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Growth of sesame (*Sesamum indicum* L.) plants with mediated compost biochar on coastal sandy land area in Bantul Regency Indonesia

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Abstract

This study aims to determine the growth of sesame plants that applied biochar organic matter on coastal sandy land. The coastal sandy land area of Indonesia is large enough. It is known as one of the marginal lands that have low productivity due to dominant soil constituent material of sand (>80%) so that it affects the availability of water and plant nutrient negatively. To improve the water-holding capacity, an applied technology is urgently needed so that it can be used as a growing material of sesame. A novel technology through the use of specific biochar, activated coconut shell charcoal, was proposed. Due to its functions in optimizing growing medium, improving soil properties physically, chemically, and biologically as well as in holding water and providing nutrients, the used biological charcoal would work as biological soil amendments. It is expected that biochar can be continuous sources for plant needs. The experiment was factorial design laid out in Randomized Complete Block Design involved 14 treatments with three replications consisting of combinations of seven charcoal applications and two sesame varieties. The data were subjected to analysis of variance and Tukey's Honestly Significant Difference test were used as a post-hoc analysis ($p<0.05$). The experimental results showed that the optimum plant growth was obtained from the application of coconut shell charcoal at a dose of 10 ton/ha combined with chicken manure at a dose of 30 ton/ha, such as tallest in height, highest net assimilation rate, and had most flowers.

Keywords: growth sesame plant, biochar, biochar on sand land, Coastal Sandy Land

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INTRODUCTION

The background of this study was the continuous shrinkage of the agricultural area because of the change a function. It means that fertile soils as a home base for agriculture are getting lesser. Coastal sandy land area is one of the alternatives, but it is classified as marginal land. Up to now, coastal sandy land has not been used yet by coastal society for agricultural activities because it is not suitable for growing plant. In fact, the use of marginal or impotent land, such as coastal sandy land for crop production actually becomes the innovation of natural land resources empowerment as well as society empowerment. The society around the coast is generally a part of poor society that socio-economically depends on the coast or sea resources and commonly uses the land for certain crop, viz corn, coconut, and papaya. Meanwhile, the waste of coconut shell is only used for household need (dried for gasoline) instead of using it as activated biological charcoal (biochar).

Biochar increasing the topsoil nitrate concentration and likely reducing nitrate leaching to subsoils. This was particularly seen after a dry year in the re-picked and analyzed particles. However, in the field experiment this aged, nitrate-enriched biochar did not improve crop yields. As a way to cope that marginal land, the rehabilitation is needed through the application of biochar (Lempang and Tikupadang, 2013). In order to obtain a suitable growing medium to optimize sesame productivity, biochar is needed as it provides a good environment for soil microbes, but it cannot be consumed by the microbes, retain and supply water and nutrient so that it is more available for the plant (Weil et al. 2003). Concerning to the abovementioned studies, the present study about the development of biochar as a way to empower coastal society was urgently needed.

Coastal Sandy Land and Plant Nutrient

The decrease in agricultural area impacts on the decrease in food production. In order to fulfill the food need, the solution alternatives are needed. One of those is by using marginal or unproductive land to be grown with staple food or industrial crop. Coastal sandy land is

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classified as one of the marginal lands. Besides, coastal sandy land has a great potency if it is developed maximally without the high budget of maintenance. Sandy land is generally not suitable for plant growth, with a low level of a nutrient, low organic matter, low water-holding capacity, infertile, and high level of salinity. It is due to the dominance of sand that fills macro pores so that it gives more air and faster the drying process.

Prior to use, sandy land needs to be manipulated by using biochar or manure. The high specific surface area (BET-SSA) of the used biochar considerably increased the sorption ability of the sandy soil through significant modifications in the internal soil pores' structure. This (Baiamonte et al. 2019, Özer et al. 2018)

Biochar and Manure

Charcoal is a porous solid-state produced by pyrolysis of carbonated materials (Kinoshita 2001). Some of the porous charcoal is enclosed by hydrocarbon or another organic compound. The activation of charcoal is to remove the carbon so that it produces activated charcoal. Activated charcoal can be differentiated from common charcoal based on characteristics of the outer surface. The outer surface of common charcoal is still covered with deposit hydrocarbon that inhibited its activation, whilst the outer surface of activated charcoal relatively free from the deposit and can absorb due to large surface and opened pores (Gómez-Serrano et al. 2003). Recently, this activated charcoal is developed as a soil conditioner for horticultural crops production (Gusmailina et al. 2001).

