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Research Article

Soil Physico-Chemistry in the Habitat of *Rafflesia* in Kinabalu Park, Sabah, Malaysia.

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Abstract
This study was conducted to identify the type of soil texture, and its relationship with *Tetrastigma* sp., a host of the *Rafflesia* sp. in Kinabalu Park, Sabah, Malaysia. The soil samples were collected from five study areas: Losou Podi, Losou Minunsud, Sayap Substation, Langanan and Gansurai. The plot was selected when the host exhibited traits of being infected by *Rafflesia,* either by the presence of buds, flowers or residual scar marks found on the host. The result reveals that the soil in the habitat of *Rafflesia* sp. and their host is sandy loam type, with a high volume of sand compared to silt and clay, between 65.40-79.25%. The soil moisture in the area is low, ranging from 14.89% to 27.96%. The soil in the plots was less fertile due to low value of soil organic matters (1.12-1.40%), with slightly acidic soil pH value (4.08-4.73). The most abundant elements contained in the soil were Fe, Al and Mg. The different *Rafflesia* habitats were observed to have a relationship with different soil factors: either physical, chemical, or both to promote the growth of *Rafflesia*. There was relationship between Sayap Substation with some chemical elements in the soil, rather than the soil's physical characteristic. Both Langanan and Losou Podi were only influenced by the physical characteristics of the soil. In comparisons, the Gansurai and Losou Minunsud have a relationship influenced by a combination of physical properties and chemical elements in the soil. From this study, it can be concluded the presence of *Tetrastigma* sp. in the different *Rafflesia* habitats has its own relationship with the soil and is not influenced by one factor.

Keywords: Kinabalu Park, *Rafflesia*, Soil physico-chemistry, *Tetrastigma*.

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Introduction

Kinabalu Park is located on the West Coast of Sabah, Malaysian Borneo, specifically in the Crocker Formation, underpinned by the Temburong Formation consisting of three types of rock units: thick sandstone, sandstone and shale interval unit, and thin sandstone and shale interval unit (Tracy et al., 2018). The parent soil material consists of sandstones, which explains the exceptionally high sand content in this area (Keng et al., 2020). Most of the soils in the Crocker Formation area are characterized by textured loam types (Nor Azlan et al., 2017) and clayey loams found at an altitude of 921 meters a.s.l. (Keng et al., 2020).

Both *Tetrastigma* and *Rafflesia* are often found in slightly rocky and sandy habitats (Balete et al., 2010; Barcelona et al., 2007). Several studies have recorded that the soils in their habitats were slightly acidic (Nasihah, 2016; Nur Hayati et al., 2021) to almost neutral (Ali et al., 2015; Laksana et al., 2018; Lianah, 2014). The high acidity level of the soil significantly affects the types and amount of chemicals in the soil. The increase in the number of certain chemicals present in the soil is due to decrease in soil pH value (Widowati & Sukristyonubowo, 2012). Excess trace elements in the soil will increase the soil toxicity (Purwanti et al., 2018) and soil pollution (Sellan et al., 2019). Severe soil toxicity will cause death to organisms, thus disrupting the habitat's ecosystem balance.

The *Rafflesia* sp. (Rafflesiaceae) which is famous for its spectacular large flower (Abang Hashim & Hans, 2000) can be found in Sabah (Nais, 2001). Three species have been recorded in Sabah namely *Rafflesia pricei*, *R. keithii* and *R. tengku-adlinii* (Mat-Salleh, 1991; Nais, 2001). *Rafflesia* is a holoparasitic plant (Nikolov et al., 2014) that lives on its host, the *Tetrastigma* that belongs to family Vitaceae (Mat-Salleh et al., 2011; Nasihah et al., 2016; Takhtajan, 2009). To date, there are no records reporting *Rafflesia* inhabiting a host from another genus besides *Tetrastigma*.

