Effect of hot water-treated bio-organic media on palm seedlings growth

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Abstract: Oil palm decanter cake (OPDC) from palm oil milling is a potential hazard for environment due to its elevated organic content. Direct use of OPDC for planting medium could also give negative effect to plant growth, despite its high potential due to its substantial nutrient content. This study was conducted to examine the potential of hot water-treated OPDC as bioorganic media and its effects on growth performance of oil palm seedlings. OPDC was treated with hot water to remove oil content and chemical analysis was determined on N, P, K, Ca and Mg. For bio-organic media, the treated OPDC was mixed with MPOB F1 fertilizer and soil at 25%, 50% and 75% to plant oil palm seedlings. The results showed that after hot water treatment, residual oil was reduced from 15% to 10%-11%. Once applied as planting media, highest growth performance and biomass accumulation was recorded by mixture of 25% treated OPDC with soil and MPOB F1 fertilizer. Plant height, stem girth, leaf number, leaf area, leaf dry weight, stem dry weight and root dry weight were improved by 28%, 15%, 10%, 60%, 72%, 45% and 18%, respectively as compared to control. Higher percentage at 50% and 75% did not improved oil palm seedlings growth. In conclusion, appropriate amount of treated OPDC addition in growing media could improve the growth of oil palm seedling after oil content removal.

Keywords: oil palm decanter cake, oil content, bio-organic media, growth performance

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1 Introduction

Oil palm industry is continuously expanding since it has been planted more than 100 years ago in Malaysia. Currently, Malaysia is the second largest country with oil palm cultivation after Indonesia. Oil palm plantation area in Malaysia has increased from 5.23 million hectares in 2013 to 5.81 million hectares in 2017 (Malaysian Palm Oil Board [MPOB], 2018). As the oil palm plantation industry has expanded, the waste productions from the palm oil mills has also increased. Approximately, there are about 416 palm oil mills operating in Malaysia. From the mill, the estimated waste generation from 1 ton of fresh fruit bunch (FFB) is in the range from 0.6 to 0.8 m^3 of palm oil mill effluent (POME), 22% to 23% of empty fruit bunch (EFB), 3.5% of oil palm decanter cake (OPDC) and 13.5% palm mesocarp fibre (PMF) (Ooi and Kumar, 2008; Ng et al., 2011). In recent years, OPDC has been produced in higher amount due to more decanter machine installation in the mills to recover the remaining oil from the underflow of the sludge tank. Usually OPDC is dumped and left to degrade naturally in the dumping ponds.

Despite high generation of OPDC, its utilization is still low and not yet commercialized. Several studies have

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been conducted to utilize OPDC as natural polymer composite (Adam et al., 2014), solid fuel (Husin et al., 2009), cellulose and polyoses production (Razak et al., 2012), composting, and alternative energy and protein source for growing goats (Gafar et al., 2012). Currently, only few studies have focused on the utilization of OPDC as bio-organic media. OPDC is known to be rich in N (2.42%), P_2O_5 (0.51%), K_2O (1.24%), CaO (1.68%) and MgO (0.54%) (Haron et al., 2008). Its application together with inorganic fertilizer had showed synergistic effects and improved crops nutrient uptake by plants (Haron et al., 2008). The addition of decanter cake also improved plant physiological function, such as increasing the size of cell stomatal opening of brinjal from 36.3 to 40.6 µm with 10% addition of decanter cake (Embrandiri et al., 2016). Thus, OPDC has a potential as bio-organic media to enhance crop growth and performance. The pH of OPDC were ranged between 4.4–5.0 (Embrandiri et al., 2016; Razak et al., 2012; Sahad et al., 2014), considered as moderate to high by Goh and Chew (1997) (4.0–5.5) to provide condusive growth for plants.

