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Effect of Soil Parent Materials on Oil Palm Yield

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Abstract
The research aimed to analyze performance of oil palm production induced by its soil parent materials. Soil samples were collected from granite soils and basalt soils and were completely analyzed in laboratory. The research results showed that soil properties characters of granite soil is more acid, has very low to low chemical soil fertility and is dominated by sand fraction, furthermore basalt soil is acid, has low to moderate chemical soil fertility and is dominated by clay fraction. Granite and basalt soils are able to produce fresh fruit bunches of oil palm (FFB) 13-18 ton/ha in a year and 19-24 ton/ha in a year respectively.
Keywords: Performance, oil palm production, soil parent materials

Introduction

On the geological maps of West Malaysia, it can be seen that soil variability can be mostly derived from different parent material, so that opens the possibility to compare soil productivity based on different soil parent material or rocks (Nordin, 1980, Paramananthan, 1977). In general the soil parent material may be acid (granite) or basis (basalt rocks). After the intensive weathering process, the soil boundaries between the soil derived from granite and basalt rocks are difficult to distinguish morphologically in the field because soil formation is generally dominantly influenced by drainage conditions, degree and level of physical, chemical and biological rock weathering. The research results can provide basic information on potential reserves of nutrients to improve soil productivity for oil palm.

Materials and Methods

The research location is based on the different soil parent materials (granite and basalt rocks) by using geology maps with 1:100,000 scale. The soils derived from granite are called the granite soils and from basalt are named basalt soils respectively. The soil profiles of granite soils (located in Tebolang Estate, Tebong, Malacca) and Basalt soils (from Jabor Valley Estate, Kuantan, Pahang) were intensively described and classified according to Soil Taxonomy (Soil Survey Staff, 2010). Composite soil samples were taken after completing soil profile descriptions and then analyzed in the laboratory (Sparks, 1996). Fresh Fruit Bunches (FFB) of oil palm was recorded by using field square method of 25 m x 25 m size and combined with the questionnaire results and interview to the farmers.

Results and Discussions

Descriptions of Soil Morphology

Horizons: A pedogenetically characteristic horizon is given for granite soils by the Bt-horizon (clay migration). Clayey C-horizons are characterized by clay contents (> 57%), but the more intensively percolated clay has no organic C throughout profiles. There are systematical changes of horizons in all profiles. The horizons are dominated by combinations of Ap-B_{1t}-B_{21t}-B_{22t} horizons. The basalt horizons are characterized by five classes (Ap, AB, B_{21ox}, B_{22ox} and B_{23ox} combinations), however both soils the "C"-horizons are weathered. The clay migration is not pronounced (thus B horizon is not indexed by a t). Generally, both soils are well drained and ground water tables are located at depth of > 150 cm and become poorly drained with decreasing depths. Most horizons are highly oxidized as shown by thick of ox layers, which predominate from 19-150 cm (Table 1).

Table 1. Soil variability as affected by its parent materials

Soil characters	Granite soils		Basalt soils	
	5-18 cm	18-40 cm	10-19 cm	19-56 cm
Bulk density (kg/dm^3)	Nm	1.31	nm	0.93
pH (H_2O)	4.8 (va)	4.8 (va)	4.4 (va)	4.6 (va)
C-organic (%)	0.99 (h_3)	0.56 (h_2)	2.11 (h_3)	2.15 (h_3)
N-total (%)	0.09 (l)	0.06 (vl)	0.18 (m)	0.10 (l)
C/N	10.4 (h)	8.9 (vh)	11.8 (h)	11.4 (h)
CEC (cmol(+)/kg soil)	3.87 (vl)	3.45 (vl)	12.52 (l)	8.19 (l)
Ca (cmol(+)/kg soil)	0.09 (vl)	0.09 (vl)	0.04 (vl)	0.06 (vl)
Mg (cmol(+)/kg soil)	0.05 (vl)	0.02 (vl)	0.05 (l)	0.02 (l)
K (cmol(+)/kg soil)	0.06 (l)	0.03 (vl)	0.01 (l)	0.06 (vl)
Base saturation (%)	6.0	4.9	1.76	1.96
MR (0 bar, %)1/	nm	46.6	nm	59.3
MR (0.1 bar, %)	nm	30.5	nm	44.3
MR (0.33 bar, %)	nm	23.5	nm	39.3
MR (15 bar, %)	nm	17.2	nm	26.8
AW (mm/1.5 m) 2/	--	199.5	--	265.2
Soil texture class	Sandy clay loam	Sandy clay	Clay	Clay
Coarse sand (%)	44.6	46.5	2.6	1.9
Fine sand (%)	16.8	9.6	5.8	9.6
Silk (%)	4.2	3.3	28.1	32.9
Clay (%)	34.4	40.6	63.5	55.6
	0.12	0.08	0.44	0.59

Explanation: 1/ MR: Moisture retention, 2/ AW: Available water (mm/1.5 m soil depth),
nm: not measured, na: not available, va: very acid, h_3: humus, h_2: weakly humus, vh: very high, h: high, m: middle, l: low, vl: very low
Description: */ Assessment is based on the general nature of soils.

