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Orchids of UNIMAS: Diversity in a Developed Campus Landscape

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ABSTRACT

For the past three decades, various biotic components in Universiti Malaysia Sarawak (UNIMAS) natural habitats have been studied but less attention given to the largest family of flowering plants, the Orchidaceae. A preliminary survey in the campus areas has resulted in the discovery of more than ten species of orchids. Therefore, in this study more field samplings were conducted throughout the UNIMAS campus focusing on the developed areas to unveil the potential of UNIMAS-developed areas as a growth ground for orchids. To date, 37 orchid species have been recorded from these areas; mainly found on the planted trees at the roadside and landscaped areas surrounding the academic buildings, while the terrestrial species were found to inhabit different types of disturbed habitat. Among them, *Dendrobium pensile* was identified as a new record to Sarawak while *Dendrobium pseudostriatellum* and *Pinalia biglandulosa* were endemic to Borneo. This study provides an insight into the orchid resiliency towards habitat alteration, landscape phorophytes species that can host orchids, and management of species in a developed landscape.

Keywords: Biodiversity, Borneo, orchids, phorophyte, university ecosystem.

INTRODUCTION

Universiti Malaysia Sarawak (UNIMAS) is a young university (established in 1993) and currently still undergoing some landscape changes for the development of many facilities such as the examination hall and hospital. The campus was initially developed in a lowland area with several natural habitats - which are represented by kerangas forest, mangrove area, peat swamp forest and secondary forest. These natural areas have caught the interest of many researchers to study their various biological components (UNIMAS Institutional Repository, 2022). However, for the past three decades less attention has been given to the largest family of flowering plants, the Orchidaceae. Recent botanical surveys on the campus areas extended from the parking lots of the Faculty of Resource Science and Technology to the forest fringes by the roadside have resulted in the discovery of more than ten species of orchid from different genera. The presence of the orchids outside of UNIMAS natural habitats indicates that its developed landscapes to some extend are suitable for the orchid's growth thus more species are anticipated to be enumerated (Wolken *et al.*, 2001; Stipkova & Kindlmann, 2021). The recorded epiphytic orchids were observed to benefit from the planted trees as hosts while the terrestrials were found to adapt to several types of environments – of which some were acknowledged to be uncommon for orchids (Beaman *et al.*, 2001; Wood, 2014). The capability of the developed landscapes for orchid growth was also evidenced by the high number of individuals among the sighted orchids (McCormick & Jacquemyn, 2013). This situation can infer the orchid's adaptation in disturbed and altered habitats to ensure their survivability. Thus, it is important to assess the species diversity to unveil the potential of UNIMAS-developed areas as a growth ground for orchids. This finding will add information on the orchid's resiliency in disturbed habitats and the planted landscape trees capability as orchid phorophytes in the developed landscapes.

MATERIALS & METHODS

Field Sampling and Samples Collection

This study was conducted at UNIMAS, Samarahan Campus (1° 28' N, 110° 25' E) from

February of 2021 to April of 2023. Convenience sampling (Speak *et al.*, 2018) was employed in a developed landscape of UNIMAS consisting of the areas surrounded by the building complexes and along the paved roads located in the main and east campus (Figure 1). The sighted orchids were photographed and their respective habitats and phorophytes (for epiphytic orchids) were documented accordingly. Samples were collected and kept as living specimens in the Orchidarium of UNIMAS.

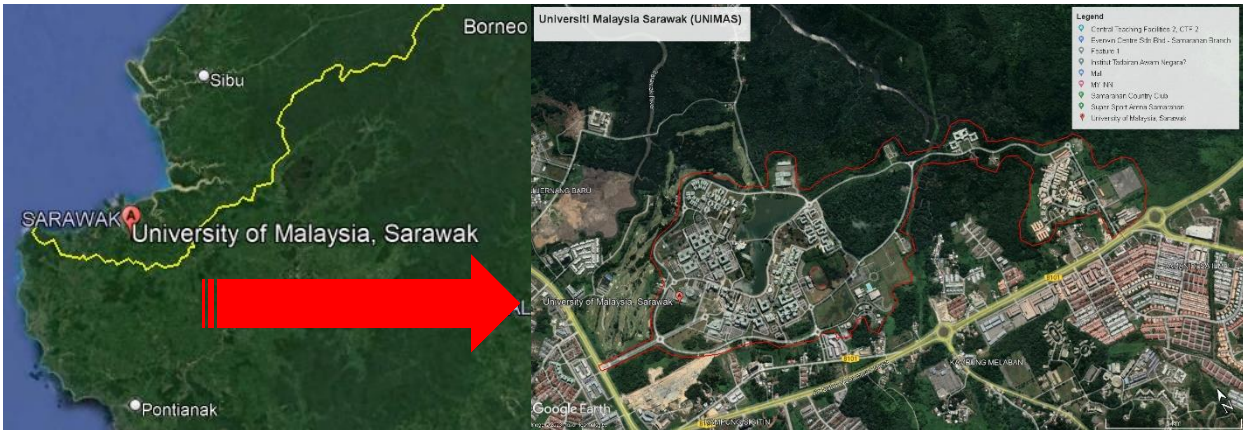

Figure 1. Location of Universiti Malaysia Sarawak (UNIMAS) indicating sampling sites (1° 27’ 34.79” N, 110° 26’ 23.39” E). Photo credit: Google Earth

Species Identification

The orchids’ taxonomic classification and distribution were determined using reliable sources such as Beaman *et al.* (2001), Wood (2014) and Plants of the World website: https://powo.science.kew.org/ (POWO, 2022). For the species that were not able to be identified up to species level (absence of flower), sp. will be denoted. Tree species that served as the phorophytes were identified based on the information provided by Boo *et al.*, (2006), Jabatan Landskap Negara (2008) and the National Parks of Singapore Flora & Fauna website : https://www.nparks.gov.sg/florafauna web/ (Nparks, 2022). The orchid's diversity was assessed *via* species richness where the number of the taxa in UNIMAS-developed campus landscapes was enumerated accordingly (Moore, 2013).

