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Utilisation of DOBE: Palm oil mill waste as organic fertiliser

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Abstract
Depleted oil bleaching earth (DOBE) is a waste discharge from spent bleaching earth (SBE) processing facilities of palm oil refineries. This material is acidic (pH <5.0) and hydrophobic. Currently, DOBE is disposed to landfills, thereby posing environmental hazard due to its intrinsic properties. A study was undertaken to de-oil DOBE by composting with palm oil mill effluent (POME) only, POME mixed with commercial microbes, and commercial microbes only to eliminate the acid reactivity and DOBE hydrophobic property. The study found that the results produced by POME were as good as those by commercial microbes. The C/N ratio and oil content for DOBE pile added with POME alone decreased from 58.8 to 9.5 and from 8.5% to 0.5%, respectively. A field trial comparing composted DOBE against three conventional organic fertilisers showed that composted DOBE performed as good as those conventional organic fertilisers. Further research is needed to establish whether frequent usage of composted DOBE will lead to the reduction of soil pH. Whilst using liquid POME to treat DOBE into an organic fertiliser is virtually cost-free, the composting process helps solve the problem with DOBE disposal.

Keywords: bleaching earth, Ca-montmorillonite, depleted oil, organic fertiliser, residual oil

Introduction

During the processing of palm oil, crude palm oil has to go through a refining process for degumming, neutralising, bleaching, and deodorising. These processes are to eliminate impurities in order to improve the quality of oil up to certain standards (Farihahusnah et al., 2011). A common bleaching method used in palm oil refinery is absorption using bleaching earth. Bleaching earth, also known as Fuller's earth, consists of bentonite clay with a high capacity of absorption. It has been used widely since the end of the 18th century (Beneke et al. 2002). The filter containing bleaching earth is regularly replaced to produce oil of good quality and the used filter, called 'spent bleaching earth', is turned into waste.

Spent bleaching earth contains a high amount of oil (20 – 40%). This oil is partially extracted using hexane before the spent bleaching earth is dumped at landfills for disposal (Nursulihatimarsyila et al. 2010). This waste material is then called 'depleted oil bleaching earth' (DOBE). It is estimated that about 150,000 tonnes of DOBE is produced yearly based on 19 million tonnes of crude palm oil production (Econ, MPOB, 2011). DOBE is acidic (pH <5.0) and hydrophobic in nature. The hydrophobic property is due to the presence of oil in DOBE. After the extraction of oil from spent bleaching earth,

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it is estimated that the remaining oil content in DOBE is around 8%, thereby making the disposal of DOBE at landfills problematic due to the potential environmental pollution. Moreover, the industry has to incur logistic costs to dispose this material. This situation is untenable because landfill disposal will probably become impossible due to environmental concerns and land scarcity.

Loh et al. (2011) found that this waste material is beneficial as bio-organic fertiliser and provides adequate amount of nutrients for plant growth. Organic fertiliser is used not only to provide plant nutrition but also as soil amendment. Organic fertiliser is derived from plant- or animal-based materials that are either by-products or end products of naturally occurring processes such as animal manure and composted organic materials. It is rich in organic matter that can improve the soil structure, soil quality and water holding capacity (Li et al. 2017). The presence of a high amount of bentonite clay in DOBE provides an opportunity for it to be used as soil amendment, which can enhance soil quality. Bentonite clay (montmorillonite) consists of 2:1 dioctahedral clay mineral with alumina octahedral layer in the middle of two silica tetrahedral (Deng et al. 2017). Montmorillonite has a high specific surface area, high adsorption capacity, chemical and mechanical stability, high cation exchange capacity and swelling ability as well as being rich in nutrients (Madejova 2003; Noble et al. 2001). Because of these properties, putting DOBE on soil may enhance soil quality and improve plant production. It strengthens the negative charge on soil surface by exchanging the positively charged ions in most of the nutrients including K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^+, and Mn^{2+} (Loh et al. 2013). DOBE has other nutrients that are essential for plant growth. Hence, DOBE has a potential to be used as fertiliser that provides nutrients for plant production.

