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Effects of Oil Palm Trunk Biochar on Nutrient Uptake and Growth Performance of Oil Palm Seedlings in Pre-Nursery

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Abstract

Due to soil is an important factor as a growing media to obtain good oil palm in pre-nursery. Meanwhile, soil degradation has occured in many places throuhgout the oil palm plantations such as ultisols. Therefor, it is crucial improving soil quality by application biochar. One identified option is biochar derived from oil palm trunk (OPT) application. This study objectives were to determine the growth, macronutrient status, and nutrient uptake of oil palm (*Elaeis guineensis* Jacq) to the addition of biochars derived from the top, middle, and bottom section OPT in ultisols pre-nursery planting media. The experiment was arranged in a non-factorial randomized complete block design (RCBD) with three replications in a polyethylene bag. Biochars were added to ultisols at 1, 2, 3, and 4 % (w/w) in a green house experiment for 12 weeks pre-nursery. The application of biochars derived OPT increased plant height, shoot and root dry weight, content of N, P, K uptake, and N, P, K-total in soil acchieved by the dose of 2%. The addition of biochar derived top section OPT provided better growth and N, P, K uptake than biochar derived bottom and middle section OPT. The findings revealed the application of biochars OPT at 2% (w/w) was more efficient for soil amendment to ultisols soil.

Keywords: Biochar, Macronutrient, Nutrient Uptake, Oil Palm Trunk, Soil amendment

1. Introduction

Oil palm (*Elaeis guineensis* Jacq) is a valuable commercial crop that generates cash and jobs in Indonesia. Currently, Indonesia is the biggest producer of palm oil worldwide, with plantations covering 14.62 million hectares in 2021 compared to 0.3 million hectares in 1980 (Directorate General of Estates, 2019; BPS-Statistics Indonesia, 2022). However, most of soils in Indonesia are considered dominated by the highly weathered soils such as inceptisols 59.69 million hectares, ultisols 54.20 million hectares and oixsols 23.08 million hectares; occupy about 31.99%, 29.05% and 12.37% of the total area of Indonesia respectively (Pertanian, 2009). The predominant soils planted with oil palm in North Sumatera are Ultisols and Inceptisols which dominate about 47% of the total area. The distribution of Ultisols in North Sumatera Province is 1,549,000 ha (Soil Research Institute, 2006). These soils are naturally low in fertility (Goh et al., 2003) hence become a limiting factor when used as a growth medium in nursery.

In oil palm nurseries, improving soil fertility is very crucial. A number of factors that hinder plant growth have limited the use of ultisols as a planting medium, which are marginal soils in Indonesia (Subagyo et al., 2004). Low pH (<5.0) with high Al saturation (>42%), low organic-C (<1.15%), low base saturation (29%), and low nutritional content (range of N and P concentration: 0.14% and 5.80 ppm, respectively) are a few of these characteristics (Alibasyah, 2016). Furthermore, while heavy rains can lead to erosion and a quick loss of nutrients, excess Al and Fe can restrict the availability of nutrients in the soil and affect plant growth (Panhwar et al., 2014). After that, the soil's fertility rapidly decreases, particularly the soil organic carbon required for farming that is sustainable over the long run.

Due to soil is an important factor as a growing media and the limitation of good soil to obtain good oil palm in pre-nursery. The palm oil industry conventionally used topsoil in the media for the oil palm nusery, which is crucial improving nutrient uptake and growth of oil palm

