International Journal of Recycling of Organic Waste in Agriculture (2023)12: 85-95
Doi: 10.30486/IJROWA.2022.1942099.1355

ORIGINAL RESEARCH

Improvement in soil properties and soil water content due to the application of rice husk biochar and straw compost in tropical upland

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Received: 07 October 2021 / Accepted: 20 April 2022 / Published online: 13 July 2022

Abstract

Purpose Rice biomass waste can be used as a soil amendment. This study examined the effect of the application of rice husk biochar and straw compost on several soil properties and yields of rice and soybeans in tropical upland.

Method Field experiments were carried out with two applications of rice husk biochar and straw compost on upland rice and soybean cultivation, respectively. Three-levels of rice husk biochar application (5, 10, and 20 t ha^{-1}) and straw compost (5 t ha^{-1}) along with the control. The changes in soil chemical properties like pH, C, N, CEC, P, K, Mg, Ca, Na, and physical properties including soil bulk density, particle density, total porosity, macropores, micropores, permeability, and soil water content at various pressures were measured. The grain yields of rice and soybean were also recorded.

Results Total-C and exchangeable-K increased after the second application of rice husk biochar and straw compost. There was a significant improvement in total porosity and micro-pores, soil water content especially at PF 2.54 (0.33 Pa) and PF 4.2 (15 Pa), and increased soybean yield compared to control. Based on the overall results, we got a significant effect of rice husk biochar at higher doses (10 and 20 t ha^{-1}).

Conclusion The application of rice husk biochar (at doses 10 or 20 t ha^{-1}) and straw compost 5 t ha^{-1} gave a positive effect on several soil properties including total-C, soil porosity, and soil water content, especially at pF 2.54 and pF 4.2, and also increased soybean yields.

Keywords Rice biomass waste, Soil chemical properties, Soil physical properties, Soybean, Upland rice

Introduction

Rice is usually grown in paddy fields irrigated by canal irrigation. Recently, the upland rice cultivation is increasing but the yields are often low due to low soil fertility. The major soil type in Indonesia is Ultisols, which is characterized by low base saturation (<35%), soil acidity, low cation exchange capacity (CEC), low organic C content, and the availability of elements such as N, P, K, Ca, Mg, and Mo are relatively low (Prasetyo and Suriadikarta 2006). Under humid tropical climate, the macro- and micro-nutrients are easily leached out and organic matter is low. Therefore, the

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addition of organic matter into the soil is one of the best practices in agriculture to improve soil fertility in tropical upland. In 2019, approximately 55 million tons of rice grains was produced in Indonesia (Statistics Indonesia 2020). The most biomass waste produced from rice plants is the straw. Another rice biomass waste is rice husk which forms about 22% of the weight of rice grains (Gautam et al. 2019). The Husk is a hard material and difficult to decompose because of its relatively high amount of lignin and silicate elements (Lu and Luh 1991; Milla et al. 2013). The material is not utilized optimally yet and can be used to improve soil fertility. Rice husk is an organic material that can be used as biochar. Biochar produced from burning under limited oxygen supply can be a good soil amendment because the carbon lasts for a long time in the soil (Sujana and Pura 2015). Rice Husk Biochar (RHB) showed a potential for ameliorating acidity, especially in slightly acidic sandy soil (Gamage et al. 2015). There have been many studies on the effect of RHB application on soil properties, with varying results. Some research results showed that application of RHB could improve chemical properties especially soil pH (Tsai and Chang 2020), soil nutrient availability (Oladele et al. 2019), decrease soil bulk density (Masulili et al. 2010), and increase soil water content at 5–10 cm depth (Vitkova et al. 2017). Rice husk dust application significantly increases soil pH, organic carbon, total N, C/N ratio, available P, and maize grain yield (Njoku et al. 2015). The Application of compost and biochar improved the water retention of soil and improved the uptake of water and nutrients by plants (Agegnehu et al. 2015). The Positive effects of straw compost applications on soil fertility have been reported widely. Compost improves soil water content (Evanylo et al. 2008) and increases the water holding capacity (Milla et al. 2013). During the days without rain (during dry seasons), the flow of water occurs from the bottom up (negative flux) through the micropores in an unsaturated manner because of the evapotranspiration process. In dry conditions, plants depend on the amount of water stored in the soil that can be readily available to plants without stress (Wahjunie et al. 2008), so added organic matter improves the soil porosity and increases the water retention by the soil. The addition of organic matter in every season improves pore structure and pore size distribution (Zaffar and Gao 2015). Zangiabadi et al. (2017) reported that soils with smaller pores and higher pore size diversity have more available water and less growth limitation factor for the plant. Although many research results have reported the effectiveness of RHB and SC on several parameters of soil properties, however, this study aims to examine comprehensively their effect on physic-chemical properties of soil in upland rice, the relationship to soil water content, and on yields of upland rice and soybean.