Orchids – Phorophyte Relationship

The analyses that were subjected to the individual counts were not included in this study due to the orchids' growing patterns that mostly documented growing in many clumps consisting of innumerable individuals with different growing phases and commonly found on the high point of host trees. Therefore, the relationships between epiphytic orchids and their phorophytes were analysed using the frequency of phorophytes (FP%) and orchids incidence (OI%). The analyses were adapted from Yulia and Budiharta (2011) with modifications as follows:

a. Frequency of phorophytes (FP%)

$$FP\% = \frac{\text{Number of phorophyte species (Np)}}{\text{Total number of phorophyte}} \times 100\% \quad \text{Eq.(1)}$$

b. Orchids incidences (OI%)

$$OI\% = \frac{\text{Number of incidences of epiphytic orchids (Ni)}}{\text{Total number of incidences}} \times 100\% \quad \text{Eq.(2)}$$

Subsequently, the zonation characteristics of the epiphytic orchids and the phorophyte were determined. For this investigation, a tree species with the highest incidences was chosen as the model phorophyte. The determination of the zonation of epiphytes on the host tree was adapted from Rasmussen and Rasmussen (2018) with a few modifications as follows: a) Zone I, the basal trunk (50 cm from ground), b) Zone II, the trunk (51 cm to primary branch), c) Zone III, basal part of the branch (primary branch to second branch), d) Zone IV, the middle part of the branch (second branch to third branch) and e) Zone V, the outer branch (third branch and its extension). While their respective numbers were enumerated based on the following categories: a) zero individuals b) small clump (1-10 individuals), c) medium clump (11-20 individuals) and robust clump (21 and more).

The bipartite network between phorophyte and epiphytic species was generated using RSoftware, Bipartite package (R Core Team, 2020) to create a graphical interaction between both variables (Morales-Linares *et al*., 2022). Data was tabulated in binary form according to the presence of epiphytic species on the phorophyte tree regardless of the number of orchid incidences.

RESULTS & DISCUSSION

Species Diversity in the Developed Area of UNIMAS Campus

In general, the distribution pattern of the orchids in the developed areas of UNIMAS was best described as constantly sparse and widespread in different environments. A total of 37 species from 19 genera were successfully recorded during the study (Table 1). All the genera belonged to the subfamily of Epidendroideae except *Zeuxine strateumatica* which was a member of Orchidoideae. Among the genera, *Dendrobium* displayed the highest number of species with 11 taxa followed by *Bulbophyllum* and then *Thrixspermum* while the remaining genera were represented by lesser species respectively. Although UNIMAS is a developed campus it had many to offer in terms of species diversity (Figure 2 & Figure 3) where we were able to document *Dendrobium pensile* (Figure 2e) which was later identified as a new record to Sarawak. The species diversity in the campus was also enriched by the documentation of two endemic taxa to Borneo *Dendorbium pseudostriatellum* (Figure 2f) and *Pinalia biglandulosa* (Figure 2h) that were previously localized in the peat swamp, hill forest and lower montane mossy forest habitats (Beaman *et al.*, 2001; Wood, 2014).

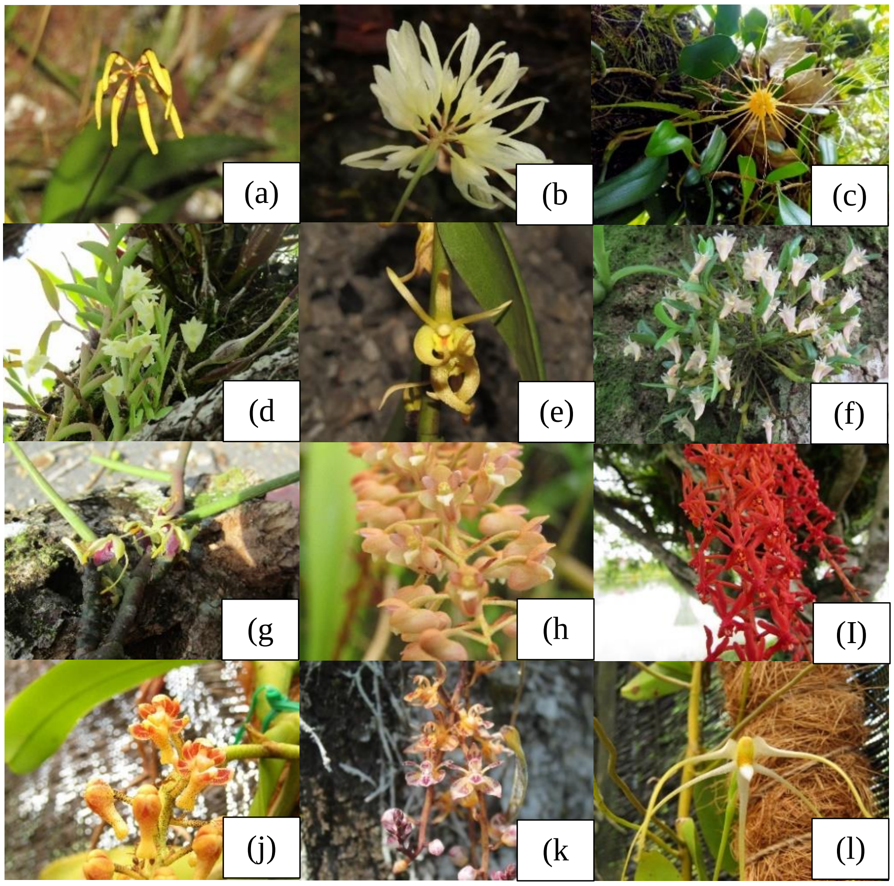

Figure 2. Selected epiphytic orchid species in UNIMAS developed campus landscape: (a) *Bulbophyllum brienianum*, (b) *Bulbophyllum purpurascens*, (c) *Bulbophyllum vaginatum*, (d) *Dendrobium kentrophyllum*, (e) *Dendrobium pensile**, (f) *Dendrobium pseudostriatellum***, (g) *Luisia antennifera*, (h) *Pinalia biglandulosa***, (i) *Renanthera elongata*, (j) *Robiquetia spathulata*, (k) *Thecostele alata* and (l) *Thrixspermum centipeda*. Photo credit: Akmal Raffi (c), Almunah A.M (a-b, d-j and l), & Haziah Musa (k)
*New record to Sarawak **Endemic to Borneo

