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The Effect of Rice Husk Biochar and Cow Manure on Some Soil Characteristics, N and P Uptake and Plant Growth of Soybean in Alfisol

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ABSTRACT

The effect of biochar on dryland in Madura has not been fully assessed. The objective of this study was to investigate the effect of biochar and animal manure on some soil characteristics, namely water content at field capacity, CEC, N total, available P, and N and P absorption, and plant growth of soybean in Alfisol. The research was arranged on a Randomized Completely Block Design (RCBD) with four replications. Rice husk biochar was mixed with cow manure and applied at the range of 2.5 - 10 Mg ha^{-1}. The result showed that biochar (2.5 Mg ha^{-1}) and cow manure (7.5 Mg ha^{-1}) improved soil characteristics, plant growth, and soybean yield by 22%. Cow manure in this study would function as a source of nutrients while rice husk biochar acted as storage of nutrients that were then released slowly to soil solution for plant uptake. It was concluded that the mixture of 2.5 Mg rice husk biochar ha^{-1} and 7.5 Mg cow manure ha^{-1} could be the best combination of soil amendments to apply in an Alfisol in Madura.

Keywords: Animal manure, biochar, crops, soil characteristics

INTRODUCTION

The soil in Madura dry land is mainly low productivity, possibly due to low soil organic matter (SOM) content. Most soils in Madura have an organic content (OC) of < 2% (Supriyadi 2008). The content of organic C in soil determines soil capacity to support plant production; the increased OC can increase plant production (Lal 2006).

Application of organic matter may improve soil organic matter (SOM), but the effects must be managed to get the highest efficiency. The application of cow manure reduces soil temperature, increases soil water content and nutrients, improves soil structure, soil microbe activities, and nutrients, and alleviates Al and Fe toxicity (Berek dan Neonbeni 2018). However, mineralization of animal manure in tropical areas proceeds fast, and whereby the effect of the application of animal manure may add little C organic compound in the soil as the majority of the C compound is released as CO_2 gas to the atmosphere (Glaser *et al*. 2002). Also, the effects of cow manure in improving soil characteristics may not last long. Therefore, to overcome this problem, the application of cow manure could be mixed with biochar containing refractory Compounds.

Biochar is black carbonaceous material resulting from biomass pyrolysis, used as a soil amendment (Lehmann and Joseph 2015). Biochar can improve soil conditions, increase soil C content, reduce fertilizer need and improve plant growth (Atkinson *et al.* 2010; Jeffery *et al.* 2011). Biochar has different characteristics depending on the raw material, pyrolysis temperature, and nature of pyrolysis (Gaskin *et al*. 2008). Rice husk biochar, for example, has higher ash content and pH compared to biochar from wood (Keiluweit *et al.* 2010; Wang *et al.* 2013).

Application Rice husk biochar at 15 Mg ha^{-1} slightly reduces pH from 7.7 to 7.3 on an Inceptisol and increases CEC from 16.27 to 22.25 cmol kg^{-1} (Salawati *et al*. 2016). Rice husk biochar at 10 Mg ha^{-1} on saline soil can avoid the negative effect of salinity on soybean (Nisak and Supriyadi 2019). Sadzli and Supriyadi (2019) found that application of rice husk biochar (5 Mg ha^{-1}) mixed with *Tithonia* straw (5 Mg ha^{-1}) in a pot trial with an Alfisol reduces soil Bulk Density and increases C organic content up to 180% compared to that of Control.

Cow manure, which is usually called organic fertilizer contains C (20.10%), N (1.62%), P (0.5%), S (0.55%), Lignin (14.71%). High-quality organic material if it contains lignin <15% (Sismiyanti 2018). The addition of cow manure on agricultural land can reduce soil temperature, increase soil moisture content, maintain soil moisture, improve soil structure, increase soil organism activity, provide nutrients, and neutralize aluminum and iron toxicity (Berek and Neonbeni 2018). In a tropical environment, the benefits are short-lived because the process of oxidation and mineralization takes place very quickly, so controllers are needed, including biochar.

