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Biochar from Different Sections of Oil Palm Trunk Improves Biomass Accumulation and Nutrient Uptake in Pre-Nursery Oil Palm (*Elaeis guineensis* Jacq.) in Ultisol Media

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Abstract

The production of high quality seedlings is dependent on soil as planting media. Application of biochar derived from oil palm trunk onto oil palm seedling has been scarcely studied, especially on ultisol planting media. This research investigated the effect of oil palm trunk biochar on vegetative growth and nutrient uptake of belowground and aboveground tissues of oil palm (Elaeis guineensis Jacq) in ultisol pre-nursery planting media. Three types of oil palm trunk biochar derived from top, middle, and bottom section were used in this research. The application rates were 1, 2, 3 and, 4 % (w/w) during 12 weeks in a green house. This experiment used a non factorial randomized complete block design with three replications. The addition of biochars derived oil palm trunk (OPT) amendment significantly increased stem diameter, plant height, root biomass, shoot biomass. The highest respon rasio (RRs) for root and shoot biomass was 0.40, and 0.55, respectively, recorded at 2% application rates. The highest increase of N, P, and K uptake for belowground and aboveground tissues were resulted from B3 (3 % biochar top section), B2 (2 % biochar top section), and B2 (2 % biochar top section) treatments, respectively. Overall, the addition of biochar derived top section OPT at 2 % (w/w) could enhance stem diameter, RRs plant biomass, N, P, K uptake of belowground and aboveground tissues. The addition of biochar OPT at 2 % (w/w) should be recommendation in order to used as rate of biochar OPT for ultisols ammendment in oil palm pre-nursery.

Keywords: *Biochar; Biomass; Oil palm seedlings; Soil amendment*

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INTRODUCTION

The development of oil palm plantation area in Indonesia was dominated by the highly weathered soils. The orders of the highly weatheres soils in Indonesia are inceptisols 59,690,000 ha, ultisols 54,200,000 ha, and oixsols 23,080,000 ha; occupy about 31.99 %, 29.05 % and 12.37 % of the total area respectively (Soil Research Institute, 2006). The largest part of dry land in Indonesia were dominated by ultisols (Hardjowigeno, 1993). The largest of ultisol is coveraged in Kalimantan 21,938,000 ha, followed by Sumatra 9,469,000 ha, Maluku and Papua 8,859,000 ha, Sulawesi 4,303,000 ha, Java 1,172,000 ha, and Nusa Tenggara 53,000 ha (Subagyo et al., 2004). Unfortunately, ultisols had various restrictions that constrain for oil palm cultivation.

Ultisols are marginal soils Indonesia (Subagyo et al., 2004), with several factors that constrain plant growth are pH <5.0 (acid), Al saturation >42 % (high), organic-C <1.15 % (low), base saturation 29 % (low), and range of N and P concentration: 0.14 % and 5.80 ppm (low), respectively are a few of these characteristics (Alibasyah, 2016). Furthermore, excess Al, Fe and limited cation exchange capacity can restrict the availability of nutrients in the soil that limit plant growth (Panhwar et al., 2014; Borchard et al., 2014). However, the production of high quality seedlings is dependent on soil as planting media. The usage of ultisols in nursery often resulted in non-uniform and stunted seedlings growth. In light of this, biochar can be used as a promising soil amendment to improve plant growth by modulating soil conditions (Jiang et al., 2019).

Biochar is an organic carbon-rich, solid material that is generated from the thermochemical conversion of agricultural bio-waste in an oxygen limited environment (pirolysis) that is used as a soil amendment to improve nutrient availability and act as a stable form of C (Lehmann, 2007; Lehmann & Joseph, 2015; Boateng et al., 2006). Biochar utilization constitutes a clean and green technology for the effective recycling of biomass and organic wastes. One identified option is biochar derived from oil palm trunk application. Oil palm trunk is a promising feedstock for biochar production and has been a lot of attention recently in turning these wastes into biochar (Ainatul et al., 2012); globally approximately 40,2 million ton, is generated annually in Indonesia (Directorate General of Estates, 2019). Biochar derived from OPT can be an alternative substitute for wood shortages as feedstock resulting from deforestation. Numerous international researches have shown that OPT biochars characteristic for various functions (Hassan et al., 2021; Sakulkit et al., 2020; Razali & Kamarulzaman, 2020).

