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THE ROLE OF DIFFERENT TYPES OF BIOPORY TECHNOLOGY IN REPAIR OF LAND PROPERTIES AND ROOT GROWTH IN THE PALM OIL PLANTS AREA

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Abstract–The improvement of soil characteristics is an important factor to support the growth and yield of oil palm. The technology of biopore can be optimized by utilizing litter around the oil palm disc. This study aimed to determine the best litter type to increase the root volume of oil palms and to improve the physical, chemical, and biological properties of the soil. The study was conducted from October 2014 to December 2016 at Teaching Farm of Oil Palm IPB-Cargill, Bogor, Indonesia. The experiment used one factor arranged in a randomized complete block design consisting of four treatment levels with four replications. The treatments level were the litter from monocotyl plant (S1), the litter from dicotyl plant (S2), the litter from part of oil palm organs (S3), and the litter from S1 + S2 + S3 mixture (S4). The root volume of oil palm increased in each treatment of S4, S2, S3, and S1 at 26 months after treatment (MAT). The root volume of oil palm on S4, S2, S3, and S1 treatments was 305 mL m^{-3} (312.16%), 207 mL m^{-3} (276.00%), 175 mL m^{-3} (177.78%), and 153.5 ml m^{-3} (143.65%), respectively. The treatment of mixed litter (S4) could improve the physical, chemical, and biological properties of the soils characterized by increasing of soil water content, soil macronutrients, cation exchange capacity (CEC), the number of soil macroorganisms, and the type and number of soil microorganisms. The soil water content decreased from 0-20 cm depth to 40-60 cm as deeper soil layer on sufficient water content condition, while the soil water content in topsoil (0-20 cm) would be lower than in soil depth 20-40 cm and 40-60 cm on long drought period. The treatment of mixed litter (S4) was the best treatment to increase the root volume of oil palm, the soil water content, the soil nutrient contents (N, P, K, Ca, Mg, and C-organic), CEC, the number of soil macroorganisms, and the type and number of soil microorganisms compared to the treatment of monocotyl litter (S1), dicotyl litter (S2), and the litter from part of the oil palm organs (S3).

INTRODUCTION

Biopore is holes in the ground formed by various activities of organisms lives in it such as worms, plant roots, termites, and other soil fauna. The hole had been formed will be filled with air and will be the place for water flow in the soil. Biopore technology in Indonesia was invented by Kamir Raziudin Barata (Biopore IPB Team, 2007). This technology has been used by him for 20 years, before it was released to the public. If a biopore hole can be made with large quantities, then the ability of a land plot to absorb water is expected to increase. Increased soil capacity in water absorption will decrease the chance of water flow occurence in the soil surface hence reducing the danger of flooding (Brata, 2007).

Soil fauna is an organism which entire or most of its life cycle and survival activities are carried out in soil and soil surfaces which plays a role in assisting the process of organic matter decomposition. Soil fauna has body size equal to or greater than 1 cm (Ganjari, 2009). Organic matter is used as energy source for organism in soil, therefore activities of macroorganism and microorganism will increase. The number of small holes formed in and around the biopores will soar when the activities of macroorganisms and microorganisms in the soil increase. The synergism between biopore vertical holes that had been formed will allow these holes to be utilized as relatively affordable and environmental friendly artificial water absorber holes. The biopore absorber hole (BAH) method is one of suitable measures to increase water absorption in the field because water entering the biopore can move easily in the soil profile and infiltrate as ground water (Maharany *et al*., 2011).

Biopore may increases the rainwater absorbing on the ground. Biopore is an alternative technology of rainwater absorption in addition to absorption wells. Aside its function as water absorber land, other function of BAH is composting plant (Gulis and Suberkropp, 2003). BAH is activated by filling organic waste to the holes. Organic waste will be used as energy source by soil organisms through decomposition process. Soil fauna groups (macroorganisms and microorganisms) can decompose or break down dead plant and animal materials into organic matter (Haneda and Sirait, 2012). This decomposed waste is known as compost. Biopore is named as worm's pallace although its occupants is not only worms. There is a relationship between the biomass presence in the biopore hole with the earthworm presence inside (Han *et al*., 2014). Compost can be harvested at any given period and can be used as an organic fertilizer for oil palm plants.

