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The effects of application of biochar from oil palm empty fruit bunches on chemical properties of ultisols and the growth of cacao seedlings

Abstract. It is necessary to redevelop cacao commodity due to the decrease of cacao planting areas in Indonesia since the last decade. One of the ways is by providing a growing medium to produce cacao seedlings with good quality, such as by adding ameliorant i.e., oil palm empty fruit bunch (OPEFB) biochar to marginal soil of Ultisols. This research aimed to study and obtain the best OPEFB biochar dose to improve the chemical properties of Ultisols and the growth of cacao seedlings. This research was conducted in the Experimental Field of the 3rd Campus Andalas University from August 2021 until February 2022 using a Completely Randomized Design (CRD) with 5 treatments of OPEFB biochar (0, 60, 90, 120, 150 tons/ha) and 4 replications, each experimental unit consisted of two plants, so that 40 plants were prepared in total. Data obtained were analyzed using F Distribution Test at 5% and further analyzed using Duncan's New Multiple Range Test (DNMRT) for statistically significant results. The results showed that the application of OPEFB biochar at 120 tons/ha was the best dose to give significant results on the chemical properties of Ultisols (pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium) and several growth variables of cacao seedlings (stem diameter, leaf length, leaf width, shoot dry weight, and shoot-root ratio).

Keywords: Ameliorant · Biochar · Nursery · Oil palm empty fruit bunch · Ultisols

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Introduction

Cacao (*Theobroma cacao* L.) produces cocoa as Indonesia's leading export commodity, and Indonesia is the third largest exporter of cocoa beans in the world. However, this decade the area of cacao plantations in Indonesia tended to decrease, so an effort is needed such as by supplying high-quality cacao seedlings, which require a planting medium with ideal physical, chemical, and biological properties for its growth. But not all regions in Indonesia have an ideal soil type as a planting medium, like Ultisols, which is a marginal soil but can still be utilized if it is treated first.

According to Hardjowigeno (2003), Ultisols are soils that contain low organic matter and the structure is less stable, so it is sensitive to erosion. The nutrient content in Ultisols is generally low because of intensive alkaline leaching. At the same time, the organic matter is low because the decomposition process runs fast and some are carried away by erosion. Prasetyo and Suriadikarta (2006) added that Ultisols have some limitations when used in agriculture due to the unfavorable physical and chemical properties of the soil, such as high soil acidity (an average soil pH < 4.5), high aluminum saturation, poor macronutrient content especially P, K, Ca and Mg and low organic matter content.

Consequently, it is important to improve the properties of Ultisols by adding soil amendments (ameliorant). Ameliorants can be as inorganic or organic materials, like biochar. Handani (2017) revealed that ameliorant (biochar) can increase the Cation Exchange Capacity (CEC) in Inceptisols, which is able to support plant growth. The utilization of biochar can be an option for soil management for restoring and improving the quality of degraded soil fertility or critical agricultural land (Glaser, 2001). According to Lehmann and Joseph (2009), biochar is produced from organic materials burned imperfectly (pyrolysis) or without oxygen at high temperatures. Biological charcoal formed from this combustion will produce activated carbon. The benefits of biochar are having a high affinity for nutrients and being persistent in the soil. These properties can be used to solve problems in Ultisols with a low affinity for macronutrients.

One of the organic materials that can be used as biochar is Oil Palm Empty Fruit Bunch (OPEFB). Mandiri (2012) stated that processing 1 ton of palm oil produces solid waste as empty fruit bunches of 23 % (230 kg). Because of the abundant amount of OPEFB waste and the probability of environmental pollution, it is necessary to utilize OPEFB waste into biochar which can be used for a mixture of planting media as an ameliorant which is useful in improving the quality of the planting media, such as in growing media using Ultisols.

Ismail and Basri (2011) revealed that the addition of biochar to agricultural soil can improve soil structure, retain water and soil from erosion because it has a larger surface area, enrich organic carbon, and increase soil pH. The research of Darmawan and Harjadi (2013) evidence that the application of biochar can overcome the lack of soil organic matter on newly opened paddy fields. Gusmailina et al. (2015) also declare the effect of biochar on tea plantations for 10 years when sprinkled around the tea plants as 100 g each, it turned out to have a high growth effect and increased production by 40% compared to plants that were not sown with biochar.