The study about optimization of sesame production through amelioration by using organic fertilizers were already done. In 2002—2004, an experiment was conducted involving four regions in India where the treatments tested were combination of organic fertilizers wood ash 75 ka/ha, manure 3.75 t/ha, compost of Nimba 900 kg/ha, fishbone 75 kg/ha, Sulphur 20 kg/ha, phosphorus enriched with bacteria 5 kg/ha, *azotobacter* 5 kg/ha, and *Trichoderma viridae* (0.4%) yielded high BC ratio and net money return (NMR) (Duhoon 2007).

Besides, the use of organic ameliorant directly affects agroecology, oil content, soil health, and human health. The use of organic resources reduces the dependency of chemical fertilizer and pesticide. The experimental result showed that chicken manure at a dose of 30 ton/ha on sandy land productively increased yield (Dewi 2013) and the application of cow manure 10 ton/ha combined with NPK (100:100:50) caused total oil content more than 40% (Dewi 2012). As well as the experiment conducted on Egypt recommended that the importance of biofertilizer was to improve soil condition physically, biologically, and chemically and in long terms will show the significant result on sesame growth, including its yield (Kamprath et al. 2010, Ranjbari et al. 2015).

Near the coastal sandy land, leaf litter is still seen as a waste so it is burned. Consequently, the combustion will result in CO and other gases and will increase greenhouse gas emission. Leaf litter can be used as mulches or processed as compost so that it may serve as soil organic matter. However, the carbon inserted to the soil in the form of compost and mulch will deplete as microbial activity in decomposing and producing CO and CH released to the atmosphere. As a result, C-organic will decrease (Sukartono et al. 2011). Therefore, in order to maintain soil organic carbon, the addition of organic matter in greater amount is needed every season. This such practice will increase greenhouse gas emission. The basic principle of producing biochar is combustion (pyrolysis) minimally with or without oxygen so that the carbon inside biomass tissue is not perfectly burnt and turned into biochar instead of ash and volatile CO. Biochar is an organic matter that is resistant with microbial decomposition so that its presence beneath the soil will last longer. The application of biochar is able to improve soil quality. Some crucial benefit after applying the biochar is to retain water holding capacity so that it saves irrigation, increase soil CEC, and restore soil acidity so that soil becomes more fertile. By the application of biochar, it meant that it saves more carbon beneath the soil and emission gas will be reduced. It also supports the fixation and retention of nitrogen so that it reduces nitrogen leaching and emission of NO. In acid soil and toxic soil, biochar is able to decrease Al toxicity and other soil pollutant. Biochar is also able to increase the number of beneficial soil microbes. Therefore, biochar will help farmer from the dependency with commercial fertilizer and it increases the growth and yield of plant (Dyachuk et al. 2018, Masulili et al. 2014).

Sesame

Sesame (*Sesamum indicum* L.) is a flowering plant in the genus Sesamum. Sesame seed is one of the oldest oilseed crops known, domesticated well over 3000years ago. *Sesamum indicum*, the cultivated type, originated in India and is tolerant of drought-like conditions, growing where other crops fail. Sesame is an annual plant growing 50 to 100 cm tall, with opposite leaves 4 to 14 cm long with an entire margin; they are broad lanceolate, to 5 cm broad, at the base of the plant, narrowing to just 1 cm broad on the flowering stem. The flowers are yellow, tubular, 3 to 5 cm long, with a four-lobed mouth. The flowers may vary in color, with some being white, blue, or purple. Sesame seeds occur in many colors depending on the cultivar. The most-traded variety of sesame is off-white colored. Other common colors are buff, tan, gold, brown, reddish, gray, and black. The color is the same for the hull and the fruit. Sesame fruit is a capsule, normally pubescent, rectangular in section, and typically grooved with a short, triangular beak. The length of the fruit capsule varies from 2 to 8 cm, its width varies between 0.5 and 2 cm,

