Agrotechnology Research Journal
Volume 6, No. 2, December 2022, pp. 87–94
ISSN 2655-7924 (Print)
ISSN 2614-7416 (Online)
https://jurnal.uns.ac.id/arj
doi:10.20961/agrotechresj.v6i2.57344

Residual Effect of Rice Husk Biochar on Growth and Yield of Aerobic Rice

Suli Suswana, Dick Dick Maulana*

Department of Agronomy, Agro-technology Study Program, Faculty of Agriculture, Universitas Islam Nusantara, Bandung 40286 West Java, Indonesia

Received 13 December 2021; Accepted 6 December 2022; Published 31 December 2022

ABSTRACT
Biochar is a carbon-rich solid material made by pyrolyzing agricultural residual biomass, and it decomposes much more slowly than the biomass from which it is made. Biochar has been shown to have agronomic benefits. Biochar can provide agronomic benefits for a longer period due to its persistence in the soil. The purpose of this research is to gather evidence demonstrating that biochar has a longer effect on increasing aerobic rice productivity. A pot experiment was carried out in UNINUS. The treatments were as follows: control, 20 Mg rice husk biochar (RHB), 40 Mg RHB, 50 Mg RHB, 60 Mg RHB, 10 Mg RHB + 10 Mg composted poultry litter (CPL).ha^{-1}, 20 Mg RHB + 20 Mg CPL.ha^{-1}, 30 Mg RHB + 30 Mg CPL.ha^{-1}, and 30 Mg RHB + 30 Mg CPL.ha^{-1}. Treatments were started in September 2018, and the effects were measured from February to June 2019. The findings revealed that rice husk biochar and its combination with CPL increased aerobic rice growth (plant height, number of tillers, and yield). The most effective combination rate is the application of biochar and composted poultry litter, 20 Mg RHB + 20 Mg CPL.ha^{-1}, because it significantly extended the residual effect. The combined application increased rice productivity when compared to a single application of biochar and composted poultry. The residual effect of biochar and composted poultry litter on rice productivity was superior to fresh application.

Keywords: Biochar persistency; Biomass; Decomposition; Residual effect

***Cite this as (CSE Style)*:** Suswana S, Maulana DD. 2022. Residual effect of rice husk biochar on growth and yield of Aerobic rice. Agrotechnology Res J. 6(2):87–94. https://dx.doi.org/10.20961/agrotechresj.v6i2.57344.

INTRODUCTION
Agriculture is currently facing several challenges as a result of rising food demand and environmental concerns (Kavitha et al. 2018). Because of the rapid development of modern industry and agriculture, the carbon that was originally stored beneath the earth has been released in large quantities, resulting in a slew of ecological and environmental issues such as increased greenhouse gases and deterioration of cultivated land quality (Chen et al. 2015). As a result, reintroducing carbon and restoring it in the soil is an important way to combat global climate change. Biochar technology has gained popularity and high expectations (Chen et al. 2015).

Rice is the most important food crop for Indonesians. As a result, efforts to improve and maintain land qualities, whether lowland rice or upland rice, were required to increase productivity. However, the Indonesian government frequently encountered conversion problems of lowland rice to non-agricultural utilities while implementing programs to increase rice production in order to improve food security. As a result, upland rice cultivation has become increasingly intensive, resulting in a decline in land quality. Continuing efforts to improve and maintain upland qualities in order to increase productivity will be required. According to Indonesian statistics, upland rice yield (3.28–3.34 Mg.ha^{-1}) is lower than lowland rice yield (5.30–5.51 Mg ha^{-1}) (Statistics Indonesia 2018).

Biochar is a high-carbon (C) product made by pyrolyzing organic material at low temperatures (700°C) (Lehmann and Joseph 2015). Biochar is a recalcitrant, a mostly stable organic-C compound formed when biomass (feedstock) is heated to temperatures ranging from 300 to 1000°C while exposed to low oxygen concentrations (Jeffery et al. 2011). The presence of fused aromatic C structures is the most notable chemical difference between biochar and other organic matter (Nguyen et al. 2018).

Biochar's high stability is clearly due to the nature of these C structures (Nguyen et al. 2018). Microorganisms will be unable to use the C structure as an energy source and possibly other nutrients because a large portion of the biochar material is chemically stable. Because of its nature and properties, biochar has the potential to improve and maintain soil quality over time.

There is growing interest in using this biochar as a soil amendment due to its potential agronomic benefits (Clough et al. 2013). Soil biochar application has been proposed as a method to improve soil fertility and thus increase food security (Mao et al. 2012). The

****Corresponding Author*:**
E-Mail: dickdick.maulana@yahoo.com

incorporation of biochar into soils versus 'fresh' crop residues may provide insight into the mechanism of C sequestration via biochar application to soils (Nguyen et al. 2018).

