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The Effect of Biochar on Root Growth in Sustainable Agriculture

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Abstract.
Sustainable agriculture can be used to achieve food security by continuously producing agriculture while taking safety, soil health, and environmental and economic considerations into account. Reduced agricultural land for agricultural production could stifle the growth of sustainable agriculture. This study made use of biochar, which is made from organic waste and serves to temporarily hold soil nutrients in the root zone of plants. The focus of this research was to find new ways to expand coastal land use by using biochar made from organic waste as a soil amendment for agriculture, particularly vegetable production. The study employed a two-factor design: the first was the size of the biochar material, which was coarse and fine, and the second was the biochar dosage, which included 10, 15 and 20 tons per hectare. Coconut shell waste was used to make the biochar. According to the results, the application of course-sized biochar at a dose of 15 tons per hectare resulted in lateral root distribution. Vegetable root development tended to be reduced when fine biochar was used. We can conclude that one of the solutions for sustainable agricultural production is to use biochar ameliorant materials made from environmentally friendly organic waste.

Keywords: Biochar, Coastal land, Organic matter, Roots Areas, Soil Carbon, and Sustainaibility Agriculture.

1. Introduction

The coastal soil Samas beach has sand fraction that has low organic matter, low absorption capacity, low CEC, high permeability and high sensitivity to erosion. Ameliorant in coastal sandy soil was needed to reduce problem. Environmentally friendly soil improvement by utilizing waste with high carbon content by biochar. Biochar is an active biological carbon that functions to store nutrients in the soil. Besides that, biochar can also absorb soil water which can increase humidity and persistent so that it can last a long time in the soil. Coconut shell biochar was able to increased the cation exchange capacity (CEC) in the soil. Cation exchange capacity in soil applied with coconut shell biochar has an indirect effect on the level of nutrient leaching in the soil. The CEC showed the ability of the soil to exchange a number of cations such as K^{+}. Its can bind to NO^{3-} to form potassium nitrate compounds so that it can reduce the level of leaching of nitrogen elements. Coconut shell biochar pores have size between 0.56-10.37 μm. It can adsorb nitrogen which has a covalent radius of only 71 pm (71 x 10^{-6} μm). The specific surface area of biochar, reaching 330 m2/g causes biochar to have a high adsorption capacity for nutrients[1]. The increase in nutrients in the root area causes the availability of nutrients to increase which has an impact on root development.

2. Methodology

The Coastal sandy soil has the potential to develop agricultural areas. The limited physical and chemical characteristics of the soil require handling measures. Utilization of environmentally friendly waste is an alternative to overcome the problem of coastal sandy land. The use of carbon-rich materials as an effort to increase the absorption of nutrients and water is an improvement in sandy soil. Carbon-rich organic waste was processed into biochar to reduce soil nutrient leaching and soil moisture. Biochar made from coconut shells obtained in villages around the coast is an alternative to the use of environmentally friendly waste. The biochar material is mixed in the soil with an incubation period of 1 month by testing the material with the size of a fine about powder and coarse material about 2-3 cm flakes. Material treatment with different sizes will be tested on pakcoy vegetable plants. The research technique used a survey method to determine the location, while the coastal sand was taken descriptively, namely by direct taking the selected sand soil material which had not been added to ameliorant. The research design that will be used in the study is a completely randomized design (CRD) with two treatments, namely the particle size of biochar and the dose of coconut shell biochar and the dose of biochar. The particle size of biochar was powder form and flake size about 2-3 cm, while the dosage of biochar is 0, 10, 15 and 20 tons per hectare. Each treatment was incubated for first month before planting pakcoy at coastal sandy Samas beach Yogyakarta Indonesia.

