P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : https://tci-thaijo.org/index.php/SciTechAsia
Science & Technology Asia
Vol.28 No.4 October - December 2023
Page: [256-263]
Original research article

Effects of Different Growing Media under Soilless Culture on the Growth and Nutrient Uptake of Oil Palm Seedlings in the Pre-Nursery Stage

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Received 1 June 2023; Received in revised form 29 September 2023
Accepted 9 October 2023; Available online 27 December 2023

ABSTRACT

Soilless culture is an alternative approach to oil palm cultivation which has the potential to offer significant advantages over traditional soil-based cultivation. This study aimed to investigate the effects of different growing media under soilless culture on the growth and nutrient uptake of oil palm seedlings in the pre-nursery stage. The study consisted of eight types of growing media (topsoil-control; peat moss; cocopeat; peat moss: cocopeat (1:1); peat moss: cocopeat: perlite (1:1:1); peat moss: cocopeat: perlite (3:2:1); peat moss: perlite (3:1), and cocopeat: perlite (3:1). Results showed that oil palm seedlings grown in all substrates under soilless culture had significant growth improvement compared to those grown in soil, with increased plant height, stem diameter, number of leaves, SPAD value, and overall biomass production. In addition, soilless culture also led to improved nutrient uptake, with elevated concentrations of phosphorus, magnesium, and calcium in above-ground vegetation of up to 127%. Overall, the soilless culture formulation that provided the best plant growth and cost benefit was the cocopeat, costing RM 0.04 per oil palm seedling. The findings of this study suggest that soilless culture can be an effective method for cultivating oil palm seedlings in the pre-nursery stage. The significant growth improvement and increased nutrient uptake observed in soilless culture compared to traditional soil-based cultivation can potentially lead to palm farming with higher productivity.

Keywords: Agronomy; Nursery management; Oil palm; Soilless culture; Vegetative growth

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1. Introduction

Oil palm (*Elaeis guineensis*) is an important crop in Malaysia with significant economic contributions. According to the Department of Statistics Malaysia [1], the Malaysian palm oil industry has contributed RM34.8 billion or 35.2% of the gross domestic product (GDP) from the agriculture sector in 2021. Malaysia is currently the second-largest producer and one of the largest exporters of palm oil, accounting for 34.3% of global palm oil exports [2].

The production of vigorous and quality seedlings is essential for the successful establishment of high yielding palms. Oil palm seedlings are normally raised in a double-stage nursery where the germinated seeds are grown in plug trays or small polybags for three months in the pre-nursery under shade, and another 7-9 months in big polybags in the main nursery under open field conditions. Topsoil is widely used as a planting medium for oil palms during the nursery stage. However, the depletion of fertile topsoil has led to the usage of subsoil with poor texture and structure [3]. Tropical soils in Malaysia, such as Oxisols and Ultisols, are highly weathered, acidic, and low in nutrient content [4]. The usage of poor soil in nurseries often results in non-uniform and stunted seedling growth. In light of this, alternatives such as soilless culture are recommended.

Soilless culture is the cultivation of plants without soil, in which soil is replaced by substrate that containerises roots and supports plant growth [5]. Soilless culture is free from soil borne pathogens and weed seeds, has well balanced nutrient levels, and has good water holding capacity [6, 7]. The benefits of soilless culture on plant growth, yield, and fruit quality have been reported in previous studies. According to Salisu et al. [8], the leaf area and root length of rubber seedlings were 80% and 88% higher, respectively, when grown in soilless media. This media comprised vermiculite, perlite, coconut husk, peatmoss, compost, and burnt rice husk, in comparison to soil. Furthermore, Rezaei and Ismaili [9] reported that the essential oil yield of soilless-grown (perlite and cocopeat) geranium was threefold higher than the soil-grown plant counterparts.

The selection of substrates is crucial to tailor growing medium with desirable physical and chemical properties for optimum plant growth [10]. The popular organic substrates in soilless culture are peatmoss, sphagnum moss, coconut coir (commonly known as cocopeat), and waste compost, while the widely utilised inorganic media include perlite, vermiculite, and pumice [11]. The present study was carried out to assess the effects of different soilless media (peat moss, cocopeat, perlite, and their combinations) on the growth performance and nutrient uptake of oil palm seedlings in pre-nursery stage.

2. Materials and Methods

2.1 Experimental design

Table 1. Growing media formulations.

