

Soil Chemical Properties and Soybean Yield Due to Application of Biochar and Compost of Plant Waste

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ABSTRACT

The importance to return organic matter to the soil has been widely recognized, especially to agricultural lands that are low in organic matter and nutrients contents that will decrease the productivity of food crops. This study aimed to study the effect of biochar (rice husk and corn cob biochar) and straw compost on soil chemical properties and yield of soybean (*Glycine max* (L.) Merr. The experiments were done in the laboratory and the field experiment at February–July 2015. The first study was laboratory test using a randomized block design with three replicates. Soil samples were ground and sieved to obtain the less than 4 mm fraction for the incubation experiment. A five kg soil was mixed with amendment treatments (A: control; B: Rice husk biochar 10 Mg ha⁻¹; C: corn cob 10 Mg ha⁻¹; D: straw compost 10 Mg ha⁻¹; and E. Rice husk biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹; F: corn cob biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹) were filled into plastic pots. The treatments were incubated for 1 and 2 months. Soil samples measured were pH, Organic-C, Total-N, P₂O₅ (Bray-1), K₂O (Morgan), Na, Ca, Mg, S, and CEC. The field experiment was conducted at Sukaraja Nuban Village, Batanghari Nuban sub district, East Lampung Regency. The treatments (similar to laboratory experiment) were arranged in a randomized block design with four replicates. Plot size was 10 m × 20 m, and soybean as crop indicators. The parameters observed were plant height, number of branches, number of pods per plant, number of seeds per plant, grain weight, and stover. The results of laboratory experiment showed that application of biochar and compost improve soil fertility due to the increase in soil pH and nutrient availability for plant especially P₂O₅ and K₂O available. The treatment of a rice husk biochar and compost mixture was better than single application to improve soil fertility and soybean yield. Application mixture husk biochar 10 Mg ha⁻¹ and straw compost 10 Mg ha⁻¹ increased grain weight about 41% compared to control.

Keywords: Biochar, compost, crop waste, soil chemical properties

ABSTRAK

Pentingnya pengembalian bahan organik ke dalam tanah telah diakui secara luas, terutama pada tanah dengan kandungan bahan organik dan ketersediaan hara yang rendah yang menyebabkan penurunan produktivitas tanaman. Penelitian ini bertujuan untuk mempelajari pengaruh aplikasi biochar (dari sekam padi dan tongkol jagung) serta kompos jerami terhadap sifat-sifat kimia tanah dan hasil kedelai (*Glycine max* (L.) Merr, terdiri dari kegiatan laboratorium dan percobaan lapangan yang dilakukan pada Februari-Juli 2015. Kegiatan pertama dilakukan di laboratorium menggunakan rancangan acak kelompok dengan tiga ulangan. Sampel tanah digiling dan diayak untuk mendapatkan fraksi < 4 mm untuk percobaan inkubasi. Tanah sebanyak 5 kg dicampur dengan bahan pembenah tanah dengan perlakuan A: Kontrol; B: Biochar sekam padi 10 Mg ha⁻¹; C: Biochar tongkol jagung 10 Mg ha⁻¹; D: kompos jerami 10 Mg ha⁻¹; dan E: Biochar sekam padi 10 Mg ha⁻¹ + kompos jerami 10 Mg ha⁻¹; F: Biochar tongkol jagung 10 Mg ha⁻¹ + kompos jerami 10 Mg ha⁻¹, dimasukkan ke dalam pot plastik dan diinkubasi selama 1 dan 2 bulan. Selanjutnya diambil sampel tanah dari masing-masing perlakuan dan diukur pH, C-Organik, N-total, P₂O₅ (Bray I), K₂O (Morgan), Na, Ca, Mg, S, dan KTK. Percobaan lapangan dilakukan di Desa Sukaraja Nuban, kecamatan Batanghari Nuban, Kabupaten Lampung Timur. Perlakuan sama dengan kegiatan laboratorium, disusun dalam rancangan acak kelompok dengan empat ulangan dengan ukuran plot adalah 10 × 20 m, dan kedelai sebagai tanaman indikator. Parameter yang diamati adalah jumlah cabang, jumlah polong/tanaman, jumlah biji/tanaman, berat biji dan berat brangkasan. Hasil percobaan laboratorium menunjukkan bahwa aplikasi biochar dan kompos memperbaiki kesuburan tanah yang ditunjukkan oleh peningkatan pH tanah dan ketersediaan hara terutama P₂O₅ dan K₂O yang tersedia untuk tanaman. Aplikasi