However, DOBE will only be beneficial if its usage poses no adverse side effects. To overcome the toxicity of DOBE associated with the fats and oils that are still present and its acidity (Farihahusnah et al. 2011), it has been proposed to subject the waste material to a composting process before disposal. Zheng et al. (2007) mentioned that oil carbon in solid waste will degrade into CO_2, water and other stable forms of organic matter during composting. However, composting may take about 4 – 6 months for solid waste containing oil, which is undesirable. It has been suggested that the composting time may be reduced by using additional microbes (Manu et al. 2017). These microbes are readily available on the market but are relatively expensive. It will be more beneficial if DOBE can be composted using relatively low-cost microbes. Several studies mentioned that a suitable consortium of microbes has been found in palm oil mill waste. Hence, it is worth investigating whether these microbes can be used for composting DOBE.

Research has shown that oil in polluted water and soil can be degraded by microbes such as *Candida cylindracea, Aspergillus* spp., *Penicillium* spp., *Trichoderma* spp., and *Mucor* spp. (Adnan et al. 2018). These microbes can produce lipase that helps to degrade the hydrocarbon in crude oil, kerosene, diesel and benzine (Salmanov et al. 2008). Adding such microbes to the composting process may help to degrade oil in DOBE. Charles et al. (2011) found the presence of the previously mentioned lipase-producing microbes in treated palm oil mill effluent (POME). POME is a waste discharged from the same refinery processing plant as DOBE. Fresh POME is a thick copper-coloured colloidal mixture containing water, oil and grease that has gone through treatments under a series of large shallow ponds before discharge. POME in the final discharge pond has been biologically digested and stabilised and is safe to be discharged. It contains various fine suspended solids with the pH ranging between 4 and 5 (Rupani et al. 2010). Bala et. al (2018) found the presence of indigenous microbes in POME such as *Bacillus* spp., *Aspergillus* spp., *Providencia* spp., and *Micrococcus* spp., which are known as oil-degrading bacteria. Therefore, this study investigated whether POME has the ability to speed up and degrade the residual oil in DOBE through the composting process. It is believed that mixing DOBE with treated POME may be able to stimulate the degradation of residual oil in DOBE. If this is possible, the composting of DOBE will save logistic costs because the process can be done in-situ. A field experiment was conducted to determine the performance of composted DOBE on kailan (*Brassica alboglabra*) growth. The performance of composted DOBE on crop growth was compared with three different products: green compost, chicken manure and vermicompost that are currently applied in MARDI's Integrated Organic Farm.

Materials and methods

Raw materials

DOBE from palm oil processing plants were sourced from Eco Oil Industry Sdn. Bhd., Nilai, Malaysia. Three bags of DOBE (one tonne each) were transported to MARDI's Integrated Organic Farm, Serdang, Malaysia. Exactly 20 barrels of 160 L POME were derived from the final pond of Refined Bleached and Deodorized Oil refinery in Nilai. POME was stirred two times daily to supply oxygen for the survival of aerobic microorganisms. Commercial microbes that are used widely to compost effluent sludge from palm oil waste were used to counter check whether POME can perform as good as the commercial products. Commercial microbes (BIOTA 30C containing microbial organisms) were obtained from Bio-system Corporation. BIOTA 30C has been used widely in Malaysia to degrade lignin, grease, fat and oil in other palm oil waste such as empty fruit bunch and effluent sludge. BIOTA 30C consists of a range of aerobic and facultative anaerobic bacteria but the details on species composition are protected and not revealed for commercial reasons (Biosystem 2017).

