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Review Article

A Decade of Discovering New *Nepenthes* Species in Southeast Asia: A Review

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ABSTRACT

Nepenthes is the largest genus of carnivorous pitcher plants, with the highest diversity in Southeast Asia, where an estimated 50,000 flowering plant species exist. The estimated plant diversity in this region continues to grow with the discovery of many new species in countries such as Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Singapore, Brunei Darussalam, Indonesia, Timor-Leste, the Philippines, and Papua New Guinea. Approximately 180 species of *Nepenthes* have been identified. The number of species in Southeast Asian countries is likely underestimated due to the lack of taxonomic research on groups with many local endemic species, suggesting that many new *Nepenthes* species remain unidentified. Therefore, this mini-review aims to reveal new *Nepenthes* species discovered in Southeast Asia over the past ten years. Data were collected from various journals, including Phytotaxa, Kalpataru, Philippine Journal of Science, Philippine Journal of Systematic Biology, Plants, Thailand Forest Bulletin, Phytokeys, Journal of Sustainable Natural Resources, Reinwardtia, Kew Bulletin, PeerJ, Carnivorous Plant Newsletter, Malayan Nature Journal, and Journal of Plant Taxonomy and Geography. The collected data were analysed based on the description of *Nepenthes* sp. nov., year of discovery, and distribution area. The identification of new species was based on differences in morphological, anatomical, and molecular characteristics. Thirty-seven new *Nepenthes* species were discovered in Southeast Asia in the past decade. These findings highlight the need for comprehensive surveys in understudied areas. Future efforts should combine molecular and ecological approaches to improve species discovery and guide conservation strategies addressing habitat loss and climate impacts.

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INTRODUCTION

Carnivorous plants have fascinated scientists and the general public since the pioneering studies of Charles Darwin. Carnivorous plants are defined as plants that have the ability to absorb decomposed prey products through their leaves or roots to enhance their growth or reproduction. The term holocarnivorous, or true carnivorous, refers to plants that can attract, capture, digest, and utilise the metabolic products for their own growth. For example, *Heliamphora* cannot supply the enzymes for insect digestion and requires the help of microbes in passive traps (Givnish 2015; Thorogood et al. 2018; Mithöfer 2022). There are five families that include carnivorous plants: Droseraceae (which contains three genera), Drosophyllaceae (with only one species), Dioncophyllaceae (with only one genus), Ancistrocladaceae, and Nepenthaceae (with only one genus) (Wójciak et al. 2023).

Nepenthes is a tropical climbing carnivorous plant commonly known as the pitcher plant and is one of the most intriguing groups of carnivorous plants to study in the field of botany. These plants grow singly or in groups in various habitats with nutrient-poor and easily assimilable substrates (Gaume et al. 2016; Setiawan et al. 2018; Mansur et al. 2021). *Nepenthes* belongs to the family Nepenthaceae and was first scientifically described by the French biologist Étienne Geoffroy Saint-Hilaire in 1802 (Bauer et al. 2016).

A distinctive feature that sets *Nepenthes* apart from other plants is its leaves, which have evolved into uniquely shaped pitchers that function to trap and digest insects and other small organisms (Buch et al. 2014). These pitchers typically contain enzymatic fluids that help digest the trapped prey. The modified leaves have several important parts, such as the lid, which prevents rainwater from entering the pitcher, the peristome or pitcher lip, which is slippery and ridged to prevent prey from escaping, and nectar glands that attract insects (King & Cheek 2020). When insects perch on the pitcher, they fall into the trap and are digested by the enzyme mixture in the pitcher fluid. Additionally, the fluid serves as a habitat for a diverse community of dipteran larvae, mites, bacteria, fungi, and protists, which can help the plant obtain nutrients such as nitrogen and phosphate (Buch et al. 2014; Gilbert et al. 2020).

The carnivorous traps of *Nepenthes* are passive, retaining digestive fluids within the pitchers and waiting for potential prey, distinguishing *Nepenthes* from the Drosera group, which has Venus flytraps capable of movement (Saganová et al. 2018). The morphology of *Nepenthes* is highly variable in terms of the size, shape, and colour of the pitchers. Some pitchers can exceed up to 30 cm in length, with striking colour variations ranging from green to red to purple. These adaptations allow *Nepenthes* to thrive in diverse habitats, including humid tropical rainforests and rocky mountainous regions with low soil nutrient content (Murphy et al. 2020).

Nepenthes has various ethnobotanical uses around the world. The boiled roots of *N. ampullaria* and *N. gracilis* are used to treat stomach aches by tribes in Malaysia, while their stems are used for fever and as construction materials due to their durability. The most common use is as a source of water for thirsty hikers (Miguel et al. 2018). The aqueous extract of *Nepenthes khasiana* acts as a reducing agent in the synthesis of gold nanoparticles from gold salts, thanks to its antioxidant phytochemicals. The resulting gold particles exhibit high stability and biocompatibility, making them ideal for diagnostic and drug delivery applications in the field of nanomedicine (Dhamecha et al. 2016).

Numerous valuable metabolites have been identified across various *Nepenthes* species. These molecules play a crucial role in the plants' environmental adaptation. The *Nepenthes* pitcher fluid is inhospitable to microbial growth, partly due to the presence of specialized antimicrobial metabolites. The most extensively documented molecule is plumbagin (5-hydroxy-2-methyl-1,4-

naphthalenedione), which significantly contributes to microbial inhibition in the pitcher fluid. Furthermore, this compound demonstrates diverse potential applications, including agricultural biocontrol, natural food preservation, and various medicinal benefits. Together with its derivatives such as droserone and 5-O-methyldroserone, plumbagin establishes *Nepenthes* as a highly promising source of bioactive compounds for multiple applications (Miguel et al. 2018). However, the *Nepenthes* genus faces severe population threats due to excessive illegal exploitation by collectors for commercial gain (Renjana et al. 2024).

Nepenthes is the genus of pitcher plants with the largest number of species. In 1980, 80 species were recognized; by 2001, this number had increased to 87 species, and by 2012, it had reached 139 species. To date, around 180 species of *Nepenthes* have been identified, with new species discoveries continuing (Setiawan et al. 2018; Mansur et al. 2020). Generally, the discovery of new species in the genus *Nepenthes* is based on the morphological characteristics of the pitchers. Pitchers are actually modified leaves that come in various shapes, sizes, and colors. The morphology of the pitchers has evolved to facilitate the plant's habits, aiding in adaptation and survival in nutrient-poor soils such as those low in nitrogen. Some studies also use the anatomy of *Nepenthes* as a tool for identifying new species (Huda et al. 2022).