Treatment	Growing media
1	Topsoil (Oxisols) – control
2	Peat moss (100%)
3	Cocopeat (100%)
4	Peat moss+ cocopeat (1:1)
5	Peat moss+ cocopeat+ perlite (1:1:1)
6	Peat moss+ cocopeat+ perlite (3:2:1)
7	Peat moss+ perlite (3:1)
8	Cocopeat+ perlite (3:1)

The experiment was conducted at Dusun Durian Estate Nursery, Selangor (2° 48.1128' N 101° 27.453' E). The trial consisted of eight treatments with four replications, laid out in a randomised complete block design (RCBD) with 20 seedlings per block. The germinated D×P oil palm seeds (Calix 600, Sime Darby Plantation Seeds & Agricultural Services Sdn. Bhd.) were sowed in plug trays filled with growing media according to Table 1. The seedlings were grown for 3 months in pre-nursery in an open shed with shade netting. Control-release fertiliser NPK+MgO (17:8:9+3) was applied at a rate of 4 g per planting cell during seed planting. The seedlings were watered twice a day by drip irrigation and weeding was done manually.

2.2 Chemical characteristics growing media

The chemical characteristics of the studied growing media were analysed prior to the commencement of the study. The measured parameters included pH, electrical conductivity, total nitrogen (Kjeldahl method), total organic carbon [12], total phosphorus (dilute double acid method using H2SO4 and HCl), available phosphorus (Bray II), exchangeable potassium, calcium, magnesium, and cation exchange capacity (leaching method).

2.3 Growth performance and nutrient uptake of oil palm seedling

Growth parameters including plant height, stem diameter and total leaf number were recorded on a bi-weekly interval (week 2, 4, 6, 8, 10, 12). The height of the seedling was measured from the ground to the tallest shoot, stem diameter was taken from the seedling base using a vernier calliper, and leaf number counting only included fully opened leaves. The chlorophyll content was recorded at the third lanceolate using a chlorophyll meter (SPAD 502 Plus Chlorophyll Meters) on the 12th week. A total number of six seedlings were selected randomly from each block to be harvested for above- and below-ground biomass measurements. The dry weight of the above- and below-ground parts were recorded after oven-dried at 60°C to a constant weight, and the total biomass was obtained by adding both of the above- and below-ground biomass. The above-ground parts were then ground and bulked into two composite samples for N, P, K, Ca, and Mg analyses.

2.4 Cost analysis

The media cost per seedling was calculated using raw ingredient prices obtained from the local distributors in the currency of RM (Malaysian Ringgit). The raw ingredient price per litre was RM 0.20/L for topsoil, RM 0.64/L for peatmoss, RM 0.26/L for cocopeat, and RM 1.00/L for perlite.

The media cost per seedling was calculated through the formula below:

$$\begin{matrix}\textit{Media cost} \\ \textit{per seedling}\end{matrix} = \begin{matrix}\textit{Raw ingredient price} \\ \textit{per litre}\end{matrix} \times \begin{matrix}\textit{Volume of planting cell} \\ (0.1625\ \textit{litre})\end{matrix},$$

2.5 Statistical analyses

Analysis of variance (ANOVA) was performed for all parameters using JMP® Version 16 [13]. The results are presented as mean ± standard deviation, and the significant differences between treatment means were analysed using Tukey HSD test with the threshold for significance at 5%.

3. Result and Discussion

3.1 Characteristics of growing media

Table 2 summarizes the different growing media. The growing media were slightly acidic with pH values ranging from 4.1 to 6.6, where topsoil (T1) recorded the lowest pH. Peat moss (T2) resulted in the highest nutrient content for total nitrogen (0.95%), total phosphorus (756 ppm), calcium (95.73 $cmolkg^{-1}$), and cation exchange capacity (34.04 $cmolkg^{-1}$). Electrical conductivity is a good indicator for salinity as it measures the concentration of dissolved ions. Cocopeat (T3) reported the highest EC (795 μS/cm), as well as sodium (3.7 $cmolkg^{-1}$) and potassium levels (5.83 $cmolkg^{-1}$). The salinity of cocopeat is highly variable, mainly being affected by the source of origin and processing methods used on the coconut coir [14, 15]. Saline growing media may create an environment with high osmotic potential that may inhibit water uptake and hinder root growth [16]. Meanwhile, the EC of all growing media in this study were below the critical level of 2,500 μS/cm for optimum plant growth [17].