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seedling. However, soil degradation has occured in many places throuhgout the oil palm plantations such as ultisol. In order to achieve the favourable soil, soil may need to be amended (Rosenani et al., 2016). Biochar can be used as a soil amendment to promote the nutrient uptake and growth of oil palm seedlings in pre-nursery. Biochar, unlike bio-oil and gas, which are produced by pyrolyzing agricultural bio-waste in an oxygen-limited atmosphere, is an organic carbon-rich material (Lehmann, 2007; Boateng et al., 2006). Because oil palm wastes like oil palm trunk (OPT) have a high energy requirement, worries about greenhouse gas emissions, and the potential as a soil supplement, there has been a lot of attention recently in turning these wastes into biochar (Ainatul et al., 2012). Unlike other wood alternatives, biochar derived from OPT can help solve wood shortages such as feedstock resulting from deforestation. Additionally, OPT biochar might help with nutrient recycling and waste management in oil palm plantations. It might also be used as an amendment in the pre-nusery to produce oil palm seedlings. When oil palm trees are replanted at the end of their productive lives, a significant amount of OPT is created. It was estimated for 14.62 million ha oil palm plantation, by 4%/year rejuvenating rate there will be produced about 40.2 million tons/year OPT in Indonesia (Directorate General of Estates, 2019). Numerous researches internationally have now shown that OPT biochars characteristic for numerous function i.e. as a promising active carbon precusor (Hassan et al., 2021), biofuels (Sakulkit et al., 2020); an adsorbent for wastewater application (Razali & Kamarulzaman, 2020). However, research on the potential of biochar derived from OPT for use as soil amendment is rather scarce. Biochar in the soil has many advantages, as a high carbon content can feed soil microorganisms, and increase the cation exchange capacity (CEC) for the slow release of nutirents (Kumar & Bhattacharya, 2021). Biochar improves the nutrient retention capacity of soil, nutrient use efficiency and nutrient up take (Hossain et al., 2020). Only a limited number of studies have examined the oil palm seedlings growth performance of OPT biochar in Indonesia. The objectives of this study were to evaluate the effects of three distinct types of OPT biochars (biochar from top, middle, and bottom section OPT) on nutrient uptake and growth performance of oil palm seedlings in pre-nursery.

2. Material and Methods

2.1. Biochars Material

The oil palm trunk used in this research was Tenera variety, a hybrid Dura x Pesifera Simalungun (SP 540). Three types of biochar i.e. biochar derived from top, middle, and bottom section OPT were used, obtained from OPT biomass through a slow pyrolysis process at temperature in the range 300 °C – 400 °C in a drum retort kiln (Sianipar et al., 2024). The three biochar materials were assessed for basic characteristic, as for pH using Potentiometry (Horiba Laqua PC 1100, Japan); organic-C by gravimetry method (Ohaus Explorer 225D, and CEM Phoenix Microwave Furnace, USA); total extractable N by Kjeldahl method (Digestion block Gerhardt and Distillation Eppendorf, Germany); total-P2O5 by HNO3 method and spectrophotometry (destruction CEM MARS 6 China, Spectrophotometric UH 5300 HITACHI, Japan); total-K2O by HNO3 method and atomic absorption spectrophometer (destruction CEM MARS 6 China, Atomic Absorption Spetrophotometric Agilent), and Cation Exchange Capacity (Spectrophotometric Seal Brand Luebbe AA3).

2.2. Preparation of growing media

Using the ultisol soil of Typic Paleudults, topsoil from an oil palm plantation in Tambunan village, Selapian District, Langkat Regency, North Sumatera Province, at coordinates of 3026’6” North latitude and 98018’53’East longitude, was obtained for this experiment. After fine-mesh preparation and air drying, plant components and roots were extracted using a 2 mm sieve. To evaluate soil characteristics and nutrient concentrations, a soil sample was used for soil analysis. A glass electrode pH meter (Thermo Scientific Oriont Star A214, USA) with 1:2.5 soil to water suspension was used to monitor pH. The Walkley and Black method of acid dichromate digestion (Nelson & Sommers, 1996), the Kjeldahl method (Bremner & Mulvaney, 1982) (Digestion block Gerhardt and Distillation Eppendorf, Germany) was used to determine organic-C, the NH_4O-acetate pH 7.0 extraction method was used to determine CEC, and the Bray and Kurtz method (Bray & Kurtz, 1945) was used to measure total P. The leaching method was used to determine exchangeable K, Ca, Na, and Mg using 1 M NH_4O-acetate buffered at pH 7.0. Table 1.

2.3. Experimental Design

The experiment was conducted in the green house of The Agrotechnology Department of the Agriculture Faculty, University of Methodist Indonesia in Medan. The experiment was arranged in a non-factorial randomized complete block design (RCBD) with three replications in a polyethylene bag (polybag).