Soil Color: The colors of the granite soils have Hues of 10YR with Munsell values of 5 and chromas from 2-3. Subsoils are characterized by Hues of 10YR, Munsell values of 5-6 and chromas of 6-8. Typical red colors of Oxisols (Hue < 5YR) have not been recorded in the soils. The surface basalt soils mainly have Hue codes of 7.5 YR at soil matrices with Munsell values of 4 and chromas from 2 to 4, only. Subsoils have similar hues (7.5 YR), but Munsell values are generally 4 and chromas are 4. Thus, topsoils are discriminated from subsoil material by Munsell chromas of 4.
Bulk Density: The granite soils show significant compaction or show a decrease one with the depth. The highest bulk density takes places at the depth of more than 70 cm. The bulk density of the basalt soils is relatively stable from topsoil to subsoils (0.93 g/cm^3). The compaction effect did not happen in the profile.
Texture: The granite soils consist of 2-4 % silt and 35-50 % clay. A systematic change of soil texture transverses the depths: soils are loamy in the topsoils and become towards clayey on lowest horizon. The soils have the highest sand fractions in surface soils (66 %) and reach the lowest values at depths of 70-150 cm. In these layers, clay concretions are found at maximum concentrations. Based on differences of clay content in A- to B-horizons, clay migration of granite soils is very high (around 40 %). Texture class of the basalt soils is classified as clay. The profile does not show clay migration from A to B-horizons. The differences in clay content between A and B-horizons are less than 20 %.

Descriptions of Chemical Soil Properties

Soil Reaction: Both soils showed that pH values are very low and their ranges are also very low (4.4-4.8). Only slight changes of pH values are observable throughout the profiles. Small increases are given from upper to lower horizons, except for the Ap (recycled bases). The soil reaction is almost homogeneous for all horizons (4.4-4.6). The highest pH values are found at found at depths of more than 56 cm (pH value of 4.7). Not significantly different pH values because of clay found in these soils is dominated by caolinite clay minerals. Clay mineral of caolinite has a low activity with the charge varying pH, which causes a high buffering against changes in pH due to liming and fertilization. Only in the Ap horizon (soil pH 4.8), where there are a lot of humus that can affect and improve the exchange complex, thus the pH value can be increased by one to two units higher than the bottom layer.

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Organic C and total N: Organic C remains in topsoils from decomposed litter and crop residues, therefore a sharply decreasing depth function can be observed in most profiles of both soils. The granite soils contain generally low organic C and total N except in the first two layers. Low organic C and total N are caused by low clay contents of the granite soils which showed low capacity to hold both elements. In the basalt soils, total C and total N reach the maximum values in the first two layers and they decrease sharply with depth. Both organic C and total N are very important for soil fertility, especially considering structure and erodibility as well as the ion exchange complexes of the topsoils. The C/N ratios vary in most cases between 6.2 to 10.4 for the Granite soils and 11.4 to 11.8 for the basalt soils. Organic C and total N decrease both significantly with depth. Here a slight maximum is found at a depth of about 0-10 cm pointing to the fact of organic matter in Ap-horizon.
Cation Exchange Capacity (CEC): The CEC depth function of the granite soils follows a complex pattern affected by the overlay of two main factors i.e., increasing clay content (with depth) because of increased CEC. Acidification and formation of Al/Fe complexes induce considerable amount of pH-variable charges. But the CEC of all soils is nevertheless very low. Therefore, the soils have to be classified as those with low activity clay (‘kandic horizon”).
Exchangeable Ca, Mg, and K and Bases Saturation: Exchangeable bases predominantly were found in the basalt soils and followed by the granite soils. The dominance of the bases are exchanged in the basalt soils due to the addition of elements from soil parent material rich in dark minerals in the Basalt soils. Base saturation followed the pattern of exchangeable bases, where the basalt soils are more dominant than the granite soils.

Weathering Results of Granite and Basalt Rocks

Mineral weathering of granite and basalt rocks can be divided into three groups, namely very slowly soluble minerals such as quartz and muscovite, slowly decayed minerals, namely feldspar and biotite, and easily weathered minerals (augite, hornblende and calcite). When sorted by the order of resistance against the destruction of minerals (sand and silk size), the most resistant minerals are weathered quartz, muscovite, K-feldspar, Na and Ca-feldspar, biotite, hornblende, augite, olivine, dolomite, calcite and gypsum.
The macro and micro nutrients results of rocks weathering can be used as indicators of soil fertility productivity level. The types and kinds of soil nutrients are released by rocks or mineral primers presented in Table 2. Table 2 explains that the quartz mineral was not able to contribute to soil nutrients, calcite and dolomite are able to release Ca and Mg. Dominant black minerals release earth alkaline elements and apatite releases P. The constituent minerals lost during the destruction took place from the granite rock into clay is very diverse and determined by the constituent minerals of the rock. Mineral constituent CaO, Na_2O, K_2O, MgO and SiO_2 experience a loss of 100%, 95.0%, 83.5%, 74.7% and 52.5% (Table 2), while Fe_2O_3 only lost about 14.4% (Table 3).

