Big Hole – Oil Palm Planting Technique on Spodosol Soil in East Barito - Central Borneo - Indonesia

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Abstract

The objective of this study was to evaluate the effectiveness of big hole system on oil palm cultivation at Spodosol soil with low fertility, high sand content, low water holding capacity, acid reaction and presence of hardpan layer. There were 3 soil profile samples of the East Barito Spodosol studied and amount of 17 soil samples were collected from horizons at undisturbed soil profile named as non big hole samples and from layers at disturbed soil profile named as big hole samples. Results indicated that the mechanical holing and material mixing of soil materials of C soil profile among the upper and lower horizons i.e. A, E, B and C horizons before planting resulted a better distribution of sands. By using the mechanical holing and material mixing (C profile) caused pH, C-organic, CEC and exchangeable cations value distribution from lower to upper layer to be more uniform at 0-20 cm up to 80-100 cm depth. Big hole profile also resulted a deeper oil palm rooting zone as deep as hole constructed meanwhile the roots development of non big hole profile was limited by hardpan layer depth. The implementation of big hole system for oil palm planting on Spodosol soil of Typic Placorthod sub group is important not only to increase distribution uniformity of soil materials, soil chemical properties and enhancing of deeper roots development in the rooting zone, but also to minimize potential of negative effect of shallow planting solum for oil palms growing due to hard pan layer presence.

Keywords: Spodosol, Typic Placorthod, big hole, mechanical holing, material mixing, cation exchange capacity, exchangeable cations

Introduction

Spodosol of *Typic Placorthod* sub group is a soil which has E albic horizon, B spodic horizon with placic and/or ortstein layer. Spodosols mainly distributed in those areas rich in quartz sand with shallow ground water fluctuation (Mc. Keague et al. 1983). Actually that Spodosol of *Typic Placorthod* sub-group is a soil type which has no potential use for agricultural purpose due to presence of impermeable layer (hardpan) as severe limiting factor for oil palm growth, very light texture due to high coarse and fine sand content, very low nutrient status and very low moisture retention. Moreover, the presence of hard pan layer (placic and ortstein) ensures that the inorganic fertilizers and water were trapped on the hard layer surface and oil palm roots are not being developed well due to shallow effective soil depth and very poor drainage due to high water saturation. Therefore, a concerted effort must be made in developing an establish oil palm plantation on Spodosol land with severe limiting factors presence mainly placic and ortstein layers. The objective of this study was to evaluate the effectiveness of big hole system on oil palm cultivation which has been constructed and cultivated for five years to enhance suitability of oil palm cultivation on Spodosol soil with low fertility.

Material and Methods

This study was conducted in Spodosol soil at oil palm plantation (coordinate 115^0 05'54,9814"E – 2^0 04'22,6126"S), East Barito District, Central Borneo Province on February 2014, by surveying of placic and ortstein depth and observing soil texture and chemical properties of 3 (three) oil palm's soil profiles that have been planted in five years. In this study, we focused on soil texture and chemical characteristic among big hole and non big hole profiles. Big hole system of commercial oil palm field planting on Spodosol soil area was designed for the specific purpose of minimizing potential of negative effect of shallow effective planting depth for oil palms growing due to hardpan layer (placic and ortstein) presence as deep as 0.35 - 0.70 m. The big hole system is a planting hole type which was vertical-sided with 2.00 m x 1.50 m on top and bottom side and 3.00 m depth. The hardpan layer was mechanically broken by Excavator of PC 200 type and all the soil and hardpan materials (placic and ortstein) must be taken out and another soil materials (organic debrist, quartz sand and kaolinite minerals) exception for placic and ortstein materials should be homogenously mixed before back filling in to the planting hole. One of the main aim of this big hole system proposed is to ensure that the soil must be penetrable for oil palm roots and it is intended to achieve and retain optimum condition in the rooting zone, where the oil palm gets the nutrient and moisture it needs for good growth and production. The planting hole that was unconstructed with big hole system (undisturbed soil), the soil testing indicated that the *Typic Placorthod* soil sub group was classified as a very unfertile soil with very low status of chemical properties as well as poor physical characteristic. Palm planting with big hole system was conducted in year of 2009 and a total of 3 (three) soil profile samples were analyzed consists of secondary forest profile of Spodosol soil nearby surveyed or observed area, big hole system soil profile and normal planting without big hole system construction.

