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ORIGINAL RESEARCH

Effect of oil palm bio-organic wastes on macro-propagation of some permanent crops' seeds

Wasiu Agunbiade Lamidi [1*], Janet Oluwaseun Dada [2]

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Abstract

Purpose: Research investigated oil mill decanter cake (OPDC) and empty fruit bunch (EFB) from oil palm in varying forms as soil media for growth performances of cocoa (*Theobroma cacao*) and citrus (*Citrus sp.*) seeds during germination and growth.

Method: Factorial design with 4 levels of bio-organic: oil palm decanter cake (OPDC) treated with hot water at 70 °C, OPDC treated with hot water at 80 °C, OPDC raw and EFB; 2 levels of crops: citrus and cocoa seedlings were investigated. Each treatment was replicated thrice (4 × 2 × 3). A control experiment with normal sandy clay loam soil (NSCLS) medium, was also replicated thrice. Plant height; stem girth, number of leaves, days to seeds' emergence, leaf area, and biomass were measured.

Results: Days to emergence, number of leaves, and stem girth of cocoa seedlings were significantly different ($p \leq 0.05$) with different forms of OPDC media and EFB. Maximum growth performance was obtained for EFB, the highest number of leaves was 17.33, stem girth, 1.32. EFB has the least number of days of emergence. OPDC has high moisture and nutrient content. OPDC and EFB have lesser bulk density compared with soil medium. Biomass gains from using bio-organic wastes as soil media for the cocoa and citrus seedlings were as high as 263.5 g (citrus), 237.5 g (cocoa) for EFB and they were the highest.

Conclusion: Incorporation of OPDC and EFB as bio-organic media would boost nursery growth of permanent crops.

Keywords: Citrus, Cocoa, Leaf area, Medium, Stem girth

Introduction

Cocoa (*Theobroma cacao* L) is a significant cash crop and a key source of income for many smallholder farmers in West Africa's forest area (Bwambale et al. 2021). Global cocoa output is now estimated at 9.3 million tons, and it has been gradually expanding over the last ten years, fuelled by increased production in Côte d'Ivoire and Ghana, as well as Indonesia's ever-increasing production within a decade (Tano et al. 2019). Smallholders are projected to account for 90 percent of global cocoa output (Asigbaase et al. 2021), with the majority of this production taking place in high biodiversity regions (Nasser et al. 2020). West Africa now accounts for over 70% of global cocoa output, while Asia and the Americas provide approximately 16% and 14%, respectively (Odijie 2018). Nigeria was formerly the largest producer of cocoa but was overtaken by Côte d'Ivoire and Ghana, a feat that

✉ WA Lamidi wasiu.agunbiade@uniosun.edu.ng

1 Department of Agricultural Engineering, Faculty of Engineering, Osun State University, Osogbo, Nigeria

2 Department of Agronomy, College of Agriculture, Ejigbo Campus, Osun State University, Osogbo, Nigeria

can be returned to through concerted efforts on its seeds' propagation, growth, and development.

Citrus fruits, which are members of the *rutaceae* family, are one of the most important fruit tree crops cultivated across the globe. Sweet orange (*Citrus sinensis*) is the most important fruit in this category, accounting for around 70% of citrus output (Papadakis et al. 2018). Citrus is currently grown throughout the world's subtropical and tropical regions between 23º north and 23º south latitudes in over 137 nations across six continents, generating around 105 billion US dollars per year in the global fruit market (Grové and de Beer 2019).

Cocoa and citrus seeds can be sown directly in the polytubes and then transferred to the prepared field for their permanency. Polytube planted seeds can be cultivated in a propagation house under low light conditions (shade). Otherwise, another best way is by planting the seeds on seedbeds prepared for sowing and germination (Adeyeye et al. 2019; Lamidi 2013). The seeds can be disseminated or simply line-sowed. Under tropical circumstances, sowing can be done all year (Ertekin 2017). Planting in dry seasons, on the other hand, is recommended due to lower disease incidence. The seeds are scattered uniformly over the medium and covered with soil medium at about 2.5 cm depth.

Nigeria is well-known for being a main force in the oil palm industry. Some of the apparent waste products or local fueling products from oil palm can be used as organic media for crop growth inasmuch as various plants need organic and inorganic supplements for good growth and yield (Lamidi et al. 2022). Every year, local palm oil mills produce a large amount of biomass waste's, including empty fruit bunches (EFB), palm mesocarp fibre (PMF), palm kernel shell (PKS), oil palm decanter cake (OPDC), and others (Nanna et al. 2020). Certain wastes like OPDC and palm oil mill effluent (POME), have a high percentage of residual crude palm oils (RCPO), resulting in considerable oil losses at milling (Razali and Kamarulzaman 2020). The decanter is used to separate the residual oils from the particles through the use of clarifying tank. During the procedure, the fibrous solid holds and absorbs the oils before being released as OPDC (Sahad et al. 2014). In recent years, OPDC production has increased owing to the installation of additional decanter machines in mills to collect the residual oil from the sludge tank underflow. While OPDC is often deposited and let to decay naturally in dumping ponds and unfarmable lands, EFB are deposited aimlessly in the mill, these wastes could have been converted to soil media for raising crops' seedlings in nurseries. Although OPDC has high nutritional value, it should not only be used as animal feed but also as fertilizers and soil medium for growing fruits such as permanent crops. However, if not carefully handled it could have a detrimental impact on plant development and performance because of more nutrients it may contain than needed because of the high oil content in the raw OPDC in the effect studied by Osman et al. (2020) who used only hot water treatment on OPDC for the growth of oil palm seedlings. Osman et al. (2020) also found out that oil palm decanter cake (OPDC) has high moisture and nutrient contents required by plant seedlings.

