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Diversity and Its Implications of *Curcuma* Subgenus *Hitcheniopsis* (Zingiberaceae) with a New Record for Vietnam

Piyaporn Saensouk [1,2], Surapon Saensouk [2,3,*], Mai Thi Phuong Thuy [4], Nonthiwat Taesuk [1], Prasert Ruannakarn [5], Suriya Phimpha [6] and Thawatphong Boonma [2,3]

1 Department of Biology, Faculty of Science, Mahasarakham University, Maha Sarakham 44150, Thailand; pcornukaempferia@yahoo.com (P.S.); nonthiwat.t@msu.ac.th (N.T.)
2 Diversity of Family Zingiberaceae and Vascular Plant for Its Applications Research Unit, Mahasarakham University, Maha Sarakham 44150, Thailand; boonma.thawat@gmail.com
3 Walai Rukhavej Botanical Research Institute, Mahasarakham University, Maha Sarakham 44150, Thailand
4 Institute of Forest Tree Improvement and Biotechnology, Vietnamese Academy of Forest Sciences, Hanoi 10000, Vietnam; maiphuongthuy@vafs.gov.vn
5 Department of Educational Research and Development, Faculty of Education, Mahasarakham University, Maha Sarakham 44000, Thailand; prasert.rua@msu.ac.th
6 Faculty of Arts, Silpakorn University, Mueang Nakhon Pathom District, Nakhon Pathom 73000, Thailand; suriyappha@gmail.com
* Correspondence: surapon.s@msu.ac.th; Tel.: +66-08-8029-3958

Abstract

Curcuma subgenus *Hitcheniopsis* (Zingiberaceae) comprises species valued for ornamental and medicinal uses in Southeast Asia, yet no comprehensive assessment has been conducted in Vietnam. This study provides the first integrative evaluation of *Hitcheniopsis* in Vietnam, combining species distribution modeling, field verification, herbarium examination, and Ornamental Value Index (OVI) analysis. Ten species were confirmed, including a new national record, *C. rhabdota*, with voucher specimens establishing its verified presence and extending the known range. Predicted habitat maps highlighted southern Vietnam and adjacent regions as suitable areas, guiding targeted surveys and conservation planning. Flowering occurred from April to September, with species occupying habitats from deciduous dipterocarp to dry evergreen forests. OVI analysis identified *C. rhabdota*, *C. alismatifolia*, and *C. thorelii* as species of high ornamental potential, supporting their use in horticultural breeding and potted ornamental production. Conservation assessments revealed that the endemic *C. leonidii* and *C. pygmaea* are Critically Endangered, *C. rhabdota* is Vulnerable, and *C. sparganiifolia* is Endangered, emphasizing the urgency of habitat protection and sustainable management. By linking verified diversity, phenology, ornamental value, and habitat modeling, this study establishes a novel, distribution-based framework for research, conservation, and sustainable use of *Curcuma* subgenus *Hitcheniopsis* in Vietnam and Southeast Asia.

Keywords: *Curcuma*; diversity; *Hitcheniopsis*; new record; ornamental value; taxonomy; traditional uses; Vietnam; Zingibereae

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1. Introduction

Curcuma L., a genus of tropical rhizomatous plants in the family Zingiberaceae, is widely valued in Southeast Asia [1–6] for its ornamental, medicinal, and cultural uses [7–13]. Among its subgenera, *Hitcheniopsis* is particularly notable for its vibrant and diverse inflorescences, making it highly attractive as an ornamental plant and as parental material

for cultivated varieties [14–19]. Members of this subgenus are traditionally used by local communities in cultural or ritual practices and as auspicious ornamental plants [6–10,12].

Vietnam represents a biogeographically significant area within the Indochinese floristic region, forming a transitional zone between the tropical flora of Southeast Asia and the subtropical flora of southern China. The country harbors exceptionally high species richness and endemism, particularly within the Zingiberaceae, due to its varied topography and climatic gradients [20–26]. Moreover, Vietnam marks the eastern distribution limit of *Curcuma* subgenus *Hitcheniopsis*, as no species of this subgenus have been recorded from the forests of the Philippines or Indonesia [3,4,6]. This highlights Vietnam's pivotal role in understanding the biogeography and evolutionary history of the group across continental Southeast Asia.

Despite their aesthetic and cultural significance, knowledge of the diversity, flowering phenology, ornamental potential, and conservation status of *Curcuma* subgenus *Hitcheniopsis* in Vietnam remains incomplete. Although certain species are mentioned and illustrated in these works, no voucher specimens or collection references are clearly provided. In some cases, species are misidentified, and several taxa have not yet been included in these references [3,4]. Some species display considerable ornamental value due to their showy bracts or leaves, extended flowering periods, and adaptability to cultivation, yet their horticultural use remains underexplored. Additionally, habitat loss and overharvesting threaten some species, emphasizing the need for systematic conservation assessment to guide sustainable utilization [27,28].

This study aims to (1) document the diversity of *Curcuma* subgenus *Hitcheniopsis* in Vietnam, including the first verified record of *C. rhabdota* in Tây Ninh Province; (2) record traditional uses among local communities; (3) evaluate ornamental potential using the Ornamental Value Index; and (4) assess conservation status. By integrating ethnobotanical, horticultural, and conservation data, this work provides a foundation for sustainable cultivation, conservation planning, and the continued use of these valuable species in Vietnam and the broader Southeast Asian region.

2. Materials and Methods

2.1. Plant Material and Study Area

Specimens of *Curcuma* subgenus *Hitcheniopsis* were collected from Vietnam (Figure 1) from late February to September, during their flowering stage. Some species produce inflorescences before the leafy shoots between late February and May, while others produce terminal inflorescences from June to September. Collecting specimens during the flowering stage ensures that key morphological characteristics, particularly those of the inflorescence and flowers, are accurately observed for correct species identification. Voucher specimens were preserved as dried herbarium samples and deposited at the Vascular Plant Herbarium, Mahasarakham University (VMSU).