Materials and methods

Study site

The study place is located at Sukaraja Nuban Village, Batanghari Nuban, East Lampung, Indonesia, geographical coordinate 5.02915078S, 105.40800429E, altitude 128 m. Soil type is Ultisol with soil texture comprising sand 41%, silt 21%, and clay 38%. The soil chemical properties were as follows: pH 4.61, total-C 1.28%, Total-N 0.13%; P2O5 (Bray-1) 6.43 mg kg^{-1}; K2O 0.27 cmol kg^{-1}, and CEC 5.66 cmol kg^{-1}. The history of land use management for the past few years showed that soil did not receive any organic fertilizer or soil amendment except chemical fertilizers. The crops grown on these locations are corn, cassava, upland rice, and soybeans.

Experimental setup

The experiment comprised three rice husk biochar (RHB) treatments (5 t ha^{-1}, 10 t ha^{-1}, and 20 t ha^{-1}), rice straw compost (SC) @ 5 t ha^{-1}, and control (no application of RHB and SC). There were a total of 20 plots

(4x5) with plot size 5 x 10 m and each plot was separated by a trench 30 cm deep and 0,5 m wide.

Crop rotation, application of RHB and SC, and soil sampling

Two crops rotated continuously were: upland rice (planted in February 2018) and soybean (planted in June 2018). The seeds of upland rice (*Inpago 8 variety*) and soybean (*Anjasmoro variety*) were directly planted in the hole with a spacing of 25 x 25 cm and 40 x 20 cm, respectively. Thus, the number of plants per plot (5x10 m) were 800 (upland rice) and 625 (soybean). Application of RHB and SC was carried out twice, first before planting rice (after soil tillage: conventional tillage using plows and harrows), and second before planting soybean (after minimum soil tillage: tillage carried out on crop paths). Application of RHB and SC was done by spreading the material on the soil surface and incorporating them in the soil using a rake. Soil samples were taken two weeks after the application of RHB and SC. Soil physical properties (bulk density, particle density, total porosity, macropores, micropores, permeability, and water retention) were analyzed using a soil sample core from 0 to 20 cm depth. Bulk density was the dry weight of soil divided by its volume (the volume of soil particles and the volume of pores among soil particles). Particle density was the dry weight of soil divided by its volume (the volume does not include the volume of pores among soil particles). Total porosity was computed as the percentage of soil volume occupied by pore spaces and expressed as : Total porosity (%) = $(1 - \rho b/\rho p) \times 100$; where, ρb (bulk density), ρp (particle density). Soil water retention was determined by using an automatic compressor connected to a pressure plate apparatus by applying pressures consisting of 0.01 atm (pF 1.0), 0.1 atm (pF 2.0), 0.33 atm (pF 2.54), and 15 atm (pF 4,2). For chemical properties, soil samples were collected from five sub sample points per plot which were composited and quartered to get a representative sample for chemical analysis. Soil pH measured by using a pH meter. Soil organic-C determined following the Walkley & Black wet digestion method. Total nitrogen level in the soil determined following modified Kjeldahl's method. Available P content determined by following the Olsen's procedure, exchangeable-K with ammonium acetate 1N pH 7, and CEC of soils by NH4OAc (1N, pH 7) method. The analysis work following the procedures outlined in the technical guidelines for soil chemical analysis (Indonesian Soil Research Institute 2009) and physical properties according to Kurnia et al. (2006).