This study investigated the relationship between soil amendment compromised by biochar and cow manure mixture at 10 Mg ha^{-1} on several soil characteristics, namely soil BD, water content at field capacity (WCFC), CEC, total N (TN), available P, and N and P absorption by soybean grown on an Alfisol.

MATERIALS AND METHODS

Research Location

The research was carried out on Horticulture Field Research, Bangkalan, from October 2019 to May 2020.

Research Methods

Rice husk biochar (RH) was made traditionally on open-pit burning, and cow manure (CM) was obtained from a local farmer and composted for two weeks before being used. RH and CM mixture was applied at 10 Mg ha^{-1} with the proportion as follows:

T0 = 0 Mg ha^{-1} (Control)
T1 = 10.0 Mg RH ha^{-1}
T2 = 7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}
T3 = 5.0 Mg RH ha^{-1} + 5.0 Mg CM ha^{-1}
T4 = 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}
T5 = 10.0 Mg CM ha^{-1}

All treatment in the research was arranged on a Randomized Completely Block Design (RCBD) with four replications, so there were 24 units of research. The soybean (*Glycine max* var. Grobogan) plant was cultivated as an indicator plant.

Soil Preparation

Soil tillage was carried out by hand tractor, and then 24 research plots were made. Biochar, and cow manure was applied to the soil and mixed with the soil up to 20 cm depth to follow the rate of applications from T0 to T5.

Planting, Sampling, and Soil Analysis

Soybean seed was planted at a hole at 2.0 cm depth and arranged at a 40 x15 cm distance. Cultivation of plants involved weeding, application of fertilizer, and watering in the early growth. Growth parameters were measured from 7 DAP (the day after planting) to early generative growth. Plant harvesting was conducted at 100 DAP.

Some parameters assessed soil water content (Gravimetric Method), bulk density (Ring Method), porosity (Gravimetric Method), pH (H_2O), CEC (Colorimetric Method, BPT 2009), Organic carbon (OC) (Wet Oxidation, Walkey, and Black Method), total N (Spectrophotometer Method), available P (Olsen Method). The parameters related to plant measured N and P absorption, plant height (cm), dry matter (DM) (g), leaf area, weight seed plant^{-1} (g), filled pod number, and yield (Mg ha^{-1}). N and P absorption were determined based on the content of N and P in the plant tissue multiplied by plant biomass (DM). Nitrogen and phosphorus content in the plant tissue was prepared by wet oxidation and then measured using the spectrophotometer method.

Analysis Data

Either quadratic or linear model optimized the relationship between soil characteristics and treatments. Pearson's correlation was also employed to analyze data whenever needed.

RESULTS AND DISCUSSION

Soil Characteristics

The soil in this experiment was sandy clay soil with low organic C (OC) and total N. The soil was acidic with a medium in CEC (Table 1). Naturally, the soil possibly has low fertility, with the main obstacle being low OC and N content.

The addition of soil amendments increased CEC, OC, and soil pH (H_2O). CM raised CEC to 5.7% but not for RH; it slightly reduced CEC suggesting the RH developed a positive charge, respectively raised OC and pH (H_2O). The mixture of both soil amendments increased CEC on average was 4.7% compared to that of Control, especially when CM over RH, such as in T3 and T4, suggesting that CM overrun to RH on their effect on CEC.

The changes in OC were quite similar to CEC, whereby RH and CM increased OC, respectively, up to 4% and 7.3%. The average increase of OC

Table 1 Some basic characteristics of an Alfisol in Madura.

Aspect	Value	Category
Organic-C (%)	1.68	Low
Total N (%)	0.03	Very low
pH (H_2O)	6.12	Acid
CEC (cmol kg^{-1})	24.11	Moderate
Sand (%)	46.96	
Clay (%)	40.88	Sandy clay
Debu (%)	12.16	

because of both soil amendments was 7.3%, suggesting CM could lead to increasing OC over RH. RH and CM application separately raised soil pH (H_2O) to 0.11 and 0.17 pH units, while both amendments enhanced soil pH up to 0.13 pH unit. Between treatments and CEC, OC and soil pH (H_2O) had a linear relationship (Figure 1). Moreover, there was a strong correlation between CEC with OC (r: 0.82) and with soil pH (H_2O)(r: 0.77).