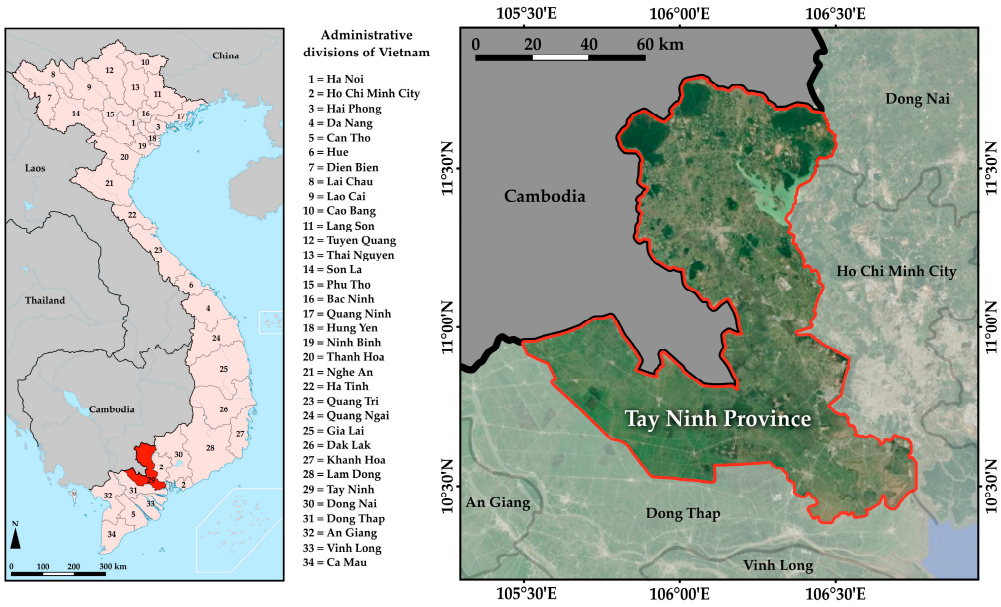

Figure 1. Map of Vietnam showing administrative division boundaries, with Tay Ninh Province highlighted in red, adapted from ref. [29], licensed under CC BY 4.0 (**left**). Topographic map of the Tay Ninh Province study area (**right**).

2.2. Taxonomic Identification

Species identification was performed using dichotomous keys and relevant literature, including the Flora of Vietnam Vol. 21 [4], Flora of China Vol. 24 [5], Flora of Thailand Vol.16 Part 2 [6], and other publications on *Curcuma* taxonomy [1,2,7,9–13,16,30–37]. Morphological traits of vegetative and reproductive structures were measured with a ruler and vernier caliper (Mitutoyo Vernier Caliper; Mitutoyo Corporation, Kawasaki, Japan) and observed in detail using a stereoscopic microscope (Stemi 2000-C; Zeiss, Oberkochen, Germany). High-resolution images of type specimens were consulted through major herbaria, e.g., BK, BKF, E, HN, HNU, IBK, IMDY, K, KKU, P, QBG, VMSU, VNM, and VNMN, including via JSTOR Global Plants (https://plants.jstor.org, accessed on 17 August 2025) and the Global Biodiversity Information Facility (GBIF) [38].

2.3. Information on Traditional Uses

Information on the traditional uses of *Curcuma* subgenus *Hitcheniopsis* was compiled from published literature, botanical references, and herbarium specimen notes. These records were used to observe and summarize the various uses of each species beyond ornamental purposes, e.g., culinary, medicinal, or other applications [39,40]. No comprehensive ethnobotanical survey or quantitative analysis was conducted, and semi-structured interviews with local informants were only consulted as Supplementary Information where available. This approach allows the study to note general traditional uses while keeping the focus on ornamental value, diversity, and conservation assessments [8,9].

2.4. Preliminary Evaluation of Ornamental Value for Cultivation as Ornamental Pot Plants

Specimens of *Curcuma* subgenus *Hitcheniopsis* were cultivated in uniform 20 cm diameter pots under standard greenhouse conditions with partial shade (~50–70% full sunlight) for 10–12 h per day. All species were grown under the same light, soil, and watering conditions to ensure that differences in Ornamental Value Index (OVI) reflected species-specific traits rather than environmental variation.

For each species, five healthy individuals were used for preliminary evaluation. The limited number of plants was chosen to reduce excessive collection from natural pop-

ulations while still providing sufficient material to observe general ornamental trends. Morphological traits were assessed during the flowering stage to ensure full development of leaves, thyrses, bracts, and flowers. Additionally, published descriptions from the original protologues of each species were consulted to supplement observations and provide a reference for species-specific traits. Evaluation traits and subtraits used for the preliminary assessment of ornamental value (Table S1).

2.4.1. The Ornamental Value Index (OVI)

The Ornamental Value Index (OVI) was calculated using a scoring system in which each sub-trait was rated on a scale of 1 to 5 (all 15 sub-traits). To standardize OVI, the minimum and maximum possible scores across all traits were denoted as S_{min} and S_{max}, respectively. S_{min} is the minimum possible total score across all sub-traits, which occurs when each sub-trait receives a score of 1. While S_{max} is the maximum possible total score across all sub-traits, which occurs when each sub-trait receives a score of 5. This approach follows the standard principle for creating a normalized index, ensuring that the OVI values range from 0 to 1. For an individual i, OVI was calculated as:

$$\mathrm{OVI}_i = \frac{\text{Total score}_i - S_{min}}{S_{max} - S_{min}}$$

This ensures that OVI ranges from 0 (lowest ornamental pot plant potential) to 1 (highest ornamental pot plant potential). For each species, the species-level OVI was obtained as the mean of all individuals:

$$\mathrm{OVI}_{\text{species}} = \frac{\sum_{i=1}^{n} \mathrm{OVI}_i}{n}$$

Interpretation of OVI (0–1 scale) for species was classified based on mean OVI as follows:

0.00–0.20→Very low ornamental value
0.21–0.40→Low
0.41–0.60→Moderate
0.61–0.80→High
0.81–1.00→Very high

Note: These interpretation ranges are designed for practical horticultural assessment and do not affect statistical analyses, which were based on raw OVI scores.

For those characters marked with an asterisk (*) in Table S1, assessment with the standard five-level scale is often uncertain because the differences among individuals are subtle and difficult to distinguish precisely. Therefore, a simplified three-level scoring system (1, 3, and 5) was adopted. This adjustment eliminates the ambiguity of intermediate scores, allowing the evaluation to better capture the actual differences among individuals. As a result, it improves the accuracy, consistency, and repeatability of the scoring process, thereby enhancing the reliability of the overall ornamental value assessment.

2.4.2. Data Analysis

The assumptions for one-way ANOVA were first tested using the Shapiro–Wilk and Kolmogorov–Smirnov tests for normality. The OVI values of some species were not normally distributed, as the p-value (Sig.) was lower than the predetermined level of significance (α = 0.05). Therefore, the assumptions for parametric analysis were not met. Consequently, a non-parametric approach was applied. The Kruskal–Wallis test was used to assess differences in OVI among species, followed by pairwise comparisons using the Mann–Whitney U test for independent samples. Descriptive statistics, including mean,

standard deviation, and range, were calculated for each species to summarize the central tendency and variability of ornamental traits. The limited sample size (five individuals per species) reflects a preliminary assessment and minimizes disturbance to natural populations while capturing general trends. All species were cultivated under uniform conditions (20 cm diameter pots, consistent soil, light, and watering) to ensure comparability of OVI scores. All statistical analyses were performed using IBM SPSS Statistics, version 29 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

Notes on Methodology: Published species descriptions (protologues) were consulted to guide scoring and ensure that species-specific morphological features were appropriately considered. Only flowering individuals were evaluated for inflorescence and floral traits, whereas non-flowering individuals were assessed for vegetative characters (leaves and plant habit). All species were cultivated under identical conditions (20 cm diameter pots, uniform soil, light, and watering) to ensure comparability of OVI scores.

