RESEARCH ARTICLE

BORNEO SCIENCE
THE JOURNAL OF SCIENCE & TECHNOLOGY

Journal homepage: https://jurcon.ums.edu.my/ojums/index.php/borneo-science

ORCHIDACEAE IN AYER HITAM UTARA, LAST REMAINING PEAT SWAMP FOREST IN JOHOR, MALAYSIA

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Received: 23 February 2025
Revised: 1 March 2025
Accepted: 20 March 2025
Published online: 31 March 2025

DOI : https://doi.org/10.51200/bsj.v46i1.6092

Keywords:
Ayer Hitam Utara Forest Reserve; Biodiversity; Conservation; Orchidaceae; Peat swamp forest.

ABSTRACT. *Ayer Hitam Utara Forest Reserve is the last remaining peat swamp forest in Johor, South Peninsular Malaysia, and represents a critical refuge for biodiversity, including the diversity of Orchidaceae. However, the peat swamp forest is exposed to various threats and pressures from land-use changes, forest fires, and drainage activities. Monitoring of biodiversity and conservation measures is urgently needed to preserve Johor's largest and only remaining peat swamp forest and, indirectly, its orchid diversity. This study aims to document the diversity of orchid species within the forest reserve and evaluate conservation aspects and concerns. Field surveys were conducted using purposive sampling methods, and species were identified according to morphological and taxonomic analyses. A total of 55 orchid species from 31 genera and four subfamilies were identified, including three species endemic to Malaysia and one species endemic to Peninsular Malaysia. Results highlight the significance of orchid diversity in Johor's peat swamp forests, contributing valuable insights into their ecological and habitat preferences. This study provides additional data to further understand regional biodiversity patterns, taxonomic significance, and highlights the importance of incorporating orchid conservation into peat swamp forest management strategies.*

INTRODUCTION

Malaysia, recognized as a megadiverse country and a biodiversity hotspot, is home to approximately 9,030 vascular plant species, encompassing 248 families and 1,651 genera (Yong *et al.*, 2021). In Peninsular Malaysia alone, 972 species belonging to 146 genera have been recorded, with 20% of these species classified as endemic and threatened (Ong *et al.*, 2017). According to Hernández-Mejía (2024), orchid species provide a variety of ecosystem services, including provisioning (food and medicine), regulating (pollination and water quality), and cultural services (ornamental use, traditional knowledge, and tourism). Despite Malaysia's rich diversity of orchid species, many are now under significant threat and require urgent conservation efforts (Gale *et al.*, 2018).

Southeast Asian tropical peat swamp forests are a unique and evolutionarily young type of vegetation characterized by highly acidic, waterlogged, and mineral-poor soils (Anamulai *et al.*, 2019; Helbert *et al.*, 2024). These peat swamps are recognized globally for their essential ecosystem services, including carbon storage and water regulation (Tonks *et al.*, 2017). The extreme conditions of these forests host a variety of specialized, rare, and threatened species (Giesen *et al.*, 2018; Posa *et al.*, 2011). However, most Southeast Asian tropical peat swamp forests have suffered severe degradation due to agricultural conversion (Koh *et al.*, 2011; Ledger *et al.*, 2023; Miettinen *et al.*, 2016). Malaysia no longer has any pristine peat swamps, and these ecosystems have been identified as the most threatened in the country (Wetlands International, 2010). The loss of peat swamp forests contributes to higher microclimate temperatures and increased soil acidity (Anamulai *et al.*, 2019) and raises serious environmental issues, such as elevated atmospheric carbon levels.