Table 1. List of orchids species found in the developed urban landscape of UNIMAS. Note: Forest Fringes (FR), Planted Roadside Tree (PRT) and Planted Landscape Tree (PLT)

Subfamily	Genus	Species	Habitation in UNIMAS
Epidendroideae	*Acriopsis*	*Acriopsis liliifolia* (J.Koenig) Ormerod	Epiphytic on PRT & PLT
	Agrostophyllum	*Agrostophyllum* sp.	Epiphytic on PRT
	Arundina	*Arundina graminifolia* (D.Don) Hochr.	Terrestrial on FR
	Bromheadia	*Bromheadia finlaysoniana* (Lindl.) Miq.	Terrestrial on FR
	Bulbophyllum	*Bulbophyllum brienianum* (Rolfe) Merr.	Epiphytic on PLT & PRT
		Bulbophyllum cf. *grotianum*	Epiphytic on PRT
		B. medusae (Lindl.) Rchb.f.	Epiphytic on PRT
		B. purpurascens Teijsm. & Binn.	Epiphytic on PRT
		B. vaginatum (Lindl.) Rchb.f.	Epiphytic on PLT & PRT
	Cymbidium	*Cymbidium* sp.	Epiphyte on PLT & PRT
	Dendrobium	*Dendrobium convexum* Blume (Lindl.)	Epiphytic on PRT
		D. crumenatum Sw.	Epiphytic on PLT & PRT
		D. kentrophyllum Hook.f.	Epiphytic on PLT
		D. indivisum (Blume) Miq.	Epiphytic on PLT & PRT
		D. indragiriense Schltr.	Epiphytic on PLT & PRT
		D. pensile Ridl.	Epiphytic on PRT
		D. pseudostriatellum J.J.Wood & P.O'Byrne	Epiphytic on PLT & PRT
		D. rosellum Ridl.	Epiphytic on PRT
		D. secundum (Blume) Lindl. ex Wall.	Epiphytic on PRT
		D. setifolium Ridl.	Epiphytic on PLT & PRT
		Dendrobium sp. section Aporum.	Epiphytic on PRT
	Eulophia	*Eulophia graminea* Lindl.	Terrestrial on disturbed semi shaded area
	Luisia	*Luisia antennifera* Blume	Epiphytic on PRT
	Micropera	*Micropera callosa* (Blume) Garay	Epiphytic on PLT
	Oberonia	*Oberonia* sp.1	Epiphytic on PRT
		Oberonia sp.2	Epiphytic on PRT
	Oxystophyllum	*Oxystophyllum atrorubens* (Ridl.) M.A.Clem.	Epiphytic on PLT
	Pinalia	*Pinalia biglandulosa* (J.J.Sm.) Schuit., Y.P.Ng & H.A.Pedersen	Epiphytic on PLT & PRT
		P. cepifolia (Ridl.) J.J.Wood	Epiphytic on PLT & PRT
	Renanthera	*Renanthera elongata* (Blume) Lindl.	Epiphytic on PLT
	Robiquetia	*Robiquetia spathulata* (Blume) J.J.Sm.	Epiphytic on PLT & PRT
	Spathoglottis	*Spathoglottis plicata* Blume.	Terrestrial on grassy open area near drain
	Thecostele	*Thecostele alata* (Roxb.) C.S.P.Parish & Rchb.f.	Epiphytic on PRT
	Thrixspermum	*Thrixspermum amplexicaule* (Blume) Rchb.f.	Epiphytic on PLT & PRT
		T. centipeda Lour.	Epiphytic on PLT
		T. trichoglottis (Hook.f.) Kuntze	Epiphytic on PLT & PRT
Orchidoideae	*Zeuxine*	*Zeuxine strateumatica* (L.) Schltr.	Terrestrial on grassy open watery area