Oil palm decanter cake is one of the promising waste materials generated in palm oil mills suitable for bio-organic media once the oil is partially removed. They used to be in large quantities as wastes at milling sites. When hot water treatment is used, the oil content of oil palm decanter cake may show improvement in crops' growth. Although normal loamy soil is not expensive and is readily available, it may not be complete with the high nutrient content required for cocoa or citrus' seedlings germination and growth from the day of emergence, therefore, instead of using some inorganic fertilizers that may be expensive nowadays, new ways are needed to be investigated to boost nursery seedling improvement. For these OPDC and EFB wastes not to be thrown away or used just for fuel or animals feeds supplements and for both to be introduced to potential new technologies to improve production (Gavrilova 2021). It is imperative to investigate their usefulness as potential media for growth of seedlings for cocoa and citrus and on their seeds' germination and growth at various research procedures.

Materials and methods

Description of experimental site

The experiment was conducted in the Osun State University Teaching and Research Farm, Ejigbo campus (latitude 7.8717 °N; longitude 4.3067 °E). The area's climatic state is generally rainforest, with two maxima (bimodal rainfall) ranging from 1,158 to 1,250 mm each year (Lamidi et al. 2021).

Experimental design

The design was a factorial design with 4 levels of bio-organic namely OPDC70 treated with hot water at 70 °C, OPDC80 treated with hot water at 80 °C, raw OPDC (no warm water treatment), and EFB, Figs. 1 [a-d]. It is of note that for OPDC70, OPDC80, OPDC and EFB, all were grounded to between 0.2-2.0 mm particle sizes]; 2 levels of crops namely citrus and cocoa seeds. Each of these treatments was replicated thrice to make a design of 4 × 2 × 3. There was a control experiment with normal sandy clay loam soil medium, NSCLS also replicated thrice each, for citrus (3) and cocoa (3), all experimental stands were thirty (30).

Material preparation and OPDC pre-treatment

The fresh OPDC was procured from a palm oil mill within the research area. According to the American Standard Test Method D1102 test method, the OPDC was dried in an oven at 105 °C to eliminate excess moisture until it reaches a consistent weight (ASTM 2013). Raw dried OPDC was thoroughly combined with hot water (at 70 °C and at 80 °C) and soaked until the oil layer rose for decantation. The oil coating and water were removed and the procedure was repeated 3 times. To evaluate the oil content loss, 10 g of treated OPDC was extracted for 8 h in a soxhlet extractor with 300 ml hexane. The extracted oil was next concentrated in a vacuum rotary evaporator before being dried in an oven. The extracted oil content was then calculated using the equation below.

$$\text{Oil (\% dry basis)} = \frac{\text{Weight of extracted oil (g)}}{\text{Initial weight of dry sample (g)}} \times 100\%$$

