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Species richness and phytogeographic affinities of rattan genus *Korthalsia* in Malaysia

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Abstract. *Shahimi S, Jamaludin AA, Ahmad A. 2023. Species richness and phytogeographic affinities of rattan genus* Korthalsia *in Malaysia. Biodiversitas 24: 5764-5778.* The clustering climbing palm genus *Korthalsia* Blume (Arecaceae: Calamoideae: Calameae) is widespread in the Malesian region with 28 documented species. However, as many as 18 species are available in Malaysian rainforests. An inquiry was carried out in 2019 throughout Malaysia that included species richness and phytogeographic affinities for *Korthalsia*. Currently, *Korthalsia* is highly diverse in Sabah and Sarawak, with 15 species documented in this region, whereas 9 species are present in the Malay Peninsula. Species of *Korthalsia* were dominated by *Korthalsia echinometra* Becc., *Korthalsia flagellaris* Miq., *Korthalsia hispida* Becc., *Korthalsia rigida* Blume, and *Korthalsia rostrata* Blume, which suggests their prevalence in richness compared to being diverse; only 5 species found in all regions. The species accumulation curve indicates that this region's rattan community is moderately rich. There is an east-west separation for the distribution of rattan species in Peninsular Malaysia. This work's novelty reflects a new record for the distribution of *K. hispida* in Penang that indicates reductions in occurrence for known distributions. Perhaps underscores on significance and inadequacies related to continuous monitoring were responsible for efforts to develop a comprehensive understanding of the diversity, distribution, and potential discoveries for *Korthalsia*. This indicates risks from development because accessibility is improved and allows researchers to reach further terrain that previously could not be explored. However, despite this weakness, a correct checklist should be constructed for existing rainforests so *Korthalsia* dispersal, diversity, and richness can be correctly archived.

Keywords: Arecaceae, Calamoideae, diversity, ecology, rattan

INTRODUCTION

The Malesia region, encompassing Southeast Asia and the western Pacific, possesses a high level of biodiversity and endemism and is the center of plant megadiversity. This region includes Malaysia, Indonesia, Philippines, and Papua New Guinea, among four of 17 global megadiverse countries (Keong 2015; Chua et al. 2023), and is also regarded as a palm diversity hotspot (Baker and Couvreur 2013b). The plant was influenced by similar environmental factors such as high light intensity, stable temperature year-round, and heavy downpours during the rainy season. However, due to local climatic variations, certain localities may have differences in microclimate patterns, which could promote certain species to success.

Rattans are spiny climbing palms with cirrus or a flagellum as a climbing structure (Henderson and Pitopang 2018) belonging to the subfamily Calamoideae of the palm family (Palmae or Arecaceae). Calamoideae is divided into three tribes: Eugeissoneae, Lepidocaryeae, and Calameae (Dransfield et al. 2008; Kuhnhäuser et al. 2021) consist of 17 genera (Baker 2015; Baker and Dransfield 2016; Kuhnhäuser et al. 2021) and ca. 550 species (Kuhnhäuser et al. 2021), making it the second largest palm subfamily. All the species within the Calamoideae have a climbing habit, whether solitary or clustered and the presence of spines and fruit with overlapping reflexed scales.

Korthalsia Blume is a genus of clustering climbing palms generally known as rattans belonging to subfamily Calamoideae (Couvreur et al. 2015; Baker and Dransfield 2016; Kuhnhäuser et al. 2021). The common name of *Korthalsia* is ant-rattan (Dransfield et al. 2008). According to Govaerts et al. (2021) and Kuhnhäuser et al. (2021), 28 species of *Korthalsia* are currently accepted. The genus *Korthalsia* is distributed from the Sunda Shelf to the north of Indochina, Burma, and the Andaman Islands and southeastward to Celebes and New Guinea, with three species being found east of Wallace's Line (Dransfield 1981). Among the 28 species, about 18 are concentrated in the Borneo, Malay Peninsula, and Sumatra, which appears to be the center of the genus with 15, 9, and 9 species, respectively (Shahimi et al. 2019). All *Korthalsia* species are limited to lowland and hill tropical rainforests and absent in montane forests.

Korthalsia is a remarkable rattan with slender to moderately-stemmed, clustered, spiny, high-climbing and aerially branching, hapaxanthic stems, inflorescences with catkin-like rachillae and monoecious rattan palm. The leaves are pinnate with cirrus and rhomboid (diamond-shaped) leaflets and leaf sheath without knee (Kalima and

Rustiami 2018; Maarif et al. 2021). In addition, all species of *Korthalsia* have a conspicuous extension of the leaf sheath above the leaf petiole known as ocrea. This structure is a specific feature of *Korthalsia* and appears in different shapes and sizes. The ocreas of *Korthalsia* are classified into four broad types: inflated, divergent, tightly sheathing, and fibrous net-like (Dransfield 1981). Shahimi (2018) studied this genus in Malaysia, focusing on the taxonomy and systematics of this genus. The study subsequently published a taxonomic revision of the myrmecophilous species of the rattan genus *Korthalsia* (Shahimi et al. 2019) with keys to 10 known species. However, our perception of species composition, site overlap, and distribution remains insufficiently explored, so the checklist is revived for re-examination. Therefore, by having a timeline of updated literature, *c.f.* Dransfield (1979), Hamid and Suratman (2010), Rozali (2014), Rozali et al. (2017); Rusdi et al. (2019) and Pesiu (2019) for the checklist contributions in Peninsular Malaysia, the revision adds coverage for *Korthalsia* in Sabah and Sarawak (Malaysia). Thus, the limited knowledge of species richness, taxonomic composition, and site affinities, with most comparisons made over large geographic scales (Gehrke and Linder 2014; González-Maya et al. 2016; Geml et al. 2017; Aksenova et al. 2018; Sun et al. 2020). Information obtained from these studies was useful for comparing species between regions of different biogeographic histories (Baker and Couvreur 2013a; Baker and Couvreur 2013b; Fayolle et al. 2014), providing insight into larger biogeographic regions (Dasgupta et al. 2021) by suggesting and enhancing the resolution of hierarchical biogeographic systems (Martinez et al. 2017; Marshall et al. 2021) and when incorporated with environmental data, allows physiological comparison to being made between or among regions (Andrade and Monjeau 2014). However, the definitions and coverage were limited to a regional radius, meaning a complete habitat coverage across vast domains remains poorly understood. With knowledge gaps on species richness, habitat overlap, and distribution of *Korthalsia* in Malaysia, we propose the addition of biogeographic affinities to resolve this concern. Additional efforts by including species richness, species composition, and site affinities are added to reach a geographic comprehension of the distribution of genus *Korthalsia*. This novelty becomes a key indicator for forest managers so that conservative actions can be prioritized in the protection of species in the remaining forest patches of Malaysia. This study evaluated about ca 400 *Korthalsia* herbarium specimens from four herbaria. We also examined all the published articles from the academic search engine using the review paper method. We aim to investigate *Korthalsia* species richness and phytogeographic affinities in Malaysia.

MATERIALS AND METHODS

Study area

An extensive study of specimens at the Royal Botanic Garden Kew Herbarium (K) and three international herbaria, namely Royal Botanic Garden Edinburgh (E), Singapore Botanic Gardens (SING) and Forest Research Institute Malaysia, Kepong (KEP) underpins this study (Table 1). In addition, existing specimens of the 2014 and 2015 sampling in Peninsular Malaysia, Singapore, and Borneo were added to the effort. Voucher specimens were made according to standard palm preparation guidelines (Griffith et al. 2021) and deposited at the Royal Botanic Garden Kew and Forest Research Institute Malaysia, Kepong herbaria. The distribution of *Korthalsia* in Sabah was extracted from Pesiu (2019), and updates for Perak were from Rozali et al. (2021).

