RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
55 (3) 927-939, 2023
http://doi.org/10.54910/sabrao2023.55.3.27
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

DIVERSITY OF PITCHER PLANTS (*NEPENTHES* SPP.) IN RIAU ARCHIPELAGO PROVINCE, INDONESIA

FITMAWATI*, SARTIKA, and E. JULIANTARI

Department of Biology, Faculty of Mathematics and Natural Sciences, Riau University, Pekanbaru, Indonesia
*Corresponding author's email: fitmawati2008@yahoo.com
Email addresses of co-authors: tikasartika758@gmail.com, erwinajuliantari24@gmail.com

SUMMARY

Nepenthes spp. is a unique carnivorous plant with the modified leaf lamina as a pitcher to trap insects. *Nepenthes* usually produce lower traps near the base of the plant, and upper pitchers form a loop in the tendril, allowing it to wrap around the nearby plant. Pitcher plants, being insectivorous plants, can grow in nitrogen-deficient soils. In the Riau Archipelago Province, the intense land conversion to establish ecotourism in national parks disturbed the pitcher plant habitat, even though the pitcher plants have great potential as ornamental plants. Therefore, for in situ conservation, the existing endemic flora may benefit tourist attractions to support local ecotourism efforts. Based on the above discussion, the presented study aimed to characterize the pitcher plants' diversity and analyze the relationship among its species using morphological markers in the islands of Bintan, Karimun, and Lingga, Indonesia. Based on the collection and identified pitcher plants, the study discovered that the genus *Nepenthes* comprises 25 accessions belonging to six different species, i.e., *N. gracilis, N.* × *trichocarpa, N. reinwardtiana, N. ampullaria, N. rafflesiana,* and *N.* × *hookeriana.* The cluster analysis grouped two main clusters that have a similarity coefficient of 31%–97% based on morphological characteristics among Bintan, Karimun, and Lingga accessions. However, the cluster constructions were more on the traits' similarity than locality based. For principal component analysis (PCA), 19 morphological traits can benefit as diagnostic features to distinguish the pitcher groups. The study revealed that pitcher plants have diverse phenotypic plasticity in the Riau Archipelago, which is experiencing land conversion for tourism activities. The pitcher plants diversity has the genetic potential for ornamental plants development and is a biological wealth that requires conservation for research, tourism activities, and future generations.

Keywords: *Nepenthes* spp., pitcher plants, genetic diversity, morphological characters, cluster analysis, principal component analysis, Riau Archipelago

Key findings: Pitcher plant exploration transpired on three large islands (Bintan, Karimun, and Lingga) of the Riau Archipelago, with ongoing development as tourist centers. The existing diversity of the pitcher plants is a biological wealth and has the potential to flourish as ornamental plants through in situ conservation to support research and tourism activities..

Citation: Fitmawati, Sartika, Juliantari E (2023). Diversity of pitcher plants (*Nepenthes* spp.) in Riau Archipelago Province, Indonesia. *SABRAO J. Breed. Genet.* 55(3): 927-939. http://doi.org/10.54910/sabrao2023.55.3.27.

Communicating Editor: Dr. Quaid Hussain

Manuscript received: March 20, 2023; Accepted: May 28, 2023.

INTRODUCTION

Nepenthes spp. is a typical plant of Southeast Asia, especially Indonesia, which has a special leaf modification called a pitcher. *Nepenthes* is a genus of carnivorous plants in the monotypic family Nepenthaceae, also known as tropical pitcher plants. The genus includes about 170 species and numerous natural and cultivated hybrids (Christenhusz and Byng, 2016). They are mainly liana-forming plants of the Old World tropics, ranging from South China, Indonesia, Malaysia, and the Philippines; westward to Madagascar (two species) and Seychelles (one species); southward to Australia (four species) and New Caledonia (one species), and northward to India (one species) and Sri Lanka (one species). The highest diversity also occurs on the Southeast Asian islands of Borneo and Sumatra, Indonesia, and the Philippines, with many endemic species (Buch *et al*., 2015; Lestari *et al*., 2018). However, 85 species of pitcher plants exist in Indonesia (Cheek and Jebb, 2001; Bunawan *et al*., 2017). Recent research showed that in Indonesia, the highest diversity of *Nepenthes* was in Sumatra, with 34 species, 29 of which are endemic (Akhriadi *et al*., 2004; Akhriadi *et al.,* 2009), and 22 species in Kalimantan, 15 of which are endemic (Clarke, 2001, 2002).

Nepenthes is also classified as a protected plant because its population continues to decrease in its natural habitat. In Indonesia, 53 species of pitcher plants are grown, with 27 species threatened with extinction, according to IUCN Red List data (IUCN, 2013). Moreover, IUCN stated the conservation status of *N. tentaculata* is in threatened status, *N. rajah* and *N. Khasiana* are in the list of CITES Appendix I, and the other species, such as *N. ampullaria*, *N. reinwardtiana*, and *N. sumatrana* are in Appendix II. Based on the Government Regulation of the Republic of Indonesia dated 07 November 1999, concerning the preservation of plant and animal species, the genus *Nepenthe* species are under protection in their natural habitat (Dino *et al*., 2016).

