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Rubber Soil Variability in Peninsular Malaysia as Affected by Its Parent Materials

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Abstract

The research objectives were to analyze soil variability induced by parent materials for rubber cultivation in Peninsular Malaysia. The research results can provide basic information on potential reserves of nutrients to improve soil productivity for rubber cultivation. Soil samples were collected from two locations (Granite soils and Basalt soils). The collected soil samples were completely analyzed in laboratory. The results showed that based on mineral resistance to weathering (sand and silt mineral sizes), mineral weathering of granite and basalt is divided into three categories, 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 rubber latex 2700-3000 kg/ha in a year and 2200-2700 kg/ha in a year respectively. The production difference of both soils is around 300 kg/ha in a year.

Key words: Soil variability, analyses, parent materials, rubber, Peninsular Malaysia

1. Introduction

It can be seen on the geological maps of Peninsular Malaysia that soil variability can be mostly derived from different parent material and opens the possibility to compare soil productivity based on different soil parent material or rocks (Noordin, 1980, Paramananthan, 1977). In general the soil parent material may be acid (granite) or basis (basaltic rocks). After the process of intensive weathering, 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 very dominantly influenced by drainage conditions, degree and level of physical, chemicals and biological rock weathering.

The soil variability caused by different soil parent material can be determined through analysis of soil parent material (rock), a comprehensive analysis of soil profiles and laboratory analysis, particularly soil parent material (rock) and the result of weathering processes.

This approach can give a general picture of variability change in the soil characters through the processes that occur in the landscapes (Armanto et. al., 2010). Such approach can explain why for the same soil environment but the rubber latex productivity in Peninsular Malaysia is different. Based on the above problems, it is necessary to do basic and applied research with the aim to analyze soil variability induced by parent materials for rubber latex production in Peninsular Malaysia. It is expected that the results of this research can provide basic information on potential reserves of nutrients to improve soil productivity for rubber.

2. Materials and Methods

The selected research location is based on the different soil parent materials (granite and basalt rocks) by using geology maps with 1:100,000 scale. For ease of discussion, the soils derived from granite are called the granite soils and from basalt are named basalt soils respectively. The soil profiles of granite soil located in Tebolang Estate, Tebong, Malacca and basalt soil from Jabor Valley Estate, Kuantan, Pahang were intensively described and classified according to Soil Taxonomy (Survey Staff, 2010). Composite soil samples were taken after completing soil profile descriptions and then analyzed in the laboratory. Soil color was determined using Munsel Soil Color Chart (2009) while bulk density was determined according to Tisdale (1951). Particle-size analysis was performed using hydrometer method (Gee and Baunder, 1986). Weathering indices was determined according to Ceram (2008). Chemical analysis (organic carbon, soil pH, total nitrogen, CEC and exchangeable cations were determined according to Sparks (1996). Latex of rubber was determined with the questionnaire results and interview to the farmers

3. Results

Descriptions and Analyses of Selected Profiles

Rocks and Mineral of Crystal Size: The main minerals contained in the granite soils are a mineral cluster of quartz, illite, vermiculite, and montmorillonite, whereas montmorillonite, illite, gibbsite, hallosit to the basalt soils. Montmorillonite is ranked on first position of basalt soils. In general, basalt soils are rich in dark minerals, containing Fe and Mg, easily weathered from the basalt rock. All these minerals play an important role in determining the degree of soil fertility. Granite soils have major clay components including vermiculite, illite, quartz, and montmorillonite, so the granite soils are rich K-feldspar and quartz. Granite rocks rich in feldspar, plagioclase, biotite and muscovite will free K gradually during the process of weathering. K content of mineral orthoclase, plagioclase and muscovite or biotite is amounting to 5-12, 0.5 to 3 and 7-9% K_2O respectively. The main field and laboratory data from selected profiles of both soils are summarized in Table 1.

Granite rocks are characterized by the mineral content of acid, for example, quartz, feldspar, large crystal size and rough structure of granite will make absolute disintegration compared with basalt with fine structure. This was due to genesis and development at granite rocks. Tension is arising causing cracks and broken rocks to follow the boundaries of constituent minerals. The constituent minerals of granite rocks with rough structure will be more easily destroyed than small-sized materials because the small size of the fine structure (basalt rocks) are more resistant to mechanical destruction.

