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The effect of oil palm frond-based compost as growing media amendment for rubber (*Hevea brasiliensis,* Müll. Arg.) planting material

Charlos Togi Stevanus[1], Ari Fina Bintarti[2], Nico Setiawan[2]

[1] Sembawa Research Center – Indonesian Rubber Research Institute (IRRI), Jln. Raya Palembang-Betung Km. 29, P.O, Box 1127, Palembang 30001, South Sumatera, Indonesia

[2] Faculty of Agriculture, Tridinanti University, Jl. Kapten Marzuki No. 2446, Kamboja Palembang 30129, South Sumatera, Indonesia

ABSTRACT

Oil palm frond (OPF) disposal is poorly managed which leads to environmental problem. With an appropriate composting management, OPF have a potential as organic compost that can be applied as soil amendment to promote rubber plant growth. This study was aimed to observe the characteristic of OPF composting process and to investigate the optimum dose of OPF-based compost to promote rubber plant growth. The study was carried out by analysis of OPF composting process and application test of the compost as media amendment of rubber planting material. Composting temperature of the chopped OPF (3 to 5 cm), reached ambient temperature on day 75 with C/N ratio of 15.32. The highest percentage of compost particles-size distribution was > 4.75 mm in size. Generally, the quality of OPF-based compost has met the minimum standard of Indonesian National Standard for compost quality, except for K_2O content. The application test revealed that treatment of 20 % compost + 80 % subsoil was the optimum dose to increase rubber plant growth compared to other treatments. The final cation exchange capacity (CEC) value of control decreased compared to the initial value, on the contrary, the CEC value of compost added media increased along with increased doses of compost. Media amended with compost also increase P, K, Ca, and Mg contents compared to control.

Keywords: Oil palm frond, compost, rubber plant, growing media.

INTRODUCTION

Oil palm agro-industries generate by-products such as organic wastes and oil palm fronds (OPF) besides empty fruit bunches (EFB), oil palm trunks (OPT), palm pressed fibres (PPF), palm shells and palm oil mill effluent (POME) whose management is of greater concern because until now disposing of this waste continues to be a major problem. Based on pruning data from the management of the Sembawa Research Center, 40 to 48 fronds of 8-14 years old plants are

*Corresponding author : E-mail: *togie-stevanus@yahoo.id*

maintained after pruning, in other words, about 16 to 24 pruned fronds per tree per year are produced by the plantations. Assuming that the frond dry weight is between 4 to 5 kg (Simanihuruk *et al.,* 2007), the potential for pruned fronds produced by the plantation reaches 64-120 kg/tree/year or approximately 8.3-15.6 ton/ha/year (population of 130 trees/ha). Because of its high content of lignin (20-21 %) and cellulose (40-50 %) (Abdul Khalil *et al*., 2012), rapid decomposition of the OPF is difficult to achieve, so the palm oil fronds are just piled on the ground or burnt.

Disposal of OPF waste is poorly managed and this leads to environmental problems. Based on the Roundtable on Sustainable Palm Oil (RSPO) guidelines, the use of fire for waste disposal should be avoided except in specific situations; this advice is also identified in the ASEAN guidelines or other regional best practice (Lord and Clay, 2006). Besides, to leave the OPF for natural decomposition not only obstructs the re-plantation process but also encourages the spread of diseases such as the *Ganoderma* as well as harbours insects like the rhinoceros beetles which are harmful to the trees in the plantation (Abdullah and Sulaiman, 2013). Alternatively, OPF can be composted in a controlled way and returned to the plantation as soil or growing media amendment. Several authors have studied the potential of OPF as organic source of compost (Ahmad, 2012; Erwan *et al.*, 2012; Vakili *et al.*, 2014; Yuniati, 2014).

Growing media play an important role in providing a suitable growing environment for root formation and initial growth of the rubber plant (Wibawa *et al*., 1993). The recent problem of a limited supply of rubber planting materials in South Sumatera was largely attributed to limitations in soil with suitable physical, chemical, and biological characteristics for promoting rubber plant growth. The addition of compost into media is an alternative to improve the quality of growing media. Several studies have reported on the composting of OPF to produce organic material as potting media in ornamental plants (Kala *et al.*, 2009), cauliflower (Erwan *et al*., 2013), etc.