Previous studied by Embrandiri et al. (2013) utilized raw OPDC as fertilizer supplement at different rates. However, it gave negative effect to plant growth performance and biochemical characteristics due to excess of nutrient present and high oil content in the raw OPDC used, with chlorophyll a content reduced from 1.02 mg at 0% to 0.11 mg at 30% while reducing yield from 4.09 g to 3.15 g per plant. Theoretically, the residual oil of OPDC need to be removed before OPDC can be used as fertilizer supplement and bioorganic media. Soxhlet extraction techniques using n-hexane and d-limonene was found to be effective in removing the oil content from OPDC completely (Sahad et al., 2015). However, this technique is expensive, time-consuming and not practical for large scale operation. The alternative technique is by thermal or heat treatment (Ariunbaatar et al., 2014).

This study was conducted to determine the physicochemical properties of raw and hot water treated OPDC and the effects of treated OPDC on the growth performances and biomass production of oil palm seedlings.

2 Materials and methods

2.1 Oil content removal

The raw OPDC was obtained from Sime Darby Kempas Oil Palm Mill, Melaka. The experiments for the oil content removal from OPDC was done by using hot water treatment adapted from Ariunbaatar et al. (2014). OPDC was mixed thoroughly with hot water and soaked until the oil layer moving upward. The oil layer and water were removed and the step was repeated 3 times. In order to determine the oil content loss, 10g treated OPDC was extracted by using 300 mL hexane in soxhlet extractor for 8 hour. Then, the extracted oil was concentrated in vacuum rotary evaporator and dried in an oven. The oil content removal was then calculated in Equation 1.

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

2.2 Physicochemical analysis of OPDC

Wet raw and treated OPDC were weighed and dried in an oven at 104°C until constant weight obtained. Then, the samples were weighed again to calculate the moisture content. The pH value was determined by using 1:10 (w v-1) method, while total nutrients were determined by using dry ashing method (Enders and Lehmans, 2012; Pushparajah, 1994). Dried raw and treated OPDC were grounded separately and passed through 2 mm sieve. 1g of each samples were put in porcelain crucible and placed in the muffle furnace at 300°C for 1 hour then gradually increased to 550°C for next 7 hours. After completed, few drops of deionized water and 2 mL of concentrated HCl were added before put on hot plate. After ash was slightly dried, 10 mL of prepared nitric acid (20% vv-1) was added and placed in a water bath for 1 hour. Then, all the mixture was transferred to a 100 mL volumetric flask and deionized water was added to volume. The solution was shaken and filtered with Whatman No.2 filter paper. The solution afterward was analysed by using ICP-OES for P, K, Ca and Mg. The sample was also analysed for N using LECO CNS-2000 elemental analyzer.

2.3 Bio-organic media preparation

The ratio of media was calculated based on the nutrient content needed by seedling for 8 months.

Approximately, 25%, 50% and 75% of the treated OPDC was mixed with 75%, 50% and 25% MPOB F1 fertilizer, 2 kg soil and cocopeat in polybag and left for 2 weeks before seedlings transplanting. Then, the polybags were arranged in triangular planting design in the open field (2°13'45.7"N, 102°27'22.2"E). Three-months oil palm seedlings were transplanted in polybags and arranged in a completely randomized design (CRD) as the field was flat and without any shading interference. The study was conducted for 8 months, from March to November 2017.

2.4 Growth performance and biomass

Plant height was measured by using measuring tape from base of stem above soil surface to the tip of highest leaf, stem girth was measured at height of 2 cm above soil surface with vernier caliper, leaf number was collected by counting number of leaves (Putra et al., 2015) for 8 months. The biomass was determined by destructive growth analysis technique (Danso et al., 2013). The leaves, stem and root were separated at the end of the experiment and washed under running water to remove the soil and dirt. Then, leaves, stem and root were dried in an oven at 70°C until obtained constant weight. Sample were weighed using digital balance for dryweight determination. Leaf area was calculated using leaf area meter.

2.5 Statistical analysis

The statistical analysis was performed using Minitab software. All data obtained were subjected to one way ANOVA to detemine the significant difference of treatments where $p \leq 0.05$. Tukey's HSD Test was conducted for means comparison.

3 Results and discussion

3.1 Oil content removal

Figure 1 showed the oil content in OPDC after treatment with hot water. During the first stage of hot water treatment, the oil content in OPDC has reduced approximately 1%, followed by 2%-3% at second stage and finally reduced approximately 4%-5%. Altogether the oil content in OPDC has reduced from 15% to 10%-11%.