Nepenthes is distributed in tropical regions, ranging from southern China, Indonesia, Malaysia, and the Philippines; westward to Madagascar with two species and the Seychelles with one species; southward to Australia with four species and New Caledonia with one species; and northward to India and Sri Lanka with one species. The highest diversity is found in Southeast Asia, particularly Indonesia, which currently hosts 85 species of *Nepenthes* (Fitmawati et al. 2023). Each new discovery enriches our understanding of biodiversity and evolution within this genus. New *Nepenthes* species are often found in remote and under-explored areas, highlighting the importance of ongoing botanical exploration. Recent discoveries in the past decade have increased the number of known species and demonstrate the dynamic process of diversification within this genus (Konwar et al. 2023). Additionally, many *Nepenthes* species face extinction due to a lack of public awareness, fires, and forest degradation. Therefore, reviews related to the presence of *Nepenthes* species are crucial to rekindle public interest in conserving these plants (Lestari et al. 2018).

Based on this statement, this article will discuss the discovery of new species of the genus *Nepenthes* found in Southeast Asia and published in the last 10 years. The results of this review article are expected to provide additional information for future research related to *Nepenthes*.

MATERIALS AND METHODS

This study was conducted at the Department of Biology, Airlangga University during May-June 2024. Data on newly described *Nepenthes* species from the last 10 years were collected from reliable sources. A total of 26 articles containing new species descriptions were identified from 14 scientific journals, including: Phytotaxa, Kalpataru, Philippine Journal of Science, Philippine Journal of Systematic Biology, Plants, Thailand Forest Bulletin, Phytokeys, Journal of Sustainable Natural Resources, Reinwardtia, Kew Bulletin, PeerJ, Carnivorous Plant Newsletter, Malayan Nature Journal, and Journal of Plant Taxonomy and Geography.

The journals were obtained from Google Scholar (https://scholar.google.com/) using the search keyword "new species of *Nepenthes*" with publication year filters set from 2014 to 2023. Google Scholar was selected as the search platform due to its broader and more comprehensive coverage of scientific literature compared to selective journal-based databases

like Web of Science or Scopus (Martín-Martín et al. 2018).

Furthermore, nomenclature validation was performed by accessing the Royal Botanic Gardens, Kew database (https://www.kew.org) to verify data completeness. When species names were not found in the database, additional literature searches were conducted using specific scientific names. All collected data were processed and analysed based on the following parameters: (1) geographical distribution, (2) describing authors, (3) identification methods, (4) discovery year, and (5) year of first formal publication using Microsoft Excel software (Brillo et al. 2024). New species were validated based on significant morphological differences, following taxonomic description criteria in the literature (Cheek & Jebb 2014; Cheek 2015; Cheek et al. 2015; Cheek & Jebb 2016a, 2016b; Cheek et al. 2018).

RESULTS AND DISCUSSION

Based on the first publication of the species, there are 37 new species of the genus *Nepenthes* distributed in Southeast Asia over the last ten years (2014-2023). The description of the new species can be seen in Table 1.

Table 1. Description of a new species in the genus *Nepenthes*.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
1.	*Nepenthes armin* Jebb & Cheek, sp. nov	Stems are climbing and rounded-rectangular in shape. There is no covering on the surface except for dense brown simple hairs in leaf axils. The leaves are thinly leathery, petiolate and either narrowly oblong or elliptic-linear in shape. The apex is acute or obtuse-rounded, and the base gradually tapers to the petiole. The upper pitchers are green with faint purple stripes and narrowly cylindrical with smooth indumentum hairs. The peristome is ovoid, the cap is orbicular, and the pitcher is curved.	Philippines	United Kingdom	Morphology	2007	Cheek & Jebb 2014
2.	*Nepenthes tboli* Jebb & Cheek, sp. nov.	Stem form terete; leaves spirally inserted; leaf blade oblong-elliptical; leaf margin hairy, young stems 50 % covered by indumentum; petiole with wings; upper midrib sub cylindrical; outer pitcher surface sparsely patterned with hairs simple; peristome ovate; cap ovate-elliptic; pitcher simple, needle-like, tapering to a point.	Philippines	United Kingdom	Morphology	1993	Cheek & Jebb 2014
3.	*Nepenthes zygon* Jebb & Cheek, sp. nov	Stems climb with internodes; rosette leaves are oblanceolate; climbing stem leaves have an acute tip and are not round; petiole is winged and U-shaped or broad V-shaped in section; leaf base blade curves into the petiole; lower pitchers (tendrils not coiled) are elliptic-cylindrical; peristome is ovate-elliptic; cap is orbicular-elliptic; basal cap appendages are strongly convex and conspicuous on the upper pitcher. Upper pitchers (circular tendrils) are ellipsoid-cylindrical.	Philippines	United Kingdom	Morphology	1997	Cheek & Jebb 2014

