Universiti Malaysia Terengganu Journal of Undergraduate Research
Volume 3 Number 4, October 2021: 67-72
eISSN: 2637-1138

SPECIES RICHNESS AND SOIL PROPERTIES IN *Nepenthes* HABITAT AT BRIS ECOSYSTEM IN SETIU, TERENGGANU

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Abstract: A study was carried out to investigate the species richness of *Nepenthes* in the BRIS ecosystem at Kampung Rhu Tapai, Setiu, Terengganu, and their relationship with soil parameters. Selective sampling was conducted in two sites (Plot A and B) using a 100 m^2 quadrat in each site. *Nepenthes* were identified to species level, and the number of individuals was counted. Soil samples were taken next to the Nepenthes' rhizosphere to determine the soil properties. A total of 689 *Nepenthes* individuals were found within the plots, which comprises three species: *Nepenthes ampullaria*, *N. gracilis* and *N. rafflesiana*. Independent samples t-test was conducted to compare the number of individuals in Plot A and Plot B. The result suggested that the abundance of *Nepenthes* spp. between these two sites was not significantly different. Regarding the species, *Nepenthes gracilis* was found in a high abundance in both plots. *Nepenthes* in these sites thrived in the soil with low pH value, ranging from 3.4 to 3.9. Meanwhile, the percentages of organic matter in the study area were ranging from 12.30% to 72.80%.

Keywords: BRIS soil, habitat preference, *Nepenthes*, nutrient-poor, species composition, pitcher plant.

Introduction

Nepenthes is a carnivorous plant that thrives by absorbing nutrients from the trapped insects that fall inside the pitcher. The pitcher is an extension and modification of the tendril, it has a sticky inner wall that prevents insects from escaping. The uniqueness of *Nepenthes* lies in the diversity of its pitcher, which can be in many forms, sizes, colors, and patterns, which can be of high economic importance as an ornamental plant. This genus can be found across Southeast Asia to Northern Australia, Madagascar, north eastern India, and southern China, with the islands of Borneo and Sumatera showing the highest diversity (Clarke, 2001). This plant can be found in both montane and lowland areas. In the lowland area, *Nepenthes* can be found growing along the roadside and open shrub.

The diversity and distribution of *Nepenthes* are primarily governed by climatic factors and vicariance, rather than soil type (Clarke & Moran, 2016). Climate factors, such as altitude and light intensity level are the key for *Nepenthes* distribution. Most of the *Nepenthe's* species are highland species (≥ 1,100 m asl). The climate at the higher altitude that is cool and wet has a great influence on the prey capture mechanisms (morphological structures). Species using either a large peristome or viscoelastic fluid prefer per humid area, while species that capture prey using wax prefer more seasonal areas (Moran *et al*., 2013). Meanwhile, vicariance, or geographical separation of a population, plays a fundamental role that causes separation and isolation of populations and presents significant barriers to gene flow, which resulted in a patchy area that is suitable for *Nepenthes'* habitat (Clarke & Moran, 2016). In contrast to climate, soil-type does not influence the distribution of *Nepenthes*. However, this genus is only abundant in the area where soil nutrients are poor, open vegetation, and high soil wetness. Sometimes, they also occur in the area after anthropogenic activities, when the topsoil was removed, leaving behind a nutrient-poor soil, a condition that mimics the natural nutrient-poor environment (Sim *et al*., 1992).

Even though the distribution of *Nepenthes* is wide through tropical and subtropical areas, the abundance of this genera is declining (Cross *et al*., 2020). Among the threats facing this species is over-collecting for horticulture trade and habitat destruction for agriculture and human development (Jennings *et al*., 2011). Therefore, the purpose of this study is to record the species richness of *Nepenthes* in Kampung Rhu Tapai, Setiu, Terengganu and to determine the habitat properties of the study area, in the hope that the results from this study can be used for in-situ conservation for *Nepenthes*.

