EXAMINING THE USE OF SUBSOIL AS MEDIA FOR OIL PALM SEEDLINGS IN THE MAIN NURSERY

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ABSTRACT

Planting media determine the quality of oil palm seedlings. However, the continued removal of topsoil from plantation areas to be used as seedling growth media caused topsoil depletion. Thus alternative media such as vermicompost needs to be investigated. The aim of this study is to examine alternative media for the main nursery. This research is an extension of a pre-nursery media study. Seedlings from the pre-nursery study were planted in the main nursery using either similar pre-nursery or subsoil media. The research design was a randomised factorial design with two factors. The first factor was: Initial pre-nursery medium, consist six treatments: 100% topsoil, 100% subsoil, 100% vermicompost, 75% subsoil + 25% vermicompost, 50% subsoil + 50% vermicompost, 25% subsoil + 75% vermicompost. The second factor was the main-nursery planting media, which consists of two treatments: similar to pre-nursery and subsoil media. The results showed that the initial pre-nursery media significantly affected the growth of oil palm seedlings in the main nursery at ages 16-22 weeks but not at 24 weeks. The best oil palm seedlings' growth was the ones grown on vermicompost and subsoil mixed with vermicompost. Subsoil could replace topsoil as a growth medium in the main nursery when the oil palm seeds were grown on fertile media during pre-nursery.

Keywords: main-nursery media, pre-nursery media, subsoil, topsoil, vermicompost.

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INTRODUCTION

The success of an oil palm plantation investment depends on the soil, climate, human resources, and the quality of seeds and seedlings. Oil palm nursery techniques are double-stage nurseries, namely pre-nursery and main-nursery. The pre-nursery aims to obtain favourable conditions for oil palm seedlings to grow consistently when transferred to the main-nursery. The main-nursery prepares the plants to thrive before being transferred to the field. One of the efforts to achieve optimal results in developing oil palm cultivation is using fertile planting media for the seedlings (Hernando *et al*., 2017).

Oil palm seeds require excellent growth media to thrive. The oil palm nursery media commonly consist of topsoil mixed with sand and organic matter to ensure good fertile soil. Nurseries commonly use polybags in the main nursery requiring 15-20 kg of soil for each polybag. As 1 ha of plantation requires 134 seedlings, around 150-170 seedlings should be prepared; therefore, the required amount of topsoil is about 2.25-3.40 t ha^{-1}. These topsoils need to be taken from the plantation area. This amount is about twice the global soil erosion rate of 1.40 t ha^{-1} yr^{-1} (Wuepper *et al*., 2020). Continuous removal of topsoil from oil palm land will deplete the soil's fertility, affecting oil palm production. Thus the continuous use of topsoil as growth media cannot be sustainable.

Several efforts have been made to obtain optimum and healthy oil palm seedling growth. For example, applying biofertilisers containing low chemical fertiliser rates has resulted in higher

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vegetative measurements (Zainuddin *et al*., 2019), while vermicompost exhibits good potential to be a viable substitute for chemical fertilisers (Hayawin *et al*., 2016). Sundram (2010) reported that inoculation of oil palm seedlings with arbuscular-mycorrhiza fungi significantly affects the vegetative growth of oil palm seedlings and nutrient uptake. Furthermore, it will overcome the phosphorus deficiency of acidic soil in most Malaysian oil palm plantations.

Vermicompost is a nutrient-rich, microbiologically active organic matter, that results from interactions between earthworms and microorganisms during the breakdown of organic matter. It is stable with a low C:N ratio, high porosity, and water-holding capacity, where most of the nutrients are present in a form available for uptake by plants (Domínguez, 2004). The addition of vermicompost to the growing media has accelerated plant growth and increased plant height and weight (Sabrina *et al*., 2013). Vermicompost has many advantages compared to other organic fertilisers. It is rich in essential macro and micronutrients, and contains plant growth hormones such as auxins, gibberellins and cytokinins for supporting plant growth (Kumar *et al*., 2022).