Table 1. Description of sesame varieties Sumberejo 1 and Winas 1

No.	Characteristics	Sumberejo 1 (M1)	Winas 1 (M2)
1.	Type	White sesame	White sesame
2.	Flower color	Purple	Pink
3.	Leaf color	Old green	Green
4.	Habit	More branches	Branches
5.	Plant height	120-160 cm	116-146 cm
6.	Harvest time	90-110 days	100-103 days
7.	Number of loculi	8	4
8.	Oil content	56%	50%
9.	Productivity potency	1-1.6 ton/ha	1-1.4 ton/ha

and the number of local varies from four to 12. The fruit naturally splits open (dehisces) to release the seeds by splitting along the septa from top to bottom or by means of two apical pores, depending on the varietal cultivar. The degree of dehiscence is of importance inbreeding for mechanized harvesting, as is the insertion height of the first capsule. Sesame seeds are small. Their size, form, and colors vary with the thousands of of-of varieties now known. Typically, the seeds are about 3 to 4 mm long by 2 mm wide and 1 mm thick. The seeds are ovate, slightly flattened, and somewhat thinner at the eye of the seed (hilum) than at the opposite end. The weight of the seeds is between 20 and 40 mg. The seed coat (testa) may be smooth or ribbed (Van-Rheenen 1981).

The higher rate of biochar addition significantly improved the seed yield of sesame in the first cropping. As the biochar addition increased, the sesame seed yield and number of seeds per plant increased and then decreased (Wacal et al. 2019).

This study purposes to determine the growth of sesame plants that applied biochar organic matter on coastal sandy land area in Bantul Regency, Indonesia.

MATERIALS AND METHODS

The coastal area of Bantul Regency is directly opposite the Indian Ocean is characterized by a stretch of sand. This region is one of the expected development assets in Bantul Regency because the region has resource potential very rich and diverse nature. The low content of clay, silt, and nutrient, as well as a low level of organic matter, resulted in the water to flow as fast as 150 cm/hour. In turn, the low level of saving water (1.6-3% of available water). The high speed of salty wind which is up to 50 km/hour. At day, high level of light intensity (109.960 lux), low level of moisture content which increases air temperature. The faster the speed of salty wind affects the plant evapotranspiration to increase. Daily soil temperature varies from 26.9 to 31.5 °C and sometimes exceeds up to 33.1 °C, loose texture of soil, high infiltration, high evaporation, and low soil fertility (Al-Omran et al. 2004) so that naturally the coastal sandy land is not suitable for plant due to low level of fertility physically, chemically, and biologically.

Table 2. *P>F-value* of main effects of types of biochar (B), sesame varieties (V) and their possible 2-way interactions for plant height (PH) on 4 and 8 weeks after planting (WAP), net assimilation rate (NAR), days to flowering (DTF), and number of flowers (FLO)

Source	d.f.	P> F-value				
		PH		NAR	DTF	FLO
		4 WAP	8 WAP			
B	6	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
V	1	<0,0001	0,008	0,408	<0,0001	0,014
B×V	6	0,244	0,008	0,571	0,004	0,556
CV (%)		3,10	2,18	4,82	1,83	2,79

d.f., degree of freedom; CV, coefficient of variation

That is why the sandy land needs an important treatment if it is used for plant production, especially for sesame.

