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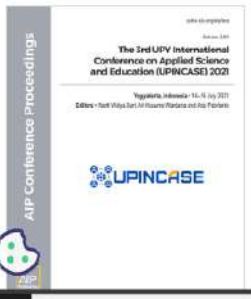

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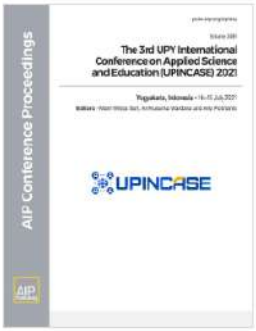

RESEARCH ARTICLE | JUNE 14 2023

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Okti Purwaningsih; Puguh Bintang Pamungkas; C. Tri Kusumastuti; Redo Aryaka
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Indonesia's coastal sandy soil has the opportunity to be used as an agricultural land but must be enforced by technological input to increase soil's fertility and to improve soil physical characteristics. This study aimed to analyze the effects of biochar and worm castings on the agronomic character of soybean (*Glycine max* L. Merril) in coastal sandy soil. The study was conducted in Completely

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The Characteristic of Growth and Protein Content of Soybean in Coastal Sandy Soil with The Application of Biochar and Worm Castings

Okti Purwaningsih [a)], Puguh Bintang Pamungkas, C.Tri Kusumastuti, and Redo Aryaka

Agriculture Faculty, Universitas PGRI Yogyakarta
Jl PGRI I No.117 Sonosewu Kasihan Bantul Yogyakarta Indonesia

[a)] Corresponding author: oktipurwaningsih71@gmail.com

Abstract. Indonesia's coastal sandy soil has the opportunity to be used as an agricultural land but must be enforced by technological input to increase soil's fertility and to improve soil physical characteristics. This study aimed to analyze the effects of biochar and worm castings on the agronomic character of soybean (*Glycine max* L. Merril) in coastal sandy soil. The study was conducted in Completely Randomized Design, consisting of two factors with three replications. The first was biochar application, consisting of two level, i.e. without biochar and with biochar. The second was worm castings dosage, consisting of four level, i.e. 0, 10, 20, and 30 ton/ha. Data were analyzed by using analysis of variance at 5% significance level and followed with DMRT (Duncan Multiple Range Test) to identify the significance difference of the treatments. Observations were done on root length, leaf area, dry crop weight, net assimilation rate, pod number, seed weight per crop, harvest index. The result showed that the interaction between biochar and worm castings did not provide significant effect on the agronomic character of *Glycine max*. Biochar application did not provide significant effect ($P>0.05$) on root length, dry root weight, leaf area, dry crop weight, net assimilation rate, pod number, seed weight per crop, harvest index. Worm castings did not provide significant effect on agronomic character of *Glycine max*. The interaction between biochar and worm castings significantly effect the increase of protein content of seeds.

Keywords:biochar, coastal sandy soil, worm casting, soybean.

INTRODUCTION

Soybean is one of food commodity that is essential and needed by the public as a source of vegetable protein. Indonesia's soybean production is considered low and cannot supply the needs of the country. To meet this supply, government has to import soybean.in the period of January – June 2018 soybean import reach about 1,17 million tons. In 2018, soybean production reach about 982,598 tons, while soybean import reach up to 2.585.809,1 ton. The deficit of soybean production scale is predicted to increase up to 2,24 million tons in 2021. Soybean productivity in 2018 is decreasing for 4,62% (ministry of agriculture, 2019). The decrease of soybean production form year to year is caused by the decrease of land area for soybean farming. Thus, it is needed a means to increase soybean production. One of the means that we can do is by utilizing sub optimal land. Sub-optimal land that scientifically has a low productivity rates because of internal factor such as material, physical, chemical, and biological characteristics and external factor such as temperature and extreme rainfall[1]. Sub-optimal land that is close to the sea is affected by salt (salinity) thus making the soil pH neutral or alkali. (pH: 6,5 – 7,5), and classified as Halaquents or Halaquepts. This type of land usually has low fertility and productivity thus needs technological input to increase.