The problems that we encountered at the research site were the condition of oil palm plantation land in Jonggol West Java Indonesia, uneven rainfall distribution during the whole year, dry month more than four months in a year, slope topography, and fertilizer supply on the market was unavailable continuously. To overcome the research area conditions, it is necessary to do further work to study the role of various type of litter in biopore technology in oil palm plants, thus plants growing well and producing more.

To solved the problem it is needed to create biopore absorber holes (BAH) on each oil palm plant. The benefits of biopore for plants are providing organic fertilizer for plants, collecting rainwater, hence the water flow will be reduced and infiltrate into the soil, inside the biopore earthworms will grow then decomposes the weeds and soil around the biopore which can be utilized by oil palm plants, water storage capacity in the soil will be larger that can be used by plants and fertilization effectiveness will improve. Surface water decreasement will led to not only prevents flooding but also floats of humus or topsoil in the oil palm plantation, and consequently increasing oil palm productivity and creating more environmental friendly oil palm plantations. Increased soil pore volume such as holes of earthworm activities will enhance water absorption into the soil and will reduce surface flow (Subowo, 2008). With the condition of the research site, to overcome it, it is necessary to research the role of various types of litter in biopori technology to overcome the inundation stress in the rainy season and the water deficit in the dry season in the oil palm plant so that the plant can grow and produce well. This study aims to study the role of different types of litter in Biopori technology, to the physical, chemical, and biological properties of soil in immature palm oil II (IPO II) plants to produce I (PP I).

MATERIALS AND METHODS

The study was conducted from October 2014 to December 2016 at Oil Palm Teaching Farm and Research Park IPB-Cargill, Jonggol, Bogor, Indonesia located at an altitude of 115 m above sea level. Biopore holes were made on the disc area or circle of oil palm plants. The plant used for the study was Tenera oil palm plant, variety Dami Mas aged 1.5 year and weed litter. Oil palm planted with plant spacing of 9.2 m x 9.2 m x 9.2 m. The experiment used one factor arranged in a randomized complete block design consisting of four treatment levels with four replications. The treatments level were the litter from grasses/ monocotyl plant (S1), the litter from broadleafed/ dicotyl plant (S2), the litter from part of oil palm organs such as leaves, midribs, male flowers and stems (S3), and the litter from S1 + S2 + S3 mixture (S4). Each experimental unit consisted of 6 discs of sample plant thus the total number observed was 96 discs. The experiment was conducted by creating 4 biopore holes on each oil palm disc. Each biopore hole was filled with 4 kg of litter in accordance with each treatment. Litter was chopped to size of 7 cm thus inserting to the biopore hole would be easier. Litter was put into biopore hole five times with interval of 6-8 months at October 2014 (0 MAT), April 2015 (6 MAT), October 2015 (12 MAT), June 2016 (20 MAT) and December 2016 (26 MAT). Every six or eight months, organic matter that had been formed in biopore hole was taken and dispersed on oil palm disc, then the biopore hole was replenished with litter.

The observed variables consisted of root volume, water content of 0-20 cm depth, water content between layers of soil depths (0-20 cm, 20-40 cm, and 40-60 cm), soil nutrient contents (N, P, K, Ca, Mg, and C-organic), cation exchange capacities (CEC), number of soil macroorganisms, type and number of soil microorganisms. The measurement of oil palm root volume was conducted by digging the soil with size 25 cm x 25 cm x 25 cm with distance 100 cm from stem of oil palm plant. The root volume is calculated using the formula:

Root volume = volume after root is put into the water - initial volume.

Observation of soil water content was conducted at the depths of 0-100 cm, 0-20 cm, 20-40 cm, and 40-60 cm. Water content analysis was measured using *Brabender* method. The soil sample was taken from the field and then 100 g was weighed using analytical scale. The soil sample was wrapped in aluminum foil then heated in an oven for three days at 105 ° C. Analysis of soil nutrient contents (N, P, K, Ca, Mg, and C-organic) and CEC were done by *Kjeltec auto destilation* method. Soil sampling was conducted on the oil palm disc using soil drill. Soil samples were taken at a distance of 2 m from oil palm plant stem base with a depth of 0-100 cm. Analysis of the number of soil macroorganisms was conducted using quantitative and qualitative methods which was hand sorting method (Balittanah, 2009). Analysis of the type and number of microorganisms present in the compost were conducted by agar plate method (dilution-plate or dilution-count) (Ottow and Glathe, 1968). Data was analyzed statistically using analysis of variance (ANOVA) at $\alpha = 0.05$. If ANOVA shows any significant difference, further analysis will be carried by Duncan's Multiple Range Test (DMRT) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Volume of Planted Oil Palm

The root volume of oil palm crops did not show any significant difference at the beginning of observation (0 BSP) with an average root volume value of 3.32 mL l^{-1}. Root volume in all litter treatments had no significant effect. Means the volume of roots before the study carried out are considered equal. Root volume is an important factor in plant growth and is closely related to the availability of macro and micro soil nutrients (G31b, 2011).

