Plant Age Influence on Soil Chemical Properties of Oil Palm Plantation in East Kotawaringin, Central Borneo

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ABSTRACT

This research was attempts on comprehended the influence of oil palm age on soil chemical properties of oil palm plantation in East Kotawaringin District, Central Borneo. Soil sample is obtained from oil palm plantation site which represent plant in age of 3, 5, 7, 9, 14 and 16 years old in four depths of soil layer. Soil sample then brought to laboratory for analysis. We also collected forest soil sample nearby the plantation site for comparison of 0 year age. The result indicates that the clearance of forest and the planting of oil palm at the age of 3 years old influencing pH H_2O and pH KCl, and both are also influential in reducing C-organic, N-total, P-available, cation exchange capacity, Ca, K, Na, H and Al exchangeable. The increase of oil palm age respectively from 3, 5, 7, 9, 14 and 16 years old is affected on the increasing content of C-organic, cation exchange capacity, H and Al exchangeable, and also affected on reducing pH H_2O, pH KCl, N-total, P-available, Ca, K and Na exchangeable. The increase of oil palm age from 3 to 14 years old is reducing the base saturation. Conversely, age increase from 14 to 16 years old is increasing the base saturation. The increase of oil palm age from 3 to 16 years old is not influencing the change of exchangeable-Mg in oil palm plantation soil.

Keywords: Oil palm plantation, plant age, soil chemical properties

INTRODUCTION

Oil palm represents a commodity of plantation with the most dramatic growth at two recent decades. It is unfortunate to see that the development of this plantation is a primary reason behind the great conversion of forest land use into farming land in Indonesia. Central Borneo has the most extensive oil palm plantation in Indonesia. In 2012, the width of oil palm plantation at Central Borneo is 858,434 ha and on April 2013, increases into 1,304,125 ha. This width is not including the width of unopened reserve area of 31,771 ha (Department of Plantation, Central Borneo, 2013a; 2013b).

The development of oil palm plantation is allegedly the main reason of forest coverage loss, deforestation, and the loss of water catchment area which causes flood during rainy season and drought during dry season, biodiversity loss, and other derivative impacts. The development of oil palm plantation also becomes a causal factor behind the occurrence of forest land degradation and the negative impact on soil productivity. Soil in farming land may change its productivity after forest conversion and it is possibly related with the change of chemical properties and fertility of the soil. Soil chemical properties and soil fertility rate are both soil crucial components that greatly subjected to the impact of the forest conversion into oil palm plantation (Handayani, 1999; Dewi, 2007).

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In the other hand, the development and the enhancement of farming area or plantation area are necessary to fulfill the food demand of community. The gap between production interest (economic) and quality and function interest (ecology) of the area, especially the farming area or plantation, must be eliminated by improving the land management. Land management of the plantation would be well implemented when the impact of plantation activities on the change of soil properties as the essential component of the soil is well comprehended.

One of oil palm plantation activity with the potential to change soil chemical properties and soil fertility rate is the planting and the maintenance of oil palm based on the plant age. Therefore, the objective of our research is to comprehend the influence of oil palm plant age on the change on soil chemical properties of oil palm plantation in East Kotawaringin District, Central Borneo.

MATERIALS AND METHODS

Soil was sampled from the oil palm plantation in East Kotawaringin District, Central Borneo, Indonesia and then analyzed in the laboratory. The sampling is obtained at block plantation sites which represent plant in age of 3, 5, 7, 9, 14 and 16 years. For comparison, forest soil nearby the plantation area was also sampled as age of 0 year. At each representative site, we sampled at 3 points (for replication) with different spatial distance. Each sampling is conducted at four depths of soil layer, i.e. layer I (0-25 cm), layer II (25-50 cm), layer III (50-75 cm), and layer IV (75-100 cm). The sampling of each layer is composited using stainless pipe with diameter 2”. Composite soil sample from each layer depth were sampled for ±1 kg and then analyzed in laboratory.