Johor is located in the southernmost part of Peninsular Malaysia. An inventory assessment of peatland distribution in the region indicates that Johor has approximately 143,974 hectares of peatland (Construction Research Institute of Malaysia, 2019). Unfortunately, much of this peatland has been degraded or lost, with Johor responsible for nearly one-third (34%) of the total area converted for oil palm plantations in Peninsular Malaysia (Wetlands International, 2010). The Ayer Hitam Utara Forest Reserve (AHUFR) is a permanent forest reserve that includes some of the last remaining intact sections of tropical peat swamp forest in southern Peninsular Malaysia, alongside lowland dipterocarp forests. Although several studies on biodiversity have been conducted in this reserve, the diversity of orchids has not been comprehensively evaluated. The forest receives an average annual rainfall of 2,215 mm and plays a vital role in the hydrological dynamics of the Ayer Hitam peatland (Mujilan *et al.*, 2023; Shamsuddin *et al.*, 2021). It helps regulate water flow within and outside its boundaries, serving as an essential water reservoir and playing a key role in flood mitigation, which indirectly supports community resilience and economic productivity. Acknowledging its ecological and socio-economic importance, the state government has allocated funding for infrastructure development and is promoting the forest reserve as an ecotourism destination (Jabatan Perhutanan Negeri Johor, 2022).

Given the peat swamp forest management plan aimed at achieving sustainable tourism (Jabatan Perhutanan Negeri Johor, 2022), it is crucial to document the orchid diversity in the forest reserve to ensure the integration of conservation measures. Thus, this study aims to create a checklist of orchid species to highlight the importance of biodiversity conservation in Johor's last and only peat swamp forest reserve.

MATERIALS AND METHODS

Study Area

The Ayer Hitam Utara Forest Reserve (2.057427°N, 102.806116°E) is situated in the Muar district of Johor, Malaysia. Spanning approximately 3,795.84 hectares, the reserve primarily comprises peat swamp, alongside some areas of freshwater swamp and lowland evergreen rainforest vegetation. Its ecological isolation is exacerbated by its proximity to human settlements and agricultural lands (Figure 1).