On observation of 26 BSP plants yielding the first year (TM 1) root volume observations are presented in Table 1. Monocotyl treatment was used as a comparison against other treatments. Treatment of dicotyl (S2) 26 BSP, root volume was higher 22.11%, compared with monocotyl treatment showed a significant effect on other treatments. Litter treatment from oil palm plantation (S3) is higher by 8.49%%, compared with monocotyl treatment and has significant effect on other treatment. Mixed litter treatment (S4) was higher by 44.71%, compared with monocotyl and significantly different from other treatments. This suggests that in litter treatments the mixture is more varied in kind the ability to store more water, each litter has a different nutrient content that will affect the number of roots, development, and root penetration horizontally in the soil.

The treatment of mixed litter (S4) was the best treatment to increase the root volume of oil palm plants compared to other treatments. The root volume of oil palm on the observation of 26 MAT from the highest to the lowest were 305 ml m^{-3} (S4), 207 mL m^{-3} (S2), 175 mL m^{-3} (S3), and 153.5 mL m^{-3} (S1) (Table 1*).* Afandi *et al., (*2015*)* suggested that the most important role of organic matter on soil chemical properties is its nutrients contribution in each type of litter through the decomposition process by soil biota will affect vegetative and generative growth of plant. The treatment of mixed litter (S4) contained various organic matter which enhance the ability to store water and has higher levels of soil nutrients. Soil nutrients and water content absorbed by plant roots and environmental factors have essential role in supporting vegetative growth of plants such as roots (Hannum *et al*., 2015). Root distribution is more significant in low fertility land conditions with complex soil nutrients distribution (Widiastuti *et al.,* 2003).

The values at the same column followed by the same letter are not significantly different based on the DMRT test at á = 5%, **: very different at á = 1%, tn: not significantly different at á = 5%, MAT: months after treatment, S1: litter from grasses (monocotyl), S2: litter from broadleafed plants (dicotyl), S3: litter from part of palm organs (leaves, midribs, male flowers, and stems), S4: mixture (S1 + S2 + S3).

Soil Water Content

Litter treatment began to show significant effect on

Table 1. Root volume of oil palm plants before and after litter treatmen

Treatment	Root volume of oil palm plants (ml L^{-1})		Compared with S1 (%)
	0 BSP	26 BSP	
Monocotyl (S1)	3.32	6.24a	-
Dicotyl (S2)	3.34	7.62c	22.11
Litter from part of oil palm organs (S3)	3.26	6.77b	8.49
Mixture (S4)	3.37	9.03d	44.71
F test	ns	**	

soil water content at 4 MAT (Fig. 1). The highest water content was found on mixed litter treatment (S4), while the lowest water content was on monocotyl litter treatment (S1). The soil water content of all treatments decreased at 8 MAT and there was a significant drop at 12 MAT. Water content decreasement during those period of month (8 and 12 MAT) occured due to 6-month long dry season during May 2015 and October 2015 with an average rainfall of 19 mm $month^{-1}$, with an average temperature ranging from 37 to 42 ^{o}C. Ayu *et al*., (2013) suggested that soil water content in dry land agriculture was affected by the amount of monthly rainfall, air temperature, and humidity of air in the region. Soil water content increasement occurred again at 16 MAT and continued to increase till 20 MAT in each litter treatment. This occurence took place because of quite high rainfall because of the rainy season in those month period. The highest soil content was found on the treatment of mixed litter (S4) with water content value of 48.73% compared to other litter treatments which were 39.28% (S2), 38.52% (S3), and 37.72% (S1). Gaiser *et al*. (2013) indicated that the presence of biopore would increase the water absorption capacity of the soil, thus water will be easier to infiltrate the soil.

