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SOIL FERTILITY AND NUTRIENT MANAGEMENT ON SPODOSOL FOR OIL PALM

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ABSTRACT

The research was carried out in Oil Palm Plantation in Ngabang, Landak Distric, West Kalimantan in May 2008. Composite soil samples were taken from the soils, in which the oil palms indicated the nutrient disorders. The aims of the research were to study the soil fertility and nutrient management of Spodosols for oil palm crops. The results indicated that spodic horizons in the oil palm plantation varied between 30 and 70 cm. Besides spodic horizons, the albic horizon, the horizon that can't be penetrated by the crops root, was also found. The texture is sandy with the sand content about 69-98 %. The soil has acidic properties, C organic varied from low to high, low phosphate, potassium, magnesium and Cation Exchange Capacity. In contrast, in the spodic horizon, the content of organic carbon, total nitrogen and CEC were higher, as well exchangeable Aluminum. There was close relationship between soil organic carbon and nitrogen and CEC in the soil. It is advice not to use spodosols for food crop and estate crops. The application of slow release fertilizers combined with organic fertilizers is highly input when oil palm planted on the Spodosol.

Keywords: Spodosols, soil characteristic, oil palm

INTRODUCTION

Oil palm is an annual crop and its economic age is up to 20-25 years old. Its highest yield obtained at the age of 5-10 years old. It grows on a wide range of acidity (pH very acid) but it cannot stand on pH > 7.5 (IFA, 2005). The optimum acidity for Oil palm is 5.0- 5.5. At pH < 5, Macro nutrients on the soil is not available for plant, but on the contrary, unneeded nutrients such as Fe, Mn, and Al are soluble, and they can bond the macro nutrient such as P, and urge K from the Exchange Cation Complex, and make those macro nnutrients unavailable for plant.

Nutrient management is the key of success on oil palm plantation management. The right nutrient management is arranged by informations of soil fertility, leaf nutrient content, land nutrition poorness, and plant nutrient needs. According to Witt, *et al*. (2005), biophysic data such as yield potential, soil nutrient availability, soil limiting factors, leaf nutrient content status, and the symptom of nutrient deficiency are needed to arrange the fertilizing recommendation. We can see the sufficiency of soil and leaf nutrient by comparing the soil and leaf analyses with nutrient threshold and critical content of nutrient on oil palm (Dierolf *et al*., 2000; IFA, 2005; Fairhurst *et al*., 2006). Fairhurst and Mutert (1999) said that the sufficiency of K, Ca and Mg by counting the percentage of respective nutrient in the leaf, and the critical limit of P as 0.0487 x N content on leaf + 0.039. Spodosols in Kutai are acid, low content of N, P, K, Ca, Mg, low CEC, and soil mineral dominated by quartz (Prasetyo *et al*., 2006). The soil has the low capacity in holding the subsoil water and holding the nutrient so that only a small quantity of added nutrients was absorbed by the plant. Spodosol soils are very acid one and too poor for plant (MacKinnon *et al*., 1996).

The experience in observing the symptom of nutrient scarcity is important basic in plantation soil nutrient management. Riwandi (2002) arranged a recommendation on oil palm fertilization by counting the difference amount between the coefficient of optimum nutrient with the actual nutrient showed by the analyses result, and then multiplied by soil mass and the width of land to be fertilized. The calculation showed that oil palm area in Kembang VLi Village requirement urea 0.66 – 2.644 kg/plant/years, SP-36 0.36 – 2.99 kg/plant/years, and KCl 1.17 – 2.99 kg/plant/years. The next fertilizing recommendation for next season will be corrected using the result of leaf nutrient content analyses.

Balance fertilization on Melanudand in equator can increase the oil palm yield (Mite *et al*., 1999). Fertilization efficiency is influenced by the amount of nutrient to be added and the method of fertilizing. Most of the field fertilizing method is by spreading the fertilizer over the ground/soil surface. So the fertilizer is on high risk to be transported by the errotion process, run off and evaporation.