Soil bulk density (BD) was reduced by soil amendments but increased when Cm exceeded Rh, such as T3 and T4. As Rh alone reduced BD up to 6%, but not for Cm; so the average reduction of BD due to the mixture of both soil amendments was 5.73%.

Treatments had a quadratic relationship with soil BD Porosity and WCFC (Figure 2).

Total porosity and WCFC increased with RH addition but reduced when CM was similar or exceeded RH. RH increased total porosity up to 3.8% but not for CM, and the maximum increase was at T2, 6.6%. Both RH and CM raised WCFC to 8.6% and 2.7%, respectively, and the maximum increase was at T4 (14.1%) due to both soil amendments addition. Total porosity and water content at Field capacity had a similar pattern of increased and then reduced after T2 (highest total porosity and water content).

Absorption of Nitrogen and Phosphorus

Total N and available P formed a quadratic relationship with treatments (Figure 3). RH and CM applications respectively raised TN to 32.4% and

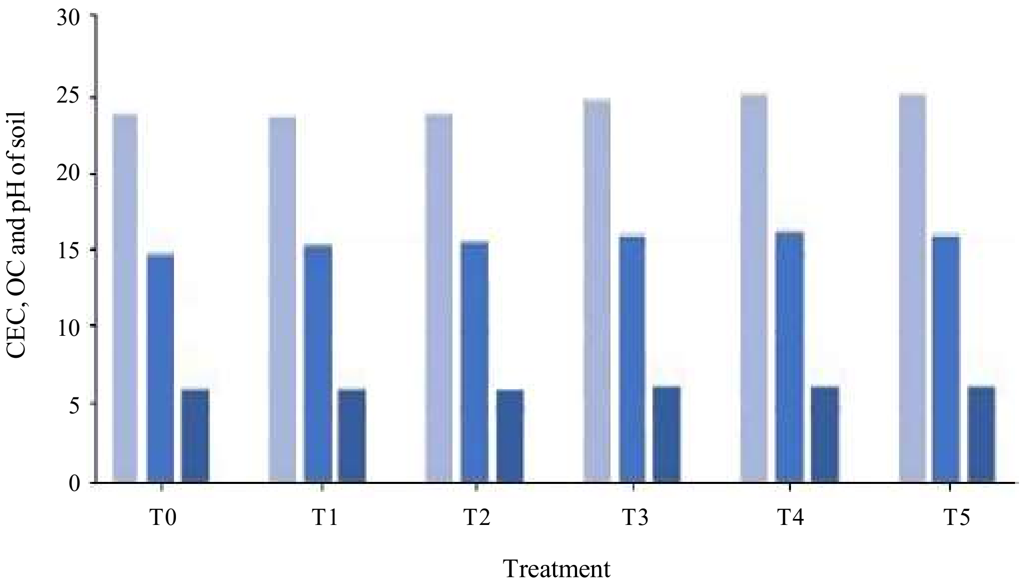

Figure 1. CEC, OC, and pH (H_2O) of an Alfisol due to application of rice husk biochar (RH) mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1 =10.0 Mg RH ha^{-1}; T2:7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). CEC = 0.3534x + 23.448; R^2 = 0.8436**; OC = 00.2314x + 15.107; R^2 = 0.7887**; pH(H_2O) = 0.0343x + 6.24; R^2 = 0.5385*. ■ : CEC (cmol kg^{-1}), ■ : OC (g kg^{-1}), ■ : pH (H_2O).