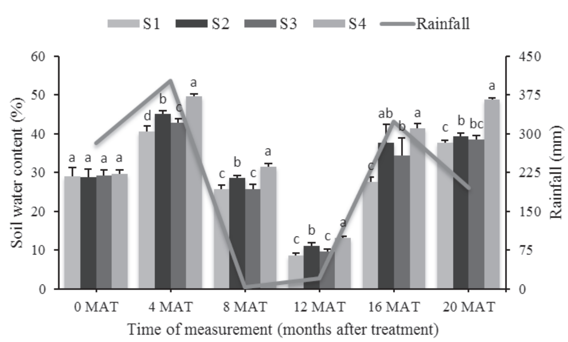

Fig. 1. Relationship between rainfall and soil water content at a depth of 0-20 cm in various litter treatments

Soil water content at the beginning of the observation (before the treatment) showed significant differences between 0-20 cm, 20-40 cm, and 40-60 cm depth on all of litter treatments. The highest water content was found at 0-20 cm of soil depth which was 29.0% on S1 treatment, 28.9% on S2 treatment, 29.1% on S3 treatment and 29.7% on S4 treatment. The deeper layer of soil to the depth of 60 cm, the lower soil water content. Raharjo (2000) stated that at the depth of 0-20 cm, soil capacity to store water will be higher than in deeper layer of soil. Soil water content at 10 MAT showed significant decrease compared to 0 MAT and 20 MAT (Table 2). Due to the long drought that occurred during those period of month. Furthermore, soil water content increasement follows in a reciprocal manner to the deeper soil layer at 10 MAT.

Soil Nutrient Contents at 0-100 cm Depth

Nutrient levels in soil such as N, P, K, Ca, Mg, and C-organic in all litter treatments (S1, S2, S3, and S4) were relatively similar at baseline 0 months after the treatment (0 MAT. The mean levels of N, P, K, Ca, Mg, and C-organic were 0.15%, 13.24 ppm, 0.19 cmol (+) kg^{-1}, 1.18 cmol (+) kg-1, 2.46 cmol (+) kg^{-1}, and 1.03%. The treatments of different types of N, P, K, Ca, Mg, and C-organic nutrient litter were higher than observations 0 months after the treatment in soil (0 BSP). Highest soil nutrient content and significantly there is a mixed litter treatment (S4) with nutrient content successively achievable. Litter contribution in changing soil chemical properties especially nutrients N and P is very large. This is not independent of the role of soil microorganisms in the decomposition process because the decomposition of many organic materials involves chemical reactions such as mineralization, fixing free nitrogen in the air and dissolving phosphate by microbes. The decomposition process is the process of breaking organic matter down into humus that may change the soil chemical properties (Portillo-Estrada *et al.,* 2016). The composition of nutrient contents in organic matter depends on the type of materials and can not replace the inorganic fertilizer as the main source (Suwarniati, 2014).

Litter treatment had an effect on soil nutrient contents such as N, P, K, Ca, Mg, and C-organic at 26 MAT. The treatment of mixed litter (S4) showed the highest level of N, P, K, Ca, and C-organic contents compared to other litter treatments. Soil Mg content on S4 treatment showed the highest results as well, but was not significantly different from S1 (3.31 cmol (+) kg $^{-1}$), S2 (2.59 cmol (+) kg $^{-1}$), and S3 (2.36 cmol (+) kg^{-1}) treatments. Nutrient contents of N, P, K, Ca, and Mg in soil on S4 treatment were N = 0.72%, P = 33.80 ppm, K = 0.37 cmol (+) kg^{-1}, Ca = 2.52 cmol (+) kg $^{-1}$, and Mg = 3.66 cmol (+) kg^{-1}. The highest N content was found in the treatment of mixed litter (S4) with N value of 0.72%, and S2 treatment (0.55%). The contents of P and C-organic in soil on S3 treatment indicated the lowest values that were significantly different from S2 and S1 treatments.

N content in the soil could be derived from inorganic fertilizers and organic fertilizers (Nascente *et al*., 2017). N fixation and P solubilizing bacteria might affect nutrient contents of N and P in the soil. Soil nutrient contents such as K, Ca, and Mg could be derived from fertilizers had been given, from organic matter weathering, and from main source material weathering, as well as from minerals found in the soil (Tarekegn *et al*., 2017).

The values inside the brackets show the percentage increase of nutrient content at observation of 0 MAT to 26 MAT; the values at the same column followed by the same letter are not significantly different based on the DMRT at the α = 5% level; **: differs significantly at α = 1%, *: significantly different at α = 5%, tn: not significantly different at α = 5%, MAT: months after treatment.