Rafflesia faces the threat of habitat destruction and extinction (Yeo et al., 2012). Their flowers have been used as an ingredient in traditional medicine (Fu et al., 2011; Lianah, 2014) and for multi-uses in daily life (Chettri & Barik, 2013; Kar et al., 2013). In addition, logging activities and natural disasters also contribute to their extinction (Latiff & Mat-Salleh, 1991; Yahya et al., 2010). In Sabah, both *Rafflesia* and *Tetrastigma* are fully protected plants under the Wildlife Conservation Enactment 1997, Schedule I (Part II, Section 54 (1) *(a)*) to prevent the public from consuming these two plants (Sabah Wildlife Department, 1997). In addition, Sabah Parks has introduced a scheme to encourage the conservation of these two plants through the *Rafflesia* Conservation Intensive Scheme (RCIS) involving private land owned by villagers around Kinabalu Park (Nais & Wilcock, 1998).

Rafflesia is extremely sensitive to changes in its surroundings, especially when the host suffers from any damage (Nais, 2001). With efforts to preserve and conserve the host, these flowers are also indirectly protected. Therefore, it is crucial to understand the ecology of *Tetrastigma* to ensure that *Rafflesia* can grow well. This study aims to evaluate the physical and chemical characteristics of soil in *Rafflesia*'s habitat at Kinabalu Park, to gain a better understanding of the soil characteristics in the habitat of *Rafflesia*. This information is crucial for in-situ conservation of *Rafflesia* sp. in Kinabalu Park and Sabah state. In-situ conservation of this plant is very important because its natural habitat is decreasing rapidly. This research will improve our knowledge of this plant, which is important for conservation.

Methods and Materials

Study location

The study was conducted in Kinabalu Park, located about 20km from Ranau Town, Sabah and it covers an area of 754 km^2. The geographical position is at latitude N 6° 5' and longitude E 160° 33', with the study area's average elevation ranging from 634 to 994 metres a.s.l., and the vegetation type varying according to altitude (Rafiqpoor & Nieder, 2006). All the five study areas surveyed in the present study comprised of hill dipterocarp forest.

Soil Sampling

Overall, there were five circular-shaped plots established within the Kinabalu Park area. There were two districts involved -- in Kota Belud: namely Losou Podi (LP) at 666 m a.s.l. (N 06° 19' 13.9", E 116° 38' 32.8"), Losou Minunsud (LM) at 634 m a.s.l. (N 06° 20' 54.7", E 116° 37' 47.1"), Sayap Substation (SS) at 909 m a.s.l. (N 06° 10' 02.8", E 116° 33' 51.6"), and Gansurai (GA) at 744 m a.s.l. (N 06° 11' 25.0", E 116° 29' 57.0"); and in Ranau: Langanan (LA) at 994 m a.s.l. (N 06° 03' 49.9", E 116° 41' 14.8"). The plot selection was made based on the presence of a *Rafflesia*'s host, (*Tetrastigma* sp.) at the study locations, and *Tetrastigma* sp. represent the centre point for the plot. The selection of hosts was based upon traits exhibited when the *Tetrastigma* sp. was infected by a *Rafflesia* (either the presence of buds, flowers or residual scar marks) (Suwartini et al., 2008).

According to van der Ent et al. (2018), the land in Kinabalu Park consists of ultramafic and non-ultramafic types. The map provided by the author indicates that none of the study plots were located within the ultramafic soil type area. Figure 1 shows the location of each study plot around Kinabalu Park, Sabah.

The plots were circular, with a radius of 20 metres (Figure 3), and they were established by applying the placement of a *Rafflesia*'s host in the plots as point zero (Nur Hayati et al., 2021). The total area of all surveyed plots was 0.6285 ha^{-1} (0.1257 hectares). An auger was used to collect soil samples at a depth of 20cm, at random, with a total of nine replications per plot (Nur Hayati et al., 2021). The soil samples were stored in plastic bags (Sarker et al., 2018) and were processed in the Faculty of Science and Natural Resources, Universiti Malaysia Sabah for soil analyses.

