Ulin - J Hut Trop Vol 9 (1): 108-118
Maret 2025
pISSN 2599 1205, eISSN 2599 1183
DOI: http://dx.doi.org/10.32522/ujht.v9i1.16916

Biochar and liquid fertilizer differently affect bulk density of spodosols and ultisols

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Artikel diterima :30 November 2024 Revisi diterima 10 Januari 2025

ABSTRACT

Ultisol and spodosol are soils with contrasting properties. Ultisols generally have a fine texture rich in clay fraction, while spodosols are coarse-textured soils with dominant sand fraction. Soil bulk density, which can limit fertility, is an important characteristic that needs improvement in degraded soils, including ultisols and spodosols. This study aimed to determine how the application of biochar combined with liquid fertilizer affects the bulk density of ultisols and spodosols. The study was designed using a randomized complete block design with biochar rate application consisting of 6 levels: 0%v, 2%v, 5%v, 10%v, 25%v and 100%v as the research factor, and biochar soaking duration in liquid organic fertilizer consisting of 4 levels: without soaking (0 hours) and soaking using liquid organic fertilizer for 1, 12 and 24 hours as the research block. All these treatments were applied to spodosol and ultisol growth media, resulting in 24 observations for each soil type. Soil bulk density sampling was conducted at three different times with varying media moisture content condition: morning, afternoon, and evening after watering that is done once a day in the evening. Overall, both soil types, ultisols and spodosols, showed different responses to biochar treatments. However, neither biochar immersion duration nor sampling moisture levels significantly affected soil bulk density

Key words: Biochar, Bulk density, Liquid fertilizer, Spodosols, Ultisols

ABSTRAK

Ultisol dan spodosol adalah tanah dengan sifat yang kontras. Ultisol pada umumnya bertekstur halus kaya fraksi liat sementara spodosol merupakan tanah bertekstur kasar dengan fraksi pasir dominan. Kerapatan lindak tanah, yang dapat membatasi kesuburan, merupakan sifat penting yang perlu diperbaiki pada tanah-tanah terdegradasi termasuk ultisols dan spodosols. Penelitian ini bertujuan untuk menentukan bagaimana penerapan biochar yang dikombinasikan dengan pupuk cair mempengaruhi kerapatan lindak tanah ultisols dan spodosols. Penelitian dirancang dengan menggunakan rancangan acak lengkap blok dengan aplikasi dosis biochar terdiri dari 6 taraf: 0%v, 2%v, 5%v, 10%v, 25%v dan 100%v sebagai faktor penelitian dan lama perendaman biochar dalam pupuk cair terdiri dari 4 taraf: tanpa perendaman (0 jam) dan perendaman menggunakan pupuk cair selama 1, 12 dan 24 jam sebagai kelompok penelitian. Semua perlakuan ini diterapkan pada media pertumbuhan spodosols dan ultisols sehingga jumlah observasi adalah 24 untuk setiap jenis tanah. Pengambilan sampel kerapatan lindak tanah dilakukan pada tiga waktu dengan kondisi kelembapan media yang berbeda, yaitu pagi, siang, dan sore hari setelah penyiraman yang dilakukan sekali sehari di sore hari. Secara keseluruhan, kedua jenis tanah tersebut baik ultisols maupun spodosols memberikan respon yang berbeda terhadap perlakuan biochar. Namun, baik durasi perendaman biochar maupun tingkat kelembapan saat pengambilan sampel tidak berpengaruh secara signifikan terhadap kerapatan lindak tanah.

Kata kunci: Biochar, Bulk density, Pupuk organik cair, Spodosols, Ultisols.

INTRODUCTION

Ultisols and spodosols are two very different soil orders in terms of texture (Putri, 2023; Hall and Thompson, 2022). Ultisols indicate clay accumulation in the subsurface argillic horizon (Lowe, 2019;) and are the most abundant mineral soils in Southeast Asia (Journey *et al*., 2015). Spodosols are sandy soils with two main horizons – the top albic horizon and the spodic horizon within two meters depth (Suwardi et al., 2022; Ho *et al*., 2019; Prasetyo, 2016). The albic horizon forms via leaching of organic acids leaving quartz grains (Valerio *et al*., 2016; Arbogast, 2000). Spodosols have light-colored albic and spodic horizons with high organic matter and iron, but are less suitable for agriculture due to nutrient deficiency, acidity, and degradation susceptibility (Oliveira *et al*., 2010; Tanner, 2023). In Indonesia, spodosols occur in wet climates covering 2.16 million hectares (Hartati *et al*., (2021).