Table 3 showed that litter treatment indicated significant differences of Ca content in the soil at 26 MAT. The treatment of mixed litter (S4) suggested that the highest yield of Ca content which was 2.52 cmol (+) kg^{-1} compared to other litter treatments. Ca content on dicotyl litter treatment (S2) was 2.42 cmol (+) kg^{-1} and was not significantly different from monocotyl litter treatment (S1). Litter from part of oil palm organs (S3) showed the lowest yield of 2.23 cmol (+) kg^{-1} and was not significantly different from the monocotyl litter treatment (S1) ie 2.36 cmol (+) kg^{-1}. Organic matter derived from mixed litter (S4) can provide larger Ca than other litter treatments. Hartati *et al*., (2012) indicated that the content of Ca in the soil could be derived from soil minerals contained and main source material weathering.

The treatment of different types of litter had an effect on soil C-organic improvement (Table 3). Afandi et al., (2015) suggested that the application of organic matter increases C-organic content. The soil C-organic content on the treatment of mixed litter (S4) showed the highest yield of 182.49% compared to other litter treatments at 26 MAT. Organic matter content is an indicator of soil fertility level and soil C-organic indicates the organic matter content in the soil (Hugar *et al*., 2012).

Table 2. Soil water content at 0-20, 20-40, and 40-60 cm of soil depth in various litter treatments

Soil depth (cm)	Soil water content (%) at 0 MAT			
	S1	S2	S3	S4
0-20	29.00a	28.88a	29.15a	29.73a
20-40	25.40b	25.40b	25.75b	25.96b
40-60	19.80c	20.17c	19.17c	20.05c
F test	**	**	**	**
Soil depth (cm)	Soil water content (%) at 10 MAT			
0-20	12.14c	13.56c	13.26c	14.16d
20-40	14.48b	15.07b	16.19b	16.60c
40-60	16.98a	17.86a	18.86a	19.92a
F test	**	**	**	**
Soil depth (cm)	Soil water content (%) at 20 MAT			
0-20	37.72a	39.28a	38.52a	48.73a
20-40	34.79b	39.30a	36.89a	46.18b
40-60	28.77c	32.79b	30.12b	44.02c
F test	**	**	**	**

Values at the same column followed by the same letter are not significantly different based on DMRT at á = 5%, **: very different at á = 1%, MAT : months after treatment.

Cation Exchange Capacity (CEC)

The cation exchange capacity (CEC) at the initial observation (before litter treatment) at each depth of the soil layer (0-20 cm, 20-40 cm, and 40-60 cm) showed relatively no significant difference (Figure 2a) . The mean value of CEC for the depth of 0-20 cm, 20-40 cm, and 40-60 cm were 15.36 cmol (+) kg^{-1}, 9.54 cmol (+) kg^{-1}, and 5.47 cmol (+) kg^{-1}, respectively. The treatment of mixed litter (S4) suggested the best result on increasing soil CEC compared to other treatments at each layer of 0-20 cm, 20-40 cm, and 40-60 cm (Figure 2b) depth. At 0-20 cm, the highest soil CEC was found on S4 treatment (26.34 cmol (+) kg^{-1}) and followed by S2 treatment (22.77 cmol (+) kg^{-1}). The lowest CEC was discovered on the S3 treatment (20.24 cmol (+) kg^{-1}) which was not significantly different from the S1 treatment (20.83 cmol (+) kg^{-1}). At the soil depth of 20-40 cm, CEC soil response pattern was relatively similar to the 0-20 cm depth. The highest soil CEC was found in the S4 treatment (16.93 cmol (+) kg^{-1}) and followed by the S2 treatment (14.72 cmol (+) kg^{-1}). The S1 treatment indicated the lowest CEC value (12.69 cmol (+) kg^{-1}) and was not significantly different from the S3 treatment (13.53 cmol (+) kg^{-1}). At the soil depth of 40-60 cm, soil cation values on treatment S1, S2, S3, and S4 were 7.80, 8.17, 7.51, and 9.89 cmol (+) kg^{-1}, respectively. S4 treatment showed the highest CEC value compared to other treatments, while the treatments of S1, S2, and S3 were not significantly different to soil CEC. Litter treatment may affected the improvement of soil CEC value differently. The addition of organic matter will increase the negative charge, consequently increasing CEC. In most cases, organic matter will contribute to soil CEC around 20-70%