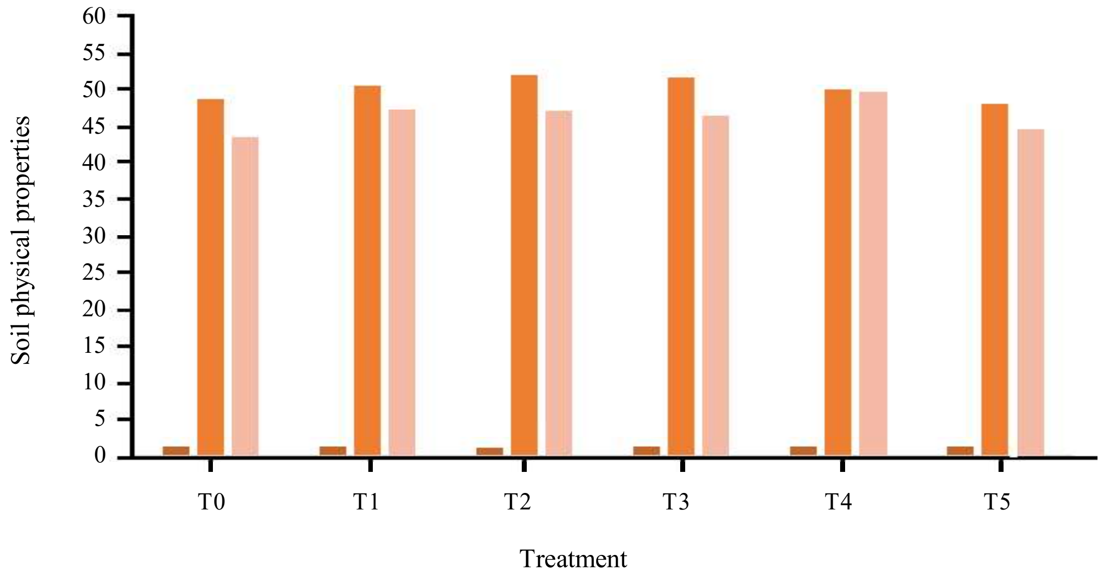

Figure 2. Bulk density (BD), total porosity (TP), and water content at field capacity (WCFC) of an Alfisol due to application of rice husk biochar (RH) mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1 =10.0 Mg RH ha^{-1}; T2:7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). Porosity = -0.5436x2 + 3.6567x + 45.624; R2 = 0.9796**; WCFC = -0.5402X2 + 4.1401x + 40.199; R2 = 0.5677**; BD = 0.017x2 - 0.1099x + 1.419; R2 = 0.7534**. ■: BD (g cm^3), ■ : porocity (%), ■ : WCFC (%).

8.8%. The mixture of both soil amendments (T2, T3, and T4) could prevent TN in optimum conditions, while cow manure alone (T5) only increased by 8.8%, suggesting N from CM may be lost as no biochar that could prevent N loss. Available P was relatively stable, which was in high status.

Nitrogen and Phosphorus absorption performed a quadratic relationship with treatments (Figure 4).