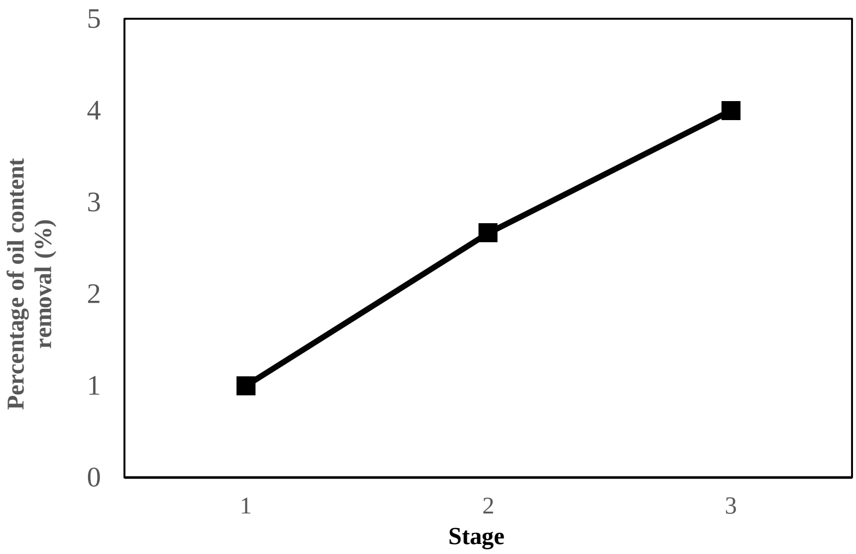

Figure 1 Percentage of oil content removal (mean) in three stages of hot water treatment

Eventhough the oil was not completely removed, this method could be practiced to make OPDC more useful as bio-organic media in large scale plantation. Because it was simple and cost effective. Soxhlet extraction method (Sahad et al., 2015) could remove oil content completely from decanter cake, but the method was not practical for large scale operation as it was expensive and time consuming.

3.2 Physicochemical properties of OPDC

Table 1 showed the physicochemical properties of OPDC used in this study as compared with the other related studies. The pH value of the raw OPDC was higher compared with other studies. After treated with hot water, the pH value has reduced from 5.47 to 4.86. According to Singh and Agrawal (2010), reduction in pH value to become more acidic can be attributed to the acidic nature of OPDC and also to release of humic acid as a result of OPDC degradation due to hot water treatment. The pH value after hot water treatment from other recent studies were 5.03±0.04 (Sahad et al., 2014) and 4.40±0.01 (Embrandiri et al., 2016), both showing the acidic nature of OPDC after treatment.

Moisture content in OPDC increased after hot water treatment, from 74.51% to 84.32%. It was comparabale with other previous studies, such as by Sahad et al. (2014) (78.20%±1.27%) and Razak et al. (2012) (76.46%±0.8%). As for oil content, hot water treatment reduced the content from 15% to 10%-11%. Study by Sahad et al. (2014) showed oil content in OPDC was 13.60%±3.33% while by Kandiah and Batumalai (2013) was 12.25%. Lower oil content is preferred for OPDC to be used as bio-organic media, as the oil has shown to bring adverse effect to growth and physiological function of plant (Embrandiri et al., 2013).

Table 1 Comparison of physicochemical OPDC

Parameters	Raw OPDC	Hot water treated OPDC
pH	5.47 ± 0.04	4.86
Moisture (%)	74.51	84.32
Oil content (%)	15	10-11
Total N (%)	2.0	2.2
Total P (%)	0.013	0.025
Potassium (%)	1.27	0.20
Calcium (%)	1.18	1.11
Magnesium (%)	0.28	0.10

Nutrient content of OPDC (Table 1) was in line with previous studies. For N, the content was 2.2% after hot water treatment, similar to study by Sahad et al. (2014) with 2.33%, while Razak et al. (2012) showed higher N content with 2.8%. With 2.2% of N, 10%-15% addition of OPDC in bio-organic media will approximately provide the oil palm seedlings with N at high level (0.15%-0.25%), according to soil nutrient status classification by Goh and Chew (1997). As for total P, the content was 250 µg g-1 after hot water treatment, classified as moderate (250-350 µg g^{-1}) by Goh and Chew (1997). The early stage of oil palm growth in nursery will very much dependant on N and P. Therefore, incorporating OPDC in bio-organic media could boost up the oil palm seedling growth as it contain sufficient level of N and P. The OPDC also contain other nutrients such as 0.20% K, 1.11% Ca, and 0.10% Mg after hot water treatment (Table 1).