Determination of rice and soybean yield

Upland rice was harvested after 118 days of planting and soybeans after 90 days. Each plot was harvested, then dry grain was weighed per plot and the yields were converted to tonnes per hectare.

Data analysis

The data were subjected to analysis of variance using SPSS v.18 and least significant difference (LSD) was calculated as a post hoc test to separate the treatment means at a 5% probability level.

Characterization of rice husk biochar and straw compost

Rice husk received from a local rice mill was used in study. Biochar from rice husk was produced through the low temperature pyrolysis process. Rice husk was put in a drum and it was burnt without oxygen at 200–300 ˚C. The rice straw used in this study was a fermenting rice straw after the addition of the effective microorganism (EM-4) as bio-activator for about 30 days. The characteristics of rice husk biochar and straw compost shown in Table 1.

Table 1 The chemical characteristics of rice husk biochar (RHB) and straw compost (SC)

Types of rice waste	**pH**	**Total-C (%)**	**Total-N (%)**	**Water content**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**Na (%)**	**CEC (cmol kg^{-1})**
RHB	7.14	7.82	6.43	0.08	0.07	0.67	0.25	0.22	0.11	11.83
SC	8.23	22.34	1.06	-	0.28	1.67	0.31	0.12	0.64	-

Results and discussion

Soil chemical properties

Chemical characteristics of soil after the first application of RHB and SC presented in Table 2. Based on statistical tests, except for the total N-value, other chemical properties (pH, total-C, P, K, and CEC) were not significantly influenced by the application of RHB and SC. Based on Table 1, the N content of straw compost in this study was relatively high (1.06%) compared to the report of Dobermann and Fairhurst (2002) that rice straw at harvest can contain 0.5–0.8% N. Added straw compost improves nutrient cycling through the decomposition process and mineralization of nutrients, continuous application of crop residues can eventually increase the N-supplying capacity of rice soils (Eagle et al. 2000).

Based on application of the highest dose of RHB (20 t ha^{-1}) brought a statistically not significant increase in soil pH by about 3.5% compared to control (Table 2). Oladele et al. (2019) stated that biochar could serve as a liming agent to improve soil pH for acidic Oxic-Paleustalf Alfisols and Oxic-Paleustult Ultisols. However, Milla et al. (2013) reported that the application of 0.5-4 kg/m^3 RHB had no effect on soil pH, but increased WHC (water-holding capacity). Compared to RHB, rice straw compost had a higher total-C and elemental Ca, Mg, and Na (Table 1). Therefore, application of RHB could improve the chemical properties with varying effects related to the effect of pyrolysis temperature and application rate (Tsai and Chang 2020). Organic matter (OM) such as straw compost application has a liming effect because of its richness in alkaline cations such as Ca, Mg, and K, which were liberated from OM by mineralization. However, in contrast to chemical fertilizers, compost made from organic wastes supplies plants nutrients slowly. Application of RHB @ 20 t ha^{-1} brought a statistically non-significant increase in CEC by 7.39% compared to the control (6.84 to 7.92 cmol $^{(+)}$/kg) Table 2). Based on the chemical characteristics of rice husk biochar (Table 1), the CEC of RHB was 11.83 cmol kg^{-1} was not effective to increase soil CEC at the time of observation. Similar result was reported by Masulili et al. (2010) that the application of biochar with a CEC value of 17.57 did not significantly increase the CEC of soil (acid sulfate soils of West Kalimantan, Indonesia). Yuan and Xu (2012) reported that application of biochar from crop residues increase the CEC of soils with relatively low initial of CEC at high level addition of biochar (1% biochar). The range of soil CEC in Table 2 (6.83-7.92 cmol $^{(+)}$/kg) was low, this is related to the type of soil (Ultisol) at this research location. Soil at the location has a soil texture with a high percentage of sand (sand 41%, silt 21%, and clay 38%) keeping the soil CEC levels low. Hartatik and Purwani (2017) also reported that the Typic Kanhapludults soil type in East Lampung (Indonesia) with a soil texture comprising 41% sand, 17% silt, and 42% clay, the CEC of this soil was low (5,4 cmol $^{(+)}$/kg). Syahputera et al. (2015) reported that CEC in the six Ultisol sub-groups of Sumatera were very low to moderate or ranged from 2.43 to 16.76 cmol $^{(+)}$/kg. Although the range of soil CEC at the research site was low, but with the application of RHB 20 t/ha, the soil CE.

