AGRIVITA VOLUME 35 No. 3 OCTOBER - 2013 ISSN : 0126-0537

THE USE OF BIOCHAR TO IMPROVE SOIL PROPERTIES AND GROWTH OF PADDY IN PEATLAND

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Received: June 12, 2013 /Accepted: September 12, 2013

ABSTRACT

The main constraint in the management of peatlands includes: high soil acidity, very low nutrient availability especially NPK. The study aimed to determine the role of biochar to improve soil properties and paddy growth in peatlands. The study was conducted in Landasan Ulin rural, Gambut district, Banjar regency, South Kalimantan. The study was conducted from June to October 2012. Research was arranged in a randomized block design, with three replications. The treatment given was a combination of the type and dose of ameliorant i.e. the 3 types of ameliorant: F1 (50% *purun tikus* grass + 50% agricultural weed), F2 (16.7% chicken manure + 83.3% biochar), F3 (9% chicken manure + 91% *purun tikus* grass), with a dose of 2.5, 5 and 7.5 t ha^{-1}, and control. The results showed that treatment of biochar could increase soil pH, total N, and exchangeable P (Bray I) though it was not significant, and significant in increasing the exchangeable K compared to controls. In the growth of rice plants giving biochar can increase plant height, number of tillers and number of panicles compared to controls.

Keywords: biochar, improvement of soil properties, peat, growth, paddy

INTRODUCTION

Peatlands have potential to be developed as a productive agricultural area. Indonesia is a country that has the largest peat land which is about 14.9 million hectares, scattered on Kalimantan, Sumatra, Papua, as well as other several small islands. Development of peat lands for agricultural land faces a problem such as low productivity due to several constraints. Peatland development constraints involve low soil fertility, water and subsidence problems. The main constraint in the management of peatlands was soil acidity due to high content of organic acids, very low NPK nutrient availability, and vulnerability to GHG emissions.

Biochar is the charcoal product obtained when biomass is heated without oxygen access. In contrast to any other biomass or compost, biochar is stable for hundred to thousand years when mixed into soils, and thus its carbon is removed from the carbon cycle (Lehmann 2007; Renner 2007). Biochar provides a unique opportunity to improve soil fertility and nutrient-use efficiency locally using available and renewable materials in a sustainable way. Adoption of biochar management does not require new resources, but it is more efficient and environmentally safer for existing resources. Biochar is able to play a major role in expanding options for sustainable soil management by improving existing management practices, not only to improve soil productivity, but also to reduce environmental impact on soil and water resources. Biochar should therefore not be seen as an alternative to existing soil management, but as a valuable addition that facilitates the development of sustainable land use (Lehman, 2007).

Biochar has a number of advantages: (1) storing carbon in the soil and thus avoiding CO_2 release, (2) reducing nutrient leaching by increasing the soil's buffering capacity, (3) reducing soil acidity (biochar is alkaline when synthesized under the proper conditions), which is especially important in the current context. (4) reducing pesticide runoff and organic pollutant bioavailability since pesticides are strongly bound by biochar, (5) reducing the formation of

Accredited SK No.: 81/DIKTI/Kep/2011
http://dx.doi.org/10.17503/Agrivita-2013-35-3-p290-295

other greenhouse gases nitrous oxide (N_2O) and methane (CH_4). For example, N_2O emission reductions of 50-80% in soybean plantation and grass, and a nearly complete suppression of methane in 2% biochar added to soil. The mechanism leading to reduced emission of N_2O and CH_4 probably increased soil aeration reducing the extent of anaerobic denitrification and methanogenesis, respectively (Lehmann, 2007; Glaser *et al.*, 2002; Renner 2007; Rondon *et al*., 2007; Cornelissen *et al*., 2005).

Biochar could improve soil characteristic through ability to increase the pH, water retention, nutrient retention, activity of the soil biota, and reduce GHG emissions. Biochar was not able to provide nutrients directly, but it could indirectly reduce the loss of nutrients through leaching, so that fertilization efficiency could be improved. Biochar was an alternative ameliorant for the improvement of soil fertility, as well as for environmental improvement for more sustainable and friendly environment. To increase the effectiveness of biochar to remedy the peat soil fertility, the addition of other materials high in nutrient is required to obtain more nutrient as well as to function as ameliorant for soil. The research was aimed at determining the role of biochar in improving soil properties and paddy growth in peatlands.