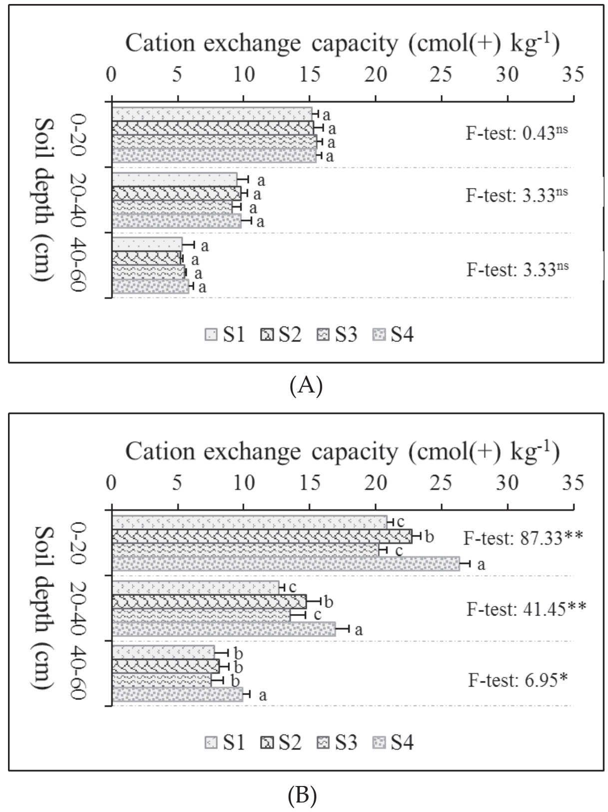

Fig. 2. Cation exchange capacity at the soil depths of 0-20, 20-40, and 40-60 cm before litter treatment (0 MAT) (a) and 26 (MAT) (b)

Table 3. Nutrient contents in soil at the depth of 0-100 cm in observation before litter treatment application (0 MAT) and after litter treatment (26 MAT)

Treatment	Nutrient contents in soil at 0 MAT					
	N(%)	P(ppm)	K(cmol(+) kg^{-1})	Ca(cmol(+) kg^{-1})	Mg(cmol(+) kg^{-1})	C-organic (%)
S1	0.15	13.24	0.19	1.18	2.46	1.03
S2	0.16	12.99	0.20	1.19	2.47	1.02
S3	0.15	12.89	0.19	1.17	2.45	1.03
S4	0.14	11.41	0.18	1.18	2.46	1.04
F test	tn	tn	tn	tn	tn	tn
Treatment	**Nutrient contents in soil at 26 MAT**					
	N(%)	P(ppm)	K(cmol(+) kg^{-1})	Ca(cmol(+) kg^{-1})	Mg(cmol(+) kg^{-1})	C-organic (%)
S1	0.37c (156.90)	26.82c (102.61)	0.28bc(44.74)	2.36bc(100.21)	3.31(34.21)	2.74b(167.32)
S2	0.55b (250.79)	29.70b (128.64)	0.32ab(62.82)	2.42ab (103.79)	3.42(38.22)	2.59c(154.68)
S3	0.50b (231.67)	23.49b (82.20)	0.25c(32.89)	2.23c(90.60)	3.16(29.14)	2.36d(129.13)
S4	0.72a (433.33)	33.80a (196.32)	0.37a(102.78)	2.52a(114.68)	3.66(48.83)	2.95a(182.49)
F test	**	**	**	**	tn	**

CEC, generally soil CEC derived from colloid humus, thus there is a correlation between organic matter and soil CEC (Oksana et al., 2012).

CEC in the soil layer (soil depth of 0-20 cm) was higher than that in the soil layer with depths of 20-40 cm and 40-60 cm. The soil CEC tended to decrease follows in reciprocal manner to the deeper layer of the soil at the initial observation (0 MAT) and after litter treatment (26 MAT). High CEC values allow nutrients to be absorbed easier by plant roots due to the base cations are not absorbed in the soil colloids. The CEC values of soil may changed depends on the organic matter content and soil pH (Hugar and Soraganvi, 2014).