Due to the policy made by the Indonesian government on integrated husbandry on plantation land, a certain amount of cow dung is available. Several composting technologies are available, one of which is vermicompost. As described in the previous paragraph, vermicompost is proven to have advantages compared to ordinary compost, including higher nutrient availability. Therefore, this study used vermicompost as a medium for growing oil palm seedlings and looked for the best composition to match the growth of oil palm seedlings with the media commonly used.

Our previous research in pre-nursery shows that subsoil mixed with vermicompost at various compositions significantly increased the growth of oil palm seedlings in the pre-nursery (Sabrina, unpublished). The wet weight and dry weight of shoots and roots of pre-nursery seedlings grown on media using 100% subsoil were lower than the wet weight and dry weight of shoots and roots of oil palm seedlings grown on 100% topsoil. The addition of vermicompost as much as 25%, 50% and 75% in the subsoil was able to significantly increase the wet and dry weights of shoots and roots of oil palm pre-nursery seedlings. The growth due to the addition of vermicompost was even better when compared to the wet and dry weights of the crown and roots of oil palm seedlings grown on the standard medium, namely topsoil, although not significantly different. The results obtained differed from the statement of Akpo *et al*. (2014), who reported that the media substrate did not affect the growth of oil palm seedlings. They showed that the seedling height and stem diameter followed exponential growth while the number of leaves increased linearly over time. The results of our pre-nursery study indicate that the topsoil growing media rich in nutrients can be replaced with subsoil by adding the right type and amount of organic matter to the subsoil. Based on this promising result, further research was conducted to determine the effect of the main nursery planting media on the growth of oil palm seedlings derived from the pre-nursery research.

MATERIALS AND METHODS

Study Site and Materials

The research was conducted at the university experimental field in Medan. The materials used in this study were oil palm seeds of D×P Simalungun variety, topsoil, subsoil, vermicompost, 50 × 40 cm polybag, urea fertiliser, NPK 16:16:16 fertiliser. Insecticides with the active ingredient deltamethrin, and fungicides with the active ingredient propineb were used to prevent pests and diseases.

The nutrient content and physical properties of the growing media used are shown in *Table 1*. Bulk density and porosity were measured by placing the media in polybags without plants. At the end of the pre-nursery, ring samples were taken to obtain bulk density and porosity values.

Experimental Design

This research is a continuation of an earlier pre-nursery study. In the pre-nursery, oil palm seeds were planted in the planting medium, which is the first treatment in this study. The research design used was a factorial randomised block design comprising two factors: (1) The planting medium for pre-nursery seeds (*i.e.*, the planting media used when the seeds are still in the pre-nursery), consisting of six treatments, namely 100% topsoil, 100% subsoil, 100% vermicompost, 75% subsoil + 25% vermicompost (w/w), 50% subsoil + 50% vermicompost (w/w), and 25% subsoil + 75% vermicompost (w/w); and (2) the main-nursery planting media, consisting of two treatments similar to the pre-nursery planting media and subsoil media. The total treatments were 12 treatments, with three replications. Each treatment replication had five plants that grew in a different polybag.

Preparing Experiment

The seedlings in pre-nursery were watered until saturated, so the planting medium compacted so that it did not crumble when transferred to

TABLE 1. THE CHARACTERISTICS OF MEDIA OF EACH TREATMENT

Characteristics		Treatments					
		100% TS	100% SS	100% VC	$SS_{75}VC_{25}$	$SS_{50}VC_{50}$	$SS_{25}VC_{75}$
pH		5.83	5.74	7.66	7.21	7.27	7.31
C-Organic	%	0.73	0.52	3.16	3.04	3.31	3.32
Nitrogen	%	0.04	0.02	1.01	0.10	0.31	0.60
C/N		18.32	25.81	3.12	30.39	10.67	5.53
P-avail	ppm	0.74	0.59	23.46	19.67	20.24	24.21
CEC	$cmol(+)kg^{-1}$	10.96	14.95	19.72	14.06	18.37	18.16
K-exch	$cmol(+)kg^{-1}$	0.39	0.68	19.80	5.71	13.68	15.25
Ca-exch	$cmol(+)kg^{-1}$	4.30	5.04	4.55	4.32	4.63	3.73
Mg-exch	$cmol(+)kg^{-1}$	2.61	5.19	21.24	6.63	8.94	13.84
Na-exch	$cmol(+)kg^{-1}$	0.32	0.68	5.01	1.22	2.25	2.94
Base-saturation	%	69.53	77.53	256.59	127.17	160.59	196.92
Bulk density	$g\ cm^{-3}$	1.02	1.03	0.58	0.99	0.88	0.66
Porosity	%	48.89	46.94	51.28	43.21	47.73	48.86