The pitcher plants can come in various beautiful shapes, sizes, and color shades (Mardianto *et al.,* 2016). The plant pitcher functions as a trap for insects and several other species of small animals (Khalid et al. 2015). Its features are a basis for distinguishing the species of *Nepenthes*, as the flowers and fruits relatively do not exhibit distinctive characteristics (Moran and Clarke, 2010, 2011; Rizqiani *et al*., 2018).

The pitcher plants can grow in nutrient-deficient habitats (marginal areas) to balance the ecosystem (Gaume *et al*., 2016; Dino *et al*., 2016). It can exist in six major habitat types: tropical lowland evergreen rainforests, heath forests, peat swamp forests, mountain forests, and limestone forests (Clarke, 2001, 2002). Pitcher plants can associate with marginal soils and cannot produce pitchers outside their natural habitat. The pitcher plants grow in substrates deficient in nitrogen and offset their N deficiency by trapping animal prey, primarily arthropods (Moran and Clarke, 2010, 2011).

Riau Archipelago Province is a tropical region of Sumatra, Indonesia, with various vegetation which can develop tourism (Fitmawati *et al*., 2020, 2021). These islands have heath vegetation in forests and low mountains. Low mountain forests generally have unique plant species, partially due to diverse vegetation, high humidity, and temperature. The Bintan, Karimun, and Lingga islands can also benefit as tourist areas. Large-scale land clearing is unavoidable, which will eventually cause genetic erosion of plants on the island, including pitcher plants. The development of pitcher plants can be in the form of in-situ protected park plants for tourist attraction. Thus, it is necessary to conduct an inventory of *Nepenthes* spp. in various regions

in Riau Archipelago because progressive land clearing can damage the habitat and existence of *Nepenthes*.

Previous research recorded the genetic diversity in pitcher plants in Batam Island, Riau Archipelago, and identified five species, i.e., *N. rafflesiana, N. gracilis, N. ampullaria, N. trichocarpa*, and *N.* × *hookeriana,* where two species (*N. trichocarpa* and *N.* × *hookeriana*) came about through natural crossing (Syamsi and Destaria, 2017). The population of pitcher plants was relatively large, and apparently, more species may still need identification.

Morphological characters of the *Nepenthes* spp. can help to investigate the phenotypic variations and group the species based on the morphometric method (Selviana *et al*., 2018). The morphometric method aids in determining the variations among the species using morphological measurements like length, width, and measuring other plant parts, i.e., stems, branches, leaves, flowers, and fruits (Chin *et al*., 2010; Chitwood and Otoni, 2017; Henzlinger *et al*., 2018). Therefore, it is intently needed to explore, identify, and characterize pitcher plants' morphological characteristics using a numerical taxonomic approach and.

The presented study aimed to identify and characterize the genetic diversity and analyze the kinship relationship among the *Nepenthes* spp. via numerical and morphometric analysis using the morphological traits and to determine the appropriate conservation strategies to maintain *Nepenthes* diversity in deforested areas of the Bintan, Karimun, and Lingga islands, Riau, Indonesia. The study findings are to become a database of protected plants in the form of an in-situ natural tourist park for pitcher plants, which has the potential to convert into a new tourist attraction and support forest areas in these islands.

MATERIALS AND METHODS

Study location and plant material

Nepenthes spp. collection proceeded from three islands in Riau Archipelago Province, i.e., Bintan (Subdistricts of Teluk Sebong, Toapaya, and Serikuala Lobam), Karimun (Subdistricts of Karimun and Tebing), and Lingga (Subdistricts of Lingga and North Lingga) (Figure 1). The exploration revealed a *Nepenthes* collection comprising 25 accessions procured from three islands in the Riau Archipelago belonging to six *Nepenthes* spp. (Table 1).

Morphological Identification and data analysis

The identification process was by recording observations based on morphological traits of stems, leaves, and pitchers of *Nepenthes* spp., according to the Guidebook entitled "Pitcher Plants of Peninsular Malaysia" (Cheek and Jebb, 2001). The data matrix helped calculate the Simple Matching (SM) similarity coefficient.

Table 1. *Nepenthes* species found at the research site.