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Indonesia is an archipelago, two third of the country are coastal area with 81.000 km coastline length. Coastal area has natural resources that can be improved. Coastal sandy land is one of the sub-optimal land that is poor in nutrients and organic matters, the temperature of the soil at noon can reach up to 55-60 ºC, soil aeration is too quick that caused slow organic matter accumulation and also the low increase of water. The compatibility of coastal sandy area in South DIY is considered incompatible or marginal suit for food and vegetable plant commodity. The intense sunlight and sea breeze that brings salt in high intensity become the environmental factor problem for agriculture at coastal land. However, coastal land has advantages such as greater and flat area, abundant sunlight, low sea level, and land preparation that only need bed to be made instead of several little trenches so it is cost efficient. All these problems in coastal land need solutions so that we can use coastal sandy land for agriculture. Many researches have been conducted to improve physical and chemical characteristics of soil and also the environmental factor. The use of soil fixing agent (soil type, organic matter, and carbide waste) on coastal land can improve the clay fraction, dust, porosity, moisture level, and decrease the soil BV, and BJ level[2]. Organic fertilizer and NPK fertilizer can increase the growth of corn in coastal sandy land of Trisik beach in Kulon Progo[3]. The use of Angsana leaf compost by 30 tons/ha can improve the chemical and physical characteristics of soil in Kulon Progo southern beach line[4]. The use of Rhizobium japonicum bacteria to soybean in coastal sandy land can increase the growth and production of soybean in coastal sandy land.

One of the organic matter that has a relatively complete nutrients is kascing ferlitizer (worm castings) that contains several matters needed for plant growth such as gibberellin, cytokinin, auxin hormones, N, P, K, MG, Ca nutrients, and *Azotobacter* sp which is a non-symbiotic N fastening bacteria[5]. Worm castings also contains micronutrients (Fe, Zn, Mn, Cu, B, Co, Mo) and Na[6]. Physically worm castings can improve solid soil structure to be more loses and porous, reversely, sandy soil become compact.

Apart from worm castings, the use of biochar can improve soil quality. The carbon content in biochar is stable and can last for thousands of years in the soil. The use of biochar in the soil potentially increases the C level of soil, water retention, and nutrients in the soil[7]. Laboratory scale research showed that biochar made from wood, rice husk, and coconut shell respectively has pH of 8,94; 6,34; and 9,49. Biochar potential as fixing agent is not only a means to improve physical, chemical, and biological characteristic of a soil, but also become the main resources of material for organic carbon conservation in the soil. Biochar can improve C-organic, P available and N total[8].). Charcoal biochar has the potential to be developed as absorbent because of its large surface area and approximately the same as colloidal soil. Active charcoal has a high adsorption level towards material in the form of liquid or steam. Biochar made from palm shell contains N 1.32%, P 0.07%, K 0,08%, C total 25,62%, KTK 4,58 cmol kg^{-1}, relative density 0.68 g ml^{-1}, particle density 1,85 g ml^{-1}, total pore space 63.30, water holding capacity 25,30%[9][10][11].

MATERIALS AND METHODS

This research is conducted at Experimental Garden Faculty of Agriculture, Universitas PGRI Yogyakarta, located in Soboman, Ngestiharjo, Kasihan, Bantul DIY. The time of research is February – Mei 2018. The research is arranged in a Completely Randomized Design that consists of two factors in three replications. The first factor is the use of biochar, which consist of without biochar and with biochar. Second factor is the dose of worm castings, which are 0, 10, 20, and 30 tons/ha. Coastal sandy soil used is taken from Samas Beach coastline, Kulon Progo, DIY. Soybean used in this research is Gema variety, the seed comes from Balitkabi (research centers for beans and tubers) Malang. The soil weight for each poly bags is 9 kg. biochar used is biochar made from charcoal that is grinded with diameter of ± 1 cm. The application of biochar and worm castings is according to the treatment. Worm castings, coastal sandy soil, and biochar are mix evenly according to the treatment dose before being put into the polybag. The amount of biochar put into the polybag is 2% from the soil weight which is 180 grams. The dose of worm castings administrated into the polybag is according to the treatment which are 10, 20, 30 tons/ha which are 25 g, 50 g, and 30 g/polybag. Soybean seeds are inoculated with soybean legin (legume inoculant) before planting, by mixing the seeds with soybean legin. Inoculation conducted in a shady place and void of contact with direct sunlight.

Observation of roots nodule, dry plant weight, leaf area, and net assimilation rate is conducted at maximum vegetative growth phase, aged 56 days. Observation of roots nodule conducted by disassembling and washing the roots, the nodule is then roasted in the oven at 80 ºC for 24 hours. Dry plant weight is measured by disassembling and washing the plant and then roasted in the oven at 24 ºC for 2x24 hours. The measurement of leaf area is conducted using leaf area meter. Net assimilation rate is measures using this formula:

$$LAB = \frac{B_2 - B_1}{T_2 - T_1} \times \frac{LnLd_2 - LnLd_1}{Ld_2 - Ld_1} \quad (1)$$

Note :

B_1 and B_2 : dry plant weight on T_1 and T_2.