Soil Macroorganism

The treatment of different types of litter increases the number of macroorganisms in biopore holes. The number of macroorganisms in biopore holes inidicated significant differences at 6, 12, 20, and 26 MAT. The types of macroorganisms discovered in biopore holes were earthworms (*Lumbricus terestris*), and simpleleaf chastetree (*Vitex trifolia*), mole crickets (*Gryllotalpa hirsuta*), millipedes (*Trigoniulus corallinus*), crickets (*Gryllus assimilis*), slugs and snails. The number of macroorganisms in biopore holes on the observation at 6 MAT showed significant difference results in each litter treatment

Table 4. Number of macroorganisms on BAHs in various litter treatments around oil palm plants

Treatment	Number of macroorganism at month				
	0 MAT	6 MAT	12 MAT	20 MAT	26 MAT
S1	6.9	24.4d	5.3c	23.6d	26.1d
S2	8.0	33.6b	7.3b	33.3b	41.6b
S3	8.0	31.6c	5.8bc	30.0c	33.8c
S4	7.6	45.6a	9.3a	44.5a	55.6a
Macroorganism increasement (%)	-	85.6	76.2	88.3	112.9
F test	tn	**	**	**	**

[a] The values at the same column followed by the same letter are not significantly different from the DMRT test at α = 5%, **: very different at α = 1%, tn: not significantly different at α = 5%, MAT : months after treatment.

Table 5. Type and number of microorganisms in biopore holes in 26 months after litter treatment

No.	Microorganism type	Scale	Litter treatment			
			S1	S2	S3	S4
1.	*Actinomycetes*	CFU g^{-1}	2.48×10^5	1.87×10^6	ttd	3.43×10^6
2.	*Azospirillum* sp.	CFU g^{-1}	1.72×10^4	2.47×10^4	1.31×10^5	3.42×10^6
3.	*Azotobacter* sp.	CFU g^{-1}	3.30×10^8	5.38×10^7	6.22×10^8	3.30×10^8
4.	*Bacillus* sp.	CFU g^{-1}	$4.57\ 10^7$	5.08×10^7	6.68×10^3	6.75×10^8
5.	P solubilizing bacteria	CFU g^{-1}	1.26×10^3	ttd	ttd	2.45×10^3
6.	N fixing bacteria	CFU g^{-1}	ttd	2.38×10^7	3.42×10^7	5.38×10^9
7.	Organic matter decomposition bacteria	CFU g^{-1}	2.47×10^4	1.86×10^4	3.39×10^5	4.20×10^5
8.	*Rhizobium*	CFU g^{-1}	ttd	1.86×10^4	ttd	5.64×10^5
9.	*Streptomyces*	CFU g^{-1}	ttd	2.72×10^5	ttd	ttd
10.	*Lactobacillus* sp.	CFU g^{-1}	4.74×10^5	ttd	5.63×10^5	9.16×10^6
11.	*Pseudomonas sp.*	CFU g^{-1}	2.60×10^5	1.86×10^4	ttd	5.64×10^7
12.	Cellulolytic bacteria	CFU g^{-1}	ttd	3.54×10^3	3.37×10^4	4.87×10^7
13.	*Saccharomycet*	propagul g^{-1}	ttd	ttd	2.45×10^3	4.53×10^7
14.	*Aspergillus*	propagul g^{-1}	4.54×10^5	7.75×10^5	3.65×10^5	2.80×10^4
15.	P solubilizing fungi	propagul g^{-1}	ttd	3.28×10^6	ttd	5.00×10^5
16.	Organic material decomposit in fungi	propagul g^{-1}	2.76×10^6	ttd	ttd	4.58×10^5
17.	*Fungi selulolitik*	propagul g^{-1}	2.59×10^4	ttd	3.73×10^4	3.63×10^8
18.	*Trichoderma* sp.	propagul g^{-1}	2.30×10^7	1.60×10^3	8.40×10^3	3.86×10^5
19.	*Mikoriza arbuscular*	spore/50 g sample	36	42	20	67
20.	Organic matter decomposition activity		negative	negative	negative	negative

which were 45.3 (S4), 33.6 (S2), 31.6 (S3), and 24.4 (S1), respectively. The highest number of macroorganisms was found at S4 treatment, while the lowest number of macroorganisms was found at S1 treatment (Table 4).

The treatment of various litter indicated significant difference at 12 MAT. The highest number of macroorganisms was found at S4 treatment with an average of 9.3 compared to other treatments. However, the number of macroorganisms on all of litter treatments decreased significantly at 12 MAT. It was suggested, due to the long dry season for 6 months in those period (May-October 2015) with average rainfall of 19 mm $month^{-1}$. Rainfall at October 2015 was 20 mm $month^{-1}$, the average temperature ranges from 26 to 35 ^{o}C, and the average humidity was 59%. Inadequate climate conditions resulted in the decreasement of microorganisms population. Macroorganisms require sufficient water, humid environmental conditions, and the availability of adequate food in order to sustaining their livehood (Anwar, 2009; Sucipta et al., 2015).