2.5. Species Distribution Modeling

A total of 265 occurrence records of the subgenus *Hitcheniopsis* were compiled from field surveys and the Global Biodiversity Information Facility (GBIF) [38], including 198 records obtained from our field surveys and the remaining 67 records from GBIF. To ensure data accuracy, we carefully checked each GBIF record by tracing back to the iNaturalist [41], which is a source database of GBIF, to verify species identifications. In addition, for certain coordinates shown on the distribution map, we conducted field surveys in those locations to confirm species presence, and also checked specimens deposited in the local herbaria of Vietnam (HN, HNPM, HNU, SGN, VNM, VNMN), particularly those cited in GBIF, to verify the species identifications. These measures were taken to minimize potential errors due to misidentification, inaccurate coordinates, or sampling bias in the GBIF dataset. Six bioclimatic variables were selected to model the current distribution of the subgenus *Hitcheniopsis* in Southeast Asia and China: annual mean temperature (BIO1), maximum temperature of the warmest month (BIO5), minimum temperature of the coldest month (BIO6), annual precipitation (BIO12), precipitation of the wettest month (BIO13), and precipitation of the driest month (BIO14). These variables were chosen based on their relevance to the physiological and ecological requirements of the subgenus. The selection was made according to ecological rationale to capture key climatic factors influencing species distribution. Although no formal statistical test for multicollinearity was conducted, the six selected bioclimatic variables were chosen based on ecological rationale to represent independent and ecologically meaningful aspects of temperature and precipitation influencing the distribution of the subgenus [42–45]. Climatic data were obtained from WorldClim version 2.1 at 30 arc-second resolutions (https://www.worldclim.org/ (accessed on 1 July 2025).

Species distribution modeling was performed using MaxEnt version 3.4.4, a machine-learning algorithm widely applied to presence-only data [46]. The model was run with 10 replicates using cross-validation to ensure full utilization of occurrence records and to reduce potential overfitting. Previous studies have recommended at least 10 replicates to achieve robust predictive accuracy in species distribution models [47].

The resulting probability map of habitat suitability from MaxEnt was subsequently converted into binary maps of “suitable” and “unsuitable” habitats using the maximum sum of sensitivity and specificity (maxSSS) threshold, which is appropriate for presence-only data [48]. Grid cells below the threshold were classified as unsuitable, while those equal to or above the threshold were classified as suitable habitat for *Hitcheniopsis*.

2.6. Conservation Assessment

The conservation status of each species was assessed following the IUCN Red List criteria [27,28], based on specimen records, field surveys, and distribution data. These sources were used to evaluate the extent of distribution, occurrence in specific areas, and major threats such as habitat loss and anthropogenic pressures. In addition, the predicted distributions from the species distribution models (Section 2.5) were incorporated to support the assessment by comparing whether currently suitable areas are projected to remain suitable or become unsuitable in the future.

2.7. Nomenclature

Scientific names follow Plants of the World Online [49] and the International Plant Names Index (IPNI) [50]. Herbarium acronyms adhere to Index Herbariorum standards [51].

3. Results

3.1. Diversity of Curcuma Subgenus Hitcheniopsis in Vietnam

A total of ten species of *Curcuma* subgenus *Hitcheniopsis* were documented across Vietnam based on field surveys and herbarium records. Data were collected on vernacular names, flowering periods, ecological preferences, distribution status globally, and voucher specimens (Table 1).

Table 1. Diversity of *Curcuma* subgenus *Hitcheniopsis* in Vietnam.

No.	Scientific Name	Vernacular Names	Flowering Periods [1]	Ecological Preferences [2]	Distribution in Vietnam	Distribution Status Globally [3]	Voucher Specimens
1	*Curcuma alismatifolia* Gagnep.	Nghệ là tủ cô, Nghệ Thái	7–9	DC	An Giang, Quảng Ngãi, Ho Chi Minh City, Tay Ninh	KH, LA, TH, VN	CHV001
2	*Curcuma campanulata* (Kuntze) Škorničk.	Tà liền chuông	4–5	DC	Hanoi, Quảng Ngãi, Tay Ninh	KH, TH, VN	CHV002
3	*Curcuma clovisii* Škorničk.	Tam thất gừng	4–5	DC	Hanoi, Lao Cai, Quảng Ngãi, Gia Lai	KH, LA, TH, VN	CHV003
4	*Curcuma gracillima* Gagnep.	Nghệ mảnh	7–9	DC, DD	Dong Nai, Lam Dong, Tay Ninh	KH, TH, VN	CHV004
5	*Curcuma harmandii* Gagnep.	Nghệ harmand	7–9	DE	Phu Tho	KH, TH, VN	CHV005
6	*Curcuma leonidii* Škorničk. & Luu	Nghệ leonid	4–6	EV	Dong Nai	VN	CHV006
7	*Curcuma pygmaea* Škorničk. & Šída f.	Nghệ lùn	7–9	DC	Dak Lak	VN	CHV007
8	*Curcuma rhabdota* Sirirugsa & M.F.Newman	Nghệ rễ dẹp, Nghệ rễ sọc	7–9	DE	Dak Lak, Quảng Ngãi, Tay Ninh	KH, LA, TH, VN	CHV008
9	*Curcuma sparganiifolia* Gagnep.	Nghệ lá hắc tim lang	7–9	DC, DD	An Giang, Lam Dong	KH, TH, VN	CHV009
10	*Curcuma thorelii* Gagnep.	Nghệ thorel	7–9	DC, DD	Dak Lak, Hue, Lam Dong, Tay Ninh	KH, LA, TH, VN	CHV010

[1] Flowering period: 1 = January; 2 = February; 3 = March; 4 = April; 5 = May; 6 = June; 7 = July; 8 = August; 9 = September; 10 = October; 11 = November; 12 = December. [2] Habitats: DC = deciduous dipterocarp forest; DD = deciduous forest; DE = dry evergreen forest; and EV = evergreen forest. [3] Distribution status globally: KH = Cambodia; LA = Lao People's Democratic Republic; TH = Thailand; VN = Vietnam.

All species are native to Vietnam, while two species, *Curcuma leonidii* Škorničk. & Luu and *C. pygmaea* Škorničk. & Šída f. are endemic to Vietnam. Although the presence of *C. rhabdota* Sirirugsa & M.F.Newman has been mentioned in Indochina, no voucher specimens or specific localities in Vietnam were cited [3], and the species is not recorded in the Flora of Vietnam [4] or in the distribution maps of Plants of the World Online [49]. During field surveys of the sixth and seventh authors in Southern Vietnam, fortunately, *C. rhabdota* was observed for the first time in Tây Ninh Province. Therefore, we provide a description of its morphological characteristics here, as this is a new record for the flora of Vietnam, which expands our understanding of the species' distribution in the country and suggests that it may occur in additional areas within Vietnam. Furthermore, species distribution modeling indicates that suitable habitats for plants in this subgenus still exist, supporting the likelihood of additional populations yet to be documented.