MATERIALS AND METHODS

The study was conducted in Landasan Ulin rural, Gambut district, Banjar regency, South Kalimantan. The study was conducted from June to October 2012. The research was arranged in a randomized block design, with three replications. The treatment given was a combination of the type and dose of 3 types of ameliorant: F1 (50% *purun tikus* grass + 50% agricultural weed), F2 (16.7% chicken manure + biochar 83.3%), F3 (9% chicken manure + 91% *purun tikus* grass), with a dose of 2.5, 5 and 7.5 t ha^{-1} and control (Table 1)

Biochar used came from coconut shell, obtained through pyrolysis. Analysis on ameliorant material consisting of biochar, agricultural weed, *purun tikus* grass, and chicken manure included: pH, CEC, total N, organic C, total P, CaO, MgO, K_2O, and total Fe.

Rice varieties used were Margasari. Seed was germinated, and after 21 days, they were planted in experimental field. All treatment application used NPK fertilizer 45 kg N, 60 kg P_2O_5 and 50 kg K_2O per hectare.

Analysis of soil properties made at the beginning and end of the vegetative phase include: pH H_20, total N, available K, available P (Bray 1). Observation of plant growth i.e. plant height and number of tillers was conducted periodically at 3 and 8 weeks after transplanting.

Data analysis was performed to determine the effect of independent variables on dependent variables by using the analysis of variance at the level of confidence at 5 %. Difference between treatments for each parameter analyzed by the DMRT test (Duncan's Multiple Range Test) with a confidence level was 5%. The analysis of data used Minitab software for windows.

RESULTS AND DISCUSSION

Characteristics of Peatland and Ameliorant Material

The characteristics of the peatlands studied had low fertility (pH H_2O; 3.19, total N ;1,1,51%, available K;0.543 cmol$^{(+)}$ kg^{-1}, P-bray 1; 31.625 mgkg^{-1}. The greatest constraints in the management of peatlands studied were soil acidity, and low availability of NPK. Ameliorant giving is needed to overcome these constraints. The characteristics of ameliorant used were biochar from coconut shells, chicken manure, agricultural weed and *purun tikus* grass presented in Table 2.

Table 1. Ameliorant formula

Ameliorant	Compositions (%)			
	Biochar	Chicken manure	Agricultural weed	*Purun tikus* grass
F1	-	-	50	50
F2	83.3	16.7	-	-
F3		9		91

Table 2. Chemical characteristics of the ameliorant materials used in the study

	Type of ameliorant			
Characteristics	**Biochar**	**Chicken manure**	**Agricultural weed**	***Purun Tikus* grass**
pH	8.63	7.17	4.45	4.12
Organic C (%)	24.79	31.93	44.86	44.48
Total N (%)	8.01	1.64	0.94	1.18
Total P (%)	0.09	0.64	0.25	0.08
K_2O (%)	0.54	1.26	1.02	0.99
C/N (%)	3.09	19.49	47.66	37.82
CaO (%)	1.12	5.30	0.91	0.85
MgO (%)	0.15	2.32	0.26	0.19
Na (%)	0.07	1.15	1.02	0.99
Total Fe (%)	2.43	1.80	0.04	0.16
Water Content (%)	10.47	10.56	20.02	16.11

Table 3. Soil characteristic at the end of the vegetative phase

No	Treatments	pH H_2O	N-tot (%)	K-dd (cmol(+) kg^{-1}	P Bray 1 (ppm P_2O_5)
1	F1 2.5 t/ha	3.75 a	1.620 a	1.136 b	18.372 b
2	F1 5.0 t/ha	3.46 a	1.820 a	2.221 a	46.138 b
3	F1 7.5 t/ha	3.44 a	1.820 a	3.835 a	51.691 b
4	F2 2.5 t/ha	3.43 a	1.540 a	2.773 b	232.031 a
5	F2 5.0 t/ha	3.81 a	1.820 a	5.623 a	50.997 b
6	F2 7.5 t/ha	3.91 a	1.778 a	2.273 b	23.925 b
7	F3 2.5 t/ha	3.62 a	1.694 a	1.136 b	58.633 b
8	F3 5.0 t/ha	3.39 a	1.820 a	3.894 a	68.813 b
9	F3 7.5 t/ha	3.81 a	1.820 a	1.259 b	201.951 a
10	control	3.63 a	1.260 a	0.646 b	11.430 b

Remarks: F1 (50% *purun tikus* grass + 50% agricultural weed). F2 (16.7% chicken manure + 83.3% biochar). F3 (9% chicken manure + 91% *purun tikus* grass). Numbers followed by the same letter are not significantly different based on DMRT α = 5%

Ameliorant materials used had different chemical compositions. Biochar had a higher pH than most other materials ameliorants. Although the Ca content in biochar was lower than in chicken manure, but higher than both *purun tikus* grass and agricultural weed. Biochar from coconut shell has the potential to be ameliorant material, because not only does it improve physical and biological properties of peat, but it is also able to increase the peat pH.