Soil bulk density (BD) is defined as the dry mass of soil per unit volume, including pore spaces. This property significantly influences various physical and chemical characteristics of the soil. High density reduces fecundity and productivity of otherwise depleted ultisol and other soil types. They also lead to the conclusion that the increase in BD contributes to the decrease of porosity and pore space which in turn reduces the chances of root development and microbial respiration. High BD values are associated with compaction which impairs soil porosity and root development in clayey ultisols (McWilliams *et al*., 2007; Lampurlanés and Cantero-Martínez, 2003; Endriani and Listyarini, 2023). For the coarse spodosols the high BD means that there are large pores through which drainage occurs but these soils have low water retention capability (Adriano and Weber, 2001). The values of ideal bulk density also differ according to the texts of the soil. For clayey ultisols, the lower values are preferred than for sandy spodosols. For plants, the ideal bulk density values are typically recommended to be less than 1.7 g/cm³ for sandy soils and 1.4 g/cm³ for clay soils, and less than 1.6 g/cm³ for silty soils. Generally, the bulk density value for sandy soils is around 1.6 g/cm³. So, the bulk density values above these numbers can hinder root development and, therefore, reduce plant yield (Sato *et al*., 2015; I. B. *et al.*, 2021; Amhakhian *et al*., 2021). Bulk density has been shown to decrease with adding of organic matter as it helps in its aggregation as indicated (Bizuhoraho et al. 2018, Tobiašová *et al.,* 2013). Biochar application enhances the organic matter content, thus an improvement in soil fertility and plant growth (Aydın *et al.*, 2020; Brozović *et al*., 2021; Schmidt, *et al.,* 2017; Liu *et al*., 2022a, b).

Generally, nutrient limited biochar should be applied together with fertilizer to obtain the maximum results (Qin, 2023). But on the same note, biochar has a high cation exchange capacity (CEC) which aids in nutrient retention (Alburquerque *et al*., 2013) it can actively bind nutrient cations for plant use. Martinsen *et al.* (2015) reported that biochar addition can increase soil pH from initially low levels, with a stronger effect on more acidic soils. This pH increase occurs because biochar typically has a higher pH, functioning as an acid neutralization agent (Marwanto *et al.,* 2021). The study by Liu *et al*. (2015) also indicated that biochar can increase soil CEC, especially at higher pH levels, demonstrating that the interaction between pH and CEC is crucial in determining the effectiveness of biochar as a soil amendment. These works make it apparent that the application of biochar keeps the soil fertile. This, however, may be enhanced by use of liquid fertilizer in order to increase the efficiency of the biochar. The use of biochar in form of slurry with liquid fertilizers has some benefits which is not the same as the dry blending of biochar with solid granular fertilizers. These form of biochar known as biochar slurries ease the application since they can be spread out over the soil uniformly and can penetrate through out the whole matrix of the soil (Gurwick *et al.,* 2013). When in form of fine particles, dry biochar aggregates with the fertilizer granules hence restricting direct contact with the soil. The application of slurry makes the biochar to be well mixed so as to maximize the biochar surface area to come into contact with the soil environment (Kammann *et al.,* 2015). This improves the effectiveness of CEC, water holding capacity, nutrient retention and other properties of biochar. Furthermore, application of biochar slurries do not lead to dust formation as it is the case with the dry biochar that reduces the aspects of safety. Based on these findings, it can be concluded that the slurry is better to prepare a liquid mixture with biochar and liquid fertilizer will have better coverage of soil, as well as get better use of the properties of biochar.

Charcoal commonly found in the market is generally made from laban wood (*Vitex sp.*) (Kurniawan *et al.,* 2017), so it is expected that if developed as biochar, it will be easier to obtain. The liquid fertilizer used in this work was derived from anaerobic fermentation of vegetable wastes from the local traditional market. Liquid organic fertilizer from vegetable waste contains 0.63%-1.27% organic-C, 0.23%-0.45% Nitrogen, 0.03%-0.08% Phosphorus, and 0.34%-0.41% Potassium (Afiyah *et al.,* 2021).