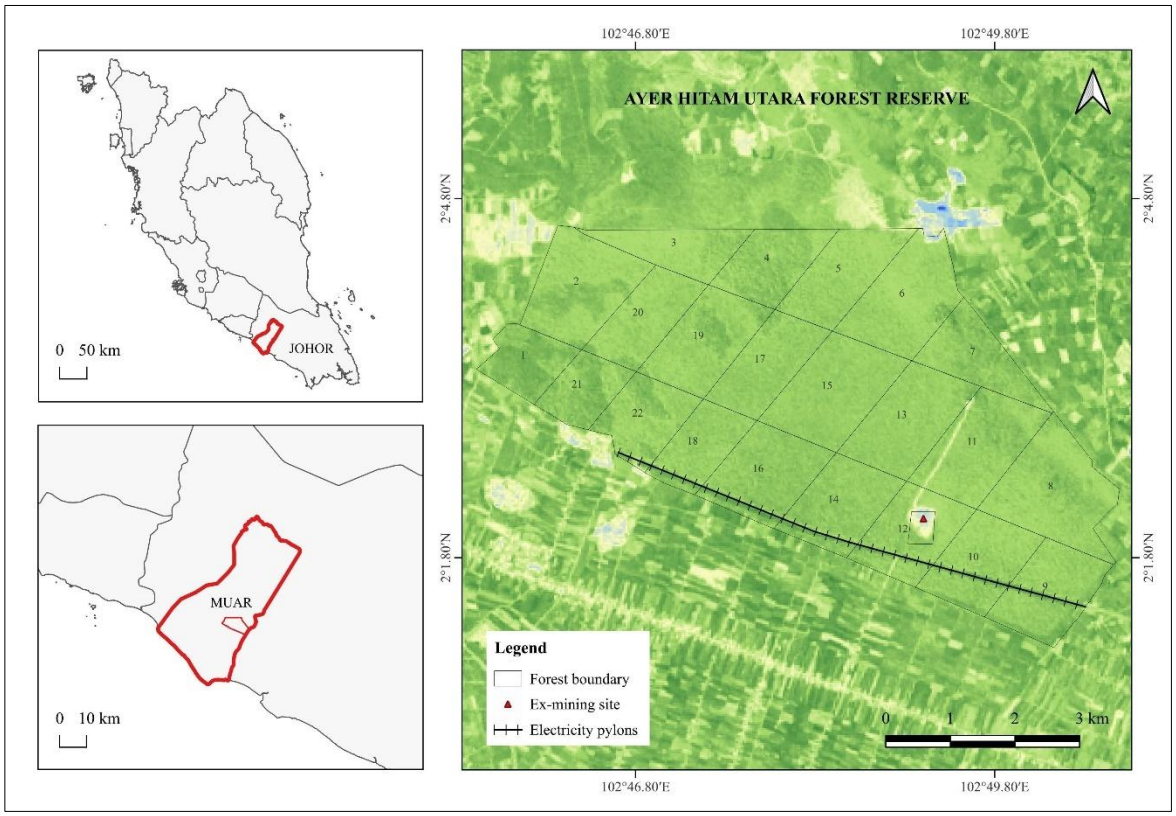

Figure 1. The location of Ayer Hitam Utara Forest Reserve, Johor.

Data Collection and Analysis

Field surveys were carried out in both established trails and off-trail areas across various sections of the forest reserve. Representative species were collected, photographed, preserved, and deposited in the herbaria at Universiti Tun Hussein Onn Malaysia, Pagoh Campus, and the Kim Ichthyologist Centre. The off-trail surveys provided access to less disturbed habitats, thereby increasing the chances of discovering rare or underrepresented species. Flowering materials were photographed, collected, and preserved as voucher specimens, while whenever feasible, non-flowering materials were gathered and cultivated in a greenhouse to aid in identification once they flowered.

Identification of species was performed through the examination of morphological characteristics both in the field and from herbarium vouchers, utilizing field guides, taxonomic keys, and consultations with experts. Growth habit observations were recorded during data collection and further corroborated with reliable taxonomic resources, such as Plants of the World Online (https://powo.science.kew.org). The ecosystems associated with each documented orchid species were also noted.

The conservation status of each species was obtained from the Malaysia Red List: Plants of Peninsular Malaysia via the Malaysia Biodiversity Information System (MyBIS) and the IUCN Red List of Threatened Species (www.iucnredlist.org). The species checklist was compared to historical flora records in Peninsular Malaysia by Ridley (1924), Corner (1978), and Turner (1995), with a focus on the documented orchid species in Johor. Distribution notes indicating widespread occurrences, specific locations in Johor, and other details were utilized in this analysis to identify overlapping species and compare differences.

RESULTS AND DISCUSSIONS

Species Composition

A total of 55 species were documented in the study (Figure 2), encompassing 31 genera and 4 subfamilies within the Orchidaceae family (Table 1). The three genera with the highest species richness were Bulbophyllum (11 species, accounting for 20% of the total), Dendrobium (7 species, 12.73%), and Thrixspermum (3 species, 5.45%). Together, these three genera comprised 41.82% of the total species diversity recorded. The remaining genera each contributed two species.

At the subfamily level, Epidendroideae was the most prevalent, representing 90.91% of the total species diversity, followed by Orchidoideae (5.55%), and both Apostasioideae and Vanilloideae (1.82% each). The taxonomic composition indicated a dominance of epiphytic species (78.18%) compared to terrestrial (30.91%) and lithophytic (10.91%) species, reflecting the habitat characteristics of the tropical peat swamp forest (Stephen *et al.*, 2022). The presence of epiphytic orchids serves as a key indicator of a well-functioning and healthy ecosystem (Sujalu *et al.*, 2021).

Further analysis examined the distribution of species across two ecological zones: lowland dipterocarp forest and peat swamp forest. The findings showed that 10.91% of the species were found in lowland dipterocarp forests, 25.45% in the transition area between lowland forests and peat swamp forests, and 63.64% in peat swamp forests. Additionally, two species (*Cystorchis javanica* and *Cystorchis variegata*) were exclusive to the waterlogged regions of the peat swamp forest (Lok *et al.*, 2011). Habitat preferences for 23 of the species were validated and documented in The Orchid of Peat Swamp Forests in Peninsular Malaysia (Go & Hamzah, 2008). The coexistence of peat swamp and lowland ecosystems facilitates diverse microhabitats and ecological niches, thereby supporting orchids with a wider range of environmental preferences (Zhang *et al.*, 2022).