The experiment was carried out at coastal sandy land area in Bantul, Indonesia. The materials prepared were seven types of biochar addition (control P0; biochar at a dose of 5 ton/ha, P1; biochar at a dose of 10 ton/ha, P2; biochar at a dose of 15 ton/ha, P3; biochar at a dose of 5 ton/ha combined with chicken manure at a dose of 30 ton/ha, P4; biochar at a dose of 10 ton/ha combined with chicken manure at a dose of 30 ton/ha, P5; and biochar at a dose of 15 ton/ha combined with chicken manure at a dose of 30 ton/ha, P6), while two sesame varieties were M1 ('Sumberejo 1') and M2 ('Winas 1'). The equipment used were water sprinkler, thermo-hygrometers, tube solar meter type ELE 505-070, and the apparatus for laboratory analysis for oil content. A Randomized Complete Block Design (RCBD), chose to the 7x2 factorial experiment, with three replications. The individual crops were planted in the land. The observation were done on agronomic aspects (plant height, net assimilation rate, days to flowering, and a number of flowers). The data were analyzed using analysis of variance (ANOVA) and Tukey's Honestly Significant Test (α = 5%) as a post-hoc analysis.

RESULTS AND DISCUSSION

The results in the following section are based on the order of statistical significance, which ranges from the highest level interaction to the main effects of treatments. From **Table 2**, the statistical analysis showed that type of biochar with sesame varieties interaction was not occurred in plant height 4 weeks after planting, net assimilation rate, and number of flowers (*P>F-value*<0.05). Meanwhile, significant interactions were found in plant height 8 WAP and days to flowering. Thus, the results are presented in a format corresponding to these significant interactions. Compost addition and a higher fertilization significantly improved plant growth. However, adding co-composted biochar always caused the largest plant growth increase. The absolute amount of biomass increase due to BCcomp addition was nearly identical at each nutrient-supply level. The amount of N taken up into the leaves closely

Table 3. The effect of sesame varieties and biochar applications on plant height on 4 weeks after planting (WAP)

Treatments	Plant Height (cm) 4 WAP		
	Sumberejo 1	Winas 1	Mean
Control	39.67	39.00	39.33 d
Biochar 5 ton/ha	43.00	41.00	42.00 c
Biochar 10 ton/ha	43.00	41.33	42.17 c
Biochar 15 ton/ha	43.67	40.67	42.17 c
Biochar 5 ton/ha + chicken manure 30 ton/ha	46.33	42.00	44.17 bc
Biochar 10 ton/ha + chicken manure 30 ton/ha	47.33	44.33	45.83 ab
Biochar 15 ton/ha + chicken manure 30 ton/ha	49.33	45.33	47.33 a
Mean	44.62 x	41.95 y	43.29 (-)

Note: (-) indicates an insignificant interaction; means followed by a similar letter within columns or rows are not significantly different according to Tukey's HSD test (p<0.05).

Table 4. The effect of sesame varieties and biochar applications on plant height on 8 weeks after planting (WAP)

Treatments	Plant Height (cm) 8 WAP		
	Sumberejo 1	Winas 1	Mean
Control	57.00 ij	55.00 j	56.00
Biochar 5 ton/ha	61.67 e-h	61.33 f-h	61.50
Biochar 10 ton/ha	63.67 c-g	59.33 hi	61.50
Biochar 15 ton/ha	62.50 d-h	59.83 g-i	61.17
Biochar 5 ton/ha + chicken manure 30 ton/ha	64.83 c-f	67.50 a-c	66.17
Biochar 10 ton/ha + chicken manure 30 ton/ha	71.17 a	70.00 ab	70.58
Biochar 15 ton/ha + chicken manure 30 ton/ha	66.33 b-d	65.67 c-e	66.00
Mean	63.88	62.67	63.27 (+)

Note: (+) indicates a significant interaction; means followed by a similar letter are not significantly different according to Tukey's HSD test (p<0.05).

mirrored the overall biomass results (Kammann et al. 2015).

Table 2 showed that only two observed variables that indicated significant interaction under biochar applications and sesame varieties, those are plant height on 8 WAP and days to flowering. It demonstrated that there were a dependency and cooperation between both factors in affecting the variables. On the other hand, three other variables did not show a significant interaction (plant height on 4 WAP, net assimilation rate, and a number of flowers). It meant that either the biochar application or sesame varieties had an independent effect in affecting those variables. The amendments of biochar or a combination of compost and biochar can be recommended as soil ameliorant to an increase of the soil water holding capacity, soil carbon flux and electrical conductivity (Zainul et al. 2017).