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.

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 %.

Weathering Indices: In general, fine-sized minerals are more sensitive to chemical destruction than the large size of mineral (rough minerals) because the surface area of the small particle-particle is wider, so it gives the chances of a larger chemical destruction. For example quartz sand size is highly resistant to chemical destruction, if the clay size quartz, the size of clay is very sensitive to weathering. In the granite soils, sand by achieving percentage of 58% is the most dominant soil characteristics compared with the basalt soils. In both soils, coarse sand and fine sand ratios may play an important role for present indices of parent material homogeneity. It seems that both soil profiles are developed from homogenous parent materials. The profile shows a relatively homogeneous content in all horizons. The indices of homogeneity that are the fine to coarse sand ratios throughout the profile may show the unique numbers- that the soils were formed from the same parent material. The ratio of silt to clay gives indices to weathering and soil development. This is based on the fact that the more weathered the soils are, the lower the silt contents. If the silt clay ratio is less than 0.15, the soils are classified as highly weathered. The granite soils show 0.04-0.12 that means the granite soils belong to highly weathered soil. However, the basalt soils give the figure of above 0.15 (0.37-0.59), the soils are (relatively) young. The Basalt soils are classified as young weathered soils except the topsoils.

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 kaolinite clay minerals. Clay mineral of kaolinite 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.

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"). Organic matter seems to have no significant impact on the CEC. The total amount of exchangeable bases decreased generally with depth. The total amount of bases and the relation of Ca. Mg, K can be rated as sufficient to well supply for crop production on a high yielding level.

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. These bases are very easily washed away as shown by the absence of differences in content of the bases are exchanged in the upper layer with the bottom layer. This means that the soils have low levels of vegetation canopy, so it does not protect the soil from the threat of soil degradation. Base saturation followed the pattern of exchangeable bases, where the basalt soils are more dominant than the granite soils. This is expected because the base saturation is strongly influenced by the bases are exchanged and the exchanged bases decreased due to intensive soil leaching that is responsible for high value of base saturation in the bottom layer.

Relationships between the Granite and Basalt Soils with Rubber Latex Yield

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). If we continue with laboratory analyses of soil samples, they are different and these differences are reflected also by the performance of rubber latex presented in Table 2. Table 2 explains that the difference of rubber latex is around 300kg/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 rubber.

4. Discussion

Researched Soil Position in the Rock Cycle and its Rocks Composition

The researched soil position in the rock cycle is located between magmatic rocks and sedimentary rocks. To become soil, the magmatic rock must undergo a process of weathering to soil formation or called pedogenesis. However, to be a sedimentary rock, the soil must undergo a sedimentation and transportation process and is followed by the diagenesis processes. During the sedimentation process, sediment mixing can only occur with biogenic material such as organisms and vegetation. If the intensive process works on sediment diagenesis which has been formed, it will be a real sedimentary rock formed. A complete rock cycle is presented in Figure 1. Figure 1 indicates that the soil is very central position in the rock cycle and occupies almost a third of the earth's surface.

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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/dm3)	Nm	1.31	nm	0.93
pH (H2O)	4.8 (va)	4.8 (va)	4.4 (va)	4.6 (va)
C-organic (%)	0.99 (h3)	0.56 (h2)	2.11 (h3)	2.15 (h3)
N-total (%)	0.09 (low)	0.06 (very low)	0.18 (middle)	0.10 (low)
C/N	10.4 (high)	8.9 (very high)	11.8 (high)	11.4 (high)
CEC (cmol(+)/kg soil)	3.87 (very low)	3.45 (very low)	12.52 (low)	8.19 (low)
Ca (cmol(+)/kg soil)	0.09 (very low)	0.09 (very low)	0.04 (very low)	0.06 (very low)
Mg (cmol(+)/kg soil)	0.05 (very low)	0.02 (very low)	0.05 (low)	0.02 (low)
K (cmol(+)/kg soil)	0.06 (low)	0.03 (very low)	0.01 (low)	0.06 (very low)
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
Soil fractions				
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
Silt/clay ratio	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, Vsa: Very strongly acid, h3: Humus, h2: Weakly humus
Description: */ Assessment is based on the general nature of soils.