Specific for biochar from OPEFB, Irwanto (2019) who apply OPEFB biochar to Ultisols at a dose of 25 g/polybag was able to increase the soil pH by 0.15 to 4.94 and a dose of 50 g/polybag increased the soil pH by 0.79 to 5.45. Based on the above framework, the objective of the present research was to study and obtain the best OPEFB biochar dose to improve the chemical properties of Ultisols and the growth of cacao seedlings.

Materials and Methods

This research was carried out on August 2021 until February 2022 at the Experimental Field of the 3rd Campus, Andalas University, Dharmasraya, and analysis of soil chemical properties was carried out at the Laboratory of Tropical Fruit Research Institute, Aripan, Solok, West Sumatra. The materials used were cacao seeds BL 50 clone, Ultisols as planting medium, polybags 35 cm x 15 cm, fertilizer (Urea, TSP, KCl), oil palm empty fruit bunches (obtained from PT. Bina Pratama Sakato Jaya, Kiliran Jao, Sijunjung), paper envelope and label. While the equipment was a biochar maker, hoe, watering can, shovels, tape measure, vernier calipers, buckets, paranet 75%, scale, camera, and stationery.

The present research was arranged based on a Completely Randomized Design (CRD) with Oil Palm Empty Fruit Bunch (OPEFB) biochar dose as a treatment that consisted of 5 levels, i.e.:
P0: 0 ton/ha biochar OPEFB (control);
P1: 60 tons/ha OPEFB biochar (100 g/polybag);
P2: 90 tons/ha OPEFB biochar (150 g/polybag);
P3: 120 tons/ha OPEFB biochar (200 g/polybag);
P4: 150 tons/ha OPEFB biochar (250 g/polybag).
It was repeated four times to obtain 20 experimental units, and each of them consisted of 2 cacao plants in different polybags, so a total of 40 samples.

The research was preceded by cleaning the area and installing a shade that used paranet 75 %. The next step was to make oil palm empty fruit bunches (OPEFB) biochar with a self-designed tool (biochar maker): the OPEFB used are dry and chopped. Coconut shell as fuel which burned immediately covered with a biochar maker. Then, the OPEFB is piled up around the tool at about half of its height and waits until white smoke comes out (± 5 minutes) from the chimney. After that, the OPEFB waste that is being burned is turned upside down until it is evenly burned. After it turns black, it is separated between the biochar and the tool to prevent further combustion. Then doused with water, after cold biochar ready to use.

The planting medium used was Ultisols which is filled in a 35 cm x 15 cm polybag (capacity of 5 kg) plus a dose of OPEFB biochar according to treatment of each polybag, and then cacao seeds (BL 50 clones) were planted there. The distance between experimental units was 30 cm, and each consisted of 2 plants in different polybags spaced out 10 cm. Plant maintenance, namely watering twice a day, replacement of dead seedlings or grow abnormally (until a month after planting), weeding, control of pests and diseases and fertilization was applied a month after planting with a dose of 5 g urea/plant, 5 g TSP/plant and 4 g KCl/plant.

Observation variables: analysis of soil chemical properties (before & after treatments and growing cacao seedlings for 16 weeks), the parameters analyzed were soil pH, organic carbon by Walkey and Black method, total nitrogen by destruction method, available phosphorus by the Bray II method, and exchangeable potassium by the 1 M ammonium acetate washing method pH 7.0 (Soil Research Institute, 2009). Besides that, observations of plant growth variables on cacao seedlings consisted of seedling height (cm), stem diameter (mm), number of leaves, leaf length and width (cm), longest root (cm), shoot and root dry weight (g), as well as shoot root ratio by comparing the shoot dry weight with root dry weight.

The data obtained from observing soil and plant samples were tested using F Distribution Test (ANOVA) at 5 % level and further analyzed using Duncan's New Multiple Range Test (DNMRT) for statistically significant results.