Previous reports had shown that application of biochar into acidic soil were significantly increase soil pH, buffering capacity, and cation exchange capacity (Yuan & Xu, 2011; Shi et al., 2018). In the literature, the range of biochar application rates in soil varied from 1% to 10%, with the lower rates being considered more sustainable and economically viable. Based on this consideration, along with the positive results of a previous study (Manolikaki & Diamadopoulos, 2017), interval 1 – 4 % were selected. The biochar obtained from OPT remains shows no phytotoxicity and is suitable for use as soil amendment (Sianipar et al., 2024). Nutrient uptake in OPT biochar-amended on ultisol soils in oil palm pre-nursery has not been fully investigated. Therefore, a green house experiment was conducted to study the effects on oil palm seedling growth and nutrient uptake of adding three distinct types of OPT biochars (biochar from top, middle, and bottom section OPT) to ultisols as pre-nursery planting media.

MATERIALS AND METHODS

Soil, Biochar Preparation

The soil used in this experiment was Ultisol soil (*Typic Paleudults,* sandy clay loam*)* collected from 0 – 30 cm depht of Tambunan village, Selapian District, Langkat Regency, North Sumatera Province, with coordinate $3^0$26'6" N and $98^0$18'53" E. The soil samples were composited, air dried, ground and passed through a 2-mm sieve. Soil analysis was conducted to evaluate soil characteristics and nutrient concentrations. Soil pH was measured in a 1 : 2.5 soil to distilled water suspension (w/v), using a glass electrode pH meter (Thermo Scientific Oriont Star A214, USA). Total organic-C concentration of soil was determined using the Walkley and Black method of acid dichromate digestion (Nelson & Sommers, 1996). Total-N concentration was determined using the Kjeldahl method (Bremner & Mulvaney, 1982) (Digestion block Gerhardt and Distillation Eppendorf, Germany). Exchangeable cations (K, Ca, Mg, Na) in soil were quantified in the NH_4O-Ac pH 7.0 extraction method (Spectrophotometric Seal Brand Luebbe AA3) to determine cation exchange capacity; and the Bray and Kurtz method (Bray & Kurtz, 1945) was used to measuring of available P_2O_5. The Bouyoucos hydrometer method was used to determine particle size analysis. The characteristics of soil is presented in Table 1.

Table 1. Selected Properties of Soil Used in The Polybag Experiment

No	Property	Unit	Value
1	pH (H_2O)		5.10
2	Total Organic-C	%	1.01
3	Total-N	%	0.12
4	C/N ratio		8.42
5	Organic matter	%	1.72
6	Total-P_2O_5	%	0.21
7	Total-K_2O	%	0.24
8	CEC	me/100 g	13.94
9	Base Saturation	%	10.00
10	Texture : sandy clay loam		
	- Sand	%	48.00
	- Silt	%	18.00
	- Clay	%	34.00

Oil palm trunk feedstock was obtained from oil palm plantation PTPN IV at Tanah Jawa, Simalungun District, North Sumatera Province, Indonesia. The OPT was devided into three parts: top, middle, and bottom section OPT. The different trunk sections of OPT (top, middle, and bottom) were sun dried to reduce the moisture content to around 15 % by weight. The biochar derived from top, middle, and bottom section OPT were produced by drum retort kiln through a slow pyrolysis process at temperature in the range 300 – 400 °C (Sianipar et al., 2022). This pyrolysis temperature was chosen because the lower pyrolysis temperature results in the higher biochar yield, the lower polycyclic aromatic hydrocarbons (PAHs) content (Keiluweit et. al., 2012; Oleszczuk et. al., 2013).