Table 2. Rubber latex as affected by granite and basalt soils.

Nr.	Soils	Soil classification	Rubber Latex Yield (kg/ha Panel B)
1.	Granite soils	Typic Kanhapludults	2700-3000
2.	Basalt soils	Typic Dystropept	2000-2700
	Average latex		2450-2800

Source: [10] and Field Survey

This clearly reflects that the soil parent material determines the character of soil to be formed. The granite soil contains a lot of SiO_2, K_2O and Na_2O respectively 74.0%, 5.1% and 3.5%, while the basalt soil is potentially dominated by Fe_2O_3 + FeO, CaO, MgO and MnO respectively 11.96%, 10.4%, 6.3% and 0.18% if the soils do not undergo a process of intensive leaching and erosion. This is consistent with the results of analysis of chemical composition of granite and basalt rocks are listed in Table 2.

Based on the analysis results of mineral composition, the mineral content of granite rocks has a high K-feldspar (35%) and quartz (28%), while the basalt rocks have a dominant mineral composition of plagioclase (51%) and pyroxene (39%) and the average mineral composition of granite and basalt rocks is presented in Table 2. If the soils undergo a process of intensive leaching and erosion, the chemical composition of soils is determined by the physical, chemical and biological characters of weathering and development process of soils.

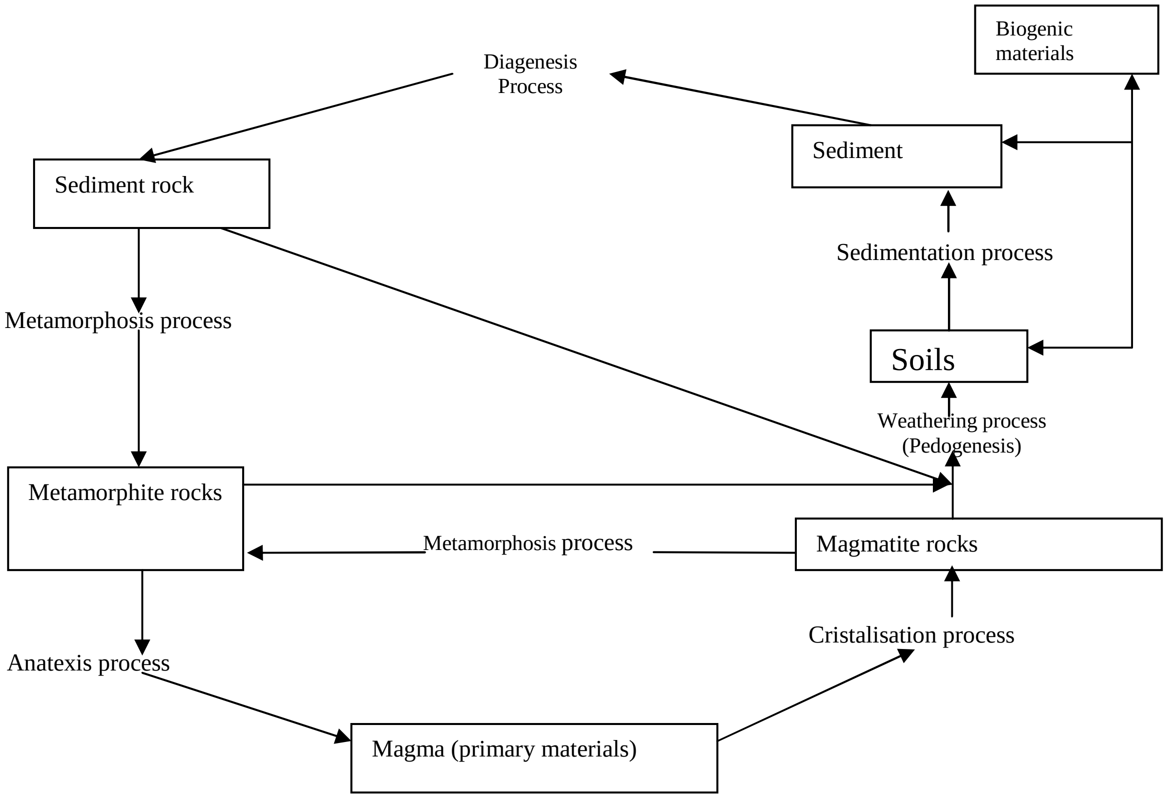

Figure 1. Researched soil position in the rock cycle

Weathering Results of Granite and Basalt Rocks