The content of both total N and total Fe in biochar was also higher than the others i.e. chicken manure, agricultural weed and *purun tikus* weed. In general, the nutrient content of manure is higher than others. Chicken manure had the highest nutrient content of P_2O_5, K_2O, CaO, MgO. Agricultural weed had good nutrient content of P, K, Ca, Mg and pH higher than that of *purun tikus*.

Influence of Biochar on Peat Soil Properties

Results of the soil analysis at the end of the vegetative phase (Table 3). All treatments showed no significant differences for pH H_2O and total N, but the K-exchanged and P-Bray showed difference. Despite this fact, treatment of 16.7% chicken manure + 83.3% biochar (F2) doses of 5 and 7.5 t ha^{-1} could increase soil pH compared with F1 (50% *purun tikus* + 50% agricultural grass) and F3 (9% chicken manure + 91% *purun tikus*). Treatment biochar from (coconut shell) had a higher pH than the others, with the content of bases was also quite high (Table 3). The addition of chicken manure that had a high content of bases could improve the effectiveness of biochar in increasing pH soils.

Giving ameliorant was able to increase the total N content of peat soils, although the effect was not significantly different. Increasing ameliorant doses given tended to increase the soil total N. Although the total N content of the materials of biochar was high (8.01%), it did not significantly affect the changes in total N in peat soil at the end of the vegetative phase. It was not caused by the condition of N in peatlands with high diversity, but it was influenced by translocation process and emissions. Although the total N in peatland was quite high, the available N for plants was less than 1%. Organic nitrogen in the peat soil is not easily available for plants, since the ratio C/N is high, ranging from 25 to 50 (Dohong, 1999; Jali, 1999).

Giving ameliorant also affected the availability of K in peat soils studied. Treatment 16.7% chicken manure + 83.3% biochar (F2) at a dose of 5 t ha^{-1} gave the best effect in the supply of K in peat soils studied. Several studies have shown that the use of biochar increased nutrient content in soil and plant productivity. Masulili et al. (2010) reported that biochar could increase soil pH and avalaible P, K, and Ca in soil. According to Glaser et al. (2002), biochar increased the availability of soil nutrients and plant productivity. However, the specific mechanism of biochar contribution to increase plant performance in peat soil has not been widely investigated. Direct effect of biochar was nutrient release, while indirect effect was through the improvement of nutrient retention capacity, soil pH, soil CEC, soil physic, and microbe (Steiner, 2007; Duku *et al*., 2011).

P availability was also affected by the type and dose given ameliorant. F2 treatment (16.7% chicken manure + 83.3% biochar) gives the best effect on the availability of P in the peat soil under study. F2 treatment was a combination of manure 16.7% with 83.3% biochar, which was able to contribute P to the soil and to increase the soil pH, so that the availability of P increased . In addition, the contribution of the Fe cations were from biochar material as bridge cations between functional groups of peat with anion P, so P was not quickly leached. Peat soil had relatively low ability to adsorb P fertilizer (Maas *et al.,* 1997; Suryanto, 1994) . This was because the peat soil contains many reactive functional groups both functional groups with low molecular weight of citric, malic, and oxalic acid, and functional groups with high molecular weight of humic and fulvic acids. The group had a negative charge, so that P elements persisted in the exchange complex.

Results of the soil analysis at the end of the generative phase are presented in Table 4. All ameliorant treatments that were given did not significantly affect pH, H_2O, total N, available K, and available P at the end of the observation. At the end of the generative phase, most nutrients from fertilizers and from ameliorant were absorbed by plants and leached out of the system, so that treatment was no longer an impact.

Effect of Biochar on Rice Growth and Yield

Treatment of ameliorant on various formulas showed not significant difference for soil characteristic at the generative phase (Table 4)., However, the effect of ameliorant treatments showed significant difference for the growth of paddy (Table 5). Increasing doses in ameliorant increased rice growth for all types of ameliorant. Dose of 5.0 and 7.5 t ha^{-1} gave difference in the control. However dose of 2.5 t ha^{-1} gave no significant effect (Table 5).