Note: 100% TS - 100% topsoil; 100% SS - 100% subsoil; 100% VC - 100% vermicompost; $SS_{75}VC_{25}$ - 75% subsoil + 25% (w/w) vermicompost; $SS_{50}VC_{50}$ - 50% subsoil + 50% (w/w) vermicompost; $SS_{25}VC_{75}$ - 25% subsoil + 75% vermicompost (w/w).

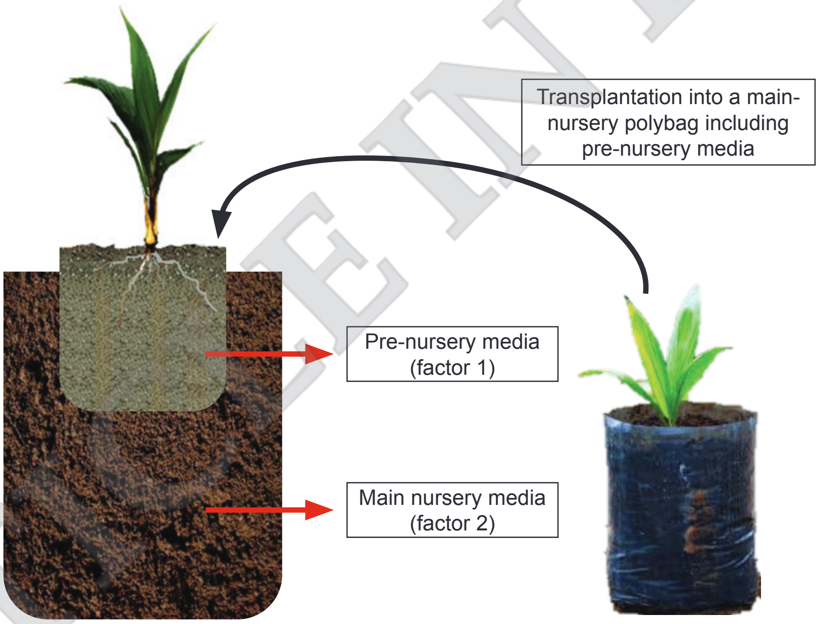

Figure 1. Building treatments.

the main-nursery polybag. The planting hole was made according to the size of the polybag in the pre-nursery (*Figure 1*).

The polybag in the pre-nursery was slashed at the bottom circle, then placed in the main-nursery polybag. The right and left of the pre-nursery seedling polybag were cut vertically. The polybag was slowly pulled into the planting hole to ensure that the soil containing pre-nursery seedlings did not break. The cavities in the planting holes were filled with the planting medium based on the type of treatment. The plants were then watered until the soil was saturated, after which the planting media compact back.

Plant Maintenance

Oil palm seedlings were watered every morning and afternoon, with the same amount of water for each polybag (2 L $polybag^{-1}$ day^{-1}). However, when it rains, watering was discontinued.

Fertiliser NPK was applied 2.5 g $polybag^{-1}$ for 12-15 weeks, 5.0 g $polybag^{-1}$ for seedlings at 16-17 weeks, 7.5 g $polybag^{-1}$ for seedlings at age

18-20 weeks, and 10.0 g polybag^{-1} for seedlings at the 22-24 weeks. Meanwhile, urea fertiliser was applied to oil palm seedlings with a dosage of 2 g L^{-1} water weekly during pre-nursery.