Studies have also reported that the addition of compost into growing media increased nutrient uptake of N, P, and K in the leaves (El-Naggar and El-Nasharty, 2009), increased plant height and root dry weight (Mikhail *et al.*, 2005), and improved soil physical properties (density, total porosity, and water holding capacity) (Mastouri *et al*., 2005) compared to media without compost. Based on those studies, the addition of compost as soil amendment is seen to have positive effects on soil quality and plant health. However, there are no studies reporting on the potential of OPF-based compost as media amendment to improve the growth of rubber planting materials in the nursery. Therefore, the objectives of this study was to observe the characteristic of OPF-based compost and to determine the effective and optimum composition and dose of OPF-based compost in promoting rubber plant growth in polybags.

MATERIALS AND METHODS

The study was carried out from July 2014 to February 2015 in Sembawa Research Center rubber plantation, Indonesian Rubber Research Institute (IRRI), South Sumatera. The study was divided into two sub-experiments: the first experiment was OPF-based compost processing while the second experiment was the application of OPF-based compost as media amendment of rubber plants in polybags.

Sampling and Preparation of Composting Materials

In this study, OPF, cow manure, and cover crop of *Mucuna bracteata* as green material were used as composting materials. The OPF and *M. bracteate* were collected from the oil palm and rubber plantations of the Sembawa Research Center, Indonesian Rubber Research Institute (IRRI). The cow manure was collected from Sembawa breeding center (BPTU). Organic C and total N contents of OPF were analysed before the composting process. Sampling for C/N ratio was randomly selected from the mix of chopped leaflets and rachis of the fronds. Based on the analysis, the percentage of organic C of OPF was very high which indicates that the wastes require a long time to completely decompose. Therefore, it is necessary to add other organic materials like cow manure and green material in order to reach the optimum C/N ratio for the composting process. The analysis of organic C and total N for each material was conducted to evaluate the best ratio of composting materials (Table 1).

The best composition of composting materials for the composting process based on previous experiment was OPF: cow manure: *M. bracteata* of 40:40:20 (data not shown). The initial C/N ratio of the mixture was determined from literature values of C/N ratios of OPF, M. bracteata, and cow manure using equation of mixed materials:

$$\text{Initial}\ \frac{\text{C}}{\text{N}}\ \text{ratio} = \frac{\left(\text{OPFm (kg)} * OPF\frac{C}{N}\right) + \left(Mbm\ (kg) * Mb\frac{C}{N}\right) + \left(CMm\ (kg) * CM\frac{C}{N}\right)}{\text{OPF m (kg)} + Mbm\ (kg) + CMm\ (kg)}$$

where OPFm = mass of OPF in kg, OPF C/N = C/N ratio of OPF, Mbm = mass of M. bracteata in kg, Mb C/N = C/N ratio of M. bracteata, CMm = mass of cow manure in kg, and CM C/N = C/N ratio of cow manure.

Based on best composition and the equation, the initial C/N ratio of the mixture was 41.84.

TABLE 1
Organic C and total N contents of composting materials

Materials	Organic C	Total N	C/N Ratio
Oil palm frond	73.25	0.75	97.43*
Mucuna bracteata	66.24	3.55	18.66
Cow manure	13.71	0.36	38.15

Note: *C/N ratio of the mix of chopped leaflets and rachis

Composting Process

The OPF were chopped into small pieces of 3-5 cm to speed up the composting process. All the materials were mixed together according to the ratio and moistened with water until the moisture level of the mixture reached 60%. The composting process was conducted by aerobic composting using the pile system. Each pile was of 1 m width and height, respectively, and 500 kg of total weight. Moisture content was maintained at around 40-60% throughout the composting period by watering. The composts were turned over every five days to ensure good aeration. The composting process was for a duration of 75 days. The compost was considered mature when ambient temperature was achieved and its structure became friable and crumbly.

Analysis of Physical and Chemical Characteristics of Compost

Observed parameters in this study included temperature, pH, particle-size distribution, and chemical content of C/N ratio, P, K, Ca, Mg, and CEC. The temperature was taken every two days during the composting period and was measured at three different points in the compost pile using a thermometer. The pH value was determined in the suspension of 1:5 (w/v) compost : deionised water using pH-meter (Mettler Toledo 320). The total Kjeldahl nitrogen (TKN) in the compost was determined using the Kjeldahl method (Mlangeni *et al.*, 2013). The total organic carbon (TOC) was determined by using Walkley and Black method for carbon analysis (Sato *et al.,* 2014). The content analysis of chemicals P, K, Ca, Mg was determined by wet oxidation with HNO_3+$HClO_4$, phosphorus content measured colorimetrically (UV-Vis Merck Pharo 300), K, Ca, Mg by atomic absorption spectrophotometry (VARIAN SPECTRAA 55B) (Meller *et al.*, 2015). Cation exchange capacity of the sample was determined at pH 7 with ammonium acetate (Saidi, 2012). The particles-size distribution of compost was measured by using a series of sieves of 4.75 mm, 2 mm, 0.85 mm, and 0.45 mm.