No.	Species	Types	Islands, Riau Archipelago, Indonesia		
			Bintan	Karimun	Lingga
1.	*N. ampullaria* Jack	Wild	2	1	2
2.	*N. gracilis* Korth.	Wild	2	2	2
3.	*N.* × *hookeriana* H. Low	Hybrid	1	1	1
4.	*N. rafflesiana* Jack	Wild	2	1	2
5.	*N.* × *reinwardtiana* Miq.	Hybrid	-	-	2
6.	*N. trichocarpa* Miq.	Wild	2	1	1
	Total accessions		9	6	10

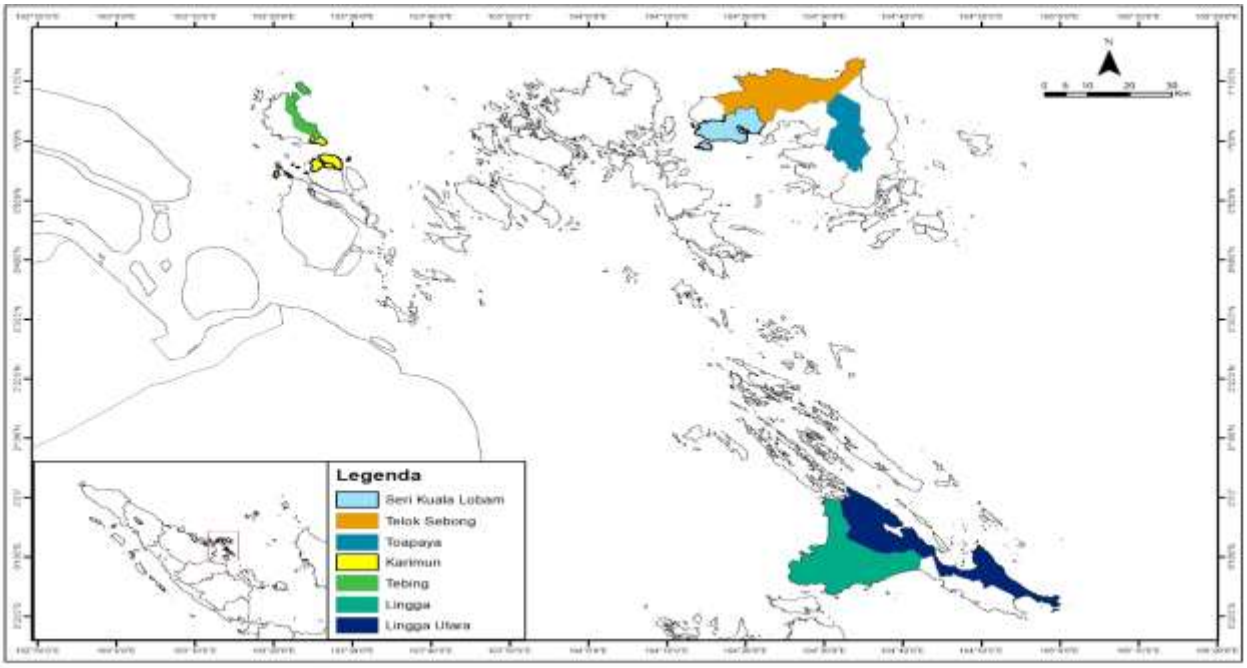

Figure 1. The study area map.

The SM similarity coefficient was the basis for constructing a dendrogram using the sequential agglomerative hierarchical and nested clustering (SAHN) analysis with the unweighted pair group method with arithmetic average (UPGMA) through the Numerical Taxonomy and Multivariate Analyses System for PC (NTSys- PC) version 2.1.1a (Exeter Software, New York) (Rohlf, 2000). Performing the principal component analysis (PCA) was with the Minitab 19 program.

RESULTS

Diversity of *Nepenthes*

The exploration results revealed that 25 accessions belonged to the six species of *Nepenthes,* i.e., *Nepenthes gracilis*, *N. ampullaria*, *N. rafflesiana, N.* × *trichocarpa*, *N.* × *hookeriana,* and *N. reinwardtiana* collected from three islands of the Riau Archipelago Province, Indonesia. The identification key for six species of *Nepenthes* based on morphological observations is in Table 2.

Nepenthes gracilis Korth.

In the species *N. gracilis*, the stems were climbing, triangular, glabrous, green to purplish red, with a diameter of up to 0.4 cm and short internodes of up to 1.9 cm. Leaves are sessile, lanceolate, 10–10.9 cm × 0.8–2.4 cm, acuminate at the apex, glabrous, green, and a red mother leaf. The tendrils were 0.9–2.7 cm long, light green, and glabrous. The lower pitcher is cylindrical with a waist 3.2 cm high and green-reddish spotted green; oval mouth, 0.3 cm thick; peristome - thin, small, green; and Lid-ovate, green-reddish, glabrous, glandular crest 1, and green to black. The upper pitcher is cylindrical with a waist 11.2 cm high, green-reddish spotted green; oval mouth, 0.04 cm thick; peristome - thin, small, green; lid - ovate, green-reddish, glabrous, glandular crest 1, and green to black. The species *N. gracilis* exists in Bintan, Karimun, and Lingga islands and has two variations, i.e., red and green. The pitcher of *N. gracilis* appears in Figure 2a.

Table 2. The key to the identification of six species of *Nepenthes* based on morphological observations.

