOM and clay particles reducing the number of exchange cites available to adsorb cautions. In the case of the subsoil, the above influence of RH was likely insignificant as the RH was applied only to the surface layer (Naisse, 2015). Also, mineralization of organic matter in the soil could have occurred which is heavily dependent upon the temperature and moisture levels of the soil.

Enriched RHB on yields

The results of this study indicated that the application of ERHB and RH in fertile soils in hill farming systems of farmers generally increased the crop yields in ERHB and compost amended soils However, it was observed that the yield difference due to addition of ERHB to soil of maize was higher than that of onion and peanut. This due to ERHB effective in enhancing the growth of tuber plants rather than the growth of onion and peanut.

CONCLUSIONS

This study has confirmed that, in general, enriched rice husk biochar (ERHB)application does improve certain soil properties like soil pH, SOM and nutrient status. Moreover, it also enhances the growth and yields of most crops as seen in the case of uphill farming in Karawang. The effects of enriched rice hush biochar (ERHB)are likely to be more pronounced when applied to soil of degraded status. Furthermore, it could be said that while the effect of enriched rice husk biochar (ERHB) as ameliorant on crop growth and yield improvement is readily observed in the short-term, improvement in soil properties is likely to be seen only in the long-term.

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