Soil organic matter (SOM) is important for agricultural sustainability due to the potential benefits to soil properties and long-term soil productivity (Aguilera et al. 2012). SOM improved soil structure for root growth and drainage, accelerated nutrient cycling, increased soil nutrient content over time, increased cation exchange capacity (CEC), and increased soil biological activity (Aguilera et al. 2012).

It is frequently suggested that poultry litter be used as a fertilizer to add SOM. Composted poultry litter has some advantages over fresh poultry litter because it contains more nutrients (Hartatik and Widowati 2005). According to Melati and Andriyani (2005), applying 10 Mg ha^{-1} poultry litter increased vegetable soybean vegetative growth. Sweet corn vegetative growth was increased by applying 15 Mg.ha^{-1} poultry litter, and the best combination to increase sweet corn vegetative growth and yield was 15 Mg.ha^{-1} poultry litter + 107 kg.ha^{-1} KCl (Liliana 2017).

However, in tropical environments, organic matter is typically mineralized very quickly, and only a small portion of the applied organic compounds are long-term stabilized in the soil before being released into the atmosphere as CO_2. Furthermore, soil cultivation, particularly tillage, has an impact on soil physical properties by altering soil structure and encouraging SOM loss (Aguilera et al. 2012). As a result of reduced SOM, poor soils can be found in tropical regions all over the world, particularly in Indonesia. Organic matter incorporation benefits such soils greatly, but its rapid decomposition in the humid tropics makes this a temporary solution.

Biochar is not completely inert, and some of its components, particularly the surface, contain significant amounts of bioavailable nutrients (Chen et al. 2015). As a result, adding biochar to soils has the same beneficial effects as organic fertilizers. Soil biochar application has been proposed as a novel way to boost crop yields while reducing greenhouse gas emissions from soil (Nguyen et al. 2018). Biochar's ability to be oxidized to CO_2 was lower (Nguyen et al. 2018). The addition of biochar to soils has a direct impact on soil microbial communities and their activity, both of which are critical in maintaining soil health and functioning (Jeffery et al. 2011).

Biochar has demonstrated the ability to reduce inorganic-N leaching, N_2O emissions, and ammonia volatilization while increasing biological nitrogen fixation (Dempster et al. 2012). Clough and colleagues (2013) High-temperature biochar removed between 0.12 and 3.7% of NO_3 from a solution, with removal varying depending on the feedstock used (Clough et al. 2013). Significant NO_3 adsorption occurred at pyrolysis temperatures of 700°C. Surface area and micropore volumes followed different trends when compared to observed NO_3 adsorption, indicating that NO_3 adsorption was caused by base functional groups rather than physical adsorption (Kameyama et al. 2012).

However, incorporating biochar into the soil may increase hydraulic conductivity around larger particles, resulting in increased NO_3 leaching (Kameyama et al. 2012). Soil amendment with biochar, on the other hand, increased water retention capacity (Clough et al. 2013), which may reduce NO_3 leaching. Nitrate-N was only weakly adsorbed onto biochar and was desorbed by water infiltration, potentially increasing the residence time of NO_3 in the soil (Kameyama et al. 2012). As a result, plants may be able to absorb more NO_3- (Clough et al. 2013).

The biochar's CEC is frequently cited as the explanation for NH_4+ adsorption and observed reductions in NH_4+ leaching. Cation retention in situ increases with biochar age and is influenced by environmental factors (Clough et al. 2013). While little is known about the stability of biochar anion exchange capacity (AEC) and how it changes as biochar ages and weathers in soil environments (Lawrinenko et al. 2016).

The surface chemistry and various physical and chemical properties of biochar are known to change over time in soil environments (Lawrinenko et al. 2016). Natural char can oxidize gradually in soil, whereas synthetic biochar has a high cation exchange capacity (Mao et al. 2012). Fresh chars have far fewer oxidized functional groups (COO-) substituents than Terra Preta soils. The structure of char residues in tropical Terra Preta soils indicates that aromatic clusters of this size and oxidation level are stable in the soil and are likely to improve soil fertility (Kameyama et al. 2012).

Biochar can age in soil environments through a variety of mechanisms, including radical addition, reaction with superoxide anions, and reaction with singlet oxygen. Soil biota-produced hydrogen peroxide may be involved in biotic oxidation (Lawrinenko et al. 2016). Tillage events increase the oxidation of biochar at the soil surface due to its susceptibility to reaction with singlet oxygen. Depending on the chemistry of the biochar surfaces and the soil's reductive-oxidative and pH conditions, reactions with peroxides, singlet oxygen, and free radicals can occur in the soil (Lawrinenko et al. 2016). Condensed aromatic carbon oxidizes slowly when exposed to reactive forms of oxygen; in contrast, plant materials and microbial biomass in various stages of decomposition oxidize much more quickly (Lawrinenko et al. 2016).

Biochar application rates of 10, 25, 50, and 100 Mg.ha^{-1} significantly increased crop productivity when compared to controls (Jeffery et al. 2011). The addition of biochar to soil increased crop productivity significantly in both 'Acidic' and 'Neutral' soils but did not affect crop productivity in 'Very Acidic' soil (Jeffery et al. 2011).