The oil palm seeds Tenera variety, a hybrid Dura x Pesifera Simalungun (SP 540) produced by Indonesia Oil Palm Research Institute (IOPRI), was used in this study with one seedling per polybag. Treatments were control (a soil media without any biochar) and four levels of biochar rate (1, 2, 3, and 4% w/w) derived from top, middle, and bottom section OPT. Therefore, there were 13 treatments (Table 1) by 3 replicates consisting of 39 units of experiment and unit experiment consisting of 3 germinated oil palms. A total of 117 germinated oil palms were used in this experiment. The air-dried soil (1 kg) was mixed with biochars thoroughly in polybags (10x12 cm with 16 cm diameter) as the growing media according to the treatments. The growing media was incubated for three days with soil moisture being maintained at 80% of field capacity through deionized water addition. Seedlings were planted into polybags allowed to establish for a month before being subjected to fertilizer. The polybags were placed at 30 cm plant-to-plant and 50 cm row-to-row distance in the greenhouse and kept under shade netting 50% shade level throughout the three months. All seedlings in the polybags received the same volumes of water, approximately 50 mL of deionized water two times per day to avoid water stress. Mineral fertilizers were applicated with the source of compound fertilizer (NPKMg: 15-15-6-4) at 5, 7, 9, 11 weeks after planted and urea at 4, 6, 8, 10 weeks after planted, fertilizers concentration 2% dilution in water by a volume 20 ml for a seedling as recommendation of IOPRI.

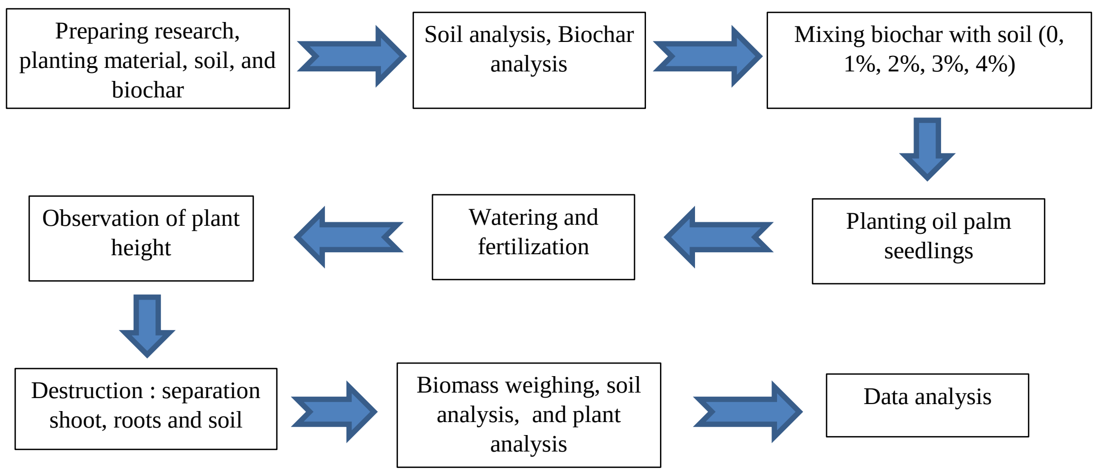

Figure 1. Research flow diagram

Table 1. List of treatment used to treat oil palm seedlings in this study

Type of OPT biochar	Treatment	OPT biochar (w/w)	Fertilizer Application*
	B0	**0% (without biochar)**	
Top	B1	1%	
	B2	2%	
	B3	3%	
	B4	4%	
Middle	B5	1%	Urea was applied at 4, 6, 8, 10 week after sowing; NPKMg (15, 15, 6, 4) at 5, 7, 9, 11 week after sowing by concentration 2% dilution in water by a volume 20 ml for a seedling.
	B6	2%	
	B7	3%	
	B8	4%	
Bottom	B9	1%	
	B10	2%	
	B11	3%	
	B12	4%	

*Recommendation of Indonesia Oil Palm Research Institute (IOPRI)

2.4. Measurement of Oil Palm Seedlings Growth

Data was gathered at 3, 6, 9, and 12 weeks after sowing, and the growth parameters of the oil palms were monitored throughout the treatment period. Plant height and dry weights make up the growth characteristics. A measuring tape was used to record the height of the plants from the base of the stem, also known as the bole, to the end of the longest fully opened leaves. The stem diameter was measured with a digital caliper. The samples were dried for 48 hours, or until their weight didn't change, in an oven preheated to 70 °C. Samples were then weighed using an electronic balance after that.