Parameter of Seedling Growth

Three replications of five seedlings in each treatment were sampled at every data collection period. Seedling height (cm) was measured using a measuring tape. The height was taken from the base of the stem (or bole) until the end of the third fully opened leaf. Stem diameter was measured using a calliper about 1 cm from the soil surface by measuring the two opposite sides of the stem, the values were averaged. Furthermore, the stem circumference was calculated (mm). The position of the stem diameter measurement point was marked with a colour mark and was sampled at every data collection period.

Data Analysis

Analysis of variance (ANOVA) was performed using Microsoft Excel and Statistical Analysis Software, SAS 9.4. Further analysis used Duncan's Multiple Range Test at $p \leq 0.05$. Graph made using Sigmaplot software v15.

RESULTS AND DISCUSSION

Pre-nursery planting media treatment significantly affected the height and stem circumference of oil palm seedlings at the age of 16 to 22 weeks in the main-nursery. In contrast, the main-nursery planting media treatment had no significant effect on oil palm seedling height and stem circumference at all ages of observation and the interaction between the initial planting media.

Pre-nursery planting media treatment still significantly affected growth in height and stem circle of oil palm seedlings up to 22 weeks of age (*Table 2*).

At 22 weeks, vermicompost growing media produced significantly higher seedlings height (*Table 3*) and stem circumference than those grown on 100% subsoil media (*Table 4*). However, the effect of pre-nursery planting media was not statistically significant on stem circumference for the 24-week-old seedling. The growth of oil palm seedlings planted on the same media as pre-nursery media was higher than that planted on subsoil media during the nursery period. The difference is seen after the seedlings were 20 weeks old.

Although the plant height and stem circumference in 100% vermicompost treatment were the best, it was not significantly different from the 100% topsoil treatment and subsoil with vermicompost mixture at all compositions at seedling ages of 22 weeks (*Table 3* and *4*). Treatment using 50% and 75% subsoil produced higher seedlings than 100% vermicompost at 24 weeks (*Figure 2*). This may be due to the supply of mineral micronutrients.

The difference in height and stem circumference of seedlings grown in similar pre-nursery media was higher than that of seedlings grown using subsoil. Further observation shows that the difference in plant height in the main-nursery media treatment was larger. It was observed that at the age of 16 weeks, there was an increase from 0.69 cm to

TABLE 2. SUMMARY OF ANALYSIS OF VARIANCE

Parameters and time of observation	Treatments			Coefficient of variability (CV)
	Pre-nursery media	Main-nursery media	Interaction pre-nursery x main-nursery media	
Seedling height				
16 weeks	*	ns	ns	8.05
18 weeks	*	ns	ns	7.05
20 weeks	*	ns	ns	6.35
22 weeks	*	ns	ns	6.44
24 weeks	ns	ns	ns	8.37
Seedling stem circle				
16 weeks	*	ns	ns	9.22
18 weeks	*	ns	ns	8.32
20 weeks	*	ns	ns	6.99
22 weeks	*	ns	ns	6.18
24 weeks	ns	ns	ns	5.81

Note: * - means significant at 5% level; ns - not significant.

1.83 cm. Many of oil palm seedling's roots at aged 24 weeks had reached the added media in the main nursery, so the effect of main-nursery media began to show a difference between treatments.

Topsoil is the standard medium for oil palm nurseries. Using 100% vermicompost growing media from pre-nursery resulted in the best seedlings' growth with the largest stem circumference. The same condition can also be observed in subsoil media with added vermicompost of 25%, 50% and 75%. These mixtures outperformed the height of oil palm seedlings planted in only topsoil or subsoil planting media. At 24 weeks, the seedling grown on vermicompost-treated media performed much better than using either topsoil or subsoil (*Figure 2*).

At the age of 18-22 weeks, the stem circumference of seedlings grown on a similar medium as in the pre-nursery showed greater yield when compared to those grown on sub-soil medium. However, the difference of seedling grown on medium similar to pre-nursery was only 1.37% than subsoil at 18 weeks seedlings age, 0.64% than subsoil at 20 weeks seedling age, and 1.17% than subsoil at 22 weeks seedling age (*Figure 3*).