Application of OPF-based Compost as Growing Media

The next experiment was the test on the application of OPF-based compost as growing media amendment of rubber plants using subsoil as the main media. This is because subsoil generally has a lower fertility level than topsoil, especially the chemical characteristics which are not suitable for the growing media of rubber planting material. This study was conducted with the objectives of determining the effectiveness of OPF-based compost in improving the quality of the growing media and promoting rubber plant growth. Rubber budded stumps clone PB 260 were the planting material in this experiment. Polybag media were prepared by mixing compost with subsoil at the ratio of 0 % compost + 100 % subsoil as control (A), 20 % compost + 80 % subsoil (B), 40 % compost + 60 % subsoil (C), 60 % compost + 40 % subsoil (D), 80 % compost + 20 % subsoil (E), 100 % compost (F). This experiment was carried out in a randomised block design (RBD) with four replications.

One budded stump was planted in each polybag of 15 cm x 35 cm with an equal volume of media. The seedlings were watered every day and weeding was conducted manually. A combination of urea : SP-36 : KCl : kieserite at the ratio of 4:3:2:2 (gram per polybag) was used for the first application and 10:9:4:4 (gram per polybag) was applied monthly for 5 months. Diameter of stem and plant height were recorded every 15 days (from day 30 until day 150). Root dry weight and total dry weight were measured on the last day of the experiment (day 150). The seedlings were harvested for shoot weight, while the roots were carefully removed from the polybag to record root weight. Fresh weight was recorded and the plant samples were oven-dried at 65^{o}C until constant weight was achieved (± 3 days).

Each medium treatment was analysed for initial and final pH (ratio of 1 :5, soil to water) and macro- and micronutrients contents as well. Total N was determined using the Kjeldahl method (Mlangeni *et al*., 2013) while total organic carbon (TOC) was determined by Walkey and Black method (Sato *et al*., 2014). The chemical contents of P, K, Ca, Mg were analysed using wet oxidation with HNO_3+$HClO_4$; phosphorus content was measured colorimetrically (UV-Vis Merck Pharo 300) while K, Ca, and Mg by atomic absorption spectrophotometry (VARIAN SPECTRAA 55B) (Meller *et al.*, 2015). Cation excahange capacity of the sample was determined at pH 7 with ammonium acetate (Saidi, 2012). Statistical data analysis was performed with SPSS version 16.0. to determine the differences between treatments and the relationship between treatments and the growth parameters.

RESULTS AND DISCUSSION

Characteristics of OPF-based Compost

Temperature

Temperature is a simple physical parameter to indicate the composting rate and the maturity of compost (Hanifarianty *et al.*, 2014). The maximum temperature of the composting process of OPF ranged between 55-61^{o}C from day 4 to day 8. The composting temperature was observed to fluctuate from day 12 to day 21 and then remain relatively constant from day 30 till day 75 (Figure 1).