3.3 Growth performance and biomass

Figures 2, 3 and 4 showed the growth performances, leaf area and total biomass of oil palm seedling for 8 months in nursery. Leaf area, leaf dryweight, stem dryweight and root dryweight were calculated at the end of experiment. The results showed that the growth performances and biomass production of oil palm seedlings were significantly affected ($p \leq 0.05$) by the various ratios of treated OPDC. Maximum growth performances and biomass production were obtained for the experiment with the ratio of 25% treated OPDC where the plant height, leaves number, stem girth, leaf area, leaf dryweight, stem dryweight and root dryweight were 117.75 cm, 22, 75.87 mm, 11568 cm², 108.31 g, 150.93 g and 82.63 g respectively.

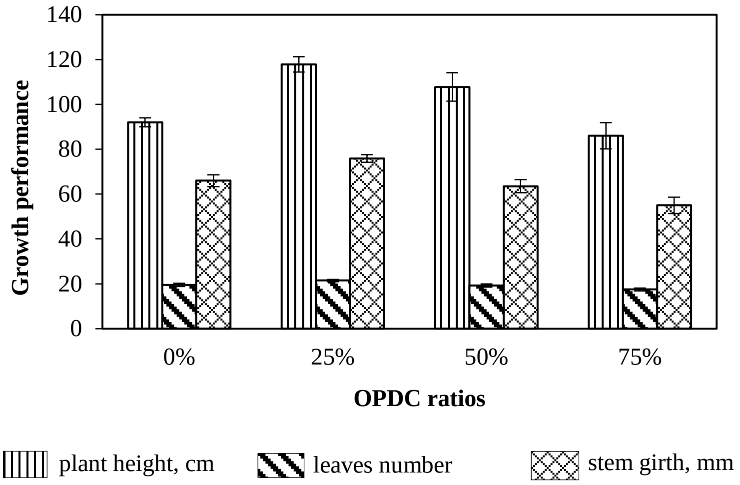

Figure 2 Growth performance of oil palm seedlings

There was significant difference as $p \leq 0.05$. Values were mean of 4 replicates in Figure 2.

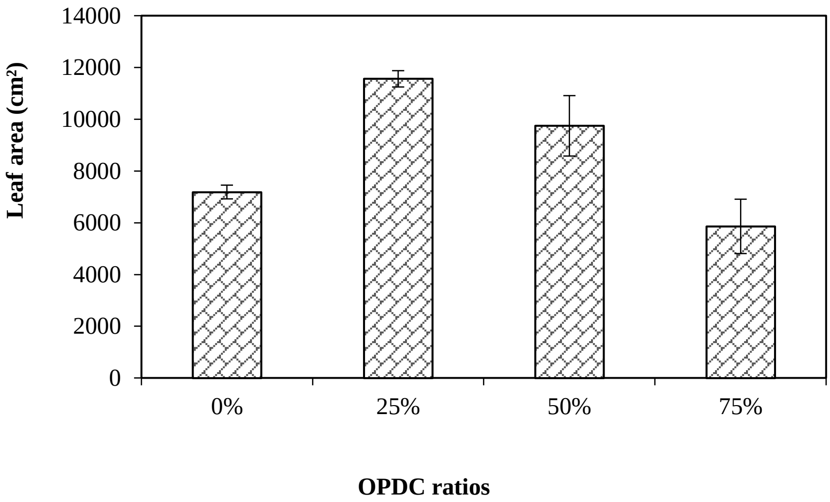

Figure 3 Total leaf area of oil palm seedlings

There was significant difference as $p \leqslant 0.05$. Values were mean of 4 replicates in Figure 3.