Taxonomic information and synonyms for each species were verified from online databases. Information from published papers was also gathered and used. Distribution information was derived from fieldwork collection and information gathered from the Universiti Kebangsaan Malaysia, Bangi (UKMB) and Forest Research Institute Malaysia, Kepong (FRIM) herbaria during the visit to Malaysia in 2014 as well as Kew herbarium and other visited herbaria. Another source of information was obtained from the Global Biodiversity Information Facility (GBIF) (2020) database.

Data analysis

Floral data set and species estimation

Incidence-based data were compiled based on published literature and authors' research to strengthen the checklist. The presence/absence data were arranged according to states (Peninsular Malaysia) or districts (Sabah and Sarawak) where the species were found (species by sites matrix). Venn diagram was used to portray the number of species unique to and overlapping among regions. Furthermore, we defined species represented by a single occurrence as unique and species represented by only two occurrences as duplicates (Chao and Chiu 2016; Chao et al. 2017) as a measure of species rarity in the assemblages. Incidence-based species richness estimators (Chao2, Jacknife1, Jacknife2, and bootstraps) were used to estimate regional species richness generated from Primer v.6.1 software. The species accumulation curve was represented by the species observed (S_{obs}) obtained from the previous exercise.

Jaccard resemblance was employed in a cluster analysis with SIMPROF test on similarity generated with the complete linkage algorithm using Primer v.6.1 software. To study the species composition of *Korthalsia* ensembles, we ordinated the samples by 2D and 3D non-metric multidimensional scaling (nMDS: Kutszegi et al. 2015) using incidence information for all species found in the region. It was assumed a stress value lower than 0.3 as a measure of clustered reliability for 2D and 3D nMDS (Alberti and Wang 2022; Steinke et al. 2022). Non-metric multidimensional scaling, based on a distance matrix, was used to observe graphically the differences in species assemblage at each region (Malay peninsula, Sabah, and Sarawak), allowing samples to be ordered according to species distribution (Roberts 2020).

Table 1. An extensive study of specimens at the Royal Botanic Garden Kew Herbarium (K) and three international herbaria, namely Royal Botanic Garden Edinburgh (E), Singapore Botanic Gardens (SING) and Forest Research Institute Malaysia, Kepong (KEP) underpins this study

Species	Collector name	Collector no.	City	State	Country
Korthalsia cheb	Andersen, J.	175	Tambunan	Sabah	Malaysia
	Diwol, S.	141821	Tambunan	Sabah	Malaysia
	Soibeh	683	Ranau	Sabah	Malaysia
	Andersen, J.	175	Tambunan	Sabah	Malaysia
	Dransfield, J.	5535	Kota Kinabalu	Sabah	Malaysia
	Baker, W.J.	513	Kuching	Sarawak	Malaysia
	Dransfield, J.	4671	Kuching	Sarawak	Malaysia
	Baker, W.J.	742	Kuching	Sarawak	Malaysia
	Lee	54529	Kapit	Sarawak	Malaysia
	Baker, W.J.	742	Kuching	Sarawak	Malaysia
	Dransfield, J.	5310	Miri	Sarawak	Malaysia
	Dransfield, J.	4671	Kapit	Sarawak	Malaysia
	Lee, B.	54592	Kapit	Sarawak	Malaysia
	Bunker, W.	51	Kuching	Sarawak	Malaysia
	Bunker, W.	12	Kuching	Sarawak	Malaysia
	Saigol	14	Kuching	Sarawak	Malaysia
	Dransfield, J.	5882	Kuching	Sarawak	Malaysia
	Dransfield, J.	5876	Kuching	Sarawak	Malaysia
Korthalsia concolor	Baker, W.J.	562	Sandakan	Sabah	Malaysia
	Dransfield, J.	5738	Beluran	Sabah	Malaysia
	Amin	70340	Beluran	Sabah	Malaysia
	Sani, S.	69	Ranau	Sabah	Malaysia
	Kinsun, B.	241	Kudat	Sabah	Malaysia
	Doinis, S.	344	Ranau	Sabah	Malaysia
	Bakia	241	Kudat	Sabah	Malaysia
	Dransfield, J.	5829	Lahad Datu	Sabah	Malaysia
	Dransfield, J.	5317	Kuching	Sarawak	Malaysia
Korthalsia debilis	Tadong	323	Ranau	Sabah	Malaysia
	Dransfield, J.	5314	Kuching	Sarawak	Malaysia
	Dransfield, J.	4621	Kuching	Sarawak	Malaysia
	Dransfield, J.	4721	Kuching	Sarawak	Malaysia
Korthalsia echinometra	Chan, Y.M.	49263	Perak Tengah	Perak	Malaysia
	Burkill, I.H.	12787	Taiping	Perak	Malaysia
	Saw, L.G.	40080	Rompin	Pahang	Malaysia
	Whitmore, T.C.	15886	Rompin	Pahang	Malaysia
	Bray, P.S.	11641	Pekan	Pahang	Malaysia
	Gianno	36	Rompin	Pahang	Malaysia
	Gianno	119	Maran	Pahang	Malaysia
	Gianno	79	Pekan	Pahang	Malaysia
	Gadoh	1775	Kuantan	Pahang	Malaysia
	Corner, E.J.H.	30467	Kemaman	Terengganu	Malaysia
	Chan, Y.M.	70620	Kemaman	Terengganu	Malaysia
	Corner, E.J.H.	30467	Kemaman	Terengganu	Malaysia
	Dransfield, J.	5019	Muar	Johor	Malaysia
	Saw, L.G.	40278	Kinabatangan	Sabah	Malaysia
	Enggoh, A.	41549	Sandakan	Sabah	Malaysia
	Meliden, G.	22	Ranau	Sabah	Malaysia
	Dius, T.	19	Ranau	Sabah	Malaysia
	Sani, S.	102	Ranau	Sabah	Malaysia
	Sani, S.	90	Ranau	Sabah	Malaysia
	Sani, S.	82	Ranau	Sabah	Malaysia
	Lomudin, T.	179	Ranau	Sabah	Malaysia
	Sani, S.	144	Ranau	Sabah	Malaysia
	Sani, S.	169	Ranau	Sabah	Malaysia
	Dius, T.	318	Ranau	Sabah	Malaysia
	Sani, S.	202	Labuk Sugut	Sabah	Malaysia
	Tadong	318	Ranau	Sabah	Malaysia
	Puasa	7404	Semporna	Sabah	Malaysia
	Sambuling	90	Ranau	Sabah	Malaysia
	Sambuling	102	Ranau	Sabah	Malaysia
	Sambuling	82	Ranau	Sabah	Malaysia
	Sambuling	169	Ranau	Sabah	Malaysia
	Sambuling	144	Ranau	Sabah	Malaysia
	Sambuling	45	Ranau	Sabah	Malaysia
	Sambuling	55	Ranau	Sabah	Malaysia
	Sambuling	202		Sabah	Malaysia
	Tadong	179	Ranau	Sabah	Malaysia
	Enggoh	7432	Sandakan	Sabah	Malaysia