Results and Discussion

Soil Chemical Properties before Treatment OPEFB Biochar. Table 1 shows soil pH of Ultisols used as the planting medium was acid, organic carbon, total nitrogen, and exchangeable potassium was very low, and available phosphorus was low. According to Hardjowigeno (2003), Ultisol is derived from very acidic parent materials and occurs in advanced weathering soils. It also contains low organic matter and the structure is unstable.

Table 1. Several chemical properties of Ultisols before treatment OPEFB Biochar.

Parameters	Value	Criteria*
pH H_2O	4.53	Acidic
C-organic (%)	0.96	Very low
N-total (%)	0.17	Very low
Available-P (ppm)	2.49	Low
Exchangeable potassium (me/100g)	0.06	Very low

*) Source: Soil Research Institute (2009)

Fitriatin et al. (2014) stated that Ultisols problems are acidity soil, low organic matter and low macronutrients. Advanced weathering of Ultisols can form high amounts of hydrous oxide clay Fe & Al and react with P to form hydroxyls which are difficult to dissolve so that P is less available in the soil. The value of N-total in this research was 0,17 % (very low criteria) due to it being associated with the C-organic content (0,96 %) in Ultisols. They have a close connection, low C-organic resulted in low N-total because organic matter is one nitrogen source in the soil (Syahputra et al., 2015).

Exchangeable potassium is also in very low criteria (0.06 me/100g). In line with Mulyani et al. (2010), Ultisols is advanced weathering soil tends to be poor in potassium. Besides that, rainfall influences exchangeable potassium value, where some areas in Indonesia have heavy rainfall, causing high washing cations base that affects low exchangeable potassium and the soil becomes acidic.

The Effects of Application OPEFB Biochar on Several Chemical Properties of Ultisols

Soil pH. The application of OPEFB biochar to Ultisols generates a significant effect on the soil pH. A significantly different effect of OPEFB biochar at 120 tons/ha compared with 0 – 90 tons/ha, while at 150 tons/ha only significantly different with without treatment (Table 2).

Table 2. Ultisols pH after Treatment OPEFB Biochar as planting media in cacao seedlings.

Treatment	pH*	Criteria**
P0: 0 ton/ha	4.60 a	Acidic
P1: 60 tons/ha	5.06 ab	Acidic
P2: 90 tons/ha	5.15 b	Acidic
P3: 120 tons/ha	6.02 c	Slightly acidic
P4: 150 tons/ha	5.77 bc	Slightly acidic
CV = 9.20 %		

*) Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %
**) Source: Soil Research Institute (2009)

Generally, OPEFB biochar is good for Ultisols, it is capable of increasing pH. In line with Nigussie et al. (2012); Putri et al. (2017); and Irwanto (2019) that biochar is the potential to improve soil chemical properties, such as increasing the soil pH. Fadilah (2020) also revealed that biochar at a dose of 60 tons/ha is capable to increase Ultisols pH (3.93 to 4.25) as a planting media in Robusta coffee seedlings.

In this research, soil pH was increased in line with adding biochar doses of up to 120 tons/ha, but it decreased after reaching 150 tons/ha. It is similar to the research results of Handani (2017) that the application of OPEFB biochar in a huge amount causes an increase in pH is not optimal. This suspected because the negative biochar particles will bind cations including H^+ ions as a reason for soil acidity. This is confirmed by Sujana (2014) that biochar particle is negatively charged so highly the ability to bind cations.

Organic Carbon. ANOVA results showed that the application of OPEFB biochar significantly affected Ultisols organic carbon (Table 3).

Table 3. C-organic after treatment OPEFB Biochar as planting media in cacao seedlings.