New Record for the Flora of Vietnam

Curcuma rhabdota Sirirugsa & M.F.Newman [16] Type: *Newman* 1201, Laos, 24 October 2000 (holotype, BKF, isotype E).

Specimens from Vietnam examined: Vietnam: Tây Ninh Province, Tân Châu District, 25 August 2025, *T.Boonma CHV008*, VMSU 08900087 (Dried specimens with inflorescence: VMSU).

Description of specimens collected in Vietnam: Rhizome ovoid, 1.5–3 × 1–2.5 cm, internally cream to pale brown, rarely branched, very short; root tubers ovoid to ellipsoid, 1.5–4 × 1–2 cm, internally white. Leafy shoot 35–50 cm tall with (2–)4–6 leaves at anthesis; bladeless sheaths 2–3, green with maroon tinge, pubescent; leaf sheaths green or with reddish to maroon tinge, pubescent; ligule shallowly bilobed, 2–4 mm long, membranous; blades elliptic, 14–28 × 7–12 cm, plicate, dark green above, lighter below, upper surface glabrous, lower surface scabrous to the touch, base obtuse, apex acuminate; petiole 4–12 cm long, green or with slight reddish tinge, glabrous. Inflorescence central, 30–50 cm long; peduncle 25–45 cm long (including part hidden in leaf sheaths), green, glabrous; thyrse composed of 8–24 bracts; fertile bracts broadly obovate with rounded reflexed apex, 2.5–4 × 2.5–4 cm, connate at basal half, pale green with longitudinal maroon to brown stripes and often with a purple spot on each side of the free apical part; cincinni with 3–6 flowers at basal bracts; coma bracts elliptic with obtuse apex, 2–4 × 1–2 cm, pink to purplish pink above, pale pink with maroon longitudinal stripes below; bracteoles ovate to triangular with blunt to acute apex, 0.5–1.2 × 0.3–1 cm, concave, semitranslucent white, glabrous. Flower gullet type, c. 3 cm long; ovary subglobose, 2–2.5 × 2–2.5 mm, white, glabrous; epigynous glands absent; stigma funnel-shaped, c. 1 mm diam., white, ostiole ciliate; calyx 5–7 mm long, unilateral incision 2–3 mm, apex tridentate, semitranslucent white, glabrous; floral tube narrowly cylindrical, widening distally, 1.8–2 cm long, externally and internally white, glabrous; dorsal corolla lobe ovate to elliptic with slightly hooded apex, 8–10 × 5–7 mm, white, glabrous; lateral lobes ovate with rounded apex, which roll back soon after anthesis, 8–9 × 5–6 mm, white, glabrous; lateral staminodes broadly irregularly obovate with rounded apex, 8–10 × 6–8 mm, violet with red line along external margin at base; labellum narrowly elliptic with emarginate apex, 10 × 5–6 mm, white with violet-red patches along margin at base and pale yellow patch in center; stamen c. 7 mm long; filament 2–3 mm long, c. 3 mm wide at base, c. 1.5 mm at point of attachment, white or with tiny red dots, glabrous; anther spurless, c. 5 mm long, connective tissue white with short glandular hairs, crest rounded, c. 2 × 1.5 mm, white and thick, anther thecae c. 3 mm long, dehiscing throughout their length, pollen white. Fruit globose to subglobose; seeds irregularly obovoid, brown with laciniate aril.

- Vernacular name in Vietnam: Nghệ rễ dẹp, Nghệ rễ sọc, and Nghệ tím.
- Phenology: Flowering in July to September, fruiting in August.
- Distribution: Native to Laos, Thailand and Vietnam.

The *Curcuma rhabdota* specimens from Tây Ninh Province, Vietnam (Figure 2) show several minor differences compared with those recorded in Thailand and Laos [12,16]. In the Vietnamese plants, the bladeless and leaf sheaths are pubescent rather than glabrous, and the lower surface of the leaves is scabrous rather than smooth. Additionally, the flowers are slightly smaller (c. 3 cm compared with c. 4 cm in Thai–Laos specimens), and there are subtle differences in the coloration of the fertile and coma bracts, with Vietnamese plants showing more pronounced pinkish tones. Despite these morphological differences, all characters fall within the normal range of intraspecific variation, and the Vietnamese population is therefore considered conspecific with *C. rhabdota*. A key to the species of the subgenus is provided in Table 2 to assist in the identification of *Curcuma* subgen. *Hitcheniopsis* in Vietnam.



Figure 2. *Curcuma rhabdota* Sirirugsa & M.F.Newman in its natural habitat, Tân Châu District, Tây Ninh Province, Vietnam (25 August 2025). Photograph by Thawatphong Boonma.

Table 2. Key to species of *Curcuma* subgenus *Hitcheniopsis* in Vietnam.

1a. Bracts not laterally connate, campanulate involucre with two slits	2
1b. Bracts laterally connate to each other for about half their length and forming basal pouches	3
2a. Petiole 5–12 cm long; anther crest with a rounded apex	*Curcuma campanulata*
2b. Petiole 1–3 cm long; anther crest subquadrate with a truncate, somewhat emarginate apex	*Curcuma clovisii*
3a. Inflorescence without coma bract	4
3b. Inflorescence with coma bracts	7
4a. Bracts pink with green or purple at tip	*Curcuma sparganiifolia*
4b. Bracts green	5
5a. Labellum and staminodes with violet	*Curcuma pygmaea*
5b. Labellum and staminodes without violet	6
6a. Thyrse elongated, 9–15 cm long; corolla lobes and lateral staminodes greenish or greenish white	*Curcuma harmandii*
6b. Thyrse compact, 4–5 cm long; corolla lobes and lateral staminodes white	*Curcuma leonidii*
7a. Fertile bracts with maroon to brown longitudinal stripes and paired pink spots	*Curcuma rhabdota*
7b. Fertile bracts green without stripe and spot	8
8a. Labellum cream-white to yellow, or orange	*Curcuma gracillima*
8b. Labellum purple	9
9a. Coma bracts pale pink to dark pink magenta, sometimes with darker apices	*Curcuma alismatifolia*
9b. Coma bracts white	*Curcuma thorelii*

Additional specimens examined in Vietnam:

Curcuma alismatifolia Gagnep.: Vietnam, Tay Ninh, Lo Go Xa Mat National Park, Trang Ta Not, 13 June 2008, Trần H.Đ. 20 (E). Vietnam, Tay Ninh, Tan Chau, 25 August 2025, T.Boonma CHV001, VMSU08900082 (VMSU). Vietnam, Tay Ninh, Tan Chau, 25 August 2025, T.Boonma CHV011, VMSU08900083 (VMSU).