	Giking	22	Ranau	Sabah	Malaysia
	Tadong	19	Ranau	Sabah	Malaysia
	Dransfield, J.	5818	Sandakan	Sabah	Malaysia
	Dransfield, J.	4688	Kuching	Sarawak	Malaysia
	Dransfield, J.	4690	Kuching	Sarawak	Malaysia
	Baker, W.J.	509	Kuching	Sarawak	Malaysia
	Baker, W.J.	509	Kuching	Sarawak	Malaysia
	Hewitt	s.n.		Sarawak	Malaysia
	Dransfield, J.	4690	Kapit	Sarawak	Malaysia
	Christensen	1211	Sri Aman	Sarawak	Malaysia
	Dransfield, J.	6115	Sri Aman	Sarawak	Malaysia
	Saigol	25	Kapit	Sarawak	Malaysia
	Bunker, W.	27	Kuching	Sarawak	Malaysia
	Bunker, W.	OX39	Kuching	Sarawak	Malaysia
	Saigol	15	Kuching	Sarawak	Malaysia
	Chung, C.S.	2768	Miri	Sarawak	Malaysia
	Dransfield, J.	4688	Belaga	Sarawak	Malaysia
	Lobb	10		Sarawak	Malaysia
	Rajasegar, G.	18			Singapore
	Ridley, H.N.	3521			Singapore
	bin Rani, H.	27			Singapore
	Furtado, C.X.	37946	Botanic Garden		Singapore
Korthalsia ferox	Saw, L.G.	40297	Kinabatangan	Sabah	Malaysia
	Fidilis, K.	87354	Tawau	Sabah	Malaysia
	Andersen, J.	234	Kinabatangan	Sabah	Malaysia
	Hoare, A.	290	Sipitang	Sabah	Malaysia
	Dransfield, J.	5648	Sabah	Sabah	Malaysia
	Cuadra	229118	Sabah	Sabah	Malaysia
	Lantoh	87891	Sabah	Sabah	Malaysia
	Fedilis, K.	87354	Sabah	Sabah	Malaysia
	Baker, W.J.	515	Kuching	Sarawak	Malaysia
	Dransfield, J.	4727	Kuching	Sarawak	Malaysia
	Dransfield, J.	4727	Sarawak	Sarawak	Malaysia
	Christensen	1080	Sarawak	Sarawak	Malaysia
	Bunker, W.	57	Sarawak	Sarawak	Malaysia
	Dransfield, J.	5904	Sarawak	Sarawak	Malaysia
	Bernard	45546	Sarawak	Sarawak	Malaysia
Korthalsia flagellaris	Dransfield, J.	4941	Klang	Selangor	Malaysia
	Dransfield, J.	4957	Petaling	Selangor	Malaysia
	Mohamed Nur	34007	Klang	Selangor	Malaysia
	Dransfield, J.	4957	Subang	Selangor	Malaysia
	Nur, Md.	34007	Klang	Selangor	Malaysia
	Dransfield, J.	4941	Telok	Selangor	Malaysia
	Wray, L. Jr.	3127	Larut	Perak	Malaysia
	Gianno	108	Pekan	Pahang	Malaysia
	Gianno	532	Bera	Pahang	Malaysia
	Dransfield, J.	5712	Beaufort	Sabah	Malaysia
	Dransfield, J.	5713	Beaufort	Sabah	Malaysia
	Baker, W.J.	702		Sarawak	Malaysia
	Rajasegar, G.	5		Singapore	Malaysia
Korthalsia furcata	Dransfield, J.	6074	Serian	Sarawak	Malaysia
	Dransfield, J.	6075	Serian	Sarawak	Malaysia
	Rantai	74544	Kuching	Sarawak	Malaysia
Korthalsia furtadoana	Baker, W.J.	553	Sandakan	Sabah	Malaysia
	Saw, L.G.	40244	Kinabatangan	Sabah	Malaysia
	Saw, L.G.	40258	Kinabatangan	Sabah	Malaysia
	Fidilis, K.	87333	Tawau	Sabah	Malaysia
	Matusop	41544	Sandakan	Sabah	Malaysia
	Kadir	2643	Sandakan	Sabah	Malaysia
	Cuadra, A.	2377	Tawau	Sabah	Malaysia
	Amin	68050	Sandakan	Sabah	Malaysia
	Sani, S.	99	Ranau	Sabah	Malaysia
	Sani, S.	114	Ranau	Sabah	Malaysia
	Sani, S.	105	Ranau	Sabah	Malaysia
	Sani, S.	93	Ranau	Sabah	Malaysia
	Sani, S.	117	Ranau	Sabah	Malaysia
	Sani, S.	95	Ranau	Sabah	Malaysia
	Sani, S.	109	Ranau	Sabah	Malaysia
	Sani, S.	228	Ranau	Sabah	Malaysia
	Sani, S.	250	Ranau	Sabah	Malaysia
	Sani, S.	198	Labuk Sugut	Sabah	Malaysia
	Andersen, J.	207	Kinabatangan	Sabah	Malaysia
	Saw, L.G.	146691	Ranau	Sabah	Malaysia
	Dransfield, J.	5763	Sandakan	Sabah	Malaysia
	Dewol	132477	Kota Kinabatangan	Sabah	Malaysia

	Argent, G.	291987	Lahad Datu	Sabah	Malaysia
	Sambuling	198		Sabah	Malaysia
	Ramos	1666		Sabah	Malaysia
	Cuadra	2498	Lahad Datu	Sabah	Malaysia
	Patrick	20607	Sandakan	Sabah	Malaysia
	Castro	3201	Sandakan	Sabah	Malaysia
	Dransfield, J.	5591	Tenom	Sabah	Malaysia
	Lenedia, A.	2377	Tawau	Sabah	Malaysia
	Abas	85854	Nabawan	Sabah	Malaysia
	Talip, A.H.	88703	Sandakan	Sabah	Malaysia
	Sambuling	250	Ranau	Sabah	Malaysia
	Leopold	64584	Pinangah	Sabah	Malaysia
	Matusop	7427	Sandakan	Sabah	Malaysia
	Sambuling	105	Ranau	Sabah	Malaysia
	Sambuling	117	Ranau	Sabah	Malaysia
	Jinuan, J.	24		Sabah	Malaysia
	Krispinus, F.	94884	Kalabakan	Sabah	Malaysia
	Sambuling	114	Ranau	Sabah	Malaysia
	Sambuling	228	Ranau	Sabah	Malaysia
	Dransfield, J.	5590	Tenom	Sabah	Malaysia
	Sambuling	93	Ranau	Sabah	Malaysia
	Sambuling	109	Ranau	Sabah	Malaysia
	Sambuling	95	Ranau	Sabah	Malaysia
	Dransfield, J.	6260	Lahad Datu	Sabah	Malaysia
	Sambuling	99	Ranau	Sabah	Malaysia
	Madani	33215	Sandakan	Sabah	Malaysia
	Howroyd, C.S.	29366	Lahad Datu	Sabah	Malaysia
	Burgess	30782	Lahad Datu	Sabah	Malaysia
	Elmer, A.D.E.	20476	Tawau	Sabah	Malaysia
Korthalsia hispida	Dransfield, J.	5035	Kota Tinggi	Johor	Malaysia
	Dransfield, J.	5090	Mersing	Johor	Malaysia
	Dransfield, J.	5037	Kota Tinggi	Johor	Malaysia
	Dransfield, J.	5227	Kuantan	Pahang	Malaysia
	Dransfield, J.	5598	Tenom	Sabah	Malaysia
	Jibrin, S.	162	Kota Marudu	Sabah	Malaysia
	Dransfield, J.	3037	Kota Tinggi	Johor	Malaysia
	Dransfield, J.	5603	Tenom	Sabah	Malaysia
	Duaneh	118	Ranau	Sabah	Malaysia
	Dransfield, J.	5803	Telupid	Sabah	Malaysia
	Dransfield, J.	4705		Sarawak	Malaysia
	Clemens, J.	22085	Kapit	Sarawak	Malaysia
	Elmer, A.D.E.	21553	Tawau	Sarawak	Malaysia
	Chin	3008	Baram	Sarawak	Malaysia
	Bunker, W.	36	Kuching	Sarawak	Malaysia
	Christensen	1188	Sri Aman	Sarawak	Malaysia
Korthalsia jala	Baker, W.J.	558	Sandakan	Sabah	Malaysia
	Saw, L.G.	40270	Kinabatangan	Sabah	Malaysia
	Diwol, S.	132478	Kinabatangan	Sabah	Malaysia
	Andersen, J.	231	Kinabatangan	Sabah	Malaysia
	Kinsun, B.	339	Kota Marudu	Sabah	Malaysia
	Meliden, G.	21	Ranau	Sabah	Malaysia
	Sani, S.	77	Ranau	Sabah	Malaysia
	Dius, T.	511	Ranau	Sabah	Malaysia
	Dius, T.	585	Ranau	Sabah	Malaysia
	Dius, T.	111	Ranau	Sabah	Malaysia
	Dius, T.	207	Ranau	Sabah	Malaysia
	Baker, W.J.	558	Sandakan	Sabah	Malaysia
	Dransfield, J.	5574	Ranau	Sabah	Malaysia
	Keith	1607		Sabah	Malaysia
	Tadong	511	Ranau	Sabah	Malaysia
	Dewol	132478	Kota Kinabatangan	Sabah	Malaysia
	Giking	21	Ranau	Sabah	Malaysia
	Tadong	585	Ranau	Sabah	Malaysia
	Sambuling	77	Ranau	Sabah	Malaysia
	Tadong	207	Ranau	Sabah	Malaysia
	Dransfield, J.	5505	Ranau	Sabah	Malaysia
	Dransfield, J.	5662	Kudat	Sabah	Malaysia
	Tadong	600	Ranau	Sabah	Malaysia
	Tadong	111	Ranau	Sabah	Malaysia
	Dransfield, J.	5809	Beluran	Sabah	Malaysia
	Sambuling	42	Ranau	Sabah	Malaysia
	Moore, H.E. Jr.	9204	Tenom	Sabah	Malaysia
	Dransfield, J.	4652	Serian	Sarawak	Malaysia
	Dransfield, J.	5941	Miri	Sarawak	Malaysia
Korthalsia laciniosa	Dransfield, J.	5388	Hulu Perak	Perak	Malaysia