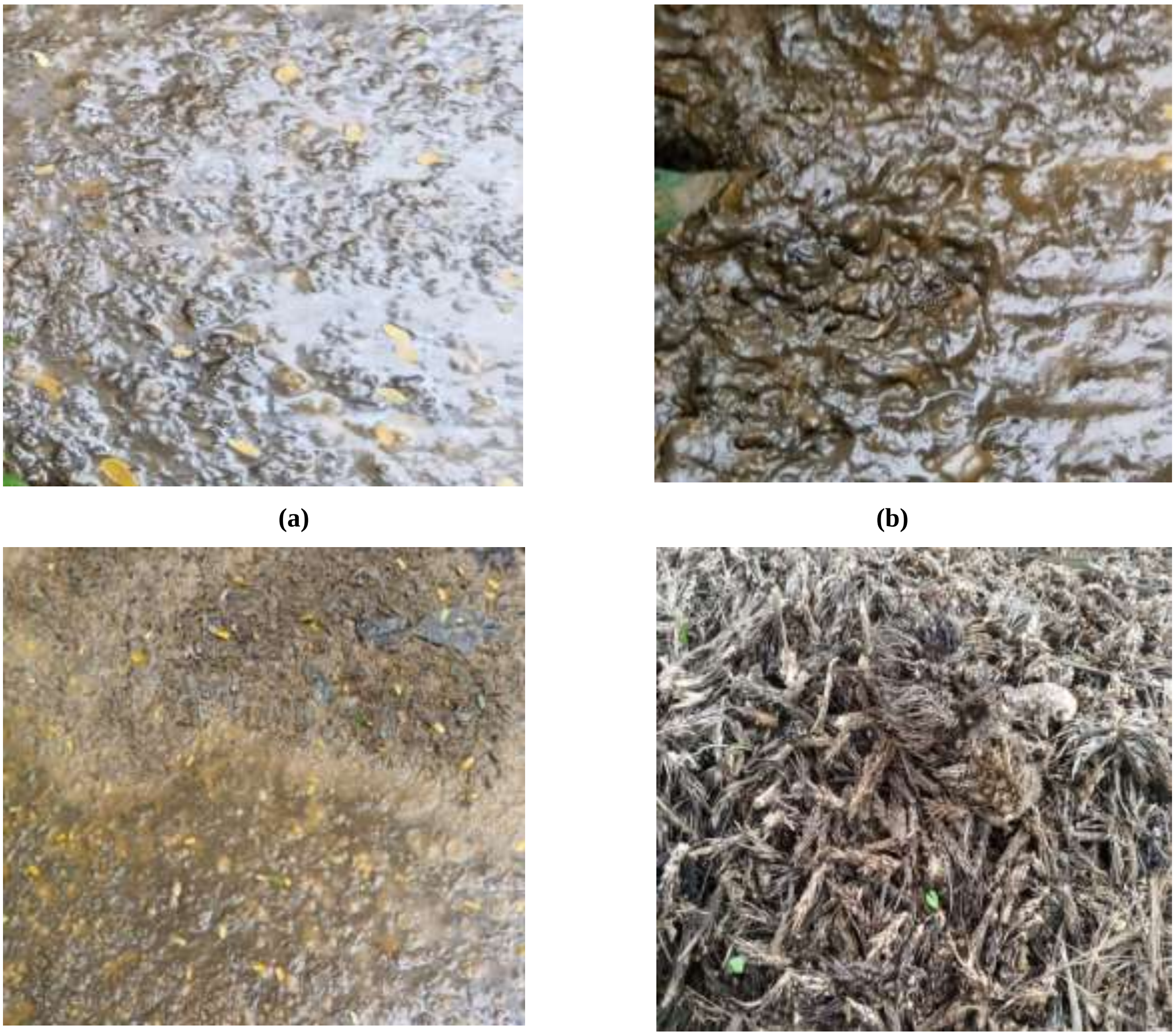
Bio-organic media preparation

The media ratio was computed depending on the nutritional content required by the seedling for the next 3 months. Approximately 2 kg of OPDC70

, OPDC80, raw OPDC, EFB, and NSCLS, after being grounded, were packed in polythene bags in 30 stands and left for 2 weeks before seedlings were transplanted. The polybags were next put in a triangle planting pattern in an open area. They were supplied at the same time and with same quantities of water. Besides, they received the same light and the same aeration of air since they were at the same open place throughout the experiment.

Physicochemical analysis of OPDC70, OPDC80, OPDC and EFB

Various OPDC samples as procedurally engaged were weighed and dried in a 105 °C oven until a constant weight was achieved for each sample. The samples were then weighed again to determine the moisture content on a dry basis. The pH value was calculated using the 1:10 (w/v) technique, and the nutrients compositions were calculated using the dry ashing method (Embrandiri et al. 2017). Separate milled and dried EFB processed-as-to-the-methodology for OPDC samples (in the experiment) was put through a 2 mm filter. 1 g of each sample was placed in a porcelain crucible and heated in a muffle furnace (XRF Scientific Muffle furnace made in UK) at 300 °C for 1 h before progressively increasing to 550 °C for the subsequent 7 h. After, a few drops of deionized water and 2 ml of concentrated HCl were added, the sample was placed on a hot plate. After the ash had been somewhat dried, 10 ml of prepared nitric acid (20% volume/volume) was added and the mixture was placed in a water bath for 1 h. The mixture was then transferred to a 100-ml volumetric flask and deionized water was added. The solution was shaken before being filtered using Whatman No. 2 filter paper. Following that, the solution was tested for chemical elements Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Nitrogen (N). The bulk density was measured by collecting a known volume of each of the materials using metal ring pressed into it (intact core) like in the case of soil sample and determining the weight after drying (McKenzie et al. 2004).



(a) (b) (c) (d)

Fig. 1 Oil palm bio-organic wastes (a) OPDC70, (b) OPDC80, (c) raw OPDC, (d) EFB (ungrounded)

(Above photos [a-d] were taken from oil palm forestation and processing farm in Araromi/Iwata, Ejigbo,Osun State, South West Nigeria)

Germination and growth parameters measured

The plant height was measured using a measuring metre rule and graduated ruler from the base of the stem above the soil surface to the tip of the highest leaf; the stem girth was measured with a vernier caliper at a height of 2 cm above the soil surface, and the leaf number was collected by counting the number of leaves (Lamidi et al. 2019). These were done twice a week for the period of 12 weeks after planting (WAP). At the end of the experiment, the leaves, stems, and roots were removed and rinsed under running water to eliminate the soil and dirt. The leaves, stems, and roots were next dried in an oven at 105 °C until a consistent weight was reached. For the dry weight determination, the samples were weighed using a digital balance (Camry 50 kg weighing scale, model CA277HL, made in Nigeria). The portable leaf area meter LI-COR LI-3000C, made in USA was used to determine the leaf area.