Species Conservation Status

The study identified three species endemic to Malaysia and one species endemic to Peninsular Malaysia, specifically within Johor (Ong *et al.*, 2017; Turner, 1995). Although these species hold ecological significance, all have been classified as "Not Evaluated" on the Malaysia Red List. This lack of a formal conservation assessment underscores the urgent need for further research to establish their conservation status, especially given the ongoing threats to peat swamp forest ecosystems. The presence of endemic species highlights the critical importance of preserving these ecosystems to safeguard biodiversity in the region. This further emphasizes the role of the Ayer Hitam Utara Forest Reserve (AHUFR) as a vital conservation refuge for orchid species in Johor.

Comparison with Historical Records

To provide context for the findings, orchid records from historical studies in Johor by Ridley (1924), Corner (1978), and Turner (1995) were compared. Ten species identified in this study were not present in these earlier records, including the Malaysian endemic *Crepidium lowii* and the Johor endemic *Pinalia atrovinosa*. The absence of these species in older records may be attributed to several factors, such as limited survey coverage in past studies, shifts in species distributions over time, or the discovery of previously overlooked or unidentified species. The presence of these endemic species emphasizes the need for ongoing fieldwork and thorough surveys of unique and localized biodiversity areas.

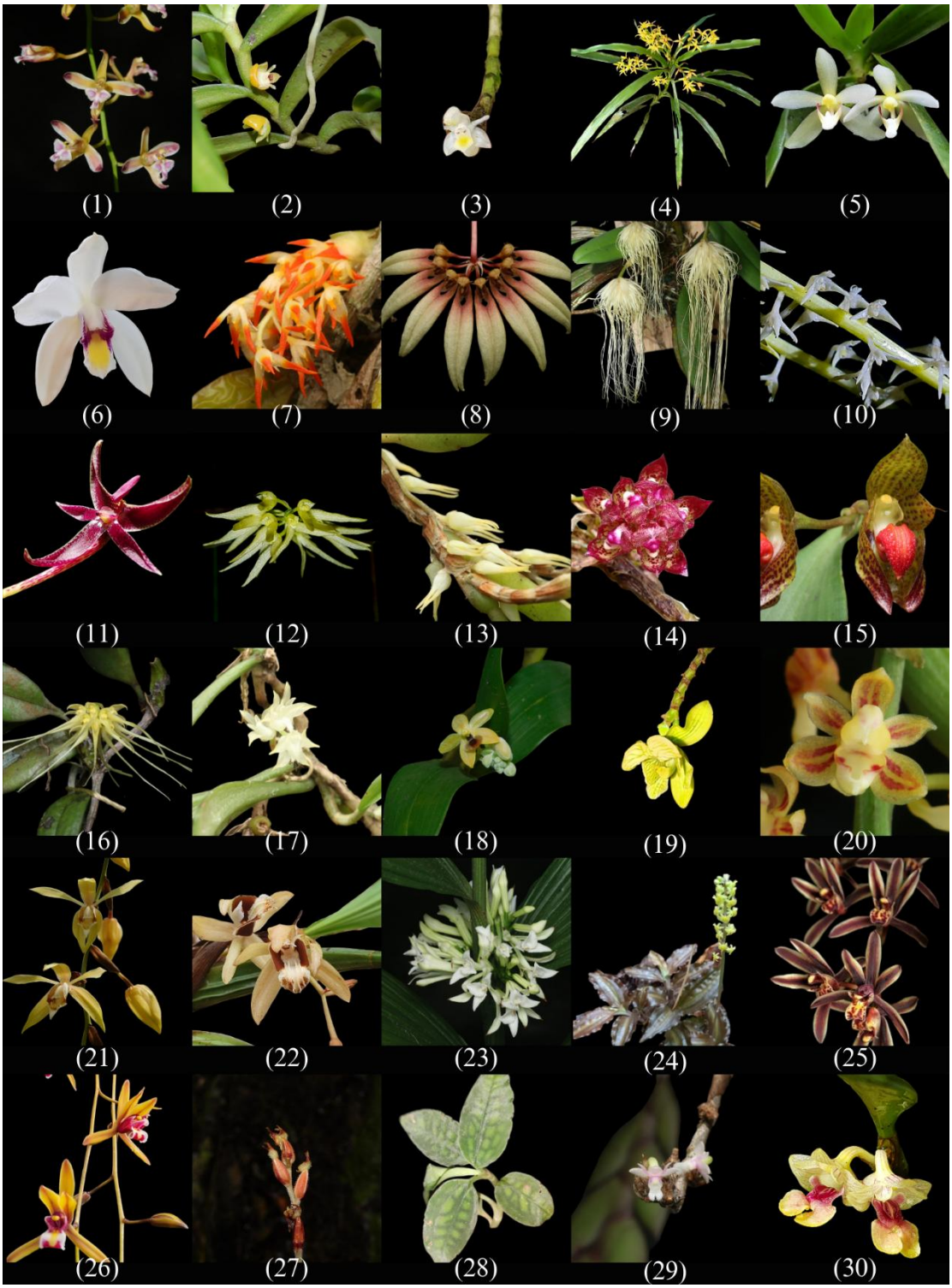