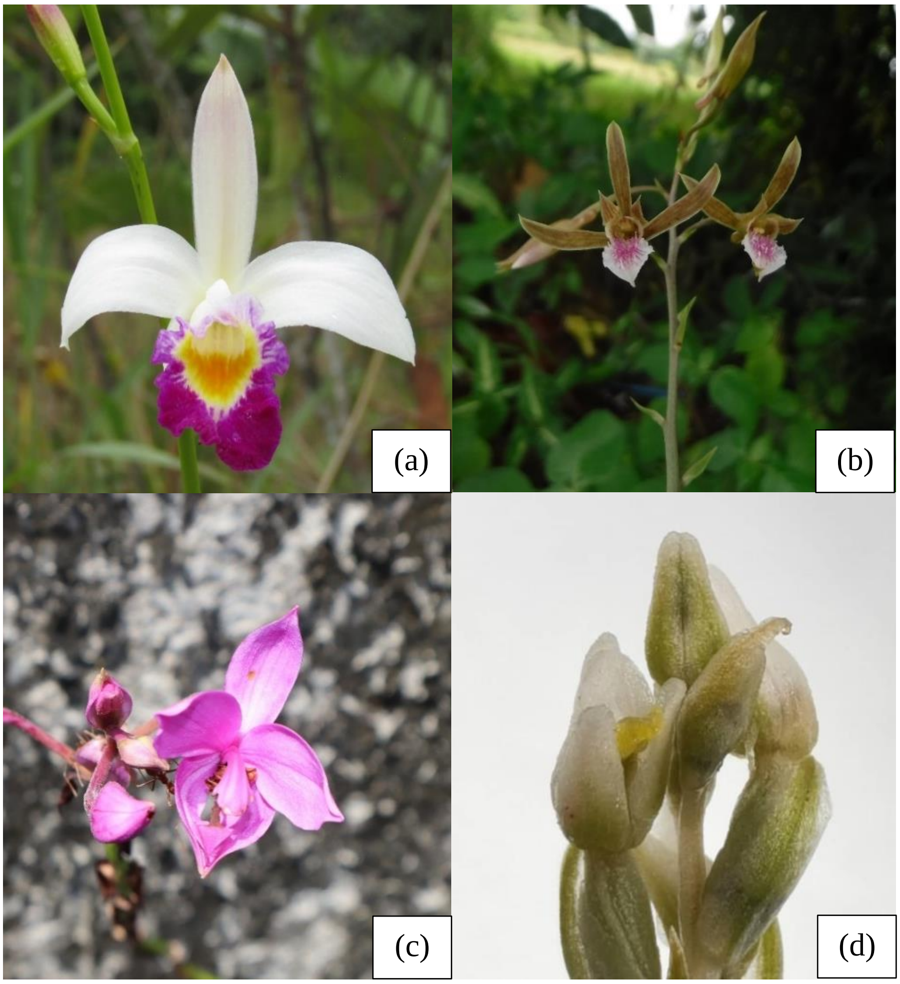

Figure 3. Selected terrestrial orchid species in UNIMAS developed campus landscape: (a) *Arundina graminifolia*, (b) *Eulophia graminea*, (c) *Spathoglottis plicata* and (d) *Zeuxine strateumatica.* Photo credit: Akmal Raffi (b & d), Almunah A.M (a) & Haziah Musa (c)

Uncharacterized Habitats for the Terrestrial Orchids in UNIMAS

Terrestrial orchids were observed to grow in the areas that were less visited by the campus community as they were not the main route for pedestrians to walk, open to semi-shaded areas, slightly wet to the water-logged ground and floored with grass. Among the terrestrial orchids, *Arundina graminifolia* and *Bromheadia finlaysoniana* were found near forest fringes, surrounded by tall grasses and layers of fern and for that, they were often to be mistakenly regarded as weeds. On the other hand, small-sized-orchid- *Zeuxine strateumatica* was found near the drain at the Faculty of Resource Science and Technology disguising itself among grasses. *Eulophia graminea* however was found in a disturbed area under a tree near the paved road meanwhile, *Spathoglottis plicata* was found in a drain with stagnant water along leaf litter and on an open area near the drain. All the terrestrial species were seen once or twice during the sampling period and could be categorized as small populations except for *Arundina gramnifolia* and *Bromheadia finlaysoniana* which could grow up to numerous individuals per population. However, maintenance activity done in the campus compound such as grass cutting and drain clearances posed a threat to these terrestrial orchids as workers were clueless about their existence and might destroy these orchids during their labour.

Epiphytic Orchids and the Phorophytic Ability of the Planted Landscape Trees in UNIMAS

The epiphytic orchids were represented by a total of 32 species and found on different planted landscape trees (Figure 4). The epiphytes displayed different propensities for host trees whereby some of them were restricted to only one phorophyte (with the lowest FP value of

0.74%) while others such as *Dendrobium crumenatum* (with the highest FP value of 31.15%) could grow up to 41 different host trees (Table 2). A higher value of FP indicated that the orchid species can be found on many different types of trees. On the other hand, the frequency for each epiphytic orchid can be depicted by the OI% where *D. crumenatum* resulted in 89.71% of incidences creating a large gap to the closest OI% of 2.73% displayed by *Pinalia biglandulosa* and the other species where the lowest percentage was 0.05%. Higher OI% indicated the species were commonly found compared to the other species with lower OI%.

In this study, more than 5000 individual trees have been observed in which they were classified to 54 tree species and about 1800 individual trees from 41 species were identified as phorophytes for orchids. Among them, *Andira inermis* (Figure 5a) which the phorophyte with the highest orchid incidences (17 orchids species) in which its zonation composition percentage was observed to be the highest in Zone IV followed by Zone III with 82.4% (14 species) and 70.6% (12 species) respectively (Figure 5b). All the orchid species were generally confined to the crown zones except four species- *Bulbophyllum medusae*, *D. crumenatum*, *D. secundum* and *P. biglandulosa* that were able to extend their occupancy to the trunk zones (Table 3). All of the epiphytic species attached to the phorophyte exist in a clump (Figure 5c) and will robustly occupied Zone III and Zone IV especially the *Bulbophyllum* group that can look like overgrown epiphytic plants and are often subjected to bark clearance by the maintenance activity by workers.

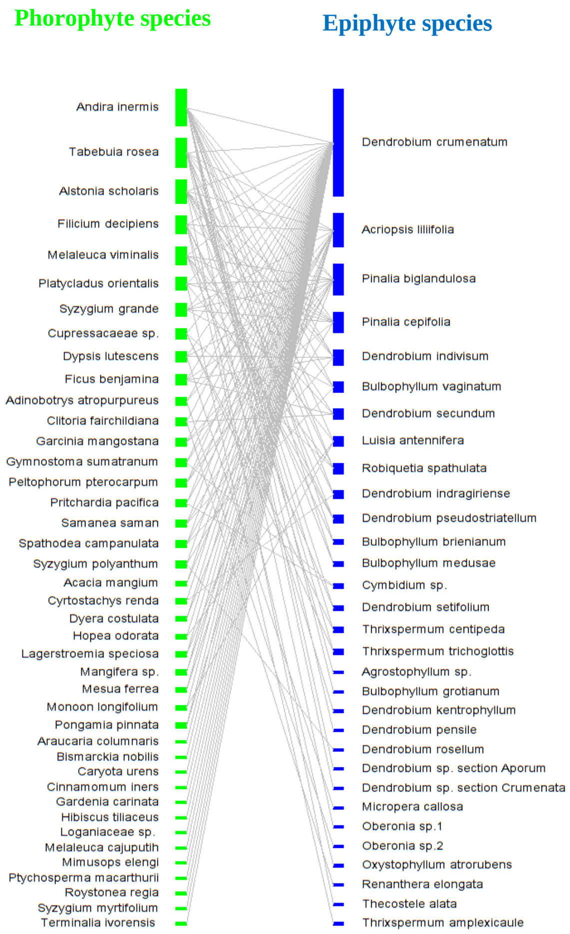

Figure 4. Bipartite Network of phorophyte and epiphytic orchid species of UNIMAS. Phorophyte species are connected by a line to their respective epiphytic orchid species that can host on the trees. The line indicates a two-way interaction between both variables with band height representing the number of connections made. Increased band height on phorophyte species means more species of orchids can be found on the tree and *vice versa*. Photo credit: RSoftware

Table 2. The epiphytic orchid species and the parametric value. Notes: Np = The number of phorophytes species of each epiphytic orchid, Ni = The number of incidences of each epiphytic orchid, FP% = The frequency percentage of phorophytes and OI% = The frequency percentage of orchid incidence.