Table 2 Some chemical properties of soil after the first application of RHB and SC

Treatments	**pH$_{H2O}$**	**Total-C (g/kg)**	**Total-N (g/kg)**	**Available-P (mg/kg)**	**Exchangeable-K(cmol$^{(+)}$/kg)**	**CEC (cmol$^{(+)}$/kg)**
Control	4.61 a	12.0 a	1.71 ab	8.93 a	0.23 a	6.84 a
RHB 5	4.67 a	13.2 a	1.83 b	13.76 a	0.29 a	7.59 a
RHB 10	4.69 a	13.3 a	1.77 ab	10.69 a	0.28 a	7.72 a
RHB 20	4.77 a	13.1 a	1.82 b	10.72 a	0.25 a	7.92 a
SC 5	4.53 a	12.8 a	1.69 a	11.77 a	0.30 a	6.83 a
LSD (5%)			0,065			

Means followed by the same letters at each column are not significantly different ($P < 0.05$; LSD test).
RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}

The second application of RHB and SC brought a statistically significant increase in total C, application of RHB 20 t ha^{-1} and SC 5 t ha^{-1} increased total-C by 14.5% compared to control (Table 3). Based on the characteristics of rice husk biochar and straw compost material (Table 1), the total-C values of RHB and SC were high enough (6.43% and 22.34%) which can contribute to increasing total-C in the soil at second application. Oladele et al. (2019) showed that SOC increased with the biochar application rate up to 12 t ha^{-1}. Biochar has the unique properties such as high porosity, low density, and the ability to keep additional carbon (Zwieten et al. 2012). Other researchers have reported similar results for biochar-amended soils in the long term increasing total-C soil (Gamage et al. 2015; Nigussie et al. 2012; Jien and Wang 2013; Tammeorg et al. 2014; Verma and Reddy 2020). The contents of Olsen's P and exchangeable K in the soil also increase at the second application of organic matter. Application of RHB 10 t ha^{-1} increased Olsen's P by 43% compared to control (Table 3). Jen et al. (2001) reported that addition of organic matter can improve P availability through solubilisation of fixed P by soil microorganisms. Furthermore, application of 5 t ha^{-1} of straw compost also increased exchangeable K (the free potassium in soil solution) compared to control (Table 3). Incubation of straw in paddy fields increased K$^+$ release rate (Li et al. 2014) and improved soil available potassium to a significantly greater magnitude than manure (Kaur and Benipal 2006). Darunsontaya and Jindaluang (2021) reported that rice straw incorporation had a beneficial effect on K availability in illite-containing soils, the readily available K (water-soluble K + exchangeable K) highly increased with the increasing rate of rice straw incorporation compared to control.

Table 3 Soil chemical properties after the second application of the RHB and SC

Treatments	**pH$_{H2O}$**	**Total-C (g/kg)**	**Total-N (g/kg)**	**Available-P (mg/kg)**	**Exchangeable-K (cmol$^{(+)}$/kg)**	**CEC (cmol$^{(+)}$/kg)**
Control	4.58 a	11.7 b	1.11 a	16.04 a	0.18 a	6.01 a
RHB 5	4.61 a	13.2 a	1.13 a	19.01 b	0.27 ab	7.44 a
RHB 10	4.67 a	13.1 a	1.82 a	22.98 b	0.28 ab	7.59 a
RHB 20	4.65 a	13.4 a	1.28 a	20.75 b	0.22 a	7.52 a
SC 5	4.66 a	13.4 a	1.65 a	21.11 b	0.31 b	6.28 a
LSD (5%)				2,82	0.08	

Means followed by the same letters at each column are not significantly different ($P < 0.05$; LSD test); RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}.