The benefits of biochar are owed to tremendous, long-term nutrient sequestration, and functioning as a soil conditioner, not as a plant nutrient provider. Biochar advantages are connected with its capability, duration, and effectiveness in nutrient capture and as a soil improver compared to a soil nutrient booster. It contains essential components as those of physical, chemical and biological fertility that are sourced naturally. Biochar use turns out to have many advantages, such as improving fertility of soil, yield of plant and carbon stock in the degraded area and finally, carbon lasts centuries to millenniums in the soil. This work was proceeded with the objectives of evaluating the impacts of the biochar application rates (0%, 2%, 5%, 10%, 25% and 100%) and liquid organic fertilizer soaking time (0, 1, 12 and 24 hours) on the BD of ultisols and spodosols growing media in polybags.

pISSN 2599 1205, eISSN 2599 1183
DOI: http://dx.doi.org/10.32522/ujht.v9i1.16916

MATERIALS AND METHOD

Study area

Growth media preparation, including arrangement and tests, was carried out at The Silviculture Laboratory, Soil Science and Forest Nutrition Research Group, Faculty of Forestry, Mulawarman University, Samarinda, Indonesia. This research was part of nursery seedling research on *Anthocepalus cadamba* conducted before preparing the planting media. The research period was three months of observation, including preparation of materials and equipment, taking spodosols and ultisols growth media samples, making biochar and liquid organic fertilizer (LOF), soaking the biochar using LOF, testing samples in the laboratory, data collection, processing, and analysis.

Procedure

Experimental design

The research design was a randomized complete block design (RCBD) with biochar application set as the research factor and length of biochar soaking in LOF set as the research block. The biochar treatments (B) consisted of 6 levels: 0%v, 2%v, 5%v, 10%v, 25%v and 100%v (B0, B2, B5, B10, B25, and B100). As for the soaking duration blocks (P) in LOF it consisted of 4 levels: without soaking (0 hours) and soaking using liquid organic fertilizer for 1, 12 and 24 hours (P0, P1, P12, and P24). All of these treatments were applied to Spodosols and Ultisols growth media then tested separately so that the number of observations is 24 for each soil type

To determine the effect of media moisture content on the bulk density value of the growth media, a Completely Randomized Design was used with different relative time ranges for taking intact soil samples after watering as treatments. Sampling times were in the morning (W1) representing the media moisture content condition 12 hours after watering, late afternoon before watering (W2) representing the media moisture content condition 24 hours after watering and late afternoon one hour after watering (W3).

Media preparation

The spodosols soil used for the planting media in this research was collected from nearby degraded spodosols soil, 40 km northeast of Samarinda, precisely in Muara Badak District, Kutai Kartanegara Regency, East Kalimantan, while the ultisols originated from Bukuan Village, Palaran District, Samarinda City, East Kalimantan. The selection of these two soils was more due to the very different textures between the two. Spodosols has a coarse texture while ultisols has a fine texture.

The biochar used was produced based on the retort biochar production method (Figure 1). The raw materials for the biochar production were wood from the stem and branches of *Vitex pinnata* waste derived from adjacent plantations. The raw materials were loaded into a kiln drum, then the kiln was closed tightly to avoid air penetration, and heated with external fuel, in this case liquid natural gas, until gases were released from the heated materials. Thereafter, the supply of external fuel was terminated, and further heating of the feedstock relied solely on the gases released by the materials. Once the produced gases were exhausted, the biochar production was completed. Peak production temperatures were about 400-500°C for a period of 30 minutes to one hour.

The LOF used in this work was derived from anaerobic fermentation of vegetable wastes from the local traditional market. The vegetable scraps were chopped into approximately one cm pieces and put into a gunny sack which was then placed in a composter tube. Sugar cane syrup, water and EM-4 (effective microorganism-4) bioactivator solution were then added. The ratio of water, EM-4 and sugar cane syrup was 15 liters:1 liter:1/2 kg for every 5 kg of waste. The mixture was then stirred until evenly distributed and the mouth of the sack was tied with raffia twine before finally closing the composter tube. The mixture was left to ferment for approximately 15 days before being harvested for use as LOF. The sack was opened daily to prevent the temperature of the mixture from rising too high which would disrupt the fermentation process by measuring the temperature of the mixture daily. The temperature of the mixture was kept below 60°C.