Epiphytes in develop landscape of UNIMAS	Np	Ni	FP%	OI%
Dendrobium crumenatum Sw.	41	1840	30.15	89.71
Pinalia biglandulosa (J.J.Sm.) Schuit., Y.P.Ng & H.A.Pedersen	13	56	9.56	2.73
Acriopsis liliifolia (J.Koenig) Ormerod	13	33	9.56	1.61
Pinalia cepifolia (Ridl.) J.J.Wood	8	11	5.88	0.54
Dendrobium indivisum (Blume) Miq.	6	12	4.41	0.59
Dendrobium secundum (Blume) Lindl. ex Wall.	5	6	3.68	0.29
Robiquetia spathulata (Blume) J.J.Sm.	4	8	2.94	0.39
Luisia antennifera Blume	4	6	2.94	0.29
Bulbophyllum vaginatum (Lindl.) Rchb.f.	4	4	2.94	0.20
Dendrobium indragiriense Schltr.	3	13	2.21	0.63
Dendrobium setifolium Ridl.	3	9	2.21	0.44
Dendrobium convexum (Blume) Lindl.	3	4	2.21	0.20
Dendrobium pseudostriatellum J.J.Wood & P.O'Byrne	3	3	2.21	0.15
Thrixspermum trichoglottis (Hook.f.) Kuntze	2	10	1.47	0.49
Bulbophyllum medusae (Lindl.) Rchb.f.	2	6	1.47	0.29
Bulbophyllum brienianum (Rolfe) Merr.	2	5	1.47	0.24
Cymbidium sp.	2	4	1.47	0.20
Renanthera elongata (Blume) Lindl.	2	3	1.47	0.15
Dendrobium rosellum Ridl.	2	2	1.47	0.10
Thrixspermum amplexicaule (Blume) Rchb.f.	2	2	1.47	0.10
Bulbophyllum cf. *grotianum*	1	3	0.74	0.15
Agrostophyllum sp.	1	1	0.74	0.05
Bulbophyllum purpurascens Teijsm. & Binn.	1	1	0.74	0.05
Dendrobium kentrophyllum Hook.f.	1	1	0.74	0.05
Dendrobium pensile Ridl.	1	1	0.74	0.05
Dendrobium sp. section Aporum	1	1	0.74	0.05
Micropera callosa (Blume) Garay	1	1	0.74	0.05
Oberonia sp.1	1	1	0.74	0.05
Oberonia sp.2	1	1	0.74	0.05
Oxystophyllum atrorubens (Ridl.) M.A.Clem.	1	1	0.74	0.05
Thecostele alata (Roxb.) C.S.P.Parish & Rchb.f.	1	1	0.74	0.05
Thrixspermum centipeda Lour.	1	1	0.74	0.05

Table 3. List of orchid species on each zonation of *Andira inermis*.

Orchid species	Zone I	Zone II	Zone III	Zone IV	Zone V
Bulbophyllum brienianum (Rolfe) Merr.			+	+	
Bulbophyllum cf. *grotianum*			+	+	
Bulbophyllum medusae (Lindl.) Rchb.f.	+	+	+	+	
Bulbophyllum purpurascens Teijsm. & Binn.			+		
Bulbophyllum vaginatum (Lindl.) Rchb.f.			+	+	
Dendrobium convexum (Blume) Lindl.				+	
Dendrobium crumenatum Sw.	+	+	+	+	+
Dendrobium indivisum (Blume) Miq.				+	+
Dendrobium indragiriense Schltr.			+	+	+
Dendrobium pensile Ridl.			+		
Dendrobium rosellum Ridl.				+	+
Dendrobium secundum (Blume) Lindl. ex Wall.		+	+	+	
Dendrobium sp. section Aporum					+
Luisia antennifera Blume			+	+	
Pinalia biglandulosa (J.J.Sm.) Schuit., Y.P.Ng & H.A.Pedersen	+	+	+	+	+
Pinalia cepifolia (Ridl.) J.J.Wood			+	+	+
Robiquetia spathulata (Blume) J.J.Sm.				+	

Figure 5. Selected phorophyte species for species diversity percentage per tree: (a) *Andira inermis* tree, (b) Different zonation for *Andira inermis* and the epiphytic orchid diversity percentage, (c) *Bulbophyllum brienianum* population on the branch of *Andira inermis* at zone III. Photo credit: Almunah A.M (a & c) & BioRender (b)