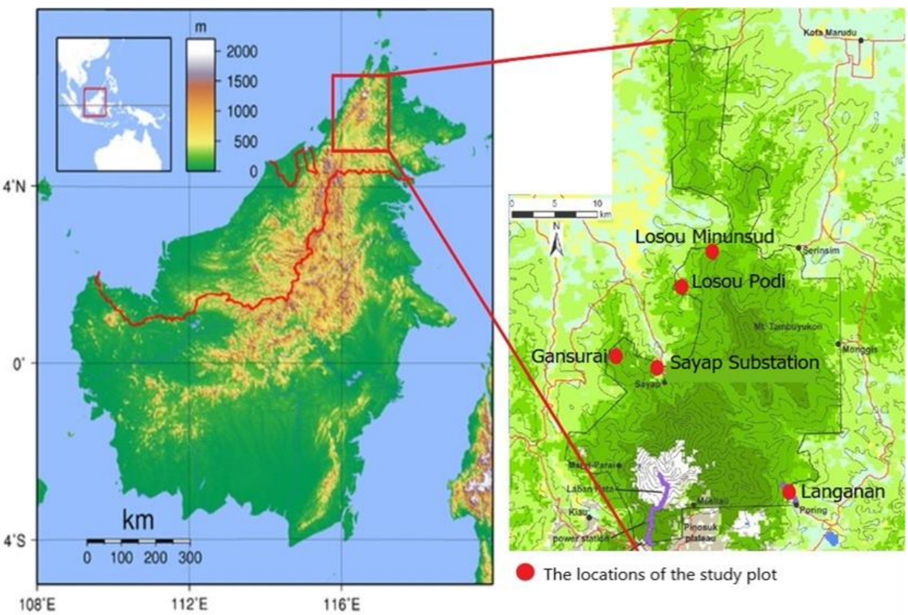

Figure 1: The red dot in the map shows the study location around Kinabalu Park, Sabah. Source: Modified from Harris et al. (2012).

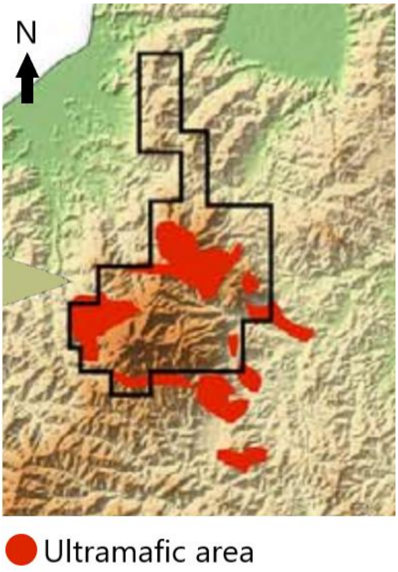

Figure 2. Shaded relief map of Kinabalu Park with ultramafic occurrences (marked in red).
Source: Modified from van der Ent et al. (2018).

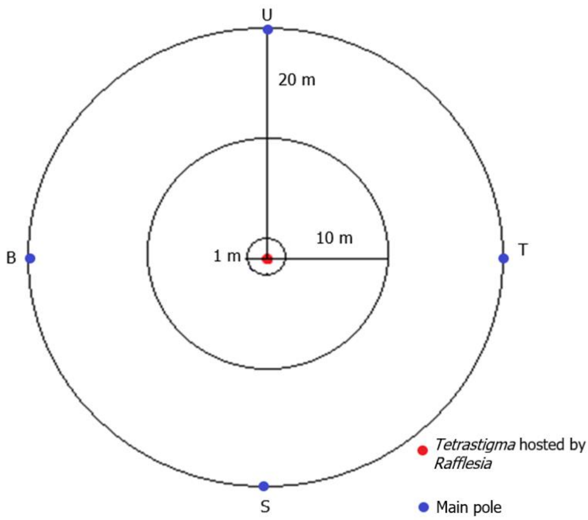

Figure 3. Plot design of the study.

The soil samples were dried by applying the air-drying method at a temperature of around 24–30^{O}C (Anderson & Ingram, 1993; Sarker et al., 2018; Tangketasik et al., 2012) before being processed. Some of the completely dried soil samples were carefully crushed to separate the roots and large rocks. Next, the soil was sieved using a 2mm filter (Alhameid et al., 2017; Anderson & Ingram, 1993; Bottinelli et al., 2017), before it was used to determine minerals in the soil. The soil texture was determined by using the closed beaker sedimentation method (Whiting et al., 2011) and the soil texture triangle (USDA, 1960). Fresh soil samples (without being dried) were used to read the soil pH value, soil moisture content and soil organic matter (SOM).