The characteristics of biochars are depicted in Table 2. The OPT biochar derived from top, middle, and bottom section were assessed for basic characteristic. Potentiometry (Horiba Laqua PC 1100, Japan) was used to determine pH biochars. Gravimetry method (Ohaus Explorer 225D, and CEM Phoenix Microwave Furnace, USA) was used to determine total organic-C. Total extractable N was detemined using Kjeldahl method (Digestion block Gerhardt and Distillation Eppendorf, Germany). Total-P_2O_5 was detemined using HNO_3 method and spectrophotometry (destruction CEM MARS 6 China, Spectrophotometric UH 5300 HITACHI, Japan). Total-K_2O was determined using HNO_3 method and atomic absorption spectrophometer (destruction CEM MARS 6 China, Atomic Absorption Spetrophotometric Agilent). Exchangeable cations (K, Ca, Mg, and Na) to quantify Cation Exchange Capacity (CEC) was determined using ammonium acetate pH 7.0 extraction method (Spectrophotometric Seal Brand Luebbe AA3). According to the European Biochar Certificate (EBC) guidelines, organic materials with total organic-C ≥ 50 % produced by pyrolysis are characterized as biochars, while according to International Biochar Initiative (IBI) guidelines total organic-C should be ≥ 10 % in order to be characterized as biochars (Meyer et al., 2017).

Table 2. Properties of Biochars Derived from Bottom, Middle and Top Section OPT

No	Property	Unit	Biochar		
			Bottom	Middle	Top
1	pH (H_2O)	-	8.50	8.20	7.60
2	Total Organic-C	%	52.93	50.32	35.63
3	Total-N	%	0.19	0.18	0.30
4	C/N ratio	-	278.00	279.55	118.76
5	Total-P_2O_5	%	0.27	0.53	0.46
6	Total-K_2O	%	3.16	4.37	3.95
7	Cation Exchange Capacity	me/ 100 g	30.00	31.04	29.69

Experimental Set Up

The experiment was conducted for 3 months in the green house of Agriculture Faculty, University of Methodist Indonesia-Medan, with an altitude of 33 m above sea level, at the coordinat point 3°33’15” North latitude and 98°38’18” East longitude. The experiment was carried out using a non factorial randomized complete block design (RBD) with 3 replications in a polyethylene bag (polybag with 10 cm in length x 14 cm height x 16 cm diameter). The level of biochar treatments were, 0 % biochar (B0), 1 % biochar of top section (B1), 2 % biochar of top section (B2), 3 % biochar of top section (B3), 4 % biochar of top section (B4), 1 % biochar of middle section (B5), 2 % biochar of middle section (B6), 3 % biochar of middle section (B7), 4 % biochar of middle section (B8), 1 % biochar of bottom section (B9), 2 % biochar of bottom section (B10), 3 % biochar of bottom section (B11), and 4 % biochar of bottom section (B12) with 3 replications. This experiment consist of 39 units and each experiment consist of 3 germinated oil palm. Therefore, 13 x 3 x 3 = 117 of germinated oil palm needed for this experiment. Tenera variety, a hybrid Dura x Pesifera Simalungun (SP 540) germinated oil palm produced by Indonesia Oil Palm Research Institute (IOPRI), was used in this experiment.

Polybag media were prepared by mixing biochars with the ultisol soil of *Typic Paleudults.* The ultisol air-dried soil (1 kg) was mixed with biochars in accordance to the treatment thoroughly into polybags as the planting media. The mixtures planting media were incubated for three days, the moisture content in all polybags was maintained at 80 % of field capacity through deionized water addition. One germinated oil palm was sowing into mixture-filled/treatment polybag. The distance of polybags were arranged at 30 cm in the row and 50 cm inter-row under shade netting 50 % shade level in green house throughout the three months. All seedlings in the polybags received the same volumes of water approximately 50 mL of deionized water for twice a day and weeding was done manually. One month after sowing, all seedlings were fertilized with mineral fertilizer (N, P, K, Mg : 15-15-6-4) at 5, 7, 9, 11 weeks after sowing, and urea at 4, 6, 8, 10 weeks after sowing, fertilizers concentration 2 % dilution in water by a volume 20 ml for a seedling (the recommendation of Indonesia Oil Palm Research Institute). No pesticides was applied, since no diseases or pest symptoms appeared. One harvest of shoot biomass and root biomass took place three months after seedlings growth (pre-nursery period).