Results and Discussion

Spodosol Morphological Characteristics

A Spodosol profile consists of (1) A horizon, an organic mineral surface horizon with dark color, (2) E albic horizon, the eluviation horizon with pale color, (3) B spodic horizon, the iluviation horizon with reddish dark or black color, consist of organic matter enriched by amorphous aluminum with or without iron; and (4) C horizon that is sandy parent material (Mc Keague *et al*. 1983). The surface horizon colors of A and B soil profiles were grey and dark grey. The dark color indicated the presence of organic matter which caused by impeded litter decomposition and accumulation of organic matter due to decreasing temperature with high rainfall (Buurman, 1984). Meanwhile Buurman and Jongmans (2005) explained that accumulation of organic matter complex in B horizon is not necessarily due to saturation of organic complexes, but may occur as results of microbial decay of organic carrier and be remobilized by supply of fresh dilution organic carbon (DOC). In the mineral rich soil, DOC is broken down rapidly by microbial activities. On the contrary, in the poor mineral soil with poor drainage, the breakdown of DOC is inhibited by Al and Fe complexes, acidity, and lack of oxygen (N. Suharta and B. H. Prasetyo, 2009). Analytical results of soil material showed that quartz (Silicon Oxide (SiO_2)) and kaolinite (Aluminum Silicate Hydroxide ($Al_2Si_2O_5$)) minerals were dominant soil elements meanwhile the spodik horizon was characterized by Oxalate and Phyrophosphate extractable of Aluminium (Al) and Iron (Fe) presence.

Discription of A profile sample
Symbol A (secondary forest profile)
Location on East Barito District, Central Borneo (115^0 02' 18, 6462" E – 2^0 07'58, 2561" S)

Depth	Horizons	Discription
0-20	A	Grey (5Y 5/1), sand texture, loose structure, loose consistency, medium tertiary roots, abrupt wavy,
20-55	E	White (5Y8/1), sand texture, loose structure, loose consistency, minimum tertiary roots, abrupt wavy,
55-60	Bh	Very dark grey (5YR3/1), sand texture, loose structure, loose consistency, clear smooth,
60-70	Bhs	Very dark grey (7.5YR3/0), loamy sand texture, massive structure, very hard consistency, abrupt smooth
70-75	BC	Brown (7.5YR5/2), sandy clay loam texture, massive structure, slightly hard consistency, diffuse smooth,
75-85	CB	Old brown (7.5YR5/6), sandy clay loam texture, massive structure, hard consistency, gradual smooth,
>85	C	Reddish yellow (7.5YR7/6), loamy sand texture, loose structure, loose consistency,

Discription of B profile sample
Symbol B (palm directly planted without big hole system)
Location on East Barito District, Central Borneo (115^0 05' 54,9814" E – 2^0 04' 22,6126" S)

Depth (cm)	Horizons	Description
0-15/24	A	Dark grey (10YR4/1), sand texture, loose structure, loose consistency, tertiary and secondary roots, clear wavy,
15/24-25/30	E	Pinkish grey (7.5YR7/2), sand texture, loose structure, loose consistency, large fine roots, minimum secondary roots, abrupt wavy,
25/30-35/40	Bh	Dark brown (7.5YR3/2), loamy sand texture, loose structure, slightly consistency, minimum tertiary and secondary roots, gradual wavy,
35/40-50	Bhs	Reddish yellow (7.5YR6/6), loamy sand texture, massive structure, very hard consistency, abrupt smooth,
>50	C	Pink (7.5YR8/4), sandy clay loam texture, loose structure, loose consistency

Discription of C profile sample
Symbol C (palm planted with big hole system)
Location on East Barito District, Central Kalimantan (115^0 02' 32, 3307" E – 2^0 07'34, 1210" S)

Depth (cm)	Layers (no horizons)	
0-20	I	Soil material were mechanically mixed, high amount of quartenary, tertiary, secondary and primary roots, homogenous soil materials
20-40	II	
40-60	III	
60-80	IV	
80-100	V	