Treatment	C-organic (%)*	Criteria**
P0: 0 ton/ha	0.89 a	Very low
P1: 60 tons/ha	0.95 a	Very low
P2: 90 tons/ha	1.13 a	Low
P3: 120 tons/ha	1.53 b	Low
P4: 150 tons/ha	2.43 c	Low
CV = 11.16 %		

*) Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %
**) Source: Soil Research Institute (2009)

The effects of biochar from oil palm empty fruit bunch at a dose of 0 – 90 tons/ha were not significantly different from each other, whereas it was significantly different if compared to 120-150 tons/ha. The highest C-organic content (2.43 %) was found in the treatment OPEFB biochar at 150 ton/ha. In this research, the increase of organic carbon is directly proportional to the increase in biochar dose. Similar results with Bella (2020), where the application of biochar at doses of 0, 20, 40, and 60 tons/ha resulted in C-organic content of 0.48 %, 0.75 %, 1.01 %, and 1.31 %, respectively. This happens because of the high carbon organic in biochar. According to Putri et al. (2017), OPEFB biochar has an organic carbon content ranging from 6-30 %. In line with Fadilah (2020) reported that OPEFB biochar has C-organic content of 9.65 % and Wahyuni et al. (2021) that OPEFB biochar contains C-organic by 22 %.

According to Lehmann (2007) biochar is able to bind CO_2 obtained from the incomplete combustion process (pyrolysis) and it is able to retain carbon so that it does not return to the atmosphere. This is in accordance with Widiastuti and Maria (2016) that biochar is resistant in soil because it contains high carbon (C) and is weather resistant so it is stable for decades in the soil. Biochar is better as a soil conditioner than compost because it much longer in storing nutrients to improve the physico-chemical properties of the soil which functions as a carbon storage (Sarwono, 2016).

Total Nitrogen. Table 4 shows the application of OPEFB biochar able to increase N-total content up to 107.14 % in Ultisols and it was significantly different results. Significantly different results were obtained on the treatment of OPEFB biochar at a dose of 120 and 150 tons/ha, i.e., 0.20 % and 0.29 % N-total.

Table 4. N-total after Treatment OPEFB Biochar as planting media in Cacao Seedlings.

Treatment	N-total (%)*	Criteria**
P0: 0 ton/ha	0.14 a	Low
P1: 60 tons/ha	0.14 a	Low
P2: 90 tons/ha	0.14 a	Low
P3: 120 tons/ha	0.20 b	Low
P4: 150 tons/ha	0.29 c	Moderate
CV = 9.25 %		

*) Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %
**) Source: Soil Research Institute (2009)

The increase of N-total in line with the enhancement of C-organic content (Table 3). Sukaryorini et al. (2016) state that increased C-organic enhances the population of microorganisms, followed by the enhancement of N nutrient. An increase in N-total soil was also found by Khasanah et al. (2020), where the application of OPEFB biochar 0.5 kg was able to increase N-total Ultisols to 0.40 %, and the dose of 1 kg increases the total-N content to 0,47 %, in comparison with N-total in Ultisols without treatment of 0.26 %. Fadilah (2020) reported that adding OPEFB biochar on Ultisols at a dose of 60 tons/ha can increase the N-total to 0.19 %.

Herlambang et al. (2021) stated that biochar can increase soil nutrient availability, microbe activity, organic matter, water retention, and retain N element because biochar effectively absorbs NO_3^- and NH_4^+ ions. Putri et al. (2017) revealed that biochar has a high capacity to water retention, so it can maintain N nutrient so not leaching and is available for plant growth. Supported by Fadilah (2020) that the addition of OPEFB to Ultisols can increase the water level to 10 % and increase the index porosity to 4 %.

Available Phosphorus. Treatment of OPEFB biochar results significantly different in available P on every dose of biochar, except at 60 tons/ha, which was not significantly different without treatment (0 ton/ha) and 90 tons/ha (Table 5). In the present research, the application of OPEFB biochar can increase available P by 22.56 % – 275.29 %, and this is in line with the results of Herlambang et al. (2021) that the application of biochar on Ultisols, which is acidic, can increase available P of 4.9 % - 142.9 %. It was also obtained by Sitompul (2020) that gift OPEFB biochar on Ultisols at a dose of 90 tons/ha can increase available P 17,52 ppm (very high criteria). Salawati et al. (2016) added that applying biochar on acidic soil can increase available P content of 277.08 %, with a dose of 15 tons/ha increasing available P content to 47.55 ppm.

Table 5. Available P after treatment OPEFB Biochar as planting media in cacao seedlings.