Curcuma campanulata (Kuntze) Škorničk.: Vietnam, Hanoi, N.Q. Binh 606 (HN). Vietnam, Quảng Ngãi, Kon Tum, L.K. Bien 570 (HN). Vietnam, Tay Ninh, Phuoc Than, C.Thorel 1222 (P).

Curcuma clovisii Škorničk.: Vietnam, Hanoi, D.H. Bich 411tA (HNPM). Vietnam, Quảng Ngãi, Kon Tum, Tap Long Tong 32 & 33 (HNPM), Vietnam, Gia Lai, Phuong, De Vi Von 108B (HNPM).

Curcuma gracillima Gagnep.: Vietnam, Dong Nai, Tan Phu Forest, Nga Tu Dong, 19 June 2008, Trần H.Đ. 48 (E). Vietnam, without precise locality, Barcode E00097678, Pierre J.B.L. s.n. (E). Vietnam, without precise locality, Barcode E00097679, Pierre J.B.L. s.n. (E).

Curcuma harmandii Gagnep.: Vietnam, Phu Tho, Hoa Binh, P.X. Truong s.n. (HNPM).

Curcuma leonidii Škorničk. & Luu: Vietnam, Dong Nai Province (Bình Phước), Bù Gia Mập National Park, Đắc Ca stream, 8 May 2012, Lưu Hồng Trương, Đinh Nhật Lâm & Võ Huy Sang LUU 807 (SGN, SING)

Curcuma pygmaea Škorničk. & Šída f.: Vietnam, Dak Lak, Ea H'Leo, 17 July 2010, Trần H.Đ. 239 (VNM).

Curcuma rhabdota Sirirugsa & M.F. Newman: Vietnam, Quảng Ngãi, Đak Na Khu Bảo Tồn, HN0000079760 (HN) (Figure 3A). Vietnam, Dak Lak Province, Dipterocarp Forest, c. 200 m a.s.l., collected by local collectors, 2019; 10 May 2024, Nguyen Van Canh, AL3130. LE 01255014 (LE).



Figure 3. Herbarium specimens: (**A**) *Curcuma rhabdota* Sirirugsa & M.F.Newman (0000079760–HN) (**B**) *Curcuma* aff. *plicata* (0000079761–HN) from Son La, originally identified as *C. thorelii* Gagnep. in the Flora of Vietnam [4], but here, re-determined as *Curcuma* aff. plicata based on morphological characters. Photograph taken on 8 September 2025 by Thawatphong Boonma.

Curcuma sparganiifolia Gagnep.: Vietnam, An Giang, Phu Quoc, Bai Thom Commune, Phu Quoc National Park, Dong Tram, 25 March 2018, Cao Ngọc Giang, Hà Văn Long, Lý Ngọc Sâm, Trần Thị Liên, Trần Minh Ngọc TNB-042 (VNM), ibid. TNB-044 (VNM). Vietnam, Lam Dong, Muong man, 19 October 1924, Evrard F. 1496 (P). Lam Dong, Muong man, 26 October 1924, Evrard F. 1578 (P).

Curcuma thorelii Gagnep.: Vietnam, Lam Dong, Binh Thuan, La Gi, 3 July 1925, Evrard F. 2322 (E). Hue, September 1877, Harmand F.J. 4891 (P). Dak Lak, Ea H'Leo, 17 July 2010, Trần H.Đ. 238 (SING). Dak Lak, Ban Don, Altitude 223 m, 25 June 2008 (E). Dak Lak, Ea H'Leo, 482 m, 30 July 2009, Trần H.Đ., Truong A.T. & Nguyen T.T. 178 (E).

Note on misidentified specimens: During a visit to the HN herbarium on 8 September 2025, the last author examined specimen LX-VN028, collected from Son La on 3 July 1976 and deposited at HN (Code 0000079761) (Figure 3B). This specimen had previously been identified as *Curcuma thorelii* Gagnep. in the Flora of Vietnam, Vol. 21, Zingiberaceae [4]. Upon careful examination, it was found that the specimen does not match *C. thorelii* Gagnep., as it exhibits morphological traits inconsistent with subgenus *Hitcheniopsis* and instead shows characters typical of subgenus *Curcuma*, such as the presence of two anther spurs and epigynous structures. Based on these observations, the specimen is here determined as *Curcuma* aff. *plicata*.

3.2. Traditional Uses

All ten species of Curcuma subgen. Hitcheniopsis in Vietnam, including C. alismatifolia, C. campanulata, C. clovisii, C. gracillima, C. harmandii, C. leonidii, C. pygmaea, C. rhabdota, C. sparganiifolia, and C. thorelii were cultivated either in pots or directly in the soil and were primarily used for ornamental purposes, such as garden decoration or placement around buildings and homes. Curcuma clovisii was additionally documented for traditional medicinal use; its rhizome was applied in decoctions, pastes, or as part of compound prescriptions for treating musculo-skeletal disorders, blood-related conditions, digestive and metabolic issues, nervous system ailments, and respiratory problems [4]. Most of the species served horticultural and decorative functions, while C. clovisii also demonstrated ethnomedicinal significance (Table 3).

Table 3. Traditional uses of *Curcuma* subgenus *Hitcheniopsis* in Vietnam.

No.	Scientific Name	Used Parts	Methods of Preparation/Cultivation	Purposes of Use
1	*Curcuma alismatifolia* Gagnep.	Whole plant Inflorescence	Cultivated in pot or in the soil Cut inflorescences for placing in a vase or arranging as bouquets	Ornamental Ornamental
2	*Curcuma campanulata* (Kuntze) Škorničk.	Whole plant	Cultivated in pot or in the soil	Ornamental
3	*Curcuma clovisii* Škorničk.	Whole plant Rhizome	Cultivated in pot or in the soil Decoction; paste; included in compound prescriptions	Ornamental Musculo-skeletal system; Blood and blood-forming organs; Alimentary tract and metabolism; Nervous system; and Respiratory system
4	*Curcuma gracillima* Gagnep.	Whole plant	Cultivated in pot or in the soil	Ornamental
5	*Curcuma harmandii* Gagnep.	Whole plant	Cultivated in pot or in the soil	Ornamental
6	*Curcuma leonidii* Škorničk. & Luu	Whole plant	Cultivated in pot or in the soil	Ornamental
7	*Curcuma pygmaea* Škorničk. & Šída f.	Whole plant	Cultivated in pot or in the soil	Ornamental
8	*Curcuma rhabdota* Sirirugsa & M.F.Newman	Whole plant Inflorescence	Cultivated in pot or in the soil Cut inflorescences for placing in a vase or arranging as bouquets	Ornamental Ornamental
9	*Curcuma sparganiifolia* Gagnep.	Whole plant	Cultivated in pot or in the soil	Ornamental
10	*Curcuma thorelii* Gagnep.	Whole plant Inflorescence	Cultivated in pot or in the soil Cut inflorescences for placing in a vase or arranging as bouquets	Ornamental Ornamental

3.3. Ornamental Potential

3.3.1. Ornamental Value Index

The Ornamental Value Index (OVI) of the ten species of *Curcuma* subgen. *Hitcheniopsis* in Vietnam varied considerably, with mean values ranging from 0.460 to 0.780 (Table S2). Based on the OVI interpretation scale (0–1), all species were classified within the moderate to high ornamental value categories (Figure 4).