1.	a. Stems triangular, internodes short	*N. gracilis*
	b. Stems cylindrical, internodes long	2
2.	a. Leaves sessile	3
	b. Leaves petiolate	4
3.	a. Pitchers upper cylindrical, lower urceolate	*N. × trichocarpa*
	b. Pitchers upper cylindrical with waist, lower cylindrical with waist	*N. reinwardtiana*
4.	a. Lid hairy, glandular crest 4	*N. ampullaria*
	b. Lid glabrous, glandular crest 1	5
5.	a. Pitchers red with green spots, mouth oval, thin	*N. rafflesiana*
	b. Pitchers green with red spots, mouth elliptic, thick	*N. × hookeriana*

Figure 2. Diversity of *Nepenthes* spp. a). *N. gracilis*, b). *N. × trichocarpa*, c). *N. reinwardtiana,* d). N. *ampullaria*, e). *N. rafflesiana,* and f). *N. × hookeriana*.

***Nepenthes* × *trichocarpa* Miq.**

In the species *Nepenthes* × *trichocarpa*, the stems were climbing, cylindrical, glabrous, green to purplish red, with a diameter of up to 0.7 cm, trichomes absent, and internodes' length was up to 3.6 cm. Leaves were sessile, lanceolate, 9–14 cm × 0.5–3.3 cm, acuminate at the apex, glabrous, green, with a green mother leaf and no trichomes. The tendrils were 2.6–9.6 cm long, light green, and glabrous. The lower pitcher is urceolate (urn-shaped) up to 5.2 cm high, green spotted purplish red; oval mouth, 0.3 cm thick; peristome - thick, small, green-reddish; lid - ovate, green-reddish, glabrous, glandular crest 1, and brown. The upper pitcher is cylindrical up to 7.5 cm high, green spotted purplish red; oval mouth, 0.2 cm thick; peristome - thick, small, green-reddish; lid – an ovate, green, hairy, pitcher with its center shrinks downward, glandular crest 1, and brown. The species *N. trichocarpa* was prominent in the Bintan island, with two variations (plain green and patterned green), and in Karimun and Lingga Islands, one distinction each (plain green and spotted green, respectively). Illustrations of the pitcher shape of *N.* x *trichocarpa* is in Figure 2b.

***Nepenthes reinwardtiana* Miq.**

The species *N. reinwardtiana* had stems climbing, cylindrical, glabrous, and green, with a diameter up to 0.5 cm, trichomes absent, and internodes long up to 5 cm. Leaves were sessile (petiole absent), lanceolate, 12.2–15.6 cm × 1.9–2.4 cm, acuminate at the apex, glabrous, green, and a green mother leaf with no trichomes. The tendrils were 5.7–-13.2 cm long, light green, and glabrous. The lower pitcher is cylindrical with a waist 10.7 cm high, green; oval mouth, 0.2 cm thick; peristome - thin, small, green-yellowish; lid - ovate, light red, glabrous, glandular crest 1, and brown. The upper pitcher is urceolate (urn-shaped) at 11.8 cm high, green to purplish red; ellipse mouth, 1.2 cm thick; peristome - thick, small, purplish red spot green; lid - ovate, light red, glabrous, pitcher center with waist, glandular crest 1, and brown. The species *N. reinwardtiana* is available in Bintan, Lingga, and Karimun islands and has one variation of green patterns. The pitcher of *N. reinwardtiana*description shows in Figure 2c.

***Nepenthes ampullaria* Jack**

In the species *N. ampullaria,* the stems were climbing, cylindrical, hairy, and green, with a diameter up to 0.8 cm, trichomes present, and internodes were 4.5 cm long. The leaves were petiolate up to 1.5 cm long, obovate-spatulate, 15–18.8 cm × 2.1–4.3 cm, obtuse at the apex, hairy, green, a green-yellowish mother leaf, with no trichomes. The tendrils were 2.4–7.2 cm long, light green, and glabrous. The lower pitcher is infundibulate (funnel-shaped), 4.8 cm high, green-spotted, purplish-red; ellipse mouth, 0.6 cm thick; peristome - thick, large, green; lid - ovate, green, hairy, glandular crest 4, and green to black. Upper pitchers are infundibulate, 5.2 cm high, green-spotted, purplish-red; ellipse mouth, 0.4 cm thick; peristome - thick, large, green; lid - ovate, green, hairy, with pitcher's center rounded, glandular crest 4, and green to black. The species *N. ampullaria* was widespread on the Bintan and Lingga islands, with two variations, i.e., plain green and spotted green, and on Karimun Island, but only with one variation (plain green). Figure 2d displays the pitcher of *N. ampullaria*.