Green compost (GC) and vermicompost (VC) were obtained from MARDI's Integrated Organic Farm, Serdang. Briefly, for GC preparation, grass cutting, rice straw, and rice bran were mixed in the ratio 4:1:1 and let to decompose for 30 days. VC was prepared by mixing 40% of vegetable waste, 30% of rice straw, and 30% of cow manure in a 2 m × 1.5 m × 1 m vermicompost pit. A total of 2000 earthworms (Eisenia fetida) were added to the pit and let to compost the mixture for about 1.5 months. Composted chicken dung (CD) used in this study was collected from an agriculture shop in Serdang, Selangor, Malaysia.

Composting of DOBE

Treatments used in composting DOBE were commercial microbes only (MO), palm oil mill effluent (POME) only (PO), and POME mixed with the commercial microbes (PM). Each product was mixed into a one-tonne heap of DOBE. For MO, 40 g of BIOTA 30C was mixed with 1 L of water and sprayed on DOBE as prescribed in the instruction manual (Biosystem product specification handout). After that, 349 L of water was mixed homogeneously in MO. For PO, 350 L of POME was mixed homogeneously into 1 tonne of DOBE. PM was prepared by mixing 20 g of BIOTA 30C with 175 L of water and 175 L of POME. The mixture was then mixed homogeneously and let to compost in a heap. The composting temperature was monitored once daily for over 21 weeks and the pile was constantly turned for aeration during the thermophilic stage. The compost sample was taken weekly after it was turned and mixed at three different points to check for homogeneity. The subsamples of all materials were dried grounded, and passed through a 2 mm sieve for physical and chemical analyses.

Physico-chemical characterisation of DOBE

The pH was measured by mixing the entire sample with deionized water (1:2.5 w/v) using a glass electrode (McLean, 1982). For total nitrogen and total carbon, the sample was analysed based on wet weight using CHN analyser (LECO Corporation, St Joseph, Michigan USA) through the combustion method. Available phosphorus in soils was extracted based on Bray and Kurtz no. 2 procedures. Cation exchange capacity (CEC) was determined by leaching the soil with NH_4OAc at pH 7, and the NH_4^+ concentration in the leachate was determined through steam distillation using the micro-Kjeldahl method (Bremner, 1996). The X-ray diffraction (XRD) pattern was obtained using the Philips high-angle diffractometer system, equipped with a goniometers angle detector (X'Pert pro MTD, Panalytical).

Field experiment

After 21 weeks of composting, composted DOBE was used for further verification. The aim was to evaluate DOBE performance as organic fertiliser compared with other current fertiliser products. The experiment was carried out at MARDI's Integrated Organic Farm, Serdang, Selangor. The test crop, *Brassica alboglabra* (kailan) was grown on 3 m × 1 m raised beds under rain shelter and treated with four different treatments: 1) depleted oil bleaching earth compost and further referred to as composted DOBE, 2) green compost, 3) chicken manure and 4) vermicompost. For all organic fertilisers, a rate of 30 tonne/ha was used three days before planting following the standard rate for organic brassica. For the control plot, no fertiliser was added throughout the experiment. The experiment was carried out using the randomised complete block design (RCBD) in five replicates for two cropping cycles.

Crop yield was collected at the end of each cycle and weighed on a fresh weight basis. The soil was sampled before applying the organic fertiliser and at the end of both the first and the second cycle. Chemical and physical properties of the soil were determined.

Data analysis

Analysis of the data obtained for DOBE composting was performed using General Linear Model (GLM) in IBM SPSS, with C/N ratio as the dependent variable, treatment as the fixed factor, and week as the covariate. One-way ANOVA was performed for the analysis of B. alboglabra yield as the dependent variable and treatment as the fixed factor. A pair-wise comparison of treatment means was done using Turkey (Turkey's test $p < 0.05$) as the criterion for significance.