Aplikasi campuran biochar sekam padi dan kompos lebih baik dari aplikasi tunggal untuk meningkatkan kesuburan tanah dan hasil kedelai. Aplikasi campuran biochar sekam padi 10 Mg ha⁻¹ dan kompos jerami 10 Mg ha⁻¹ meningkatkan bobot gabah sekitar 41% dibanding dengan kontrol.

Kata Kunci: Biochar, kompos, kesuburan tanah, kedelai

INTRODUCTION

Dry land in Lampung is dominated by Ultisols that has parent material acidic sedimentary rocks, so the soil reaction is acidic and base saturation <35% (Prasetyo and Suriadikarta 2006). The other characteristics are low of organic matter content, P and K nutrient content, cation exchange capacity (CEC), as well as the soil structure is unstable (Nurida *et al.* 2013). The low soil organic carbon content in tropic agricultural soil is due to the rapid turnover rates of organic material as a result of high soil temperatures and moisture; especially the farmers prefer the inorganic fertilizers such as urea and NPK compound than organic fertilizers. The soils fertility significantly decline in their native carbon stock through the long-term use of extractive farming practices (Mekuria and Noble 2013).

The importance to return organic matter in the soil has been widely recognized, especially plant biomass. The plant wastes are abundant around agricultural land, especially at harvest time such as rice waste (straw and rice husks). Organic waste recycling in agriculture improves the soil fertility as increase the soil organic matter (SOM) content. Various types of organic fertilizers are often used in sustainable farming systems to improve soil properties, such as biochar and compost.

Biochar is produced by thermal treatment at oxygen deficiency *e.g.* by pyrolysis or gasification, resulting in three products: char, gas and tarry oils (Fischer and Glaser 2012). Application of biochar to soils is hypothesized to increase bio-available water, build soil organic matter, enhance nutrient cycling, lower bulk density, act as a liming agent, and reduce leaching of pesticides and nutrients to surface and ground water (Laird *et al.* 2009). Application of biochar improves soil fertility, and mitigate climate change (Woolf *et al.* 2010; Lehmann *et al.* 2011), increase soil water retention (Brantley *et al.* 2014), significantly reduced soil loss (Jien and Wang 2013), for long-term soil C sequestration (Fang *et al.* 2014) and has high C sequestration potential in soils as compared to wheat straw and manures (Qayyum *et al.* 2014; Schulz *et al.* 2013).

Effect of biochar in soils may not be solely attribute able to its chemical characteristics but also to its reduced accessibility when involved in organo-mineral associations (Lehmann *et al.* 2011; Fang *et al.* 2014), application may trigger short-term improvements such as increasing microbial activity (Fischer and Glaser 2012).

The increase of crops yield was tentatively explained by a combination of an increased base saturation, CEC, and increased plant-available water (Cornelissen *et al.* 2013). Many studies have reported the use of biochar as an amendment for crop production, influenced root growth (Olmo *et al.* 2015), affected above-ground biomass (in the year-3) (Jones *et al.* 2012), increased the dry biomass of maize (Nurida *et al.* 2013), and increase faba bean yield by addressing P nutrition and ameliorating Al toxicity (Van Zwieten *et al.* 2015).

Effect of straw compost on soil properties and crop yield has been reported, it increase pH and total-N (Che Jusoh *et al.* 2013) moreover application of straw compost 5 Mg ha⁻¹ increase Soil Organic Carbon (SOC) and available P (Goyal *et al.* 2009), as well as increase grain weight of rice 27% than control (Barus 2012).

Liu *et al.* (2012) demonstrated a synergistic positive effect of compost and biochar mixtures on soil organic matter content, nutrient levels, and water storage capacity. Compost maturity and compost quality can influence its effect intensity on soil physical, chemical and biological properties. Ideal feedstocks for composting have from 60-70% moisture content, high nutrient levels, and low lignin content. Ideal feedstocks for biochar are 10 – 20% moisture and high lignin content (Camp and Tomlinson 2015).