***Nepenthes rafflesiana* Jack**

For the species *N. rafflesiana,* the stems were climbing, cylindrical, glabrous, and green, with a diameter up to 0.7 cm, absent trichomes, and internodes were 7.6 cm long. The leaves were petiolate up to 1.5 cm long, lanceolate, 18.7–28.7 cm × 3.8–4.7 cm, acute at the apex, glabrous, green, a green-yellowish mother leaf, with no trichomes. The tendrils were 22.8–24.2 cm long, green-yellowish, and glabrous. The pitcher is lower cylindrical, 15.2 cm high, green to red spotted green to purplish red; oval mouth, 1.2 cm thick; peristome - thick, large, green-reddish; lid - ovate, green-reddish, glabrous, glandular crest 1, and purplish-red. Pitchers are upper urceolate (urn-shaped), 25 cm high, green-spotted, purplish-

red; oval mouth, 0.7 cm thick; peristome - thick, small, green-reddish; lid - ovate, green, hairy, pitcher's center shrinks downward, glandular crest 1, and brown. The species *N. rafflesiana* was frequent on the Bintan and Lingga Islands, with two variations, i.e., plain green and patterned. Karimun Island only has one variant (plain green). The pitcher of *N. rafflesiana* illustrations is in Figure 2e.

***Nepenthes* × *hookeriana* H.Low**

In the species *N.* x *hookeriana*, the *s*tems were also climbing, cylindrical, hairy, and green, with a diameter up to 0.7 cm, present trichomes, and long internodes up to 5 cm. The leaves were petiolate up to 3.4 cm long, obovate, 9.7–18.7 cm × 3.6–4.2 cm, obtuse at the apex, hairy, green, a green mother leaf, and with trichomes. The tendrils were 8.5–10.7 cm long, light green, and glabrous. The pitcher is lower infundibulate (funnel-shaped), 10.3 cm high, green-spotted green to purplish-red; ellipse mouth, 0.7 cm thick; peristome - thick, large, purplish-red spot green; lid - ovate, green-reddish, glabrous, glandular crest 1, and purplish-red. The pitcher is lower cylindrical, 11.8 cm high, green to purplish-red; ellipse mouth, 1.2 cm thick; the peristome is thick, small, purplish-red spot green; the lid is ellipsoid, green, glabrous, pitcher's center shrinks downward, glandular crest 1, and purplish-red spot green. The species *N.* x *hookeriana* flourishes on Bintan, Lingga, and Karimun islands, with one variation (green patterned). Figure 2f exhibits the pitcher of *N.* x *hookeriana*.

Cluster analysis of *Nepenthes* spp.

Cluster analysis, based on 88 morphological characters of 25 accessions of *Nepenthes* collected from Bintan, Karimun, and Lingga islands, resulted in a dendrogram with similarity coefficients ranging from 0.31% to 0.97% (Figure 3). The lowest coefficient occurred between *N. reinwardtiana* (Nre2) and *N. ampullaria* (Nam2) species. However, the highest coefficient (0.97) appeared between the species of *N. gracilis* (Ngr5 and Ngr4).

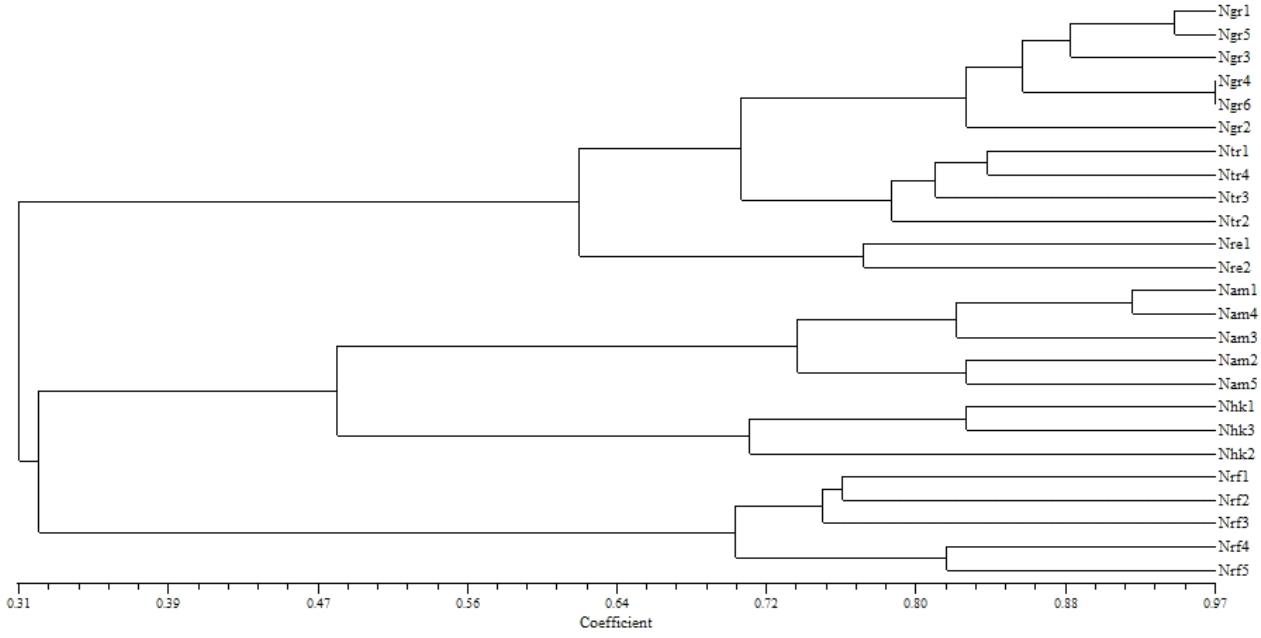

Figure 3. Dendrogram of 25 *Nepenthes* accessions in the Bintan, Karimun, and Lingga islands, Riau, Indonesia. Nam: *N. ampullaria*; Ngr: *N. gracilis*; Nhk: *N.* × *hookeriana*; Nrf: *N. rafflesiana*; Nre: *N.* × *reinwardtiana*; and Ntr: *N. trichocarpa.*