Treatment	Available P (ppm)*	Criteria**
P0: 0 ton/ha	15.38 a	Very high
P1: 60 tons/ha	18.85 ab	Very high
P2: 90 tons/ha	22.24 b	Very high
P3: 120 tons/ha	36.04 c	Very high
P4: 150 tons/ha	57.72 d	Very high
CV = 12.95 %		

*) Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %
**) Source: Soil Research Institute (2009)

Atkinson et al. (2010) revealed the increase of available phosphorus because biochar contains P elements that are released and dissolved in soil solution. Besides that, an increase of available P in the present research was suspected because of the application of TSP fertilizer that collaborate with P contained in OPEFB biochar that increases soil capacity to hold water so that a given P will also increase or not leach. Karbeka et al. (2022) also asserted an increase in available P because of the release of Al-P and Fe-P due to the OPEFB biochar application on Ultisols. It is able to release P adsorption by Al-P and Al-Fe through anion exchange, organic acid anions will replace the position of P elements which are fixed by Al and Fe so that the available P element content in the soil will increase.

Exchangeable Potassium. Application of OPEFB biochar gave a significantly different in exchangeable potassium (K) of Ultisols. There was an increase in exchangeable K content in line with the increase in the dose of biochar given, although at 120 and 150 tons/ha not significantly different (Table 6). It was conformable by Handani (2017) that there was an increase of exchangeable K along with an increase of OPEFB biochar doses, i.e., 0; 5.3; 10.6; and 21.2 g/plant produce exchangeable K was 0.18; 0.23; 0.25; and 0.28 me/100g, respectively.

It was because of the K content in the OPEFB biochar, as confirmed by Fadilah (2020) that OPEFB biochar contained 1.44 me/100g exchangeable potassium. This is in accordance with the opinion of Lehmann and Joseph (2009)

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that biochar application contributes to an increase in soil charge. Bakar et al. (2015) stated that biochar has a negative charge to retain soil cations such as K^+ ions. In line with the opinion of Sujana (2014), biochar produced from the pyrolysis process creates negatively charged particles that have a greater ability to absorb soil cations, including K^+. In addition, another factor that affects the exchangeable K is the C-organic content of Ultisols (Table 3). The increase of K balance in the soil depends on the C-organic content because C-organic can control K availability as indicated by a positive correlation with soil resistivity (Nursyamsi et al., 2007).

Table 6. Exchangeable K after treatment OPEFB Biochar as planting media in cacao seedlings.

Treatment	Exchangeable K (me/100g)*	Criteria**
P0: 0 ton/ha	0.76 a	High
P1: 60 tons/ha	2.26 b	Very high
P2: 90 tons/ha	3.00 c	Very high
P3: 120 tons/ha	3.69 d	Very high
P4: 150 tons/ha	4.16 d	Very high
CV = 15.19 %		

*) Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %
**) Source: Soil Research Institute (2009)

The Effects of The Application OPEFB Biochar on The Growth of Cacao (*T. cacao* L.) Seedlings

Seedling Height. Table 7 shows the effect of biochar from oil palm empty fruit bunches was not significantly different on the variable of seedling height. The height of cacao seedlings with 150 tons/ha of OPEFB biochar increased by 39.99 % compared to without biochar (0 ton/ha). However, overall the height growth has exceeded the minimum height of cacao seedlings at 3-6 months that must be 20-30 cm (Indonesian Coffee and Cocoa Research Institute, 2010).

Table 7. Height of cacao seedlings at 16 weeks after planting (WAP) after application OPEFB Biochar.

Treatment	Seedling Height (cm)
P0: 0 ton/ha	39.83
P1: 60 tons/ha	47.84
P2: 90 tons/ha	50.34
P3: 120 tons/ha	50.98
P4: 150 tons/ha	55.76
CV = 14.66 %	

Conversely, Syarifain et al. (2022) who used several types of soil ameliorant in oil palm nurseries obtain significantly different effects on the variable of plant height. The growth of plant height is influenced by available nutrients in growing media, especially N nutrient which functions in acceleration of cell division. Table 4 shows the total nitrogen in all treatments was categorized into low criteria, except 150 tons/ha was a moderate criterion. This is a strong reason why the result was not significantly different, where fewer nutrients in the growing medium will affect the plant height.