Materials and Methods

Study Site

The study was carried out at Kampung Rhu Tapai, Setiu, located in the northern part of Terengganu, Peninsular Malaysia (5°30'54"N 102°58'17"E). The study area is located in the BRIS ecosystem. BRIS is an acronym for Beach Ridges Interspersed with Swales. BRIS soils are sandy with >95% sand, nutrient-deficient, low pH and low water retention (Roslan *et al*., 2010). *Nepenthes* populations were identified during site reconnaissance.

Plot Census and Sample Collection

Two plots (Plot A and B) were established at two different sites in the area. The size of the plot was 100 m^2 (10 m x 10 m), which later was divided into 25 subplots with a measurement of 4 m^2 (2 m x 2 m) each. *Nepenthes* was counted as one individual if the stems or runners grow from the same roots. The species were identified based on the morphology and by referring to the book of '*Nepenthes* of Sumatra and Peninsular Malaysia' (Clarke, 2001). The number of *Nepenthes* individuals from two plots was compared using the independent samples t-test.

Soil Parameters Sampling

There were four soil parameters for soil analyses which are: soil pH, soil moisture, soil organic matter (SOM) and soil texture. Three soil replicates were taken near *Nepenthes'* clumps for each species in both plots. Forest litters, including fine roots, were removed before soil samples were taken. Meanwhile, the soils in A-horizon (0-5 cm layer) were taken using the scope for soil texture determination which was determined using the USDA soil triangle method. Soil pH values were obtained by mixing 15 g of soil samples with 40 ml of distilled water (Motsara & Roy, 2008). The soil moisture analysis was done by drying 30 g of soil in the furnace for 24 hours at 105°C. When the samples were cold, they were weighed to get the percentage of water loss in the soil after the drying. The water loss percentage is the percentage of soil moisture. The samples then were put in the furnace again for 24 hours at 550°C to get the value of soil organic matter (SOM) content (Storer, 1984). The percentage of SOM content was calculated using the Loss on Ignition (LOI) technique, where the volatile compound was released after the burning and led to the changes of the mass of the soils (Heiri *et al*., 2001).

Results and Discussion

Species Richness and Abundance

In total, five *Nepenthes* taxa were found in the study area comprising three species and two natural hybrids. Three taxa were recorded in the study plots i.e. *Nepenthes gracilis*, *N. ampullaria* and *N. rafflesiana* while two taxa were found outside the plots, i.e. *N. x hookeriana* and *N. x trichocarpa* (Figure 1). The number of *Nepenthes* taxa in this study is more than reported by Adam *et al*. (2011) where three species i.e. *N. ampullaria*, *N. gracilis* and *N. rafflesiana* were found from the similar ecosystem-type of Rantau Abang, Terengganu.

A total of 689 *Nepenthes* individuals was found in this area where Plot A recorded the highest number with 360 individuals while Plot B recorded 329 individuals. *Nepenthes gracilis* recorded the highest number of individuals (517 individuals), followed by *N. ampullaria* (138 individuals) and *N. rafflesiana* (34 individuals) (Table 1).

Table 1: Table for the number of individuals for each *Nepenthes* species in Plot A and Plot B

Species	Plot		Total Individual
	A	B	
N. gracilis Korthals	245	272	517
N. ampullaria Jack	115	23	138
N. rafflesiana Jack	0	34	34
Total	360	329	689

The estimated density for Plot A was 3.6 ind/m^2 while Plot B was 3.3 ind/m^2. However, there was no significant difference between the number of individuals in Plot A (M = 14.4, SD = 11.05) and Plot B (M = 13.16, SD = 10.14); t (48) = 0.41, p = 0.68.

Figure 1: *Nepenthes* species that were found in the BRIS ecosystem of Kg. Rhu Tapai, Setiu, Terengganu; a: *N. gracilis*, b: *N. ampullaria*, c: *N. rafflesiana*, d: *N. x hookeriana*, e: *N. x trichocarpa*

Nepenthes gracilis and *N. ampullaria* were found widespread at the higher part of the swales in both plots, while *N. rafflesiana* was only found to grow at the edge of the sand ridge of Plot B. The co-occurrence of these three species has been widely recorded in many lowland Nepenthes' studies (e.g. Robiansyah *et al*., 2018; Setiawan *et al*. 2018). According to Thorogood (2010), *N. ampullaria* often co-occurs with *N. gracilis* and *N. rafflesiana* in a shady area and at the edge between other vegetation in sandy podsol heath forest.