Based on the dendrogram, *Nepenthes* landraces divide into two main groups (I and II) at a similarity coefficient of 31%. Group II further subdivides into two subgroups (IIA and IIB). The separation of group I and group II was due to differences in morphological traits, i.e., the presence of leaf petiolate or sessile, thickness and apex leaves, the shape of pitchers, peristome and lid, and mouth thickness.

Group I clustered at a coefficient of 61%, consisting of 12 *Nepenthes* accessions of the species *N. gracilis* (Ngr1, Ngr5, Ngr3, Ngr4, Ngr6, and Ngr2), *N.* × *trichocarpa* (Ntr1, Ntr4, Ntr3, and Ntr2), and *N. reinwardtiana* (Nre1, and Nre2). These *Nepenthes* accessions' clustering refers to several morphological characteristics' similarities, i.e., smooth stem texture, lanceolate leaf, no trichomes on leaves, thin leaves, sessile (no petioles), acuminate leaf, oval mouth at 0.01 to 0.03 cm thick, thin and small peristome, and lid ovate. Group IIA clustered at a coefficient of 48% consisting of eight accessions of the species *N. ampullaria* (Nam1, Nam4, Nam3, Nam2, and Nam5) and *N.* × *hookeriana* (Nhk1, Nhk3, and Nhk2). These *Nepenthes* landraces clustered based on several similarities in morphological traits, i.e., hairy trichomes on the stem and leaves and tendrils, lower pitcher infundibulate (funnel-shaped), lower pitcher's mouth is oval, wingspan 0.1 to 1.4 cm, the lid of an upper pitcher is hairy, 1.5 to 3.3 cm long. Group IIB clustered at a coefficient of 70%, consisting of five accessions of the species *N. rafflesiana* (Nrf1, Nrf2, Nrf3, Nrf4, and Nrf5). These *Nepenthes* landraces' clustering was due to several morphological traits' similarities, i.e., long internode, no trichomes, petiolate, the pitcher is lower cylindrical, oval mouth, lid ovate, the shape of the lower pocket cover is ovate, and the pitcher's center shrinks downward.

Principal component analysis

The principal component analysis (PCA) helps to reduce a set of original characters to a new attribute without eliminating any vital information by selecting the eigenvector of the eigenvalue. Morphological characteristics analysis used PCA to determine the grouping pattern based on the traits obtained, bringing up the distribution of data from each accession in the form of plots and providing an overview of the influence of the percentage of the diversity value of several main components (Sebola and Balkwill, 2013).

The PCA results showed that out of 88 characters, 19 traits received mapping into two main components, namely, PCI and PCII, with a cumulative percentage of 70.5% (Table 3). The type of grouping of *Nepenthes* accessions based on PCA shows a similar pattern to the results of grouping based on the dendrogram at a similarity coefficient of 31%–97%. The attribute that becomes the first principal component was selected based on the feature vector value >0.1. The feature vector value indicates the correlation coefficient and distribution of 88 characters in PCI and PCII.

In the principal component I, 17 morphological characteristics affect the diversity of the pitcher plants, i.e., stem shape**;** lower pitchers' shape and length; mouth thickness, length, and width; peristome shape; lid shape, width, and length; wings width, and upper pitchers' peristome shape. Meanwhile, component II has better morphological traits, i.e., stem texture, lamina shape, petiolate, mother leaf texture, lower pitchers' lid color, and upper pitchers' lid texture. These 15 morphological features can benefit as diagnostic traits to distinguish between the collection groups (Figure 4). According to Arslanoglu *et al*. (2011), the highest genetic diversity due to positively contributing morphological traits can better serve the selection of crossbred elders to obtain new superior cultivars with desirable morpho-agronomic traits.

Table 3. Principal component analysis based on morphological and morphometric traits of *Nepenthes* spp.