Determination of the Soil pH, Soil Moisture & Soil Organic Matter

A total of 10 grams of fresh soil sample was used to read the soil pH value. The soil was dissolved in 25ml distilled water in a beaker and was stirred for 10 minutes before being left for 30 minutes before taking the pH reading by using a pH meter. This procedure was repeated 3 times to obtain the mean value (Anderson & Ingram, 1993).

To measure the soil moisture, the soil and crucible samples were weighed and recorded as M1. The samples were then heated overnight at 105°C. The sample was left to cool in a desiccator before being reweighed (M2). The water content present in the soil and the dry weight of the soil was calculated using the following formula (Anderson & Ingram, 1993):

$$\text{Percentage of soil moisture} = \frac{M1 - M2}{M1} \times 100$$

Where;
M1 = Initial weight of the soil
M2 = Final weight of the soil

The same dried soil samples were used to calculate the total soil organic matter (SOM). Soil samples were measured and labelled as M1 before being placed overnight in a furnace up to a temperature of 400°C. The sample was then reweighed and recorded as M2 after the soil sample had cooled. The formula to calculate the SOM is the same as soil moisture formula.

Determination of the Soil Texture

Roots and large rocks were removed from the soil samples after undergoing a drying process. Clumped soils were crushed to avoid any errors during the sedimentation process which may result in errors in the readings.

A long, tapered clear beaker was filled with soil and water in a 1:2 ratio. The lid of the beaker was tightly closed and shaken for 10 minutes to break up and separate the mineral particles in the soil. After 1 minute, the depth of sand was measured. The sample was left uninterrupted for 2 hours before measuring the silt depth. The sample was left again uninterrupted until the water became completely clear before measuring the depth of the clay soil. Figure 4 shows the condition of a fully completed soil layer (Whiting et al., 2011). This procedure was repeated for all samples using different beakers.

From the sediment thickness of the soil layers formed, the percentage of each soil particle was obtained using the following formula;

$$\text{Percentage of particle types in the soil } = \frac{h}{H} x100$$

Which is;
h = Particle layer thickness
H = The overall thickness of the sediment

The percentage of each layer of these particles was then applied by referring to the soil texture triangle (Figure 5) to obtain the cross point between the percentage of particles to determine the soil type.

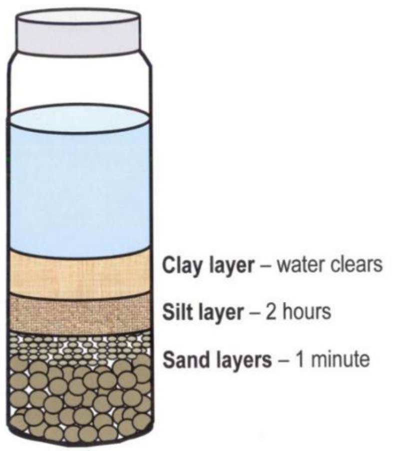

Figure 4. Measuring soil texture (Whiting et al., 2011).

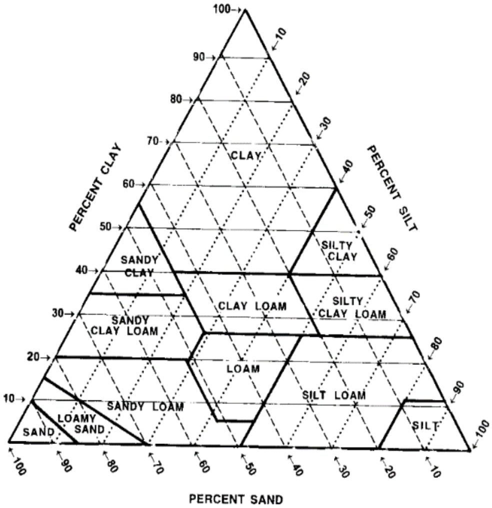

Figure 5. Soil texture triangle (USDA, 1960).

Determination of Minerals in Soil
The dried and filtered soil sample in powder was mixed with aqua-regia (a mixture of nitric acid and hydrochloric acid) and was left overnight to allow the mineralization process to complete. The sample solution was filtered and diluted to 50ml before being analysed using Inductively Coupled Plasma ICP-OES equipment Perkin Elmer Optima model 5300DV to measure the content of elements, which are Aluminium (Al), Iron (Fe), Potassium (K), Calcium (Ca), Magnesium (Mg), Manganese (Mn), Sodium (Na) and Vanadium (V) (Owens & Cornwell, 1995; Santoro et al., 2017;).