Soil Texture and Chemical Properties

Soil Texture

The soil texture analysis includes sand, loamy sand and sandy clay loam which were found in big hole soil profil meanhile in non big hole soil profile were sand, loamy sand, clay and sandy clay loam. Sands dominated the fractions of all 3 samples were analyzed varying from 60-95% in A and B profiles and more uniform (53-86%) at C profile. The highest sand fraction was found at first 2 horizons of forest soil profile (A profile), A and E horizons with 0 cm to 55 cm depth. There was difference sand content distribution between non bighole soil profil (A and B) depth and big hole soil profile depth. The sands content of A and E horizons on A and B soil profile were significantly higher than the lower horizons (B and C horizons) meanwhile the sands content in big hole soil profile showed more uniform in between lower to upper layer. Better distribution of sands content in between layer of big hole soil profiles due to a mechanical mixing of soil material among the upper and lower horizons *i.e.* A, E, B and C horizons.

Chemical Properties

A common usual chemical analysis of soil samples includes pH, N (%), C (%), CEC, Exchangeable Bases and P-available. The analysing right after sampling have been carried out to minimize changes in sample composition. pH distribution of profile of big hole technique showed more uniform from 0-20 cm upto 80-100 cm depth (C profile) and the soil pH of non broken hard pan layer was very acid to acid level ranging from 3.25 to 4.72 (A profile), 3.30 to 4.18 (B profile), and 3.58 to 3.74 (C profile). The A horizon of A profile had more acidic soil pH than the lower layer (E albic horizon). The lower pH level of A horizon of A profile due to presence of organic matter. The soil pH decreased significantly with increased organic matter. Meanwhile among the horizons of non existing palms soil profile (A profile), Bh horizon pH level was very low. This fact was same with East Kalimantan Spodosol (Prasetyo *et al*. 2006) that the lowest soil reaction was found in B spodic horizon.

The soil analysis showed that there was no significant difference in organic matter content of A horizons among A and B profiles investigated. The organic matter content in the A horizon of A and B profiles were 0.49% and 0.85% while in the eluviation horizon (E albic) that the organic matter content was much lower compared to surface layer *i.e.* 0.06% and 0.15%. In the B spodic horizon (illuviation layer), the organic matter content significantly increased by 5.15% and 4.44%, it was much higher compared to the upper layer (E albic horizon). Meanwhile in the C horizon the organic matter content decreased to 0.48% and 0.24%. This facts were still in line with conclusion of N. Suharta and B. H. Prasetyo (2009) that distribution of organic matter content by soil depth showed that accumulation of organic matter occurred in the surface layer, decreased to E albic horizon by leaching, and increased to B spodic horizon by accumulation (See Fig. 4). The C-organic of C profil showed more uniform value from the lower upto higher layer than A and B soil profiles, see Table 1 and Fig. 5. The higher pH uniformity of C profile and C-organic in between layer due to a mechanical mixing of soil material among the upper and lower horizons *i.e.* A, E, B and C horizons. This technology shows that big planting hole construction may not be a problem to oil palm planted in Spodosol soil.

The cation exchange capacity (CEC) was very low in all horizons (A and B soil profiles) and soil layer (C soil profile) investigated. The CEC varied from 0.59 to 20.04 cmol (+) kg^{-1}. The highest CEC value was found in the B spodic horizons of A and B soil profiles that had higher organic carbon while the lowest CEC was in the E albic horizons which was high leaching process. Investigation showed that exchangeable cations (Ca, Mg, K and Al) were very low in all horizons investigated (Table 02). The low exchangeable cations due to highly leached of bases to the lower horizon of non big hole soil profil (A and B soil profiles). Both very light texture (high sand content) and high annual rainfall of investigation area become agents for leaching of bases. Nutrients that are leached below the rooting zone of the palms are at least temporarily lost although they may be recycled if roots grow deeper.

The Al (aluminum) content in the E albic horizon was lower than B spodic horizon. The decrease of Al content in E albic due to eluviation process while the iluviation process in B horizon caused the Al content increased. The soil analysis result showed that the exchangeable Al in B spodic horizon ranged between 2.54 to 2.26 cmol (+) kg^{-1} while in the E albic horizon was much lower ranged 0.03 to 0.09 cmol (+) kg^{-1} only. It was also occured in the available inorganic P (Table 2) which was higher in the B spodic horizon compared to the E albic horizon. There was correlation between inorganic P and Al where the release of both inorganic P and Al from a spodic horizon (B) increased in the presence of simple organic acids that form stable complexes with Al (Fox et al., 1990).