Ld_1 and Ld_2 : leaf area on T_1 and T_2.

Observation of rooting and crop harvest is conducted at the end of the research. Seed's protein level is tested using Kjedahl method. Data analysis is using analysis of variance at real level of 5%. Real differences test between treatments using DMRT (Duncan Multiple Range Test) at real level of 5%.

RESULTS AND DISCUSSION

According to the assessment criteria of soil chemical property by land research center (LPPT) Bogor[12], planting media N Nutrient used falls under the category of very low, very high P_2O_5 and very low K_2O.

TABLE 1. Soil analysis results

Biochar & worm casting doses	C organic (%)	N total (%)	P_2O_5 potential (mg/100 g)	K_2O (mg/100g)
Without Biochar				
0 tons ha^{-1}	0,28	0,02	387	7
10 tons ha^{-1}	0,55	0,01	406	6
20 tons ha^{-1}	0,34	0,02	354	5
30 tons ha^{-1}	0,40	0,02	359	6
With Biochar				
0 tons ha^{-1}	0,32	0,03	821	11
10 tons ha^{-1}	0,42	0,03	379	8
20 tons ha^{-1}	0,45	0,05	369	16
30 tons ha^{-1}	0,50	0,03	361	10

According to soil analysis result, it can be seen that soil that has been administrated biochar has higher contents of C organic, N-total, P_2O_5 potential, and K_2O potential compared to media without biochar.

Plant Growth Analysis

Variance analysis showed that the interaction between biochar and worm castings does provide real effects toward dry roots nodule weight, root's length, dry root weight, leaf area, dry plant weight, and net assimilation rate. Biochar does not really affect plant growth variable observed, and the same can be said towards worm castings.

TABLE 2. The average of dry roots nodule weight, root's length, dry root weight, leaf area, dry plant weight, and net assimilation rate on coastal sandy with biochar addition and worm castings.

	Dry roots nodule weight (g)	Root's length (cm)	Dry root weight (g)	Leaf area (cm^2)	Dry plant weight (g)	Net assimilation rate (g/cm^2/week)
Without Biochar	0,08 p	31,79 p	1,24 p	436,00 p	4,17 p	0,00055 p
With Biochar	0,10 p	36,40 p	1,39 p	510,36 p	4,40 p	0,00055 p
Worm casting (ton ha^{-1})						
0	0,08 a	33,00 a	1,26 a	425,82 a	3,94 a	0,00069 a
10	0,10 a	36,75 a	1,41 a	444,35 a	4,13 a	0,00057 a
20	0,10 a	31,89 a	1,31 a	485,44 a	4,42 a	0,00047 a
30	0,08 a	34,75 a	1,30 a	537,10 a	4,65 a	0,00047 a

Note: the average that is followed by the same letter in the same column showed that there are no real differences according to DMRT at real level of 5%.

Plant growth is reflected from photosythate accumulation showed by the dry plant weight. Even though there are no real effect, plant that has been given biochar has higher dry root nodules weight. The application of biochar provides a good environment for the growth of *Rhizobium japonicum* bacteria. This is caused by biochar as a fixing agent contains many pore spaces, high water availability, and low water level on permanent wilting point so it creates a suitable habitat for microorganisms through its ability in keeping water and creates an environment with neutral pH[9][13]. In this research the addition of biochar does not provide real effect towards growth variable observed, this may be caused by the little application of biochar dose thus creating insignificant effect.

The increase of root nodule is essential for soybean because it will affect soybean ability in fixating nitrogen. This is strongly supported by other plant growth variable such as roots, leaf area, and dry plant weight. The application of worm castings also does not provide real effect to dry root nodule weight, root's length, leaf area, dry plant weight, and net assimilation rate. This is cause by the little dose of worm castings administrated. Even though worm castings can increase the nutrients in the planting media and also increase soil ability to bound water but the little dose in the application of worm castings makes it hard for the fertilizer to increase plant growth significantly. Coastal sandy soil is poor with nutrient and many other physical restrictions which need a lot of organic fertilizer that can significantly increase plant growth.