Biochar soaking treatment in LOF

Before soaking in fertilizer solution, the biochar was ground into powder to pass through a 2-mm sieve and placed in bags. The bags containing biochar were put into containers used for soaking then doused with fertilizer solution until the bags containing biochar were fully submerged. Biochar soaking was carried out based on soaking duration (0 hours, 1 hour, 12 hours and 24 hours). After being soaked for the predetermined time, the bags containing biochar were drained until the liquid organic fertilizer no longer dripped, the biochar was left overnight until ready to be applied to the growing media

Biochar application to growing media

Before being applied to each growing media (spodosols and ultisols) the biochar soaked in liquid organic fertilizer with different soaking durations was measured for volume according to the predetermined dosages (0%, 2%, 5%, 10%, 25% and 100%). The volume measurements of the biochar doses were carried out in 3 replications for each treatment for each growing media. The biochar doses were calculated based on the volume of the polybags used which were 10 cm in diameter and 15 cm in height. Furthermore, the biochar was mixed thoroughly with the growing media, put into polybags and incubated for 1 week before samples were taken for laboratory testing. During the incubation period the moisture content of the growing media was maintained by watering daily until the growing media appeared wet.

Data collection

Sampling for bulk density (BD) testing was carried out using sampling rings at three relative times to watering: morning representing soil moisture content after 12 hours of watering (W1), late afternoon before watering representing moisture content after 24 hours of watering (W2) and late afternoon representing moisture content 1 hour after watering (W3). So at each sampling time there were 6 intact soil samples from each biochar dosage treatment tested in each soaking block. BD testing followed the gravimetric method (Ge et al., 2020). Samples for C testing were taken from each treatment from each soaking block, that is three samples from each biochar dosage treatment which were then composited for C content testing using the Walkey and Black method (Du *et al*., 2018)

Data analysis

Data collected in this research were tested and adjusted to normal distribution (Lawal, 2014) prior to analysis of variance (de Mendiburu, 2020) and mean different tests (Lawal, 2014); de Mendiburu, 2020) with the help of SPSS software. To see the effect of real differences in variables due to treatment and interaction, the least significance diferrence (LSD) test (de Mendiburu, 2020)

RESULTS AND DISCUSSION

Soil organic matter content

The content of organic matter in the soil can be determined by analyzing the C-organic content in soil samples. One method capable of oxidizing on average up to 70% of organic matter is the Walkley and Black method. From the percentage of C-organic matter content can be known the organic matter content of the soil by multiplying the percentage of C-organic by 100/58 (Soil Research Institute, 2005). Based on the criteria for assessing soil chemical properties compiled by the Soil Research Center (1995) that the results of testing C-organic levels of spodosols and ultisols planting medium with the application of biochar concentrations at various treatment levels showed very low to high status. The growing medium criteria for high C-organic values are achieved when 100% biochar application (Table 1).

Table 1. C-organic content (%) of spodosols and ultisols as influenced by rate of biochar application

Rate of biochar	Spodosols			Ultisols		
(%v)	Av.	Std.	Status*)	Av.	Std.	Status*)
0	0.56a	0.00	VL	1.11a	0.00	L
2	0.95ab	0.24	VL	1.32ab	0.27	L
5	0.97ab	0.26	VL	1.28a	0.28	L
10	1.04b	0.22	L	1.28a	0.20	L
25	1.45bc	0.53	L	1.99b	1.00	L
100	4.57c	0.71	H	4.57c	0.71	H

**) Soil Research Center (1995); VL: verry low, L: low, H: high; mean values followed by different letters are significant at $p < 0.05$*

Table 1. showed that biochar application increased soil organic matter (SOM) availability in both spodosols and ultisols, although the effect was more pronounced in spodosols (Gurwick *et al.*, 2013). In spodosols, SOM availability sharply increased from 0.56% in the control to 4.57% in the 100% biochar treatment. In ultisols, the increase was lower, from 1.11% to 4.57%, with no significant differences up to 25% biochar application (Taisa *et al*., 2019). This indicates higher biochar rates are needed in ultisols to substantially increase SOM. However, biochar still improved SOM availability in both soil types.

Therefore, based on the results for the biochar content in spodosols and ultisols the increasing availability of SOM is observed, except that in case

pISSN 2599 1205, eISSN 2599 1183
DOI: http://dx.doi.org/10.32522/ujht.v9i1.16916

with spodosols which have the initially lower level of SOM. Higher application rates were needed in Ultisols probably because of adsorption of native SOM within the mineral surfaces on clay fraction. Still, biochar enhanced SOM across rates in both soils and thus has the vaunted ability to sequester and improve soil fertility. Future research can site specific works to fine tune biochar uses in different types of soils and environments.