Figure 2. Orchidaceae species recorded in Ayer Hitam Utara Forest Reserve: 1) *Acriopsis liliifolia*; 2) *Adenoncos parviflora*; 3) *Agrostophyllum stipulatum*; 4) *Apostasia wallichii*; 5) *Brachypeza pallida*; 6) *Bromheadia finlaysoniana*; 7) *Bulbophyllum flammuliferum*; 8) *Bulbophyllum gusdorfii*; 9) *Bulbophyllum medusae*; 10) *Bulbophyllum odoratum*; 11) *Bulbophyllum patens*; 12) *Bulbophyllum purpurascens*; 13) *Bulbophyllum clandestinum*; 14) *Bulbophyllum singaporeanum*; 15) *Bulbophyllum subumbellatum*; 16) *Bulbophyllum vaginatum*, 17) *Bulbophyllum vermiculare*; 18) *Callostylis pulchella*; 19) *Claderia viridiflora*; 20) *Cleisostoma subulatum*; 21) *Coelogyne rochussenii*; 22) *Coelogyne testacea*; 23) *Corymborchis veratrifolia*; 24) *Crepidium lowii*; 25) *Cymbidium bicolor*; 26) *Cymbidium finlaysonianum*; 27) *Cystorchis javanica*; 28) *Cystorchis variegata*; 29) *Dendrobium aloifolium*; and 30) *Dendrobium angustifolium*.

Figure 2. (continued) 31) *Dendrobium crumenatum*; 32) *Dendrobium leonis*, 33) *Dendrobium linguella*; 34) *Dendrobium plicatile*; 35) *Dendrobium lampongense*; 36) *Dienia ophrydis*; 37) *Dipodium* cf. *paludosum*; 38) *Eulophia graminea*; 39) *Goodyera rubicunda*; 40) *Nephelaphyllum pulchrum*; 41) *Phalaenopsis deliciosa*; 42) *Phalaenopsis sumatrana*; 43) *Pinalia atrovinosa*; 44) *Plocoglottis javanica*; 45) *Plocoglottis lowii*; 46) *Podochilus microphyllus*; 47) *Pomatocalpa spicatum*; 48) *Pomatocalpa diffusum*, 49) *Renanthera elongata*; 50) *Robiquetia spathulata*; 51) *Thrixspermum amplexicaule*; 52) *Thrixspermum centipeda*; 53) *Thrixspermum trichoglottis*; 54) *Trichotosia velutina*; and 55) *Vanilla griffithii*.