The aim of this paper were to study the soil characteristic on Spodosols and the land nutrient management of oil palm plantation in Ngabang, Landak District, West Kalimantan Province.

MATERIALS AND METHODS

This study was conducted in Spodosols soil, oil palm plantation at Ngabang, Landak District, West Kalimantan Province on mid May 2008, by observing the symptom of nutrient deficiency on oil palm plant and on some plant indicators of soil fertility, and also by observing the oil palm growth of some soil, and taking samples of soil and leaf of 9 young oil palm plants (<2 years).

Soil samples were taken compositely from surrounding of the oil palm plant and from the one profile horizons. One composite soil sample that consisted of 3-5 sub samples was taken from 0-20 cm depth using soil drill. The sub sample were assembled and blended, and then we took 1 kg of the blended sample as a composite soil sample. We took sample from one profile horizon, to look the degradation of soil characteristic. The samples were dried, grounded, and sieved by 2 mm sieve, and then analyzed. Physical and chemical analyses comprised texture (sand, silt, and clay by pipette method), pH (H_2O and 1N KCl), C-organic (Walkey and Black method), total N (Kjedahl method), P_2O_5 and K_2O (25% HCl), P_2O_5 extracted by Bray 1, Ca, Mg, K, Na, and CEC (extracted in 1N NH_4OAc pH 7), Al^{3+} and H^+ (1N KCl method) (Sulaeman *et al*., 2005).

The Oil palm plants attain the age of 14 months from planting. Leaf samples were taken using Fairhust method (Fairhurst *et al*., 2006). Leaf sample was taken from the ninth leaf from top (unbearing fruit one), or taken four leaves from middle midribs collected from 6-8 plants, and the rib of the leaves must be omitted. The samples were oven dried at 70^o Celcius for 24 hours and ground for nutrient content analyses (N, P, K, Ca, Mg, S, Cu, Zn and B) by wet incineration (HNO_3 + $HClO_4$) (Sulaeman *et al*., 2005).

Interpretation of soil analysis result based on the nutrient limit threshold for the soil fertility level and the oil palm's critical nutrient content (Fairhurst *et al*., 2006, IFA Fertilizer Manual\IFA-Publication-Manual Oilpalm.htm)

The Leaf Basic Amount (LBA/kg) = (% K of leaf/39.1 + % Mg of leaf/12.14 + % Ca of leaf/20.04) x 1000

X/LBA K = (% K of leaf/39.1)/% leaf nutrient * 100

X/LBA Mg = (% Mg of leaf/12.14)/ % leaf nutrient * 100

X/LBA Ca = (% Ca of leaf/20.04)/ % leaf nutrient * 100

The Ca, Mg, and K nutrient categorized as "deficience" when X/LBA < 25%, categorized "low" when X/LBA 25-30 % and categorized "moderate" when X/LBA > 30%.

RESULTS AND DISCUSSIONS

Soil Chemical Characteristic

Soil structuce of Spodosols is sandy loos from the upper solum surface up to the hard spodic or albic horizon. The sand content was between 69 – 98% (Table 1). Loos and sandy structure indicate the unability to hold water, soil nutrient nor the adding nutrients. The soluble nutrients will be leached immidiately and then accumulated over the spodic or albic layer and then transported by lateral flow, and flowing into the weaker spots of caesars. So that the added nutrient will be lost in a short time and the plant cannot take the advantages of it. Most of the existing oil palm plant showed the symptom of N, P, K, Mg, and B deficiencies.

Spodosols are characteristically very acid (pH 3.5) to moderately acid (pH 4.2). Oil Palm plant can grow well on low pH. The low pH soil conditions make the macro nutrients unavailable for the plant growth. Under the circumstances there is fixation of P nutrient made by Al, Fe and

Mn hydroxide, and K nutrient is exhorted out by Al^{3+} and H^+ from adsorption complex in mass manner. In that case, the secondary macro nutrient (Ca and Mg) were unavailable for the plant growth. Lime or dolomite can be added to provide Ca and Mg and increase the pH.