This research studied the effect of biochar and compost either solely or mixed application on upland soil chemical properties and soybean yields.

MATERIALS AND METHODS

Biochar and Soil Preparation

Rice husks and corn cobs biochar were produced through low temperature pyrolysis at (200–300 °C) using drum oil which on the bottom has been fitted with cavities. Rice husk and corn cobs were burned separately for about 6-8 hours. For composting, firstly rice straws were chopped and incubated with effective microorganisms (EM) for one month. Chemical properties of husk and corn cobs biochar, and straw compost were analyzed for pH (pH meter), Organic-C (Walkley and Black),

total-N (Kjeldahl), total-P (HCl 25%), total-K (HCl 25%), and CEC (NH₄OAc).

The soil samples (0–20 cm in depth) were collected from upland soil at Sukaraja Nuban Village, Sub district Batanghari Nuban, East Lampung Regency, at February 2015. The soil properties were pH(H₂O) 4.89, 1.25 g kg⁻¹ organic C (Walkley and Black method); 0.15 g kg⁻¹ total-N (Kjeldahl); 5.60 ppm P (Bray-1), CEC 6.94 mol(+)kg⁻¹ soil, 10.5 g kg⁻¹ sand, 53.5 g kg⁻¹ silt and 36 g kg⁻¹ clay.

Laboratory Experiment

Soil samples were air-dried, and roots and other visible plant remains were removed. Soil samples sieved to obtain the <4 mm fraction for the incubation experiment. Then, soil samples (5 kg) were filled into plastic pots and mixture with amendment as treatments (A. unamendment/control; B. husk biochar 2.5%; C. corn cob biochar 2.5% (w/w); D. straw compost 2.5% (w/w); E. husk biochar 2.5% (w/w) + straw compost 2.5% (w/w); F. corn cob biochar 2.5% (w/w) + straw compost 2.5% (w/w)). The treatments were arranged in a randomized block design with three replications. All treatments were incubated for 1 and 2 months, then the chemical properties were analyzed as following: pH (pH meter), Organic-C (Walkley and Black), Total-N (Kjeldahl), P₂O₅ (Bray-1), K₂O (Morgan), Na, Ca, Mg, S, and CEC (NH₄OAc). Soils were analyzed at the laboratory of Assessment Institute of Agricultural Technology Lampung.

Field Experiment

The field experiment has been conducted at Sukaraja Nuban Village, Batanghari Nuban sub district, East Lampung Regency in March – July 2015.

The experiment was arranged in a randomized block design with four replicates, whereas treatments tested were some kind of amendment, that were A: control; B: Rice husk biochar 10 Mg ha⁻¹; C: corn cob 10 Mg ha⁻¹; D: straw compost 10 Mg ha⁻¹; E: Rice husk biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹; F: corn cob biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹. The amendments were incubated for one month after soil tillage (minimum tillage), then Soybean Varieties Anjasmoro as crop indicators was planted with planting space of 30 × 30 cm. The plot size of each treatment was 10 × 20 m. Anorganic fertilizers application that were urea, SP-36, and KCl, respectively as follows 50, 100, and 50 kg ha⁻¹, applicated two weeks after planting. Measurement of plant parameters were conducted at harvest (90 days) : plant height, number of branches, number of pods/plant, number of seeds/plant, and stover. The grain yield (kg ha⁻¹) was determined based on grain weight per plot.

Statistical Analysis

The collected data was statistically analyzed using analysis of variance (F-Test) at level (P ≤ 0.05) and differences in each treatment were adjudged by Tukey's test (P ≤ 0.05) using Minitab Version 12.

RESULTS AND DISCUSSION

The characteristic of rice husk biochar, corn cob biochar, and straw compost (*n* = 3) are shown in Table 1. Both of biochar and compost have pH > 7 and others chemical properties is quite different. Some of the previous studies are also showing pH of rice husk or corn cob biochar > 7 (Milla *et al.* 2013; Nurhidayati, 2014; and Abrishamkesh *et al.* 2015).