Growth of plant height goes on vegetative phases that relate to three important processes, i.e., cell division, elongation, and differentiation. Those processes need carbohydrates that compound with N element at the growing point that influence the increase of plant height. The optimal cell division must be supported by N availability which plays a role for stimulate overall growth, especially stem growth and if the availability of it is a low criterion so plant growth will slowdowns (Mardianto, 2014).

Stem Diameter. Based on analyzed of variance shows that the application of OPEFB biochar gives a significant effect on the stem diameter of the cacao seedling. Dose 120 and 150 tons/ha were not significantly different, but they were significantly different when compared to the dose of 0 and 60 tons/ha. The largest stem diameter (11,.0 mm) was found in the treatment of 120 tons/ha OPEFB biochar (Table 8). According to the standard growth of cacao seedlings, the stem diameter in this research has fulfilled it, where a minimum stem diameter of > 6 mm at seedlings of 3-6 months (Indonesian Coffee and Cocoa Research Institute, 2010).

Table 8. Stem diameter of cacao seedlings at 16 WAP after application OPEFB Biochar.

Treatment	Stem Diameter (mm)
P0: 0 ton/ha	10.11 a
P1: 60 tons/ha	10.25 a
P2: 90 tons/ha	10.54 ab
P3: 120 tons/ha	11.20 b
P4: 150 tons/ha	11.15 b
CV = 5.32 %	

Note: Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %.

The growth of stem diameter is absolutely influenced by nutrient availability in the soil or growing media, such as potassium (K). Potassium nutrient plays a role in accelerating meristematic growth, especially stem diameter and strengthening plant. The content of exchangeable potassium in this research shows in Table 6, a growing medium without treatment (0 ton/ha OPEFB biochar) containing 0.76 me/100g exchangeable K (high criterion), while the exchangeable K contained in the growing medium at a dose of 150 tons/ha OPEFB biochar reached 4.16 me/100g (very high criterion). This is directly proportional to the increase of stem diameter of cacao seedlings in the present study.

Besides the nutrient availability, stem diameter growth is also influenced by soil pH. According to analysis results of soil pH (Table 2) the pH at a dose of 120 and 150 tons/ha OPEFB biochar were 6.02 and 5.77, respectively. It is related to Susanto (1995) opinion that cacao will grow optimally at soil pH 6.0 – 7.0 because soil pH influences ability of cacao plant to absorb nutrients. On the other hand, Hayati et al. (2021) stated that although there was an increase in soil pH in Ultisols, it was still relatively low because the presence of Al and Fe ions predominate will make nutrient uptake becomes decreased.

Number of Leaves. Table 9 shows no significant effect of OPEFB biochar on the leaves number of cacao seedlings aged 16 weeks after planting (WAP). It was increased by 26.47 % at a dose of 120 tons/ha OPEFB biochar compared to without biochar (0 ton/ha). This results in line with Yonedi (2021) that the application of OPEFB biochar not a significantly different effect on the leaves number of rubber seedlings. Also, by Siboro (2018) who gift biochar on Ultisols as growing medium on the growth of oil palm in the main nursery, it was no significantly different effect to the leaves number.

Table 9. Leaves number of cacao seedlings at 16 WAP after application OPEFB Biochar.

Treatment	Number of Leaves
P0: 0 ton/ha	23.80
P1: 60 tons/ha	26.10
P2: 90 tons/ha	27.30
P3: 120 tons/ha	30.10
P4: 150 tons/ha	28.00
CV = 15.30 %	

In this study, it was suspected that there was a connection between the plant height and leaves number, where obtained not significantly different results on the both of growth variables. This opinion is supported by Haryadi (2015) that increase plant height will stimulate the formation leaf young that grows on stems.

Pangaribuan (2001) opine that besides depending on age plant, the increase of leaves number is genetic characteristic of each plant. Besides that, the development of cacao leaves affected by speed of production leaves that depend on local climate and soil conditions. On fertile soil, leaves will fast open so that the more effectively do function as photosynthesis place and respiration tools.