Soil analysis is conducted at Laboratory of Institute for Agricultural Technology - Balai Pengkajian Teknologi Pertanian (BPTP), Yogyakarta. The observed parameters of soil chemical properties include: soil acidity (pH H_2O and pH KCl), cation exchange capacity analyzed by NH_4OAc extraction method, base saturation analyzed by NH_4OAc extraction method, C-organic rate analyzed by oxidation method (Walkley and Black), N-total analyzed by Kjehdahl method, P-available analyzed by Bray I, K_2O analyzed by 25% HCl extraction, bases-exchangeable (Ca, Mg, K and Na) analyzed by NH_4OAc extraction method, aluminum and hydrogen exchangeable analyzed by NH_4OAc extraction method. Data of laboratory analysis for each plant age averaged and standard deviations were also calculated, then compared between the average age of the plants with other plant age in accordance with the purpose of the research.

RESULT AND DISCUSSION

The soil of the site is classified as ultisol, and according to Soil Research Center (1983), it belongs to podsolic group. Preliminary result indicates that soil type around the research area has low fertility rate (Basuki, 2008). The variation of soil chemical properties based on oil palm age is elaborated as following.

Soil Acidity, Exchangeable-Hydrogen and Exchangeable-Alumunium

Soil acidity or soil reaction indicates acidity or alkalinity of the soil. It is symbolized by pH which represents the negative logarithm of H^+ ions concentration measured in gram per liter of soil solution (Harjowigeno, 1987). Result indicates that oil palm age influences the change of soil acidity (pH), exchangeable-H and exchangeable-Al (Table 1). The planting of oil palm till 3 years old will increase pH soil – which initially is a forest area – from pH H_2O 4.62 to 4.88 or from pH KCl 4.11 to 4.19 (Figure 1). The increase of pH is caused by the decrease of exchangeable-H and exchangeable-Al contents due to the opening of forest land for land preparation of oil palm plantation. Exchangeable-H decreases from 0.09 me/100 g (age of 0

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year old of forest soil) to 0.05 me/100 g (age of 3 years old), while exchangeable-Al is reduced from 0.11 me/100 g to 0.09 me/100 g.

Table 1. Oil Palm Age Influence on pH H_2O, pH KCl, H-exchangeable and Al-exchangeable

Plant Age (Year)	*pH H_2O*	*pH KCl*	*H-Exchangeable (me/100 g)*	*Al-Exchangeable (me/100 g)*
0	4.62 ± 0.21	4.11 ± 0.06	0.09 ± 0.01	0.11 ± 0.02
3	4.88 ± 0.14	4.19 ± 0.05	0.05 ± 0.01	0.09 ± 0.01
5	4.55 ± 0.12	4.06 ± 0.06	0.05 ± 0.01	0.10 ± 0.01
7	4.48 ± 0.16	4.05 ± 0.06	0.06 ± 0.01	0.10 ± 0.01
9	4.46 ± 0.16	4.03 ± 0.07	0.06 ± 0.01	0.10 ± 0.01
14	4.39 ± 0.14	3.99 ± 0.09	0.07 ± 0.01	0.11 ± 0.02
16	4.28 ± 0.13	3.97 ± 0.06	0.08 ± 0.01	0.13 ± 0.01

Source: Result of soil laboratory analysis.