Table 1. Chemical analysis of husk, corn cobs biochar and straw compost.

Types of Analyzed	Husk biochar	Corn cobs biochar	Straw compost
pH (H ₂ O)	72.4	78.9	8.65
Organic-C (g kg ⁻¹)	234.0	213.0	18.78
N-total (g kg ⁻¹)	14.6	6.4	0.79
Na (g kg ⁻¹)	0.2	0.1	0.03
Ca (g kg ⁻¹)	2.2	2.5	0.38
Mg (g kg ⁻¹)	1.5	1.6	0.19
S (g kg ⁻¹)	2.2	1.8	0.18
Fe (g kg ⁻¹)	1491	-	-
Mn (g kg ⁻¹)	553	-	-
Cu (g kg ⁻¹)	0.0	-	-
Zn (g kg ⁻¹)	195	-	-
CEC (Cmol(+)/kg)	9.83	11.72	15.45
Total-P (g kg ⁻¹)	2.4	3.7	5.6
Total-K (g kg ⁻¹)	7.0	5.7	8.7

Table 2. The values of soil pH, available P and K, and CEC after biochar and compost application in the 1st and 2nd months.

Month	Soil chemical properties	Treatments*				
		A	B	C	D	E
1	pH H ₂ O	4.67 ± 0.059	4.73 ± 0.064	4.83 ± 0.006	4.74 ± 0.070	4.83 ± 0.025
2		4.73 ± 0.02	4.78 ± 0.035	4.78 ± 0.040	4.97 ± 0.087	5.09 ± 0.087
1	P ₂ O ₅ (mg kg ⁻¹)	6.81 ± 1.32	7.68 ± 0.778	6.34 ± 0.292	6.68 ± 0.478	10.67 ± 0.624
2	Bray-1	8.02 ± 0.450	14.99 ± 1.412	14.06 ± 0.281	15.67 ± 1.243	18.10 ± 0.366
1	K ₂ O (mg kg ⁻¹)	139.7 ± 18.00	197.0 ± 33.70	203.0 ± 15.10	236.0 ± 10.15	233.7 ± 12.50
2	Morgan	157.7 ± 9.61	224.0 ± 18.20	239.33 ± 4.93	248.0 ± 17.60	256.0 ± 12.12
1	CEC	6.88 ± 0.144	7.16 ± 0.244	7.04 ± 0.116	7.45 ± 0.122	7.98 ± 0.255
2	(cmol kg ⁻¹)	6.45 ± 0.348	7.18 ± 0.154	6.94 ± 0.301	7.45 ± 0.265	7.95 ± 0.366

*A. control; B. husk biochar 10 Mg ha⁻¹; C. corn cob 10 Mg ha⁻¹; D. straw compost 10 Mg ha⁻¹; E. husk biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹; F. corn cob biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹.

Table 3. The values of soil organic-C, total-N, and C/N after biochar and compost application.

Treatments	Organic-C (g kg ⁻¹)		Total-N (g kg ⁻¹)		C/N	
	1-Month	2-Month	1-Month	2-Month	1-Month	2-Month
A. Control	1.26 ± 0.025	1.24 ± 0.042	0.10 ± 0.015	0.11 ± 0.006	12.00	11.63
B. Husk biochar 10 Mg ha ⁻¹	1.35 ± 0.036	1.32 ± 0.015	0.13 ± 0.006	0.13 ± 0.006	10.67	10.74
C. Corn cob biochar 10 Mg ha ⁻¹	1.28 ± 0.075	1.27 ± 0.046	0.11 ± 0.010	0.11 ± 0.015	11.70	12.01
D. Straw compost 10 Mg ha ⁻¹	1.36 ± 0.015	1.33 ± 0.021	0.12 ± 0.006	0.12 ± 0.006	11.07	11.48
E. B + D	1.38 ± 0.06	1.34 ± 0.03	0.12 ± 0.010	0.12 ± 0.000	11.53	11.14
F. C + D	1.33 ± 0.027	1.32 ± 0.01	0.11 ± 0.060	0.12 ± 0.006	11.42	10.72