The observation results on 20 MAT indicated that the number of macroorganisms on all of treatments experienced a significant improvement compared to the previous observations (12 MAT). The number of microorganisms increased continously at 26 MAT. The increasement of the number of macroorganisms on all of litter treatments might be caused by suitable climate conditions for soil macroorganisms growth. The rainfall conditions at June 2016 (20 MAT) was 196 mm with temperatures ranging from 26 to 31 ^{o}C and humidity by 78%, while rainfall at December 2016 (26 MAT) was 133 mm with temperatures ranging from 26 to 31 ^{o}C with humidity by 79%. Sucipta *et al.*, (2015) suggested that optimum humidity for macroorganism growth such as earthworms ranges from 15 to 30% because 85% of earthworm weight body consists of water. Treatment of different types of litter showed significant differences in the number of soil macroorganisms in biopore holes at 20 MAT and 26 MAT. The highest number of macroorganisms was found at S4 treatment with average number of macroorganisms of 44.5 at 20 MAT and 55.6 at 26 MAT.

Soil Microorganisms

The type of litter affects the number and types of soil microorganisms in biopore holes (Table 5). Based on observations at 26 MAT, soil microorganisms in biopore holes ranged from 13 to 18 types of microorganisms. Types of soil microorganisms in biopore holes on monocotyl treatment (S1), dicotyl litter treatment (S2), litter treatment of oil palm plantation (S3), and mixed litter (S4) treatment were 13 species of microorganisms, 16 types of microorganisms, 12 types of microorganisms, and 18 types of microorganisms, respectively. Soil organisms (decomposers) are living organisms which function to decompose organic matter derived from dead plants and animals (Haneda and Sirait, 2012). Soil microorganisms are in charge of breaking the organic matter down to be smaller and microorganisms shall carry out the decomposition process further of this destructed organic matter (Andriuzzi *et al.*, 2016).

Description: S1: litter of grasses (monocotyl), S2: litter of broadleafed plants (dicotyl), S3: litter from part of oil palm organs (leaves, midribs, male flowers, and stems), S4: (S1 + S2 + S3).

The treatment of mixed litter (S4) was the best treatment with the highest type and number of microorganisms compared to other treatments. It can be concluded that there is a relationship between litter diversity with the genome and the number of soil microorganisms. The decomposition process of organic matter in the nature is not carried out by a single microorganism, but is carried out by the consortia of microorganisms (Gao et al., 2015). The type of plant litter affects soil microorganisms community through the supplied carbon supply which is the carbon supply derived from the decomposition process (Esmaeilazadeh and Ahangar, 2007). Changes in the quality and quantity of food due to the changes in litter diversity will alter the amount, activity, and diversity of soil microorganisms (Shahbaz *et al.*, 2017).

CONCLUSIONS

The root volume on mixed litter treatment (S4) 26 MAT was 9.03 mL l^{-1}, 44.71% higher than the monocotyl treatment (S1), and had significant effect on other treatments. Soil water content decreasement follows in a reciprocal manner to the deeper soil layer till 60 cm depth when water content condition is sufficient, while water content in topsoil (0-20 cm), it will be lower than in soil depths of 20-40 cm and 40-60 cm at long drought season. Treatment of litter mixture (monocotyl, dicotyl, and palm oil plant part) higher levels of N, P, K, Ca, Mg, and C-organic nutrients, at a distance of 0-5 cm and 5-10 cm from the hole biopore absorption (HBA). The highest total soil macroorganisms were found in the mixed litter treatments (S4) of 162.25 individuals in the LRB, from observations of 0 BSP, 6 BSP, 12 BSP, 20BSP, and 26 BSP. Monocotyl litter treatment of 86.25 individuals in LRB, was the lowest compared to other treatments. The mixed litter treatment (S4) is the best in the variables, namely: root volume, soil moisture depth 0-20 cm, nutrient content of N, P, K, Ca, Mg, and C-organic depth 100 cm, nutrients N, P, K, Ca, Mg, and C-organic at a distance of 0-5 cm and 5-10 cm from the hole biopore absorption (HBA), cation exchange capacity, number of soil macroorganisms, and soil microorganisms, and followed by dicotyl litter, monocotyl, and from the oil palm plantation section. Biopori technology to overcome the inundation stress in the rainy season and water deficit in the dry season in oil palm plant so that plants can grow and produce well.

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