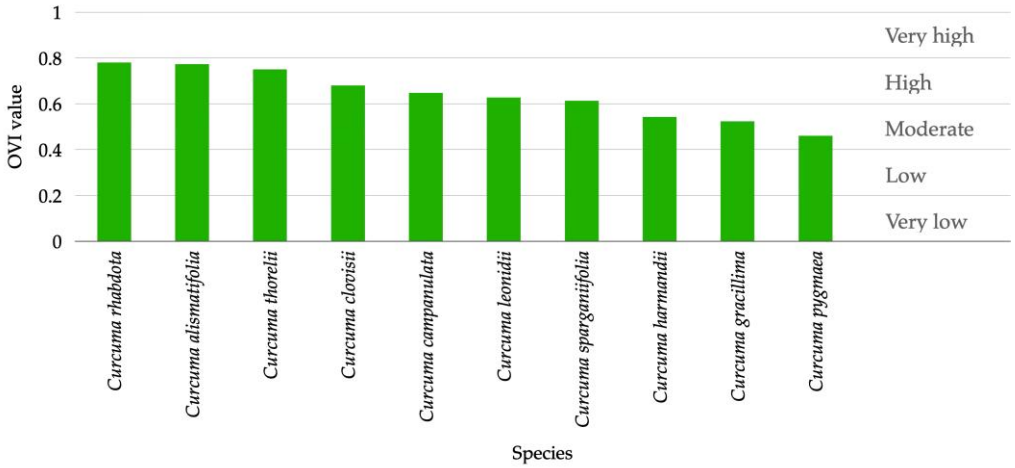

Figure 4. Ornamental Value Index (OVI) of *Curcuma* subgenus *Hitcheniopsis* species in Vietnam, arranged from high to low OVI.

The highest mean OVI was recorded in *Curcuma rhabdota* (0.780 ± 0.014), followed closely by *C. alismatifolia* (0.773 ± 0.032) and *C. thorelii* (0.750 ± 0.024) (Table S2). These three species were therefore classified as having high ornamental value. Intermediate values were found in *C. clovisii* (0.680 ± 0.045), *C. campanulata* (0.647 ± 0.018), *C. leonidii* (0.627 ± 0.015), and *C. sparganiifolia* (0.613 ± 0.022), all of which also fell within the high ornamental value category. Notably, *C. clovisii* exhibited the widest range among the taxa, suggesting some degree of variability within the species. In contrast, *C. harmandii* (0.543 ± 0.009) and *C. gracillima* (0.523 ± 0.009) showed lower but stable scores, while *C. pygmaea* recorded the lowest mean OVI (0.460 ± 0.009). These three taxa were classified as having moderate ornamental value. Across the studied taxa, none were categorized as very low, low, or very high in ornamental value. The findings point to a predominance of high-value species within the sampled set, with *C. rhabdota*, *C. alismatifolia*, and *C. thorelii* standing out as particularly noteworthy.

3.3.2. Results of Kruskal–Wallis Test

A Kruskal–Wallis test was conducted to determine if there were statistically significant differences in the mean ranks of the OVI variable across ten different *Curcuma* subgen. *Hitcheniopsis* species in Vietnam. The test revealed a highly significant difference, with a Kruskal–Wallis H statistic of 46.298 and a *p*-value (Asymp. Sig.) of 0.000 (Figure 5). This result indicates that at least one of the species groups' mean ranks is significantly different from the others. *Curcuma rhabdota* had the highest mean rank (45.20), while *C. pygmaea* had the lowest (3.00) (Figure 5).

The highly significant *p*-value of 0.000 (which is less than the typical alpha level of 0.05) leads us to reject the null hypothesis. The null hypothesis states that the medians of all groups are equal. Therefore, we can conclude that there are significant differences in the OVI variable among the different *Curcuma* subgen. *Hitcheniopsis* species in Vietnam.

Ranks

	Species	N	Mean Rank
OVI	*Curcuma alismatifolia*	5	43.80
	Curcuma campanulata	5	27.90
	Curcuma clovisii	5	31.00
	Curcuma gracillima	5	8.40
	Curcuma harmandii	5	12.60
	Curcuma leonidii	5	22.80
	Curcuma pygmaea	5	3.00
	Curcuma rhabdota	5	45.20
	Curcuma sparganiifolia	5	20.70
	Curcuma thorelii	5	39.60
	Total	50	

Test Statistics[a,b]

	OVI
Kruskal–Wallis H	46.298
df	9
Asymp. Sig.	0.000

a. **Kruskal–Wallis Test**

b. Grouping Variable: Species

Predetermined significance level ($\alpha = 0.05$)

Figure 5. Results of the Kruskal–Wallis Test on the variable OVI across ten *Curcuma* subgen. *Hitcheniopsis* species. The table of ranks shows the mean rank for each species, while the test statistics table indicates a significant difference among the groups (H = 46.298, df = 9, $p = 0.000$), lower than the predetermined significance level ($\alpha = 0.05$).

However, since the Kruskal–Wallis test is an overall test, it is necessary to conduct post hoc pairwise comparisons using the Mann–Whitney U test.

The Kruskal–Wallis test indicated statistically significant interspecific differences in OVI values among the ten *Curcuma* species (H = 46.298, df = 9, $p < 0.05$). To visually support these findings, both a boxplot and a violin plot were constructed to illustrate the distributional patterns and rank-based variability of OVI scores across species (Figure 6). Species with visibly higher median OVI values exhibited narrower distributional spread, whereas species with lower OVI values demonstrated wider dispersion and pronounced skewness. These visual patterns are consistent with the inferential results and reinforce the presence of meaningful interspecific variation in ornamental potential.