Soil with loose sand texture and low C-organic content will get dry immediately on the dry season, for such soil cannot hold the water. This condition makes the water and nutrients evaporated quickly. Water is an important media for nutrient reaction. Lacking the water will disturb the biochemical reaction process and it means that the fertilizer will not quickly available for plant. In consequence we will see the plant with the symptoms of some nutrients deficiency in the dry soils. It is not because of lacking nutrients in the soils but the dry soil made the reaction process does not running well.

Spodosol soils have the very low to very high level of C-organic content. The darker color of the soil surface (unerroded organic matter) means the higher content of C-organic, and the paler color of the soil surface (where spodic horizon getting out to the soil surface) means that the soil has a lower content of C-organic. Thus we can say that leaching process will run fast on the soil with loose sand texture and low C-organic content. The C-organic role can be seen clearly at the growth of oil palm planted near the log pond (greener and healthier than others).

The clay content is getting higher on the compact/spodic layer, and get on increasing in the lower layer (Table 2). The content of C-organic, total-N, CEC and Al^{3+} are higher in the spodic layer than the topsoil layer. Just like the soil texture case, the rapid nutrient leaching causes accumulation. Those facts proof that there was a leaching process of clay, C-organic, N and Al nutrient from the topsoil layer. The hard spodic layer is formed by the reaction between C-organic and Al, Fe, and Mn elements.

The roots of oil palm planted on the soil having the spodic layers cannot freely develop for they cannot go through the hard layers (Figure 1). Consequently the roots cannot adsorb the nutrients and there will be the symptoms of nutrient deficiency.

The total-N content ranges from “very low” to “very high”, but mostly “low”. The high total-N content occurs where C-organic content is high. While CEC, P and K nutrient content of Spodosol soils are very low. The CEC is very low, it means that the soil cannot hold the nutrient added, or in other words, the fertilizer was leached and transported by the lateral flow.

Table 1. Texture, pH and C-organic content on Spodosol soil

Code of location	Texture (%)			pH		C organic
	Sand	Silt	Clay	H_2O	1<u>N</u> KCl	%
AL01	79	20	1	4.0	3.0	2.95
AL09	94	6	0	3.8	3.3	0.71
AL10	92	8	0	4.0	3.2	2.10
AL14	69	31	0	4.2	3.6	2.91
AL19	85	12	3	3.9	3.1	2.05
AL22	89	9	2	4.4	4.0	1.34
DS01	98	2	0	4.1	3.1	1.97
DS02	92	5	3	3.5	3.0	1.77
DS03	95	3	1	3.5	3.2	1.10
RR03	91	2	7	3.8	3.1	3.60
RR08	93	5	2	4.3	4.2	0.09
AL21	98	2	0	4.0	3.1	1.67
DS04	96	4	0	3.9	3.0	3.54

Table 2. The result of physical and chemical soil analysis characteristic on soil profile in Spodosol

Profile code	Sand	Silt	Clay	pH H_2O	C orgnaic	Total N	KTK CEC	Al^{3+}
	...............%.............				........%.......		me/100 g	
DS 01/1	98	2	0	4.1	1.97	0.13	2.42	0.12
DS 01/2	97	1	2	4.2	0.19	0.02	0.40	0.00
DS 01/3	-	-	-	3.5	11.05	0.43	20.26	8.03
DS 01/4	68	0	32	4.1	2.77	0.23	10.67	2.60
DS 01/5	26	5	69	3.7	1.63	0.13	10.45	3.23