Vermicompost is also able to improve the physical properties of the subsoil. However, it also provides better physical and chemical properties and adds nutrients to the plants in nutrient-poor subsoil (*Table 1*). Subsoil treated with vermicomposts showed higher pH that is neutral, higher organic carbon, nitrogen content,

TABLE 3. THE EFFECT OF PRE-NURSERY MEDIA AND MAIN NURSERY MEDIA ON THE SEEDLING HEIGHT AT THE MAIN NURSERY

Treatments	Seedling age (week)				
	16	18	20	22	24
		…………………….	cm	…………………	
Initial pre-nursery media					
100% *Top soil*	29.07 ab	32.65 ab	35.72 ab	40.18 ab	45.34
100% *Sub soil*	26.65 b	30.27 b	34.13 b	37.08 b	44.10
100% vermicompost	33.56 a	37.01 a	39.73 a	42.66 a	48.26
75% *Subsoil* + 25% vermicompost	31.53 ab	35.02 ab	37.76 ab	41.29 ab	49.52
50% *Sub soil* + 50% vermicompost	31.12 ab	34.33 ab	37.28 ab	40.53 ab	48.33
25% *Sub soil* + 75% vermicompost	33.46 a	36.33 a	38.78 ab	42.48 a	47.85
Main nursery Media					
Similar to *pre-nursery media*	30.90	34.48	37.43	41.11	48.03
Subsoil	30.21	33.22	36.34	39.59	46.20

Note: Values within a column followed by a different alphabet are significant a≤0.05 using Duncan'multiple range test.

TABLE 4. THE EFFECT OF PRE-NURSERY MEDIA AND MAIN-NURSERY MEDIA ON SEEDLING STEM CIRCUMFERENCE AT MAIN- NURSERY

Treatments	Seedling age (week)				
	16	18	20	22	24
		…………………….	cm	…………………	
Initial pre-nursery media					
100% *Top soil*	4.10 ab	4.44 ab	4.75 ab	5.14 ab	5.50
100% *Sub soil*	3.68 b	3.95 b	4.40 b	4.94 b	5.36
100% vermicompost	4.59 a	4.90 a	5.22 a	5.58 a	5.93
75% *Subsoil* + 25% vermicompost	4.27 ab	4.61 ab	5.02 ab	5.52 ab	5.86
50% *Sub soil* + 50% vermicompost	4.35 ab	4.68 ab	4.99 ab	5.43 ab	5.85
25% *Sub soil* + 75% vermicompost	4.43 ab	4.73 ab	5.06 ab	5.48 ab	5.76
Main nursery Media					
Similar to *pre-nursery media*	4.26	4.59	4.94	5.40	5.76
Subsoil	4.16	4.48	4.84	5.29	5.68

Note: Values within a column followed by different alphabet are significant a≤0.05 using Duncan'multiple range test.