Orchids Diversity and the Survivability in the Built Environment of UNIMAS

The research on the diversity of orchid species among building complexes in tropical region were relatively new and limited study has been done on this topic but the attempts to introduce various species of orchids outside of their natural habitat for conservation have been a success (Izuddin *et al*., 2018, 2019a, 2019b). Figuratively, 37 species from this finding was relatively low compared with the number of orchid species in Sarawak's natural areas as such kerangas forest, limestone forest and mixed dipterocarp forest were all recorded more than 100 taxa however species in UNIMAS developed landscapes were closer to the number of orchid in peat swamp forest in Sarawak: 52 taxa but higher than mangrove forest species: less than 20 taxa (Beaman *et al*., 2001; Stephen *et al*., 2022). UNIMAS was built upon a natural lowland forest creating a unique mix of developed and natural areas where its developed areas were separated into the main campus and east campus by a natural forest in between that stretches for about a kilometre away from each area. The natural and developed areas on the campus were constantly altered such as land clearance for the development of new buildings and subjected to regular landscape maintenance, pruning, weeding and mowing. Additionally, UNIMAS in general experiences higher degree of temperature as a result of more buildings on the campus and lower rate of precipitation compared to natural tropical forests thus, all the orchid species found in this study can be categories as resilient types as they have been adapted to this environment. Their survivability can be inferred by the ecological attributes of the UNIMAS campus and the morphological characteristics of the orchids with their surroundings. Seeds from species such as *Dendrobium crumenatum*, *Spathoglottis plicata* and *Thrixspermum trichoglottis* were observed to be small, orchid seeds reportedly ranging from 0.1 to 6.0 mm and resulting them to be lightweight that can be produced massively inside the seed pod (Barthlott *et al*., 2014). Likewise, they would easily be dispersed by wind and can remain airborne longer and further away which could facilitate seed distribution in developed areas (Jersakova & Malinova, 2007). Where the fate of the dispersed seeds is highly dependent on the presence of needed factors for growth such as light, substrate moisture, mycorrhizal fungi, mineral nutrients and temperature on the medium they landed on (Rasmussen *et al*., 2015). The orchids on the campus most likely originated from the adjacent natural areas and the landscape transitions have allowed certain species to thrive in the altered environment. As such, all species were reported only inhabiting the natural forest of Sarawak where some of the areas were similar to that in UNIMAS except *Acriopsis liliifolia, Bromheadia finlaysoniana, Dendrobium crumenatum* and *Zeuxine strateumatica* that have been knowingly assimilating themselves in the open disturbed and developed ecosystem (Beaman *et al*., 2001; Rewicz *et al*., 2017). The occurrence of numeral orchid species in the UNIMAS campus landscape indicates that its land and planted trees were providing beneficial aid to accommodate their growth and survivability throughout the year. During the sampling period, the terrestrial species were mainly found in damp or watery and open spaces thus creating a better condition for juvenile orchids to grow. The water from the area would become a cellular source of electrons for photosynthesis to occur and the light from open space help them to boost their photosynthetic capacity especially by promoting their vegetative growth such as leaf expansion, stem extension and chloroplast development (Kami *et al*., 2010; Bidlack & Jansky, 2017). Moreover, orchids have been reported to have lack of competitiveness and would thrive the best in area that has undergone land clearance in which there would be less struggle for orchids to uptake the nutrient that available in the area (Adamowski, 2006). Thus, reflecting the incidences of terrestrial orchids in this study that were mainly seen growing at forest fringes and roadside perimeters in which they were mainly covered with grasses or not more than three species of plants existing in the area. Apart from that, orchids are known to be associated with the presence of mycorrhizal fungi (McCormick & Jacquemyn, 2013). Therefore, the occurrence of terrestrial orchid species to some extent marked the existence of the mycorrhizae in the UNIMAS soil ecosystem. Mycorrhizal fungi were important towards orchid's seed germinations by providing exogenous 'endosperm' for nutrient supply to the seed growth until they reach photosynthetic phases (Arditti & Ghani, 2000; Jersakova & Milanova, 2007; Go & Raffi, 2017). Moreover, high number of epiphytic orchid species on the campus indicated the abundance of mycorrhizal fungi inside the planted landscape trees of UNIMAS as trees in developed areas have been reported able to support the growth of orchid mycorrhizal fungi as well as orchids growth (Izuddin *et al*., 2018, 2019b). The seeds of epiphytic orchids would land on the tree barks of planted landscape trees of UNIMAS and get trapped within the bark crevices and can persist for years and remain viable even after experiencing different urban conditions (Izuddin *et al*., 2019b). Thus, the seed will germinate when their surrounding environments are suitable for their growth, in this case, the campus environment was proved to be favourable for the orchids to grow thus their significant incidences number throughout the campus developed landscape.

Three epiphytic species with higher FP% and OI% were observed to have larger pseudobulb namely *D. crumenatum*, *P. biglandulosa* and *A. liliifolia* in which the capability and efficiency of plants in storing water were reportedly increased with pseudobulb size (Li & Zhang, 2019) thus improving their survivability during dry season. Orchids species in the campus were likely exposed to harsher environment compared to forest as developed area were drier, hotter and windier (Chow *et al.,* 2019) therefore by having modification on their organ such as fleshy leaves, roots and stems especially in epiphytic species were helpful to accommodate their growth in the adverse climate. These modifications weren't only used to facilitate water uptake, but also nutrient absorption and storage as well as to reduce desiccation (De & Biswas, 2022). Orchids with high FP% were usually seen flowering and fruiting throughout the year and a similar phenomenon was reported in (Adamowski, 2006) where orchids in anthropogenic habitats were regularly and abundantly generating their reproductive structure. It has also been reported that a higher degree of urbanization initiates plants to advance their phenological phases such as leaf development, flowering and fruiting (Wohlfahrt *et al.,* 2019). Orchid's fertilization success in developed areas where its pollinator diversity was reduced (Wenzel *et al.,* 2019) was eased by having their pollen packed into pollinaria which helped to increase the efficacy of pollen transfer (Johnson *et al.,* 2005). This will allow orchids to produce numerous young recruits annually and able to increase their population size thus explaining why species with high FP% also have higher incidences (OI%). However, the population expansion of epiphytic species would rely more on the availability of phorophytes around the premises likewise, the campus offered more than 1800 individual trees that can support the existence of this epiphytic orchid. Among the 41 species of phorophyte that were able to host the epiphytic orchids four of them have been reported to be the phorophyte for orchids. The species were namely *Alstonia scholaris*¸ *Ficus benjamina*¸ *Tabebuia rosea* and *Samanea saman* as well as genera *Andira*, *Cinnamomum*, *Lagerstromia*, *Mangifera*, *Mesua* and *Syzygium* (Trapnell, 2006; Wood, 2014; Choden *et al.,* 2021; Rahayu & Yusri, 2022). This suggests the inclination of epiphytic orchids species in choosing certain phorophytes among other available tree species given they were occupying the same premises especially in a developed areas where the trees were planted prior and this preferable phorophyte species might have morphological characteristic such as bark rugosity, diameter, water holding and retention capacity and light penetration that can support the attachment and growth of orchids (Callaway *et al.,* 2002; Soetopo & Utami, 2020). It also opens the possibilities of planting known or suitable phorophyte will harbour more diverse epiphytic species including orchids (Sayago *et al.,* 2013). The result on species richness on phorophyte (*Andira inermis*) was profoundly on the crown strata of host tree which it was dense with the branches and twigs. This would provide an area for seed landing and population colonization as the angle between branches enables dust and leaf litter to accumulate and decompose thus supplying nutrients for the orchid to enhance their growth (Mojiol *et al.,* 2009; Izuddin *et al.,* 2018). Apart from that, the high distance of the crown from the ground would help the epiphytic orchid to reach for better light requirements as they were unable to extend their biomass to reach from the ground to the canopy (Spicer & Woods, 2022).