Results and discussion

Physico-chemical characteristics of DOBE before and after composting

Table 1 shows the chemical characteristics of the organic fertilisers used in the experiment. All organic fertilisers were used at the 30 tonne/ha rate. Composted DOBE had the lowest total nitrogen with 0.44% N, whereas the other three fertilisers had more than 1% nitrogen content. The physico-chemical characteristics of DOBE and POME at the beginning of the expriment, as well as the characteristics of DOBE in the three treatments after 21 weeks of composting are presented in *Table 2*. Fresh DOBE consisted of 9.44% oil. DOBE was then composted with different substrates, namely POME (PO), commercial microbes (MO) and a mixture of both (PM). POME and commercial microbes were found to contain oil-degrading microbes such as *Bacillus* spp. and *Aspergillus* spp. (Bala et al., 2018). Fresh DOBE had 2% phosforus, 3% calcium, and 2% of magnesium which may enhance the compost nutrient content. All the macro nutrients in DOBE increased to at least 5% at the end of the composting period (*Table 2*). PO and PM showed double the amount of nitrogen compared to MO at the end of composting. After 21 weeks of composting, the oil content of the compost pile dropped to 0.1% for DOBE composted

Table 1. Chemical characteristics of organic fertilisers used in the experiment

Type	pH (H2O)	Organic carbon (%)	Total N (%)	P2O5 (%)	K2O (%)	Rate of application (ton/ha)
Composted DOBE	5.58	4.45	0.44	2.50	0.70	30
Green compost	6.35	24.5	1.57	0.77	2.83	30
Chicken manure	5.66	3.00	1.72	1.82	2.18	30
Vermicompost	6.69	n.a	1.79	1.02	1.75	30

with PO, 1% for DOBE composted with PM and 2.8% for DOBE composted with MO. Fresh DOBE had a very high C/N ratio of 91. Even after 21 weeks of composting, MO still gave a high C/N ratio (34.7), which corresponded to the observation that the amount of oil was still high (2.8%). PO gave a low level of C/N ratio, conductivity and pH compared to PM and MO with 9.48 for the C/N ratio, 3.2 $dScm^{-1}$ for conductivity, and 5.8 for pH. PO also showed a high CEC (36 $cmol^{(+)}kg^{-1}$) compared to MO (32 $cmol^{(+)}kg^{-1}$) and PM (34 $cmol^{(+)}kg^{-1}$).

Efficacy testing of composted DOBE

The evaluation on crop yield of *Brassica alboglabra* for composted DOBE and three other organic fertilisers was done for two consecutive cropping cycles. The performance of composted DOBE on crop growth was compared with that of chicken manure, green compost, and vermicompost based on fresh yield. The total fresh yield for each cycle is shown in *Figure 1*. The yield results of *B. alboglabra* did not show any significant differences among treatments in the first cropping cycle. The average *B. alboglabra* yield was 0.9 t/ha in the first cycle and increased to 1.8 t/ha in the second cycle. Composted DOBE produced a high yield (2.2 t/ha) compared to green compost (1.7 t/ha) and the control (0.8 t/ha) but was not significantly different from chicken manure (2.3 t/ha) and vermicompost (1.9 t/ha). The control treatment with no fertiliser added produced a significantly lower yield in the second cycle than the yields of all fertiliser treatments. This study demonstrates that composted DOBE is not phytotoxic to plants eventhough the pH is lower than 6. The higher yield performances of four treatments compared to the control