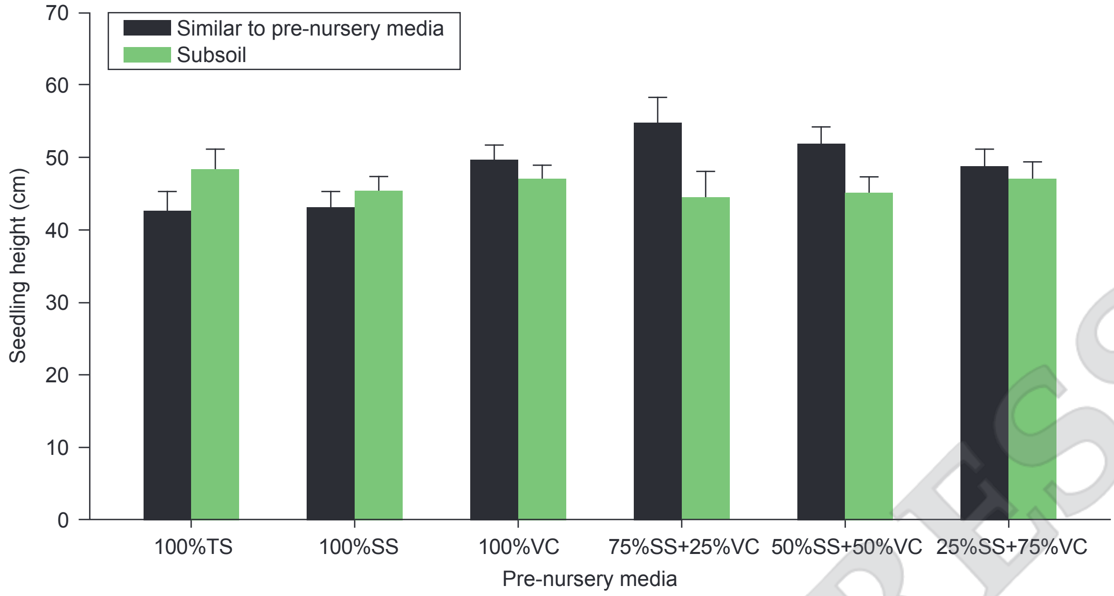

Figure 2. Effect of planting media in the pre-nursery and main-nursery on the height growth of 24-week-old oil palm seedlings in the main-nursery.

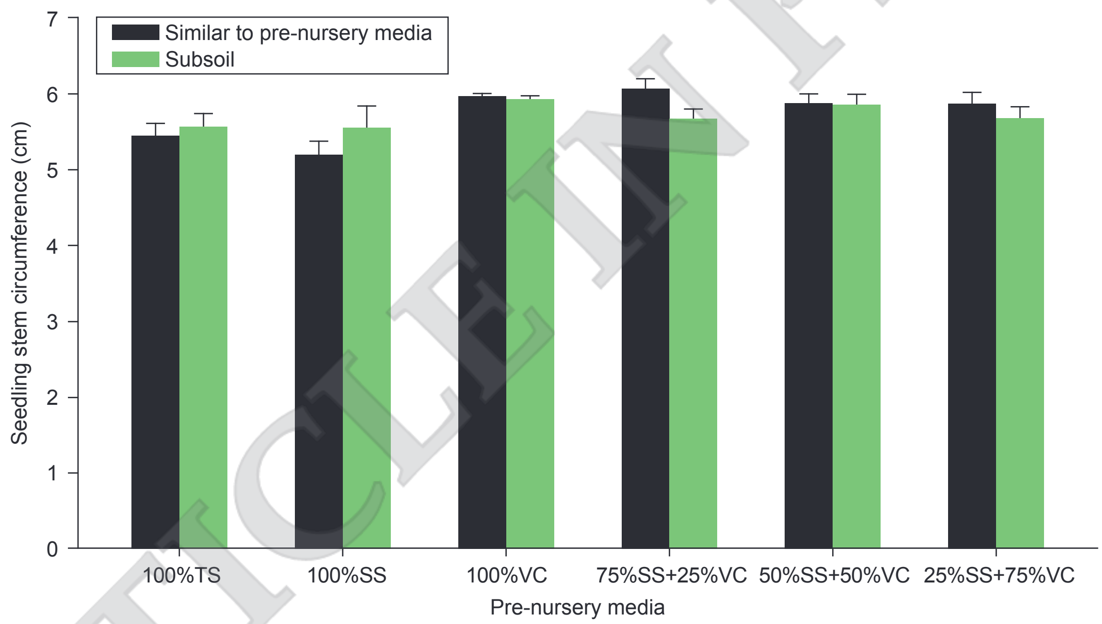

Figure 3. Effect of planting media in pre-nursery and main nursery on the increase in stem circumference at 24 weeks of age in the main nursery.

available P, CEC and exchangeable cations. The physical properties also improved with lower soil bulk density and more significant porosity (*Table 1*). The results confirm the finding of Sabrina *et al.* (2009) who found that vermicomposting can improve the quality of the compost materials by increasing the nutritional content, such as total N, K and Mg. Applying biological fertilisers such as vermicompost increased microbial diversity and population, soil moisture-holding capacity, cation exchange capacity and crop yields (Hargreaves *et al.*, 2008; Xue *et al.*, 2018). An essential feature of vermicompost is that many nutrients are converted into forms more easily taken up by plants, such as nitrate or ammonium nitrate, available phosphorus, and soluble potassium, calcium and magnesium (Suthar and Singh, 2008).