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
4.	*Nepenthes pantaronensis* Gieray, Gronem., Wistuba, Marwinski, Micheler, Coritico, V.B. Amoroso, spec. Nov.	The stem can reach up to 3 meters in length and is cylindrical in cross-section. The leaves on the bare stem are linear to oval with broad-winged petioles for climbing. Lower pitchers can grow up to 35 cm high and 6 cm wide, while upper pitchers can reach up to 40 cm long and 5 cm wide. The lower one-fifth to one-quarter of the trap is inflating and rounded, narrowing above this section before becoming cylindrical towards the pitcher opening. The inflorescences are panicles. Indumentum, consisting of orange-brown bristles up to 1 cm in length and up to 1 mm in width, is present throughout the foliage, inflorescences, and pitchers.	Philippines	Germany	Morphology	2012	Gronemeyer et al. 2014
5.	*Nepenthes cornuta* Marwinski, Coritico, Wistuba, Micheler, Gronem., Gieray, V.B.Amoroso, spec. nov.	The climbing stem can grow up to 3 meters long. The leaves on the stem have stems of their own and are long and narrow, with a pointed tip and a flared, finger-like base. The leaf's stem partly encloses the stem. The pitcher's opening is oval and can be up to 2.8 cm wide. The lower part of the pitcher is rounded, while the upper part is narrower. The lower third of the pitcher is swollen, and it tapers towards the tendril, giving it a distinctive horn-like shape. There are two flowering stalks in the inflorescence. The developing pitcher bud is covered with tiny and orange-brown hairs.	Philippines	Germany	Morphology	2012	Gronemeyer et al. 2014
6.	*Nepenthes talaandig* Gronem., Coritico, Wistuba, Micheler, Marwinski, Gieray, V.B.Amoroso, spec. nov.	The climbing stem can grow up to 8 meters long. The leaves of the climbing stem are elliptical, with four longitudinal veins evenly distributed on each side of the midrib and numerous pinnate veins running obliquely toward the leaf margin. The tip of the leaf blade is pointed. The lower pitcher is egg-shaped and slightly narrows towards the opening. The rosette pitchers are also egg-shaped and much smaller than the lower pitchers. The upper pitcher is slender, with the lower third of the trap slightly expanding. The pitcher narrows toward the middle of the cylinder before widening towards the oblique opening. The inflorescence is in the form of a panicle, with sparse bracts and indumentum.	Philippines	Germany	Morphology	2012	Gronemeyer et al. 2014

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
7.	*Nepenthes amabilis* Wistuba, Gronem., Micheler, Marwinski, Gieray, Coritico, V.B.Amoroso, spec. nov.	The plant has short green stems with minimal space between them. Its leaves spread out and have broad, winged petioles. The top pitcher has short, climbing stems and is cylindrical, with a slightly funnel-like lower third and a distinct puckered area below the peristome. The inflorescence is a panicle with a 15 cm long leaf and an additional 15 cm long rachis bearing two flowers on pedicels that are 20 mm long. The foliage, inflorescence, and pitchers are covered in a noticeable layer of brownish hairs up to 1 mm long, especially along the edges of young leaves.	Philippines	Germany	Morphology	2012	Gronemeyer et al. 2014
8.	*Nepenthes halmahera* Cheek, sp. nov	Upper and lower surfaces lack indumentum except for sessile globose glands and a few simple short hairs on the distal midrib. The petiole is winged and canaliculate. Lower pitchers (short shoots) are ellipsoid-cylindrical with a narrowly ovate mouth and an ovate-elliptical cap with short and dense overall hairs. Bifurcated pitchers are present. Upper pitchers (climbing stems) are green and ovate-cylindrical, with 5 – 10 % of the outer surface covered in simple golden-brown hairs. The mouth is ovate, concave, and oblique, with a pale, waxy greenish-white inner surface and red spots. The peristome is flattened cylindrical, and the cap is ovate-elliptical. The pitchers are oblong. The inflorescence is terminal on the central axis.	Halmahera, Maluku Utara, Indonesia	United Kingdom	Morphology	2013	Cheek 2015
9.	*Nepenthes weda* Cheek, sp. nov.	Stems horizontal, underground, having vertical rosette shoots along the stem; leaves petiolate, coriaceous; rosette shoot leaves anemophilous; shoot leaves short with elliptical-oblong blade; edge densely dark brown hairy; upper surface of blades glabrous, yellow-brown; climbing stem leaves with very narrow elliptical blades; upper surface of blades shiny; petioles canalized; xanthophyll rosette shoots located above the ground, dense dark red, broadly sub cylindrical; mouth ovoid; lower pitchers (short stems) brownish-red, narrowly elliptic; upper pitchers of stems climbing is dark red or greenish-yellow, more or less speckled with brownish red.	Halmahera, Indonesia	United Kingdom	Morphology	2012	Cheek 2015

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
10.	*Nepenthes barcelonae* Tandang & Cheek, sp. nov	Stems are climbing; leaves are sessile and oblong-ligulate in shape. The upper pitchers are dimorphic and dichromic, slightly curved, and cylindrical, with an inconspicuous mouth that is spherical. The peristome is shiny, dark red, and subcylindrical, with the outer edge gradually thinning to membranous and appearing wavy. Additionally, the cap is ovoid. The primary upper pitchers are produced at the bottom of the stem, while the secondary upper pitchers are made from stems over 1.5m high. The plant also has racemose inflorescences.	Philippines	United Kingdom	Morphology	2014	Cheek et al. 2015
11.	*Nepenthes krabiensis* Nuanlaong, Onsanit, Chusangrach & Suraninpong, sp. nov	Dioecious shiny climbing herb with axillary buds present at the top of the plant. The leaves are green above and brown below, with an indumentum of brown hair. When young, the leaves are shiny and light green in a rosette. The lower pitcher is green to orange with red stripes outside and red blotches on the inside. The peristome is green to red with a green-to-red cap on the upper surface and a conspicuous central rib with two tufted wings. The upper pitcher is light green with a red spot on the inner surface, a white peristome, and a light green cap. The tendrils are whorled. Male and female inflorescences are clustered.	Thailand	Thailand	Morphology and Anatomy	2015	Nuanlaong et al. 2016
12.	*Nepenthes minima* Jebb & Cheek, sp. nov	Stems are short, cylindrical, or slightly rounded. They have a mix of branched and star-shaped hairs. The leaves have petioles and elliptic-oblong blades with pointed tips. The upper pitchers are green, slightly curved along the central axis, and narrowly funnel-shaped with a narrowly ovate mouth and cap. Female flowers have 4-6 tepals; the seeds are slender and spindle-shaped, pale yellow, with smooth centres.	Sulawesi Tenggara	United Kingdom	Morphology	2016	Cheek & Jebb 2016b
13.	*Nepenthes aenigma* Nuytemans, W. Suarez, Calaramo, sp. nov.	The plant has stems that can grow up to 5 meters in length. The stems are smooth, and they can be round or three-sided. There are dormant buds located 3 to 5 mm above each leaf base. The creeping stems produce short stems above ground, producing traps buried in the leaf litter. The leaves are attached directly to the stem and are long and narrow with rounded or pointed tips. The midrib of the leaf emerges suddenly from the tendrils. The upper pitchers are fewer in number compared to the middle pitchers; they are cylindrical and slightly curved forward with a broad, funnel-shaped base. Inflorescences develop from the axils, and the plant is mostly bare. The cap is pale green with small red spots, and the peristome is cream to reddish. The tendrils on the middle trap are red, while the upper trap has red and green tendrils.	Philippines	Germany	Morphology	2009	Gronemeyer et al. 2016