Some of the recent studies have revealed that biochar application and liquid organic fertilizer enhance SOM content. Biochar is an effective carbon source derived from the pyrolytic process of organic residuals in which its use enhances soil quality and promotes carbon storage (Singh *et al*. (2022). Incorporation of biochar especially when mixed with compost or liquid fertilizer has been seen to increase microbial population and growth rates and thus improving soil nutrient conversion and crop productivity (Trupiano *et al.*, 2017) due to the highly porous and negatively charged surface of biochar it may fix the organic matter and nutrient better than soil alone (Sarma, 2024). The studies have not fully matured, and probably successful field trials employing biochar, compost and other organic manure, for the improvement of soil organic nutrients and health care without reliance on chemical manure and nutrients seem possible. Subsequent research has to be carried out in order to ascertain the right rates and interactions under various conditions.

The potential of enhancing organic carbon by biochar is described to be more significant in the coarse-textured soils, for illustration, sands rather than under the fine-textured soils, such as clays (Singh *et al*., 2022). One of the reason is because coarse soils contain lower levels of native soil organic matter and therefore, biochar contributes a high percentage of the total inherent organic carbon (Akingbola *et al*., 2020). Also, with clay particles, there is the tendency for organic matters to be coated and compacted hence held in a state that cannot be decomposed by microbes. As earlier indicated, sandy soils have no means of doing this. Biochar probably has a stronger association with mineral phases in clayey soils than the provision of freestanding stable C (Yang *et al*. (2021). Moreover, lesser aeration as well as water holding capacity in clays entails that microbial and plant root operations that sequester biochar into stable soils are limited (Menesi, 2023). Adjusting application rates and feedstock for the resultant biochar with relation to the desired soil textures can try to improve on the sequestration of carbon and the fertility of the soils.

Yang *et al*. (2021). researched the physical and chemical effect of the biochar on the stock and quality of the SOC (soil organic carbon) in an ultisol. Biochars were added at rates of 0, 5, 10, and 20 ton/ha to acidic Sandy clay loam soil and SOC was determined after two years. The researchers also observed that total SOC, particulate organic carbon and mineral-associated organic carbon was boosted by the application of biochar. In addition, because of biochar, SOC had a shift in chemistry constituents, including a rise in aryl C and acidic functional groups. Biochar perhaps influenced reactive soil mineral surfaces by forming stable organo-mineral complexes. Using these findings, the authors opined that the use of biochar can enhance the SOC stocks and its stability in the tropically derived ultisols and added that long-term field experiment is required. This work outlines the prospect of biochar in increasing soil fertility and the rate of carbon stock in relation to soil from Indonesia.

Effect of different concentrations of biochar on bulk density of spodosols and ultisols soil planting medium

Bulk density (BD) is a representation of soil density in its natural state. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g cm^{-3}. Soils with a high percentage of pore space will have low BD and vice versa so bulk density is an indicator of low soil porosity and soil compaction but cannot always be used as a measurement of how fast water moves in the soil or soil permeability. To estimate soil permeability requires knowledge of pore types based on their size (macro, meso or micro) as well as their continuity, so to suspect soil permeability requires knowledge of soil texture and structure. Sandy soils have a high BD of 1.8 g cm^{-3} with a low porosity of 30% and are highly permeable because they are dominated by continuous macro-sized pores. In contrast, clay soil has a low BD of 1.2-1.3 g cm^{-3} with a high porosity of 50% but low permeability because it is dominated by micro-size pores and is often discontinuous

High BD is a sign of poorly permeable structure or low permeability of the soil mass and also comes with high compaction of soil. It may cause restriction to root growth, and also poor air and water movement through the layer of soil. Shallow plant root development results from this condition, which negatively affects both crop yield and the amount of vegetation available to protect the soil from erosion. Compaction primarily reduces water infiltration into the soil and consequently leads to increased surface runoff and erosion, particularly on sloping land or waterlogged soil areas in lowlands. Normally, to some extent soil compactions to prohibit the flow of water in the soil profile is useful under conditions of drought, while under the humid condition's compaction reduces yield.