Beside it, naturally that acidic soils dissolved Al predominantly in an organically complexed form (David and Driscoll, 1984; Driscoll et. al., 1985). The P (phosphorus) level in the E albic was lowest upto trace level than A horizon and the lower horizon (B and C horizons) at non big hole soil profiles (A and B) meanwhile the big hole profiles (C profile) the P level was more uniform in between upper and lower soil layers. Phosphorus is may also be lost if surface soil particles are eroded in runoff especially at Spodosol soil which had very high sand content where actually that the phosphate is immobile in most soils because of precipitation and adsorption to mineral surfaces except in certain very sandy soil such as Spodosol.

Oil Palm Roots Penetration

The treatment of big hole caused changes in the soil chemical and physical properties distribution mainly in between layer depths which then affected oil palm root development. The palm which was planted on the big hole system showed good adaptation and responsed positively by growing well of tertiary and quaternary roots that the roots were penetrable in to deeper rooting zone as much as 1.00 m depth. The roots can grow well and penetrate much deeper (Fig. 6) compared with undisturbed hard pan layer (Fig. 7). The directional growth of oil palm roots in response to gravity. The oil palm main root is positively gravitropic (growing downwards). The thin soil effective depth of A (0-55 cm) and B (0-30 cm) profiles to be a severe growth limiting factor for oil palm roots development on Spodosol soil Typic Placorthod sub group meanwhile the big hole profile (C profile) showed a different condition where the palm roots easily penetrated in to the soil solum up to 100 cm depth. The minimum soil solum depth for oil palm cultivation reported around 1.00 m.

Conclusion

Big hole system in oil palm planting technique is a long-term soil management of chemical and physical properties of Spodosol land under the influence of annual high rainfall, erosion, fertilizers, other agronomic practices and time. Unsuitable climatic condition in Spodosol area affected soil properties, so that big hole system and soil material mixing among soil horizons for planting media have the advantage to increase the land suitability for oil palm development. The oil palm growth and production on Spodosol soil are not only depend on agronomic input such as fertilizing and others but largely determined also by suitable land preparation technique implementation before planting.

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Figure 1: Profile of A sample

Figure 2: Profile of B sample

Figure 3: Profile of C sample

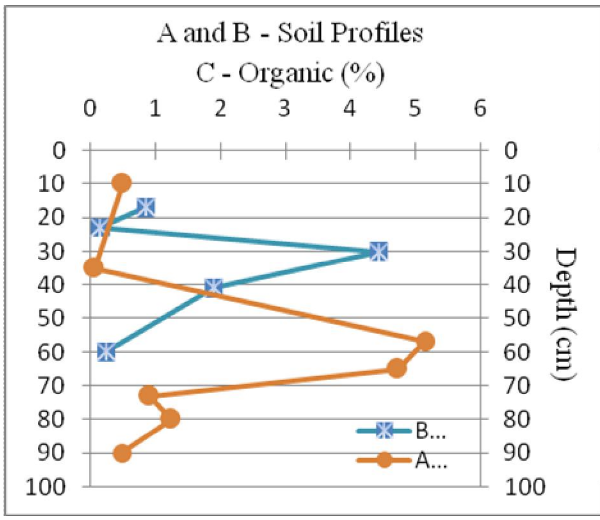

Figure 4: The relationship between soil depth and C-organic of A and B profiles.

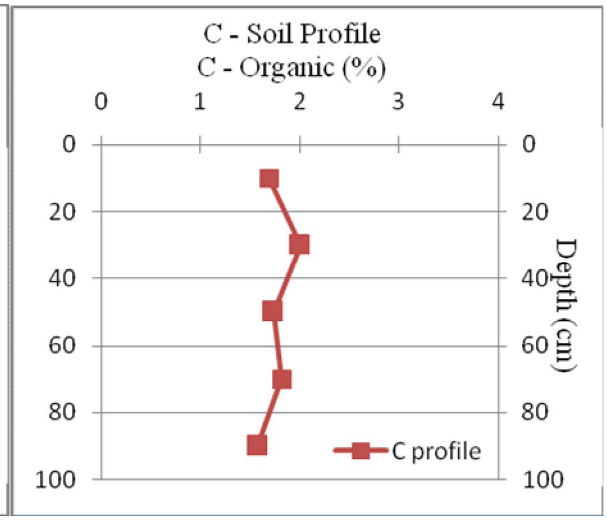

Figure 5: The relationship between soil depth and C-organic of C profile.