The verification of biochar's effects on crop yields would thus demonstrate biochar's potential to aid global food security (Jeffery et al. 2011). Whether biochar's persistence in the soil allows it to provide agronomic benefits for a longer period. If the agronomic benefits of this long-delayed decomposition are confirmed in modern agricultural systems, biochar could contribute to long-term production increases in some of the most disadvantaged agricultural environments.

The purpose of this experiment is to investigate the long-term effect of biochar on soil quality by examining the residual effect of biochar on aerobic rice growth and yield, either alone or in combination with poultry litter, in order to add agronomic evidence to support the use of biochar as a soil amendment to improve crop productivity. The primary goal of this research is to identify a soil amendment material that has a long persistence in the soil, allowing it to function for a longer time in maintaining soil quality. It is critical in order to reduce resource and labor investment while increasing farming activity sustainability.

MATERIALS AND METHODS

Site description

Silty Clay (sand 140g.kg^{-1}, silt 41 g.kg^{-1}, clay 45 g.kg^{-1}) Oxic Haplustepts of a fallow field area at the foot slope of Manglayang Mountain in Cigagak - Cibiru Bandung, site location 6º54'30"S and 107º43'46"E were sampled for growing media in the pots experiment. According to the results of an Agro-Chemical Laboratory test at BPTPH Lembang, the soil had pH 5.69, organic-C 24 mg.kg^{-1}, total-N 0.9 mg.kg^{-1}, C/N-ratio 27, P_2O_5 (HCl 250 mL.L^{-1}) 140 mg.kg^{-1}, K_2O (HCl 250 mL.L^{-1}) 71 mg.kg^{-1}, P_2O_5 Bray 4 ppm, cation exchange capacity (CEC).

Biochar and poultry litter

Biochar, which was used as a material treatment, was created by slow pyrolysis of rice husk. The composition of the biochar typically contains total-C 307.8 g.kg^{-1}, N 0.5 g.kg^{-1}, P 2.3 g kg^{-1}, K 0.6 g.kg^{-1}, pH 8.3, and water holding capacity of 40% (Nurida et al. 2009). The composted poultry litter was obtained from broiler husbandry in Cipulus, Cikoneng - a Bandung Regency District that is known for its composition N 17.0 g.kg^{-1}, C/N-ratio 10.8, P_2O_5 21.2 g.kg^{-1}, and K_2O 14.5 g.kg^{-1} (Hartatik and Widowati 2005).

Pot experiment

A series of pot experiment were conducted at Experiment Garden in the Faculty of Agriculture - Islamic Nusantara University Bandung, at elevation 680 meters from sea level and site location 6º56'42" S and 107º38'42" E. The used pots were black plastic with 27 x 27 cm^2 in up wide, 25 x 25 cm^2 in bottom wide, and 25 cm deep. The climate conditions of Bandung in February-June were averaged temperature minimum of 18.7-20.5 ºC and maximum of 29.5-30.0 ºC, rainfall 298.9-26.5 mm month^{-1}, and relative humidity 78-81% (BMKG Indonesia 2018).

The goal of this study was to gather evidence that biochar has a longer effect on enhancing the productivity of aerobic rice (*Oryza sativa* L.), it was conducted between February and June of 2019. This study is a continuation of the experiment conducted between September and December 2018 (Suswana 2019). As a result, the treatments of the experiment that were intended in this study were the same treatments that were used in the previous study. The experiment was carried out using Randomized Block Design / RBD, with eight treatments and three replications (Table 1).

Table 1. Rates of the treatments per pot

Treatments	Rates	
	(Mg.ha^{-1})	(g/pot^{-1})
Control (no biochar applied)	0	0
Biochar	20	135
Biochar	40	270
Biochar	50	338
Biochar	60	406
Biochar + Poultry litter	10 + 10	68 + 68
Biochar + Poultry litter	20 + 20	135 + 135
Biochar + Poultry litter	30 + 30	203 + 203

The aerobic rice was grown in each pot directly from the grain seed, without passing through the making of the seedbed, as many 5 grains per pot. This experiment used the "Situ Bagendit" variety that was obtained from Indonesian Center for Rice Research (BB Padi) Sukamandi. To maintain water is always available to meet the water requirement of the plant during the growing season, we irrigated with the flushing method, when no rainfall or was rainfall in a day but too low in deep. Weed control was done manually. To protecting the plant from mice invade we made fence of the thin zinc-plate in around the experiment area, and to prevent birds invade we covered all the rice plants with soft-net in hight 1.5 meters above ground and in their around.

Data collection

Variables of plant vegetative growth, which compromised plant height and the number of tillers were observed at 8, 10, and 12 weeks after emergences (WAE). While variables of the rice yield, which compromised panicle numbers, panicle length, number of full-filled grains, and grains yield, were observed at the harvesting time (132 days after emergences).