The use of biochar as an ameliorant for the improvement of soil properties has been widely studied. The response obtained varies greatly, one of which depends on the type of soil (Abdulwahhab & Şeker, 2021). Biochar has a very porous structure, when applied into the soil can affect soil physical properties such as porosity, pore size distribution, Bulk Density, soil capacity to hold water, moisture content available to plants, infiltration, hydraulic conductivity and aggregation

Table 2. Bulk density (g cm^{-3}) of spodosols and ultisols as influenced by rate of biochar application

Rate of biochar (%v)	Spodosols		Ultisols	
	Av.	**SD**	**Av.**	**Std.**
0	1.57^c	0.06	1.39^b	0.06
2	1.55^c	0.07	1.40^b	0.10
5	1.46^b	0.10	1.37^b	0.08
10	1.47^b	0.07	1.35^b	0.05
25	1.39^b	0.08	1.35^b	0.07
100	0.27^a	0.02	0.27^a	0.02

Note: mean values followed by different letters are significant at $p < 0.05$

Table 2 shows that based on its BD that the Spodosols planting media (0% biochar) used in this study is classified as ideal (BD<1.6 g cm^{-3}) for root development while the ultisols planting media both pure (0% biochar) and mixed with biochar (2-25% biochar) are classified as not ideal (BD >1.1 g cm^{-3}) for root development. In general, BD value decreases as the concentration of biochar in the growing medium increases (Table 2). However, each planting media responds differently to biochar, where for spodosols planting media, 5% biochar has given a significant difference. The mixture of biochar in ultisols growing media did not provide a significant difference. The response of soil to biochar is highly dependent on the complex interaction mechanism between biochar and soil (Solaiman *et al.,* 2019). Biochar is most effectively applied one of them to soils with a sandy texture (Abdulwahhab & Şeker, 2021) such as Spodosols in this study. Biochar application as much as 5% in spodosols planting media can reduce BD by 0.11 g cm^{-3} and increase soil porosity by 4.15% while in ultisols planting media biochar application up to 25% only decreases BD by 0.04 g cm^{-3} and increases soil porosity by 1.52%.

Effects of different biochar immersion time period in liquid organic fertilizer on bulk density of spodosols and ultisols planting medium

There are two perspective in concluding the effect of biochar on soil physical properties, namely: 1) the addition of porous biochar will directly affects soil physical properties such as increasing porosity, soil capacity to hold water, and reducing soil BD (Chaves *et al*., 2018); and 2) the application of biochar indirectly supports the process of soil structure formation by creating a good and comfortable habitat for microorganisms and encouraging root development in the rhizosphere area (Yan *et a*l., 2022)

Soaking biochar with LOF is intended not only to enrich the nutrition of the growing media as well as a source of microorganism feed which is expected to help speed up the soil aggregation process. The difference in biochar soaking time period applied to spodosols and ultisols planting media did not have a significant effect on BD in both growing medium

pISSN 2599 1205, eISSN 2599 1183
DOI: http://dx.doi.org/10.32522/ujht.v9i1.16916

Tabel 3. Bulk density (g cm^{-3}) of spodosols and ultisols as influenced by by time duration soaking biochar in liquid organic fertilizer

Soaking time duration (hr)	Spodosols		Ultisols	
	Av.	**Std.**	**Av.**	**Std.**
0	1.27[a]	0.23	1.19 [a]	0.21
1	1.33 [a]	0.25	1.18 [a]	0.21
12	1.25 [a]	0.23	1.20 [a]	0.21
24	1.29 [a]	0.24	1.18 [a]	0.22

Note: mean values followed by different letters are significant at $p < 0.05$

In sandy soils, the application of ameliorant biochar significantly increases the pores of available water and decreases the pores of rapid drainage after a period of one year (Pham et al., 2021; Carvalho *et al.,* 2020; Devereux *et al.,* 2012; Li *et al.,* 2021). The addition of organics including liquid organic fertilizers in addition to lowering BD, increasing water retention also increases aggregate stability. A minimum of 2% soil organic matter content is required to maintain aggregate stability. There are three main binders in the process of formation and stabilization of soil aggregates. Binders of depleted organic matter consisting of glucose components (mono- and polysaccharides) that will be overhauled by soil microorganisms within a few weeks and after that their role in soil aggregation ends. Polysaccharides among them are derived from plant residues and are rapidly overhauled by microorganisms. The process of formation and stabilization of aggregates is determined by the type of organic matter. Introducing glucose into the soil produces soil aggregates that are able to last for 2-3 weeks whereas the stabilization of aggregates is controlled by humus (Шеин & Milanovskiy, 2014).