Plant Growth

Plant height, stem diameter and biomass of plant (root, shoot, and total plant biomass) make up the growth characteristics. The plant height was measured using a measuring tape from the base of the stem (the bole) to the end of the longest fully opened leaves. A digital caliper was used to record the stem diameter at the base of the stem. Plant height was recorded at 6 and 12 weeks after sowing; meanwhile stem diameter was recorded at 12 weeks after sowing. At the 12th week, the seedlings were harvested by cutting at the base of the stem for the shoot weight, while the roots were carefully cleared from soil particle to record the root weight. Both the shoot and the root were packed in paper envelops and dried in an oven preheated to 70 °C for 48 hours, or until a consistent weight. The shoot and root biomass were weighed using an electronic balance after that and weights recorded.

Plant biomass data was used to calculate the mean response rasio (RRs) of each biochar treatment relative to the unamanded (control). The RRs, defined as the natural logarithm of the ratio of biomass production in a given biochar treatment over zero-biochar control. The RRs ensures that variabilty in the ratios denominator has no greater influence than the variability in the numerator (Hedges et. al., 1999). Thus, the value of RRs is 0, positive or negative ratio; which indicates nochange from the control, increased biomass, or decreased biomass, respectively.

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$$RRs = \ln\left[\frac{biomass_t}{biomass_c}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where : RRs = The mean response rasio
ln = natural logarithm
$biomass_t$ = biomass biochar treatment
$biomass_c$ = biomass control (zero-biochar)

Plant Analysis

The belowground and aboveground biomass were pulverized with a grinding machine to 1 mm size and sieved through. The dry ashing digestion method was generated in a furnace at 300 °C for one hour and then at 500 °C for five hours. The Total-N concentration was determined using the Kjeldahl digestion method (Nelson & Sommers, 1982) (Digestion block Gerhardt and Distillation Eppendorf, Germany). The ash sample was added with HNO_3 and allowed to break down in a water bath for one hour for analysing P and K. Then the digested material was filtered and poured to capacity in a volumetric flask. A flame photometer (ICP-OES Optima 7300 DV Pelkin Elmer USA) was used to determine concentration of P and K (Mills & Jones 1996).

Statistical analysis

One-way analysis of variance (ANOVA) was performed with the SPSS software (IBM SPSS Statistic for Windows 20) to compare the means of stem diameter, plant height, oil palm seedlings biomass (root, shoot, and total biomass), and nutrients uptake. Duncan's Multiple Range Test (DMRT) was used as post hoc test at a p-value of <0.05 to analyse the differences between treatments.

RESULT AND DISCUSSION

Growth Performance

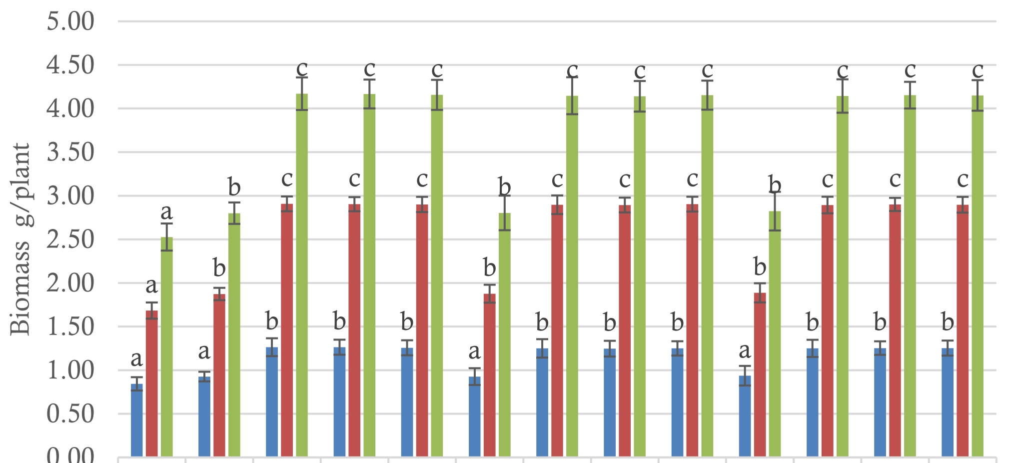
Stem diameter was significantly higher at B3 (3 % biochar top section) and B12 (4 % biochar bottom section). The plant height at 12 week after sowing were significantly higher with 2 % biochar rate (Table 3.). OPT biochar amendment up to 2 % i.e. B2 top section, B6 middle section, and B10 bottom section increased in plant height up to 30.50 cm, 29.57 cm, and 29.50 cm respectively at 12 week after sowing. Then, there were no significants differences in stem diameter due to biochar amendment up to 1 – 2 % (B1, B2, B5, B6, B9, and B10, B11). Similarly, biochar amendment at 1 % (B1, B5, and B9) were no significants differences compared to without biochar amendent (B0) 24,87 cm plant height.