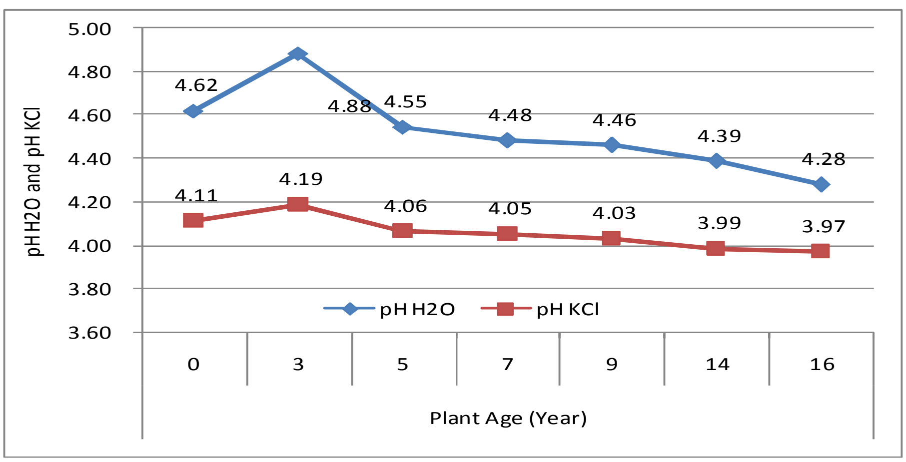

Figure 1. Oil Palm Age Influence on pH H_2O and pH KCl

The increase of oil palm age from 3 to 16 years old has reduced pH soil from 4,88 to 4,28 (pH H_2O) or from 4.19 to 3.97 (pH KCl). The decrease of pH soil or the increase of soil acidity is caused by the increase of exchangeable-H ion from 0.05 me/100 g to 0.08 me/100 g, and also by the increase of exchangeable-Al ion from 0.09 me/100 g to 0.13 me/100 g. As already noted, H^+ and Al^{3+} ions are the source of soil acidity (Nyarko, 2012; Nweke and Nsoanya, 2013). The decrease in pH has also been reported by Ng et al. (2011) as a result of nitrification of given N fertilizer, organic fertilizer or legumes that contains or produces NH^{4+} which can increase the soil acidity.

Comparison between pH H_2O and pH KCl of each plant age show that pH KCl is little bit lower than pH H_2O. The lower rate of pH KCl is related to the fact that in the complex of soil adsorption, aluminum is expelled out by potassium from KCl extractor salt. The hydrolysis of aluminum by potassium will produce hydrogen ion so that pH KCl became lower (Thunjai et al, 2007; Gavriloaiei, 2012).

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We estimated that the increase of exchangeable-H and exchangeable-Al along with the increase of oil palm age from 3 to 16 years old is closely related to the increase of the nutrient absorption by the root of oil palm – precisely the absorption of bases cations (Ca, Mg, K and Na). The absorption of bases cations by plant root may change the relative concentration between acid cation and bases cation. The greater bases cation absorbed by the plant, the greater is the cation concentration of H^+ and Al^{3+} ions in the soil solution. The mechanism of cation absorption by root hairs will occur through the mechanism of root contact exchange where cation in the soil solution or in the soil absorption colloid is absorbed by plant root. In exchange, the root will replace base cations with H^+ ion on root surface (Syekhfani, 2010). Both phenomena stimulate the increase of H^+ and Al^{3+} ions by the increase of oil palm age from 3 to16 years old (Figure 2).

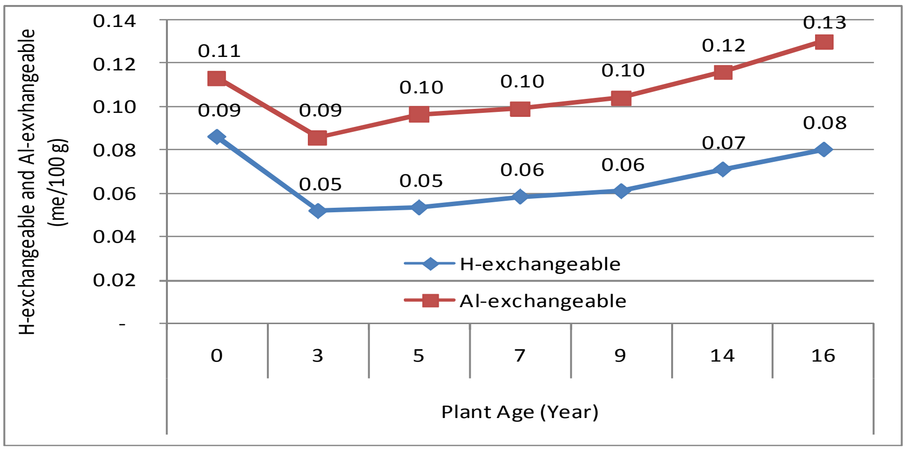

Figure 2. Oil Palm Age Influence on H-exchangeable and Al-exchangeable

Base Cations, Cation Exchange Capacity and Base Saturation

Cation exchange capacity is the consequence of negative charge in the soil. The source of soil negative charge came from negative charge of inorganic colloid (clay mineral) and organic colloid (humus). Inorganic colloid negative charge can develop from: the isomorphic crystal substitution of clay mineral; negative charge at the tip of crystal break of mineral clay; and the dissociation of H^+ ion from –OH cluster at the tip or edge of the crystal. Otherwise, the source of negative charge of organic colloid came from the dissociation of H^+ ion from carboxylate cluster (-COOH) and hydroxyl or phenol cluster (-OH). The consequence of this negative charge is that soil absorbtion complex allow the absorption of the cation and this absorbed cation can be exchanged for the cation in the soil solution. The higher negative charge in the soil, the higher is cation exchange capacity of this soil (Tisdale et al., 1999).