From the above results it can been seen that the growth performances and biomass production had decreased as the ratios of the treated OPDC were increased. Plant height, leaves number, stem girth, leaf area, leaf dryweight, stem dryweight, and root dryweight had decreased from 107.75 cm to 86.00 cm, 19 to 17, 63.52 mm to 54.97 mm, 9752 cm² to 5861 cm², 84.06 g to 49.06 g, 132.1 g to 68.91 g, 62.33 g to 30.8 g while oil palm seedlings were grown at 50% and 75% treated OPDC media. This could be due to the high nutrient content and toxicity effect of OPDC (Embrandiri et al, 2013). Similar results were observed by earlier studies using raw and decomposed OPDC on other types of crops.

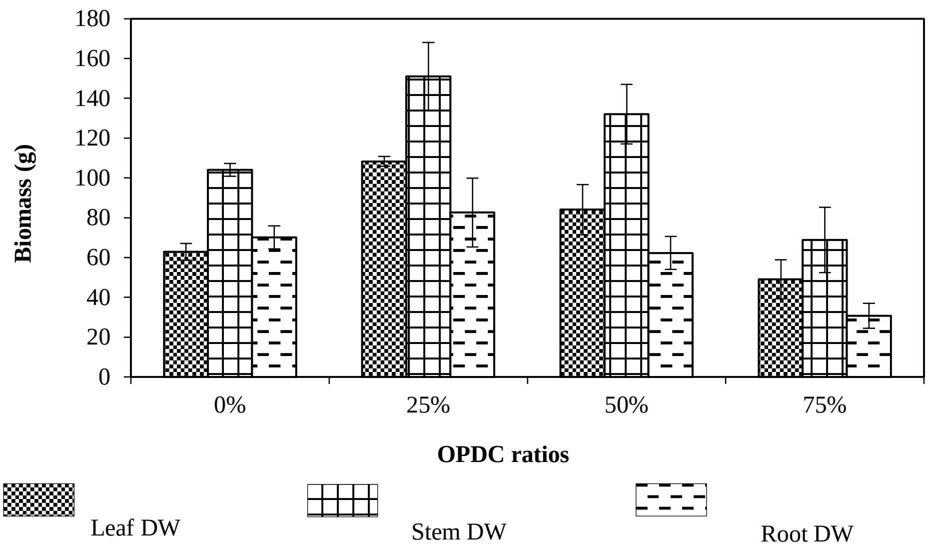

Figure 4 Biomass of oil palm seedlings

There was significant difference as $p \leqslant 0.05$. Values were mean of 4 replicates in Figure 4.

Embrandiri et al. (2013) and Singh and Agrawal (2009) reported that lady's finger maximum growth of shoot length and leaf number were obtained at 10% and 20% of raw OPDC and sewage sludge which were lower than this study. Radziah et al. (1997) showed that the highest growth of tomato and spinach were obtained by using 6% of decomposed OPDC. In this study, higher ratios of OPDC could be used compared to previous study which were between 25% to 75% treated OPDC after oil content removal. Oil content in media could cause stress to plant and created a situation of physiological drought where it interfered with water uptake and gaseous exchange (Omosun et al., 2008), blocked the xylem and phloem vessels and also slowed down root elongation (Bengough, 2003). More recent study on lettuce indicated that oil content could cause phytotoxic effects, causing non-germination and sublethal effects on root growth (Filho et al., 2017). Thus, removing oil content before used improved the efficiency of OPDC as bio-organic media.

OPDC had high organic carbon which was 74.4 % (Embrandiri et al., 2016). Organic carbon encouraged microbes multiplication and enzymatic activities which led to availability of nutrients in soil (Liu et al., 2016). Microbes decomposes the substrate and releases the nutrients from it which will be absorbed by plants at suitable environmental condition. Thus, by reducing the oil content it had increased the rate of microbial activities that was previously blocked by the oil layer and also improved the media condition, water and nutrient uptake, gaseous exchanging and translocation process. These conditions enhance the growth of oil palm seedlings and biomass production.