Statistical analysis

Minitab software was used for the statistical analysis. All the collected data were subjected to one-way ANOVA to determine the significant difference between treatments with a $p \leq 0.05$, Least Significant differences (LSD) were used to separate mean values that were not significant.

Results and discussion

Fig. 2 shows the oil contents in OPDC70 and OPDC80 after treatment with hot water and the oil contents in raw OPDC and EFB that were not treated with hot water. In the three stages of hot water treatment, the oil contents in OPDC70 reduced to approximately 13.1%, and in OPDC80 it was reduced to 12%; the oil content was intact up to 14% in raw OPDC and it was found to be 0.12% (nearly zero) in EFB. It could be observed that higher volume of oil was drained from OPDC80 than from OPDC70, this was a result of the use of higher water temperature, 80 °C. As observed in Table 1, raw EFB has lesser bulk density while raw OPDC has the highest bulk density, this could be due to varying oil contents in each of the media. This higher bulk density in raw OPDC was due to its high oil content, high bulk density is not good for plant's growth and development. Oil may increase water and nutrient availabilities in the soil medium; however, it could also increase the soil compaction as a result of high soil bulk density. The seedlings could have been affected negatively when compared to what could be obtained in the EFB and NSCLS media; they could directly affect plant growth and development. Oil-contaminated soil leads to different chemical processes in the soil like cracking and toxicosis and these and any other soil reactions can result in negative effects on biomass, changes in leaves, and roots because toxic chemicals in oil can prevent photosynthesis in plants. Thus, the observed spots and apparent dryness in the leaves, as shown in the seedlings in Figs. 3 a-c, could be from the effects of residual oil in the OPDC70 and OPDC80 (this effect was apparently more severe in OPDC70 than in OPDC80) compare to seedlings in the EFB medium without any dryness spot. The nutrient contents of OPDC (Table 1) exhibited contradictory results from previous studies. For N, the content ranged from 2.72-2.80% after hot water treatment, 2.98% for raw OPDC and 2.19% for EFB compared to previous studies of 2.20% by Osman et al. (2020) and Sahad et al. (2014) with 2.33%. The result shows that N was at 2.98% in raw OPDC, Table 1. This could be as a result of differences in the places where the oil palm with their raw OPDC were secured. This higher N obtained in raw OPDC imply that where raw OPDC is used as bio-organic media for growing cocoa and citrus seedlings or any other crops, it will approximately provide the crops with N at high level (Embrandiri et al. 2017).

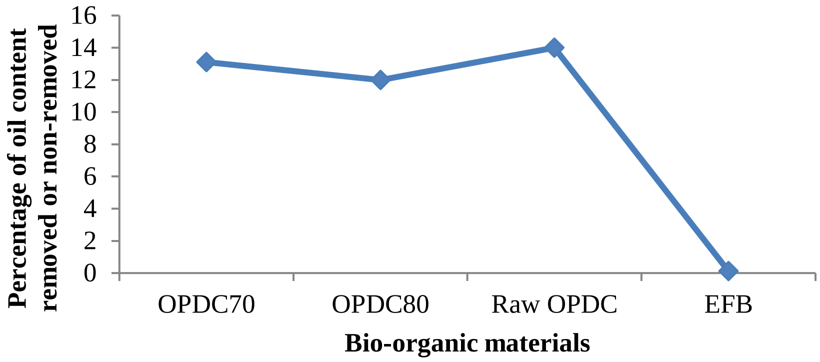


Fig. 2 Percentages of oil content removed at three times and percent of oil not removed (oil was not removed in raw OPDC and EFB)

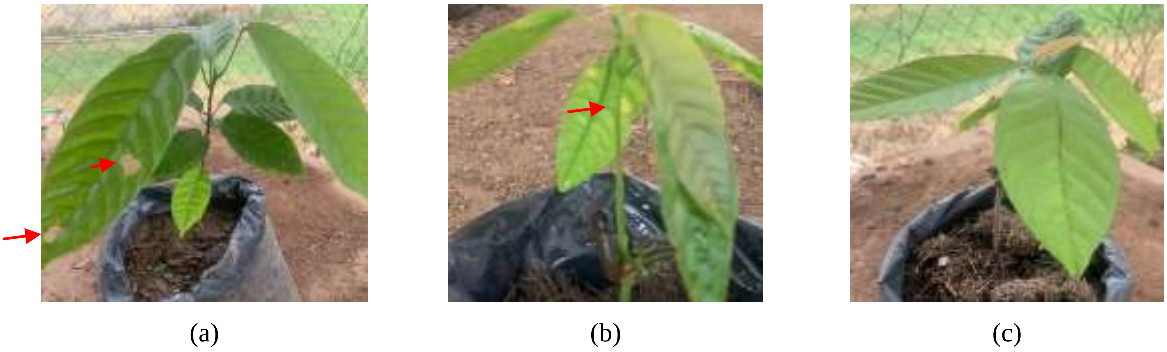


Fig. 3 Cocoa seedlings in (a) OPDC70: showing leaf spots (with red arrows) (b) OPDC80: showing leaf spots (with red arrow) (c) EFB: showing no any leaf spot