Soil physical properties

Bulk density, particle density, macropores, and permeability of soil were not significantly influenced by RHB and SC application in the first and second crop (Table 4 and 5). The total porosity increased after the second application of all amendments, except in the case of RHB @ 5 t ha^{-1} (Table 5). The proportion of soil micro-pores increased after the first application of RHB @ 20 t ha^{-1} and SC.@ 5 t ha^{-1}. (Table 4). With the second application of RHB @10 t ha^{-1}, a notable increase in the proportion of micropores was also recorded. The average soil permeability values were 5.13-6.43 cm/hour, this shows that the soil permeability was rather fast. Permeability value shows the ability of soil to pass water either laterally or horizontally. Permeability is influenced by the porosity and bulk density of the soil and closely related to soil texture (Arora et al. 2011). The soil texture in this study had high sand content (41%), so the bulk density value is low (1.07 to 1.15). Biochar application reduced bulk density and particle density and increased soil porosity (Blanco-Canqui 2017). Reduced bulk density can improve roots–soil contact and pore connectivity, allowing higher nutrient and water transport and supply to plant roots. Higher applications increase the dilution effect of biochar because of its relatively lower bulk density compared to soil mineral particles (Lehmann et al. 2011).

Table 4 Soil physical properties after application of the RHB and SC soil amenders in the first crop

Treatment	**Bulk density (g/cm^3)**	**Particle Density (g/cm^3)**	**Total Porosity (%)**	**Macropores (%)**	**Micropores (%)**	**Permeability (cm/hour)**
Control	1.15 a	2.13 a	45.21 a	17.73 a	6.53 a	5.13 a
RHB 5	1.15 a	2.11 a	45.27 a	18.05 a	6.83 a	5.86 a
RHB 10	1.11 a	2.08 a	46.73 a	18.63 a	6.87 a	5.37 a
RHB 20	1.11 a	2.08 a	47.63 a	19.96 a	8.63 b	6.13 a
SC 5	1.07 a	2.13 a	48.87 a	19.91 a	8.71 b	6.43 a
LSD (5%)					0.67	

Means followed by the same letters at each column are not significantly different ($P < 0.05$; LSD test); RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}

The increase in the proportion of soil micropores is very useful in soils with high sand content because soil pore spaces play a very important role in soil structure, aggregate stability, moisture content, nutrients availability, and microbial diversity (Sweed and Awad 2020). Soil pore characteristics play a role in the movement of water in the soil and affect the ability of the soil to keep water. Slow drainage pores are pores with a diameter between 8.6 - 28.8 microns (Kurnia et al. 2006), the pores hold water very strongly (with a pressure of pF 2.54 - 4.2). While fast drainage pores were larger, so that the water in it ran out faster. Application of compost can effectively be used to improve soil pore characteristics and permeability (Eusufzai and Fujii 2012). Application of organic manures increased available water content (Soil water contents between retained at 0.3 Pa and 15 Pa) (Sweed and Awad 2020).

Soil water content

Application of RHB @ 20 t ha^{-1} and SC @ 5 t ha^{-1} increased soil water content at first and second application, especially at high pressures (pF 2.54 and pF 4.2) (Fig. 1 and 2). In this study, with a pF pressure of 4.2, addition of RHB 20 t ha^{-1} increased soil water content 18.82% compared to control at first application (Fig. 1). Further, addition of SC 5 t ha^{-1} at second application increased soil water content 31% (Fig. 2). Porosity and pore-size distribution mainly affected the increase in soil water content, which could relate to the improvement of soil porosity and water retention in soil. Porosity and pore-size distribution mainly affected water retention and flow in soil. Gamage et al. (2015) reported that at a matric potential (–0.01 to –0.1 bar), the volumetric water content was higher with the application of biochar (any rate) compared with no application of biochar. Many studies have shown that biochar was effective in water retention and increased the pores of available water (Yu Ok et al. 2013). According to Fischer and Glaser (2012), high surface area and porous structure of biochar offer suitable abode to several kinds of microbes and enhance the ability of soil to retain water and nutrients resulting in a stimulation of microbes. The study result of Faloye et al. (2019) showed that application biochar improves soil water status in the increasing order of amount of added biochar which was mainly attributed to the ability of biochar to modify soil pores structure. Fischer and Glasser (2012) reported that field capacity and available water holding capacity (AWC, pF 1.8–4.2) were influenced by the particle size, structure and content of organic matter.