Data Analysis
The collected samples were analysed for physical and chemical soil parameters such as soil pH, soil texture, and chemical in the soil. By using one-way ANOVA, significant difference in physical and chemical characteristics in each study plot was tested. To investigate the relationship between soil factors and *Rafflesia* hosts, Principal Component Analysis (PCA) was conducted. All statistics were analysed using Paleontological Statistic (PAST) version 3.26.

Results and Discussions

Physical properties of soil
Table 1 shows that the soil has significant difference for physical characteristics between surveyed plots with $p<0.05$. All plots have a higher content of sand

(65.40±8.39 - 79.25±9.84%) when compared to the content of clay (10.76±7.4 - 11.93±7.75%) and silt (9.84±8.06 - 23.84±9.80%). According to the soil texture triangle by USDA (1960), all soil textures in the study area are sandy loam type. The soil moisture content and SOM were low with the range from 14.89% to 27.96% and 1.12% to 1.40%, respectively. Only soil moisture showed a significant difference between the plots (p<0.001). Meanwhile, soil texture that comprised of sand, clay and silt did not show any significant differences between the plots (p>0.05).

Table 1. Physical content of soil at the study site.

Plot	Soil Moisture (%)	SOM (%)	Sand (%)	Silt (%)	Clay (%)	Soil Type
LP	20.38±1.65^{bc}	1.21±0.45^{a}	65.40±8.39^{ab}	23.84±9.80^{a}	10.76±7.4^{a}	Sandy loam
LM	19.42±5.49^{bc}	1.26±0.43^{a}	73.66±8.08^{ab}	14.94±9.44^{ab}	11.40±4.91^{a}	Sandy loam
SS	14.89±5.41^{c}	1.12±0.54^{a}	79.25±9.84^{a}	9.84±8.06^{b}	10.91±6.98^{a}	Sandy loam
LA	27.96±6.66^{a}	1.40±0.59^{a}	72.98±12.19^{ab}	15.95±7.88^{ab}	11.07±5.78^{a}	Sandy loam
GA	25.82±2.62^{ab}	1.25±0.89^{a}	71.89±9.97^{ab}	16.17±11.48^{ab}	11.93±7.75^{a}	Sandy loam
***p*-value**	0.000	0.915	0.078	0.054	0.994	-

Values are mean ± SD; Values with similar alphabets were not significantly different with p>0.05 based on Tukey HSD test.
Note: LP=Losou Podi; LM=Losou Minunsud; SS=Sayap Substation; LA=Langanan; GA=Gansurai; SOM=Soil organic matter.

The soil moisture in the study area is slightly higher when compared to the lower soil moisture in Royal Belum State Park (RBSP) (3.81-7.13%) (Nur Hayati et al., 2021). The soil in the study area was found to be less fertile due to low SOM value (Subowo, 2010; Tangketasik et al., 2012) when compared with the findings of Nur Hayati et al., (2021), with 2.30-8.17% and Nasihah (2016) with 2.36-4.19% in Lojing Highlands, Kelantan. A high level of SOM can help improve soil aggregates to reduce soil permeability to water (Zulfahmi et al., 2007).

Sandy loam soil type can accommodate a sufficient amount of water (Noborio & Kubo, 2017) for the use of both *Rafflesia* sp. and *Tetrastigma* sp. without damaging the host's roots and the decay of *Rafflesia* due to excess water. The soil with higher percentage of sand content can provide sufficient amount of water during the dry season, which allows the soils in *Rafflesia* and *Tetrastigma* habitats to have a good underground drainage system (Balete et al., 2010; Barcelona et al., 2007).

As stated in Nur Hayati et al. (2021), *Rafflesia* and *Tetrastigma* habitat soils in RBSP were more characterized by loamy soils with higher sand content, compared to silt and clay. However, the percentage of silt and clay content in RBSP were similar. The total percentage of sand content in RBSP was lower when compared to that from this study. However, Ali et al. (2015) stated that the *Rafflesia* habitat in West Java is characterized as silty clay loam habitat type with high clay content, followed by silt and the lowest was sand. The percentage of soil content between these areas were significantly different.