Source: Experimental Site

The total P content was between 0.25 and 0.34% either after hot water treatment or non-hot water treatment, this is a moderate range of values, 0.250-0.340% range is not too high or low for cocoa and citrus, both need a moderate balance of both N and P at their early stages in the nursery (Wongnaa et al. 2022). NSCLS has a higher total P of 0.36% compared to other soil media. As Table 1 depicts, using only OPDC and EFB as bio-organic soil media could boost up these permanent crops' seedling growth as it contains sufficient levels of N and P and high C/N ratio especially in OPDC 80 and EFB when compared to low C/N ratio in NSCLS. The OPDC also contains other nutrients as shown in Table 1, which are equally in sufficient measure for the growth of the permanent crops in their early lives in the nursery (Lamidi et al. 2018). Since N contributes to the structural components, generic and metabolic compounds in a plant cell and P is important in cell division and development of new plant tissue. It is needed, as essential nutrient for plant growth, their substantial and moderate content in the media are advantageous. The results could be seen on the leaves, stems and other plant components as depicted in Figs. 3 (a)-(c) and in the growth parameters, Tables 2 and 3; Figs. 4 and 5 and in the biomass gains by both crops from the use of bio-organic wastes in lieu of soil medium as presented in Figs. 6 and 7.

Table 2 shows that the growth performance parameters, namely days to emergence/germination, number of leaves, and stem girth of cocoa seedlings, have statistical differences among themselves and thereby they were significantly affected ($p \leq 0.05$) by the various OPDC media and EFB. Maximum growth performance was obtained in the experiment with EFB (with the highest number of leaves of 17.33 and stem girth, 1.32 cm) followed by treated OPDC80 where the number of leaves was 16.33 and stem girth was 1.22 cm, and OPDC70 where the number of leaves was 16.10 and stem girth was 1.09 cm. This depicts that cocoa or citrus seedlings could have been affected by the residual oils in the three OPDC media, especially in the OPDC70 and raw OPDC. This same trend was observed for the citrus seedlings' development in the nursery with the EFB and OPDC media substrates.

Table 1 Comparison of physicochemical properties of the bio-organic and normal soil

Parameters	OPDC70	OPDC80	Raw OPDC	EFB	NSCLS
pH	5.40±0.25	5.38±0.04	5.48±0.05	5.23±0.03	6.38±0.02
Organic carbon C, %	71.12±3.02	71.40±3.12	65.42±3.20	70.12±3.22	3.27±0.02
Oil content, %	13.10±2.04	12.00±3.02	14.00±3.01	2.10±3.02	0.02±0.01
Moisture, %	8.12±3.02	9.40±0.02	8.42±0.02	8.12±0.40	-
Total N, %	2.80±3.02	2.72±0.02	2.98±0.02	2.19±0.02	0.18±0.02
C/N ratio	25.40±3.12	26.25±4.02	21.95±3.10	32.02±2.02	18.17±0.22
Total P, %	0.28±0.02	0.31±0.02	0.25±0.02	0.34±0.02	0.36±0.02
Available K, %	1.31±0.02	1.18±0.13	1.22±0.02	1.20±0.01	0.66±0.03
Ca, %	1.28±0.03	1.22±0.12	1.18±0.01	1.10±0.02	0.46±0.02
Mg, %	0.44±0.01	0.48±0.02	0.52±0.02	0.54±0.03	1.25±0.01
Bulk Density, g cm^{-3}	0.64±0.02	0.62±0.02	0.87±0.22	0.48±0.02	1.16±0.02
Clay					18.30±3.10
Loam/Silt					8.28±1.02
Sand					67.22±5.22
Soil classification					Sandy clay loam

C-Carbon; N-Nitrogen; P- Phosphorus; K- Potassium; Ca-Calcium; Mg-Magnesium, NSCLS-Normal sandy clay loam soil

High organic carbon and low bulk density in EFB were observed as these could have positively affected these plants' growth at early stages of their development. Besides, from the results in Table 2, it can be seen that the growth performances in term of the number of leaves and stem girth decrease as the ratios of the oil contents increases (Tables 2 and 3).