Statistical analysis

The treatment's effects were assessed statistically using analysis of variances (ANOVA) for randomized block design, as described by (Gaspersz 1995). By comparing the mean of difference presented in the summary table, critical differences at 5% of the range of significance are calculated.

RESULTS AND DISCUSSION

Results

Plant height. The residual effect of RHB showed that plant height in applied 50 Mg RHB.ha^{-1} was significantly higher than control, and so do in its combination (10 Mg RHB +10 Mg CPL.ha^{-1} and 30 Mg RHB + 30 Mg CPL.ha^{-1}) significantly higher than control (Table 2). There was a difference between the direct effect and residual effect in applied 50 Mg RHB.ha^{-1}, where its direct effect on plant height was nonsignificantly different from the control. However, plant height in 40 Mg RHB.ha^{-1} was nonsignificant different from in combination (20 Mg RHB + 20 Mg CPL.ha^{-1}); likewise in 60 Mg RHB.ha^{-1} nonsignificant different with 30 Mg RHB + 30 Mg CPL ha^{-1}. While the residual effect of applied 20 Mg RHB.ha^{-1} and 40 Mg RHB.ha^{-1} nonsignificantly affected plant height.

Table 2. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on plant height

Treatments	Plant Height (cm)		
	8 WAE	10 WAE	12 WAE
B_0: RHB 0 Mg ha^{-1}	44,33 ab	53,50 b	59,83 b
B_1: RHB 20 Mg ha^{-1}	47,83 a	59,00 ab	64,67 ab
B_2: RHB 40 Mg ha^{-1}	45,33 ab	57,00 ab	64,83 ab
B_3: RHB 50 Mg ha^{-1}	48,33 a	61,33 a	67,50 a
B_4: RHB 60 Mg ha^{-1}	46,83 ab	60,67 ab	64,17 ab
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	46,17 ab	59,67 ab	65,83 ab
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	43,50 b	56,67 ab	66,67 a
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	47,00 ab	61,67 a	66,50 a

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Number of tillers. The number of tillers per clump at 60 Mg RHB.ha^{-1} was significantly higher than the control, either at 8, 10, or 12 weeks after emergence (WAE). Whereas the number of tillers at 20, 30, 40, and 50 Mg RHB.ha^{-1} treatments were nonsignificantly different compared to the control (Table 3). There was an indication that a higher amount of biochar increased the growth of tillers number. The number of tillers of combination 20 Mg RHB + 20 Mg CPL.ha^{-1} at 12 WAE was significantly higher than control, or 100,11% higher than control, and it was the highest tillers number observed of all treatments. Whereas the tillers number of the 10 Mg RHB + 10 Mg CPL.ha^{-1} and 30 Mg RHB + 30 Mg CPL.ha^{-1} were nonsignificantly different compared to the control.

Table 3. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on number of tillers

Treatments	Number of Tillers per Clump		
	8 WAE	10 WAE	12 WAE
B_0: RHB 0 Mg ha^{-1}	7,33 c	7,83 b	9,33 c
B_1: RHB 20 Mg ha^{-1}	8,17 abc	9,00 ab	12,50 abc
B_2: RHB 40 Mg ha^{-1}	7,83 abc	9,33 ab	11,83 bc
B_3: RHB 50 Mg ha^{-1}	7,50 bc	9,50 ab	13,83 abc
B_4: RHB 60 Mg ha^{-1}	9,17 a	10,67 a	17,50 ab
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	7,67 abc	9,17 ab	12,67 abc
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	7,50 bc	9,83 ab	18,67 a
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	9,00 ab	10,33 a	14,00 abc

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Panicle initiation. The residual effect of RHB and its combination with CPL treatments on the age of panicle initiation were nonsignificantly different compared to the control, except at the treatment of 30 Mg RHB + 30 Mg CPL.ha^{-1} was significantly longer than the control (Table 4).

Table 4. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on panicle initiation

Treatments	Age of Panicle Initiation (Days)
B_0: RHB 0 Mg ha^{-1}	91,17 a
B_1: RHB 20 Mg ha^{-1}	91,00 a
B_2: RHB 40 Mg ha^{-1}	91,83 a
B_3: RHB 50 Mg ha^{-1}	93,50 ab
B_4: RHB 60 Mg ha^{-1}	91,33 a
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	93,17 ab
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	95,00 ab
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	97,17 b

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Number of panicles. Panicles number per clump at application 60 Mg RHB.ha^{-1} and 20 Mg RHB +20 Mg CPL.ha^{-1} were significantly higher than control but at the other treatments nonsignificantly different from control (Table 5). While panicles number at 60 Mg RHB.ha^{-1} was nonsignificantly different compared to 30 Mg RHB + 30 Mg CPL ha^{-1}; likewise at 20 Mg RHB + 20 Mg CPL ha^{-1} was nonsignificantly different with 40 Mg RHB ha^{-1}. Indeed, the panicles number in combination (20 Mg RHB + 20 Mg CPL.ha^{-1}) was substantially a higher than alone (40 Mg RHB.ha^{-1}); on the contrary panicles number in other combination (30 Mg RHB + 30 Mg CPL.ha^{-1}) substantially lower than alone (60 Mg RHB.ha^{-1}). There was an indication that higher amount of biochar increased the growth of panicles number, and the combined application of biochar and composted poultry increased the panicles number as compared to the alone application.