Application biochar showed significantly ($p<0.05$) increased stem diameter at B3 (3 % biochar top section) and plant height at B2 (2 % biochar top section). This increase in stem diameter and plant height could be due to improvement of water holding capacity as well as cation exchange capacity of soil, which increased nutrients availability, which in turn increased plant growth (Rondon et al., 2007). The rate of growth of oil palm is related to water availability, which could in turn potentially increase the effectiveness of mineral nutrient uptake and translocation of photosynthate into plant tissue and increased plant growth (Darmosarkoro et al., 2001).

Table 3. Stem Diameter and Height of The Oil Palm Seedlings at 12 WAS

Treatment	Stem diameter (cm)	Plant height (cm)
B0 (without biochar)	0.60 ± 0.05a	24.87 ± 0.93a
B1 (1 % biochar top section)	0.63 ± 0.02ab	27.63 ± 0.67ab
B2 (2 % biochar top section)	0.66 ± 0.03ab	30.50 ± 2.05b
B3 (3 % biochar top section)	0.71 ± 0.03b	30.13 ± 1.64b
B4 (4 % biochar top section)	0.65 ± 0.04ab	30.07 ± 1.76b
B5 (1 % biochar middle section)	0.63 ± 0.04ab	27.77 ± 1.80ab
B6 (2 % biochar middle section)	0.67 ± 0.04ab	29.57 ± 2.11b
B7 (3 % biochar middle section)	0.66 ± 0.06ab	29.40 ± 1.25b
B8 (4 % biochar middle section)	0.65 ± 0.06ab	29.40 ± 1.21b
B9 (1 % biochar bottom section)	0.66 ± 0.07ab	27.77 ± 2.08ab
B10 (2 % biochar bottom section)	0.68 ± 0.03ab	29.50 ± 2.07b
B11 (3 % biochar bottom section)	0.68 ± 0.03ab	29.50 ± 1.25b
B12 (4 % biochar bottom section)	0.69 ± 0.02b	29.23 ± 1.50b

When the p-value is less than 0.05, different letters in the same column mean that there is a significant difference between the treatments (Duncan's multiple range test). The values are presented as means ± standard deviation of data obtained in the experiment with n = 3).



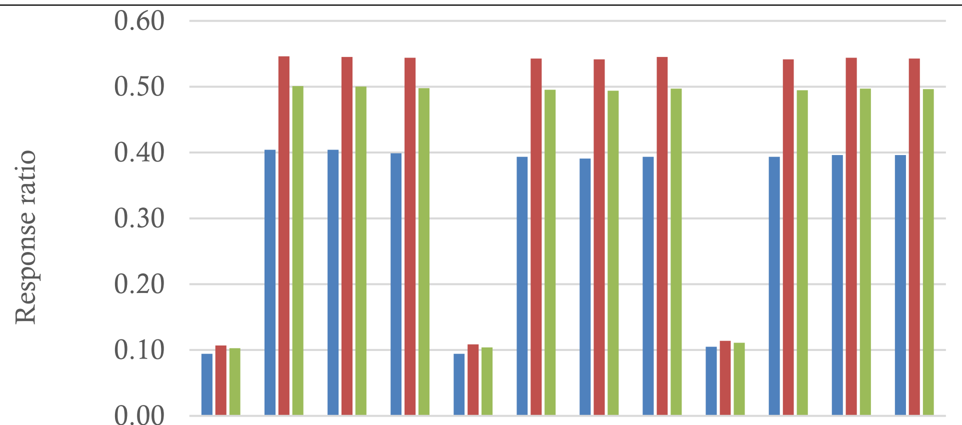
	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
Root	0.84	0.93	1.26	1.26	1.26	0.93	1.25	1.25	1.25	0.94	1.25	1.25	1.25
Shoot	1.68	1.87	2.91	2.90	2.90	1.88	2.90	2.89	2.90	1.89	2.89	2.90	2.90
Total	2.53	2.80	4.17	4.17	4.16	2.80	4.15	4.14	4.15	2.82	4.14	4.15	4.15