Raw OPDC had more oil content than OPDC80, so the stem girth and number of leaves in the former were less than their corresponding values in the OPDC80. Oil content in these media could have affected the cocoa seedlings' development as any oil-contaminated soil leads to different aspects of phytotoxicity in plants and will affect any crop accordingly to other accompanying characteristics of the soil and plants. It could also be due to the high nutrient content that oil and the toxicity effect of OPDC. Similar results were observed by Embrandiri et al. (2017) and Singh et al. (2009) in their earlier studies using raw and decomposed OPDC on other types of crops when a certain percentage of raw OPDC and hot water-treated OPDC were used to grow some arable crops. Oil content in a plant's growing media could cause stress to the plant through the creation of physiological drought when it interferes with soil water and its uptake and/or the gaseous exchange in the plants (Omosun et al. 2008). It can also help to block the xylem and phloem vessels, and slow down root elongation (Bengough 2003). It is a known fact that in lettuce, oil content could cause non-germination of their seeds and sublethal effects on root development (Filho et al. 2017). Thus, removing oil content before use will improve the efficiency of oil palm decanter cake as bio-organic media as seen in OPDC80 which had more of its oil content removed. This assertion is evident in the seedlings' growth as the cocoa seedlings performed well, Fig. 3, Tables 2 and 3. Again, the days to emergence (which was between 2 and 3 weeks after planting) in all the media were statistically different to one another (Table 2). The control had the highest number of days both for the cocoa and for the citrus while EFB had the least number of days before the seeds emerged. The reason could be related to the nature of the media in all the cases as the media have different permeability for water and airflow. Because of its lowest bulk density among other media used, air penetration into the EFB was higher than that of the normal soil, NSCLS that served as the control. Since water and air are needed for germination in any seed, thus, the smaller number of days in EFB. This could also be a result of the high nitrogen as well as high phosphorus present in the oil palm decanter cake. This is, in line with the study of Osman et al. (2021) which surmised that incorporating oil palm decanter cake as bio-organic media could boost up the performances of permanent crop like oil palm seedling growth because it contains sufficient level of N and P.

Table 2 Mean values of growth performances for cocoa seedlings from bio-organic media and control

Treatments	Days of emergence	No of leaves	Stem girth (cm)
OPDC70	$13.67^{d} \pm 2.34$	$16.10^{b} \pm 2.40$	$1.09^{c} \pm 0.03$
OPDC80	$13.60^{d} \pm 1.52$	$16.33^{b} \pm 3.00$	$1.22^{b} \pm 0.04$
OPDC	$15.67^{c} \pm 2.24$	$15.67^{c} \pm 2.20$	$1.08^{c} \pm 0.00$
EFB	$14.33^{b} \pm 2.00$	$17.33^{a} \pm 1.64$	$1.32^{a} \pm 0.03$
NSCLS (control)	$16.63^{a} \pm 2.40$	$14.77^{d} \pm 2.34$	$1.10^{c} \pm 0.02$
LSD	5.84	7.80	3.21

[abc]Means on the same column with different superscripts are significantly different (P<0.05); OPDC80: Oil palm decanter cake washed with 80 °C water; OPDC70: Oil palm decanter cake washed with 70 °C water, OPDC: Oil palm decanter cake with no wash, EFB: Empty fruit bunch, NSCLS: Normal sandy clay loam soil, LSD-Least Significant Difference (separating closer mean values)

Table 3 Mean values of growth performances for citrus seedlings from bio-organic media and control

Treatments	Days of emergence	No of leaves	Stem girth (cm)
OPDC70	$16.33^{a} \pm 2.03$	$16.40^{b} \pm 2.40$	$1.09^{a} \pm 0.00$
OPDC80	$17.33^{a} \pm 1.49$	$18.00^{b} \pm 1.42$	$1.17^{b} \pm 0.02$
OPDC	$16.00^{a} \pm 2.31$	$16.00^{b} \pm 2.30$	$1.07^{a} \pm 0.04$
EFB	$15.09^{b} \pm 2.04$	$18.20^{b} \pm 1.33$	$1.21^{b} \pm 0.00$
NSCLS (control)	$15.00^{c} \pm 3.34$	$17.33^{a} \pm 2.43$	$1.08^{a} \pm 0.03$
LSD	9.20	11.12	3.23

[abc] Means on the same column with different superscripts are significantly different (P<0.05); OPDC80: Oil palm decanter cake washed with 80 °C water, OPDC70: Oil palm decanter cake washed with 70 °C water; OPDC: Oil palm decanter cake with no wash, EFB: Empty fruit bunch, NSCLS: Normal sandy clay loam soil

Other growth performance parameters, namely plant heights and leaf area, are depicted in Figs. 4 and 5. There were statistical differences ($p \leq 0.05$) among the corresponding values for the plant height, and leaf area for cocoa seedlings, but only the leaf area was statistically different for the citrus and the plant height was not. The crops' physiological features were not the same and their metabolic activities could be responsible for these observations since they all had the same conditions apart from different substrate media of growth. The high moisture contents and oil contents in the OPDC70 and OPDC80 could also be responsible for the statistical differences observed as the water and the oil; both were capable of increasing the nutrient uptake for the seedlings at their fragile early stages as in the experiment.