The carbon-to-nitrogen (C/N) ratio is an important parameter for planting media, as a high C/N ratio may lead to the immobilisation of nitrogen nutrients. The optimum C/N ratio of planting media ranges from 20 to 40 [18]. In the present study, the C/N ratio of the planting media ranged from 14 to 129. The high C/N ratio is primarily caused by low indigenous nitrogen content of cocopeat. Consequently, fertilisation programs are essential to overcome the nitrogen deficits in the planting media. The addition of perlite did not affect much of the chemical properties of growing media (T5, T6, T7, and T8). This is because perlite is an inert volcanic glass with low buffering and cation exchange capacity [19].

Table 2. Chemical properties of different growing media.

Parameters	Treatment							
	1	2	3	4	5	6	7	8
pH	4.1	5.8	5.5	5.7	5.8	6.6	6.5	5.8
EC (μS/cm)	53	543	795	562	538	588	790	525
C (%)	1.28	39.42	39.77	54.47	37.4	44.48	41.45	20.98
Total N (%)	0.09	0.95	0.47	0.83	0.29	0.64	0.75	0.28
C/N ratio	14	41	85	66	129	70	55	75
Total P (ppm)	253	756	262	614	435	347	412	117
Avail P (ppm)	9.44	9.59	15.97	48.92	46.88	19.13	29.84	26.24
Na (cmolkg^{-1})	0.01	0.68	3.7	1.99	1.95	1.83	0.85	2.28
K (cmolkg^{-1})	0.06	2.95	5.83	5.23	4.18	4.58	2.29	3.8
Ca (cmolkg^{-1})	0.43	95.73	11.07	65.39	63.31	68.03	86.21	8.39
Mg (cmolkg^{-1})	0.08	7.64	10.17	10.27	8.71	9.93	6.55	7.63
CEC (cmolkg^{-1})	3.96	34.04	14.56	37.04	48.84	33.16	31.48	16.36

3.2 Vegetative growth performance and biomass of oil palm seedling

The effects of different growing media on the vegetative growth of oil palm seedlings are summarised in Table 3. The highest mean plant height was observed in T4 (25.55 cm), followed by T3 (23.90 cm), and then T5 (23.97 cm), while the lowest was observed in T1 (18.08 cm). The increased plant height in T4 compared to other growing media could be due to its perfect balance of texture, porosity, and nutrient availability which enhances good establishment of root systems which ultimately promotes ideal shoot growth [20]. The positive effects of peatmoss-cocopeat mixture (T4) were also observed in stem diameter and leaf number. Oil palm seedlings grown in T4 recorded the largest stem diameter (0.93 cm) and produced the highest number of leaves (4.17) compared to control (T1). Meanwhile, the highest SPAD value reading was observed in T3 (55.98), followed by T2 (55.95), and T4 (55.92).

The biomass of soilless-cultivated seedlings ranged from 1.49-1.54 g (above-ground), and 0.66-0.69 g (below-ground), which differed significantly to topsoil cultivated seedlings that yielded the lowest above-ground (1.12 g) and below-ground (0.40 g) dry weights (Table 4). Oil palm seedlings with the highest dry matter (above- and below-ground biomass) were cultivated in T4 (1.54 g and 0.69 g), followed by T6 (1.53 g and 0.68 g), and T7 (1.51 g and 0.69 g).

The higher SPAD readings, enhanced vegetative growth, and increased biomass observed in oil palm seedlings across all soilless culture substrates (T2 to T8) can be attributed to the higher availability of magnesium (Mg) in the growing media (Table 2), and an improved Mg nutrient uptake (Table 5). Magnesium plays a crucial role as a vital constituent of chlorophyll, influencing the processes of photosynthesis, photoassimilate transport, and utilisation [21-23]. An adequate supply of Mg within the growing media can result in increased chlorophyll content and elevated production of photosynthates. As a result, these effects collectively contribute to a substantial improvement in overall plant growth and dry matter production. This phenomenon finds further support in a study conducted by Guan et al. [24], where a deficiency in Mg supply resulted in a significant reduction of leaf Mg content by 46-75%, a decline in SPAD values by 17-41%, and a substantial decrease in photosynthesis rates by 41-62% in cherry tomato plants cultivated under a soilless culture system. Furthermore, Tränkner [25] reported a noteworthy 34% decrease in dry matter production in barley when subjected to a Mg-deficient environment, as compared to control conditions.