Cation is positive charge ion such as $Ca^{2+,}$ $Mg^{2+,}$ H^+, etc. In the soil, these cations are adsorbed in the adsorbtion complex of soil colloids. Cation exchange capacity is the number of exchangeable-cations adsorbed in colloid surface which is measured by mili-equivalent/100 gram (me/100 g). It also represents the ability of the soil to supply nutrient or gross guide about the type of mineral clay and the presence of organic material (Rashidi and Seilsepour, 2008). These cations can be differentiated into base cations (Ca, Mg, K and Na) and acid cations (H and Al). The number of adsorbed cations in soil is per soil weight unit (usually per 100 g), which is then called as cation exchange capacity of the soil. Base saturation shows the relative comparison between base cations and all cations (base cation and acid cation) in the soil adsorbtion complex. In other words, base saturation is the relative percentage of base cation against cation exchange capacity rate (Hardjowigeno, 1987; Nduwumuremyi *et.al.*, 2013).

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Result also indicates that oil palm age influences base cations of Ca, Mg, K and Na exchangeable, cation exchange capacity and base saturation (Table 2). The opening of forest followed by the planting of oil palm from 3 to 16 years old will decrease Ca, K and Na exchangeable (Figure 3). However, it does not influence the exchangeable-Mg. The decrease of cations of Ca, K and Na exchangeable is caused by the oil palm planting which is led on nutrient losing from soil column. The rate of the losing may be greater either through plant absorption or due to leaching. Erhabor and Filson (1999) and Simanjutak (2008) also explained that nutrient in soil is influenced by nutrient absorption, leaching, type and quantity of fertilizer. The loss of nutrient due to leaching is estimated as quite significant due to high rainfall at the site, which is 2,563 mm/year.

Table 2. Oil Palm Age Influence on Base Cations Exchangeable, Cation Exchange Capacity (CEC) and Base Saturation (BS)

Plant Age (Year)	*Base Cations Exchangeable (me/100 g)*				*CEC (me/100 g)*	*BS (%)*
	Ca	*Mg*	*K*	*Na*		
0	4.32 ± 0.32	0.40 ± 0.07	0.06 ± 0.03	0.07 ± 0.07	17.05 ±0.53	28.41 ±1.98
3	3.95 ± 0.39	0.39 ± 0.07	0.05 ± 0.03	0.06 ± 0.03	16.04 ±0.55	27.69 ±2.44
5	3.77 ± 0.35	0.37 ± 0.09	0.05 ± 0.02	0.05 ± 0.03	16.08 ±0.44	26.31 ±2.33
7	3.56 ± 0.40	0.36 ± 0.11	0.04 ± 0.02	0.04 ± 0.02	16.11 ±0.59	24.73 ±2.45
9	3.47 ± 0.48	0.35 ± 0.09	0.04 ± 0.01	0.04 ± 0.02	16.31 ±0.53	24.58 ±2.88
14	3.40 ± 0.46	0.33 ± 0.09	0.04 ± 0.01	0.03 ± 0.01	16.44 ±0.35	23.26 ±2.66
16	3.34 ± 0.42	0.33 ± 0.11	0.04 ± 0.02	0.03 ± 0.01	16.62 ±0.33	22.63 ±3.26