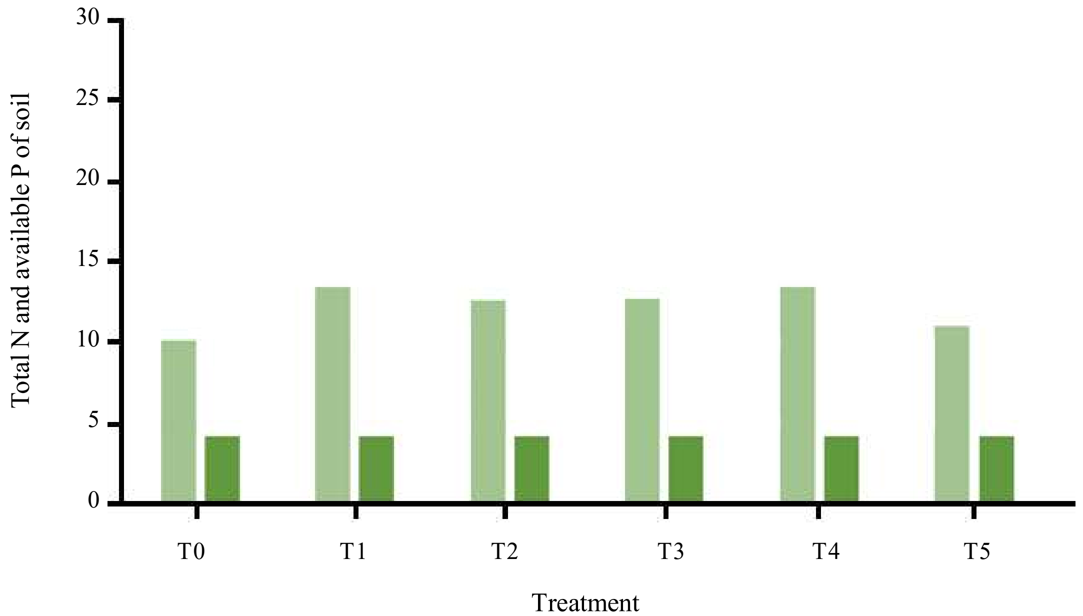

Figure 3. Total N (g kg^{-1}) and available P (Olsen P) (g kg^{-1}) of an Alfisol due to the application of rice husk biochar (RH) mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1: 10.0 Mg RH ha^{-1}; T2: 7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). TN= $-0.4018x^2 + 2.9439x + 8.09$; $R^2 = 0.6925$; Olsen P = $0.0044x^2 - 0.0305x + 4.2692$; $R^2 = 0.322$. ■ : TN (g kg^{-1}), ■ : Olsen P (g kg^{-1}).