Table 1. Species list: Comparison of orchid species recorded in AHUFR with Johor records by Ridley (1924), Corner (1978), and (Turner, 1995).

No.	Genus	Species	Ridley (1924)	Corner (1978)	Turner (1995)
1	*Acriopsis*	*Acriopsis liliifolia* Rolfe		√	√
2.	*Adenoncos*	*Adenoncos parviflora* Ridl.			
3.	*Agrostophyllum*	*Agrostophyllum stipulatum* (Griff.) Schltr.		√	
4.	*Apostasia*	*Apostasia wallichii* R.Br.			
5.	*Brachypeza*	*Brachypeza pallida* (Blume) Kocyan & Schuit.			√
6.	*Bromheadia*	*Bromheadia finlaysoniana* (Lindl.) Miq.		√	√
7.	*Bulbophyllum*	*Bulbophyllum flammuliferum* Ridl.			
8.		*Bulbophyllum gusdorfii* J.J.Sm.			√
9.		*Bulbophyllum medusae* (Lindl.) Rchb.f.	√		√
10.		*Bulbophyllum odoratum* (Blume) Lindl.			
11.		*Bulbophyllum patens* King ex Hook.f.	√		
12.		*Bulbophyllum purpurascens* Teijsm. & Binn.	√	√	
13.		*Bulbophyllum clandestinum* Lindl.	√	√	
14.		**Bulbophyllum singaporeanum* Schltr.		√	√
15.		**Bulbophyllum subumbellatum* Ridl.	√	√	√
16.		*Bulbophyllum vaginatum* (Lindl.) Rchb.f.	√	√	√
17.		*Bulbophyllum vermiculare* Hook.f.			√
18.	*Callostylis*	*Callostylis pulchella* (Lindl.) S.C.Chen & Z.H.Tsi	√	√	
19.	*Claderia*	*Claderia viridiflora* Hook.f.		√	√
20.	*Cleisostoma*	*Cleisostoma subulatum* Blume	√		√
21.	*Coelogyne*	*Coelogyne rochussenii* de Vriese	√	√	√
22.		*Coelogyne testacea* Lindl.		√	
23.	*Corymborkis*	*Corymborkis veratrifolia* (Reinw.) Blume			√
24.	*Crepidium*	**Crepidium lowii* (É.Morren) Szlach.			
25.	*Cymbidium*	*Cymbidium bicolor* Lindl.			√
26.		*Cymbidium finlaysonianum* Lindl.	√	√	√
27.	*Cystorchis*	*Cystorchis javanica* (Blume) Blume			
28.		*Cystorchis variegata* Blume	√		√
29.	*Dendrobium*	*Dendrobium aloifolium* (Blume) Rchb.f.		√	√
30.		*Dendrobium angustifolium* (Blume) Lindl.		√	
31.		*Dendrobium crumenatum* Sw.		√	√
32.		*Dendrobium leonis* (Lindl.) Rchb.f.	√	√	√
33.		*Dendrobium linguella* Rchb.f.			√
34.		*Dendrobium plicatile* Lindl.	√	√	
35.		*Dendrobium lampongense* J.J.Sm.			
36.	*Dienia*	*Dienia ophrydis* (J.Koenig) Seidenf.			

Table 1. (continued) Species list: Comparison of orchid species recorded in AHUFR with Johor records by Ridley (1924), Corner (1978), and (Turner, 1995).