	Chan, Y.M.	70311	Petaling	Selangor	Malaysia
	Gadoh, U.	1005	Hulu Langat	Selangor	Malaysia
	Ani, S.	33102	Maran	Pahang	Malaysia
	Dransfield, J.	4601	Bentung	Pahang	Malaysia
	Whitmore, T.C.	8566	Jerantut	Pahang	Malaysia
	Dransfield, J.	4602	Bentung	Pahang	Malaysia
	Rubeli, K.	s.n.	Kuala Tahan	Pahang	Malaysia
	Chan, Y.M.	49257	Kuala Pilah	Negeri Sembilan	Malaysia
	Dransfield, J.	4982	Jelebu	Negeri Sembilan	Malaysia
	Dransfield, J.	5148	Setiu	Terengganu	Malaysia
	Dransfield, J.	5149	Setiu	Terengganu	Malaysia
	Dransfield, J.	5209	Kemaman	Terengganu	Malaysia
	Whitmore, T.C.	4304	Gua Musang	Kelantan	Malaysia
	Dransfield, J.	5058	Kota Tinggi	Johor	Malaysia
	Ridley, H.N.	38773			Singapore
	Furtado, C.X.	37945	Botanical Gardens		Singapore
Korthalsia lanceolata	Dransfield, J.	4495	Kuala Kangsar	Perak	Malaysia
	Dransfield, J.	4496	Kuala Kangsar	Perak	Malaysia
	Baker, W.J.	504	Hulu Langat	Selangor	Malaysia
	Dransfield, J.	6240	Mersing	Johor	Malaysia
	Dewol	129693	Lahad Datu	Sabah	Malaysia
	Dewol	129753	Lahad Datu	Sabah	Malaysia
Korthalsia paucijuga	Dransfield, J.	4641	Kuching	Sarawak	Malaysia
	Tiggi, A.	3310	Mukah	Sarawak	Malaysia
Korthalsia rigida	Dransfield, J.	4504	Manjung	Perak	Malaysia
	Dransfield, J.	5389	Hulu Perak	Perak	Malaysia
	Kunstler, H.	6563	Larut	Perak	Malaysia
	Ave, W.	115	Tapah	Perak	Malaysia
	Ave, W.	17	Tapah	Perak	Malaysia
	Ave, W.	219	Tapah	Perak	Malaysia
	Ave, W.	53	Tapah	Perak	Malaysia
	Baker, W.J.	498	Gombak	Selangor	Malaysia
	Weiner	36063	Kuala Selangor	Selangor	Malaysia
	Dransfield, J.	4944	Hulu Langat	Selangor	Malaysia
	Manokaran, N.	18556	Petaling	Selangor	Malaysia
	Gianno	135	Petaling	Selangor	Malaysia
	Dransfield, J.	4568	Kuantan	Pahang	Malaysia
	Dransfield, J.	5219	Kuantan	Pahang	Malaysia
	Whitmore, T.C.	3557	Temerloh	Pahang	Malaysia
	Saw, L.G.	40070	Rompin	Pahang	Malaysia
	Dransfield, J.	4977	Jelebu	Negeri Sembilan	Malaysia
	Latiff, A.	1741	Jeli	Kelantan	Malaysia
	Yong, J.W.H.	16	Mersing	Johor	Malaysia
	Kiah	32344		Johor	Malaysia
	Ridley	11208		Johor	Malaysia
	Saw, L.G.	40257	Kinabatangan	Sabah	Malaysia
	Saw, L.G.	44545	Kinabatangan	Sabah	Malaysia
	Doinis, S.	685	Ranau	Sabah	Malaysia
	Sani, S.	92	Ranau	Sabah	Malaysia
	Diwol, S.	124596	Kinabatangan	Sabah	Malaysia
	Sani, S.	86	Ranau	Sabah	Malaysia
	Sani, S.	106	Ranau	Sabah	Malaysia
	Sani, S.	112	Ranau	Sabah	Malaysia
	Sani, S.	101	Ranau	Sabah	Malaysia
	Tungking, S.	25	Kota Belud	Sabah	Malaysia
	Jusimin, D.	123	Kota Belud	Sabah	Malaysia
	Sani, S.	165	Ranau	Sabah	Malaysia
	Ramos, M.	1275	Sandakan	Sabah	Malaysia
	Tadong	323	Ranau	Sabah	Malaysia
	Simbayan	25	Kota Belud	Sabah	Malaysia
	Sundaling	135134	Kudat	Sabah	Malaysia
	Dransfield, J.	5566	Ranau	Sabah	Malaysia
	Soibeh	685	Ranau	Sabah	Malaysia
	Soibeh	344	Ranau	Sabah	Malaysia
	Sambuling	165	Ranau	Sabah	Malaysia
	Dransfield, J.	5748	Sandakan	Sabah	Malaysia
	Dransfield, J.	5765	Sandakan	Sabah	Malaysia
	Dewol	124596	Kota Kinabatangan	Sabah	Malaysia
	Keith	6257	Semporna	Sabah	Malaysia
	Duaneh	123	Ranau	Sabah	Malaysia
	Dransfield, J.	5990	Lundu	Sarawak	Malaysia
	Dransfield, J.	6138	Kuching	Sarawak	Malaysia
	Dransfield, J.	5980	Baram	Sarawak	Malaysia
	Furtado, C.X.	37947			Singapore
	Furtado, C.X.	37947a			Singapore