Table 2. Chemical composition of granite and basalt rocks

Nr.	Chemical composition (% weight)	Granite rocks	Basalt rocks
1.	SiO_2	74.0	50.8
2.	TiO_2	0.23	2.0
3.	Al_2O_3	13.9	14.2
4.	Fe_2O_3 + FeO	2.18	11.96
5.	MnO	0.05	0.18
6.	MgO	0.26	6.3
7.	CaO	0.72	10.4
8.	Na_2O	3.5	2.2
9.	K_2O	5.1	0.82
10.	H_2O	0.47	0.91
11.	P_2O_5	0.15	0.23
	Total	100	100

Source: (Armanto, 1992)

Table 3. Constituent minerals loss during granite weathering process to clay

Nr.	Constituent minerals	Loss (%)
1.	CaO	100,0
2.	Na_2O	95,0
3.	K_2O	83,5
4.	MgO	74,7
5.	SiO_2	52,5
6.	Fe_2O_3	14,4
7.	Al_2O_3	0,0

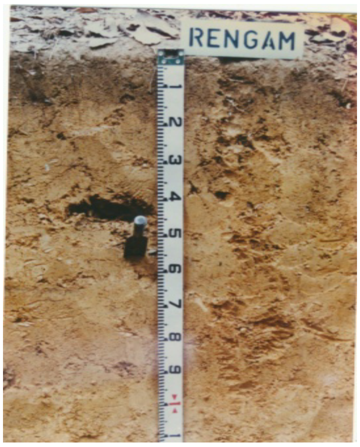
Description: */ Loosing compared with Al is considered to be constant during the destruction process takes place. Loss is expressed in (%) of the amount originally contained in the rock.
Source : (Armanto, 1992,Paramananthan, 1977)

Granite and Basalt Soils and Fresh Fruit Bunches of Oil Palm (FFB)
The granite soils are classified as Typic Kanhapludults and the basalt soils are named Oxic Dystropept. According to management records of both soils received the same treatment in terms of fertilizer, pesticide and other maintenance and same production environment. The difference of soils is strongly influenced by the soil parent materials (granite and basalt as in Fig. 1). Table 4 explains that the difference of FFB is around 6.0 ton/ha in a year. This phenomenon indicates that fertilizer application should also consider the soil variability created by the soil parent material. Beside that the both soils still need more input of fertilizer to make the soils more suitable for plant growth and development of oil palm.

Table 4. Fresh Fruit Bunches (FFB) of oil palm as affected by granite and basalt soils

Nr.	Soils	Soil classification	Fresh Fruit Bunches of Oil Palm (FFB, ton/ha in a year)
1.	Granite soils	Typic Kanhapludults	13-18
2.	Basalt soils	Typic Dystropept	19-24
	Average FFB		16-21

Source: (Adzemi, 1999)



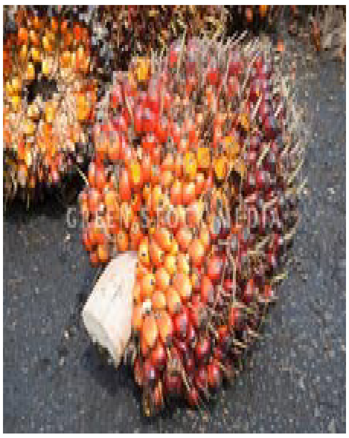
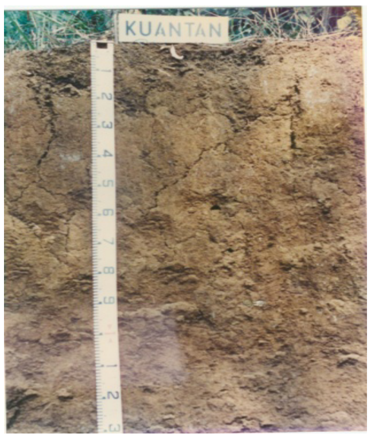



Fig. 1: Granite (Rengan Series), oil palm fresh fruit bunch and Basalt (Kuantan Series)

Conclusions

Mineral weathering of granite and basalt is divided into three categories, i.e. very slow weathered mineral (quartz and muscovite), slowly weathered mineral (K- feldspar, Na and Ca-feldspar and biotite), and easily weathered mineral (hornblende, augit, olivine, dolomite, calcite and gypsum). Losing mineral during weathering process from granite to clay is determined by containing mineral in rocks. Such minerals (CaO, Na_2O, K_2O, MgO and SiO_2) loosed 100 %, 95.0 %, 83.5 %, 74.7 % and 52.5 % respectively, but Fe_2O_3 is disappeared only 14.4 %. Soil properties characters of granite soil is more acid, has very low to low chemical soil fertility and is dominated by sand fraction, furthermore basalt soil is acid, has low to moderate chemical soil fertility and is dominated by clay fraction. Granite and basalt soils are able to produce FFB 13-18 ton/ha in a year and 19-24 ton/ha in a year respectively. The production difference of both soils is around 6.0 ton/ha in a year.

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