Chemical properties of soil

The soil in the study area was slightly acidic with a pH range of 4.08-4.73. GA has the highest Fe, Al and V concentration compared to the other habitats, 131.01±95.76 ppm, 75.65±57.67 ppm and 0.42±0.34 ppm, respectively. SS has the highest concentrations of Mg, K, Ca and Na with readings of 20.86±16.90 ppm, 11.26±8.81 ppm, 9.75±6.77 ppm and 0.76±0.60 ppm respectively. LM had the highest concentration of Mn elements with a value of 4.05±2.70 ppm (Table 2). From the one-way ANOVA analysis, only Al and Na did not show any significant difference between the plots ($p > 0.05$).

The pH values obtained from this study were similar to van der Ent et al. (2018), where the pH ranged between 4.6–6.0 in Kinabalu Park. However, Quintela-Sabarís et al. (2020) stated that the pH value of ultramafic soils in Northern Sabah is almost neutral, at around pH 7. Several *Tetrastigma* habitats in Peninsular Malaysia also recorded pH values between 3.51 to 5.80 (Mohd Afiq Aizat, 2018; Nasihah, 2016; Nur Hayati et al., 2021; Syamsurina et al., 2018). However, the pH value of soils in *Tetrastigma* habitat in Indonesia was close to neutral with pH of 5.7–7.0 (Ali et al., 2015; Laksana et al., 2018; Lianah, 2014).

Based on Kitayama et al. (1998), the serpentinite rocks around Mount Kinabalu located in the Kinabalu Park area have a higher content of Fe, Mg, Ni, Cr and Co. Meanwhile, Ca, K and P were found in lower concentrations. This study recorded similar results where the habitat shows higher amounts of Fe, Al and Mg compared to the other elements: Ca, K, V, Mn and Na (Table 2). Additionally, van der Ent et al. (2018) also noted higher concentrations of Ca, Fe, Mg, and Mn in the ultramafic region; whereas the elements K, Na, P and Si had higher concentrations in the non-ultramafic region.

Table 2. Chemical composition of soil at the study site (ppm).

Plot	LP	LM	SS	LA	GA	*p*-value
pH	4.25±0.1^{4b}	4.71±0.27^{a}	4.73±0.40^{a}	4.08±0.21^{b}	3.8±0.24^{b}	0.000
Al	16.09±9.53^{b}	48.54±38.75^{ab}	48.69±53.33^{ab}	33.35±28.79^{ab}	75.65±57.67^{a}	0.055
Ca	1.99±0.96^{bc}	7.63±5.31^{ab}	9.75±6.77^{a}	1.08±0.90^{c}	4.56±5.74^{abc}	0.001
Fe	42.70±26.96^{b}	83.96±68.21^{ab}	59.32±50.34^{ab}	56.56±49.67^{ab}	131.01±95.76^{a}	0.039
K	1.68±0.87^{a}	4.75±4.07^{a}	11.26±8.81^{a}	5.72±8.12^{a}	2.57±1.92^{a}	0.009
V	0.04±0.03^{b}	0.09±0.07^{b}	0.18±0.16^{b}	0.07±0.07^{b}	0.42±0.34^{a}	0.000

Mg	1.30± 1.02[b]	15.09±14.84[ab]	20.86±16.90[a]	9.08± 11.01[ab]	16.85±13.99[ab]	0.023
Mn	1.47±1.14[bc]	4.05±2.70[a]	0.87±0.74[c]	0.88±0.83[c]	3.62±2.78[ab]	0.001
Na	0.35±0.20[a]	0.68±0.52[a]	0.76±0.60[a]	0.33±0.23[a]	0.51±0.34[a]	0.115

Values are mean ± SD; Values with similar alphabets were not significantly different, with p>0.05 based on Tukey HSD test. Note: LP=Losou Podi; LM=Losou Minunsud; SS=Sayap Substation; LA=Langanan; GA=Gansurai; Al=Aluminium; Ca=Calcium; Fe=Ferum; K=Potassium; V=Vanadium; Mg=Magnesium; Mn=Manganese; Na=Sodium.