2.5. Plant Analysis

After being planted for 12 weeks, the seedlings were picked. The roots were meticulously extracted from the soil and cleared of any remaining dirt particles. The roots were cut out from the seedlings by making a cut at the base of the stem. Before estimating the dry weight, both the above ground and root biomass were oven-dried for 48 hours at 70 °C until they reached a consistent weight. To analyze macronutrients (N, P, and K), both above ground biomass and roots were ground separately with a grinding machine (<2 mm). Dried leaves, stems, and roots were pulverized to 1 mm size and sieved through. One gram of the materials was burned in a furnace for one hour at 300 °C and then again for five hours at 500 °C using the dry ashing digesting method. The samples were then exposed to N, P, and K analysis. Plant nitrogen content was calculated using the Kjeldahl digestion method (Nelson & Sommers, 1982).

The soil sample was treated with sodium thiosulphate pentahydrate, sulfuric–salicylic acid, and a catalyst to achieve a clear solution. After the digested solution was added to sodium hydroxide (NaOH), it was distilled, and using methyl red and methylene blue as indicators, it was titrated against 0.02 N H2SO4 (made from concentrated acid of 98%). The phosphovanadate-molydate complex technique was used to calculate the total-P2O5 (Mills, 1996). An equal parts solution of sulfuric and perchloric acid was used to break down the soil. The extract was then mixed with vanadate molybdate to produce a yellow solution appropriate for UV-Vis spectrophotometer (Shimadzu, UV1800) examination at 425 nm. For the total-K2O extraction with 25% HCl. The 0.1 g plant sample was broken down using strong sulfuric acid and a catalyst mixture containing 1 g of selenium and 100 g of sodium sulfate until the mixture became transparent. In a conical flask containing boric acid, the digested solution was added along with distilled water and NaOH. After that, it was distilled and titrated using screen purple indicator, an ethanolic mixture of methyl red and methylene blue, against 0.02 N H2SO4. For P and K, HNO3 was added to the ash sample. For one hour, the samples were allowed to break down in a water bath. The digested material was filtered and then poured to capacity in a volumetric flask. K concentration was determined using a flame photometer (Watson & Isaac, 1990). A 1-hour incubation period was allowed for 1 milliliter of the digested sample solution and 5 milliliters of ammonium vanadate/molybdate (Mills, 1996). With the use of a UV-Vis spectrophotometer (ICP-OES Optima 7300 DV Pelkin Elmer USA), the sample's absorbance was determined at 425 nm. Utilizing plant biomass multiplied by the entire amount of N, P, and K in the plant, plant N, P, and K uptake was determined.

2.6. Soil Nutrient Analysis

Twelve weeks after planting, the soil was checked for total N, P, and K. Using the Kjeldahl digestion method, the total nitrogen (N) in the soil was calculated (Nelson Sommers, 1982).

2.7. Statistical Analysis

Utilizing IBM SPSS Statistic for Windows 20, the data were analyzed to determine the treatment's impact. To find treatment differences that were statistically important, one-way ANOVA was used. The difference between treatment combinations was quantified using Duncan's Multiple Range Test (DMRT) at a p-value of <0.05.

3. Results and Discussion

3.1. Soil and Biochar Properties

The laboratory analysis results showed that the chemical properties of soil were pH 5,10 (Acid), organic-C 1,01% (low), total-N 0,12% (low), C/N ratio 8,42 (low), cation exchange capacity (CEC) 13,94 me/100 g (low), base saturation 10,00% (low). Soil particles were dominated by sand particles and the texture was determined by the hydrometer method to be sandy clay loam. Table 2 has detailed information on the soil's properties. The chemical fertility status of the soil according to Soil research center Bogor (PPT Bogor), which is based on CEC, base saturation, organic-C content, total K_2O, and total P_2O_5 was classified as low. The main limiting factor that causes low soil fertility is the low organic matter content (Siregar, et al., 2024)