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3. Result and Discussion

The Coastal sandy soil [2]. Cultivation of plants on coastal sandy land requires additional application of technology to overcome the characteristics of coastal sandy land. Utilization of organic waste to be processed into biochar is one of the environmentally friendly based land management. Making biochar with combustion technology by pyrolysis is combustion with low environmental emissions[3], [4]. The use of organic coconut shell waste is an effort to improve coastal sandy land to enrich soil carbon which functions as a framework to prevent leaching of nutrients for plants. Carbon in the soil affects the level of fertility and soil quality to provide nutrients for plants. The carbon source comes from plant biomass which was environmentally friendly[5]–[7].

TABLE 1: Results of analysis on sandy beach soil and coconut shell biochar.

Kind of Analysis	Coastal Sandy soil	Coconut of Biochar
pH	5,4	9.8
CEC (cmol(+)kg^{-1})	0.43	2.0
N tot (ppm)	27,50	0.35
P avl (ppm)	20	0.60
K avl (ppm)	99	0.65

Coastal sandy soil in Samas beach has the potential to develop environmentally friendly agricultural production with minimal chemical properties (Table 1). Soil reaction with a pH of 5.4 was good potential for agricultural production. The low cation exchange capacity can be increased by adding an ameliorant in the form of a material that can increase the large specific surface[2][8]-[10]. While the low nutrients in coastal sandy land can be added by providing organic and inorganic nutrients. The addition of environmentally friendly ameliorants by utilizing organic waste in the surrounding area is an alternative to preserve the environment and carbon emissions.

Treatment of biochar with different sizes on sandy soils has a different effect on soil carbon yields. The application of biochar is more effective on carbon availability than the use of crude biochar (Figure 1). Refined coconut shell biochar contributes to the supply of carbon in the biochar material because the fine particles have a large surface area. Nutrient absorption by carbon in fine-sized biochar at doses of 10 and 15 tons per hectare gave the highest increase in carbon yield of 0.2% compared to control (Figure 1). The increased supply of organic C comes from biochar made from coconut shell which is burned by pyrolysis to produce stable carbon[11]–[13]. Statistically, the increase in carbon availability was not significant, but the fine biochar contributed to a higher carbon increase than the crude biochar. The sand fraction is a single fraction

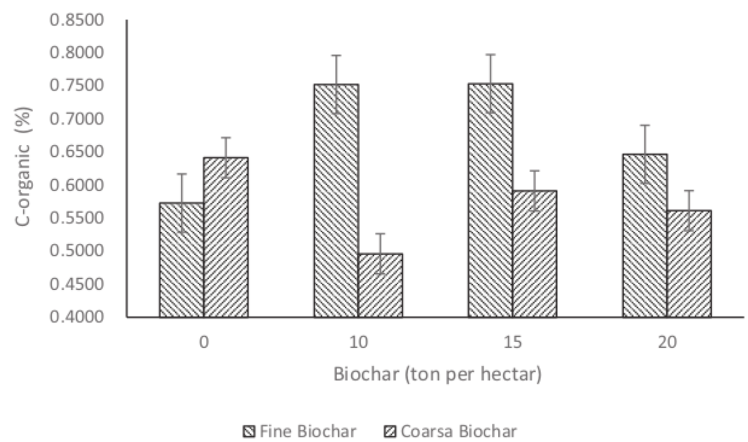

Figure 1: Content C-organic in application of biochar coconut at sandy soil Samas beach [8].

in which the grains of the fraction are not bonded to each other which results in the presence of macro pores between large particles. This causes the low nutrient bound in the sand grains causing the cation exchange capacity to also be small. The treatment of fine and coarse sized biochar has an effect on the storage of nutrients due to the addition of the surface area between the sand particles. This is because the sand has a dominant fraction or coarse particles so that the presence of biochar with a smaller size fraction than the sand fraction will fill the macro pores which are used as a temporary housing framework for soil nutrients. The characteristics of biochar are porous, capable of absorbing water and soil nutrients. Biochar is a place to store nutrients temporarily in the pores of the material so that biochar can reduce the loss of nutrients due to leaching in sandy soils [12], [14]–[17].