Table 5. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on panicles number

Treatments	Panicles Number per Clump
B_0: RHB 0 Mg ha^{-1}	8,83 b
B_1: RHB 20 Mg ha^{-1}	12,33 ab
B_2: RHB 40 Mg ha^{-1}	11,50 ab
B_3: RHB 50 Mg ha^{-1}	13,67 ab
B_4: RHB 60 Mg ha^{-1}	17,17 a
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	12,50 ab
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	18,67 a
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	13,33 ab

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Length of panicle and number of full-filled grains. The residual effect of RHB and its combination with CPL was nonsignificantly on the panicle length of aerobic rice (Table 6). Grains number per panicle at 10 Mg RHB + 10 Mg CPL.ha^{-1} was significantly higher than the control, whereas at other treatments nonsignificantly different compared to control. There was also appeared that the number of grains number per panicle applied with 20 Mg RHB.ha^{-1} nonsignificantly different compared to the control, but at 10 Mg RHB + 10 Mg CPL.ha^{-1} significantly higher than the control. This evidence indicated that in the lower rate RHB application, the residual effect of RHB in combination with CPL is better than alone.

Yield of Rice Grains. Grains yield at 60 Mg RHB.ha^{-1} and 20 Mg RHB + 20 Mg CPL.ha^{-1}, 209.84%, and 210,62% respectively, higher than control, whereas at other treatments nonsignificantly different compared to control (Table 7). Grains yield in combination with 20 Mg RHB + 20 Mg CPL.ha^{-1} is 135.49% higher than at 40 Mg RHB.ha^{-1} alone, where the grains yield at 40 Mg RHB.ha^{-1} is nonsignificantly different compared to control. On the contrary, grains yield at 60 Mg RHB.ha^{-1} alone 118,47% higher than in combination 30 Mg RHB + 30 Mg CPL.ha^{-1}, and grains yield in combination 30 Mg RHB + 30 Mg CPL.ha^{-1} nonsignificantly different compared to control. This evidence also indicated that the residual effect of RHB in combination with CPL better than alone for a lower RHB rate; on the contrary, the residual effect of RHB alone is better than in combination with CPL for a higher RHB rate.

Throughout the results, a higher amount of biochar increased the yield of aerobic rice, and a combined application of biochar and composted poultry increased the yield of aerobic rice when compared to a single application. The combined application of biochar and composted poultry litter, 20 Mg RHB + 20 Mg CPL.ha^{-1}, can be considered the most effective combination rate, because the combination rate significantly extended the residual effect, whereas neither the lower combination rate nor the higher combination rate did.

Table 6. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on length of panicle and number of full-filled grains

Treatments	Length of Panicle	Number of Full-filled Grains per Panicle
B_0: RHB 0 Mg ha^{-1}	18,90 a	50,02 b
B_1: RHB 20 Mg ha^{-1}	19,30 a	60,16 ab
B_2: RHB 40 Mg ha^{-1}	19,10 a	57,67 ab
B_3: RHB 50 Mg ha^{-1}	19,04 a	64,10 ab
B_4: RHB 60 Mg ha^{-1}	19,47 a	62,92 ab
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	20,01 a	75,21 a
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	19,87 a	66,07 ab
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	18,96 a	56,90 ab

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Table 7. Residual effect of Rice Husk Biochar (RHB) and its combination with Composted Poultry Litter (CPL) on yield of rice grains

Treatments	Yield of Rice Grains (g/clump)	Yield of Rice Grains (Mg ha^{-1})
B_0: RHB 0 Mg ha^{-1}	8,13 b	2,032
B_1: RHB 20 Mg ha^{-1}	12,69 ab	3,173
B_2: RHB 40 Mg ha^{-1}	12,65 ab	3,161
B_3: RHB 50 Mg ha^{-1}	14,57 ab	3,643
B_4: RHB 60 Mg ha^{-1}	17,06 a	4,266
B_5: RHB 10 Mg ha^{-1} + CPL 10 Mg ha^{-1}	15,31 ab	3,828
B_6: RHB 20 Mg ha^{-1} + CPL 20 Mg ha^{-1}	17,14 a	4,285
B_7: RHB 30 Mg ha^{-1} + CPL 30 Mg ha^{-1}	14,40 ab	3,600

Note: Means followed by the same letters are not significantly different from each other (*P<0.05*)

Discussion

The residual effect of the application of 50 Mg RHB ha^{-1} has significantly increased plant height compared to the control, whereas it was a nonsignificant effect in the first growing season (Suswana 2019). It might be due to the occurrence of oxidation on the surface of biochar after being applied to the soil. Oxidation caused changes in the oxygen and nitrogen-containing functional groups on the surface of biochar. Biochar and P addition, for example, increased nutrient availability in nutrient-limited soil while also stimulating microbial activity. The same thing was observed at the application of 30 Mg RHB + 30 Mg CPL.ha^{-1}, where its residual effect significantly increased plant height compared to the control, but in the first growing season nonsignificant (Suswana 2019). Probably, weakly the direct effect of the treatment, might be due to the immobilization of N by microorganisms during the decomposition process of CPL. Furthermore, in the second growing season, or its residual effect, the nutrient-N has been released and became more available. However, these effects were inconsistent with their effects on other variables of growth and yield of the aerobic rice.