Table 3. The result of chemical Spodolsol soil analysis on oil palm plantation

Location code	Total N %	Total P mg/100 g	Available P mg P/kg	Exch.-K	Ech.-Mg $cmol_c/kg$	CEC
AL01	0.23 T	4.4 VL	1.70 VL	0.07 VL	0.22 L	5.26 VL
AL09	0.07 VL	4.4 VL	2.01 VL	0.02 VL	0.22 L	1.99 VL
AL10	0.18 M	13.1 VL	1.53 VL	0.02 VL	0.41 VH	5.38 VL
AL14	0.23 M	8.7 VL	1.96 VL	0.03 VL	0.51 VH	6.68 VL
AL19	0.16 M	13.1 VL	2.93 VL	0.02 VL	0.31 VH	5.45 VL
AL22	0.11 L	4.4 VL	1.22 VL	0.02 VL	0.22 M	1.75 VL
DM01	0.13 L	4.4 VL	1.27 VL	0.06 VL	0.19 VL	2.42 VL
DM02	0.15 M	13.1 VL	0.92 VL	0.06 VL	0.16 VL	2.68 VL
DM03	0.09 L	8.7 VL	0.79 VL	0.00 VL	0.12 VL	1.83 VL
LL03	0.27 VH	17.5 VL	3.23 VL	0.03 VL	0.52 VH	4.84 VL
LL08	0.01 VL	13.1 VL	0.44 VL	0.00 VL	0.09 VL	0.47 VL
AL21	0.13 L	8.7 VL	2.05 VL	0.03 VL	0.13 VL	3.09 VL
DM04	0.27 VH	13.1 VL	2.05 VL	0.03 VL	0.56 VH	6.34 VL

Remarks= VL = very low, L = Low, M = Middle, H= High, VH = Very High, Ech = Exchangeable

Figure 1. Oil Palm growth on the upper spodic layer

There is a close relationship between N and C-organic content in the soil. The equation is r^2 = 0.98 (Figure. 2). The N content in the soil will increase by suppressing decomposition, leaching, and C-organic losing (through the runoff and erosion), and planting land cover crop and managing the water drainage could perform such effort. There is also a close relationship between soil C-Organic content with CEC (Figure.3). Thus, in other words, we can improve the soil fertility by managing the soil organic matter.

The Leaf Nutrient content

According to the field observation most of oil palm planted in Spodosol soils are having the symptom of N, P, K, Mg, and B deficiency. So that the sample leaves do not represent healthy plant nor plant unsurprising by nutrient deficiency. There are 4 oil palm leaves sample taken from the plantation.