The weathering process of granite and basalt rock in acidic conditions followed a systematic plot as shown in Figure 2. 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.

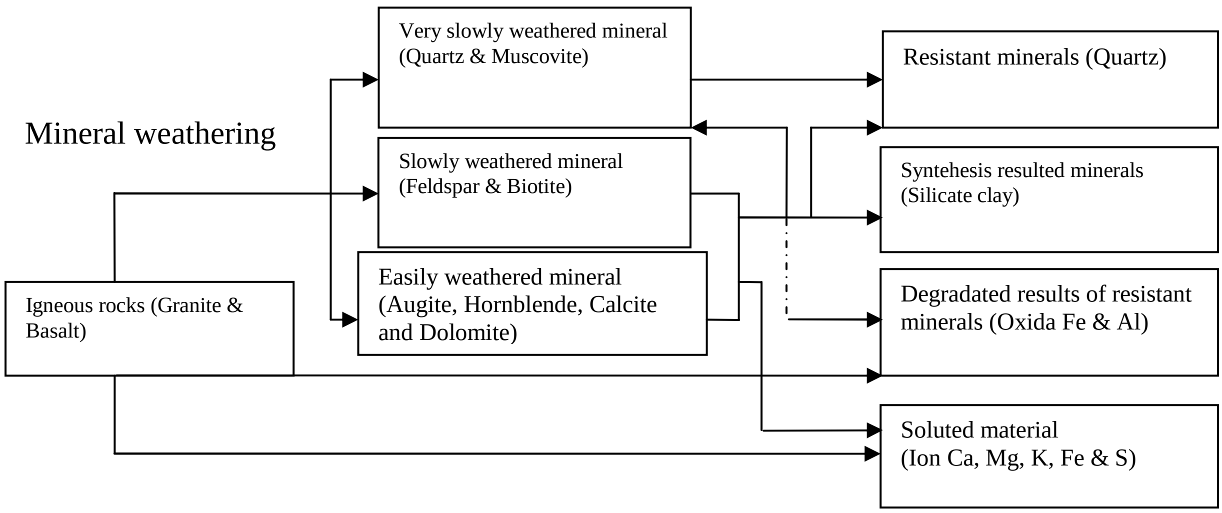

Figure 2. Rock weathering diagram in acid conditions

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 3. Table 3 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. Although the dominant parent material can show the level of soil fertility, but the soil characters will ultimately be determined by soil weathering processes and environment. 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 4). While Fe_2O_3 only lost about 14.4%

Table 3. 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 4. Average mineral composition of granite and basalt rocks

Nr	Mineral composition (% volume)	Granite	Basalt
1.	Quartz	28	1
2.	K-Feldspar	35	--
3.	Plagioclase	29	51
4.	Biotite	5	--
5.	Amphibole	1	--
6.	Pyroxene	--	39
7.	Olivine	--	3
8.	Magnetite/Ilmenite/Apatite	2	6
	Total	100	100

Source: (Armanto, 1992)

Table 5. Constituent minerals loss during granite weathering process to clay

No.	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: (Noordin,1980, Paramananthan, 1977)

5. Conclusions

Based on mineral resistance to weathering (sand and silt mineral sizes), 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 latex 2,700-3,000 kg/ha in a year and 2,200-2,700 kg/ha in a year respectively. The production difference of both soils is around 300kg/ha in a year.

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