Figure 6. Big Hole Planting Profile with Deeper Roots Growth

Figure 7. Non Big Hole Planting Profile with Shallow Roots Growth

Table 1: Particle size (%), N (%), pH H_2O and pH KCl

Horizon	Depth (cm)	Particle Size (%)			N (%)	Org. C	pH	pH
		Sand	Silt	Clay		(%)	H_2O	KCl
A, forest non big hole and no palm plantings, 31 m elevation, clay stone, coordinate 115^0 02' 18, 6462" E – 2^0 07'58, 2561" S								
A	0-20	95	1	4	0.02	0.49	4.41	3.61
E	20-55	95	1	4	0.02	0.06	5.39	4.72
Bh	55-60	89	4	7	0.07	5.15	3.99	3.25
Bhs	60-70	84	11	5	0.08	4.73	4.17	3.46
BC	70-75	68	11	21	0.02	0.91	4.14	3.54
CB	75-85	66	13	21	0.03	1.24	4.23	3.68
C	>85	79	12	9	0.04	0.48	4.59	4.01
B, hardpan non big hole, 54 m elevation, coordinate 115^0 05' 54,9814" E – 2^0 04' 22,6126" S								
A	0-15/24	92	3	5	0.02	0.85	4.41	4.18
E	15/24-25/30	93	4	3	0.01	0.15	4.41	3.79
Bh	25/30-40	82	5	13	0.09	4.44	4.05	3.88
Bhs	35/40-50	85	9	6	0.06	1.90	3.66	3.30
C	> 50	60	14	26	0.03	0.24	4.22	3.97
C, big hole, 38 m elevation, coordinate 115^0 02' 32, 3307" E – 2^0 07'34, 1210" S								
No horizon	0-20	77	13	10	0.06	1.69	4.56	3.74
No horizon	20-40	85	10	5	0.07	2.01	4.41	3.63
No horizon	40-60	86	8	6	0.06	1.74	4.30	3.60
No horizon	60-80	86	10	4	0.05	1.82	4.26	3.58
No horizon	80-100 53	16	31	0.05	1.58	4.27	3.62	

Table 2: CEC (cmol (+) kg^{-1}), Exchangeable Cations (cmol (+) kg^{-1})

Horizon	Depth (cm)	CEC	Exch. Bases (cmol (+) kg^{-1})			P Available	
		cmol (+) kg^{-1}	Ca	Mg	K	Al	(mg kg^{-1})
A, secondary forest without oil palm plantings, 31 m elevation, clay stone, coordinate 115^0 02' 18, 6462" E – 2^0 07'58, 2561" S							
A	0-20	1.16	0.02	0.04	0.01	0.06	4.67
E	20-55	0.59	0.06	0.01	0.01	0.03	trace
Bh	55-60	13.97	0.02	0.06	0.01	2.54	0.68
Bhs	60-70	15.09	0.04	0.03	0.01	2.75	2.00
BC	70-75	4.32	0.03	0.03	0.02	3.02	9.38
CB	75-85	8.63	0.02	0.01	0.02	1.83	25.87
C	>85	4.28	0.03	0.03	0.02	0.88	1.35
B, hardpan non big hole, 54 m elevation, coordinate 115^0 05' 54,9814" E – 2^0 04' 22,6126" S							
A	0-15/24	4.06	0.23	0.19	0.06	0.24	2.67
E	15/24-25/30	0.84	0.05	0.04	0.03	0.09	trace
Bh	25/30-40	20.04	0.03	0.03	0.03	2.26	2.20
Bhs	35/40-50	10.91	0.02	0.03	0.05	1.67	2.04
C	> 50	3.74	0.04	0.03	0.03	0.87	2.31
C, big hole, 38 m elevation, coordinate 115^0 02' 32, 3307" E – 2^0 07'34, 1210" S							
No horizon	0-20	6.11	0.11	0.06	0.05	1.36	19.07
No horizon	20-40	5.85	0.06	0.04	0.03	0.99	4.08
No horizon	40-60	4.55	0.04	0.03	0.01	1.31	0.68
No horizon	60-80	5.06	0.02	0.03	0.01	1.02	1.35
No horizon	80-100	7.96	0.05	0.03	0.02	2.61	2.04