Table 2. Properties of soil and biochars derived bottom, middle and top section OPT

No	Property	Soil	Biochar		
			Bottom	Middle	Top
1	pH (H_2O)	5,10	8,50	8,20	7,60
2	Organic-C (%)	1,01	52,93	50,32	35,63
3	Total-N (%)	0,12	0,19	0,18	0,30
4	C/N ratio	8,42	278,00	279,55	118,76
5	Total-P_2O_5 (%)	0,21	0,27	0,53	0,46
6	Total-K_2O (%)	0,24	3,16	4,37	3,95
7	CEC (me/100 g)	13,94	30,00	31,04	29,69
8	CCE (%)		0,47	2,35	0,25
9	Ash Content (%)		8,76	13,25	38,57
9	Exchangeable-K (me/100 g)	0,25	-	-	-
10	Exchangeable-Ca (me/100 g)	0,80	-	-	-
11	Exchangeable-Na (me/100 g)	0,11	-	-	-
12	Exchangeable-Mg (me/100 g)	0,30	-	-	-
13	Base Saturation (%)	10,00	-	-	-
14	Texture: sandy clay loam				
	- Sand (%)	48,00	-	-	-
	- Silt (%)	18,00	-	-	-
	- Clay (%)	34,00	-	-	-

CEC: Cation Exchange Capacity, CCE: Calcium Carbonat Equivalent

On the other side, the chemical property of biochar as follows: pH is classified alkaline (7,60 – 8,50), organic-C content is classified very high (35,63 – 52,93%), CEC is classified high (29,69 – 31,04 me 100g-1, total K2O is classified very high (3,16 – 4,37%).

3.2. Growth Performance

There were no significants differences in plant height until 6 weeks after sowing. OPT Biochar amendment up to 2% (B2) increased in plant height up to 30.5 cm at 12 weeks after sowing (Table 3). Then, there were no significants differences in plant height due to biochar amendment up to 2%-4%. Similarly, biochar amendment at 1% (B1, B5, B9) increased in plant height, of 27.63, 27.77, and 27.77 cm respectively, were no significants differences compared to without biochar amendent (B0) 24,87 cm plant height. This study showed that OPT biochar improved plant growth during the first 9 weeks after sowing pre-nursery in the Ultisol, being suitable as soil amendment at 2% rate of application.

Table 3. The height of the oil palm seedlings at 3, 6, 9, and 12 weeks after sowing (WAS)

Treat-ment	3 WAS	6 WAS	9 WAS	12 WAS
	....	cm	....	
B0	3,50 ± 0,56	10,17 ± 0,81	17,47 ± 0,71a	24,87 ± 0,93a
B1	3,57 ± 0,68	10,60 ± 0,82	19,17 ± 0,85ab	27,63 ± 0,67ab
B2	3,53 ± 0,85	11,83 ± 0,70	21,13 ± 1,37b	30,50 ± 2,05b
B3	3,67 ± 0,57	11,87 ± 0,40	21,07 ± 0,78b	30,13 ± 1,64b
B4	3,60 ± 0,70	11,87 ± 0,87	21,03 ± 0,78b	30,07 ± 1,76b
B5	3,53 ± 0,65	10,63 ± 0,68	19,13 ± 1,14ab	27,77 ± 1,80ab
B6	3,63 ± 0,64	11,83 ± 0,55	20,63 ± 1,30b	29,57 ± 2,11b
B7	3,57 ± 0,75	11,83 ± 1,11	20,77 ± 0,85b	29,40 ± 1,25b
B8	3,60 ± 0,75	11,97 ± 0,72	20,80 ± 0,95b	29,40 ± 1,21b
B9	3,50 ± 0,62	11,13 ± 0,95	19,30 ± 1,31b	27,77 ± 2,08ab
B10	3,60 ± 0,66	11,83 ± 0,83	21,03 ± 1,21b	29,50 ± 2,07b
B11	3,60 ± 0,62	11,87 ± 1,00	20,47 ± 1,22b	29,50 ± 1,25b
B12	3,63 ± 0,71	11,87 ± 0,70	20,67 ± 1,69b	29,23 ± 1,50b

A significant difference between the treatments at $p < 0.05$ is indicated by different letters in a single column. (The multiple range test by Duncan). The values from the experiment with n = 3 are shown as means ± standard deviation.