Figure 1. Root, Shoot and Total Biomass of Oil Palm Seedlings (mean ± stdev. n=3) Values not sharing the same letter indicate a significant difference (DMRT *p*<0.05)

Data of oil palm seedlings biomass used from previous study (Sianipar et al., 2025). In this experiment, the 2 % OPT biochar amended media (B2, B6, and B10) showed comparatively higher root, shoot, and total plant biomass

(Figure 1). Oil Palm seedlings biomass (root, shoot, and total plant biomass) increased significantly by 1.26 g, 2.91 g, 4,17 g (B2), 1.25 g, 2.90, and 4.15 g (B6), and 1.25 g, 2.89 g, and 4.14 g (B10) respectively with application biochar as soil amendment, compared to without biochar application (B0). According to Yahya et al., (2010) biochar increased the length and thickness of tertiery and quaternary roots. Therefore the optimum amount of roots greatly influence plant growth and development as its function for point of water and nutrients intake to the plant.

The application of biochar rate up to 2 % (w/w) increased soil pores and CEC, therefore, increased the water and nutrient availability for oil palm seedling growth. In addition, the influence of liming effect of biochar in acidic soils is considered to be responsible significantly increased plant biomass and growth (Farrell et al., 2014).



	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
Root Biomass	0.09	0.40	0.40	0.40	0.09	0.39	0.39	0.39	0.10	0.39	0.40	0.40
Shoot Biomass	0.11	0.55	0.55	0.54	0.11	0.54	0.54	0.55	0.11	0.54	0.54	0.54
Total Biomass	0.10	0.50	0.50	0.50	0.10	0.50	0.49	0.50	0.11	0.49	0.50	0.50

Figure 2. Oil Palm Seedlings Biomass Response Ratio of Root, Shoot and Total

The respon ratio (RRs) of plant biomass on harvest to biochar addition were positive biomass responses (Figure 2.). Biochar addition resulted a positive rate-dependent impact on oil palm growth in the ultisol. The highest RRs of root biomass 0.40 (B2, B3, B4, B11, and B12), shoot biomass 0.55 (B2, B3, B8) and total plant biomass 0.50 (B2, B3, B4, B6, B8, B11, and B12). Overall, the highest response rasio 0.55 on shoot biomass at 2 % application rates, having strongest impact on shoot production. Previous study resulted that plant growth responses were positive responses in acidic soil types (Atkinson, et. al., 2010; Biederman & Harpole, 2012). OPT biochars used in this study have an alkaline pH with initial pH of top, middle and bottom OPT biochars are 7.6, 8.2, and 8.5 respectively (Table 2.). Thus, addition of OPT biochar could affect the pH value of the planting media. This explained the liming effect of OPT biochar, improving the pH of planting media, which increased the availability of key nutrients N, P, K, S Mg and Mn (Macdonald et al., 2014). The liming effect of biochar is regarded as one of the most important mechanisms for improving plant growth directly via affecting nutrients availability, especially for acidic soils Mn (Dai et al., 2017).

NPK Uptake in Belowground Tissue

The uptake of macronutirents N, P, and K by oil palm seedlings in belowground tissues are presented in Table 4. The uptake of macronutrients are in order N > K > P. The application of OPT biochars significantly increased N, P, and K uptake by belowground tissue compared to the control (B0). The lowest uptake of N, P, and K was found in control (B0). The highest uptake of N by belowground tissues was detected 34.46 mg/plat in B3 (3 % biochar top section), while the highest uptake of P and K by belowground tissues were detected in B2 (2 % biochar top section); 2.36 mg/plant, and 25.69 mg/plant, respectively. However, there were no significants differences in macronutients N, P, K uptake due to biochar amendment up to 2 – 4 % (B2, B3, B4, B6, B7, B8, B10, B11, and B12).