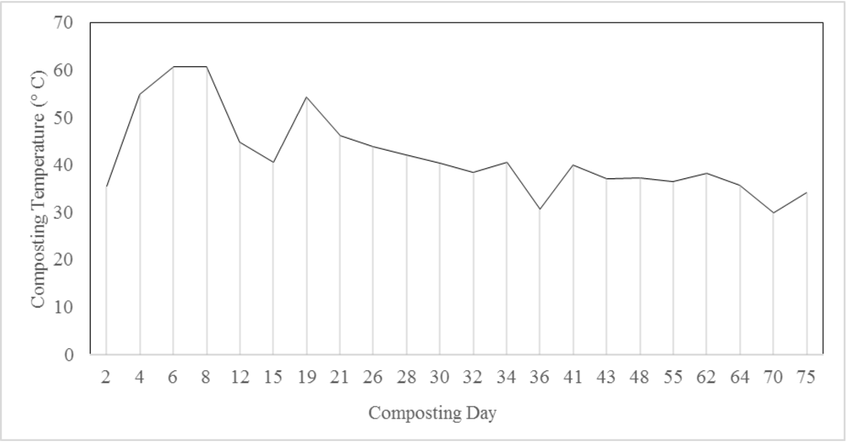

Figure 1. Temperature fluctuation of OPF composting process

The fluctuation in temperature during the composting process will automatically change the microbial community in the compost pile (Faatih *et al.*, 2008). There are three phases of temperature change associated with decomposing activity of microbes: mesophilic, thermophilic, and cooling phase or compost maturation. The first phase of temperature starts with the mesophilic at the initial stage of the composting process. Faatih *et al*. (2008) reported that generally, mesophilic microbes actively decompose at the temperature range < 45^0C. Then, the temperature increases rapidly from day 2 till day 4 and reaches a maximum temperature on day 6 which lasts till day 8. This indicates that the composting process has reached the thermophilic phase. Insam *et al*. (2011) said that composting process reaches the thermophilic phase at a temperature of 65^oC. This is a very important phase as most of the pathogenic microbes as well as insect larvae and weed seeds in the compost will be killed. The thermophilic microbes play a crucial role in degrading carbohydrate and protein including cellulose and lignin; thus, they can speed up the decompostion process of organic material and the maximum temperature can be reached (Faatih *et al*., 2008).

The temperature of the compost decreased continuously, approaching ambient temperature on the third week, indicating that the cooling phase or maturation of compost had occurred. In this phase, the microbial metabolism activity decreased because all of the organic materials had been decomposed (Dewi *et al*., 2007). The thermophilic microbial population began to decline and was replaced by mesophilic microbes that decomposed the cellulose remains. Oil palm frond composting process reached ambient temperature on day 75. A previous study conducted by Tiqua *et al.*, (1997) showed that compost reached ambient temperature on day 74. Their study also concluded that compost is considered mature when the temperature inside the compost pile has reached the ambient temperature.

Particle Size Distribution

The result of particle size distribution analysis of OPF-based compost was grouped into five size fractions i.e. < 0.42 mm, 0.42-0.85 mm, 0.85-2 mm, 2-4.75 mm, and > 4.75 mm. In general, the largest percentage of particle size distribution was > 4.75 mm, while the remaining was 2-4.75 mm and < 2 mm (Figure 2). Faatih *et al.* (2008) stated that microbes play an important role in reducing the particle size of organic material at the mesophilic phase. In addition, the particle size is also determined by raw materials for composting. The smaller the particle, the bigger the surface area for microbes to degrade the material and the faster the composting process.

Too small particle size can cause anaerobic condition, meanwhile too large material particle will cause a large pore space so the optimum temperature for the composting is not reached (Olds College Composting Technology Center, 1999). Therefore, it is necessary to chop the OPF before composting process. The size of chopped OPF in this study ranged between 3-5 cm. This resulted the largest distribution of compost particles was in the fraction > 4.75 mm. The addition of manure as a raw material in this study may have contributed to the particle size of compost, because according to Gómez-Muñoz *et al*. (2012) in the presence of manure can improve particle fineness.

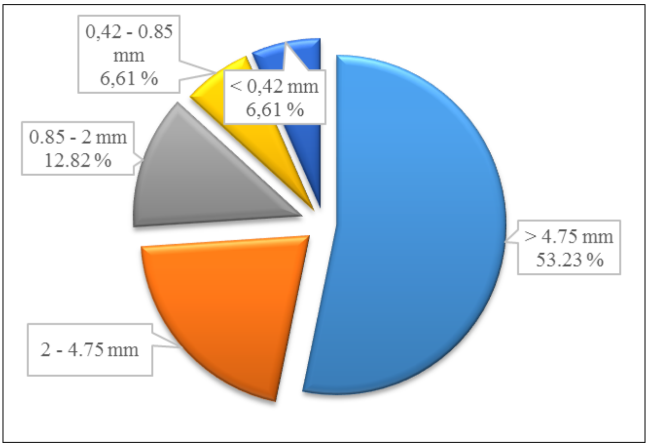

Figure 2. Particle size distribution of OPF-based compost

Total weight loss and characteristic of compost

The initial weight of compost pile was 500 kg, meanwhile the final weight of mature compost was 389.6 kg. Hence, the total weight loss of OPF-based compost after composting process was 110.4 kg or 22.08 %. Final C/N ratio was15.32 and final pH of compost was above neutral (pH>7). Indonesian National Standard (Standar Nasional Indonesia or SNI) of compost quality is a regulation of the quality of certain organic product for consumer safety and environmental pollution prevention in Indonesia. Most of all macronutriens contents in OPF-based compost after maturity at day 75 has met the minimum SNI compost quality except K_2O content (Table 2).