Leaf Length and Width. Results of ANOVA shows that OPEFB biochar has a significant effect on the leaf length and width of cacao seedlings (Table 10). The longest leaf length (29.33 cm) was obtained at a dose 120 tons/ha which is significantly different with the other four doses. Meanwhile, for leaf width at doses of 90 and 120 tons/ha were significantly different with 0 ton/ha (control), while doses of 60 and 150 tons/ha were no significantly different to each other. Such results are certainly related with the chemical properties of Ultisols which are affected by the OPEFB biochar, specifically N nutrient. Ulfa (2018) stated that the nutrient that has most influence on leaf growth and development is N.

Table 10. Leaf length and width of cacao seedlings at 16 WAP after application OPEFB Biochar.

Treatment	Leaf Length (cm)	Leaf Width (cm)
P0: 0 ton/ha	23.66 a	8.39 a
P1: 60 tons/ha	24.16 a	8.78 ab
P2: 90 tons/ha	25.39 a	10.06 b
P3: 120 tons/ha	29.33 b	9.98 b
P4: 150 tons/ha	25.59 a	9.68 ab
	CV = 8.95 %	CV = 8.96 %

Note: Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %.

High levels of N generally produce longer and larger leaves because it is used in cell division and elongation. Nitrogen is used to form amino acids where it will be converted into proteins. Nitrogen is also needed to form important compounds, such as chlorophyll, nucleic acids and enzym. Therefore, nitrogen is needed in relatively large quantities at each stage of plant growth, especially the vegetative growth including on the formation of shoots and the growth of stems and leaves (Novizan, 2005).

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The result on the variable of leaf width was similar with Jelvina (2019), where the application of OPEFB biochar had a significant effect on the leaf width of oil palm in the main nursery. Treatment of OPEFB biochar at 90 tons/ha has provided nutrients for the growth of leaf width, due to application of OPEFB biochar is assist the mineralization of N element. According to Nguyen et al. (2017), the application of biochar can increase soil moisture and pH, thereby stimulating N mineralization and nitrification processes which cause plant uptake to increase. Biochar increases the inorganic N required for plant assimilation by increasing retention and reducing the impact of N leaching.

Lakitan (2010) stated that nitrogen affects the formation of new cells, phosphorus affects activating enzymes, and potassium influences the development of meristem tissue which affect the length and width of leaves. In line with Dhani et al. (2013), the formation of leaves in plants is greatly influenced by the availability of nitrogen, phosphorus and potassium nutrients in the growing medium. These elements play a role in the formation of new cells and main components of organic compounds in plants such as amino acids, nucleic acids, chlorophyll, ADPs and ATPs. Tables 4, 5 and 6 show an increase in those nutrient contents in line with the additional dose of OPEFB biochar given. It is a fundamental reason for the significant effect of the application of OPEFB biochar on the leaf length and width of cacao seedlings.

Root Length. Table 11 shows the application of OPEFB biochar has no significantly different effect on the root length of cacao seedlings, while the root length with 120 tons/ha of OPEFB biochar increased by 1.99 % compared to without biochar. This result was similar with Fadilah (2020) that the application of OPEFB biochar also did not have a significant effect on the root length of the robusta coffee seedlings.

Table 11. Root Length of Cacao Seedlings at 16 WAP after Application OPEFB Biochar.

Treatment	Root Length (cm)
P0: 0 ton/ha	41.70
P1: 60 tons/ha	42.35
P2: 90 tons/ha	38.80
P3: 120 tons/ha	42.53
P4: 150 tons/ha	41.70
CV = 15.13 %	

The results are not significantly different on the variable of root length presumably because of the root growth had reached the lowest point on the polybag sized 35 x 15 cm so that roots could not grow more because the limitations of growing spaces. According to The Ministry of Agriculture (2011), at the beginning of seed germination, the taproot grows rapidly ranging 1 cm in length (1 week old) to 25 cm (3 months old). After that, speed development will down and reach 50 cm.