No.	Genus	Species	Ridley (1924)	Corner (1978)	Turner (1995)
37.	*Dipodium*	*Dipodium* cf. *paludosum* (Griff.) Rchb.f.			
38.	*Eulophia*	*Eulophia graminea* Lindl.	√	√	√
39.	*Goodyera*	*Goodyera rubicunda* (Blume) Lindl.			√
40.	*Nephelaphyllum*	*Nephelaphyllum pulchrum* Blume			√
41.	*Phalaenopsis*	*Phalaenopsis deliciosa* Rchb.f.			
42.		*Phalaenopsis sumatrana* Korth. & Rchb.f.			√
43.	*Pinalia*	***Pinalia atrovinosa* (Carr) Schuit., Y.P.Ng & H.A.Pedersen			
44.	*Plocoglottis*	*Plocoglottis javanica* Blume	√	√	√
45.		*Plocoglottis lowii* Rchb.f.			√
46.	*Podochilus*	*Podochilus microphyllus* Lindl.	√	√	√
47.	*Pomatocalpa*	*Pomatocalpa spicatum* Breda			
48.		*Pomatocalpa diffusum* Breda		√	
49.	*Renanthera*	*Renanthera elongata* (Blume) Lindl.			√
50.	*Robiquetia*	*Robiquetia spathulata* (Blume) J.J.Sm.		√	√
51.	*Thrixspermum*	*Thrixspermum amplexicaule* (Blume) Rchb.f.	√	√	√
52.		*Thrixspermum centipeda* Lour.	√	√	√
53.		*Thrixspermum trichoglottis* (Hook.f.) Kuntze			√
54.	*Trichotosia*	*Trichotosia velutina* (Lodd. ex Lindl.) Kraenzl.		√	√
55.	*Vanilla*	*Vanilla griffithii* Rchb.f.	√	√	√
	Total		19	27	34

*Note: *Endemic to Malaysia, **Endemic to Peninsular Malaysia*

The results highlighted the diversity of Orchidaceae in the Ayer Hitam Utara Forest Reserve (AHUFR), with a significant number of species showing habitat tolerance and specificity to peat swamp forests. This taxonomic analysis emphasizes the high species richness and ecological importance of the study area, underscoring the necessity for targeted conservation strategies in the remaining sensitive forest reserves. The ecological significance of AHUFR was first acknowledged in 1995 through a rapid survey by Giesen *et al.* (1995), which identified its biodiversity potential; however, no orchid species were recorded, creating a gap in the understanding of the forest's overall floral diversity. Interest in the forest reserve was renewed following a scientific expedition in 2019, which led to more detailed biodiversity research. Subsequent studies have further enhanced knowledge of the forest's flora, including a comprehensive inventory of ferns conducted by Akomolafe *et al.* (2022) and an analysis of tree species diversity by Izwan *et al.* (2022).

Comparing the orchid species recorded in this study with those in historical publications underscores the ecological and floristic significance of the forest reserve. Corner (1978) shows a higher species similarity compared to Ridley (1924), as the study specifically examines freshwater peat swamps in Johor, a habitat type that the forest reserve shares (Figure 3). Turner (1995) demonstrates the highest similarity, despite his work being limited to species records from Johor.

This is likely due to its comprehensive nature, compiling floral literature and documentation from across Peninsular Malaysia, thereby covering a wider range of habitats and species.