The treatment ameliorant biochar was mixed with soil minerals contributed to direct contact with the soil fraction. so that it would form a weak bond in the sand fraction. Organic waste or organic residue that contains a lot of carbon is a material derived from wood material with the quality of the material being a parameter in determining the amount of C content in the network [9]. The application of biochar in the soil will react with soil minerals which can increase soil C-organic levels and increase the availability of nutrients in the soil[1], [2], [18]–[20]. Nitrogen availability increased in the presence of coconut shell biochar ameliorant (Figure 2a). The increase in N as a nutrient does not come from biochar material because the function of biochar was not as a fertilizer but serves to bind nutrients with weak bonds in soil minerals. Nutrients bound to biochar are in the biochar pore spaces (Figure 2b).

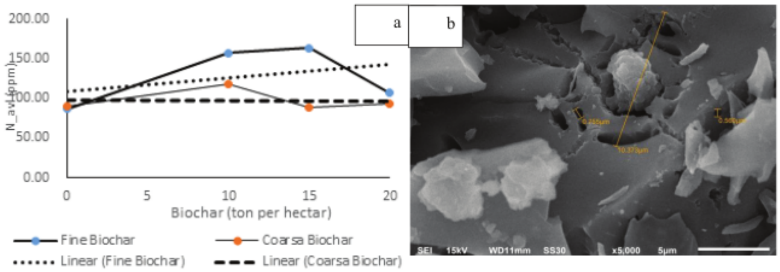

Figure 2: Application biochar of coconut in sandy soil at Samas beach Yogyakarta, Indonesia. a) Nitrogen avalaibility [9]. b) SEM in the fine biochare.

The increase in soil nitrogen content in caostal sandy soil that was applied with biochar in the form abaout fine-sized fraction gave higher yields than the biochar in coarse fraction. Its surface of the fine fraction provides a larger particle surface area than the sand and biochar fraction in the form of flakes. Pore size in fine biochar 0.56–10.37µm can adsorb nitrogen which has a covalent radius of only 71 pm (71 x 10-6 µm). The specific surface area of biochar material reaches 330 m^2/g causing biochar to have a high adsorption capacity for nutrients so that fine biochar is able to store higher nitrogen nutrients [1]. Meanwhile, in the application of coarse fraction biochar in sandy soil, availability decreased at doses of 10 and 15 tons per hectare and increased N availability at doses of 20 tons per hectare (Figure 2a). The addition of a dose of C in first month's incubation gives an opportunity for a higher amount of C that comes from the results of the decomposition process in the soil and the amount of supply of C from an additional dose of 5 tons per hectare. In the treatment of refined biochar at a dose of 15 tons per hectare, the amount of N decreased (Figure 3). Its because the supply of N in the soil was used by plants in the vegetative phase in the growth and development of pokcay plants. The development of plant physiological growth correlated significantly with the application of coconut shell biochar (Figure 3).

The biochar in the form of fine fraction and flakes gave a positive contribution to physiological development (Figure 3). Decomposition of fine fraction biochar contributes faster than the decomposition of biochar in the form of flakes. The grain size of starch-sized biochar tends to be faster in capturing nutrients and exchanging soil cations that can be utilized by plant roots for plant growth [1], [2], [7], [21]. This can be proven in the development of pakcoy plant growth with plant height and number of leaves formed in the fine fraction biochar higher than in the crude fraction biochar treatment (Figure 3). Treatment of crude fraction biochar showed good development in the development of root complexes in the soil. This illustrates that the treatment of crude fraction biochar