Table 3. Effects of different growing media on the vegetative growth of oil palm seedling at the 12th week after planting.

Treatment	Height (cm)	Stem diameter (cm)	Number of leaves	SPAD
1	18.08 ± 1.77^{b}	0.62 ± 0.07^{b}	3.29 ± 0.28^{b}	43.60 ± 5.95^{b}
2	23.90 ± 2.55^{a}	0.87 ± 0.08^{a}	4.00 ± 0.24^{a}	55.95 ± 1.36^{a}
3	24.30 ± 1.03^{a}	0.84 ± 0.06^{a}	4.13 ± 0.16^{a}	55.98 ± 1.75^{a}
4	25.55 ± 1.46^{a}	0.93 ± 0.08^{a}	4.17 ± 0.24^{a}	55.92 ± 1.73^{a}
5	23.97 ± 3.10^{a}	0.87 ± 0.01^{a}	4.04 ± 0.25^{a}	54.99 ± 3.12^{a}
6	23.98^{a} ± 1.47^{a}	0.85 ± 0.03^{a}	4.04 ± 0.28^{a}	55.79 ± 4.46^{a}
7	22.59^{a} ± 1.55^{a}	0.81 ± 0.02^{a}	3.88 ± 0.21^{a}	54.19 ± 0.40^{a}
8	21.90 ± 1.41^{ab}	0.81 ± 0.01^{a}	3.83 ± 0.24^{ab}	53.01 ± 2.02^{a}

*T1-Control; T2-Peat moss; T3-Cocopeat; T4-Peat moss: cocopeat (1:1); T5-Peat moss: cocopeat: perlite (1:1:1); T6-Peat moss: cocopeat: perlite (3:2:1); T7-Peat moss: perlite (3:1); T8-Cocopeat: perlite (3:1).

Table 4. Effects of different growing media on above- and below-ground dry weights of oil palm seedling.

Treatment	Above-ground dry weight (g)	Below-ground dry weight (g)	Total biomass (g)
1	1.12 ± 0.12b	0.40 ± 0.05b	1.52 ± 0.16b
2	1.50 ± 0.07a	0.66 ± 0.05a	2.16 ± 0.12a
3	1.50 ± 0.04a	0.69 ± 0.05a	2.19 ± 0.09a
4	1.54 ± 0.09a	0.69 ± 0.06a	2.23 ± 0.15a
5	1.51 ± 0.11a	0.66 ± 0.08a	2.17 ± 0.19a
6	1.53 ± 0.06a	0.68 ± 0.03a	2.21 ± 0.09a
7	1.51 ± 0.06a	0.69 ± 0.05a	2.19 ± 0.11a
8	1.49 ± 0.04a	0.67 ± 0.02a	2.16 ± 0.05a

*T1-Control; T2-Peat moss; T3-Cocopeat; T4-Peat moss: cocopeat (1:1); T5-Peat moss: cocopeat: perlite (1:1:1); T6-Peat moss: cocopeat: perlite (3:2:1); T7-Peat moss: perlite (3:1); T8-Cocopeat: perlite (3:1).

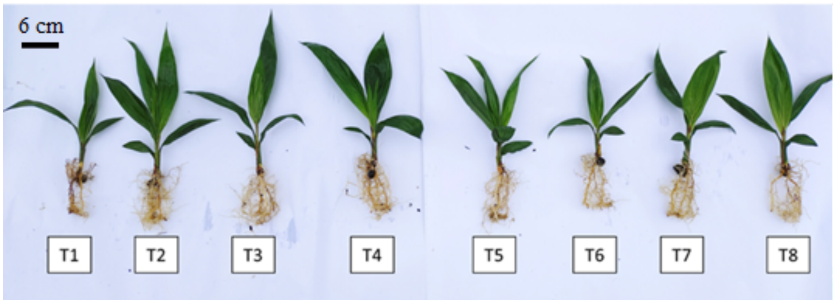

Fig. 1. Growth of seedlings at the 12th week of pre-nursery stage.

3.3 Nutrient uptake of oil palm seedling

Oil palm seedlings in all growing media appeared healthy with no nutrient deficiency symptoms in pre-nursery stage (Fig. 1). There was no significant difference in nitrogen or potassium uptake between topsoil (T1) and soilless media culture (T2, T3, T4, T5, T6, T7, T8). The highest nitrogen concentration was recorded with seedlings cultivated in T6 (3.16%), followed by T5 and T8, while the highest potassium concentration was recorded in T2 (0.88%), followed by T1 (0.86%), and T3 (0.81%).