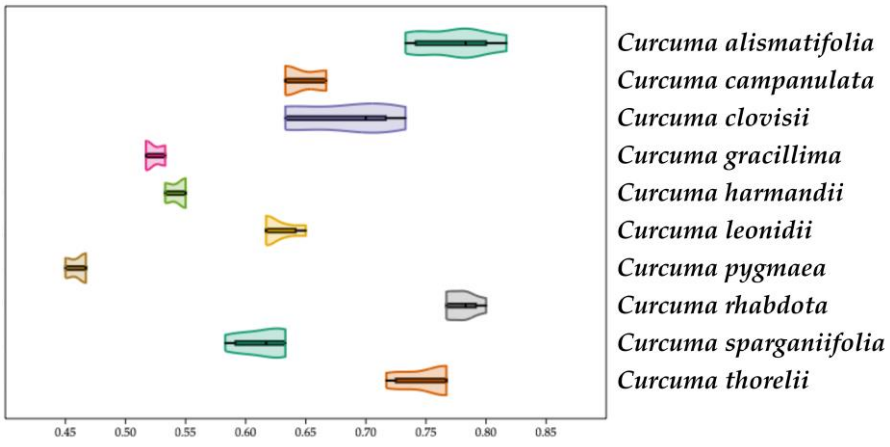

Figure 6. Violin and box plots showing the distributional patterns and rank-based variability of Ornamental Value Index (OVI) scores across the ten *Curcuma* species.

The combined visualization highlights differences in central tendency, dispersion, and density structure, thereby revealing interspecific variation in ornamental attributes. Species with higher OVI scores display narrower and more concentrated distributions, whereas species with lower scores exhibit broader spread and skewness. These graphical patterns are consistent with the Kruskal–Wallis test results and reinforce the presence of statistically significant differentiation in ornamental potential among species.

3.3.3. Result of Mann–Whitney U Test

To further investigate differences in ornamental value among the ten *Curcuma* subgen. *Hitcheniopsis* species, post hoc pairwise comparisons were conducted using the Mann–Whitney U test for all 45 possible species pairs, with a predetermined significance level of $\alpha = 0.05$. The Mann–Whitney U test was chosen as a non-parametric method suitable for comparing ordinal data like the Ornamental Value Index (OVI).

Most species pairs differed significantly, indicating substantial variation in OVI values across species. However, no significant differences were observed between *C. alismatifolia* and *C. rhabdota* (U = 11.000, Z = −0.324, $p = 0.746$) (Figure 7A), or between *C. alismatifolia* and *C. thorelii* (U = 6.500, Z = −1.277, $p = 0.202$) (Figure 7B), suggesting that these species have similar ornamental values. The post hoc analysis confirms that the OVI effectively distinguishes ornamental potential among most species, while the few non-significant comparisons reflect closely related species with comparable floral and inflorescence traits. These results support the reliability of OVI as a tool for horticultural evaluation, breeding selection, and conservation prioritization.

A

Ranks

	Species	N	Mean Rank	Sum of Ranks
OVI	*Curcuma alismatifolia*	5	5.20	26.00
	Curcuma rhabdota	5	5.80	29.00
	Total	10		

Test Statistics [a]

	OVI
Mann–Whitney U	11.000
Wilcoxon W	26.000
Z	−0.324
Asymp. Sig. (2-tailed)	0.746
Exact Sig. [2*(1-tailed Sig.)]	0.841[b]

a. Grouping Variable: Species

b. Not corrected for ties.

B

Ranks

	Species	N	Mean Rank	Sum of Ranks
OVI	*Curcuma alismatifolia*	5	6.70	33.50
	Curcuma thorelii	5	4.30	21.50
	Total	10		

Test Statistics [a]

	OVI
Mann–Whitney U	6.500
Wilcoxon W	21.500
Z	−1.277
Asymp. Sig. (2-tailed)	0.202
Exact Sig. [2*(1-tailed Sig.)]	0.222[b]

a. Grouping Variable: Species

b. Not corrected for ties.

Figure 7. Results of the Mann–Whitney U test comparing the Ornamental Value Index (OVI): (**A**) Mann–Whitney U test between *Curcuma alismatifolia* and *C. rhabdota*; (**B**) Mann–Whitney U test between *C. alismatifolia* and *C. thorelii.* Mean ranks, sum of ranks, U values, Z scores, and significance levels (2-tailed) are presented for each comparison. No significant differences were found at a predetermined significance level of $\alpha = 0.05$. * indicates that the Exact Sig. value is calculated as 2 × (1-tailed Sig.).

The Mann–Whitney U test results support the reliability of the Ornamental Value Index (OVI) by demonstrating that most pairwise comparisons among the ten *Curcuma* subgen. *Hitcheniopsis* species differed significantly, confirming that the OVI effectively reflects variation in ornamental traits. The few non-significant differences, such as between *C. alismatifolia* and *C. rhabdota* or *C. thorelii*, indicate that these species possess similar ornamental features. These findings validate the OVI as a meaningful tool for distinguishing ornamental potential among species and provide important insights for their horticultural evaluation, breeding, and conservation planning.

The dendrogram derived from the raw OVI scores (Figure 8) revealed distinct clustering among the *Curcuma* species according to ornamental similarity. Species with high OVI values, such as *C. alismatifolia* and *C. rhabdota*, consistently clustered together, reflecting their prominently expressed floral traits and well-balanced aesthetic profiles. In contrast, species with moderate to low OVI values (e.g., *C. gracillima*, *C. pygmaea*) formed separate clusters, corresponding to their relatively inconspicuous floral and vegetative characters. Notably, *C. sparganiifolia* appeared as a discrete subgroup despite high scores on certain traits, likely due to divergence in inflorescence architecture or peduncle morphology. Overall, the cluster structure corroborates the ability of the OVI to differentiate species based on both aggregate ornamental merit and trait-specific variation.