Total Organic Carbon (OC) contents of husk and corn cobs biochar were higher than straw compost (23.40% and 21.30 % than 18.77 %). The kinds of feedstock and pyrolysis conditions (temperature, holding time, etc.) may affect both stability and nutrient content availability of biochar (Novak *et al.* 2009, Brantley *et al.* 2015). According to Abrishamkesh *et al.* (2015), husk biochar which was produced by pyrolysis temperature of 450 - 500°C contained OC values of 44.24%. Then, Nurhidayati (2014), maize cob biochar which was produced a temperature of 300-400 °C for about six hours contained OC values of 18.73%.

Application of biochar and compost increased soil pH, available P and K, and cation exchange

capacity (Table 2). The ameliorating effect of biochars on chemical properties of acidic soil was consistent with their chemical composition (Chintala *et al.* 2014; Olmo *et al.* 2015). Biochar produced in this study had alkaline pH (> 7) which was higher than initial soil pH before application (4.89), therefore, the mixing of biochar and soil allowed to increase soil pH (Brantley *et al.* 2015). Then, Nurida *et al.* (2013) reported that application some kinds of biochar of agricultural waste increase soil pH in the range of 14.88 - 17.07%. The liming effects of the biochar samples on soil acidity were correlated with it's alkalinity, a close linear correlation between soil pH and biochar alkalinity was $R^2=0.95$ (Yuan and Xu 2011). Jien and Wang (2013) reported soil

Table 4. Effect of biochar and compost on maximum plant height, number of branches, and number of pods of Soybean.

Treatment:	Plant height (cm)	Number of branches	Number of pods	Number of Unfilled Pods
A. Control	64.15 a	3.05 a	34.77 b	5.03 a
B. Husk biochar 10 Mg ha ⁻¹	70.25 a	3.55 a	43.48 ab	3.18 a
C. Corn cob biochar 10 Mg ha ⁻¹	67.05 a	2.95 a	40.65 b	3.48 a
D. Straw compost 10 Mg ha ⁻¹	70.05 a	3.30 a	46.55 ab	2.78 a
E. B + D	70.95 a	3.65 a	54.10 a	2.70 a
F. C + D	70.75 a	3.15 a	42.05 ab	3.15 a

Note : Using the Tukey is test and 95% Confidence, number in the same column followed by the same letter are not significantly different