No.	Characters	PCI	PCII
1	Stems texture	0.054	-0.190
2	Stems shape	0.110	-0.082
3	Lamina shape	0.069	-0.143
4	Petiolate	-0.126	0.171
5	Mother leaf texture	0.054	-0.190
6	Lower pitcher shape	0.138	0.129
7	Lower pitcher length	0.156	0.119
8	Lower pitcher mouth thickness	0.174	-0.003
9	Lower pitcher mount long	0.163	0.066
10	Lower pitcher mount width	0.158	0.110
11	Lower pitcher peristome shape	0.179	0.018
12	Lower pitcher lid shape	0.179	0.018
13	Lower pitcher lid color	0.099	0.165
14	Lower pitcher lid width	0.157	0.116
15	Lower pitcher lid length	0.156	0.108
16	Lower pitcher wings width	0.148	0.122
17	Upper pitcher shape	0.102	-0.046
18	Upper pitcher peristome shape	0.141	-0.107
19	Upper pitcher lid texture	0.054	-0.190

PCI = Principal component I, PCII = Principal component II.

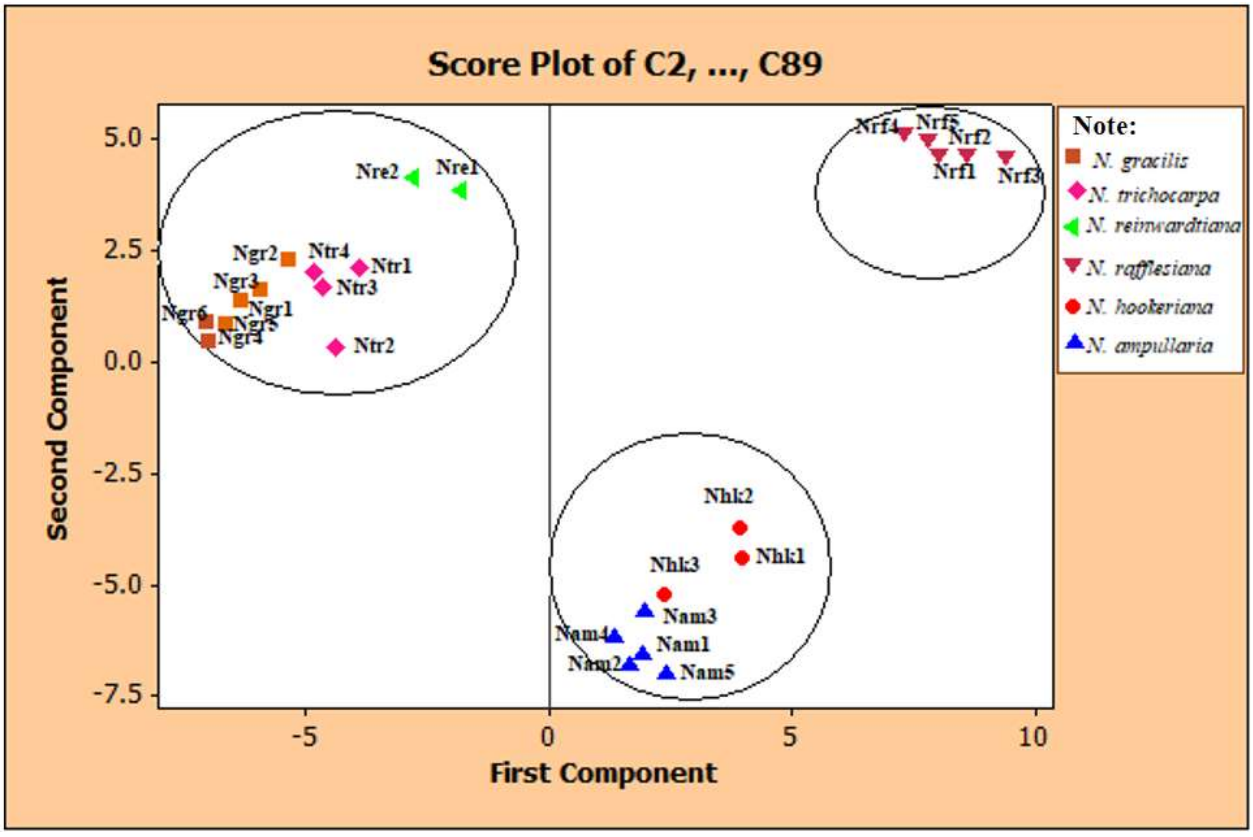

Figure 4. Principal component analysis of 25 *Nepenthes* accessions in Bintan, Karimun, and Lingga islands based on morphological and morphometric markers mapped on two principal component axes.

DISCUSSION

Nepenthes spp. is a plant with varied pitcher shapes and colors, making them unique. The shape and color of each species are different, serving an essential character for identifying the members of the family Nepenthaceae as the pitchers, which is a modification of the leaf apex (Ginting and Jalillah, 2017; Dančák *et al*., 2022). The exploration results of the 25 accessions of the *Nepenthes* collected from three islands of the Riau Archipelago Province belong to six different species, i.e., *Nepenthes gracilis*, *N. ampullaria*, *N. rafflesiana, N.* × *trichocarpa*, *N.* × *hookeriana,* and *N. reinwardtiana*. *Nepenthes* spp. bloom in open-area habitats (Lingga Island), secondary forests and shrubs (Bintan Island), and low mountains (Karimun Island). Previous research found five species of pitcher plants on Batam Island, Riau Archipelago, namely, *N. rafflesiana, N. gracilis, N. ampullaria, N. trichocarpa*, and *N.* × *hookeriana* (Syamsi and Destaria, 2017).