Plant biomass is shown in Table 4. Application biochar as soil amendment, an increase in root dry weight, shoot dry weight, plant dry weight and shoot: root ratio by 26 g (B2), 2.91 g (B2), 4,17 g (B2) and 2.33 g (B7, B8) respectively, was observed when compared to without biochar application (B0). Oil palm biomass is produced through the process of photosynthesis, where carbon dioxide (CO_2) and water (H_2O) are converted into carbohydrates (CH_2O). Yulianti (2009) studied the conversion results from biomass using carbon content of the oil palm biomass is obtained 0,7 – 16,43 tons H-1. Biochar application increased water retention capacity in soil. Higher water permeability enables faster germination and earlier seedling establishment which allows for competitive advantage for vigorous initial seedling growth (Mohamed-Yasseen et al., 1994).

Table 4. Root, shoot and plant dry weight with shoot:root ratio

Treatment	Root dry weight	Shoot dry weight	Plant dry weight	Shoot:root ratio
		.... g	....	
B0	0,84 ± 0,08a	1,68 ± 0,09a	2,53 ± 0,16a	2,00 ± 0,14a
B1	0,93 ± 0,06a	1,87 ± 0,07b	2,80 ± 0,12b	2,02 ± 0,06a
B2	1,26 ± 0,10b	2,91 ± 0,09c	4,17 ± 0,19c	2,31 ± 0,13b
B3	1,26 ± 0,09b	2,90 ± 0,08c	4,17 ± 0,17c	2,30 ± 0,10b
B4	1,26 ± 0,09b	2,90 ± 0,09c	4,16 ± 0,17c	2,31 ± 0,09b
B5	0,93 ± 0,10a	1,88 ± 0,10b	2,80 ± 0,20b	2,03 ± 0,10a
B6	1,25 ± 0,11b	2,90 ± 0,11c	4,15 ± 0,21c	2,32 ± 0,11b
B7	1,25 ± 0,09b	2,89 ± 0,09c	4,14 ± 0,18c	2,33 ± 0,10b
B8	1,25 ± 0,08b	2,90 ± 0,09c	4,15 ± 0,17c	2,33 ± 0,08b
B9	0,94 ± 0,11a	1,89 ± 0,11b	2,82 ± 0,22b	2,02 ± 0,12a
B10	1,25 ± 0,10b	2,89 ± 0,10c	4,14 ± 0,19c	2,32 ± 0,12b
B11	1,25 ± 0,08b	2,90 ± 0,08c	4,15 ± 0,15c	2,32 ± 0,08b
B12	1,25 ± 0,09b	2,90 ± 0,09c	4,15 ± 0,18c	2,32 ± 0,09b

Significant differences between teeatments are indicated by different letters in the same column ($p<0.05$). (The Duncan's Multiple Range Test). The values are presented as means ± standard deviation of data obtained in the experiment with n = 3.

The highest dry weight of root, shoot, and plant which 1,26 g, 2,91 g, and 4,17 g respectively were obtained by 2% OPT biochar amended media (B2). Table 3 and Table 4 showed the average height and biomass of oil palm seedlings treated with oil palm trunk biochar. As observed, the seedlings grown in soil amended with 2% OPT biochar showed improved plant height and biomass, in comparison to those planted in untreated soil (0 % OPT biochar) and 1 % OPT biochar. The positive effects of biochar in combination with mineral fertilizer on plant growth (plant height and biomass) were similarly reported by Hwong et al. (2022).These results indicated that the increased biochar rate up to 2% (w/w) enhanced the growth longer and thicker tertiary and quaternary roots (Yahya, et al., 2010), which improved the water and nutrient availability for oil palm seedling growth. Plants in biochar-amended soils had larger rhizosphere zones than the control treatment (Prendergast-Miller et al., 2013). In contrast to Suryanti et al., (2023) reported that the application of biochar did not significantly affect the growth of oil palm seedlings in the pre-nusery.