Besides that, OPDC has high nutrient contents. Application of treated OPDC with MPOB F1 fertilizer showed synergic effects and gave better growth performances of oil palm seedlings. The result obtained from this study is in agreement with previous study by Haron et al. (2008) where seedlings treated with OPDC and inorganic fertilizer have better growth due to increasing in nutrient content and improving the efficiency of nutrient uptake by crops. The use of OPDC as growing media for 8 months allowed the decomposition process to be completed within that time and therefore, the nutrients became available for plant uptake and further increase growth performances. Media mixed with OPDC compost had 46.4% nitrogen, 17.9% phosphorus, 17.7% potassium and 23.1% calcium more than that media without OPDC (Yahya et al., 2010). Thus, treated OPDC gives positives effect in plant growth performances and biomass accumulation.

4 Conclusions

OPDC is one of the promising waste materials generated in the palm oil mills suitable for bio-organic media once the oil is partially removed. In this study, it shows that OPDC has high moisture and nutrient contents required by the plants. Through hot water treatment, the oil content of OPDC was able to be reduced from 15% to 10%-11%. Treated OPDC incorporated as bio-organic media at the ratio of 25% and 50% showed significant improvement for oil palm seedlings growth. The height increment were between 17.0%-27.9% compared to the control, while the total leaf area was increased by 35.6%-60.9% and total biomass by 17.4%-44.1%. In conclusion, appropriate amount of treated OPDC incorporation in growing media could improve the growth of oil palm seedling after OPDC oil content removal.

References

Adam, M. A., A. Sulaiman, C. M. S. Said, A. M. Som, A. S. Bahruddin, and M. N. Mokhtar. 2014. Preliminary study of oil palm decanter cake natural polymer composite (OPDC-NPC). Advanced Materials Research, 911: 40-44.

Ariunbaatar, J., A. Panico, L. Frunzo, G. Esposito, P. N. Lens, and F. Pirozzi. 2014. Enhanced anaerobic digestion of food waste by thermal and ozonation pretreatment methods. *Journal of Environmental Management,* 146: 142-149.

Bengough, A. G. 2003. Root growth and function in relation to soil structure, composition and strength. *Root Ecology*, 168:151-171.

Danso, F., C. Adu, A. Opoku, A. Okyere, and E. Larbi. 2013. Raising oil palm seedlings using sole and amended green-gro compost. *International Research Journal of Agricultural Science and Soil Science*, 3(10): 362-368.

Embrandiri, A., R. P. Singh, and M. H. Ibrahim. 2013. Biochemical, morphological and yield responses of lady's finger plants to varying ratios of palm oil mill waste (decanter cake) application as a biofertilizer. *International Journal of Recycling of Organic Waste in Agriculture,* 2(7): 1-6.

Embrandiri, A., P. F. Rupani, S. A. Ismail, R. P. Singh, M. H. Ibrahim, and M. O. A. Kadir. 2016. The effect of oil palm decanter cake on the accumulation of nutrients and the stomatal opening of *Solanum melongena* (brinjal) plants. *International Journal of Recycling of Organic Waste in Agriculture,* 5: 141-147.

Enders, A., and J. Lehmann. 2012. Comparison of wet-digestion and dry-ashing methods for total elemental analysis of biochar. *Communications in Soil Science and Plant Analysis,* 43:1042-1052.

Filho, S. T., J. L. De Paiva, H. A. Franco, D. V. Perez, and M. R. C. Marques. 2017. Environmental impacts caused by residual vegetable oil in the soil-plant system. *Ciência e Natura*, 39(3): 748-757.

Gafar, A. A., A. R. Alimon, A. Q. Sazili, and Y. C. Man. 2012. Utilization of palm oil decanter cake (PODC) as protein and energy sources for small ruminants. In *33rd Annual Conference of Malaysian Society of Animal Production*, 210-211. Langkawi, Kedah, 4-7 June.

Goh, K. J., and P. S. Chew. 1997. Interpretations of analytical data from soil survey reports for manuring recommendations: some pointers, 25-30. *Royal Johore Planters' Association Annual Report.* Royal Johore Planters' Association.

Haron, K. M. A. T., R. M. Halim, and A. K. Din. 2008. Palm-based bio-fertilizer from decanter cake and boiler ash of palm oil mill. *Malaysian Palm Oil Board (MPOB), Information Series (MPOB TT No.412)*, 1-4.