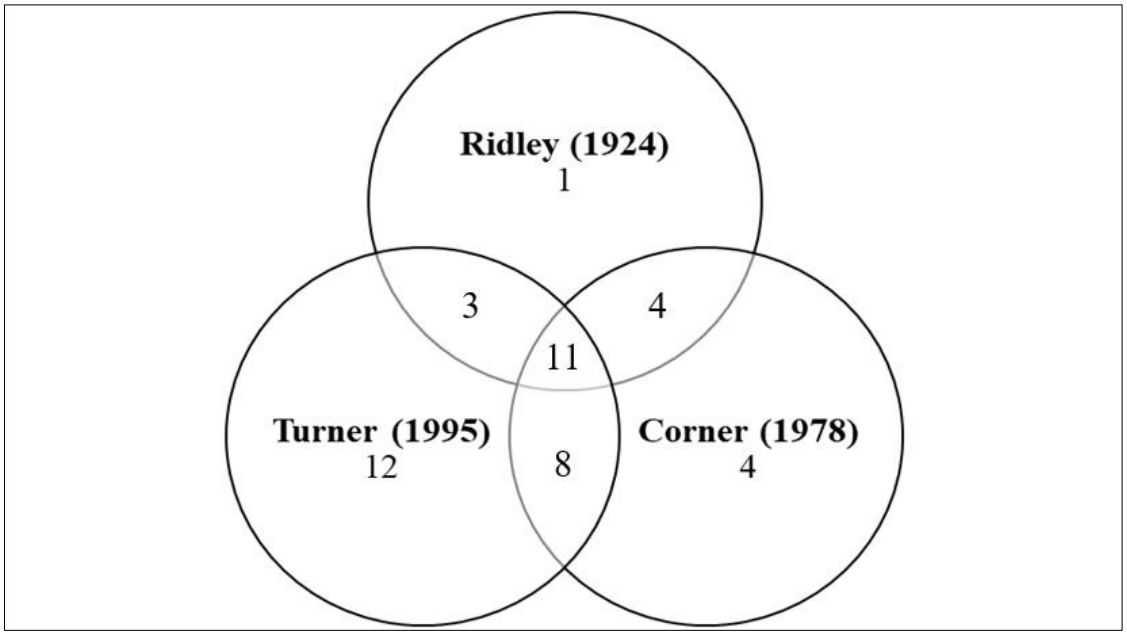

Figure 3. Comparison of orchid species records in Johor.

One of the major challenges facing biodiversity research in Malaysia is the lack of accessible and comprehensive records of flora organized by individual states. Although national-level inventories and regional assessments are available, detailed data specific to states are often fragmented or nonexistent. This limitation impairs the ability to thoroughly evaluate local biodiversity and identify conservation priorities at more localized levels. In the case of AHUFR, the absence of orchid records in previous studies illustrates this broader issue, highlighting the need for systematic floristic inventories at the state level. Strengthened efforts to document and digitize state-specific biodiversity data, including both historical and contemporary records, would create a more robust foundation for conservation planning. By integrating local knowledge, utilizing advanced technologies such as remote sensing and species distribution modeling, and fostering collaborative research initiatives, these gaps can be addressed, leading to more effective conservation strategies for Malaysia's unique ecosystems.

CONCLUSION

This study significantly advances our understanding of orchid diversity within the Ayer Hitam Utara Forest Reserve (AHUFR) by documenting 55 species across multiple genera and emphasizing the ecological importance of habitats such as peat swamp forests. The dominance of epiphytic species and the presence of endemic orchids highlight the urgent need for targeted conservation strategies to safeguard this biodiversity hotspot. These findings not only bridge gaps in historical records but also stress the vital need for ongoing research and systematic inventories to assess the conservation status of these species considering the ongoing threats to peat swamp ecosystems.

Furthermore, the comparison with historical studies reveals the fluid nature of species distributions and the necessity for enhanced recordkeeping at the state level. The absence of certain species in previous surveys suggests the possibility of discovering new records, reinforcing the importance of continued field research. By enhancing efforts to document and digitize biodiversity data and leveraging advanced technologies along with local expertise, we can promote effective conservation planning.

ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance provided by the Forestry Department of Peninsular Malaysia (JPSM) for facilitating this study. This project is funded by the Faculty of Applied Sciences and Technology Universiti Tun Hussein Onn Malaysia Grant Tier 1 (Vot H966) and acknowledgement to Skim Tenaga Akademik Baru (L8922). The authors would like to also thank Jeremiah Sia and Azlinawati Che Noh for the photographs of *Goodyera rubicunda* and *Bulbophyllum singaporeanum* provided respectively. The authors are grateful to Assoc. Prof. Dr. Alona Cuevas Linatoc, University of the Philippines Los Banos (UPLB) for providing important insights and recommendations, and Mohammad Aidel Wafie Bin Miswan, Herbarium Kepong (KEP), Forest Research Institute Malaysia for providing taxonomy literature and references.

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