Source: Result of soil laboratory analysis

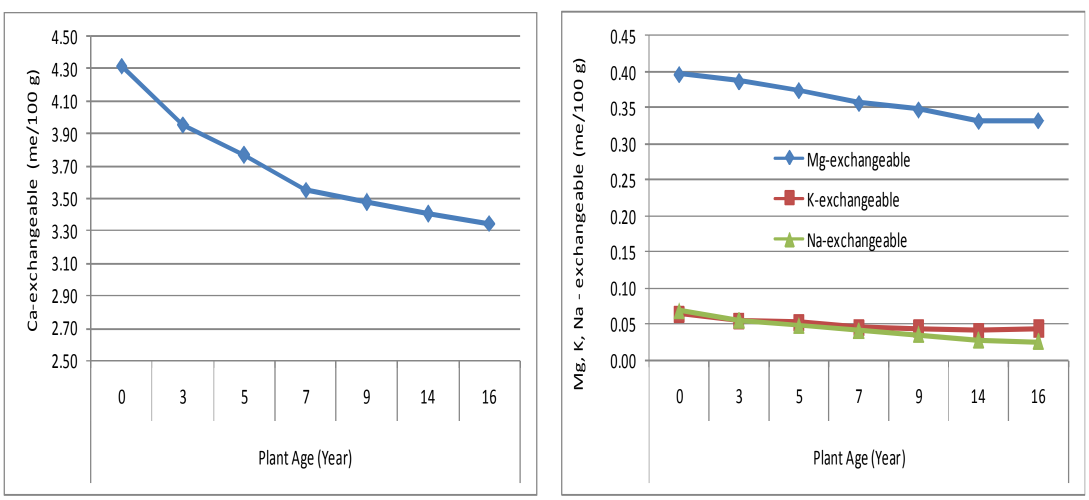

Figure 3. Oil Palm Age Influence on Ca, Mg, K and Na exchangeable

The planting of oil palm till 3 years old is reducing cation exchange capacity of the soil – which is initially a forest soil, from 17.05 to 16.04 me/100 g (Figure 4). The reduction of cation exchange capacity of the soil is caused by the decrease of organic material (organic carbon) due to the forest opening for the preparation of the oil palm planting where organic carbon declines from 2.10% (forest soil) to 0.99% (soil of 3 years old oil palm). This organic material is one source of soil negative charge, and therefore, the lower organic material, the lower soil negative charge and cation exchange capacity is.

The increase of oil palm age from 3 to 16 years old is followed by the increase of cation exchange capacity of the soil. The increase of cation exchange capacity with the increase of oil palm age is caused by the fact that the increased oil palm age from 3 to 16 years old has increased the content of organic material (organic carbon) and also reduced soil pH. Organic material of the soil is a source of soil negative charge which may develop from dissociation of H+ ion from carboxyl cluster (-COOH) and phenol cluster (-OH) which are always leaves negative charge. Therefore, the greater organic material content of the soil, the greater is negative charge and cation exchange capacity of the soil (Hardjowigeno, 1987).

Base saturation is decreased along with the increase of oil palm age, respectively from forest soil (0 year), 3, 5, 7, 9, 14 and 16 years old with the lowest base saturation. The decrease of base saturation from 0 to 16 years old is caused by the reduction of base cations (Ca, K and Na exchangeable), so that total base cation reduced, at the similar age the content of acid cations (H and Alexchangeable) show relatively increase, or in other words, base saturation is reduced (Fig. 4). Suitable to the definition, the change pattern of base saturation is determined by the change pattern of relative comparison between base cations against total base and acid cation (Syekhfani, 2010).

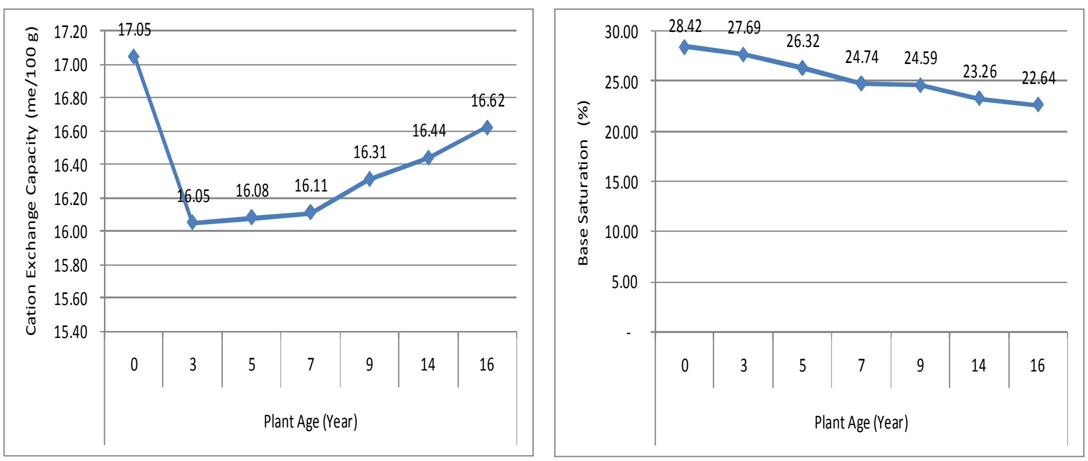

Figure 4. Oil Palm Age Influence on Cation Exchange Capacity and Base Saturation

The Contents of Organic Carbon, Total Nitrogen and Phosphor-Available

Almost all organic materials in the soil come from plant residue. It is expected that these materials contain nutrient with the similar relative proportion to the plant. Soil organic materials - in the term of soil chemical fertility – act as the buffer of available N, P and S; and the adsorbtion of Ca, Mg, K and Na. Physically, organic materials are useful to improve the ability of soil to retain water and to improve the stability of soil structure (Soemarno, 2010). In general, soil organic carbon is assigned into 3 groups, i.e. fixed carbon, dissolved carbon, and biomass carbon. The decomposition of plant remnants involved three processes: *leaching* of easily dissolved compound, the *catabolism* of the decomposer organism and the *comminution* of material by soil fauna (Handayanto and Hairiah, 2007).