Husin, M., M. Haizal, N. Dewayanto, and M. N. Ridzuan. 2009. Solid fuel from decanter cake: a preliminary study. In *3rd Malaysian Technical Universities Conference and Exhibition on Engineering and Technology (MUCEET 2009).* Kuantan, Pahang, 20-22 June.

Kandiah, S., and R. Batumalai. 2013. Palm oil clarification using evaporation. *Journal of Oil Palm Research*, 25(2): 233-235.

Liu, Y., P. Wang, Y. Ding, H. Lu, L. Li, K. Cheng, J. Zheng, T. Filley, X. Zhang, J. Zheng, and G. Pan. 2016. Microbial activity promoted with organic carbon accumulation in macroaggregates of paddy soils under long-term rice cultivation. *Biogeosciences*, 13: 6565-6586.

Malaysian Palm Oil Board (MPOB). 2018. Oil palm planted area. Available at: http://bepi.mpob.gov.my/index.php/en/area/area-2018/oil-palm-planted-area-as-at-dec-2018. Accessed 28 Dcember 2021.

Ng, F. Y., F. K. Yew, Y. Basiron, and K. Sundram. 2011. A renewable future driven with Malaysian palm oil based technology. *Journal of Oil Palm, Environment & Health*, 2: 1-7.

Omosun, G., A. A. Markson, and O. Mbanasor. 2008. Growth and anatomy of *Amaranthus hybridus* as affected by different crude oil concentrations. *American-Eurasian Journal of Scientific Research 3*, 1: 70-74.

Ooi, H. S., and S. S. Kumar. 2008. Co-composting for sustainable crude palm oil production in Malaysia. Jurutera Buletin. 22-26. Malaysia, Institution of Engineers Malaysia (IEM).

Pushparajah, E. , and T. K. Teng. 1994. Leaf analysis and soil testing for plantation tree crops. In *The International Workshop: leaf diagnosis and soil testing as a guide to crop fertilization*, pp. 1-9. ASPAC & FFTC.

Putra, E. T. S., Issukindarsyah, Taryono, and B. H. Purwanto. 2015. Physiological responses of oil palm seedlings to the drought stress using boron and silicon applications. *Journal of Agronomy*, 14(2): 49-61.

Radziah, O., H. Azizah, and A. R. Zaharah. 1997. The phytotoxic effects of palm oil dry solids on plant growth. *Pertanika Journal of Tropical Agricultural Science*, 20(2/3): 91-99.

Razak, M. N. A., M. F. Ibrahim, P. L. Yee, M. A. Hassan, and A. S. Abd. 2012. Utilization of oil palm decanter cake for cellulose and polyoses production. *Biotechnology and Bioprocess Engineering*, 17: 547-555.

Sahad, S., A. M. Som, A. S. Baharuddin, N. Mokhtar, Z. Busu, and A. Sulaiman. 2014. Physicochemical characterization of oil palm decanter cake (OPDC) for residual oil recovery. *BioResources*, 9(4): 6361-6372.

Sahad, N., A. M. Som, A. S. Baharuddin, N. Mokhtar, Z. Busu, and A. Sulaiman. 2015. Recovery of residual crude palm oil (RCPO) from oil palm decanter cake (OPDC) using D-limonene. *Advanced Materials Research*, 1113: 405-410.

Singh, R. P., and M. Agrawal. 2009. Use of sewage sludge as fertilizer supplement for *Abelmoschus esculentus* plants: physiological, biochemical and growth responses. *International Journal of Environment and Waste Management*, 3: 91-106.

Singh, R. P., and M. Agrawal. 2010. Effect of different sewage sludge applications on growth and yield of *Vigna radiata* L. field crop: metal uptake by plants. *Ecological Engineering*, 36: 969-972.

Yahya, A., C. P. Sye, T. A. Ishola, and H. Suryanto. 2010. Effect of adding palm oil mill decanter cake slurry with regular turning operation on the composting process and quality of compost from oil palm fruit bunches. *Bioresource Technology*, 101(22): 8736-8741.