Correlation analysis result showed that there a positive and real relations between dry root nodule weight and dry root weight (r = 0,44*), leaf area (r = 0,39), dry plant weight (0,53*). This result indicates the rising of dry root nodule weight will raise the dry root weight, leaf area, and dry plant weight. The more root nodule formed will increase root's ability to fixate N_2. Fixation result is used to supply nitrogen needs for plant growth. Nitrogen availability often becomes limiting factor of plant growth and harvest. Nitrogen availability in sufficient numbers can improve plant growth. Apart from that biochar application on coastal sandy soil can improve soil characteristics because biochar can increase nutrients availability, water retention and water[8]

Plant Harvest Analysis

Variance analysis result towards pod numbers, seed weight per plant, and harvest index showed that there are no interactions between biochar and worm castings. Biochar does not affect the pod numbers, seed weight per plant, and harvest index, the same can be said to worm castings application.

TABLE 3. The avarage of harvest index, pod numbers, and seed weight per plant in coastal sandy soil with addition of biochar and worm castings..

	Harvest index	Pod numbers	Seed weight per plant (g)
Without Biochar	0,50 p	31,67 p	5,86 p
With Biochar	0,47 p	29,67 p	6,04 p
Worm casting (ton ha^{-1})			
0	0,50 a	30,03 a	5,86 a
10	0,46 a	29,97 a	5,93 a
20	0,47 a	30,30 a	5,75 a
30	0,49 a	32,37 a	6,26 a

Note: the average that is followed by the same letter in the same column showed that there are no real differences according to DMRT at real level of 5%.

Soybean vegetative growth affected the harvest components. Observation towards growth variable conducted at maximum vegetative showed that the use of biochar does not have real effects; the same can be said towards the use of worm castings. The same result also found in the observation of harvest index, pod numbers, and seed weight per plant. This is caused by the little application of biochar and worm castings, so it does not show any real effect. Coastal sandy soil needs more biochar and worm castings compared to ordinary soil to increase soil fertility. Even though there are no real effects, the use of biochar can increase the pods number and the weight of seed per plant. Correlation analysis results showed that there are positive and real correlations between seed weight per plant and pod numbers (r = 0,84**), dry root nodule weight (r = 0,56*), and dry root weight (r = 0,62*). The increase of dry root nodule weight will be followed by the increase of seed weight per plant, the same can be said with the increase of dry root weight will also increase the seed weight per plant. This is related to the ability of root nodule in fixating N_2 and root ability in absorbing water and nutrients for plant growth. The fulfillment of nitrogen, nutrients, and water needs for plant can

increase the harvest. Correlation analysis results showed that there are negative and real correlation between harvest index and root length (r = -0,56*) and dry root weight (r = -0,46*). This indicated the increase of root length; dry root weight will decrease the harvest index. When assimilate formed is used in the growth of root so the distribution of assimilate for growth and formation of seed is decreased thus decreasing the harvest index.

Interactions between biochar and worm castings have real effect to the protein level of soybean. The use of biochar and worm castings can increase the protein level of soybean.

TABLE 4. Protein level of soybean average (%) on coastal sandy soil with biochar and worm castings.

Biochar	Worm casting dose ton ha^{-1}				Average
	0	10	20	30	
Without Biochar	36,38d	37,55c	35,59e	36,73d	36,56
With Biochar	38,08b	38,28ab	38,54a	38,29ab	38,29
Average	37,23	37,91	37,06	37,51	(+)

Note: the average that is followed with same letter and on the same column showed that there are no real differences based on DMRT at real level of 5% (+): there are interaction.

The soybean grown in coastal sandy media with biochar charcoal and worm castings of 20 ton/ha has higher seed protein level and has real difference compared to other treatment combinations. Soybean plant that grew in media without biochar even though given worm castings still yield seed with lower protein level compared to soybean harvested from plant that grew on planting media with charcoal biochar. This is caused by charcoal biochar that can increase the N content in the soil. Nitrogen is a compound needed in the formation of protein, amino acid, and nucleic acid. Nitrogen needs of a plant can be obtained from N_2 fixation, adsorption of $NH4^+$, or $NO3^-$[14][5]. The use of biochar can make a suitable soil media for the growth of microorganism[10], including *Rhizobium japonicum* bacteria, and the same can be said to the application of worm castings. This condition triggered the formation of root nodule thus increasing the plant ability in fixating nitrogen[15]. The result of nitrogen fixation is then used in plant growth including seed formation that can increase the seed protein level.

CONCLUSION

The use of biochar and worm castings in coastal sandy does not have real effects toward growth variable and soybean harvest. Interaction between biochar and worm castings can increase the protein level of soybean. The most seed protein level is found in the soybean grew in the planting media with biochar and worm castings of 20 ton/ha.

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