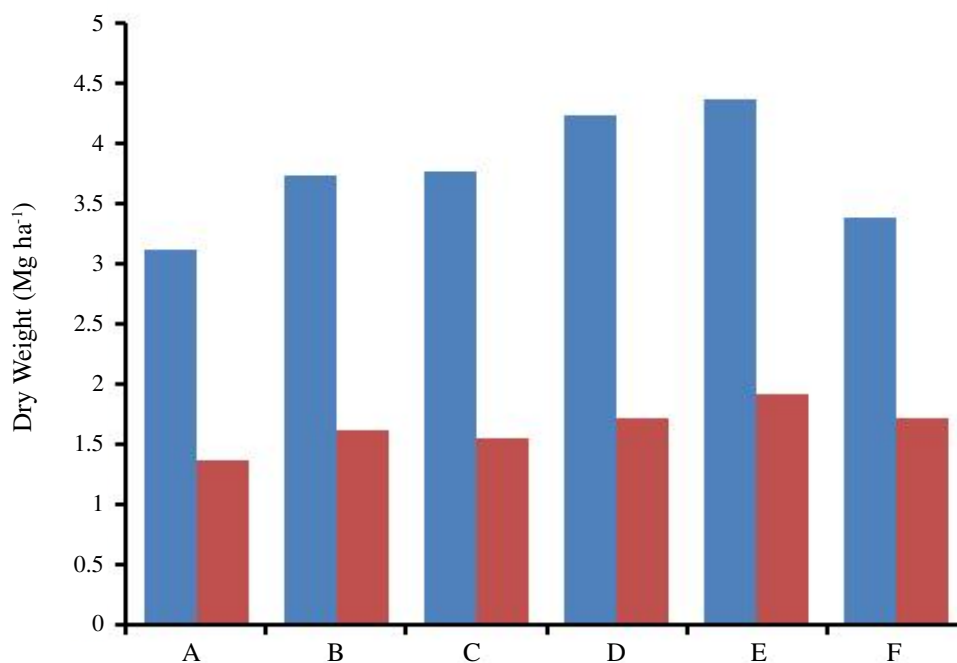


Figure 1. Effect biochar and compost on stover and dry grain weight of Soybean. (A. control; B. husk biochar 10 Mg ha⁻¹; C. corn cob 10 Mg ha⁻¹; D. straw compost 10 Mg ha⁻¹; E. husk biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹; F. corn cob biochar 10 Mg ha⁻¹ + straw compost 10 Mg ha⁻¹). ■: Stover weight (Mg ha⁻¹), ■: Dry grains weight (Mg ha⁻¹).

incubated by 2.5% that biochar was likely to increase soil pH after 20, 40, and 60 days.

Increasing soil pH, which may affect nutrient availability, likely in this study increased the values of available P (P_2O_5) and K (K_2O) particularly in the second month after incubation (available-P increase 75.31 – 125.69%, and available-K increase 42.04 – 62.33% than control) (Tabel 2). Biochar may modify soil nutrient availability by processes such as sorption, desorption and precipitation, which are also strongly influenced by changes in pH (Chintala *et al.* 2014). According to Nurida *et al.* (2013), effect of biochar on concentration of soil P and K-available was significantly correlated with the levels of P and K contained in some kinds of biochar on agricultural waste as correlation coefficient (r) respectively 0.351. Mahmoud *et al.* (2009) reported that straw compost application increase potassium and phosphorus availability of tropical soil.

Application of biochar and compost increase soil CEC, this is reasonable because of the increasing levels of exchangeable cations such as P and K. The highest increasing mixed application (husk biochar and compost) at second month was 23.25% compared to control. Jien and Wang (2013) reported that application of wood biochar 2.5% for 105 days incubation significantly increase soil CEC. Biochar appears to increase nutrient retention in soil at two possible mechanisms, adsorption and microbial immobilisation (Foereid 2015). Organic material generally has some adsorption capacity, so the material usually increases the adsorption capacity of soil. Moreover, the porous nature of biochar and high surface area may increase ion exchange capacity of soil.

Application of biochar and compost increased soil Organic-C values, but total-N and C/N were relatively constant in the first and the second month of incubation (Table 3). Rice husk biochar mixed with compost increased Organic-C as much as 9.5% at the first month and and 8.1% at the second month. According to Nurida *et al.* (2013) application some kinds of biochar of agricultural waste did not significantly increase soil Organic-C. Then, Agegnehu *et al.* 2015 explained there is a linear relationship between C content in the amendments and the SOC content at the end of the experiment.

Application of biochar and compost did not significantly effect plant height and number of branches, but significantly increased number of pods per plant (Table 4). Treatment of mixed husk biochar and compost (E) significantly increased number of pods (increasing 55%) compared to control. Number of pod is one of yield component on soybean.

According to Agegnehu *et al.* (2015a), there was a significant relationship ($R^2 = 0.96$) between yield of pods and yield of grains of soybean. Application of biochar and compost decrease number of unfilled pods including the pods which were attacked by pest.

Mixed of husk biochar and compost significantly increased dry grain weight and biomass of soybean compared to control, the grain weight increased about 41% (Figure 1). But, on stover weight, all treatments did not significant compared to control. The resultant change in soil nutrient status may affect both plant growth and productivity. Yield responses to biochar application will depend on the type and rate of biochar applied, as well as soil physico-chemical characteristics (Agegnehu *et al.* 2015 b). Nurida *et al.* (2012) reported that doses of husk biochar significantly affect dry grain and biomass of maize at Kanhapludults, Lampung.

CONCLUSIONS

Application of biochar and compost on acid soils improved soil fertility due to the increase in soil pH and nutrient availability especially P- and K-available. The treatment of mixed biochar and compost better than single application for improve soil fertility and soybean yield. Application to mixed husk biochar 10 Mg ha⁻¹ and straw compost 10 Mg ha⁻¹ increased grain weight about 41% than control.

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