Rubber plant growth

Diameter, height, root dry weight, and total dry weight of rubber planting material

The observation data of plant growth for 120 days show that stem diameter of treatment B (20 % compost + 80 % subsoil) is not significantly different from control (no added compost) but significantly different from other treatments. Treatment B resulted in the highest stem diameter, meanwhile treatment F resulted in the lowest stem diameter (100 % compost) (Table 3). The observation data of plant height parameter show that treatment B is not significantly different from control, yet significantly different from treatment E (80 % compost + 20 % subsoil) and treatment F (100 % compost). Treatment B resulted in the highest plant height compared to other treatments, meanwhile treatment F showed the lowest plant height.

TABLE 2
Final weight and nutrient content of OPF-based compost

Analysis	Value	Indonesian minimum standard of compost quality (National Standardization Agency of Indonesia, 2004)	Unit
Total weight loss	22.08		% (w/w)
pH H_2O	7.45	6.80	
Organic matter	61.83*	27	%
Total N	2.34	0.40	%
C/N ratio	15.32	10	%
P_2O5	0.62	0.10	%
K_2O	0.13	0.20	%
Ca	0.18	n.a	%
Mg	0.06	**	%

annotation : n.a = not available

* the value obtained by multiplying the conversion factor of 1.724 with C organic

** the value can not exceeds the maximum standard of 0.6 %

TABLE 3
Plant growth parameters (height and diameter) and plant dry weight

Treatment	Plant height (cm)	Plant diameter (mm)	Root dry weight (gram)	Total dry weight (gram)
A (control)	60.50[abc]	7.61[ab]	3.98[a]	52.97[ab]
B	71.08[a]	8.07[a]	6.30[b]	65.54[b]
C	59.27[abc]	6.95[c]	3.07[a]	49.23[ab]
D	64.56[ab]	7.23[bc]	2.76[a]	62.09[b]
E	53.43[bc]	6.64[c]	3.30[a]	47.33[ab]
F	46.42[c]	6.66[c]	3.00[a]	39.30[a]

annotation: values followed by the same letter within a column are not significantly different at the 0.05 level

Treatment B resulted in the highest root dry weight and significantly different from control and other treatments. Meanwhile, the highest total dry weight was obtained in treatment B, however there is no significant difference compared to control. The use of OPF-based compost with application doses of 75 - 100 % has a decreasing pattern in plant growth compared to control. This is consistent with another study conducted by Do and Scherer (2013) and López *et al.* (2008) stated that the application of compost with the maximum dose of 50 % can promote the plant growth. This is because the higher the percentage of compost as media amendment the higher electrical conductivity and nutrient excess level that lead to plant growth inhibition (Arancon and Edwards, 2005; López *et al.*, 2008).

Final nutrient content of growing media

Nutrients release of organic materials that play an important role for plant growth is very slow (Seran *et al.*, 2010), therefore, there is possibility that nutrients of compost are not optimally used by plant. The nutrient content analysis of growing media at the end of experiment was conducted to determine the nutrient residues of compost that are still available in the soil.

Each of soil nutrients analyzed (Table 4) was compared to the soil nutrient classification for rubber (Table 5). Comparison of pH values among initial soil, control, and other treatments shows that the addition of compost increased the pH value of acid (4.5-5.5) to slightly acid (5.6-6.5). The CEC values of initial soil and control are low but the CEC values of the compost treatments tend to increase slowly with the increasing dose of compost. The addition of compost increased the organic C, especially for the 80 and 100 % compost treatment. Moreover, growth media supplemented with compost also have an increased P, K, Ca, and Mg contents compared to control. In addition, the N contents of treatments with compost application dose of 50 % - 100 % were also slightly increased compared to control. Mikkelsen and Hartz (2008) stated that compost generally behave as a slow-release source of N over many months or years since the rapidly decomposable compounds have been previously degraded during the composting process. The OPF-based compost residue can be used as a "nutrient bank" for the growth of rubber plants in the field.