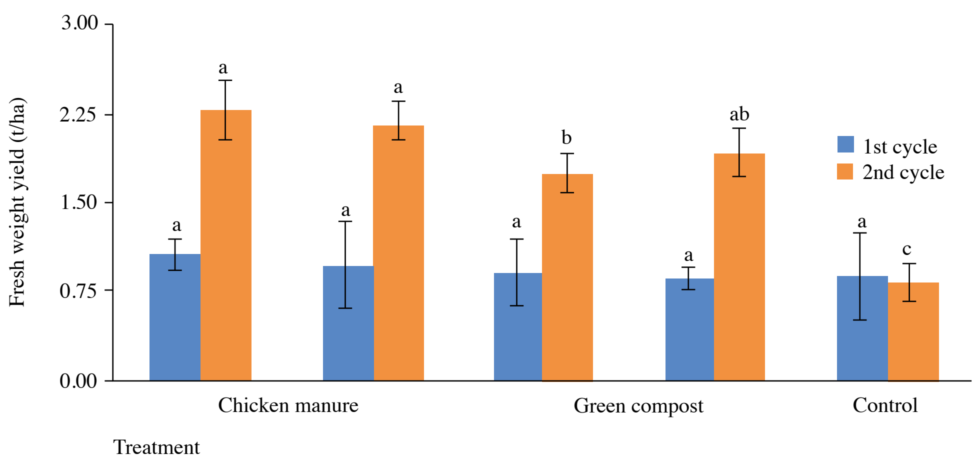

Figure 1. Fresh weight of ***Brassica alboglabra*** *for different type of organic fertilizer, chicken dung (CD), depleted oil bleaching earth compost (PO), normal green compost (NC) and Vermicompost (VC). Values are the means with standard deviation bars (n=5)*

treatment is well explained by the chemical characteristics of treated DOBE with POME, which contains important nutrients mainly phosphorus, potassium and trace elements that are essential for crop growth (*Table 2*). The findings prove that treated DOBE with POME has a good potential for usage as a cropping medium without a further addition of fertiliser, thereby reducing the cost of crop production. The control treatment, which consisted of soil only, did not produce a cabbage head. The soil used in the control treatment had very low nutrient content, insufficient to supply nutrients for plant growth. Filho et al. (2013) reported that phosphorus is an essential element for cabbage growth and has a significant influence on the development of cabbage leaves and heads.

Changes in soil properties

The changes in total nutrient (N, P, K, Ca, Mg), CEC, pH and organic carbon contents in soils were studied for two cropping cycles of *B. alboglabra*. Soil properties at the initial stage before fertiliser application, after the first cycle, and after the second cycle are presented in *Table 3*. Initial soil properties recorded a high carbon content (2.2%), good CEC (11.4 $cmol^+/kg$) and a suitable pH (7.1) for vegetable production (Stiles, 2004). After the first cycle, no significant differences in soil carbon and calcium were observed among the treatments. The pH value for the treatment with composted DOBE (7.2) was significantly different from the treatments with chicken manure and green compost; however, it did not show any significant difference against the treatments with vermicompost and control. Green compost had a high N content (0.4%) compared to the initial N in the soil (0.14%). Control recorded a low N content

Table 2. Physico-chemical characteristic of fresh DOBE and fresh POME; and DOBE after 21 weeks composting with commercial microbes only (MO), POME only (PO), and mixture of commercial microbes and POME (PM)

Element	Fresh		After 21 weeks of composting		
	DOBE	POME	MO	PO	PM
N (%)	0.13	0.07	0.20	0.40	0.40
P_2O_5 (%)	2.27	0.02	2.50	2.40	2.50
K_2O (%)	0.43	0.19	0.60	0.60	0.70
CaO (%)	3.17	0.04	3.30	3.10	3.30
MgO (%)	2.34	0.03	2.60	2.50	2.70
Zn (mg/kg)	40.0	0.00	50.0	52.0	60.0
Cu (mg/kg)	43.0	0.00	32.0	30.0	34.0
Mn (mg/kg)	386	0.00	394	367	401
Fe (%)	1.20	0.00	1.40	1.30	1.50
C/N	91.0	0.36	34.7	9.48	10.1
Oil (%)	9.44	–	2.80	0.10	1.00
CEC ($cmol^{(+)}/kg$)	–	–	32.0	36.0	34.0
Total carbon (%)	11.8	0.03	6.24	4.17	4.45
pH	4.86	4.80	5.37	5.76	5.58
	2.50	7.60	2.55	3.21	2.95

Table 3. Soil property measured at the initial start (before fertilizer application), after the first cycle and after the second cycle. Chicken manure, composted DOBE, green compost, vermicompost and treatment with bare soil (control) were tested on *Brassica alboglabra*