Table 5 Soil physical properties after application of the RHB and SC soil amenders in the second crop

Treatment	**Bulk density**	**Particle Density**	**Total Porosity (%)**	**Macropores (%)**	**Micropores (%)**	**Permeability (cm/hour)**
Control	1.18 a	2.16 a	44.01 a	19.57 a	4.81 a	11.31 a
RHB 5	1.14 a	2.17 a	46.93 ab	18.45 a	5.20 a	12.56 a
RHB 10	1.11 a	2.14 a	49.51 b	22.93 a	5.57 ab	13.12 a
RHB 20	1.19 a	2.10 a	48.73 b	21.13 a	6.83 b	14,92 a
SC 5	1.12 a	2,14 a	48,37 b	21.33 a	6,61 b	13,78 a
LSD (%)			3.13		0.62	

Means followed by the same letters at each column are not significantly different ($P < 0.05$; LSD test); RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}.

The increased ability of the soil to hold water between the soil pores after RHB and SC applications may be due to the fact that biochar alters the water holding capacity and improves the hydrological properties of the soil such as the soil water absorptivity and hydraulic conductivity. Application of biochar and poultry manure increased soil moisture content due to improving soil porosity (Agbede et al. 2020). Zangiabadi et al. (2017) reported that a positive relationship between the organic carbon content and two factors of plant available water (PAW) and least limiting water range (LLWR) showed improvement in soil aggregation and structure and increase in water retention capacity. The fact in this study is that rainfall during the second cropping season was on an average low; average rainfall figures in June, July and August were 113; 18.2; and 16.4 mm (Table 6). During the dry days, the flow of water occurs from the bottom up (negative flux) through the micropores in an unsaturated manner because of the evapotranspiration process, and plants depend on the amount of water stored in the soil that can be readily available to plants without stress. Ma et al. (2016) reported significant relationships between soil organic carbon and water, as well as between mean weight diameter of aggregates and water available and confirmed a close connection between improvement of soil structure and its ability to supply water.