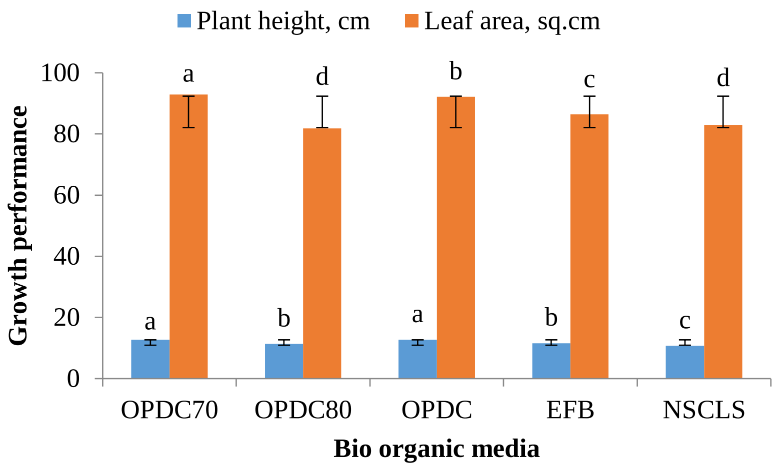


Fig. 4 Plant height and leaf area for cocoa seedlings using bio-organic media
abc- Means on the same shape fill with different letters are significantly different (P<0.05)

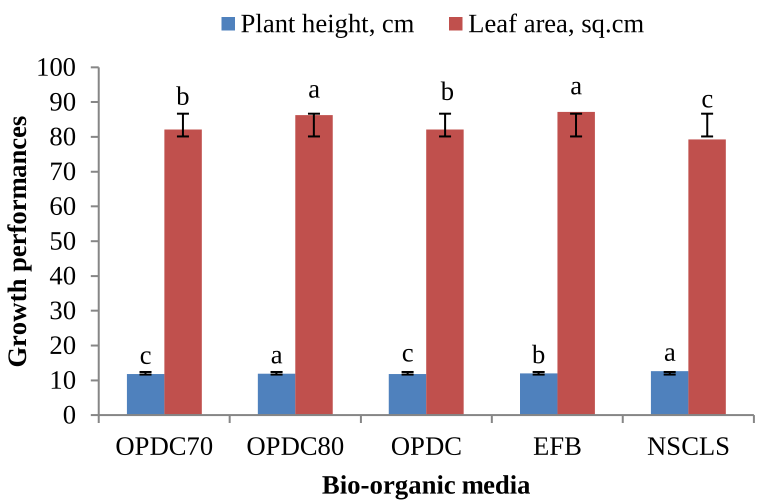


Fig. 5 Plant height and leaf area for citrus seedlings using bio-organic media
abc: Means on the same shape fill with different letters are significantly different (P<0.05)

Table 4 presents the correlation coefficients (*r*) between increasing oil contents in the oil palm bio-organic wastes and the growth parameters of both cocoa and citrus. From Table 4, we can see that leaf area had a strong positive correlation (0.863 at $p \leq 0.05$) and significant at $p \leq 0.05$ for the number of leaves and plant heights at varying OPDC and EFB media used for growing of cocoa seedlings. Besides, the plant height had a strong positive correlation (0.649 at $p \leq 0.05$), and significant at $p \leq 0.05$ for the number of leaves, stem girth and leaf area at varying OPDC and EFB media used for growing of citrus seedlings. However, it was not correlated and non-significant for the days to emergence in both crops but not also significant for the stem girth in the cocoa.

It is evident that there were strong positive effects of the oil palm bio-organic wastes on the growth parameters of the cocoa and citrus as shown through the values of their growth parameters and biomass values as depicted in Figs. 6 and 7. There were statistical differences among the biomass values (leaves, stems and roots) obtained for cocoa and citrus using different oil palm bio-organic wastes as shown in Fig. 6 for cocoa and Fig. 7 for citrus.

Table 4 Correlation coefficient (*r*) between growth parameters and usage of oil palm bio-organic wastes

Growth parameters	*r* values (cocoa)	*r* values (citrus)
Days to emergence	0.367ns	0.361ns
Number of leaves	0.494**	0.141**
Stem girth, cm	0.388ns	0.642**
Plant heights, cm	0.552**	0.649**
Leaf area, cm^2	0.863**	0.330**

**correlation is significant at p≤0.05; ns = not significant

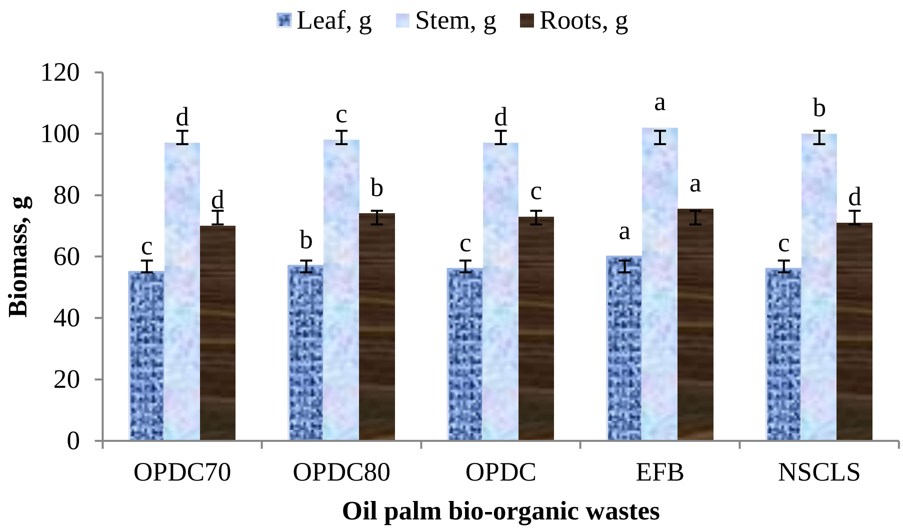


Fig. 6 Biomass of cocoa seedlings from usage of oil palm bio-organic wastes
abc- Means on the same shape fill with different letters are significantly different (P<0.05)