Table 4. Soil characteristic at the end of the generative phase

No	Treatment	pH H_2O	N-tot (%)	K-dd ($cmol^{(+)}$ kg^{-1})	P Bray 1 (ppm P_2O_5)
1	F1 2.5 t/ha	3.683 a	1.189 a	0.319 a	50.771 a
2	F1 5.0 t/ha	3.720 a	1.145 a	0.453 a	39.534 a
3	F1 7.5 t/ha	3.670 a	1.279 a	0.628 a	32.881 a
4	F2 2.5 t/ha	3.580 a	1.213 a	0.288 a	28.224 a
5	F2 5.0 t/ha	3.630 a	1.140 a	0.195 a	82.780 a
6	F2 7.5 t/ha	3.633 a	0.915 a	0.878 a	78.196 a
7	F3 2.5 t/ha	3.610 a	1.215 a	0.458 a	26.672 a
8	F3 5.0 t/ha	3.680 a	0.971 a	0.337 a	26.749 a
9	F3 7.5 t/ha	3.373 a	1.014 a	0.484 a	60.159 a
10	control	3.640 a	1.014 a	0.237 a	43.600 a

Remarks: F1 (50% *purun tikus* grass + 50% agricultural weed). F2 (16.7% chicken manure + 83.3% biochar). F3 (9% chicken manure + 91% *purun tikus* grass). Numbers followed by the same letter are not significantly different shows based on DMRT $\alpha = 5\%$

Table 5. The effect of ameliorant treatments on the growth of paddy

No	Treatments	Plant height (cm)		number of tillers		number of penicle
		3 WAP	8 WAP	3 WAP	8 WAP	
1	F1 2.5 t/ha	35.42 a	61.76 bc	9.63 abc	12.66 ab	12.433 bc
2	F1 5.0 t/ha	42.89 cd	65.11 cd	10.11 abc	11.55 ab	11.777 ab
3	F1 7.5 t/ha	43.47 cd	70.16 d	10.97 c	13.78 bc	15.433 c
4	F2 2.5 t/ha	40.89 bcd	59.63 abc	9.00 abc	12.11 ab	11.111 ab
5	F2 5.0 t/ha	42.66 cd	61.38 bc	9.89 abc	12.97 ab	12.000 b
6	F2 7.5 t/ha	44.43 d	67.27 cd	10.64 bc	15.89 c	13.323 bc
7	F3 2.5 t/ha	39.39 abc	55.86 ab	7.32 a	12.44 ab	12.890 bc
8	F3 5.0 t/ha	42.33 cd	65.72 cd	9.45 abc	12.88 ab	12.570 bc
9	F3 7.5 t/ha	43.22 cd	71.38 d	8.20 abc	12.78 ab	12.220 bc
10	Control	37.44 ab	52.27 a	7.42 ab	10.22 a	8.657 a

Remarks: F1 (50% *purun tikus* grass + 50% agricultural weed). F2 (16.7% chicken manure + 83.3% biochar). F3 (9% chicken manure + 91% *purun tikus* grass). Numbers followed by the same letter are not significantly different shows based on DMRT α = 5%

Giving biochar combined with manure (F2) could increase plant height and number of tillers compared with the control. Biochar given had high nutrient content, so the role not only improved physical and biological soil properties, but it also contributed nutrients to the plants. The addition of manure with high nutrient content also increased effectiveness in improving plant growth.

Biochar had a number of advantages: (1) storing carbon in the soil and thus avoiding CO_2 release, (2) reducing nutrient leaching by increasing the soil's buffering capacity, (3) reducing soil acidity (biochar was alkaline when synthesized under the proper conditions), which is especially important in the current context, (4) reducing pesticide runoff and organic pollutant bioavailability since pesticides were strongly bound by biochar, (5) reducing the formation of other greenhouse gases nitrous oxide (N_2O) and methane (CH_4). (Lehmann and Joseph 2007; Glaser *et al.*, 2002; Renner 2007; Rondon *et al*., 2007; Cornelissen *et al*., 2005).

Number of tillers in week 3 was mostly shown by F1 treatment (50% *purun tikus* grass + 50% agricultural weed) at a dose of 7.5 t ha^{-1}. However, at week 8, the highest number of tillers was indicated by F2 treatment (16.7% chicken manure + 83.3% biochar) at a dose of 7.5 t ha^{-1}. Giving biochar increased both the number of tillers and number of penicles of rice over 50% compared with controls. Biochar could improve the availability of water and nutrients to be more available to plants (Rice Research Institute, 2009). Biochar could improve the major cations, total P, total N, CEC and pH, so the availability of nutrients in the soil increased (Gani, 2009). Santi and Gunadi (2010) reported that the pH value of biochar was very suitable with the microorganisms, so that they grew optimally.

CONCLUSIONS

The results showed that the peat used had a very low fertility with very low pH (3.19), and the nutrient content of N, P, K was very low as well. The treatment of biochar could increase soil pH, total N, and exchangeable P (Bray 1) though it was not significant and significant in increasing the exchangeable K compared to controls. For the growth of rice plants, biochar could increase plant height, the number of tillers, and the number of panicles compared to controls.

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