The application of OPT biochar obviously increased uptake of NPK in belowground tissue in the present study. Soil pH increased with the application of biochar and thus increased N, P, and K availability (Rizwan et al., 2016). Generally, biochar contained high mineral ash (Sianipar et al., 2022), in which contained a plenty of Ca^+, Mg^+, and K^+ which can replace H^+ and thereby increase soil pH (Yuan et al., 2011; Sianipar et al., 2024).

Table 4. The Uptake of NPK by Oil Palm Seedlings in Belowground Tissue

Treatment	N (mg/plant)	P (mg/plant)	K (mg/plant)
B0	21.23 ± 2.96a	1.27 ± 0.18a	14.09 ± 1.57a
B1	24.70 ± 1,31a	1.58 ± 0.18a	18.27 ± 1.65b
B2	34.03 ± 2.04b	2.36 ± 0.15b	25.69 ± 1.44c
B3	34.46 ± 1.71b	2.36 ± 0.17b	25.64 ± 1.69c
B4	34.22 ± 3.33b	2.34 ± 0.10b	25.46 ± 1.58c
B5	24.67 ± 2.47a	1.54 ± 0.18a	17.82 ± 2.27b
B6	33.60 ± 3.27b	2.21 ± 0.34b	25.63 ± 2,39c
B7	33.70 ± 2.49b	2.24 ± 0.14b	24.92 ± 2.58c
B8	33.75 ± 2.41b	2.25 ± 0.16b	25.62 ± 2.50c
B9	24.51 ± 2.61a	1.53 ± 0.24a	18.51 ± 1.66b
B10	33.08 ± 3.35b	2.25 ± 0.19b	27.07 ± 2.48c
B11	33.10 ± 2.40b	2.25 ± 0.13b	25.33 ± 2.39c
B12	33.20 ± 2.91b	2.26 ± 0.25b	25.33 ± 1.17c

When the p-value is less than 0.05, different letters in the same column mean that there is a significant difference between the treatments (Duncan's multiple range test). The values are presented as means ± standard deviation of data obtained in the experiment with n= 3).

Biochar is considered has abundant surface charges, which were helpful increased N, P, and K phyto-availability through mechanism of adsorb nutrients via complexation, ion exchange, chemical precipitation, and electrostatic interaction (Nartey & Zhao, 2014). In comparison to absorbed nutrients, adsorbed nutrients are the most significant since they are readily absorbed by plants. Temperature, floods, redox potential, pH buffering capacity, and soil pH all have a major impact on nutrient adsorption (Dada et al., 2012). The application of biochar increased concentration of

N, P, and K nutrients in soil solution, even in minimal levels, so the roots can absorb the nutrients (Sianipar et al., 2024; Wang et al., 2015).

Chan et al., (2007) further reported that there was a synergistic relationship between biochar and nitrogen fertilizer. Chan et al., (2008) There was a positive effect of biochar on N fertilizer utilization efficiency, which greatly boosted plant growth. In the present study, the soil pH of the planting media was 5,1 (acidic soil), phosphorus fixation tends to occur when phosphorus reacts with iron and aluminum to form insoluble compounds, which becomes unavailable and prevents phosphorus from being absorbed by the plants (Sung et al., 2017; Penn & Camberato, 2019). Addition biochar could increase phosphorus availability, by directly releasing P from the biochar and indirectly enhancing P usage efficiency by affecting soil pH (Xu et al., 2014).

NPK Uptake in Aboveground Tissue

The uptake of macronutirents N, P, and K by oil palm seedlings in aboveground tissues are presented in Table 5. The uptake of macronutrients in aboveground tissues were greater than belowground tissue, whereas similar nutrients uptake in order N > K > P. The application of OPT biochars significantly increased N, P, and K uptake by aboveground tissue compared to the control (B0). The lowest uptake of N, P, and K was found in control (B0). The highest uptake of N by aboveground tissues was detected 79.24 mg/plat in B3 (3 % biochar top section), while the highest uptake of P and K by aboveground tissues were detected 5.42 mg/plant in B2 (2 % biochar top section) and 59.45 mg/plant in B8 (4 % biochar middle section), respectively. However, there were no significants differences in macronutients N, P, K uptake due to biochar amendment up to 2 – 4 % (B2, B3, B4, B6, B7, B8, B10, B11, and B12).