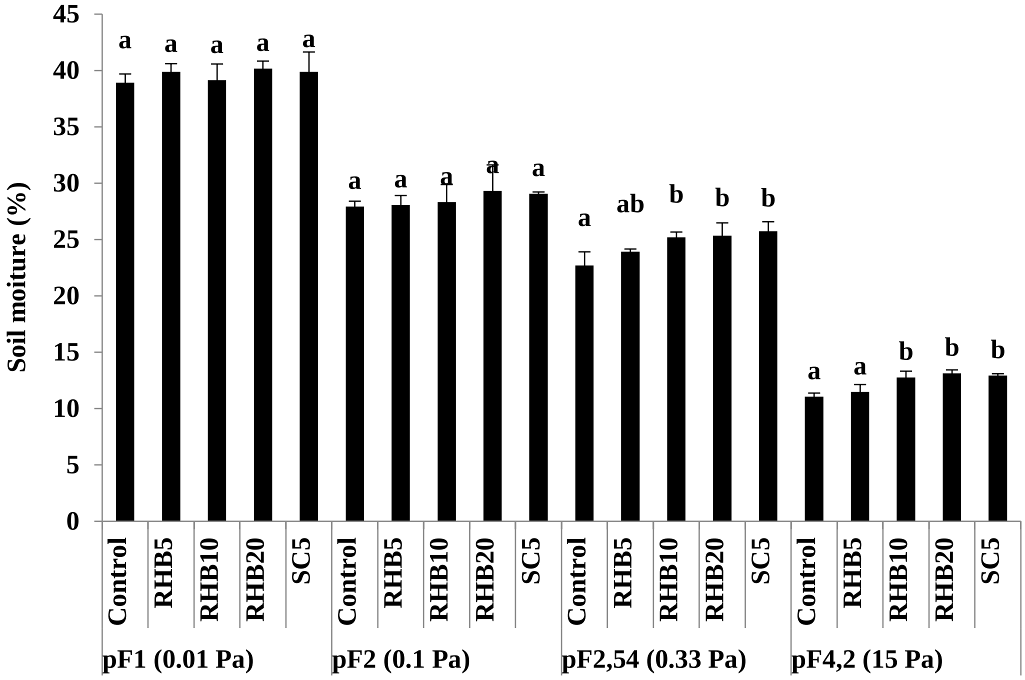

Fig. 1 Response of soil water contents with certain pressure after application of rice husk biochar and straw compost at the first application

Bars represent standard error and the different small letters at the top of the bars indicate significant differences between treatments ($P < 0.05$; LSD test). RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}.

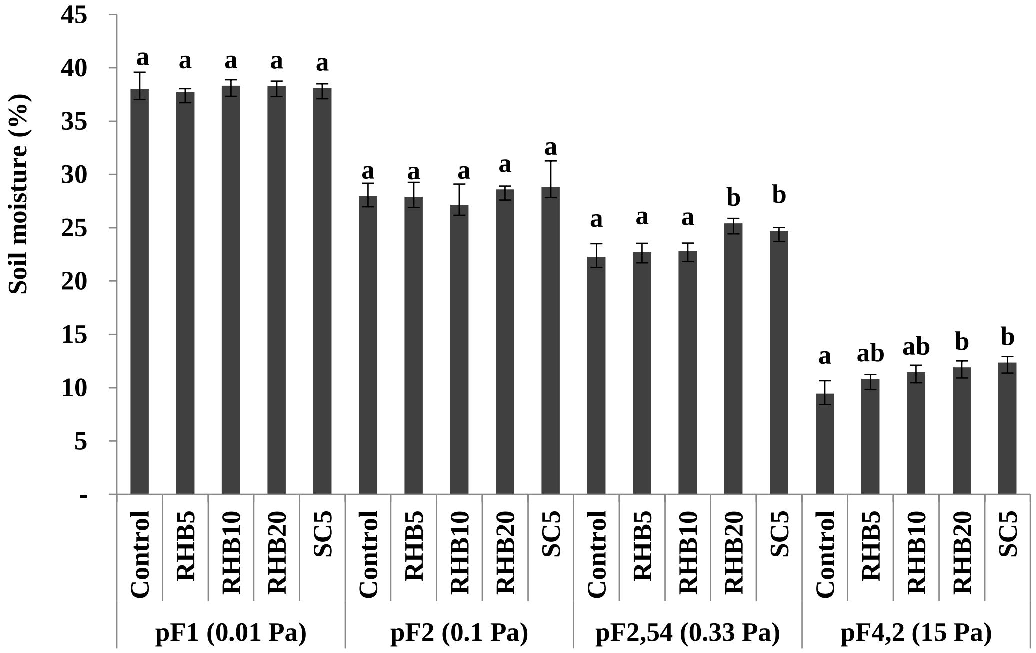

Fig. 2 Response of soil water contents with certain pressure (pF) after application of rice husk biochar and straw compost at the second application

Bars represent standard error and the different small letters at the top of the bars indicate significant differences between treatments ($P < 0.05$; LSD test). RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}.

Table 6 Average amount of precipitation and number of rainy days by month in East Lampung Regency, 2018*)

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Okt	Nov	Dec
Precipitation (mm)	295	520	337	213	169	113	18	16	125	35	121	120
Number of rainy days	13	20	17	12	9	9	2	2	6	5	10	9

*) Source : Indonesian Agency for Meteorological, Climatological and Geophysics (Climatology Station Pesawaran Lampung, Indonesia)

Crops yields (rice and soybean)

Application of RHB and SC did not significantly increase the rice grain yield; however, the highest rice yield (3.43 t ha^{-1}) was recorded with the application of SC @ 5 t ha^{-1} (Fig. 3). The application of RHB @ 10, and 20 t ha^{-1} and SC @ 5 t ha^{-1} significantly increased soybean yields by 17%, 18%, and 22%, respectively over the control. Many studies have shown that the application of biochar and straw compost increases crop yields. Yooyen et al. (2015) reported that application of biochar 20 and 30 t ha^{-1} significantly increased soybean yield by 28.0 and 36.8%, respectively over the control.. Arabi et al. (2018) also reported that application of biochar 8 t ha^{-1} and bio-fertilizers can improve grain yield of soybean by 51% over the control.