CONCLUSION

Overall, this study presented a total of 37 species of orchids has been found in UNIMAS and the phorophyte species for the epiphytic orchids were successfully identified. The general characteristics of the orchids to sustain their survivability in the campus area were discussed. The list of the orchid species provides an insight of the resiliency of certain species towards habitat alteration and the epiphytic dependency on the phorophyte species to survive in campus area. Despite the rapid urbanization progress, we hope to raise awareness on orchids conservation and preservation program as it will help to curb the issues involving habitat destruction and illegal activities done towards the orchids. Furthermore, the study on urban orchids was still relatively low and more variables and parameters should be studied for orchids in their urban ecosystem to provide more information for further research.

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REFERENCES

Adamowski, W. (2006). Expansion of native orchids in anthropogenous habitat. *Polish Botanical Studies*, 22, 35-44.

Arditti, J. & Ghani, A.K.B. (2000). Tansley Review No. 110.: Numerical and physical properties of orchid seeds and their biological implications. *New Phytologist*, 145: 367-421. DOI: 10.1046/j.1469-8137.2000.00587.x

Barthlott W., Große-Veldmann B. & Korotkova N. (2014). *Orchid seed diversity: A scanning electron microscopy survey*. Berlin: Botanic Garden and Botanical Museum Berlin-Dahlem.

Beaman, T.E., Wood, J.J., Beaman, R.S. & Beaman, J.H. (2001). *Orchids of Sarawak*. Kota Kinabalu, Malaysia: Natural History Publications (Borneo).

Bidlack, J.E. & Jansky, S.H. (2017). *Stern's introductory: Plant biology*. Fourteenth Edition. New York: McGraw-Hill. pp. 168.

Boo, C.M., Omar-Hor, H., Ou-Yang, K. & Ng, C.K. (2006). *1001 Garden Plants in Singapore*. Singapore: National Parks Board.

Callaway, R.M., Reinhart, K.O., Moore, G.W., Moore, D.J. & Pennings, S.C. (2002). Epiphyte host preferences and host traits: Mechanism for species-specific interactions. *Population Ecology*, 132: 221-230. DOI: 10.1007/s00442-002-0943-3

Choden, K., Jambay., Nepal, A., Choden & Suberi, B. (2021). Habitat ecology of epiphytic & terrestrial orchids in Langchenphu, Jomotsangkha Wildlife Sanctuary, Bhutan. *Indonesian Journal of Social and Environmental Issues*, 2(2): 143-154. DOI: 10.47540/ijsei.v2i2.256

Chow, W.T.L., Akbar, S.N.A.A, Heng, S.L. & Roth, M. (2016). Assessment of measured and perceived microclimates within a tropical urban forest. *Urban Forestry & Urban Greening*, 16: 62-75. DOI: 10.1016/j.ufug.2016.01.010

De, L.C. & Biswas, S.S. (2022). Adaptation mechanisms of epiphytic orchids: A review. *International Journal of Bio-resource and Stress Management*, 13(11): 1312-1322. DOI: 10.23910/1.2022.3115a

Go, R. & Raffi, A. (2017). *Discovering the wonders of Malaysian orchid: Unveiling Vanilla norashikiniana*. Selangor: Universiti Putra Malaysia Press.

Izuddin, M., Srivathsan, A., Lee, A.L., Yam, T.W. & Webb, E.L. (2019a). Availability of orchids mycorrhizal fungi on roadside trees in a tropical urban landscape. *Scientific Reports*, 9: 1-12. DOI: 10.1038/s41598-019-56049-y

Izuddin, M., Yam, T.W. & Webb, E.L. (2018). Specific niche requirements drive long-term survival and growth of translocated epiphytic orchids in an urbanised tropical landscape. *Urban Ecosystem*, 21: 531-540. DOI: 10.1007/s11252-018-0733-2

Izuddin, M., Yam, T.W. & Webb, E.L. (2019b). Germination niches and seed persistence of tropical epiphytic orchids in an urban landscape. *Journal of Plant Research*, 132(3): 383-394. DOI: 10.1007/s10265-019-01110-0

Jabatan Landskap Negara (2008). *Pokok utama berbunga*. Kuala Lumpur, Malaysia: Jabatan Landskap Negara.