Table 5. The Uptake of NPK by Oil Palm Seedlings in Aboveground Tissue.

Treatment	N (mg/plant)	P (mg/plant)	K (mg/plant)
B0	42.30 ± 4.14a	2.53 ± 0.20a	28.15 ± 2.75a
B1	49.94 ± 1.34b	3.19 ± 0.31b	36.94 ± 1.27b
B2	78.35 ± 1.55c	5.42 ± 0.19c	59.17 ± 1.23c
B3	79.24 ± 1.49c	5.42 ± 0.24c	58.99 ± 1.53c
B4	78.93 ± 4.67c	5.41 ± 0.12c	58.82 ± 1.68c
B5	49.97 ± 2.69b	3.12 ± 0.24b	36.06 ± 2.87b
B6	77.84 ± 3,89c	5.13 ± 0.39c	59.37 ± 2.99c
B7	78.21 ± 3.16c	5.20 ± 0.14c	57.80 ± 2.63c
B8	78.39 ± 2.97c	5.23 ± 0.30c	59.45 ± 2.67c
B9	49.40 ± 2.26b	3.09 ± 0.29b	37.31 ± 1.61b
B10	76.62 ± 4.46c	5.20 ± 0.25c	58.01 ± 2.31c
B11	76.57 ± 3.14c	5.22 ± 0.16c	58.70 ± 2.75c
B12	76.69 ± 3.78c	5.22 ± 0.38c	58.58 ± 2.28c

When the p-value is less than 0.05, different letters in the same column mean that there is a significant difference between the treatments (Duncan's multiple range test). The values are presented as means ± standard deviation of data obtained in the experiment with n = 3).

Addition of biochar increased N, P, and K availability in soil solution through mechanism of adsorb nutrients via ion exchange, complexation, redox potential, and pH enhancing (Nartey & Zhao, 2014; Dada et al., 2012). Lehmann et al., (2003) also observed an increase in nutrients uptake in plants with increasing biochar addition rates. Based on the result of this experiment showed that the highest macronutirents uptake was Nitrogen. Nitrogen is the macronutirent needed by plants in high quantity, because Nitrogen is the main constituent of essential organic compounds such as amino acids, nucleic acids, protein and chlorophyll (Walworth, 2013). An adequate supply of N within the growing media can result in increased chlorophyll content and elevated production of photosynthates. Subsequently, addition of biochar increased soil pH by increasing the concentration of alkaline metal (Ca^{2+}, Mg^{2+}, and K^{+}) oxides associated with the biochar, thereby shifting P availability (DeLuca et al., 2015). A possible explanation is that the biochar, increasing pH, CEC, N, P, and water content, could enhance available nutrients for plants and, consequently, biomass accumulation (Scotti et al., 2015). As a result, these effects collectively contribute to a substantial improvment in overall plant growth and biomass production.

CONCLUSION

The addition of biochars derived oil palm trunk (OPT) amendment significantly increased stem diameter 0.71 cm (B3), plant height 30.50 cm (B2), root biomass 1,26 g/plant (B2), shoot biomass 2,91 g/plant (B2) compared to the control (B0). The highest respon rasio (RRs) for root and shoot biomass was 0.40 and 0.55 respectively. The highest increase of N, P, and K uptake of belowground tissue resulted from B3 (34.46 mg/plant), B2 (2.36 mg/plant), and B2 (25.69 mg/plant), respectively. Whereas the highest increase of N, P, and K uptake of aboveground tissue resulted from B3 (79.24 mg/plant), B2 (5.42 mg/plant), and B2 (59.17 mg/plant), respectively. Over all the application of biochars OPT (B2 and B6) at 2% (*w/w*) were more efficient for soil amendment to ultisols soil. Further work is required to determine the complex interaction between biochar application rate, soil properties and fruit bunch yield.

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