The result shows that the age of oil palm influences the change of C-organic, N-total and P-available (Table 3). The planting of oil palm age till 3 years old reduce C-organic soil, precisely from 2.10% to 0.99% (Fig. 5). The reduction of C-organic soil is caused by the forest opening for oil palm plantation preparation which removed most vegetation cover. This vegetation cover is actually the source of litter on soil surface. The loss of this cover triggers the loss of C-organic supply into the soil, and therefore, the content of organic material is declining dramatically.

The increase of oil palm age from 3 to 16 years old is stimulating C-organic content to increase gradually from 0.99% to 15.2%. The increase of C-organic content in the oil palm age from 3 to 16 years old is caused by the fact that the planting in this age interval has increased the supply of organic material from the plant's stalk cuts litter and also from those of fallen male blossom (Chew and Pushparajah, 1996). Both reserve the nutrient of oil palm (Ng and Thamboo, 1967; Pahan, 2010). The nutrient from plant's stalk cuts litter and fallen male blossom are respectively as follows: 67.2 kg and 11.2 kg of N; 8.9 kg and 2.4 kg of P, 86.2 kg and 16.1 kg of K, 22.4 kg and 6.6 kg of Mg, and for 61.6 kg and 4.4 kg of Ca – all per ha per year.

Table 3. Oil Palm Age Influence on C-Organic, N-total and P-available

Plant Age (Year)	*C-organic (%)*	*N-total (%)*	*P-available (ppm)*
0	2.10 ± 0.80	0.10 ± 0.05	8.42 ± 7.51
3	0.99 ± 0.96	0.07 ± 0.04	6.42 ± 5.45
5	0.93 ± 0.97	0.07 ± 0.04	6.58 ± 4.29
7	1.01 ± 0.66	0.07 ± 0.05	7.08 ± 5.18
9	1.12 ± 0.61	0.06 ± 0.04	6.58 ± 5.20
14	1.24 ± 0.69	0.06 ± 0.03	5.58 ± 4.38
16	1.52 ± 0.79	0.06 ± 0.03	4.75 ± 3.31

Source: Result of soil laboratory analysis

Different pattern occurs on total nitrogen variable. The increase of oil palm age from forest soil condition (0 year old) and 3 to 16 years old gradually decreasing the total nitrogen content from 0.10% (0 year old), 0.07 % (3 years old), to 0.06% (16 years old).

C-organic content also influences the total nitrogen content because source of total nitrogen is the decomposition of organic nitrogen such as protein and amino acid that mostly found in the organic material (Rezig et al., 2012). Nevertheless, the dynamic of total nitrogen is also influenced by fertilization on oil palm plantation and by plant's nutrient absorption. Simanjutak (2008) stated that the nutrient rate in the soil is influenced by nutrient absorption, leaching, and type and quantity of fertilizer.

The reduction of soil's total nitrogen in oil palm plantation from 0, 3 and 16 years old indicate that the increase of oil palm age is related to the greater nitrogen absorption by the plant and the greater nitrogen loss either through leaching or volatilization, compared to the addition of nitrogen into soil through fertilization and decomposition of organic material. Consequently, the increased age of the plant, the lower nitrogen total content of the soil is.