The phosphorus, magnesium, and calcium concentrations were significantly higher when grown in soilless media compared to topsoil. The highest P concentration was observed in T8 (0.092%), followed by T6 (0.087%), and T2 (0.086%). The lower phosphorus concentration in T1 might be attributed to the low nutrient availability due to low pH. At low pH, phosphorus fixation tends to occur when phosphorus reacts with other minerals (aluminium and iron) to form insoluble compounds and becomes unavailable to crops [26].

In addition, the highest magnesium and calcium concentrations were observed in T2 (0.19% Mg and 0.43% Ca) and T4 (0.18% Mg and 0.41% Ca). This is due to the high indigenous CEC in peatmoss and cocopeat that are rich in organic matter. Organic matter positively correlated with CEC as it provides a large number of negative functional groups that serves as cation exchange sites [27].

Table 5. Effects of different growing media on the above-ground nutrient concentrations (w/w %) of oil palm seedling.

Treatment	N	P	K	Mg	Ca
1	2.96 ± 0.16[a]	0.056 ± 0.01[b]	0.86 ± 0.09[a]	0.11 ± 0.02[b]	0.18 ± 0.04[b]
2	2.97 ± 0.14[a]	0.086 ± 0.01[a]	0.88 ± 0.05[a]	0.19 ± 0.01[a]	0.43 ± 0.03[a]
3	3.00 ± 0.16[a]	0.082 ± 0.02[a]	0.81 ± 0.16[a]	0.17 ± 0.03[a]	0.38 ± 0.06[a]
4	3.05 ± 0.11[a]	0.082 ± 0.01[a]	0.78 ± 0.07[a]	0.18 ± 0.02[a]	0.41 ± 0.07[a]
5	3.11 ± 0.16[a]	0.081 ± 0.01[a]	0.78 ± 0.04[a]	0.17 ± 0.01[a]	0.40 ± 0.05[a]
6	3.16 ± 0.11[a]	0.087 ± 0.01[a]	0.78 ± 0.06[a]	0.16 ± 0.01[a]	0.39 ± 0.02[a]
7	3.03 ± 0.07[a]	0.081 ± 0.01[a]	0.80 ± 0.09[a]	0.17 ± 0.02[a]	0.41 ± 0.03[a]
8	3.11 ± 0.12[a]	0.092 ± 0.01[a]	0.80 ± 0.06[a]	0.16 ± 0.01[a]	0.36 ± 0.02[a]

*T1-Control; T2-Peat moss; T3-Cocopeat; T4-Peat moss: cocopeat (1:1); T5-Peat moss: cocopeat: perlite (1:1:1); T6-Peat moss: cocopeat: perlite (3:2:1); T7-Peat moss: perlite (3:1); T8-Cocopeat: perlite (3:1).

3.4 Media cost for oil palm seedling

Table 6 shows the cost analysis of different growing media per seedling. The cheapest growing medium was topsoil (T1) with a cost of RM 0.03 per seedling, followed by cocopeat (T3) with a cost of RM 0.04 per seedling. On the other hand, the most expensive growing medium was the combination of peatmoss and perlite in a 3:1 ratio (T7) with a price of RM 0.12 per seedling.

Table 6. Cost of different growing media for oil palm seedling in pre-nursery stage.

Treatment	Growing media cost per seedling (RM)
1	0.03
2	0.10
3	0.04
4	0.07
5	0.10
6	0.09
7	0.12
8	0.07

4. Conclusion

The results of this study demonstrated the potential benefits of soilless culture for the growth and nutrient uptake of oil palm seedlings in pre-nursery stage. Soilless culture allowed for improved vegetative growth and increased nutrient uptake (phosphorus, magnesium, and calcium) compared to soil cultivation. Nonetheless, there was no statistical difference within the growing media under soilless culture. Hence, cocopeat was found to be the best soilless planting medium for oil palm seedling in pre-nursery stage due to its low cost. Further research is suggested to optimise the fertiliser requirement of oil palm seedling in soilless culture media, thus reducing the risk of overfertilisation as well as minimising operational cost.

Acknowledgements

The authors would like to offer particular thanks to Sime Darby Plantation Research for permission to publish this article. We would also like to show our gratitude to the staff of Banting Research Substation for their assistance in conducting research activities.

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