	Rajasegar, G.	25			Singapore
	Holttum, R.E.	s.n.			Singapore
	Holttum, R.E.	s.n.			Singapore
Korthalsia robusta	Baker, W.J.	552	Sandakan	Sabah	Malaysia
	Dransfield, J.	5563	Ranau	Sabah	Malaysia
	Saw, L.G.	40288	Kinabatangan	Sabah	Malaysia
	Cuadra, A.	2158	Kinabatangan	Sabah	Malaysia
	Cuadra, A.	2226	Sandakan	Sabah	Malaysia
	Cuadra, A.	248	Lahad Datu	Sabah	Malaysia
	Doinis, S.	828	Ranau	Sabah	Malaysia
	Sani, S.	164	Ranau	Sabah	Malaysia
	Sani, S.	133	Ranau	Sabah	Malaysia
	Cuadra	2383	Tawau	Sabah	Malaysia
	Cuadra	2275	Sandakan	Sabah	Malaysia
	Bakia	339	Kota Marudu	Sabah	Malaysia
	Abas	85923	Tambunan	Sabah	Malaysia
	Soibeh	828	Ranau	Sabah	Malaysia
	Dransfield, J.	5772	Sandakan	Sabah	Malaysia
	Sambuling	164	Ranau	Sabah	Malaysia
	Sambuling	133	Ranau	Sabah	Malaysia
	Sambuling	3	Ranau	Sabah	Malaysia
	Christensen	185	Miri	Sarawak	Malaysia
	Saigol	33	Kapit	Sarawak	Malaysia
	Dransfield, J.	5262	Miri	Sarawak	Malaysia
	Wee-Lek, C.	1086	Baram	Sarawak	Malaysia
Korthalsia rostrata	Dransfield, J.	4477	Kinta	Perak	Malaysia
	Dransfield, J.	5381	Kuala Kangsar	Perak	Malaysia
	Dransfield, J.	5381	Kuala Kangsar	Perak	Malaysia
	Dr King's collector	8144	Larut	Perak	Malaysia
	Dr King's collector	5047	Larut	Perak	Malaysia
	Dr King's collector	3504	Larut	Perak	Malaysia
	Dr King's collector	3583	Larut	Perak	Malaysia
	Dr King's collector	5041	Larut	Perak	Malaysia
	Wray, L. Jr.	1917		Perak	Malaysia
	Gianno	320		Perak	Malaysia
	Dransfield, J.	4477	Ipoh	Perak	Malaysia
	Gadoh, U.	1775	Hulu Langat	Selangor	Malaysia
	Dransfield, J.	4950	Hulu Langat	Selangor	Malaysia
	Chan, Y.M.	70262	Rompin	Pahang	Malaysia
	Dransfield, J.	4583	Rompin	Pahang	Malaysia
	Saw, L.G.	40076	Rompin	Pahang	Malaysia
	Chan, Y.M.	49255	Kuala Pilah	Negeri Sembilan	Malaysia
	Dransfield, J.	5002	Port Dickson	Negeri Sembilan	Malaysia
	Dransfield, J.	5142	Setiu	Terengganu	Malaysia
	Ahmad, S.	84203	Muar	Johor	Malaysia
	Ahmad, S.	84204	Muar	Johor	Malaysia
	Dransfield, J.	5064	Mersing	Johor	Malaysia
	Hamzah, T.	81506	Segamat	Johor	Malaysia
	Holttum, R.E.	10916	Kluang	Johor	Malaysia
	Gianno	151	Endau Rompin	Johor	Malaysia
	Saw, L.G.	44552	Kinabatangan	Sabah	Malaysia
	Dransfield, J.	5636	Nabawan	Sabah	Malaysia
	Cuadra, A.	2383	Tawau	Sabah	Malaysia
	Dransfield, J.	5855	Tawau	Sabah	Malaysia
	Dransfield, J.	5798	Telupid	Sabah	Malaysia
	Dransfield, J.	4680	3rd Division	Sarawak	Malaysia
	Awa, D.	47554	5th Division	Sarawak	Malaysia
	Baker, W.J.	514	Kuching	Sarawak	Malaysia
	Joseph, J.	36609	Kuching	Sarawak	Malaysia
	Baker, W.J.	694	Lundu	Sarawak	Malaysia
	Baker, W.J.	514	Kuching	Sarawak	Malaysia
	Lobb	s.n.		Sarawak	Malaysia
	Hock	53881	Kuching	Sarawak	Malaysia
	Dransfield, J.	5322	Miri	Sarawak	Malaysia
	Dransfield, J.	6085	Serian	Sarawak	Malaysia
	Awa	46688		Sarawak	Malaysia
	Moore, H.E. Jr.	9084		Sarawak	Malaysia
	Dransfield, J.	5272	Miri	Sarawak	Malaysia
	Ashton, P.S.	21471	Kuching	Sarawak	Malaysia
	Bunker, W.	30	Kuching	Sarawak	Malaysia
	Awa	47554	Limbang	Sarawak	Malaysia
	Dransfield, J.	4680	Ulu Belaga	Sarawak	Malaysia
	Jawa	36609	Kuching	Sarawak	Malaysia
	Tomlinson	6	Kuching	Sarawak	Malaysia
	Bunker, W.	33	Serian	Sarawak	Malaysia

	Saigol	35	Kapit	Sarawak	Malaysia
	Christensen	1183	Lubuk Antu	Sarawak	Malaysia
	Ara, R.	73906	Kuching	Sarawak	Malaysia
	Stockdale, M.	137	East Kalimantan	Borneo	Malaysia
	Rajasegar, G.	24			Singapore
Korthalsia scortechinii	Dransfield, J.	5106	Kuala Muda	Kedah	Malaysia
	Chee, B.J.	47289	Sik	Kedah	Malaysia
	Whitmore, T.C.	12894	Larut & Matang	Perak	Malaysia
	Ave, W.	179	Tapah	Perak	Malaysia
	Ave, W.	178	Tapah	Perak	Malaysia
	Baker, W.J.	497	Bentung	Pahang	Malaysia
	Dransfield, J.	4968	Bentung	Pahang	Malaysia
	Whitmore, T.C.	3360	Temerluh	Pahang	Malaysia
	Yap, S.K.	28431	Maran	Pahang	Malaysia
	Baker, W.J.	497	Genting Highlands	Pahang	Malaysia
	Somerville, G.W.	10484	Kuala Lipis	Pahang	Malaysia
	Gianno	512		Pahang	Malaysia
	Dransfield, J.	4973	Jelebu	Negeri Sembilan	Malaysia
	Dransfield, J.	4976	Jelebu	Negeri Sembilan	Malaysia
	Manokaran, N.	18520	Jelebu	Negeri Sembilan	Malaysia
	Weiner	36080	Kuala Pilah	Negeri Sembilan	Malaysia
	Chan, Y.M.	60534	Jelebu	Negeri Sembilan	Malaysia
Korthalsia tenuissima	Saw, L.G.	37327	Timur Laut	Penang	Malaysia
	Saw, L.G.	44333	Rompin	Pahang	Malaysia
	Dransfield, J.	4464	Kinta	Perak	Malaysia
	Dransfield, J.	5368	Kinta	Perak	Malaysia
	Dransfield, J.	4468	Kinta	Perak	Malaysia
	Dransfield, J.	4484	Kuala Kangsar	Perak	Malaysia
	Saw, L.G.	44272	Kuala Kangsar	Perak	Malaysia
	Dransfield, J.	5380	Kuala Kangsar	Perak	Malaysia
	Dransfield, J.	5384	Kuala Kangsar	Perak	Malaysia
	Kunstler, H.	4657	Larut	Perak	Malaysia
	Dransfield, J.	4468	Ipoh	Perak	Malaysia
	Dransfield, J.	4484	Ipoh	Perak	Malaysia
	Dransfield, J.	5380	Kuala Kangsar	Perak	Malaysia
	Dransfield, J.	5368	Ipoh	Perak	Malaysia
	Dransfield, J.	4963	Petaling	Selangor	Malaysia
	Baker, W.J.	505	Hulu Langat	Selangor	Malaysia
	Dransfield, J.	4963	Subang	Selangor	Malaysia

RESULTS AND DISCUSSION

Regional species composition

Moreover, 18 species of rattan from the genus *Korthalsia* were known to occur in the Malay peninsula (9), Sabah (13), and Sarawak (13) (Figure 1, Table 2). *Korthalsia echinometra* Becc., *Korthalsia flagellaris* Miq., *Korthalsia hispida* Becc., *Korthalsia rigida* Blume, and *Korthalsia rostrata* Blume were the most common species in all regions. Sabah and Sarawak share 6 common species, i.e., *Korthalsia cheb* Becc., *Korthalsia concolor* Burret, *Korthalsia debilis* Blume, *Korthalsia ferox* Becc., *Korthalsia jala* J.Dransf., and *Korthalsia robusta* Blume. Three unique species can be found in Malay peninsula, which are *Korthalsia laciniosa* (Griff.) Mart., *Korthalsia scortechinii* Becc. and *Korthalsia tenuissima* Becc., whereas *Korthalsia furcata* Becc. and *Korthalsia paucijuga* Becc. only present in Sarawak and the only unique species to Sabah is *Korthalsia furtadoana* J.Dransf. In addition, *Korthalsia lanceolata* J.Dransf. present in Malay Peninsula and Sabah but not Sarawak.