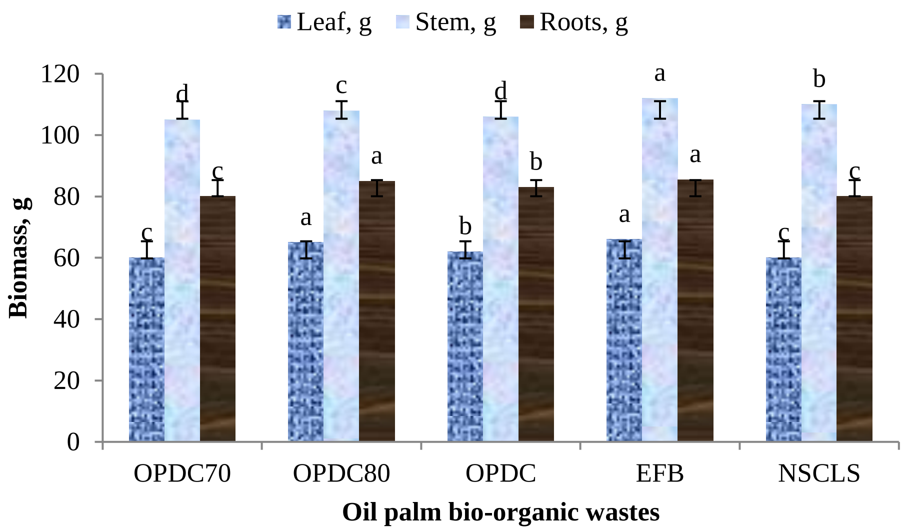


Fig. 7 Biomass of citrus seedlings from usage of oil palm bio-organic wastes
abc- Means on the same shape fill with different letters are significantly different (P<0.05)

This resulted in the EFB having a higher biomass (leaves, stems and roots in grammes, g) than any other in the research, it was closely followed by OPDC80. It could therefore be said that EFB increased the growth of the cocoa and citrus when used to propagate their seeds in the nursery than ordinary loamy clay soil. The physiology of both crops is evident as more nutrients (as were needed by these crops before and during emergence and during the first early life of the seedlings) must have been used up to build the biomass (Figs. 6 and 7) by these crops and especially the citrus that was healthy (without any spots) throughout the research. It could be seen that the total biomass gains from using bio-organic wastes for cocoa and citrus seedlings were high, as far as 263.5 and 237.5 g as the total for EFB for citrus and cocoa respectively (Figs. 6 and 7). The reasons could be due to the fact that bio-organic wastes contain a lot of nutrients needed for the plants' early life, these biomass gains were from the organic carbon in the OPDC and EFB media.

Economic feasibility

The volume of soil needed for raising cocoa or citrus in the nursery is small compared to the volume needed on the field, it is 0.0094 m^3 of soil per seedlings (at 20 cm diameter polythene bag and 30 cm height of soil in the polythene bag). So, the volume of OPDC or EFB needed is less. In addition, the cost of energy to raise the substrate's temperature to 80 ^oC for OPDC was ₦2,450 (Nigeria naira) per 100 seedlings. This was the cost price when the experiment was done, by conversion; it was $3(in USD). Therefore, for a thousand stands of crops, the cost of energy would be less than $30. So, the experiment was feasible even though, there are many other costs that would be necessary during the nursery propagation of the seedlings namely the cost of collection of the OPDC and EFB from the farmers (usually women-in-agriculture). The cost of drying the OPDC at 105 ^oC, polythene bags, labour, cost of heating the water for temperature rise to 70^o or 80 ^oC etc. None of these costs could be isolated; however, this research did not have to do with the economic analysis of the OPDC or EFB but the agronomic practices and waste recycling to clean the environment for man's advantages.

Conclusion

By incorporating oil palm decanter cake as bio-organic media, it could boost the permanent crops' seedlings' growth because it contains sufficient levels of N and P. Through hot water treatment, the oil content of oil palm decanter cake would show significant improvement for citrus seedlings, especially in the growth of the leaves. Besides OPDC, empty fruit bunch (EFB) when grounded contains higher needed nutrients for the growth of cocoa and citrus seedlings and if these wastes are harnessed for agricultural use, they will go a long way to increase the developmental stages of the permanent crops which will lead these crops to develop well and to yield well in their later years after transplanting to the fields.

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Compliance with ethical standards

Conflict of interest : The authors declare that there are no conflicts of interest associated with this study.

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