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
14.	*Nepenthes justinae* Gronem., Wistuba, Mey, V.B.Amoroso, sp. nov.	The climbing stem leaves are ovate. The lower pitchers are rounded in the lower 2/3 and slightly infundibulate in the upper 1/3. The outside of the lower pitcher is yellow with purple blotches, while the inside is greenish-white, sometimes coated with angular purple blotches. The peristome is dark red and unevenly streaked with yellow. The entire surface of the lower pitcher is covered with dense and very short brown hairs.	Philippines	Germany	Morphology	2004	Gronemeyer et al. 2016
15.	*Nepenthes maryae* Jebb & Cheek, sp. nov	Please remember the following information: The climbing stem is terete, and its indumentum is densely covered with hairs. The leaf blades of the climbing stem are coriaceous, sessile, and lanceolate-oblong. The upper pitchers (coiled tendrils) are cylindrical with a rhombic mouth. The nectar glands are dense, and the surface has hairs and inconspicuously branched bracts in male inflorescences present at the proximal part.	Central Sulawesi, Indonesia	United Kingdom	Morphology	2000	Cheek & Jebb 2016a
16.	*Nepenthes malimumuensis* Lagunday, Acma, Cabana, Sabas, V.B. Amoroso, sp. nov	The leaves have winged stalks. The lower pitcher is cylindrical and slightly funnelled towards the opening, which is oval and leads to the lid. The peristome has short, triangular tooth-like projections with concave nectar glands nearby. The closing nectar gland is ovoid. The cover of the pitcher is filiform. The outer part of the lower pitcher is green with red blotches, and the inside is similarly coloured. The upper pitcher is funnel-shaped in the lower third and tapers towards the tendril. The female inflorescence is a panicle. The indumentum consists of multicellular trichomes with short pseudo-branches arising from basal, glandular to non-glandular cells found on the tendril, outer part of the pitcher, and inflorescence.	Philippines	Philippines	Morphology	2014	Lagunday et al. 2017
17.	*Nepenthes manobo* Lagunday, Acma, Cabana, Sabas, V.B. Amoroso, sp. nov	The leaves are directly attached and broadly linear. Wings cover the entire front of the trap. The peristome is ribbed, slightly flattened, and tapers backward to form a vertically oriented neck. The cap is oval, with evenly distributed large and small round nectar glands on the lower surface. The exterior of the pitcher is wholly red or yellow. The bottom of the pitcher forms a hip. The pitcher's opening tapers obliquely towards the lid. The peristome is ribbed and cylindrical in cross-section. The male inflorescence is a panicle. The indumentum, present on flowers, outside pitchers, and leaves, is a multicellular trichome that can be glandular or non-glandular.	Philippines	Philippines	Morphology	2014	Lagunday et al. 2017

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
18.	*Nepenthes alfredoi* V.B. Amoroso and Lagunday sp. nov	The leaf blade is broad and ovate with a blunt to rounded tip. The opening of the pitcher is ovate. The outer surface of the lower pitcher is green with red blotches, while the inner surface is green. The tendrils and midribs are red. The peristome is cylindrical. The upper pitcher is funnel-shaped and slightly swollen in the lower third, tapering towards the back where the tendril is located, and cylindrical in the middle part, with a somewhat funnel-shaped opening.	Philippines	Philippines	Morphology and Anatomy	2016	Amoroso et al. 2017
19.	*Nepenthes biak* Jebb & Cheek, sp. nov.	A short stem, which is not very different from a climbing stem, has cylindrical internodes. The leaves of the short stem are glossy, leathery, and oblanceolate and are spirally inserted. The lower midrib has erect and not curled tendrils, with tufted wings, while the midrib has tendrils that emerge laterally from the base and are not curled. The upper pitcher gradually narrows laterally at the centre in frontal view and has a yellow peristome.	Biak Island, Indonesia	United Kingdom	Morphology	1966	Cheek et al. 2018
20.	*Nepenthes dactylifera* A.S.Rob., Golos, S.McPherson & Barer, spec. nov.	The stems of this plant are rosette-shaped and cylindrical, while the leaves in the rosette are ovate and have broad, oblong-elliptic shapes. The lower pitcher is ellipsoid, cylindrical, and slightly narrower at the top, widening towards the mouth, while the upper pitcher is broadly tubular to infundibular. The plant has a covering of short, fine brown hairs. In terms of colour, the mature stems are usually reddish to black, the leaves are bright green with some red, the lower pitcher is often dark, and the upper pitcher is pale green with a whitish peristome streaked with dark red.	Malaysia, Brunei, and Kalimantan Indonesia	Australia	Morphology	1992	Robinson et al. 2019a
21.	*Nepenthes erucoides* A.S.Rob. & S.G.Zamudio, sp. nov	The pitcher has an elliptical shape, a more comprehensive peristome, and a transparent border. The bracts on most stalk are partial, about 1 mm long, and never emerge from the stalk. Additionally, the filaments are well-developed.	Philippines	Australia	Morphology	2018	Robinson et al. 2019b
22.	*Nepenthes cabanae* Lagunday & V.B. Amoroso, sp. nov.	The plant has a climbing stem with leaves that attach directly to the stem and have parallel nerves running alongside the midvein. The lower or middle pitcher is shaped like a cylinder, and the peristome has a short triangular tooth, approximately 0.3-0.5 mm long, that does not extend beyond the margin.	Philippines	Philippines	Morphology	2015	Lagunday & Amoroso 2019