Furthermore, of the 18 species identified, only 5 species occurred in all the regions, and another 6 *Korthalsia* species were exclusive to Malay peninsula (3), Sarawak (2), and Sabah (1). The species composition between different localities are shown in Figure 2. With composition of 13 species, most *Korthalsia* were recorded in Sabah and Sarawak. Sabah and Sarawak shared the highest number of species (11), whereas Malay peninsula shared only 6 species with Sabah and 5 species with Sarawak.

Regional species richness estimation

Accumulation of species richness indicates that this region's rattan genus Korthalsia community is moderately rich. S_{obs} curve and bootstrap gradually increased as more samples were added and slowly stabilized toward the end of the sample. Four species richness estimators (Chao2, Jacknife1, Jacknife2, and Bootstrap) were used to extrapolate the possible species richness that can be found in this region. All estimators showed the sign of flattening at the end of curves. Based on the curves, the maximum number of samples that can be expected for this genus in this region is close to 20 species (Figure 3).

Species richness estimators estimated higher species richness from a small sample size; Chao2 sharply increased but later slowly decreased and reached asymptote when all samples were added. Meanwhile, the two Jacknife estimators steadily increased but gently decreased and stabilized rather quickly, reaching asymptote with Jacknife1settled down slightly higher than Jacknife2. All estimators except bootstrap began to decrease at half of the sample size, reaching asymptotic shortly.

Table 2. List of *Korthalsia* species found in Malay peninsula, Sabah, and Sarawak

Species	Malay peninsula									Sabah				Sarawak						Total
	P-K	A	S	N	J	C	T-D	SG	KD	WCD	ID	SD	TD	1D	2D	3D	4D	7+9D	11-12D	
K. cheb	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	5
K. concolor	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	4
K. debilis	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	3
K. echinometra	0	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	14
K. ferox	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	7
K. flagellaris	0	1	1	0	0	1	0	1	0	0	1	0	0	0	1	1	0	0	0	7
K. furcata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
K. furtadoana	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	4
K. hispida	1	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	0	1	0	10
K. jala	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	0	0	1	5
K. paucijuga	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2
K. laciniosa	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	7
K. lanceolata	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
K. rigida	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	14
K. robusta	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	1	7
K. rostrata	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	16
K. scortechinii	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5
K. tenuissima	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Total	5	8	7	5	6	8	4	5	6	8	7	9	8	8	2	5	3	7	8	

Note: The locations are abbreviated as P: Penang; K: Kedah; A: Perak; S: Selangor; N: Negeri Sembilan; J: Johor; C: Pahang; T: Terengganu; D: Kelantan; SG: Singapore; KD: Kudat Division; WCD: West Coast Division; ID: Interior Division; SD: Sandakan Division; TD: Tawau Division; 1D: First Division, 2D: Second Division; 3D: Third Division; 4D: Fourth Division; 7D: Seventh Division; 9D: Ninth Division; 11D: Eleventh Division and 12D: Twelfth Division

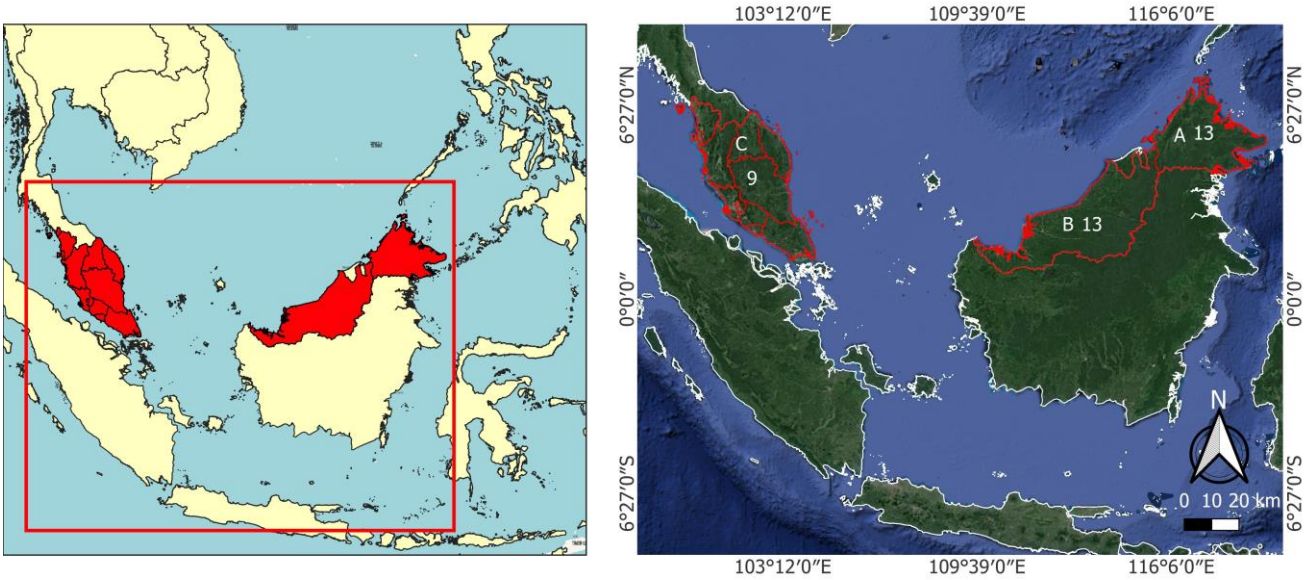

Figure 1. Distribution map of *Korthalsia* spp. in A. Sabah; B. Sarawak; and C. Malay Peninsula. The number represents the available species for each territory

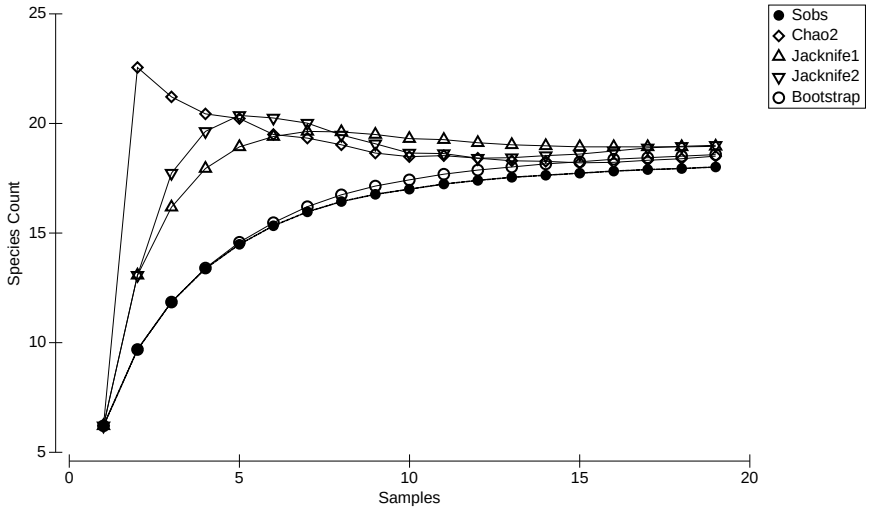

Figure 3. The estimated number of *Korthalsia* species in Malay Peninsula, Sabah, and Sarawak versus the sample collected. The dotted black line indicates the species observed (S_{obs}), while other lines were estimators

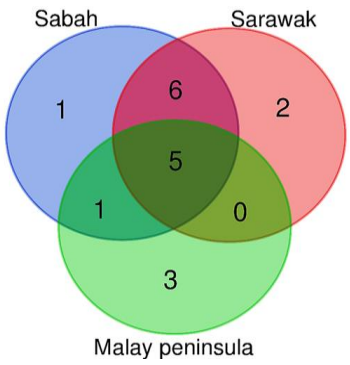

Figure 2. Venn diagram showing the overlapping and individuality species composition between three different localities