The residual effect of application 60 Mg RHB.ha^{-1} and 20 Mg RHB + 20 Mg CPL.ha^{-1} both significantly increased tillers number, panicles number, and grains yield of aerobic rice compared to the control. While the direct effect of applied 60 Mg RHB.ha^{-1} was nonsignificant on tillers number, but significantly increased panicles number compared to control. This effect might be due to the aging process of the biochar after being applied to the soil fresh biochar has a high specific surface area and may have a positive net surface charge (Mia et al. 2017a). Biochar oxidizes in the soil over time, causing changes in its physical and chemical properties. Surface functional groups are formed, particularly carboxylic and hydroxyl groups (Mia et al. 2017b). As a result, as biochar ages, its negative surface charge and cation exchange capacity (CEC) increase. As a result, the nutrient retention capacity and availability of aged biochar increased, and its residual effect outperformed its direct effect. During the 8.5 years, however, only about 6% of the initially added biochar was mineralized to CO_2 (Kuzyakov et al. 2014). The biochar decomposition rates estimated by $^{14}CO_2$ efflux between the 5th and 8th years are less than 0.3% per year under optimal conditions (Kuzyakov et al. 2014).

Applied 60 Mg RHB.ha^{-1} significantly increased panicles number compared to the control, either its direct effect (Suswana 2019) or its residual effect. This evidence might be due to when the plant grows up to the generative stage, the fresh biochar applied has partially oxidized and consequence in increasing CEC, and subsequently affected panicles generating.

In the short term, partially oxidizing fresh, pyrolysis char could improve the fertility of char-amended soils (Kameyama et al. 2012). Biochar condition was relatively fresh during the vegetative stage. Because fresh chars have far fewer COO substituents, they have a lower CEC (Kameyama et al. 2012). After 30 days of growth, the total 15 N recovery in plant and soil was 41% greater with NH_4+-N addition than with NO_3-N addition, according to an examination of 15 N recovery and P uptake in mixtures of clover (*Trifolium repens*) and ryegrass (*Lolium perenne*) after biochar amendment at different oxidation states and addition of 15 NH_4+-N and NO_3-N. However, the 15N recovery from NH_4+-N addition was greater in the oxidized biochar treatments than in the control and fresh biochar treatments (Fungo et al. 2019).

Biochar reduced cumulative emissions of NH_3 and N_2O by 47 ± 5 and 22% ± 3, respectively, over the 3 years. The effect size of biochar was reduced by 53 and 59% for NH_3 and N_2O, respectively, indicating that the residual effect of biochar on NH_3 and N_2O persists for at least up to 3 years under field conditions (Fungo et al. 2019). The residual effect of application 30 Mg RHB + 30 Mg CPL.ha^{-1} is nonsignificant in panicle number compared to the control, which was contrary to its direct effect (significantly increased panicle number) (Suswana 2019). It might be due to the decomposition of CPL releasing more nutrient availability and increased microbial activities in the first growing season period than in the second growing season. The direct effect of alone poultry manure application is higher than its residual effect (Komahan and Premanandarajah 2015).

From the standpoint of the biochar component of the combination treatment, the higher the oxidized state of biochar, the more exchange sites there will be, resulting in increased NH_4+-N retention and biomass production (Mia et al. 2019). However, chemical oxidation increased NO_3-N and phosphate-P leaching (Mia et al. 2019). However, these findings contradicted previous findings that biochar could remove between 0.12% and 3.7% of NO_3 from a solution (Clough et al. 2013).

According to Kameyama et al. (2012), NO_3 adsorption was caused by base functional groups rather than physical adsorption because surface area and micropore volumes followed different trends when compared to observed NO_3 adsorption (Clough et al. 2013). Biochar significantly increased the gross rates of mineralization, immobilization, autotrophic nitrification, and dissimilatory nitrate reduction to ammonium, but did not effect on the net rates of mineralization and nitrification (Clough et al. 2013).

The residual effect of 20 Mg RHB + 20 Mg CPL.ha^{-1} application significantly increased tiller number, panicle number, and grain yield when compared to the control. In contrast, the residual effect of 30 Mg RHB + 30 Mg CPL.ha^{-1} on aerobic rice growth and yield was insignificant. It was because the former combination created a more favorable physical, chemical, and biological soil condition, resulting in increased nutrient uptake, growth, and yield of aerobic rice. The applied biochar has a positive residual effect on pH, improved nutrient retention through cation adsorption changed soil biological community composition and abundance, or increased soil macroaggregates and structure formation (Ventura et al. 2019).