Trt	pH	C (%)	N (%)	P (ppm)	K^+ (ppm)	Ca^{2+} (ppm)	Mg^{2+} (mg/kg)	CEC ($cmol^{(+)}/kg$)
Before cropping cycle								
Initial	7.1 ± 0.17	2.22 ± 0.19	0.14 ± 0.04	459 ± 132	88.6 ± 23.9	133 ± 29.5	56.1 ± 8.8	11.4 ± 1.8
After 1st cycle								
Chicken manure	7.5^a ± 0.22	1.70^a ± 0.44	0.26^b ± 0.03	608^a ± 168	125^a ± 20	122^a ± 44	34.6^b ± 9	11.9^a ± 1.3
Composted DOBE	7.2^b ± 0.07	1.54^a ± 0.24	0.20^{bc} ± 0.01	694^a ± 34	69.5^{bc} ± 30	123^a ± 5	39.1^{ab} ± 25	10.8^a ± 2.7
Green compost	7.7^a ± 0.19	1.72^a ± 0.62	0.40^a ± 0.11	705^a ± 66	130^a ± 26	95.4^a ± 13	82.1^a ± 35	15.1^a ± 3.8
Vermi-compost	7.4^{ab} ± 0.12	1.51^a ± 0.09	0.21^{bc} ± 0.01	404^b ± 13	92.2^{ab} ± 9	107^a ± 25	32.7^b ± 19	10.7^a ± 1.3
Control	7.4^{ab} ± 0.21	1.50^a ± 0.18	0.13^c ± 0.02	390^b ± 29	46.1^c ± 14	105^a ± 28	35.3^b ± 20	11.9^a ± 3.6
After 2nd cycle								
Chicken manure	7.33^a ± 0.14	2.63^a ± 0.47	0.24^b ± 0.04	640^a ± 156	142^a ± 17	124^b ± 28	41.5^a ± 19	10.2^{ab} ± 2.4
Composted DOBE	7.00^b ± 0.09	2.34^a ± 0.99	0.21^b ± 0.01	780^a ± 58	68.1^c ± 10	166^a ± 22	42.5^a ± 18	12.2^a ± 1.3
Green compost	7.41^a ± 0.16	2.44^a ± 0.59	0.34^a ± 0.05	619^a ± 68	136^{ab} ± 14	102^b ± 8.9	62.0^a ± 31	13.0^a ± 2.5
Vermi-compost	7.21^{ab} ± 0.12	2.07^a ± 1.13	0.23^b ± 0.02	424^b ± 40	114^b ± 14	98.6^b ± 13	37.8^a ± 12	9.7^{ab} ± 1.4
Control	7.22^{ab} ± 0.09	2.12^a ± 0.48	0.10^c ± 0.00	404^b ± 67	44.3^c ± 6.4	99.1^b ± 9.0	30.1^a ± 7.2	8.0^b ± 2.0

Lower case letter (a, b, c) denote significant differences between treatments (p <0.05). Values are the means with standard deviation (n=5)

(0.13%), but it was not significantly lower than that of vermicompost and composted DOBE. The P content for vermicompost (404 ppm) was significantly lower than that of other treatments and decreased by 12% from the initial soil's P content. This content was not significantly different from that of control. Green compost showed a high increase in the P content (705 ppm) but not significantly different from that of chicken manure and composted DOBE. After the first cycle, green compost showed a high exchangeable K amount (130 ppm) compared to composted DOBE (69.5 ppm) and control (46.1 ppm). This content was not significantly different from those of chicken manure and vermicompost. Green compost had a high exchangeable Mg content (82.1 ppm) that was not significantly different from that of composted DOBE. After two cropping cycles, the pH value of composted DOBE was lower than that of chicken manure and green compost. For carbon (C) and magnesium (Mg) content, there were no significant differences among treatments. Soil nitrogen content in the treatment with composted DOBE showed a low value (0.21%) compared to other treatments except for the control plot. Soil P in the composted DOBE treatment had markedly increased by 70% (780 ppm). For the potassium (K) content in soil after two cropping cycles, chicken manure had a high K content (142 ppm) compared to other treatments, but it did not show any significant difference against green compost. The composted DOBE plot had a significantly high soil calcium (Ca) content

(166 ppm) compared to other treatments and was able to increase soil Ca by 25%. Soil CEC in the composted DOBE treatment was higher than the initial soil CEC, but there was no significant difference against other treatments except for the control.