TABLE 4
Initial nutrients content of soil and final nutrients content of media of each treatment

Treatment	pH	CEC cmol(+) /kg	Organic C (%)	N (%)	P (mg/kg)	K cmol(+) /kg	Ca cmol (+) /kg	Mg cmol (+) /kg
Initial soil	4.59	9.86	3.02	0.19	43.21	0.03	0.12	0.02
A (control)	4.8	9.7	1.33	0.06	199.1	0.23	2.59	9.7
B	6.3	11	2.41	0.09	427.3	0.44	2.42	11
C	6.4	10.8	1.9	0.07	412.7	0.4	2.52	10.8
D	5.8	13.8	2.79	0.12	482.8	0.4	2.84	13.8
E	6.3	24.9	6.09	0.33	370.6	0.58	3.11	24.9
F	6	37.3	6.3	0.7	413.1	0.45	3.05	37.3

TABLE 5
Soil nutrient classification for rubber

Parameters	Very Low	Low	Intermediate	High	Very High
C (%)	< 1.00	1.00-2.00	2.01-3.00	3.01-4.00	> 4.00
N (%)	< 0.10	0.10-0.20	0.21-0.50	0.51-0.80	> 0.80
P_2O_5 (ppm)	< 5	5 - 15	16 - 25	26 - 35	> 35
K (me/100 g)	< 0.10	0.10-0.30	0.31-0.50	0.51-0.70	> 0.70
Ca (me/100 g)	< 0.25	0.25-1.00	1.01-1.75	1.76-2.50	> 2.50
Mg (me/100 g)	< 0.20	0.20-0.50	0.51-0.80	0.81-1.10	> 1.10
CEC (me/100 g)	< 5	5 - 16	17 - 28	29 - 40	> 40
pH	Acid	Slightly Acid	Neutral	slightly Alkaline	Alkaline
	4.5-5.5	5.6-6.5	6.6-7.5	7.6-8.5	> 8.5

Source: Adiwiganda *et al*. (1994)

Nutrients content of Leaf

Each of leaf nutrient analyzed was compared with nutrient sufficiency ranges (NSR) from references (Table 6). Generally, the addition of compost was able to increase N nutrient of plants. N nutrient of treatment C and D were deficient, B was sufficient, while E and F were high. In this research, treatment B or 20 %

TABLE 6
A comparison of obtained optimum plant nutrient range for rubber in each treatment

Element		value	range	Status	
N (%)	A (control)	2.90	3.30 – 3.50	Deficient	Adiwiganda *et al.*
	B	3.31		Sufficient	(1994)
	C	2.96		Deficient	
	D	2.91		Deficient	
	E	3.63		High	
	F	3.62		High	
P (%)	A (control)	0.14	0.23 – 0.24	Deficient	Adiwiganda *et al.*
	B	0.25		High	(1994)
	C	0.19		Deficient	
	D	0.23		Deficient	
	E	0.18		Deficient	
	F	0.23		Deficient	
K (%)	A (control)	1.06	1.31 – 1.40	Deficient	Adiwiganda *et al.*
	B	1.12		Deficient	(1994)
	C	1.15		Deficient	
	D	1.16		Deficient	
	E	1.15		Deficient	
	F	1.1		Deficient	
Mg (%)	A (control)	0.24	0.21 – 0.22	High	Adiwiganda *et al.*
	B	0.38		High	(1994)
	C	0.38		High	
	D	0.33		High	
	E	0.62		High	
	F	0.41		High	
Ca (%)	A (control)	0.86	0.60 – 1.00	Sufficient	Thiagalingam, *et al*.
	B	0.93		Sufficient	(2000)
	C	1.14		High	
	D	0.89		Sufficient	
	E	1.11		High	
	F	0.83		Sufficient	

compost application was able to increase N absorption compared to treatment C and D. Meanwhile, high levels of N nutrient in treatment D and E due to high level of N soil (Table 4) as a result of high application dose of compost. In addition, the B treatment also increased the absorption of P compared to other treatments. Meanwhile, the compost addition did not affect the level of K, Ca and Mg nutrient absorption in plants. This can be seen from the same nutrient status of K, Ca and Mg in all treatments and control.

CONCLUSION

Oil palm frond-based compost reached maturity on day 75 which was indicated from the decline of compost pile temperature until it reached ambient temperature and its C/N ratio < 20. Generally, the OPF-based compost characteristic has met the minimum standard of SNI for compost quality with the exception of K_2O content. The compost application with treatment B (20 % OPF-based compost + 80 % subsoil) was the optimum mixed media to promote the growth of rubber planting material. Media supplemented with OPF-based compost has an increased pH, CEC, C organic, P, K, Ca, and Mg content in soil compared to control. These OPF-based compost residues are beneficial as "nutrient bank" for further development and growth of rubber plant in the field. Furthermore, the comparison of leaves nutrients showed that treatment B also increased N and P absorption.

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