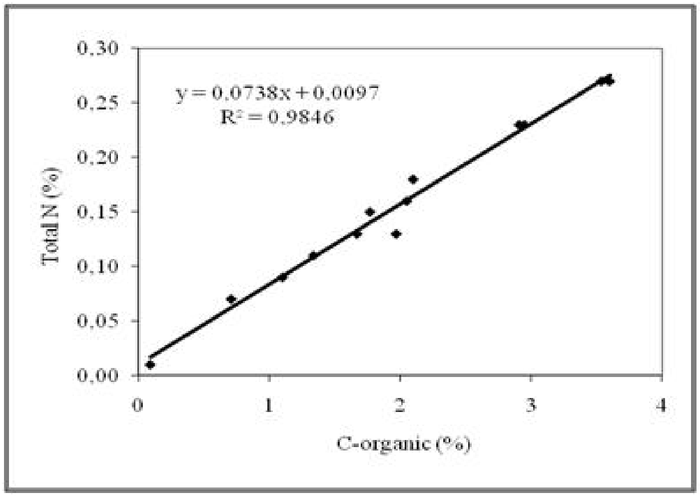

Figure 2. Relation between soil organic C and total N on Spodosol

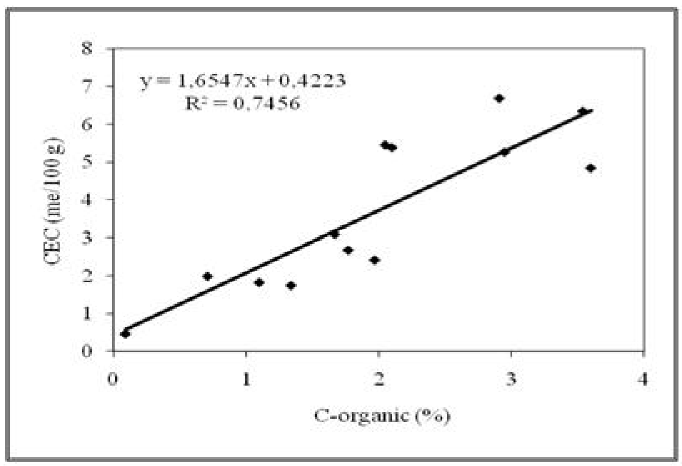

Figure 3. Relation between soil organic C and CEC on Spodosol

Table 4. The result of oil palm leaf analysis from Spodosol soil

Profile code	N	P	K	Ca	Mg	S	Cu	Zn	B
			……………………………%...............................				………ppm…………		
DS1	2.63 o	0.23 o	0.62 k	0.51 o	0.52 o	0.11 k	2 k	22 o	19 o
DS2	1.40 k	0.12 k	0.40 k	0.33 k	0.46 o	0.06 k	2 k	21 o	16 o
DS3	2.31 k	0.15 k	0.60 k	0.24 k	0.35 o	0.05 k	3 k	14 o	17 o
DS4	2.87 o	0.22 o	0.78 k	0.37 k	0.41 o	0.12 k	2 k	19 o	20 o

Remarks: o = optimum, k = nutrient deficiency

The N, P, K, Ca, S, and Cu nutrient content of the leaves are "low", while the Mg, Zn and B content are "optimum". Despite of the fact we found that there were Mg and B deficiency in the plant. B deficiency usually occurs on land having highly sunshine/radiation intensity but the temperature low (Shorrocks, 1997). The oil palm analyses result can be used to make some correction of the next fertilization. The equation of fertilizing recommendation correction was proposed by Abdoellah and Pujianto (1992) *in* Riwandi (2002).

Based on critical threshold calculation P (= (0.0487 x N content) + 0.039, P content in all oil palm leaves samples were less than the critical threshold. So that P fertilization is needed in Ngabang oil palm plantation.

It was found that there were lacking of Ca and K in the leaves samples oil palm planted over the Spodosol soils. While Mg was insufficient status. It means that the plant needs Ca and K fertilization to support the oil palm growth.

Field Plant Observation of Oil Palm

Qualified and effective fertilizer to support the oil palm growth is one good infestation. In sandy soils with quartz minerals the plant growth is only depend on the fertilization. Slow released fertilizer can optimized the fertilization effectiveness and efficiency. Ameliorant (such as organic matter) was also needed to increase the capacity of soil in holding the nutrient added.

Oil palm growth in Spodosol soils (Typic Haplorthods and Lithic Haplorthods) was much worse than those in Ultisols (Typic Hapludults) and Inceptisol (Typic Dystrudepts). It because of the albic and spodic layer between 30 – 70 cm depth below the topsoil surface, and that spodic layers was hard, have sandy texture, have 20-40 cm thickness, and poor drainage condition on the hard albic and spodic layers. Oil palm needs $\geq$80 cm depth sollum without rock/fragipan layers.

The difference of oil palm growth in Typic Haplorthods and Lithic Haplorthods caused by the different depth of spodic layer. The spodic layer of Lithic Haplorthods is < 30 cm, and this condition become to constraints the oil palm roots the worse growth (Figure. 4).

Ultisols and Inceptisols have higher pH and CEC than Spodosols (Table 6). This condition influence significanly defference to the oil palm growth.

Nutrient Management on Oil Palm Planted over Spodosols

Oil palm growth in Typic Haplorthods is better than that growth in Lithic Haplorthods (Figure. 4). This caused by the fact that spodic layer in Typic Haplorthods is lying in deeper depth. Oil palm root cannot grow freely in Lithic Haplorthod (Figure. 2) for the spodic layer is laid in shallower depth. Based on the facts we can say that Lithic Haplorthod is unsuitable for oil palm plantation. This study is having a mutual accord with the previous study made by Prasetyo *et al*., (2006) who concluded that Spodosol Soils is better localized and used for forestry only or it will inflict a financial loss to farmers.