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
23.	*Nepenthes maximoides* Cheek, sp. nov.	Stem climbing round; leaves spiral; axillary buds inconspicuous; indumentum glabrous. Leaves petiolate, leaflets acuminate, base gradually declining to petiole; midrib when young dense. Petiole clasping the stem by ½ its circumference, not radius, winged, T-shaped. Pitcher's upper (tendrils coiled, cap facing away from tendrils), infundibular narrow; the outer surface of pitcher shiny, drying yellowish brown, hairless. The mouth ovate is slightly concave, forming a column under the cap; the peristome is rounded or flattened and inverted U-shaped in a transverse section. Spur 4 mm below the cap insert, straight, erect, the tip bifurcated, the surface instead densely covered with brown hairs.	Philippines	United Kingdom	Morphology		King & Cheek 2020
24.	*Nepenthes malayensis* A.Amin, M.N.Faizal & Dome sp. nov.	Cross-section of climbing stems hairy, broadly angled, and cylindrical towards the shoot; margin of leaf base (climbing stem) clasping the stem ½ of the circumference, not fingered; pitcher cap ovate with a midline indentation in the centre, base cordate; nectar glands present; mouth slightly indented on the back; peristome loosely cylindrical in the middle; lower pitcher emerging from the tendril; lower part ovate, upper part slightly ovate; hip ½ high; lower pitcher 1/3 broadly infundibuliform, broadly cylindrical at the top and constricted towards the mouth; and peristome on the upper pitcher conspicuously reddish-striped with a green band.	Malaysia	Malaysia	Morphology, Anatomy, and Molecular	2019	Tamizi et al. 2020a
25.	*Nepenthes latiffiana* M. N. Faizal, A. Amin & N. Dome, sp. nov.	Rosette tendrils and climbing leaves with a slender circular formation in the middle, covered with small hairs; the colour of the lower pitcher is yellowish-green-brown with a few red blotches on the upper 1/3 of the pitcher body; the lower pitcher cap has blotches; the base of the cap is cordate retuse; the colour of the upper pitcher is light green; the upper pitcher cap is rounded.	Malaysia	Malaysia	Morphology, Anatomy, and Molecular	2019	Ghazalli et al. 2020
26.	*Nepenthes domei* M. N. Faizal, A. Amin, & A. Latiff, sp. nov.	Rosette tendrils and slightly whorled climbing leaves; lower pitcher colour whitish red to deep ruby red with slight red-purple flaws on the inner surface and lid; lower pitcher lid ovate, pitcher lid rounded; upper pitcher colour green; upper pitcher lid ovate.	Malaysia	Malaysia	Morphology, Anatomy, and Molecular	2019	Ghazalli et al. 2020

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
27.	*Nepenthes x setiuensis* A.Amin, M.N.Faizal *et* N.Domenothosp.nov.	The lower pitcher's colour is green to dark purple with black-purple blotches; the peristome is black to dark purple; the middle pitcher's shape and colour are similar to the upper pitcher; the mature upper pitcher slightly ovate at bottom narrowing to cylindrical towards the top, mouth rounded to oblong; the colour of upper pitcher dark purple with a combination of black spots; peristome dark purple; shape of upper/lower pitcher lid rounded; upper/lower pitcher lid downy simple white; peristome medium-sized; and inner pitcher wall surface greenish with red spots, waxy surface.	Malaysia	Malaysia	Morphology and Anatomy	2019	Tamizi et al. 2020b
28.	*Nepenthes longiptera* Victoriano spec. nov.	There are upper wings developed, the shape of the upper pitcher is slender at the basal part, the shape of the lower pitcher is cylindrical at the basal part, the upper pitcher lip is oval with a heart-like base, slightly protruding or rounded upwards, the lower pitcher lip is elliptical with an oval base, the stem is rhombic, the leaf shape is oval and sub petiolate, the leaf veins are amplexicaul, auriculate, clasping 2/3 of the stem.	Aceh, Indonesia	Indonesia	Morphology	2019	Victoriano 2021
29.	*Nepenthes pudica* Dančák & Majeský, sp. nov	The short basal shoots are located underground, the stem indumentum is glabrous, the stem colour is brownish green, the shape of the climbing leaves is oblanceolate, the climbing leaves have stalks, the base of the climbing leaves is auriculate and short, the texture of the climbing leaves is thick and stiff, the tips of the climbing shoot leaves are pointed, the mature midrib indumentum is glabrous, the shape of the lower midrib is fingered, the lower midrib is infundibular, and the male flowers are paired. Rosette pitchers are produced only briefly. The lower pitchers emerge abruptly from the uncoiled tendrils and ventricose, broadly ovate to rounded on the underside, and the outer surface red-purple in colour. Upper pitchers are rarely produced; the outer surface is green, and the inner surface near the mouth is yellowish.	North Kalimantan, Indonesia	Czech Republic	Morphology and Anatomy	2012	Dančák et al. 2022
30.	*Nepenthes bracteosa* Suran. & Nuanlaong sp. nov.	The leaf shape is linear to lanceolate, the leaf tip is acute, the lower pitcher cap is ovate, the spur has fine hairs with branches, the male flower has one flower, the androphore is 2.0-2.5 mm long, has bracts on all flowers, and there is no layer of fine hairs on the stem, lamina, leaf margins, and shoots.	Thailand	Thailand	Morphology, Anatomy, and Molecular	2019	Nuanlaong et al. 2022

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
31.	*Nepenthes hirtella* Nuanlaong & Suran. Sp. nov.	Leaf shape oblanceolate, leaf tip rounded, lower pitcher cap ovate, spur bearing hairs with branches, male inflorescence bearing one flower or rarely two flowers and a partial peduncle, bract present at the base of the rachis (1-2 flowers) of both male and female inflorescences, and an indumentum covering all vegetative parts.	Thailand	Thailand	Morphology, Anatomy, and Molecular	2019	Nuanlaong et al. 2022
32.	*Nepenthes harauensis* Hernawati, R.Satria & Chi.C.Lee spec. nov.	Stem cylindrical; internodes closed on short shoots; leaves pinnate, pinching the stem, lamina elliptic; tendril inserts pinnate/subapical; 2 longitudinal veins on each side of midrib; lower pitchers ovate then cylindrical above; peristome cylindrical, widening towards the back; cap ovate to orbicular with a simple thickened ridge near the apex; upper pitchers narrowly ovate-cylindrical and widened above, and inflorescence single-flowered.	West Sumatera, Indonesia	Indonesia	Morphology	2021	Hernawati et al. 2022a
33.	*Nepenthes berbulu* H.L.Tan, G.Lim, Mey, Golos, Wistuba, S.McPherson & A.S.Rob., spec. nov.	Leaves oblong-elliptic with rounded tips; cover hairs thick and unevenly coarse; lower pitcher broadly infundibular at the bottom, cylindrical at the top; the size of lower pitcher up to 25 cm long and 6 cm wide; the colour of lower pitcher yellowish-green or dark pink, spotted with dark red or purple. Peristome yellowish green with reddish stripes, sometimes entirely red; lid on lower pitcher orbicular; upper pitcher broadly infundibular below, slightly constricted just above the hip, cylindrical above; the colour of upper pitcher essentially pale green; and lid on upper pitcher orbicular.	Malaysia	Malaysia	Morphology	2022	Tan et al. 2023
34.	*Nepenthes sericea* Golos, Wistuba, G.Lim, Mey, S.Mcpherson & A.S.Rob.	Lower pitchers have a flattened peristome with teeth, an oval cap with fine abaxial hairs (up to 2 mm), hips primarily positioned in the centre (sometimes close to the mouth), and a mottled outer surface. The upper pitchers are mainly white with pinkish, yellowish-green spots towards the tendrils.	Malaysia	United Kingdom	Morphology	2022	Tamizi et al. 2023
35.	*Nepenthes ulukaliana* A.S.Rob., Wistuba, Mey, Golos, G.Lim & S.Mcpherson.	The lower pitcher is amphora-shaped (because the hips are positioned close to the peristome), has short (≤1 mm long) and dense covering hairs, and the front of the peristome is planar.	Malaysia	Bangladesh	Morphology	2023	Tamizi et al. 2023