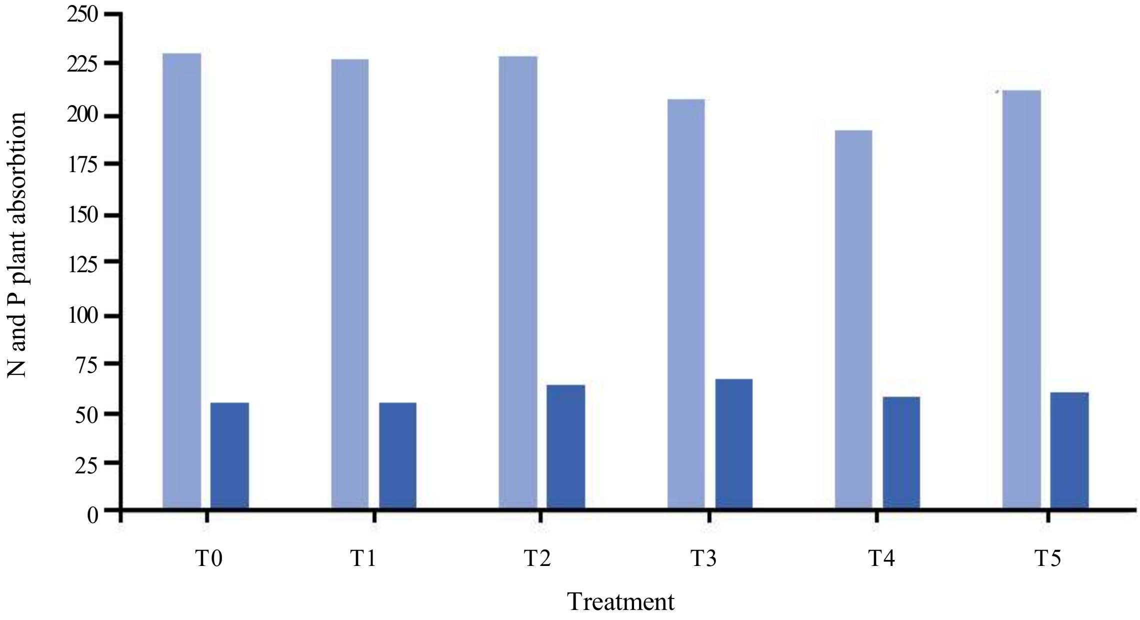

Figure 4. Nitrogen (N_{Abs}) and phosphorus (P_{Abs}) absorption by soybean (mg plant^{-1}) grown on an Alfisol due to application of rice husk biochar (RH) mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1: 10.0 Mg RH ha^{-1}; T2: 7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). ■ : N abs (mg plant^{-1}), ■ : P abs (mg plant^{-1}). Nabs = $0.7893x^2 - 11.864x + 246.38$; $R^2 = 0.6137$*. P abs = $-1.0384x^2 + 8.2536x + 46.543$; $R^2 = 0.5275$*.

Nitrogen absorption reduced as cow manure applied increased. The lowest N absorption was at T4, about 83% of the Control (T0), suggesting higher N used efficiency. Phosphorus absorption increased with increasing Cm application and then reduced; it reached the highest value at T3, about 119.5% of Control (T0). The P absorption at T4 was about 104% of that of Control (T0). The changes in the

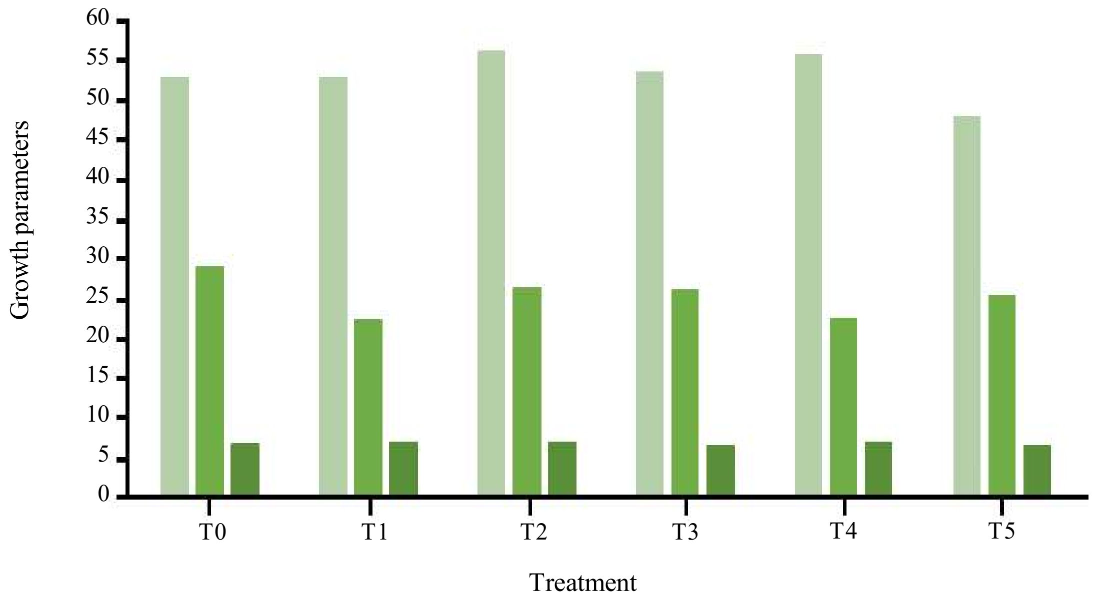

Figure 5. Plant height (cm), DM (g plant^{-1}), and leaf area (LA) of soybean (cm plant^{-1}) grown on an Alfisol due to application of rice husk biochar (RH mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1: 10.0 Mg RH ha^{-1}; T2: 7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). ■: Plant height (cm), ■: DM (g plant^{-1}), ■ : Ln LA (cm^2 plant^{-1}). Plant height = $-0.7648x^2 + 4.8292x + 48.081$; $R^2 = 0.6404$*. DM = $0.3255x^2 - 2.7825x + 30.253$; $R^2 = 0.2548$. In LA = $-0.3886x^2 + 2.3823x + 30.23$; $R^2 = 0.1552$.