The addition of base cations had the greatest effect in the peanut hull biochar study; this had a short-term effect on soil pH and increased available K, Ca, and Mg (Sadegh-Zadeh et al. 2018). While rice husk biochar increases macroaggregates larger than 0.25 mm and decreases microaggregates smaller than 0.25 mm (Lu et al. 2014). The mean residence time of the more recalcitrant biochar fraction in the absence of plant roots was 24.3 years; in the presence of plant roots, the mean residence time of the more recalcitrant biochar fraction was 12.6 years, confirming the previously observed positive effect of plant roots on biochar decomposition (Ventura et al. 2019). Biochar, on the other hand, reduced the decomposition of the original SOM by 16% in the absence of roots, indicating a long-term protective effect on SOM (Ventura et al. 2019).

The residual effect of applied 40 Mg RHB ha^{-1} was nonsignificant either on plant height, tillers number, panicles number, or grains yield compared to control; whereas applied 20 Mg RHB + 20 Mg CPL.ha^{-1} significantly increased plant height, tillers number, panicles number, and grains yield of aerobic rice compared to control. This evidence indicated that the residual effect of biochar in combination with composted poultry litter at the rate was better than its residual effect of applied biochar in the sole. Although, it is still necessary to reconfirm in subsequently growing seasons.

Biochar and compost application increased soil total N and available P concentrations; additionally, soil available K increased as the rate of biochar and compost incorporation increased (Sadegh-Zadeh et al. 2018). The use of biochar in conjunction with compost increased soil available concentrations of Fe, Zn, Cu, and Mn (Sadegh-Zadeh et al. 2018). A higher application rate of biochar and compost resulted in a higher grain yield. Concurrent application of biochar and compost increased grain yield more than separately applied biochar and compost; crop yields can be increased even more when charcoal amendments are applied in conjunction with inorganic or organic fertilizers compared to control soils. Grain yield could have increased due to improvements in soil chemical properties and nutrient enhancement.

CONCLUSIONS

Rice husk biochar, when combined with composted poultry litter, increased aerobic rice growth and yield. A higher amount of biochar increased rice growth and yield compared to the control. The combined application of biochar and composted poultry increased rice productivity when compared to a single application of biochar and composted poultry. The residual effect of 20 Mg rice husk biochar + 20 Mg composted poultry litter ha^{-1} on rice productivity outperforms fresh application.

REFERENCES

Aguilera J, Motavalli PP, Gonzales MA, Valdivia C. 2012. Initial and residual effects of organic and inorganic amendments on soil properties in a potato-based cropping system in the Bolivian Andean Highlands. Am J Exp Agric. 2(4):641–666. https://doi.org/10.9734/AJEA/2012/2006.

[BMKG Indonesia] Board of Meteorologic, Climatologic, dan Geophysic. 2018. Climatic Condition in Bandung. Jakarta (ID): BMKG Indonesia.

Chen J, Kim H, Yoo G. 2015. Effects of biochar addition on CO2 and N2O emissions following fertilizer application to a cultivated grassland soil. Lehman RM, editor. PLoS One. 10(5):e0126841. https://doi.org/10.1371/journal.pone.0126841.

Clough T, Condron L, Kammann C, Müller C. 2013. A review of biochar and soil nitrogen dynamics. Agronomy. 3(2):275–293. https://doi.org/10.3390/agronomy3020275.

Dempster DN, Jones DL, Murphy D V. 2012. Clay and biochar amendments decreased inorganic but not dissolved organic nitrogen leaching in soil. Soil Res. 50(3):216–221. https://doi.org/10.1071/SR11316.

Fungo B, Lehmann J, Kalbitz K, Thionģo M, Tenywa M, Okeyo I, Neufeldt H. 2019. Ammonia and nitrous oxide emissions from a field Ultisol amended with tithonia green manure, urea, and biochar. Biol Fertil Soils. 55(2):135–148. https://doi.org/10.1007/s00374-018-01338-3.

Gaspersz V. 1995. Teknik analisis dalam penelitian percobaan. 1st ed. Bandung (ID): Tarsito.

Hartatik W, Widowati L. 2005. Pupuk kandang. In: Simanungkalit RDM, Suriadikarta DA, Saraswati R, Setyorini D, Hartatik Wiwik, editors. Pupuk organik dan pupuk hayati. Bogor (ID): Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. p. 59–82.

Jeffery S, Verheijen FGA, van der Velde M, Bastos AC. 2011. A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agric Ecosyst Environ. 144(1):175–187. https://doi.org/10.1016/j.agee.2011.08.015.

Kameyama K, Miyamoto T, Shiono T, Shinogi Y. 2012. Influence of Sugarcane Bagasse-derived Biochar Application on Nitrate Leaching in Calcaric Dark Red Soil. J Environ Qual. 41(4):1131–1137. https://doi.org/10.2134/jeq2010.0453.