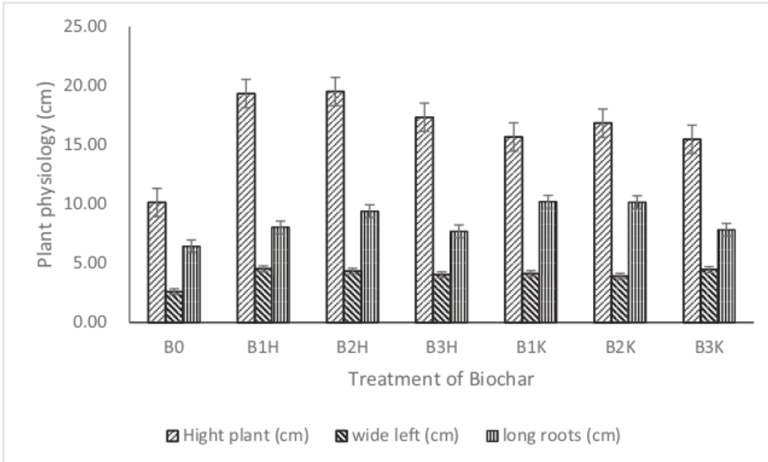

Figure 3: Treatment of coconut shell biochar on the physiological development of Pokcay plants in Samas beach sand, Yogyakarta.

was slower in the decomposition of biochar material so that it provides a smaller supply of plant nutrients captured in the biochar pores which contributes to the supply of plant nutrients, especially in supporting the growth and development of the vegetative part of the pokcay plant, which is only sufficient and supports root area plant.

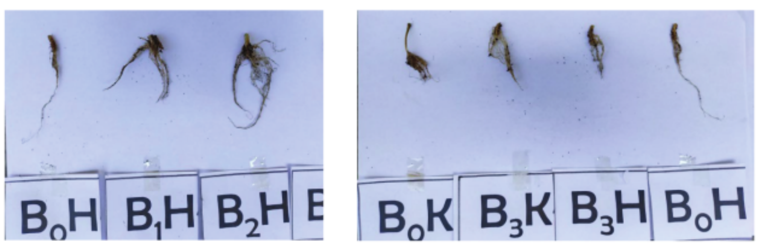

Figure 4: Application biochar for roots development in sandy soil beach Samas Yogyakarta, a) roots development with biochar fine aplication b) roots development with biochar coarse aplication.

Root development due to the application of coconut shell biochar amelioration on coastal sandy soil gave a significant difference in root development. In the case of root development without biochar, the root development was lateral downwards, while with the application of fine and coarse-sized biochar, the impact of root development tends to be horizontal and grouped (Figure 4). Root development is due to the presence of biochar temporarily storing nutrients around the root complex for the growth and development of plant roots [2],[5], [7], [20], [22]–[25]. The coastal sandy soil was dominated by more than 90% of the sand fraction. The application of fine biochar appears to give more distribution development than the application of coarse-sized biochar. This is because the fine fraction in biochar will give more direct effect quickly in coagulation with the sand fraction which gives a larger surface area for the type of coagulation compared to the coarse fraction biochar application [2],[10], [25],[26]. Nutrients in the application of fine fraction biochar are possible because the application of biochar on sandy soils has an absorption pore width of 10.37 μm (Figure 2 b). Nitrogen has a covalent radius of only 71 pm (71 x 10-6 μm) while the specific surface of biochar about 330 m^2/g causing biochar to have a high adsorption capacity of nutrients [1], [2]. The growth of vegetable crops on coastal sandy land produced is the vegetative part in the form of leaves and stems requiring relatively more nitrogen absorption than other elements for growth. Biochar in the fine fraction with a storage pore width of 10.37 μm provides a large enough opportunity for adsorption.

4. Conclusion

The application of fine and coarse sized biochar ameliorants had a significant effect on the enrichment of C-organic in coastal sandy soils. Biochar with fine fraction size has a storage capacity of 10.37 μm prom wide and provides lateral root development in groups. In coastal sandy areas, the application of fine fraction biochar is more effective than coarse-sized biochar. The coastal sandy soil was potential land for the expansion of agricultural areas although it is dominated by the sand fraction. Limited soil chemical properties can be added from organic and inorganic fertilizers. Soil irrigation can be designed with various irrigation techniques. The combined treatment of organic waste management with nutrient amelioration techniques and irrigation techniques is a combination of environmentally friendly coastal soils.