The species *N. reinwardtiana* has a narrow distribution area, occurring only in open areas of Lingga Island with full sunlight intensity, with this species also found by Hariyadi (2013) in the same habitat. *N. reinwardtiana* has low adaptability to environmental conditions, while the other five species showed in various habitat types, i.e., open, shaded, and mountainous areas. The five species are lowland *Nepenthes* that are in demand because of their highest growth rate, tolerant to various abiotic stress conditions, and easily accessible in many locations, thus, the potential for cultivation. The presented study also revealed that *N. gracilis* had a wide distribution compared with other *Nepenthes*. The *N. gracilis* grows attached to the trunk and branches of nearby trees, and some live terrestrially above the ground.

Most crop plants need nutrients to grow and thrive; however, it is not the case with the pitcher plant. The said plant can even grow in nutrient-deficient areas, such as, beaches and limestone mountains to dense forests (Khairil, 2015; Maysarah *et al*., 2017), lowlands and highlands (Yudaputra, 2021), shady cliffs of sandstone hills (Hernawati *et al*., 2022), dry vegetation (Idham *et al*., 2015), open forest vegetation (Sintaro *et al*., 2017), and peat swamps (Hariyadi, 2013). The *Nepenthes* spp. is also resistant to nutrient stress conditions because it has pitchers that produce and provide nutrient reserves. The pitchers serve as a tool to fulfill the lack of nutrient supply, especially nitrogen and phosphorus (Morohoshi *et al.*, 2011).

Overall, there are two types of *Nepenthes* spp. found at the research site, wild and hybrid species. The four are wild species, i.e., *N. gracilis, N. ampullaria, N. rafflesiana,* and *N. reinwardtiana*, and the two are cross-species, i.e., *N.* × *trichocarpa* and *N.* × *hookeriana*. The three species, viz., *N. ampullaria, N. gracilis,* and *N. reinwardtiana,* were reported with hybrids and supposedly allowed crossing among them. The species *N.* × *trichocarpa* is a natural hybrid between *N. gracilis* and *N. ampullaria*, which has a lower pitcher shape similar to *N. ampullaria* and a thin mouth shaped like *N. gracilis*. Likewise, the species *N.* × *hookeriana* is also a natural hybrid between *N. ampullaria* and *N. rafflesiana,* with a pitcher shape similar to *N. rafflesiana* and a mouth shaped like *N. ampullaria* (Meriko, 2012).

This recent study used two approaches for identifying and characterizing *Nepenthes* spp., i.e., numerical and morphometric analyses based on various morphological traits. The numerical method helped prepare classification based on kinship relationships, especially on the similarities of phenotypic features (Shukla and Misra, 1982; Tong and Nikoloski, 2021). The morphometric method determined the variation of a species by measuring the length and width and observing the measurement of plant body parts (Selviana *et al*., 2018).

The principal component analysis formed the same main groups based on the dendrogram, with the grouping not based on the origins of the species. It is possible because *Nepenthes* spp. show a wide range of tolerance, and the differences in the origin geography do not show grouping based on the origins. According to Mansur (2006), *Nepenthes* spp. can live in lowland tropical rainforests, mountain, peat, and kerangas

forests, limestone mountains, savannas, and lakes. Factors that influence these differences in distribution are light, wind, temperature, water availability, and soil organic matter. Thus, the same species appear in different locations.

The pitcher plants' population continues to decline in nature due to forest fires, mining (gold and coal), forest conversion to agricultural sites, land plantation, and overexploitation of pitcher plants for commercial purposes. Therefore, developing endemic flora for tourist attraction is a good prospect and an in-situ conservation effort for pitcher plants. In-situ conservation needs immediate implementation using domestication through cultivation and breeding mechanisms to remain sustainable, considering that all *Nepenthes* spp. are protected in Indonesia. The presented study recorded many variations of the pitcher plants on the three islands in the Riau Archipelago, Indonesia, experiencing land conversion for tourism activities. The diversity of pitcher plants has the potential for ornamental and medicinal plant development, and it is a biological wealth that needs further exploration as the carrying capacity of the area, as well as, supporting research, conservation, and tourism activities.

CONCLUSIONS

The timely study concluded the discovery on Bintan, Karimun, and Lingga islands of 25 different accessions of *Nepenthes*, belonging to six species, i.e., *N. gracilis, N. ampullaria, N. rafflesiana, N. trichocarpa, N. hookeriana,* and *N. reinwardtiana*. The cluster analysis showed that the diversity of *Nepenthes* spp. on three islands ranged from 31% to 97%, forming two main groups based on morphological characteristics, and clusters were based on the similarity of attributes but not on the origins. Based on the principal component analysis, 19 morphological traits can benefit as diagnostic features to distinguish *Nepenthes* accessions.

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