This result demonstrates the clear effects of composted DOBE and three organic fertilisers which can improve soil fertility and at the same time increase crop yields. Further research should be conducted to ascertain their long-term effects on plant production. The soil chemical changes of the treatments were used as indicators of soil quality. The soil profile for this study location was characterised as Serdang series (Paramanathan, 2000). Soil in the test plots had sandy loam to loamy textures with more loamy content in deeper soil. The study site had a high initial soil pH due to the amendment application for about five years before the experiment. Plots with composted DOBE recorded a lower soil pH after two cropping cycles, which could be due to the low pH value (5.58) of the initial composted DOBE material compared to the other fertilisers. The higher amount of H^+ in composted DOBE might have influenced soil acidity, resulting in a lower pH at the end of the second cycle, where composted DOBE lowered the soil pH at the end of second cycle by 1%. Overall, soil pH increased during the first cycle and then decreased by about 0.2 units for each treatment by the end of the second cycle. The pH increase during the first cycle was caused by either mineralization that converted organic anion into CO_2 and water or the addition of the alkaline nature of the fertiliser itself (Helyar, 1976). Nonetheless, the short-term experiment does not offer sufficient information to establish the long-term effects of organic fertiliser on soil acidity. A long-term experiment should be conducted to check the pattern of pH changes and the mechanism causing soil acidity due to DOBE application.

The application of composted DOBE was expected to increase soil CEC more than other treatments due to the presence of montmorillonite clay as a base material in composted DOBE. Montmorillonite is known as a good absorption material with a high charge, CEC and surface area. These characteristics allow montmorillonite to retain water, nutrient and heavy metals (Murray, 1999). In this study, soil CEC for the treatment using composted DOBE increased but not significantly different from the other treatments, except the control. The experiment was carried out for only two cropping cycles, which might not be enough to increase the soil CEC. The addition of organic matter can increase the soil CEC but requires many years to take effect. Soil carbon did not record significant differences among treatments even after two cropping cycles. The increase in carbon in soil will only appear after a long-term application of organic amendment (Diacono et al., 2010). Calcium (Ca) content in the soil with composted DOBE was found to be significantly higher compared to the other treatments due to the high amount of Ca (3%) in composted DOBE, which contains Ca-montmorillonite. The plot with composted DOBE demonstrated the highest increase (70%) in soil P from the initial soil P compared to the other treatments. Composted DOBE contains a high amount of P (2.5%) derived from the P absorbed from the crude palm oil refining process. The higher soil CEC, carbon, nitrogen, and phosphorus content in the composted DOBE treatment produced a comparable yield result for the first cycle but a significantly different yield result from green compost and control at the second cycle.

Conclusion

DOBE treated with POME attained a mature condition after 21 weeks of composting. The results demonstrated that composted DOBE with POME only produced the fastest and cheapest way to de-oil DOBE. POME was effective enough to be used as a single component application without combining with other microbial sources, thus giving a cost-effective option for managing DOBE. However, detailed studies on various rates of treated DOBE and DOBE-based fertiliser are required in order to establish the positive effects of this material on soil improvement and crop production, as well as to develop the recommended application rates for organic crop production. The result suggests that composted DOBE has a potential to be utilised as organic fertiliser. This alternative will help stimulate the attempts to breakdown the oil in DOBE.

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Abstrak

Peluntur bumi ternyah