In addition, the primary mechanism of biochar's liming actions in acidic soils was thought to be responsible for increasing plant biomass and growth (Farrell et al., 2014). The oil palm growth responses significantly correlated with increasing pH resulting from the liming effect of the biochar. Acidic soil conditions constrain plant growth through limiting the availability of key nutirents N, P, K, S, Mg and Mn (Macdonald, et. al., 2014).

3.3. Soil Macronutrient Status

Significant variations were between the control treatments and biochar applications in terms of soil total N, P, and K. By applying biochars, the total N, P, and K content of the soil was raised to 0,37-0,49, 0,23-0,40, and 0,06-0,14%, respectively (Table 5). The application rates of B6 (2% biochar derived from middle OPT), B4 (4% biochar generated from top OPT), and B8 (4% biochar derived from top OPT) yielded the highest increases in soil total N, P, and K, respectively. The results also revealed that increasing the biochar up to 2% increases the soil total N, P, and K. The lowest total N, P, and K of soil content was found without biochar application (B0).

The degree to which fertilizers' nutrients are absorbed and desorbed determines how beneficial they are. Adsorption is the process via which ions carrying nutrients—K^+, Ca^{++}, Mg^{++}, NH_4^+, and so on—attach themselves to the negatively charged surfaces of minerals, such as zeolite and clinoptilolite, as well as organic compounds (Ahmed et al., 2008). Additionally, biochar particles retained soil nitrogen (N) (Prendergast-Miller, et al., 2013) and enhanced the fixation of N_2 in soil (Clough et al., 2013), The adsorption isotherms of soil alone showed the maximum bonding energy when phosphorus was fixed by exchangeable Al^{3+} and Fe^{2+} ions. For instance, this reaction turns soluble P (or orthophosphates) into insoluble P (Hinsinger, 2001).

Table 5. Soil macronutrient content (N, P, K)

Treatment	Total-N	Total-P	Total-K
	....	%	....
B0	0,37 ± 0,02a	0,23 ± 0,03a	0,06 ± 0,03a
B1	0,44 ± 0,04b	0,27 ± 0,02b	0,09 ± 0,02ab
B2	0,47 ± 0,03b	0,29 ± 0,03bcd	0,11 ± 0,02bc
B3	0,48 ± 0,03b	0,33 ± 0,02def	0,11 ± 0,02bc
B4	0,48 ± 0,03b	0,40 ± 0,03g	0,11 ± 0,02bc
B5	0,44 ± 0,04b	0,25 ± 0,04ab	0,08 ± 0,02ab
B6	0,49 ± 0,03b	0,32 ± 0,02cde	0,11 ± 0,02bc
B7	0,45 ± 0,03b	0,35 ± 0,02ef	0,12 ± 0,01bc
B8	0,46 ± 0,04b	0,37 ± 0,02fg	0,14 ± 0,02c
B9	0,44 ± 0,04b	0,25 ± 0,03ab	0,09 ± 0,02ab
B10	0,46 ± 0,04b	0,28 ± 0,02bc	0,10 ± 0,02ab
B11	0,45 ± 0,04b	0,35 ± 0,02ef	0,11 ± 0,02bc
B12	0,47 ± 0,04b	0,34 ± 0,03ef	0,11 ± 0,04bc

Significant differences between teeatments are indicated by different letters in the same column ($p<0.05$). (The Duncan's Multiple Range Test). The values are presented as means ± standard deviation of data obtained in the experiment with n = 3.

The aforementioned ions are absorbed by organic additives' carboxyl, phenolic, and alcoholic functional groups, which then gradually release (desorb) the ions for opportune plant uptake. When nutrients that have been absorbed are released from the surface of inorganic minerals and organic materials in the soil, desorption takes place (Latifah et al., 2018).

3.4. NPK uptake by the oil palm seedlings

Table 6. showed that all biochar treatments increased N, P, and K uptake compared to the control (B0). This uptake in B0 plants had the lowest N, P, and K content when compared to the biochar treatment. However, plant absorption increased by 2% across all biochar material applications (B2, B6, and B10). The addition of biochar to the soil has a considerable impact on the uptake of these chemicals. Furthermore, biochar generated from top OPT contained larger levels of these chemicals for plant development than middle and bottom biochars.