Relationships between the Abundance of Nepenthes and Soil Parameters

The distribution of *Nepenthes* was influenced by physico-chemical environmental factors in their microhabitats such as soil properties, light intensity, and associated vegetation. Soil pH in the study area was found acidic, ranging from 3.4 to 3.9 (Table 2). Since the study area is a BRIS ecosystem, it is common to get the soil pH values between that range. Comparison of the findings with those of other studies confirms that *Nepenthes* in this area also grow in the acidic substrate.

Table 2: Table of soil pH, soil moisture, soil organic matter (SOM) and soil type for each *Nepenthes* species in Plot A and Plot B in Kg. Rhu Tapai, Setiu

Plot	Species	Soil pH (n = 3) Mean ± stdev	Soil Moisture (%) (n = 3) Mean ± stdev	SOM (%) (n = 3) Mean ± stdev	Soil Type
A	*N. gracilis*	3.7 ± 0.2	59 ± 18.6	15.0 ± 11.8	Silt loam
	N. ampullaria	3.9 ± 0.1	60 ± 4.1	20.0 ± 8.1	Sandy loam
B	*N. gracilis*	3.7 ± 0.3	65 ± 11.0	16.0 ± 10.7	Clay loam
	N. ampullaria	3.4 ± 0.2	71 ± 5.8	12.3 ± 7.0	Loamy sand
	N. rafflesiana	3.6 ± 0.4	17 ± 17.8	72.8 ± 30.6	Loamy sand

Meanwhile, a distinct difference was observed for soil organic matter (SOM). Habitat of *N. rafflesiana* recorded the highest SOM content (72.8%) compared to the other species that ranged between 12.3% to 20%. This result reflects those of Setiawan (2017) who also found *N. rafflesiana* in the study area growing in the site with high organic matter content. However, *N. rafflesiana* is a common lowland species that can be found widespread at the margin of heath forest or on the open scrubland (Moran, 1996) and also at the edge of peat swamp forest (Whitmore, 1984). Therefore, there is no clear indication that this species is associated with high SOM content for its survival.

Soils in the habitat of *N. rafflesiana* were found less water content (17%) compared to the soils for *N. ampullaria* and *N. gracilis* (59% and 71%). This is clearly due to the habitat for each species, in which *N. rafflesiana* occurs at the ridge area, while *N. ampullaria* and *N. gracilis* were found in the lower area (swales). The occurrence of *N. ampullaria* and *N. gracilis* in the wetter area such as peat swamp forests are common (Clarke 2001; Hidayat *et al*., 2018). However, the previous study has demonstrated that both species, *N. ampullaria* and *N. gracilis*, can be found widespread in dry or less inundated area (Adam *et al*., 2009). This suggests that *N. ampullaria* and *N. gracilis* do not prefer specific soil wetness.

There was a variation of soil type recorded for each site. *N. gracilis* in Plot A was found on 48% sand, 52% silt, which makes the soil fall into the silt loam category, while *N. ampullaria* in the same plot has a sandy loam soil type with

65% sand and 35% silt. Meanwhile, soils for *N. ampullaria* and *N. rafflesiana* were characterized as loamy sand, with the percentage of sand higher (~80%) than silt (~20%) for both species.

Conclusion

Five *Nepenthes* species were documented from this study, three of which them (*Nepenthes rafflesiana, N. gracilis* and *N. ampullaria*) were found within the research plot while two natural hybrids (*N. x hookeriana* and *N. x trichocarpa*) were found outside the research plot. Within BRIS ecosystem landscape, each species has its habitat preference. *N. gracilis* and *N. ampullaria* were found to acquire the swale area while *N. rafflesiana* prefers the ridge area at the forest edge. Therefore, this finding has important implications in developing the strategy for in-situ conservation on *Nepenthes*.

Acknowledgements

The authors would like to acknowledge the Faculty of Marine and Science Environment, Universiti Malaysia Terengganu, for supporting logistics. We also would like to thank Mohd. Razali Salam for helping us in the field.

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