Table 1. Contd.

No.	Species Name	Description	Distribution	Author's Origin	Identification Methods	Year of Discovery Species	References
36.	*Nepenthes limiana* Wistuba, Mey, Golos, S. McPherson & A.S. Rob., spec. nov.	Stems slightly angular. Leaf lamina of the rosette are generally oblanceolate, sometimes lanceolate, tendrils of the rosette and lower pitchers unrolled, the shape of rosette pitchers variable, ovate or infundibular basally, forming a slightly ovate base with a hip in the centre and cylindrical above, the cap having fine hairs on the lower surface. Lower to middle pitchers are similar to rosette pitchers in shape. The peristome ovate is often slightly widened and furrowed, and the upper pitchers have conspicuous venation and narrow infundibular basal. Cap sub-orbicular to ovate. Inflorescence is a racemose panicle, and the female inflorescence is two-flowered. Indumentum conspicuous and stem colour red.	Malaysia	United Kingdom	Morphology	2022	Golos et al. 2023
37.	*Nepenthes samudera* R. Chiu, E. Goh, D. Lim, & M. Balahadia sp. nov.	Leaf shape oblong spathulate, stem attachment clasping the stem along ¾ of its circumference, tendrils subapical; lower pitcher broadly infundibulate below and cylindrical above; peristome shape cylindrical, peristome colour dark red; pitcher body colour red; male inflorescence 2-flowered; has bractea and filiform.	Sumatera, Indonesia	London	Morphology	2023	Chiu 2023

The discovery of 37 new species of the *Nepenthes* genus over the past 10 years shows yearly variation, as presented in Figure 1. Next, a comparison of the countries that discovered new species can be seen in Figure 2. Although new species of *Nepenthes* are spread in Southeast Asia, researchers who discovered them come from various countries, with the largest number of researchers from the United Kingdom (Figure 3). Identifying and discovering new species of the genus *Nepenthes* involves several methods, namely based on morphological, anatomical, and molecular comparisons (Figure 4).

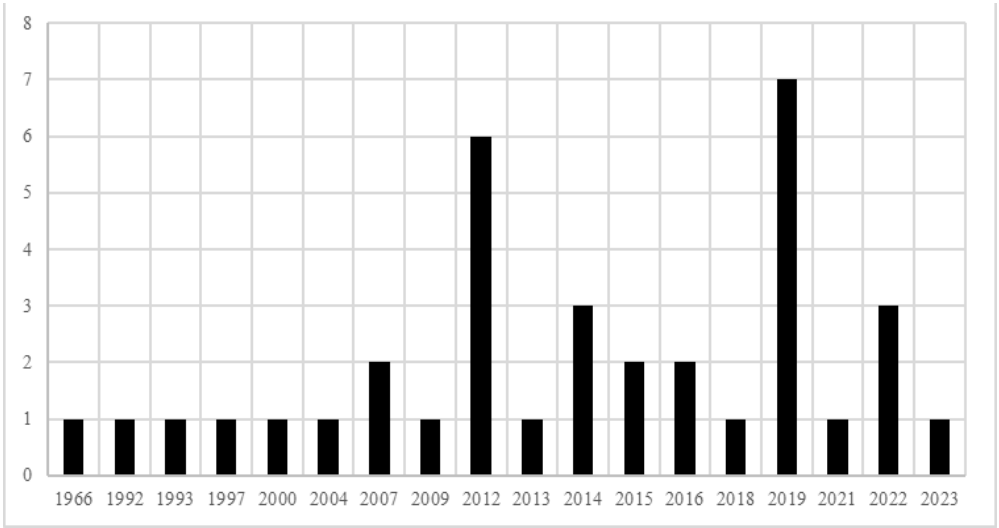

Figure 1. Diagram of the number of new species discovered in the last decade.

Figure 2. Distribution map of new *Nepenthes* species in Southeast Asia.

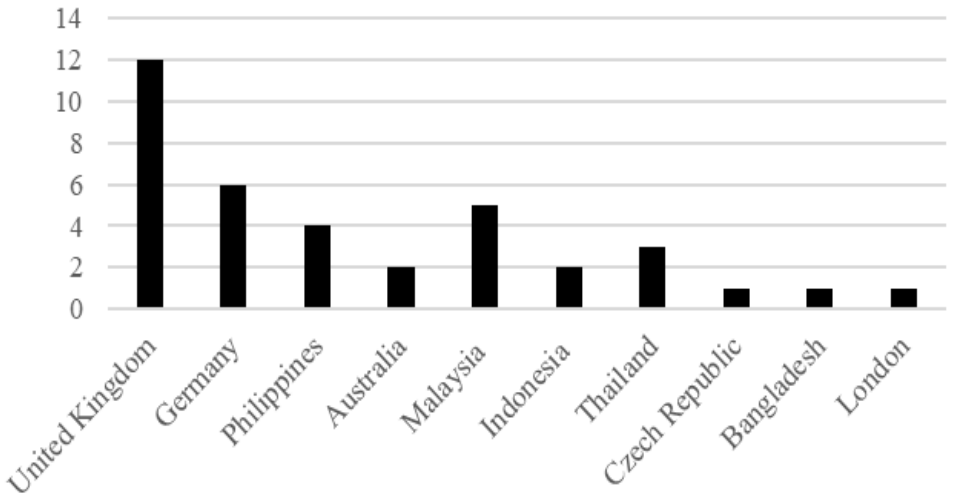

Figure 3. Countries of origin of researchers who discovered new species.