Biochars must contain critical nutrients such as N, P, and K, even in minimal levels, so the roots can absorb the nutrients (Sianipar et al., 2024); (Wang et al., 2015). As a result, it is probable that the predominant source of N, P, and K in all treatments is the solubilization of chemical fertilizer with biochar. This was associated with the enhanced soil cation exchange capacity upon biochar treatment (Hwong et al., 2022). Biochars adsorb nutrients via complexation, ion exchange, chemical precipitation, and electrostatic interaction (Nartey & Zhao, 2014). In comparison to absorbed nutrients, absorbed nutrients are the most significant since they are readily absorbed by plants.

Table 6. NPK uptake by the seedlings at time of harvest.

Treatment	N-uptake	P-uptake	K-uptake
	....	mg/plant	....
B0	63,54 ± 6,95a	3,79 ± 0,38a	42,24 ± 4,1a
B1	74,64 ± 2,59b	4,77 ± 0,48b	55,21 ± 0,9b
B2	112,38 ± 2,56c	7,78 ± 0,22c	84,86 ± 2,1c
B3	113,69 ± 2,79c	7,78 ± 0,39c	84,63 ± 1,4c
B4	113,15 ± 7,97c	7,75 ± 0,10c	84,28 ± 0,5c
B5	74,63 ± 5,13b	4,67 ± 0,41b	53,88 ± 5,1b
B6	111,44 ± 7,15c	7,34 ± 0,93c	85,00 ± 5,3c
B7	111,91 ± 5,49c	7,44 ± 0,10c	82,72 ± 6,2c
B8	112,14 ± 5,34c	7,47 ± 0,44c	85,07 ± 6,2c
B9	73,91 ± 4,85b	4,62 ± 0,53b	55,82 ± 2,7b
B10	109,60 ± 7,73c	7,45 ± 0,43c	83,08 ± 7,1c
B11	109,67 ± 5,47c	7,47 ± 0,15c	84,09 ± 5,7c
B12	109,89 ± 6,69c	7,48 ± 0,63c	83,90 ± 1,3c

Significant differences between treatments are indicated by different letters in the same column ($p < 0.05$). (The Duncan's Multiple Range Test). The values are shown as means ± standard deviation of data acquired in the experiment with n=3.

According to Chan et al. (2008), the application of biochar greatly boosted plant production and N (nitrogen) utilization efficiency when N fertilizer was present. This indicates a favorable (synergistic) relationship between biochar and nitrogen fertilizer (Chan et al., 2007). Applying phosphate fertilizers to soil with a lower pH sometimes results in its quick precipitation by iron and aluminum, which prevents P from being absorbed by the crops (Sung et al., 2017). By directly releasing P from the biochar and indirectly enhancing P usage efficiency by affecting soil pH, biochar can increase P availability when incorporated into soil (Xu et al., 2014).

Figure 2. Seedling growth at 12-week age

The biochar treatment was discovered to significantly enhance the uptake of N, P, and K. Despite being slightly acidic in pH. Temperature, floods, redox potential, pH buffering capacity, and soil pH all have a major impact on nutrient adsorption (Dada et al., 2012). The quantity of nutrient uptake by plants has a significant impact on photosynthetic outcomes and photosynthate transfer, particularly dry weight (Neoriky et al., 2017). However, because of the excess total N, P, and K in the soil because of the chemical fertilizer given, the rates of applied NPK fertilizers on the ultisol must be adjusted. To prevent overfertilization, more research on the combination of a higher rate of biochar and a lower amount of mineral fertilizer is necessary.

4. Conclusion

The research indicated that OPT biochars application increased oil palm seedlings growth, the N, P, K soil nutrient status, and the N, P, K uptake by the seedlings. The application of biochar derived from top section OPT provided better growth and N, P, K uptake than biochar derived bottom and middle section OPT. The findings revealed the application of biochars OPT at 2% (w/w) was more efficient for soil amendment to ultisols soil.

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