The incubation period in three weeks is thought to be insufficient to stabilize the soil aggregate. Liquid organic fertilizer derived from organic waste contains 0.32% organic-C, 1.54% total N, 0.00771% P, 0.14831% K, and 155.97 ppm Ca and 268.00 ppm Mg (Suyanto *et.al*, 202). If viewed LOF raw materials come from vegetable waste, it is suspected that the organic material is a type of polysaccharide which in the aggregate formation process plays a very short role if there is aggregate formation, even the condition is not stable. It takes quite a long time to figure out the role of LOF in soil aggregation. Syahrinudin et al. (2019) found that soaking biochar with LOF increases nutrient levels, especially N in spodosols planting media.

Effect of sampling time on bulk density of spodosols and ultisols planting medium after watering

Various previous studies have shown that biochar has the potential to encourage increased water retention in sandy soils that have low water capacity values available to plants (Sutono and Nurida 2012; Carvalho *et al*. 2020; Abdulwahhab and Şeker, 2021). Conversely, several studies also inform the positive influence of biochar on soil physical properties such as aggregation, porosity, and water retention in clay-textured soils (Libutti *et al.,* 2021). The ability of biochar to physically retain water results in water not quickly disappearing from the root zone as has been proven in various previous studies (Carvalho *et al*. (2020). Testing the bulk density of the planting media in the morning, evening before watering and evening after watering is intended to determine the effect of the humidity of the planting media on the bulk density of the planting media concerned.

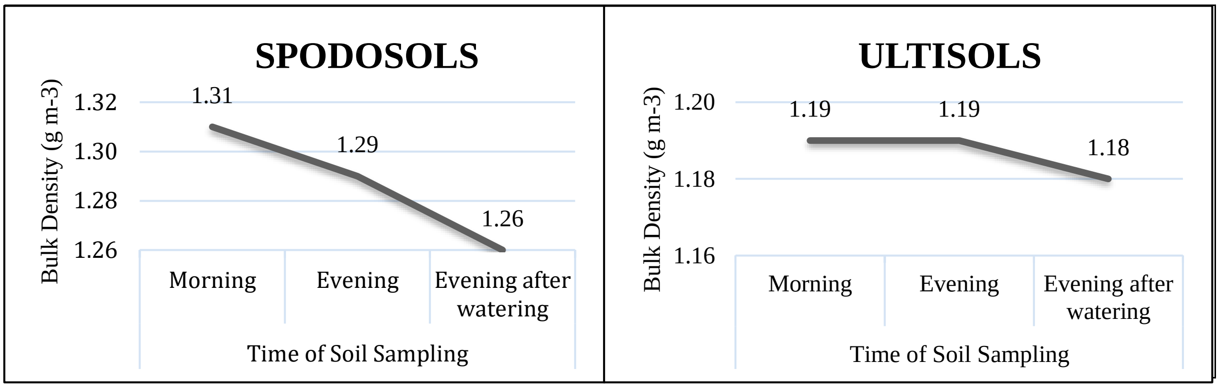

Figure 1. The effect of sampling time treatment on bulk density values in spodosols and ultisols growing medium; The points on the curve represent the mean observation values while the vertical lines represent their standard deviations; Mean values with the same notation are not significantly different at α=0.05

Sampling at different times for the Bulk density test is carried out in the morning, evening and evening after watering. This is done to see if there is a significant difference in the value of bulk density and soil sampling time

Soil moisture content can modify several physical-mechanical properties of soil such as: consistency, plasticity, compactness, bulk density, porosity and infiltration rate (Li, 2024). Although there are differences for each soil type, the BD of mollisols soil increases with the decrease in groundwater content (Zhang *et al*. 2019). However, Figure 1 shows that there was no significant difference in BD values at all sampling times representing differences in the soil moisture of planting medium. Similar results were also stated by Torres (2024).

In general, BD decreased with increasing concentration of biochar in the planting media of spodosols and ultisols. In spodosols planting media, the application of 5% biochar gave a significant difference in soil BD as compared to control. On ultisols this is not the case. Mixing biochar responds to changes in BD. There was no significant effect of the immersion time of biochar in liquid organic fertilizer on BD of spodosols and ultisols planting medium. There was no significant difference in BD of Spodosols and Ultisols soil planting medium along the soil moisture

ACKNOWLEDGMENTS

The authors would like to thank to the Ministry of Research, Technology and Higher Education of the Republic of Indonesia for funding the research.

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