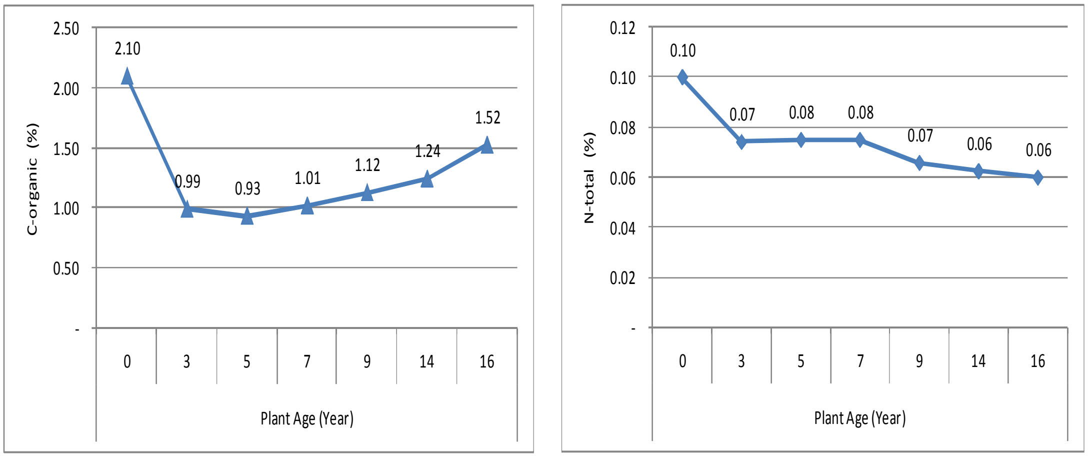

Figure 5. Oil Palm Age Influence on Carbon Organic and Nitrogen Total

The planting of oil palm plant to 3 years old decrease the soil's P-available from the forest soil condition, i.e. 8.42 ppm to 6.42 ppm (Fig. 6). The decrease of soil's P-available is due to the removes of most land cover vegetation, therefore, the supply and content of organic material is drastically reduced. As already mentioned previously, a source of P-available is from the decomposition of P-organic such as inositol and phospholipids compounds that found in organic material. The increase of oil palm age from 3, 5, 7 to 9 years old, show indifferent P-available content, which ranges from 6.42 ppm to 7.08 ppm. However, the next 14 and 16 years old age increase is followed by the reduction of P-available to 5.58 pm (14 years old) and 4.75 ppm (16 years old). The reduction of P-available content is assumed related to the reduction of soil organic material as a source of P-available in the soil. Besides, the decrease dynamic of P-available content in the soil is also influenced by the increase absorption of P-available by the oil palm because the demand of nutrient is increasing with the increase of plant age.

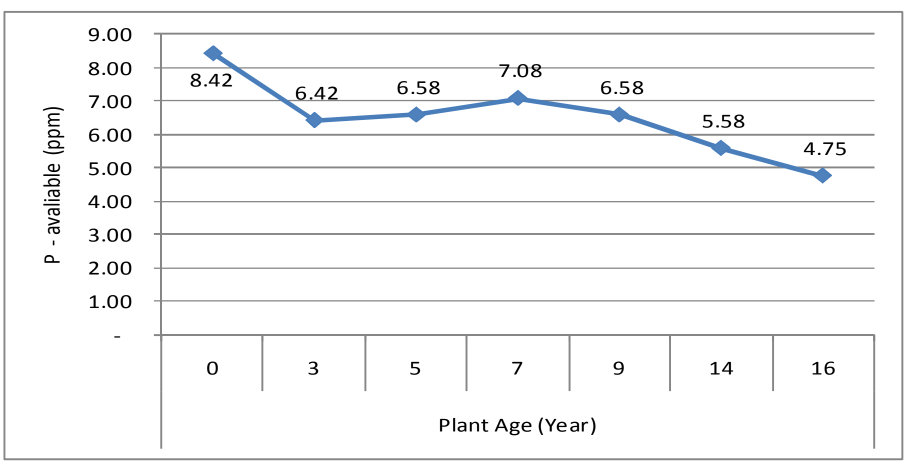

Figure 6. Oil Palm Age Influence on P-available

CONCLUSION

We concluded that the opening of forest area that followed by the planting of oil palm till 3 years old is increases the pH H_2O and pH KCl, and also reduces C-organic, N-total, P-available, cation exchange capacity, Ca, K, Na, H and Al exchangeable. The increase of oil palm age from 3, 5, 7, 9, 14 and 16 years old is increase the C-organic, cation exchange

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capacity, exchangeable-H and exchangeable –Al, but conversely reduced the pH H_2O, pH KCl, N-total, P-available, and Ca, K and Na exchangeable. The increase of oil palm age from 3 to 14 years old reduced the base saturation, but 14 to 16 years old increased the base saturation. The increase of 3 to 16 years old oil palm is not affecting the change of exchangeable-Mg in the oil palm plantation soil.

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