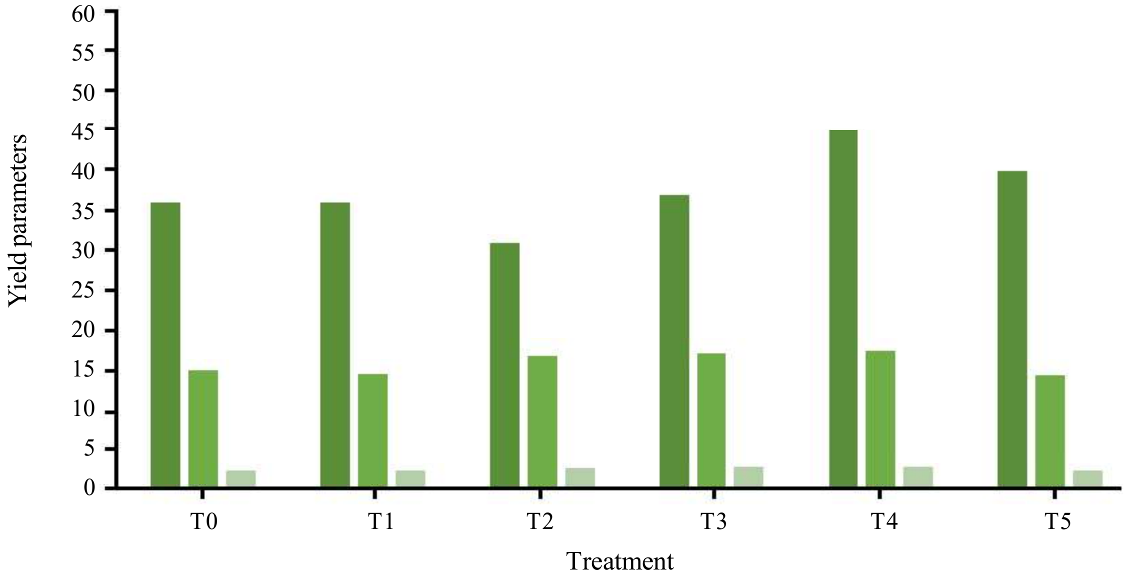

Figure 6. Number of filled pods, seed weight (g plant^{-1}), and yield of soybean (Mg ha^{-1}) grown on an Alfisol due to application of rice husk biochar (RH) mixed with cow manure (CM) in various proportions (T0: no added RH or CM; as Control; T1: 10.0 Mg RH ha^{-1}; T2: 7.5 Mg RH ha^{-1} + 2.5 Mg CM ha^{-1}; T3: 5.0 Mg RH ha^{-1} + 5 Mg CM ha^{-1}; T4: 2.5 Mg RH ha^{-1} + 7.5 Mg CM ha^{-1}; and T5: 10.0 Mg CM ha^{-1}). : Number of filled poods, : Seed weight (g plant^{-1}), : Yield (Mg ha^{-1}). Filled poods = $0.4821x^2 - 1.8607x + 36.7$; $R^2 = 0.4457$*. Seed weight = $-0.3677x^2 + 2.7426x + 11.919$; $R^2 = 0.5809$*. Yield = $-0.0705x^2 + 0.5395x + 1.825$; $R^2 = 0.6964$*

N:P ratio from T0 toT5 respectively were 12.54,12.45,10.80, 9.30, 9.96, and 10.65.

Plant Growth and Yield

Plant height, dry matter, and log-normal of leaf area performed a quadratic relationship with treatments (Figure 5). The dominancy of biochar and cow manure reduced leaf area. Application of biochar and cow manure at 3:1 (T2) and 3:1(T4) tended to give the highest leaf area, with the optimum being at T3 (1:1). Biochar and cow manure increased leaf area by about 15% compared to Control (T0).

The soybean's optimum dry matter (DM) was reached at T3 (1:1; RH: CM; w/w). Biochar and cow manure could raise the DM to 25%. Plant height significantly correlated (r: 0.62) to Leaf area but not with DM. While DM negatively correlated (r: -0.68) to leaf area.