Relationship between soil physical characteristics and Rafflesia's host (Tetrastigma)

The principal components, PC-1 and PC-2 contributed about 84.29% of the total variance in the data (Table 3). The first principal component, as given in Table 3, had variance (Eigenvalue) of 2.55 and accounts for 51.08% of the total variance. PC1 was contributed from soil moisture, sand, silt and SOM. The second principal component had variance of 1.66 and accounted for 33.21% of the data variability. PC2 is influenced by all five variables. However, clay is the stronger contributor to this PC2 (Table 4).

Table 3. Summary of the Eigenvalues for soil physical.

PC	Eigenvalue	% variance	Cum. % Var.
1	2.55	51.08	51.08
2	1.66	33.21	84.29
3	0.72	14.33	98.61
4	0.07	1.39	100.00

Table 4. Correlation matrix of PCA for soil physical.

	PC 1	PC 2	PC 3	PC 4
Soil Moisture (%)	0.52	0.39	-0.13	-0.75
Sand (%)	-0.51	0.42	-0.26	-0.09
Silt (%)	0.49	-0.47	0.18	0.07
Clay (%)	0.12	0.56	0.78	0.25
Soil organic matter (%)	0.46	0.37	-0.53	0.61

In Figure 6, it was observed that the habitat of *Rafflesia* was not affected by a single factor; with three main groups observable from the PCA analysis. Both Langanan and Gansurai habitats which were located near each other, were strongly influenced by soil organic matter and soil. Losou Podi exhibited a strong interrelation with silt. The third group showed that Losou Minunsud was strongly interrelated with sand in the habitat. The results obtained in this study were similar in Nasihah (2016) and (Nur Hayati et al., 2021) by having sand and silt in the same group. However, Sayap Substation was observed to have no relation with any soil physical characteristics. Soil moisture in *Rafflesia*'s habitat has a strong positive correlation with SOM values, similar to Sumarno et al. (2009) and Tangketasik et al. (2012), whereby the percentage of sand, clay, and silt, and the amount of SOM affects the soil moisture in a habitat.

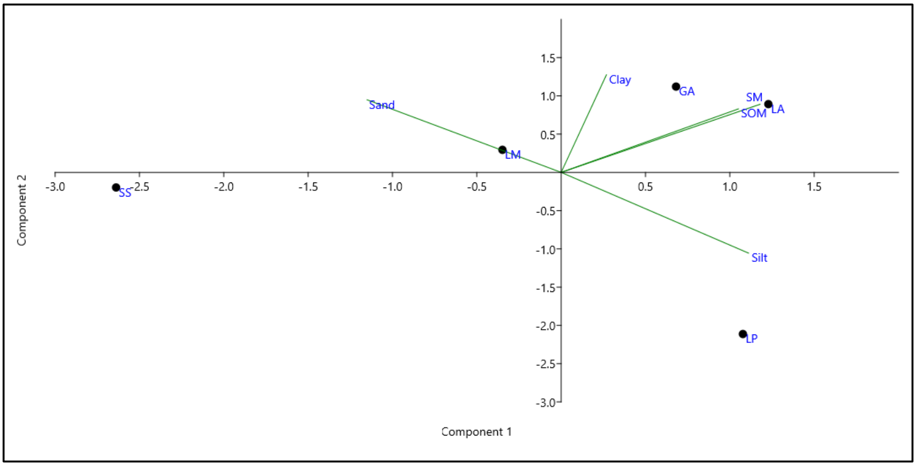

Figure 6: PCA of soil physical characteristics in *Rafflesia* habitat at Kinabalu Park, Sabah. (LP=Losou Podi; LM=Losou Minunsud; SS=Sayap Substation; LA=Langanan; GA=Gansurai; SM=Soil Moisture; SOM=Soil Organic Matter).

Relation between pH and chemistry in soil and Rafflesia's host (Tetrastigma)

The principal components, PC-1 and PC-2 contributed approximately 86.88% of the total variance in the data (Table 5). Table 5 shows the first principal component had a variance (Eigenvalue) of 4.94 and accounted for 54.86% of the total variance. PC1 was contributed by pH, Al, Ca, Mg and Na. The variance of the second principal component was 2.88, accounting for 32.02% of the data variability. PC2 was contributed by pH, Al, Fe, K, V and Mn (Table 6).