In the present study, using vermicompost or its mixture with subsoil in various compositions as growth media in the pre-nursery still significantly impacted seedlings' growth until they were 22 weeks old. Talashilkar *et al.* (1999) suggested that vermicompost is a type of slow-release organic fertiliser with most of the macro and micronutrients in chelated form and thus can fulfil the nutritional needs of plants for a longer period. Vermicompost could increase plant nutrient absorption (Nagavallemma *et al.*, 2004). Furthermore, Sabrina *et al*. (2013) showed that vermicompost contains 100% higher humic acid than compost. Moreover, Bhattacharya *et al*. (2012) also showed that vermicomposting was able to convert properties of the thermal power plant's fly ash by adding organic matter, which improved nutrients were increased and reduced the extractable heavy metals (Pb, Cr, Cd) in fly ash. Enzymatic activities were higher in vermicompost in comparison to compost on the 30th day. The phytotoxic heavy metals were reduced with the vermicomposting process reflects in germination index results (Karwal and Kaushik, 2020). The application of biological fertilisers such as vermicompost has been recognised as an effective way to improve soil aggregation, structure, and fertility, increase microbial diversity and population, soil moisture-holding capacity, soil cation exchange capacity, and soil cation exchange capacity leading to higher crop yields (Hargreaves *et al*., 2008).

Moreover, Celikcan *et al*. (2021) found that vermicompost enhances nutrient uptake by the plants, which is then positively manifested in the growth and development of sweet basil (*Ocimum basilicum* L). Vermicompost amended substrates at the rate 10% and 20% enhanced productivity under stress or non-stress conditions. In the past, Pandey *et al*. (2016) discovered that higher amounts of organic amendments boost the basil antioxidant's (DPPH) activity. Vermicompost and poultry manure treatments had the highest basil DPPH activity (64%), whereas the control had the lowest (52%). Vermicompost treated as fertiliser significantly changed the volatile organic compound of aromatic rice, according to Ruan *et al.* (2023). Vermicompost considerably boosted the grain yield and grain filling rate of aromatic rice when compared to inorganic fertiliser. It also caused the absence of 40 VOCs and the addition of 10 new VOCs.

Using subsoil as a planting medium in the main nursery did not affect stem circumference growth compared to seedlings grown on topsoil, vermicompost, and the mixture of vermicompost and subsoil at 24 weeks. Although seedlings with 75% subsoil and 25% vermicompost performed best, there was no overall significant difference in media treatment. The use of subsoil is more feasible. The availability of nutrients strongly influences plant growth and development. In the earlier germination period, oil palm seedlings obtain their nutrients from their cotyledons. The primary and secondary roots have formed and began to enlarge the stem at the seedling age above 3 months. The leaves change shape from lanceolate to bifurcate and then pinnate at 5-6 months (Lubis, 2008). The availability of nutrients is in accordance with the plant's needs, and the seedling's survival will be guaranteed and achieve optimal growth.

CONCLUSION

The initial planting medium used for oil palm seedlings in the pre-nursery largely determines the oil palm seedlings' growth in the main nursery for up to 22 weeks. The type of main nursery media did not contribute significantly to the growth of oil palm seedlings in the early period after transplanting (2-20 weeks). The use of topsoil as a media in the main nursery can be replaced with subsoil with the condition that the pre-nursery oil palm seeds need to be planted in a modified planting medium with vermicompost. Vermicompost, renewable and environmentally friendly material, is recommended as a substitute for topsoil as nursery growing media.

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