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References

[1] Ding Y, Liu Y-X, Wu W-X, Shi D-Z, Yang M, Zhong ZK. Evaluation of biochar effects on nitrogen retention and leaching in multi-layered soil columns. Water, Air & Soil Pollution. An International Journal of Environmental Pollution. 2010;213(1):47–55.

https://doi.org/10.1007/s11270-010-0366-4

[2] Herlambang S, Purwono BS, Sutiono HT, Rina SN. Application of coconut biochar and organic materials to improve soil environmental. IOP Conf. Ser.: Earth Environ. Sci. 2019;347: 353. https://doi.org/10.1088/1755-1315/347/1/012055

[3] Herlambang S, Purwono BS, Muamar G, Astrid WA. Biochar making machines design for increasing food security. Proceeding on Engineering and Science Series (ESS).Vol 1 No 1 (2020): 1-10. LPPM UPN 'Veteran' Yogyakarta Conference Series 2020. DOI: https://doi.org/10.31098/ess.v1i1.88.

[4] Oliveira LS, Oliveira DS, Bezerra BS, Pereira BS, Battistelle RAG. Environmental analysis of organic waste treatment focusing on composting scenarios. Journal of Cleaner Production. 2017;155:229–237. https://doi.org/10.1016/j.jclepro.2016.08.093

[5] Finney DM, White CM, Kaye FP. Biomass production and carbon/nitrogen ratio influence ecosystem services from cover crop mixtures. Agronomy Journal. 2016;108(1):39-52. https://doi.org/10.2134/agronj15.0182

[6] Chen Z, Huoyan W, Xiaowei L, Xinlin Z, Dianjun L, Jianmin Z, Chang ZL. Changes in soil microbial community and organic carbon fractions under short-term straw return in a rice–wheat cropping system. Soil and Tillage Research. 2017;165:121–127. https://doi.org/10.1016/j.still.2016.07.018

[7] Muhammad S, Yakov K, Muhammad S, Felix H, Vladimir Z, Amit Kr & Evgenia B. Microbial decomposition of soil organic matter is mediated by quality and quantity of crop residues: Mechanisms and thresholds. Biology and Fertility of Soils Journal. 2017;53(3):287–301. https://doi.org/10.1007/s00374-016-1174-9

[8] Binh QA, Kajitvichyanukul P. Adsorption mechanism of dichlorvos onto coconut fibre biochar: The significant dependence of H-bonding and the pore-filling mechanism. Water Science and Technology Journal. 2019;79(5):866–876. https://doi.org/10.2166/wst.2018.529

[9] Hua YJ, Ren KXU, Ning W, Jiu YLI. Amendment of acid soils with crop residues and biochars. Pedosphere Journal. Pedosphere. Vol 21, Issue 3, June 2011, Pages 302-308. https://doi.org/10.1016/S1002-0160(11)60130-6

[10] Smith P. Soil carbon sequestration and biochar as negative emission technologies. Global Change Biology. 2016;22(3):1315–1324. https://doi.org/10.1111/gcb.13178

[11] Xia L, Lam SK, Chen D, Wang J, Tang Q, Yan X. Can knowledge-based N management produce more staple grain with lower greenhouse gas emission and reactive nitrogen pollution? A meta-analysis. Global Change Biology. 2017;23(5):1917–1925. https://doi.org/10.1111/gcb.13455

[12] Haipeng W, Cui L, Guangming Z, Jie L, Jin C, Jijun X, Juan D, Xiaodong L, Junfeng L,Ming C, Lunhui L, Liang H & Jia W. The interactions of composting and biochar and their implications for soil amendment and pollution remediation: A review. Critical Reviews in Biotechnology. 2017;37(6):754–764. https://doi.org/10.1080/07388551.2016.1232696

[13] Pengfei L, Jianwei L, Yang Wang, Sen W, Saddam HTR, Rihuan C, Xiaokun L. Nitrogen losses, use efficiency, and productivity of early rice under controlled-release urea. Agriculture, Ecosystems & Environment. 2018;251:78–87. https://doi.org/10.1016/j.agee.2017.09.020

[14] Herlambang S, Maas A, Utami SNH, Widada J. The dynamics of C and N by combination of composted fresh organic waste as soil amendment in the soil thickness at pineapple plantation, Lampung Indonesia. International Journal on Advanced Science, Engineering and Information Technology. 2019;9(4):1352–1356.