Table 5: Summary of the Eigenvalues for soil chemicals.

PC	Eigenvalue	% variance	Sum. % Var.
1	4.94	54.86	54.86
2	2.88	32.02	86.88
3	1.02	11.36	98.24
4	0.16	1.76	100.00

The results of this analysis indicated two main groups. Langanan and Losou Podi were observed to have no interrelation with any minerals found in the soil of the study area. Meanwhile, Gansurai had high positive interrelation with the elements Fe, V, Mn and Al. Sayap Substation did not exhibit any interrelation to the physical characteristics of the soil, but had strong interrelations with minerals (K, Ca, Na, and Mg) and pH was observed in Figure 7. This second group also showed that Losou Minunsud had a direct contact with Mg. Sellan et al. (2019) explained that the different mineral content and pH found in soil can influence the growth of a species in its habitat. However, it was clear that the habitat of *Rafflesia* was not influenced by single specific factor, as observed in Nur Hayati et al. (2021).

Table 6. Correlation matrix of PCA for soil physical.

	PC 1	PC 2	PC 3	PC 4
pH	0.33	-0.32	0.38	-0.22
Al	0.37	0.30	-0.21	0.20
Ca	0.39	-0.26	0.14	-0.30
Fe	0.28	0.46	-0.03	0.13
K	0.22	-0.44	-0.43	0.36
V	0.27	0.38	-0.37	-0.64
Mg	0.43	-0.06	-0.26	0.36
Mn	0.22	0.36	0.61	0.35
Na	0.40	-0.24	0.18	-0.13

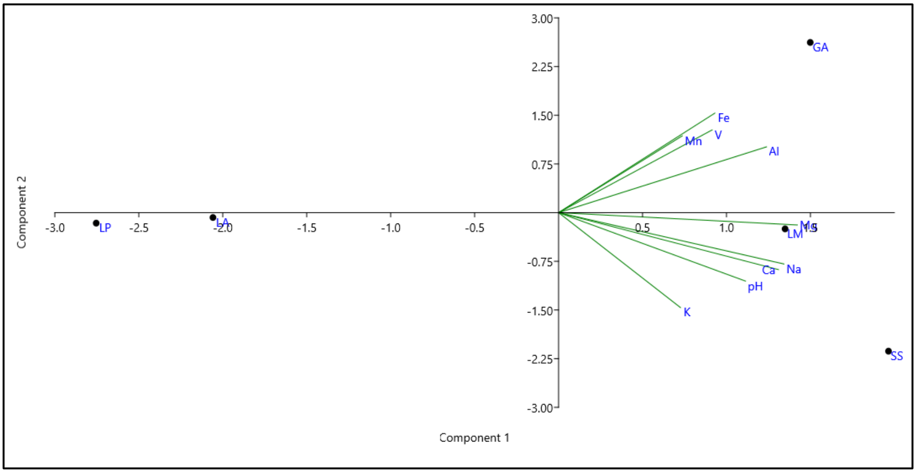

Figure 7: PCA of soil chemical elements in *Rafflesia* habitat at Kinabalu Park, Sabah. (LP=Losou Podi; LM=Losou Minunsud; SS=Sayap Substation; LA=Langanan; GA=Gansurai).

Conclusion

This study revealed that the habitat of *Rafflesia* host i.e., *Tetrastigma* in Kinabalu Park, Sabah is interrelated to soil conditions with a high percentage of sand content compared to silt and clay elements. The soil type is sandy loam with a high soil moisture content. In comparison, the SOM readings in the study area were very low, indicating that the soil in this habitat is less fertile.

We also discovered that soils in the *Rafflesia* habitat in Kinabalu Park have high levels of Al, Fe and Mg content. Only Gansurai, Sayap Substation and Losou Minunsud have an interrelation with the chemical factor; especially the elements Fe, Mn, V, Mg and soil pH.

The soil characteristics of different habitats of *Rafflesia* sp. and *Tetrastigma* sp. are influenced by different factors such as the percentage of sand content in the soil, soil moisture, and the mineral content of the element Mg. This proves that the habitat for these flowers can be complex and not affected by a single common soil factor.

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