Table 5. The calculation result of leaf base total Ca, Mg, and K nutrient on the oil plam leaf from Spodosol soil

Code	Ca		Mg		K	
	…………………………%..............................					
DS1	30.25	Medium	50.91	Medium	18.85	Deficiency
DS2	25.49	Low	58.67	Medium	15.84	Deficiency
DS3	21.33	Deficiency	51.34	Medium	27.33	Low
DS4	25.58	Low	46.79	Medium	27.64	Low

Table 6. Everage soil pH, organic C content and CEC on Ultisol, Inceptisol and Spodosol soil from research area

Soil type	pH	CEC (me/100 g tanah)
Ultisol	4.5	5.31
Inceptisol	4.7	4.88
Spodosol	4.0	3.71

Typic Hapludults *Typic Dystrudepts*

Typic Haplorthods *Lithic Haplorthods*

Figure 4. Oil palm growth on the deference soil type

Nutrient Management on Oil Palm Planted over Spodosols

Oil palm growth in Typic Haplorthods is better than that growth in Lithic Haplorthods (Figure. 4). This caused by the fact that spodic layer in Typic Haplorthods is lying in deeper depth. Oil palm root cannot grow freely in Lithic Haplorthod (Figure. 2) for the spodic layer is laid in shallower depth. Based on the facts we can say that Lithic Haplorthod is unsuitable for oil palm plantation. This study is having a mutual accord with the previous study made by Prasetyo *et al*., (2006) who concluded that Spodosol Soils is better localized and used for forestry only or it will inflict a financial loss to farmers.

Planting oil palm in Spodosol soils it needs to make holes with suitable dimension for oil palm root growth level, or using pot system. Oil palm with its fiber roots branch out laterally, so that it is better to make holes break through the spodic layer for every single plant. Then burry the hole using dark color topsoil (enriched by organic matter). The minimum depth of the hole is 80 cm. A hole with 60 x 60 cm (length and width) will need to burry with 288 kg soil.

It is important to add organic matter to achieve the 3% C-organic content, for C-organic content of Spodosol soil is only 1.98%, and it needs another 1.02% or equal to 4.65 kg organic matter/hole. It also needs liming to increase the pH from 3.5 -4.4 (average pH in Spodosols) to 5.0-5.5 (optimum for oil palm). Al saturation was calculated <10%, while <30% is consider to "low" for oil palm (Dierolf *et al*., 2000). It means that there need no more lime to neutralize the Al saturation. The medium Ca and Mg nutrient soil content for oil palm is 2.0 and 0.3 cmol(+)/kg. It means that it needs 0.05 kg dolomite/hole.

Nitrogen and K fertilizer are highly water soluble. On loose sandy soil texture it needs to add such fertilizer not only once. Dierolf *et al*. (2000) said that it needs 150 kg N/ha or equal to 0.64 – 1.2 kg/hole or equal to 0.051 – 0.68 kg KCl/hole. Soil K content classified as "moderate" when it has 0.3 cmol(+)/kg.

Rock Phosphate is most suitable phosphate fertilizer for Spodosol soils. It is slow released fertilizer and has Ca content. It needs 0.05 – 0.34 kg Rock Phosphate having 30% P_2O_5 each hole.

CONCLUSIONS

Spodosol soil's productivity is low, and it is not feasible to cultivate, but its proper allocation is for protected forest.

Spodosol soil needs high input to cultivate it for farming purpose, and the slow released fertilizer is most suitable for it, but still it requirement much more fertilizer to add. It is better to add N and K fertilizer 3-4 times each year.

Fertilizer is not the only input for Spodosol soils, but it also needs ameliorant to increase the soil capability in holding the soil nutrient and those nutrients added by fertilization.

For plantation purpose it needs to apply wide and deep hole system to give secure medium for optimum root growth

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