Phytogeographic affinities

The resulting dendrogram (Figure 4) separated the localities into three groups, A, B, and C. Groups A and B are totally dissimilar from group C, which is close to zero similarity (100% dissimilarity). Groups A and B consist of an array of mainly the Malay peninsula (Group A) dissimilar to Group B, which consists of localities in Sabah and Sarawak, particularly the northeastern sites. In comparison, group C consists of three localities in the southwestern part of Sarawak. Locations in group A may be divided into groups A (i) and A (ii). Group A (i) consists of J, T-D, and SG, while group A (ii) was divided into two subgroups consisting of C, A, and S (known as group A (ii)(a)) and P-K and N (regarded as group A (ii)(b)). Group B's locations are divided into groups B (i) and B (ii). All

localities in group B belong to Bornean, consisting of inland and coastal areas. The sub-cluster in cluster B (i) consists of localities northwest of Sabah (WCD) and northern Sarawak (11-12D), whereas 1D is located in southern Sarawak. Meanwhile, in B (ii)(b), the cluster consists of all northern Borneo localities. However, in sub-cluster B (ii)(a), the ID group together with 7 + 9 D, of which 7 (included) was a coastal district. Close inspection of the dendrogram indicates a sensible division at 19%, dividing the groups into 3 groups. In comparison, localities in group C were solely from Sarawak and formed a separate group from the rest, including the Malay peninsula. This group's localities are a mix of two inland and one coastal sites and are closely situated in the lower part of Sarawak. The cluster A (i) consists of T-D, J, and SG, the Malay peninsula's northeastern and southern sites. Cluster A (ii) consist of location mostly in the west coast states except C (= Pahang). Pahang samples were collected from mostly inland locations that were more similar to the Malay peninsula's west coast, which is close to Selangor. Malay peninsula shows an east-west separation in terms of species diversity.

Altogether, a statistical stress (Jaccard Index) of 0.130 was reached, meaning the locations are supported by rich plant diversity (Figure 5). The stress value indicated a good separation in species distribution in nMDS analysis based on the Jaccard index. Malay peninsula is definitely not similar to Sabah and Sarawak in terms of the presence of rattan species of the genus *Korthalsia*, and Sarawak shares partly with Sabah, especially the upper half of Sarawak almost equal to the lower part of Sabah, including ID and WCD in term of the presence of rattan of the genus *Korthalsia*.

The 3D nMDS (Figure 6) using the similar Jaccard index produced a better stress value (0.08), indicating that species resemblance in 3D is highly trustworthy. The 3D nMDS clearly resembled the location of *Korthalsia* species that clearly split up the Malay peninsula from Bornean locations. As for the Bornean localities, the southern localities in Sarawak seem very much dissimilar from the rest. However, the northern localities are closely related to many localities in Sabah, especially in the ID and WCD. This trend was entirely different for Sabah and Sarawak because the distribution distance was separate, and the samples from South Sarawak had exclusive lineage.

Discussion

Clustering climbing palm diversity of the genus *Korthalsia* in the Malay Peninsula and Borneo (Sabah and Sarawak) is rich, totaling 18 recorded species of the 28 documented listings throughout the Malesia region (Shahimi 2018). The distribution of rattan of the genus *Korthalsia* in the Malay peninsula shared very low similarity with many localities in Borneo (Sabah and Sarawak). Three species of *Korthalsia* are endemic to Peninsular Malaysia, whereas six species of *Korthalsia* are known to be endemic to Sabah and Sarawak. The number of unique species is low, and the number of species is also low. Thus, the estimation of species richness is considered accurate and reliable. Three localities in Sarawak have *Korthalsia* species almost dissimilar to any known location in the Malay peninsula and Borneo site. In the Malay Peninsula, Korthalsia distribution was observed to have an East-West pattern. In Sabah, the northern and inland locations are more similar to the west coast district, probably because of more accessibility for species inventory. Half of Sarawak and the south part of Sabah shared many similar species. The inclusion of 1D in the cluster of the northern half of Sarawak and Sabah is rather expected; this indicates that species richness is highly similar due to continuous geography. Endemic rattan species such as *Calamus* sp. were observed to distribute in connected forest compartments (Sreekumar and Sasi 2019), which, for this case, reflects on the geographical boundary that separates a connected forest.

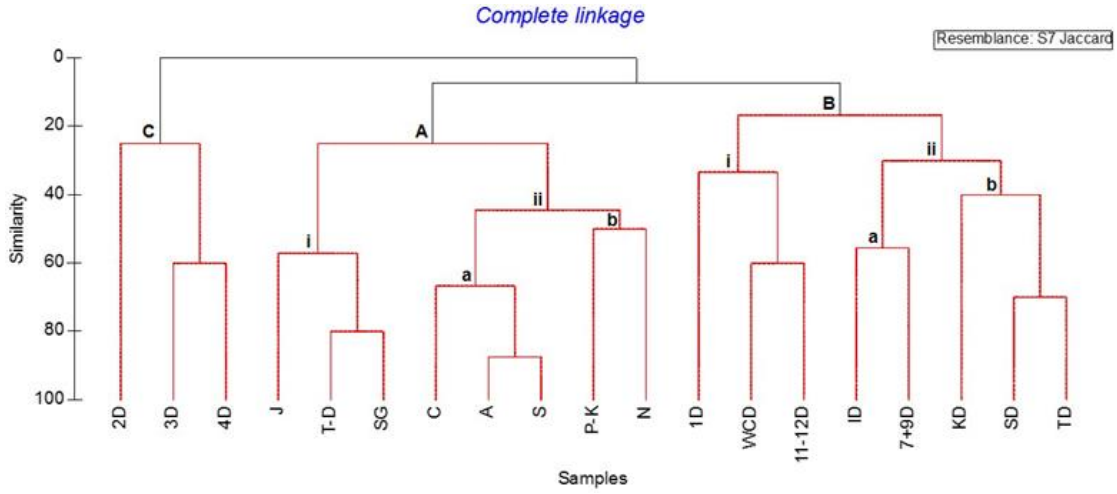

Figure 4. Dendrogram derived from cluster analysis with SIMPROF test on similarity of *Korthalsia* species from the Malay peninsula, Sabah, and Sarawak. For details, see the explanation in Table 2

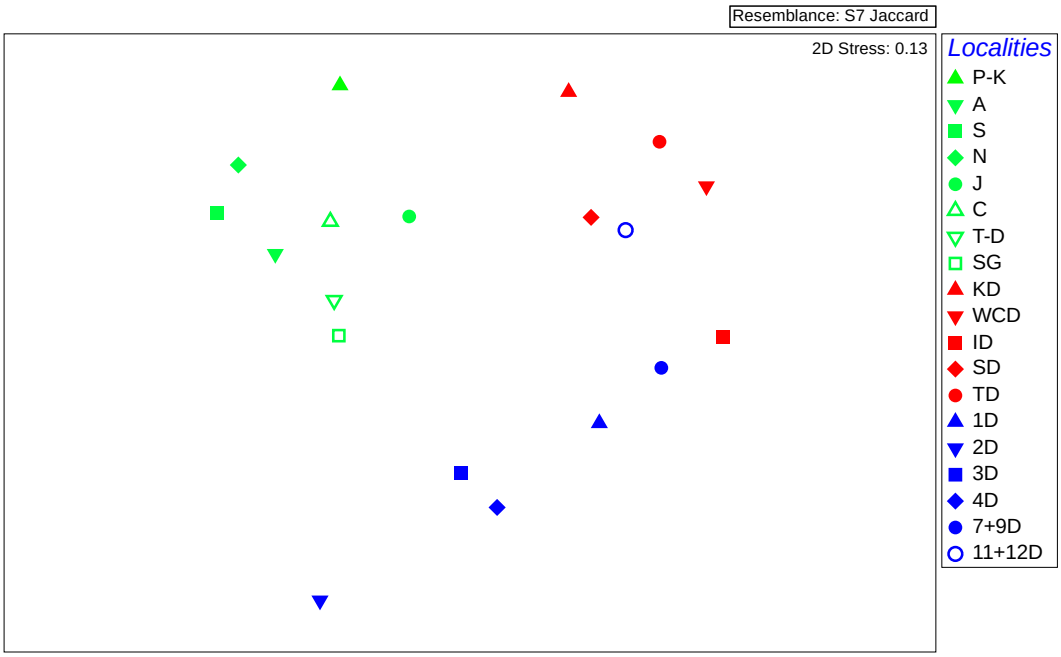

Figure 5. Non-metric multidimensional scaling (2D NMDS) plot showing the species diversity of *Korthalsia* species based on localities in Malay peninsula, Sabah, and Sarawak. The symbols represent the states/divisions while the colors represent the localities (Green: Malay peninsula, Red: Sabah, Blue: Sarawak). For details, see the explanation in Table 1