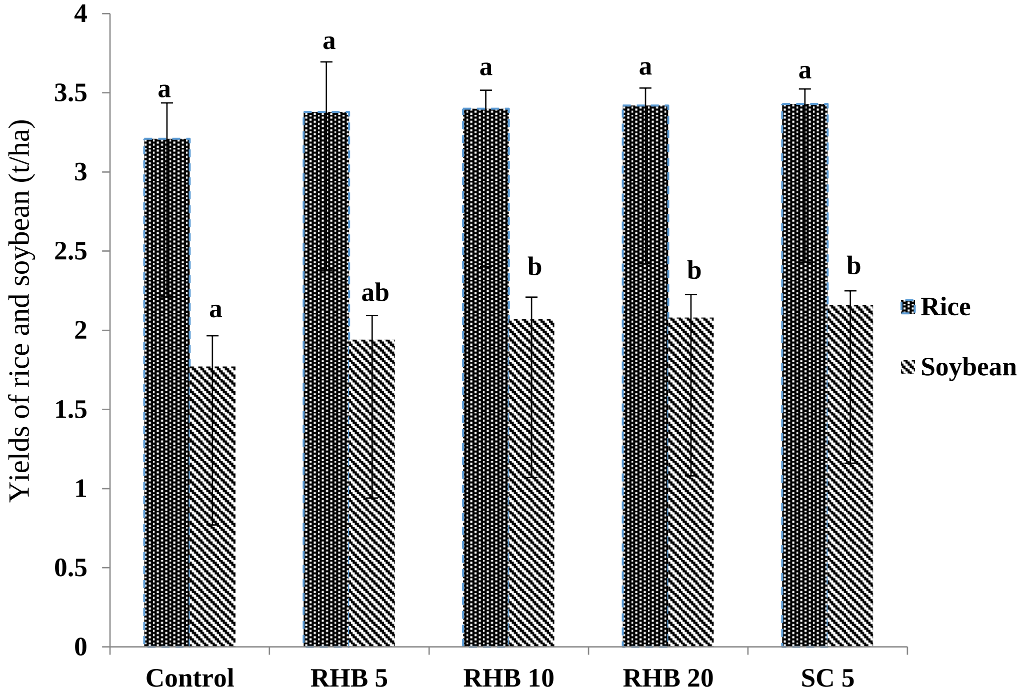

Fig. 3 The yield of upland rice (at first season) and Soybean (at second season) with application of rice husk biochar and straw compost

Bars represent standard error and the different small letters at the top of the bars indicate significant differences between treatments ($P < 0.05$; LSD test). RHB 5, application of rice husk biochar 5 t ha^{-1}; RHB 10, application of rice husk biochar 10 t ha^{-1}; RHB 20, application of rice husk biochar 20 t ha^{-1}; SC 5, application of rice straw compost 5 t ha^{-1}

Conclusion

Application of rice husk biochar and straw compost have positive effects on the physio-chemical properties of soil. This research found that total-C increased after the second application of RHB and SC. These results suggest that the addition of RHB and SC is beneficial for maintaining soil organic matter level. Another positive effect on chemical properties is the increase in total-N and exchangeable-K. Improvement in soil physical properties is through the increase in total porosity and micropores. Increasing the percentage of micropores is important in sandy soils to better hold water in the pores. Utilization of RHB and SC in agricultural soils also improves soil water content (especially at pF 2.54 and pF 4.2).

The positive effect of RHB and SC on soil water content is more obvious when the soil is dry. Application of RHB and SC did not increase rice yields; the first crop, but increased yields of the second crop; soybean.

Acknowledgements We thank Mr. Tusrimin as an assistant in the implementation of this research in the field. We are also grateful to the participating farmer for providing land for this research.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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