Plant height on 4 WAP under sesame varieties and biochar applications can be seen in **Table 3**. Interaction between both factors was not significant. On 4 WAP, 'Sumberejo 1' was taller than 'Winas 1'. The addition of biochar gave some effects to consider. The control plant was the smallest compared to other treated plants. Plant supplied with chicken manure was taller than a plant

Table 5. The effect of sesame varieties and biochar applications on net assimilation rate (NAR)

Treatments	NAR (g/m²/day)		
	Sumberejo 1	Winas 1	Mean
Control	0.058	0.061	0.060 c
Biochar 5 ton/ha	0.061	0.060	0.061 c
Biochar 10 ton/ha	0.062	0.063	0.063 bc
Biochar 15 ton/ha	0.060	0.063	0.062 c
Biochar 5 ton/ha + chicken manure 30 ton/ha	0.065	0.065	0.065 bc
Biochar 10 ton/ha + chicken manure 30 ton/ha	0.073	0.077	0.075 a
Biochar 15 ton/ha + chicken manure 30 ton/ha	0.069	0.066	0.068 b
Mean	0.064 x	0.065 x	0.065 (-)

Note: (-) indicates an insignificant interaction; means followed by a similar letter within columns or rows are not significantly different according to Tukey's HSD test (p<0.05).

without supplement from chicken manure. The effect of biochar application without chicken manure at any dose levels on plant height was not significantly different. However, biochar applied at a dose of 15 ton/ha mixed with chicken manure resulted in the higher plant than biochar applied at a dose of 5 ton/ha mixed with chicken manure, but it did not significantly differ with biochar applied at a dose of 10 ton/ha.

Plant height on 8 WAP under sesame varieties and biochar applications can be observed in **Table 4**. Interaction between both factors was found significantly. On 8 WAP, the interaction effect on plant height of 'Sumberejo 1' and 'Winas 1' was different. Generally, the untreated plant performed negatively as the plant tended to be smaller. The application of biochar at doses of 5 and 15 ton/ha did not significantly affect plant height for both varieties, but 'Sumberejo 1' applied with biochar at a dose of 10 ton/ha was higher than 'Winas 1'. By the addition of chicken manure on biochar at any dose levels showed similar effects for both varieties. When the interaction effect was observed per sesame variety, plant height of 'Sumberejo 1' was tallest under the application of biochar at a dose of 10 ton/ha added with chicken manure compared to other treatments, whereas 'Winas 1' treated with biochar at any dose levels mixed with chicken manure was taller than those treated only with biochar. Biochar additions seem to potentially be an effective means of sequestering C in soils as no detectable loss of soil organic carbon (SOC) occurred during the 67-day incubation (Novak et al. 2009). During the composting, carbon and nitrogen can be used by microorganisms for energy production and cell growth (Wei 2014).

Net Assimilation Rate (NAR) under sesame varieties and biochar applications were shown in **Table 5**. Interaction between both factors was not significant. NAR of 'Winas 1' did not significantly differ to that of 'Sumberejo 1'. Meanwhile, the addition of biochars gave certain effects. Plant treated with biochar at a dose of 10 ton/ha mixed with chicken manure showed higher NAR compared to other treatments. The increase or decrease of biochar applied more or less than 10 ton/ha slower

Table 6. The effect of sesame varieties and biochar applications on days to flowering

Treatments	Days to flowering (day)		
	Sumberejo 1	Winas 1	Mean
Control	37.33 cd	35.00 e	36.17
Biochar 5 ton/ha	39.67 ab	37.33 cd	38.50
Biochar 10 ton/ha	37.67 b-d	38.33 a-c	38.00
Biochar 15 ton/ha	39.33 a-c	38.33 a-c	38.83
Biochar 5 ton/ha + chicken manure 30 ton/ha	40.33 a	39.00 a-c	39.67
Biochar 10 ton/ha + chicken manure 30 ton/ha	38.33 a-c	35.67 de	37.00
Biochar 15 ton/ha + chicken manure 30 ton/ha	39.67 ab	39.00 a-c	39.33
Mean	38.90	37.52	38.21 (+)

Note: (+) indicates a significant interaction; means followed by a similar letter are not significantly different according to Tukey's HSD test (p<0.05).