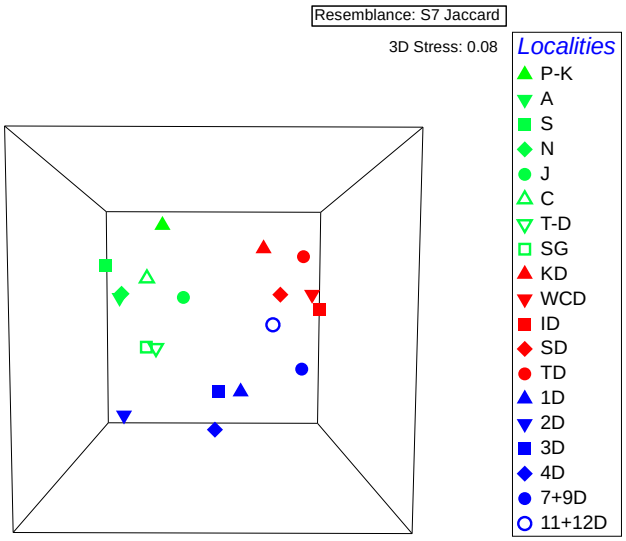

Figure 6. Non-metric multidimensional scaling (3D NMDS) plot showing the species diversity of *Korthalsia* species based on localities in the Malay peninsula, Sabah and Sarawak. The symbols represent the states/divisions while the similar colors represent the regions (Green: Malay peninsula, Red: Sabah, Blue: Sarawak). For details, see the explanation in Table 1

Our description of *Korthalsia* spp. in the present study was assisted by sample availability in the herbarium. The comparison between the previous checklist and the diversity of *Korthalsia* spp. informs on their population coverage in low altitude (<1,000 masl) dipterocarp forests (Stiegel et al. 2011; Thonhofer et al. 2015). This similar forest could also host different types of rattan (Rozali et al. 2014). In another scenario, rattan from the *Calamus* group was discovered at 800-2,000 masl (Nfornkah et al. 2022). Moisture may have a role in rattan distribution in the forest and perhaps play an important role in diversity (Dransfield 1979). Since *Korthalsia* sp. was also influenced by moisture, only certain species could tolerate forest conditions above 1,000 masl (Maarif et al. 2021; Atria et al. 2023). Therefore, *Kortalsia* becomes rich instead of being diverse with altitude. This accounts for the increased diversity in lowlands and richness only for certain *Korthalsia* sp. in highland areas (Dransfield 1979; 1984; 1992; Dransfield and Manokaran 1994; Rozali et al. 2014; Rozali et al. 2021). Therefore, allopatric diversity caused by moisture could be responsible for local and geographical rattan species separations, which means the clustering climbing palms like *Korthalsia* sp. were thought to become exclusive from North to South of Peninsular Malaysia and Borneo (Sabah and Sarawak) (Lim et al. 2022).

However, the diversity of *Korthalsia* was similar from East to West on the same region matrices, indicating phototaxis sensitivity. This behavior is not only limited to *Korthalsia* but generally applies to several tropical rattans (Jasni et al. 2017) and bamboo species (Huang 2021). Some rattan species are light-demanding (Couvreur et al. 2013) and prefer environments with high light intensity (Rozali et al. 2017; Campbell et al. 2017). Thus, each rattan individual can easily reach higher light intensities (Stiegel et al. 2011; Thonhofer et al. 2015). On this account, the rattan genus *Korthalsia* has widespread occurrences from the West compared to the East Malay peninsula, giving rise to identical yields on the same latitude. For instance, the diversity of *Korthalsia* from Perak appeared to be more similar to those in Selangor; likewise, *Korthalsia* species

from North Sabah forests are identical to those in the West coasts of Sabah (KD and WCD). Likewise, the northern sections of Sarawak share almost identical species of *Korthalsia* with South sections of Sabah.

The crucial strength of this study is the coverage area for the ability to attain insights into species richness between the explored localities. Many studies have gained data accuracy by reattempting their visits and increasing the sampling efforts. Despite recording the number availability of endemic and unique species is much lower than the sum of *Korthalsia* recorded between localities, the reliability of sampling effort is a strength that is better achieved than past attempts (Dransfield 1979; 1984; 1992). Increasing the coverage areas by including Peninsular Malaysia and Borneo makes the present finding most recent and answerable to information gaps past studies could not resolve. In this manner, attaining a new record for *K. hispida* in Penang (Bukit Panchor Forest Reserve) (Rozali et al. 2017) indicated that *Korthalsia* is, in fact, diverse in Peninsular Malaysia and *K. hispida* is not limited to Southern sections of Peninsular Malaysia but has extended the northward distribution in Malay peninsula. This finding highlights the importance of expanding survey coverage to uncover new distributions and further explore the potential for discovering new species within the rainforests of Malaysia. However, further study is needed to confirm their finding.

The study by Watanabe and Suzuki (2008) showed that rattan inhabits any altitude of the forested habitat, from the lowland to the mountainous region. Thus, to obtain a better picture of the numbers of *Korthalsia* throughout Peninsular Malaysia plus Sabah and Sarawak (Borneo), gathering more information on clustering climbing palms (rattans) is only possible when sampling across altitudinal (Stiegel et al. 2011; Rozali et al. 2014; Rawal et al. 2018; Sekar et al. 2023) and latitudinal (Shi et al. 2014; Cuesta et al. 2017) were conducted. In this case, the discovery of *K. scortechinii* was reported from Peninsular Thailand in this study collected from Narathiwat, Thailand, and it was deposited to Kew herbarium (Accession No. Niyomdham & Puudjaa 6446) narrowed down past perceptions for its limited availability to Thailand. The discovery *of K. scortechinii* in northern sections of Peninsular Malaysia affirms that this species is also occurring in Malaysia. The discovery supports endemism, in which some rattan species have wide distribution while the majority could be restricted to certain localities (Weidelt 1992; Joshi et al. 2017; Dev et al. 2019). Therefore, the presence of this species in Peninsular Thailand is expected. However, we did not include this data in the analysis.

In conclusion, Malaysia is home to 18 species of *Korthalsia*, but low similarities indicate completely different lineages between species in the Malay peninsula and Borneo (Sabah and Sarawak). Also, most rattan occupies between lowland areas and hill slopes, and none are available in mountainous regions. The availability of a new record, *K. hispida*, is an almost completely developed island (Penang), implying the need for extensive surveys to improve reporting coverage. Hence, the construction of checklists and the distinguishing *Korthalsia* identity reduced the mismatched perceptions of their limited distribution in Malaysia. Further increased sampling efforts may add more species but not drastically increase. Overall, rattan species richness of the genus *Korthalsia* in this region may be higher than it was reported in this study, but more efforts are needed to sample previously unexplored localities in the Malay peninsula, Sabah, and Sarawak that may lead to increased species richness of this species. It is hoped that increased efforts are possible so that the biodiversity of rattan in Malaysia can be accurately projected for sustainable reforms of fragmented forests amidst globalization efforts through the Convention of Biological Diversity and the National Biological Diversity Programme of Malaysia. Perhaps in the next attempt, a comparison between forest conversion and fragmentation statistics would be integral to explaining the disparity between species richness of *Korthalsia* species in Malaysia and elsewhere throughout Southeast Asia.

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