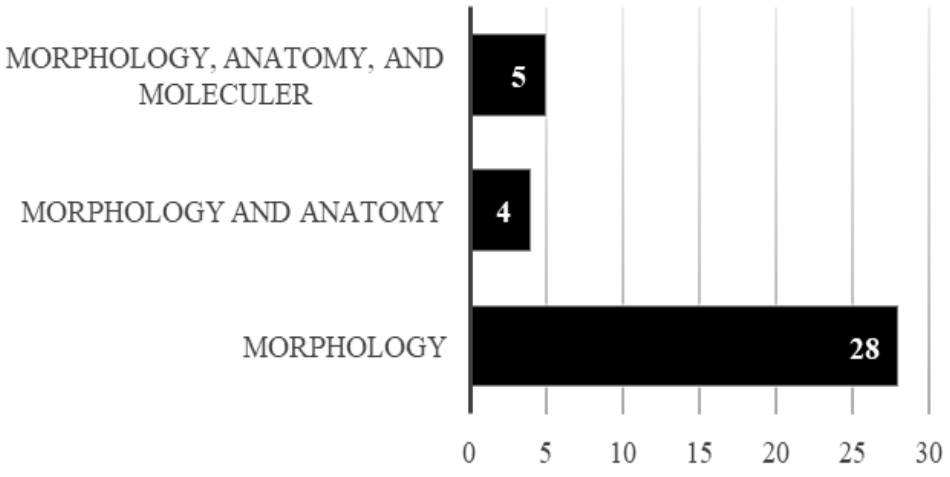

Figure 4. Comparison of new species identification methods.

Discussion

In general, *Nepenthes* has unique and interesting morphological characteristics. *Nepenthes* leaves are lanceolate with elongated tips forming tendrils. These tendrils help the plant climb or drape itself over other plants. One of the most distinctive parts of *Nepenthes* is the trap pouch formed at the end of the tendril. This pouch comes with a flap on top. The inner walls of the pouch are smooth and contain enzymatic fluids and bacteria that help digest the trapped prey. In addition, the relatively small and shallow roots of *Nepenthes* are well suited to their habitat in nutrient-poor soils (Miguel et al. 2018).

Nepenthes play an important ecological role. It helps control insect populations by capturing and digesting them as an additional source of nutrients, particularly nitrogen and phosphorus. This can reduce herbivore pressure on other nearby plants (Buch et al. 2014). The shallow roots of *Nepenthes* also play a role in soil stabilization, especially in vulnerable habitats such as limestone cliffs or peatlands. In addition, as part of the tropical ecosystem, *Nepenthes* contributes to biodiversity by providing habitat for various organisms, including insects, frogs, and even small rodents trapped in their pouches. Some *Nepenthes* species even have symbiotic relationships with animals, such as ants, which help clean the pouches of prey remains and prevent decay (Bazile et al. 2012). *Nepenthes* can also be an indicator of environmental conditions. The presence and health of *Nepenthes* populations often reflect moisture conditions, soil quality, and the level of human disturbance in the habitat (Mansur et al. 2023).

Nepenthes is the only genus in the Nepenthaceae family whose members are all carnivorous plants (Mansur et al. 2024). Research on the genus *Nepenthes* in the last 10 years has resulted in various new species discovered in several countries in Southeast Asia. The Philippines has the highest number of discoveries, reaching 16 new species. Indonesia followed with 10 new species identified. Malaysia also showed a significant contribution with the discovery of eight new species. Meanwhile, Thailand recorded the discovery of three new species. These discoveries reflect the region's incredible biodiversity and researchers' persistent efforts in exploring and documenting the local flora.

Over the past 10 years, research on the *Nepenthes* genus has resulted in numerous discoveries of new species. 2014 recorded the peak of discoveries with seven new species, followed by a decline in 2015 with three species. In 2016, there was another increase with five new discoveries, but this declined to three in 2017 and only one in 2018. Slight stability was achieved in 2019 with three new species, while 2020 saw a resurgence with five discoveries. In 2021, only one new species was discovered, but this number rose to four in 2022 and five in 2023. In 2024, no new species discoveries were recorded. The fluctuation in the number of discoveries each year reflects the challenges and dynamics researchers face in exploring and studying this genus. *Nepenthes* is classified as a protected plant due to its dwindling population in its natural habitat. Discoveries of *Nepenthes* species in Southeast Asia show remarkable diversity, but their habitats are threatened by deforestation, drainage, drought, and climate change (Gaume et al. 2019).

Indonesia has discovered 10 new species that have never been recorded before in the last 10 years, consisting of *N. halmahera*, *N. weda*, *N. minima*, *N. maryae*, *N. biak*, *N. longiptera*, *N. pudica*, *N. harauensis*, *N. oceanic*, *and N. dactylifera*. The worldwide diversity of *Nepenthes* sp. is in line with data from the International Union for Conservation of Nature (IUCN), which records around 122 species, and 116 of them are found in Southeast and South Asia, with 63 of them detected in Indonesia. *Nepenthes* diversity in Indonesia has been sufficiently documented, especially in the main islands such as Sumatra (31 species), Kalimantan (20 species), Papua (12 species), Sulawesi (10 species), Maluku (4 species), and Java (3 species). Among these islands, Sumatra

has the highest number of *Nepenthes* species in Indonesia (Nainggolan et al. 2020).

The Indonesian government has also designated the genus *Nepenthes* as a priority plant for conservation through the Minister of Forestry Regulation No. P.57/Menhut-II/2008. However, there are no adequate species data to support the designation of Nepenthaceae as a priority plant group in Indonesia, so no conservation priorities have been determined at the species level (Hernawati et al. 2022b). Under international convention, the entire *Nepenthes* genus is listed in CITES (Convention on International Trade in Endangered Species) Appendix II, meaning all species within this genus are protected from international trade without proper authorization. This CITES protection applies universally, regardless of individual species' national conservation status. Certain species such as *Nepenthes rajah* and *Nepenthes khasiana* receive even stricter protection under CITES Appendix I, which explicitly prohibits all forms of international commercial trade (https://cites.org/).