Table 7. The effect of sesame varieties and biochar applications on the number of flowers

Treatments	Number of flowers		
	Sumberejo 1	Winas 1	Mean
Control	49.00	51.67	50.33 c
Biochar 5 ton/ha	50.33	50.33	50.33 c
Biochar 10 ton/ha	51.00	54.00	52.50 c
Biochar 15 ton/ha	58.67	60.33	59.50 b
Biochar 5 ton/ha + chicken manure 30 ton/ha	59.67	60.33	60.00 b
Biochar 10 ton/ha + chicken manure 30 ton/ha	63.00	63.67	63.33 a
Biochar 15 ton/ha + chicken manure 30 ton/ha	60.00	60.33	60.17 b
Mean	55.95 y	57.24 x	56.60 (-)

Note: (-) indicates an insignificant interaction; means followed by a similar letter within columns or rows are not significantly different according to Tukey's HSD test (p<0.05).

NAR. The addition of biochar without chicken manure did not significantly affect NAR.

The observed variable of days to flowering under sesame varieties and biochar applications was shown in **Table 6**. Interaction between both factors was significant in affecting days to flowering where its effect differed between both varieties. The control plant of 'Winas 1' showed the fastest days to flowering. The application of biochar at doses of 10 and 15 ton/ha did not significantly affect days to flowering between varieties, whilst the application of biochar at 5 ton/ha caused days to flowering of 'Sumberejo 1' were slower than that of 'Winas 1'. The addition of chicken manure on biochar at doses of 5 and 15 ton/ha gave similar effect for both varieties, but days to flowering of 'Winas 1' at a dose of 10 ton/ha was faster than that of 'Sumberejo 1'. When the interaction effect was observed per varieties, all 'Sumberejo 1' had similar days to flowering, whereas 'Winas 1' treated with biochar and or without mixture of chicken manure had slower days to flowering compared to control, except for the application of biochar at a dose of 10 ton/ha mixed with chicken manure. Biochar has a positive effect on the physical and physicochemical characteristics of composting chicken manure (Wei et al., 2014). Elevated doses of biochar with a higher level of N fertilizer application significantly increased the index of aggregate stability and the proportion of water-stable macro- aggregates, especially in the size fractions from 3 to 2 mm (Simansky et al. 2018). The availability of water will help plants to transport nutrients throughout the plant's body for its vegetative and generative growth.

A number of flowers in response to types of charcoal and sesame varieties can be seen in **Table 7**. The interaction between sesame varieties and types of charcoal was not significantly found. A number of flowers of 'Winas 1' were greater than the number of flowers of 'Sumberejo 1'. Meanwhile, the addition of types of charcoals showed certain effects. Plant treated with charcoals at a dose of 10 ton/ha added with chicken manure had most flower compared to other treatments, followed by charcoals at a dose of 15 ton/ha, charcoals at a dose of 5 and 15 ton/ha added with chicken manure, whereas control plant and charcoals at a dose of 5 and 10 ton/ha gave the least flowers.

CONCLUSIONS

The crucial requirement for soils to be used as a growing medium is a well-managed condition of soil physically and chemically. Physically good soil can sustain root growth and be able to be an aeration and moisture content site which all related to the role of biochar combined with organic matter. The combination of biochar with chicken manure has a significant effect and optimal produced on plant height, Net Assimilation Rate (NAR) and number of flowers in the application of 10 tons/ha of biochar which is combined with 30 tons/ha of chicken manure. The interaction of the treatment of biochar and chicken manure with sesame plant varieties is shown in the parameters of high plants 8 WAP and days of flowering. The optimal value is shown in the interaction of Biochar treatment 10 tons/ha + chicken manure 30 tons/ha with the Sumberejo varieties.

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