Shoot-Root Dry Weight and Shoot-Root Ratio. ANOVA results showed a significant effect on the shoot dry weight of cacao seedlings at 16 WAP due to the application of OPEFB biochar. Treatments of P3 and P4 (doses of 120 and 150 tons/ha) were significantly different with doses of 0, 60, and 90 tons/ha (P0, P1, and P2), and the heaviest shoot dry weight (41.71 g) was obtained at a dose of 150 tons/ha. On the contrary, the OPEFB biochar effect was not significantly different for root dry weight and an increased of 25.89 % was found at a biochar dose of 150 tons/ha compared to without biochar (Table 12).

Shoot dry weight is the main indicator of the accumulation of dry matter (photosynthate) in above-ground which is strongly influenced by the growth of stems and leaves. In line with Sahroni et al. (2008), shoot dry weight is the accumulation of photosynthetic results which cause growth such as increasing plant height and leaf area.

Table 12. Shoot-root dry weight and shoot-root ratio of cacao seedlings at 16 WAP after application OPEFB Biochar.

Treatment	Shoot Dry Weight (g)	Root Dry Weight (g)	Shoot-Root Ratio
P0: 0 ton/ha	18.17 a	5.87	3.09 a
P1: 60 tons/ha	21.64 a	6.05	3.58 a
P2: 90 tons/ha	29.46 b	4.10	7.18 b
P3: 120 tons/ha	39.28 b	6.23	6.30 b
P4: 150 tons/ha	41.71 b	7.39	5.64 b
	CV = 13.91 %	CV = 13.39 %	CV = 22.18 %

Note: Mean followed by the same lowercase alphabet in the same column is not significantly different based on Duncan's multiple range test at the level of 5 %.

Sitompul and Guritno (1995) revealed that calculating plant dry weight is important because dry weight is an indicator of plant metabolism. The dry weight can represent the results of plant metabolites. It is also used as an indicator of plant growth because dry weight shows organic compounds that are translocated to all plant organs.

Roidi (2016) declares that the root dry weight depends on the uptake of nutrients and the root length. If photosynthesis goes well, the root will grow well too, followed by enhancement of heavy root dry. Root dry weight is the accumulation of organic matter and is closely related to the growth of root length. Table 11 shows that OPEFB biochar did not significantly effect on the variable of root length and it was a strong reason why in the variable of root dry weight that not significantly different also, because both of it was closely related.

Gardner et al. (1991) revealed that root growth includes root elongation and widening which are influenced by media and environmental factors. The application of biochar can improve soil structure, organic matter will improve the soil properties so creating a better environment for roots to absorb more nutrients. Organic matter contributes to pore space and higher water-holding capacity in the root zone resulting in heavier and stronger roots.

Root hairs are the part of the root that is most active in absorbing nutrients and water. The more root hairs are formed, the greater amount of nutrients and water absorbed by the plant roots. The heaviest root dry weight was obtained on the treatment of P4 (150 tons/ha), presumably related to the organic carbon content on that treatment, namely 2.34 % (Table 3).

On the variable of shoot root ratio, it was shown that the application of OPEFB biochar had a significant effect. Its value was obtained from the comparison of shoot dry weight and root dry weight. This is necessary to know the direction of photosynthate allocation and growth of cacao seedlings, whether to the shoot or root. That is related to the opinion of Sari (2013) that a value of shoot root ratio more than one (> 1) indicates the growth of the plant is more towards the shoot and vice versa if less than one (< 1) indicates the growth of the plant is more towards the roots.

In this study, the value of shoot root ratio whole > 1 indicates that photosynthate allocation and growth of cacao seedlings are more towards the shoot. Moreover, in the vegetative phase, roots function as nutrient absorption so that the growth of the shoot is greater than the root and dry weight through photosynthesis is more translocated to the shoot rather than the root.

Conclusion

Based on the results and discussion, it can be concluded that the application of biochar from oil palm empty fruit bunches at 120 tons/ha (equivalent to 200 g/polybag) was the best dose to give significant results on several chemical properties of Ultisols (pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium) and several growth variables of cacao seedlings (stem diameter, leaf length and width, shoot dry weight, and shoot-root ratio).

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