Kavitha B, Reddy PVL, Kim B, Lee SS, Pandey SK, Kim K-H. 2018. Benefits and limitations of biochar amendment in agricultural soils: A review. J Environ Manage. 227:146–154. https://doi.org/10.1016/j.jenvman.2018.08.082.

Komahan DHS, Premanandarajah P. 2015. Direct and residual effect of organic manures, urea integration on okra grown in sandy regosol. Int J Environ Sci. 5(5):980–987.

Kuzyakov Y, Bogomolova I, Glaser B. 2014. Biochar stability in soil: Decomposition during eight years and transformation as assessed by compound-specific 14C analysis. Soil Biol Biochem. 70:229–236. https://doi.org/10.1016/j.soilbio.2013.12.021.

Lawrinenko M, Laird DA, Johnson RL, Jing D. 2016. Accelerated aging of biochars: Impact on anion exchange capacity. Carbon N Y. 103:217–227. https://doi.org/10.1016/j.carbon.2016.02.096.

Lehmann J, Joseph S, editors. 2015. Biochar for environmental management: Science, technology and implementation. London (UK): Routledge.

Liliana Y. 2017. Pengaruh aplikasi kombinasi pupuk kandang ayam dan pupuk KCl terhadap pertumbuhan dan hasil produksi jagung manis (*Zea mays Saccharata* Sturt.) [undergraduate's thesis]. Bandar Lampung (ID): Universitas Lampung.

Lu S-G, Sun F-F, Zong Y-T. 2014. Effect of rice husk biochar and coal fly ash on some physical properties of expansive clayey soil (Vertisol). CATENA. 114:37–44. https://doi.org/10.1016/j.catena.2013.10.014.

Mao J-D, Johnson RL, Lehmann J, Olk DC, Neves EG, Thompson ML, Schmidt-Rohr K. 2012. Abundant and stable char residues in soils: Implications for soil fertility and carbon sequestration. Environ Sci Technol. 46(17):9571–9576. https://doi.org/10.1021/es301107c.

Melati M, Andriyani W. 2005. Pengaruh pupuk kandang ayam dan pupuk hijau Calopogonium mucunoides terhadap pertumbuhan dan produksi kedelai panen muda yang dibudidayakan secara organik. J Agron Indones. 33(2):8–15.

Mia S., Dijkstra FA, Singh B. 2017a. Long-term aging of biochar: A molecular understanding with agricultural and environmental implications. In: Sparks DL, editor. Advances in Agronomy. Academic Press. p. 1–51.

Mia S, Singh B, Dijkstra FA. 2017b. Aged biochar affects gross nitrogen mineralization and recovery: a 15 N study in two contrasting soils. GCB Bioenergy. 9(7):1196–1206. https://doi.org/10.1111/gcbb.12430.

Mia S, Singh B, Dijkstra FA. 2019. Chemically oxidized biochar increases ammonium-15N recovery and phosphorus uptake in a grassland. Biol Fertil Soils. 55(6):577–588. https://doi.org/10.1007/s00374-019-01369-4.

Nurida NL, Dariah A, Rachman A. 2009. Kualitas limbah pertanian sebagai bahan baku pembenah tanah berupa biochar untuk rehabilitasi lahan. In: Proceeding National Seminar and dialogue Agricultural Land Resources; November 18-20 2008; Bogor, ID. Bogor (ID): BBSDLP. hal. 209–215.

Nguyen BT, Trinh NN, Le CMT, Nguyen TT, Tran T Van, Thai BV, Le T Van. 2018. The interactive effects of biochar and cow manure on rice growth and selected properties of salt-affected soil. Arch Agron Soil Sci. 64(12):1744–1758. https://doi.org/10.1080/03650340.2018.1455186.

[Statistics Indonesia] Indonesian Central Statistics Agency. 2018. Ringkasan eksekutif luas panen dan produksi beras di Indonesia. Jakarta (ID): Indonesian Central Statistics Agency.

Sadegh-Zadeh F, Tolekolai SF, Bahmanyar MA, Emadi M. 2018. Application of biochar and compost for enhancement of rice (*Oryza Sativa* L.) grain yield in calcareous sandy soil. Commun Soil Sci Plant Anal. 49(5):552–566. https://doi.org/10.1080/00103624.2018.1431272.

Suswana S. 2019. Pengaruh biochar terhadap pertumbuhan padi dalam sistem aerobik. Agrotechnology Res J. 3(1):44–49. https://doi.org/10.20961/agrotechresj.v3i1.30396.

Ventura M, Alberti G, Panzacchi P, Vedove GD, Miglietta F, Tonon G. 2019. Biochar mineralization and priming effect in a poplar short rotation coppice from a 3-year field experiment. Biol Fertil Soils. 55(1):67–78. https://doi.org/10.1007/s00374-018-1329-y.