[15] Hagemann N, Kammann CI, Schmidt H-P, Kappler A, Behrens S. Nitrate capture and slow release in biochar amended compost and soil. PLOS ONE. 2017;12(2):78-87. https://doi.org/10.1371/journal.pone.0171214

[16] Jing W, Chen T, Guodong Y, Dongxue B, Hailong W, Lijuan Z & Benny KGT. Pyrolysis temperature-dependent changes in the characteristics of biochar-borne dissolved organic matter and its copper binding properties. Bulletin of Environmental Contamination and Toxicology. 2019;103(1):169–174. https://doi.org/10.1007/s00128-018-2392-7

[17] Herlambang S, Santoso PB, Sutiono HT, Susanti RN. The application of biochar and organic matter for proper cultivation on paddy soil. Journal of Degrade and Mining Lands Management. 2020;7(3):2133–2137. https://doi.org/10.15243/jdmlm.2020.073.2133

[18] Yuan J-H, Xu R-K, Wang N, Li J-Y. Amendment of acid soils with crop residues and biochars. Pedosphere. 2011;21(3):302–308. https://doi.org/10.1016/S1002-0160(11)60130-6

[19] Singh BP, Cowie AL, Smernik RJ. Biochar carbon stability in a clayey soil as a function of feedstock and pyrolysis temperature. Journal Enviromental Science and Technology. 2012;46(21):11770–11778. https://doi.org/10.1021/es302545b

[20] Nithyapriya S, 1 , Sundaram L, Sayyed, RZ , Reddy M S , Daniel JD, Hesham AE , Ni Luh Suriani NL and Herlambang S. Production, purification, and characterization of bacillibactin siderophore of *Bacillus subtilis* and its application for improvement in plant growth and oil content in sesame. Sustainability. 2021;13(10): 2-18 . https://doi.org/10.3390/su13105394

[21] Jonathan SJ, Mark A. Bradford. Pathways of mineral‐associated soil organic matter formation: Integrating the role of plant carbon source, chemistry, and point of entry. Journal Global Change Biology. 2019; 25 (1); 12-24. https://doi.org/10.1111/gcb.14482

[22] Yehong X, Zengming C, Sébastien FWW, Jiafa L, Jianling F, Weixin D. Dominant effects of organic carbon chemistry on decomposition dynamics of crop residues in a mollisol. Soil Biology and Biochemistry. 2017;115:221–232. https://doi.org/10.1016/j.soilbio.2017.08.029

[23] Tesfaye MA, Bravo F, Ruiz-Peinado R, Pando V, Bravo-Oviedo A. Impact of changes in land use, species and elevation on soil organic carbon and total nitrogen in Ethiopian Central Highlands. Geoderma. 2016;261:70–79. https://doi.org/10.1016/j.geoderma.2015.06.022

[24] Chenghao L, Fan L, Liming S, Pinjing H. Application of eco-compatible biochar in anaerobic digestion to relieve acid stress and promote the selective colonization of functional microbes. Journal Water Research (2015) 68(1):710-718. https://doi: 10.1016/j.watres.2014.10.052.

[25] JingjingD, Yuyan Z, MingxiangQ, YutingY, Kang F, Bin HHZ, Mingbao Wei, Chuang M. Effects of biochar on the microbial activity and community structure during sewage sludge composting. Bioresource Technology. 2019;272:171–179. https://doi.org/10.1016/j.biortech.2018.10.020

[26] Frouz J. Effects of soil macro- and mesofauna on litter decomposition and soil organic matter stabilization. Geoderma. 2018;332:161–172. https://doi.org/10.1016/j.geoderma.2017.08.039

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