Jersakova, J. & Malinova, T. (2007). Spatial aspect of seed dispersal & seed recruitment in orchids. *New Phytologist*, 176: 237-241. DOI: 10.1111/j.1469-8137.2007.02223.x

Johnson, S.D., Neal, P.R. & Harder, L.D. (2005). Pollen fates and the limits on male reproductive success in an orchid population. *Biological Journal of the Linnean Society*, 86(2): 175-190. DOI: 10.1111/j.1095-8312.2005.00541.x

Kami, C., Lorrain, S., Hornitschek, P. & Frankhasuer, C. (2010). Light-regulated plant growth and development. *Current Topic in Developmental Biology*, 91: 29-66. DOI: 10.1016/S0070-2153(10)91002-8

Li, J.W. & Zhang, S.B. (2019). Physiological responses of orchid pseudobulbs to drought stress are related to their age and plant life form. *Plant Ecology*, 220: 83-96. DOI: 10.1007/s11258-018-00904-x

McCormick, M.K. & Jacquemyn, H. (2013). What constrains the distribution of orchid populations? *New Phytologist*, 202(2): 392-400. DOI: 10.1111/nph.12639

Mojiol, A.R., Jitinu, A.M.A., Adella, A., Ganang, G.M. & Nasly, N. (2009). Vascular epiphyte diversity at Pusat Sejadi, Kawang Forest Reserve, Sabah, Malaysia. *Journal of Sustainable Development*, 2(1): 121-127. DOI: 10.5539/jsd.v2n1p121

Morales-Linares, J., Carmona-Valdovinos, T.F. & Ortega-Ortiz, R.V. (2022). Habitat diversity promotes and structures orchid diversity and orchid-host tree interactions. *Flora*, 297: 1-8. DOI: 10.1016/j.flora.2022.152180

Moore, J.C. (2013). Diversity, taxonomy versus functional. In Levin, S.A. (ed.). *Encyclopedia of Biodiversity*. Second Edition. Amsterdam: Elsevier. pp. 648-656.

Nparks. (2022). *National Parks of Singapore: Flora & Fauna Web*. Retrieved August 10, 2022, from https://www.nparks.gov.sg/florafaunaweb/

POWO. (2022). *Plant of the World Online*. Retrieved May 15, 2022, from https://powo.science.kew.org/

R Core Team. (2020). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. Downloaded on 20 October 2022.

Rahayu, E.M.D. & Yusri, S. (2022). Habitat preferences of wild orchids in Bantimurung Bulusaurung National Park to model their suitable habitat in South Sulawesi. *Biodiversitas*, 23(1): 43-54. DOI: 10.13057/biodiv/d230106

Rasmussen, H.N., Dixon, K.W., Jersakova, J. & Tesitelova, T. (2015). Germination and seedling establishment in orchids: A complex of requirement. *Annals of Botany*, 116: 391-402. DOI: 10.1093/aob/mcv087

Rasmussen, H.N. & Rasmussen, F.N. (2018). The epiphytic habitat on a living host: Reflections on the orchid-tree relationship. *Botanical Journal of the Linnean Society*, 128: 456-472. DOI: 10.1093/botlinnean/box085

Rewicz, A., Bomanowska, A., Shevera, M.V., Kurowski, J.K., Krason, K. & Zielinska, K.M. (2017). Cities and disturbed areas as man-made shelters for orchid communities. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 45(1): 126-139. DOI: 10.15835/nbha45110519

Sayago, R., Lopezaraiza-Mikel, M., Quesada, M., Alvarez-Anorve, M.Y., Cascante-Marin, A. & Bastida, J.M. (2013). Evaluating factors that predict the structure commensalistic epiphyte-phorophyte network. *Proceeding of the Royal B Society*, 280(1756): 1-9. DOI: 10.1098/rspb.2012.2821

Soetopo, L. & Utami, A.P. (2020). Biodiversity exploration of host trees (phorophyte) of epiphyte orchids in the natural habitat. *IOP Conference Series: Earth and Environment*

Science, 449: 1-13. DOI: 10.1088/1755-1315/449/1/012029

Spicer, M.E & Woods, C.L. (2022). A case for studying biotic interaction in epiphyte ecology and evolution. *Perspective in Plant Ecology, Evolution and Systematics*, 54: 1-18. DOI: 10.1016/j.ppees.2021.125658

Speak, A., Escobedo, F.J., Russo, A. & Zerbe, S. (2018). Comparing convenience and probability sampling for urban ecology applications. *Journal of Applied Ecology*, 55(5): 2332-2342. DOI: 10.1111/1365-2664.13167

Stipkova, Z. & Kindlmann, P. (2021). Factors determining the distributions of orchids – A review with the examples from the Czech Republic. *European Journal of Environmental Sciences*, 11(1): 21-30. DOI: 10.14712/23361964.2021.3

Stephen, M., Almunah, A.M., Meekiong, K., Nordin, F.A., Razali, H., Haziah, M. & Raffi, A. (2022). Current state of knowledge on the orchids of Sarawak's peat swamps. *Sarawak Museum Journal*, LXXXV(106): 145-160. DOI: 10.61507/SMJ22-2022-9QRH-07

Trapnell, D.W. (2006). Variety of phorophytes species colonized by the neotropical epiphytes, *Laelia rubescens* (Orchidaceae). *Selbayana*, 27(1): 60-64. DOI: 10.2307/41760261

UNIMAS Institutional Repository. (2022). *Search results for orchid*. Retrieved June 20, 2022, from https://ir.unimas.my/.

Wenzel, A., Grass, I., Belavadi, V.V. & Tscharntke. T. (2019). How urbanization is driving pollinator diversity and pollination - A systematic review. *Biological Conservation*, 241: 1-15. DOI: 10.1016/j.biocon.2019.108321

Wohlfahrt, G., Tomelleri, E. & Hammerle, A. (2019). The urban imprint on plant phenology. *Nature Ecology & Evolution*, 3: 1668-1674. DOI: 10.1038/s41559-019-1017-9

Wolken, P.M., Sieg, C.H. & Williams, S.E. (2001). Quantifying suitable habitat of the threatened western prairie fringed orchid. *Journal of Range Management*, 54(5): 611-616. DOI: 10.2307/4003592

Wood, J.J. (2014). *Dendrobium of Borneo*. Kota Kinabalu, Malaysia: Natural History Publications (Borneo).

Yulia, N.D. & Budiharta, S. (2011). The diversity of epiphytic orchid and its host tree along Cemoro Sewu hiking pathway, Lawu Mountain, district of Magetan, East Java, Indonesia. *Journal of Nature Studies*, 10(2): 26-31.