The number of filled pods, seed weight, and plant yield had a quadratic relationship with treatments (Figure 6). The filled pods significantly increased with the maximum yield at T4 due to increased CM or reduced RH application. The plant seed weight was significantly enhanced due to the RH and CM application mixture, with the maximum in T3. RH or CM alone did not improve the seed weight, suggesting the effect of the mixture compared to each soil amendment. A similar pattern was shown by yield in which the mixture of both soil amendments gave a better result, with the optimum being in T3. On average, the mixture of RH and CM increased yield up to 19.11% compared to that of Control. However, RH or CM alone reduced the yield, suggesting a better effect when RH biochar was mixed with cow manure rather than applied separately.

Discussion

This research showed that the mixture of RH biochar with CM improved soil characteristics, especially soil pH, porosity, WCFC, CEC, OC, and TN. The enhancement of porosity and bulk density of soil is possibly due to the new creation of pores around the biochar particle and the direct addition of pores from biochar itself. On the other hand, CM reduced the positive effects of biochar on porosity, possibly due to the formation of organic substances that clogs biochar-soil porosity and whereby the porosity is reduced. Possibly increasing OC, TN, CEC, soil pH, and WCFC overcame the effect of reducing soil porosity, and hence, soybean plants grew better and gave higher yields. In general, applying the mixture of RH biochar and cow manure improved soil characteristics in better conditions, thereby increasing plant growth and yield. Similar phenomena were also shown by Fischer and Glaser

(2012) when working with compost and biochar. Glaser *et al.* (2002) and Lehman and Joseph (2015) added that tropical soils only appeared to respond after being given 1% (-20 Mg biochar ha^{-1}).

Cow manure was easier to decompose and release nutrients, while RH would control the nutrient released from CM. Such conditions were well presented by the parabolic equation between treatments with almost all parameters. The highest value of leaf area, DM, number of filled pods, weight of seed $plant^{-1}$ and yield was reached when biochar and CM were added at 2.5 Mg ha^{-1} and 7.5 Mg ha^{-1}, respectively. Application of RH biochar over 5.0 Mg ha^{-1} tended to reduce the result. CM took the role as the source of nutrients as it was mineralized faster than the organic compounds in RH biochar. Combining both soil amendments could create slow-release fertilizer (Dong *et al.* 2020), where RH would store the released nutrients from CM and later be released slowly into soil solution for plant uptake. Such phenomena were critical in terms of Nitrogen, as this nutrient is prone to loss, but when CM mixed with RH, the loss of N could be avoided, and hence the fertilizer value of the soil amendments increased (Agyarko-Mintah *et al.* 2017 a, b).

Soybean planted in this research grew normally with a plant height was 48.23 - 56.32 cm, and DM was 22-29 g $plant^{-1}$. Increased plant height enhanced leaf area and the number of filled pods, and seed yield per plant. Increased CM (with reducing RH) application increased pod number, with T4 giving the highest number of filled pods, which was 125% of that of Control, to result in the highest yield, about 122% compared to that of Control. Increased CM further reduced filled pod number and yield (Figure 6), possibly due to enhancement of plant nutrients as no biochar could buffer the nutrients so that plant absorbs N higher than that needed to result in changes of N:P to 10.65 so that the yield reduced.

CONCLUSIONS

Application of biochar (2.5 Mg ha^{-1}) and cow manure (7.5 Mg ha^{-1}) (T4) gave better soil conditions; in terms of SOC, soil pH, SWC at FC, and total N. The treatment of T4 also gave the lowest Nitrogen and phosphorus absorption as well as N/P ratio in the plant, suggesting N and P utilized more efficient with this treatment. The highest leaf area, number of filled pods, and weight of dry seed $plant^{-1}$ due to T4 resulted in the highest yield. The biochar mixture at 2.5 Mg ha^{-1} and cow manure at 7.5 Mg ha^{-1} could be the right proportion in applying both soil amendments on an Alfisol in Madura.

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