The Philippines is now recognized as having the greatest diversity of pitcher plants of the genus *Nepenthes*. Over the past ten years, a number of field expeditions, mainly in Mindanao, have yielded 16 new species, comprising *N. armin*, *N. tboli*, *N. zygon*, *N. pantaronensis*, *N. cornuta*, *N. talaandig*, *N. amabilis*, *N. barcelonae*, *N. aenigma*, *N. justinae*, *N. malimumuensis*, *N. manobo*, *N. alfredoi*, *N. erucoides*, *N. cabanae*, and *N. maximoides*. This high species diversity is related to the wide variety of ultramafic plains exposed in Mindanao, which includes many isolated mountain peaks. Less fertile soil conditions, which tend to be toxic to plants, as well as often poor water availability, together with special climatic factors around ultramafic rocks, all contribute significantly to high levels of speciation and endemism (Galey et al. 2017).

Over the past 10 years, the discovery of new species in Malaysia, especially in Peninsular Malaysia, totalled eight species, consisting of *N. malayensis*, *N. latiffiana*, *N. domei*, *Nepenthes x setiuensis*, *N. hairy*, *N. sericea*, *N. ulukaliana*, and *N. limiana*. According to Ghazalli et al. (2021), there are 14 species of *Nepenthes* recorded in parts of Peninsular Malaysia and are mostly distributed in scrub forests, lowlands, and mountains up to 1000 metres in altitude. Of the 14 *Nepenthes* species recorded, 10 are endemic. The current classification of *Nepenthes* in Peninsular Malaysia is based on morphological characteristics, with clear differences seen between species found at high, middle, and low altitudes (Bunawan et al. 2017).

Thailand is one of the countries in Southeast Asia with 14 recognised species of the genus *Nepenthes* to date. Of these, three new species, including *N. krabiensis*, *N. bracteosa*, and *N. hirtella*, were discovered during the last 10 years. Among these, seven species belonging to the *Pyrophytae* section predominantly occur in highland areas at elevations of 300-760 metres. Members of the *Pyrophytae* section are characterised by several distinct morphological features: tuberous rootstocks, absence of climbing stems and upper pitchers, uncoiled tendrils in upper pitchers, and partial peduncles bearing single flowers (Nuanlaong et al. 2022).

The species identification process for the genus *Nepenthes* typically utilises morphological characteristic differences, particularly pitcher traits, as each species possesses specific morphological features that distinguish it from others (Gilbert et al. 2020; Ghazalli et al. 2021). These distinctive characteristics serve as simple field identification markers for *Nepenthes*, with the most significant variations observed in pitcher morphology and colouration. As modified leaves, the pitchers not only reflect adaptations to nutrient-poor environments but also correlate with dietary specialisation (Setiawan et al. 2018; Huda et al. 2022). However, this approach has limitations. *Nepenthes* are heteroblastic species characterised by leaf ontogenetic dimorphism, which is par-

ticularly pronounced in certain species (Gaume & Di Giusto 2009). This change in leaf form is often associated with the transition from juvenile to mature, flowering stages. Consequently, anatomical studies are now being developed as an alternative approach to address identification ambiguities (Huda et al. 2022).

Nepenthes is a carnivorous plant genus that serves a source of inspiration and value for research development. However, the survival of this plant is threatened, with 17 species classified as endangered and eight as critical based on data from the IUCN. To overcome these threats, it is necessary to conserve exclusively based on the knowledge gathered by scientists (Miguel et al. 2018).

CONCLUSIONS

Nepenthes is a genus of carnivorous plants. This genus belongs to the Nepenthaceae family and can be found in several countries. Based on journals published between 2014-2023, data on newly described *Nepenthes* species were collected from a range of reputable scientific journals that specialise in plant taxonomy, biodiversity, and conservation. These journals include Phytotaxa, Kalpataru, Philippine Journal of Science, Philippine Journal of Systematic Biology, Plants, Thailand Forest Bulletin, Phytokeys, Journal of Sustainable Natural Resources, Reinwardtia, Kew Bulletin, PeerJ, Carnivorous Plant Newsletter, Malayan Nature Journal, and the Journal of Plant Taxonomy and Geography.

A total of 37 new species of *Nepenthes* have been identified across Southeast Asia, particularly in the Philippines, Indonesia, Malaysia, and Thailand. In the Philippines, newly described species include *Nepenthes armin*, *Nepenthes tboli*, *Nepenthes zygon*, *Nepenthes pantaronensis*, *Nepenthes cornuta*, *Nepenthes talaandig*, *Nepenthes amabilis*, *Nepenthes barcelonae*, *Nepenthes aenigma*, *Nepenthes justinae*, *Nepenthes malimumuensis*, *Nepenthes manobo*, *Nepenthes alfredoi*, *Nepenthes erucoides*, *Nepenthes cabanae*, and *Nepenthes maximoides*. In Indonesia, the following new species have been discovered: *Nepenthes halmahera*, *Nepenthes weda*, *Nepenthes minima*, *Nepenthes maryae*, *Nepenthes biak*, *Nepenthes longiptera*, *Nepenthes pudica*, *Nepenthes harauensis*, *Nepenthes samudera*, and *Nepenthes dactylifera*. From Thailand, newly recorded species include *Nepenthes krabiensis*, *Nepenthes bracteosa*, and *Nepenthes hirtella*. Meanwhile, in Malaysia, the new species identified are *Nepenthes malayensis*, *Nepenthes latiffiana*, *Nepenthes domei*, *Nepenthes* × *setiuensis*, *Nepenthes berbulu*, *Nepenthes sericea*, *Nepenthes ulukaliana*, and *Nepenthes limiana*.

Nepenthes plants play an important ecological role by controlling insect populations and stabilising soil in nutrient-poor habitats. Nonetheless, *Nepenthes* populations are threatened by deforestation, climate change, and human activities, so more intensive conservation efforts are needed to protect the survival of this genus.

AUTHOR CONTRIBUTION

S.W.I., M.S., R.K.A., S.A.J., and K. collected, analysed the data and wrote the manuscript; B.I. and F.R.P.D. supervised the entire process.

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CONFLICT OF INTEREST

This study was conducted without any conflict of interest.

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