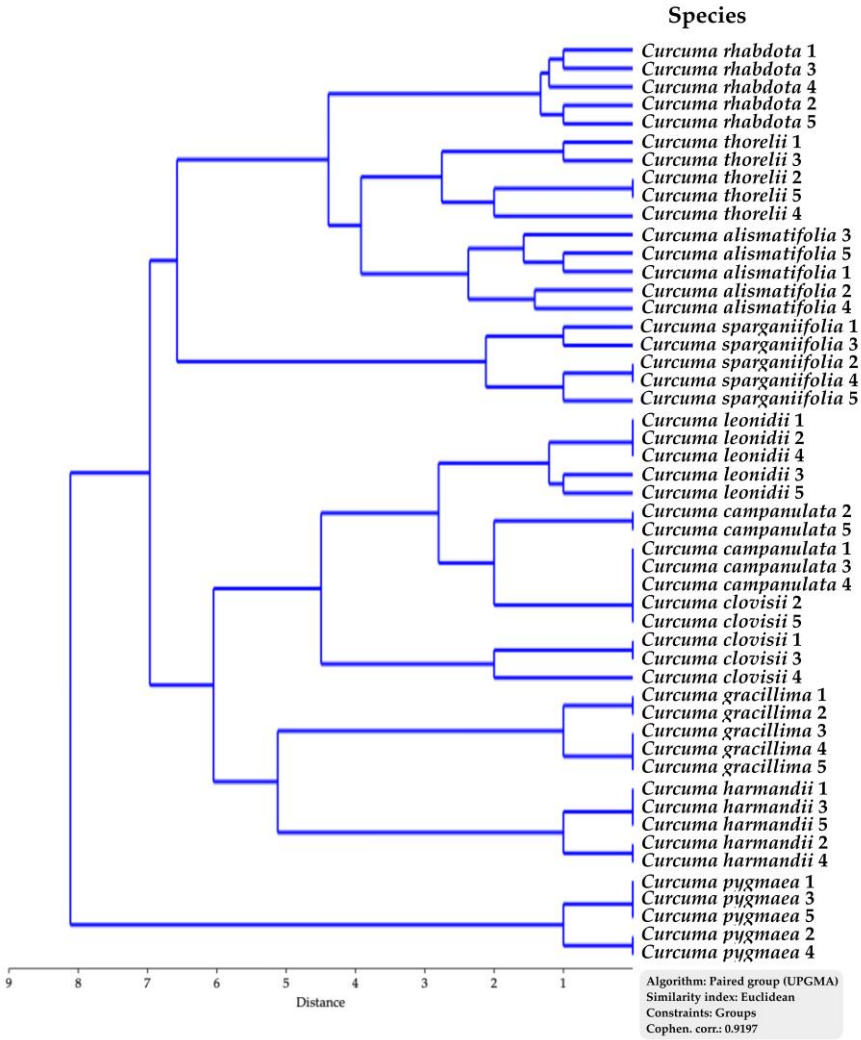

Figure 8. Dendrogram of *Curcuma* spp. based on Ornamental Value Index (OVI) raw scores. Clustering was performed using UPGMA with Euclidean distance, revealing groups with similar flower and leaf traits. Cophenetic correlation = 0.9197.

3.4. Potential Distribution Modelling

The modelling results for the *Curcuma* subgen. *Hitcheniopsis* demonstrate high predictive performance and excellent discriminatory ability, with an average AUC of 0.9475. Under current climatic conditions, the model estimates that suitable habitats for *Curcuma* subgen. *Hitcheniopsis* are concentrated across large areas of mainland Southeast Asia, particularly in Thailand, Laos, Vietnam, Cambodia, and Myanmar. Substantial suitable regions are also projected in southern China, extending from Yunnan and Guangxi Provinces east-

ward along the subtropical belt. Additional suitable habitats are identified in parts of the Philippines and the Indonesian archipelago, including Java and Sulawesi (Figure 9).

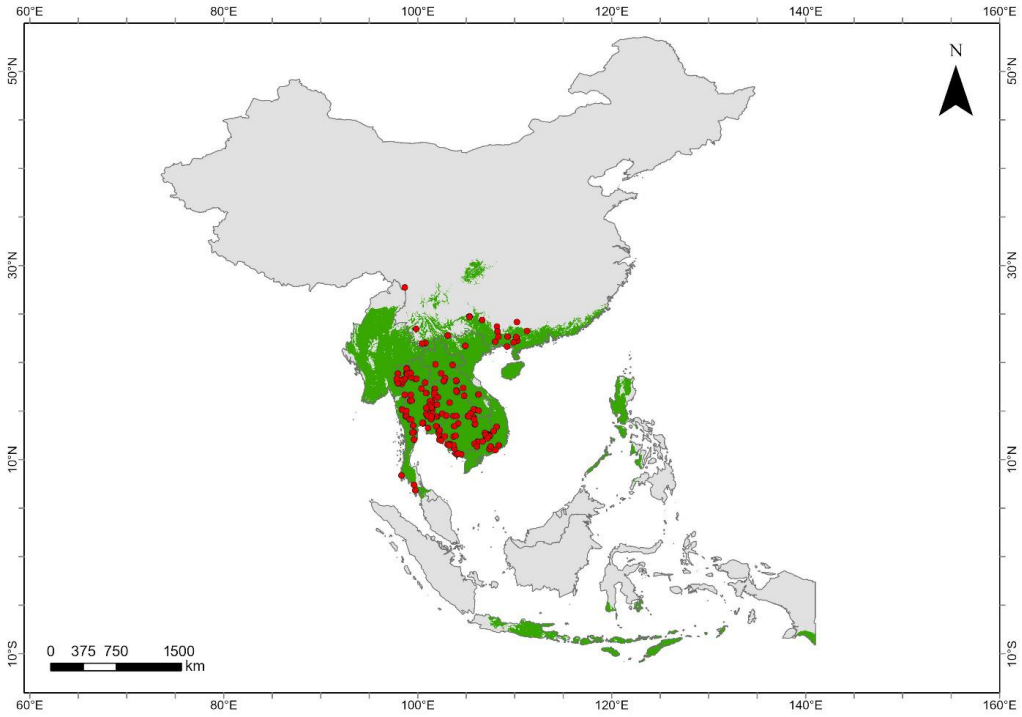

Figure 9. Estimated potential distribution of the *Curcuma* subgenus *Hitcheniopsis* in Southeast Asia and China under current climatic conditions. Areas in green represent suitable habitat, whereas grey areas represent unsuitable habitat. Points denote known occurrence records.

The predicted areas extend beyond currently documented localities, highlighting regions that may harbor yet-undiscovered populations. For example, the model identifies suitable habitats in northern Myanmar and island regions such as Sumatra and Java, where field records remain scarce or absent. This indicates that targeted field surveys in these areas may reveal previously undocumented populations, thereby contributing to a more comprehensive understanding of the subgenus' distribution.

The potential distribution modeling for *Curcuma* subgen. *Hitcheniopsis* strongly supports this study, particularly in Vietnam, by identifying areas with high habitat suitability and providing a predictive framework for discovering new populations. The model, which achieved an average AUC of 0.9475, highlights regions with suitable climatic conditions that extend beyond known localities, indicating areas likely to harbor previously undocumented populations. Notably, field surveys in Vietnam confirmed a new record, *C. rhabdota*, in Tay Ninh within one of the predicted suitable regions, validating the model's accuracy and demonstrating its practical value for guiding future exploration. These results not only corroborate observed distribution patterns in Vietnam but also enhance understanding of the subgenus' ecological preferences and potential range across the region, and suggest that new species may potentially be discovered in the future.

3.5. Conservation Status Assessment

The conservation assessment of species within the *Curcuma* subgenus *Hitcheniopsis* was conducted following the IUCN Red List criteria. As shown in the distribution modelling results (Section 3.3), suitable habitats extend across broader areas of Southeast Asia and southern China than currently documented, suggesting the possibility of undiscovered populations. However, in the absence of confirmed field records from these predicted regions, threat evaluations must rely primarily on verified occurrences.

Most species of *Curcuma* subgenus *Hitcheniopsis* exhibit narrow distribution ranges; e.g., *C. leonidii* and *C. pygmaea*, which are endemic to Vietnam, are often restricted to specific habitats that are subject to ongoing threats such as agricultural expansion, infrastructure development, and habitat degradation. These pressures highlight the vulnerability of the subgenus, particularly for species with few known localities (Figure 10).

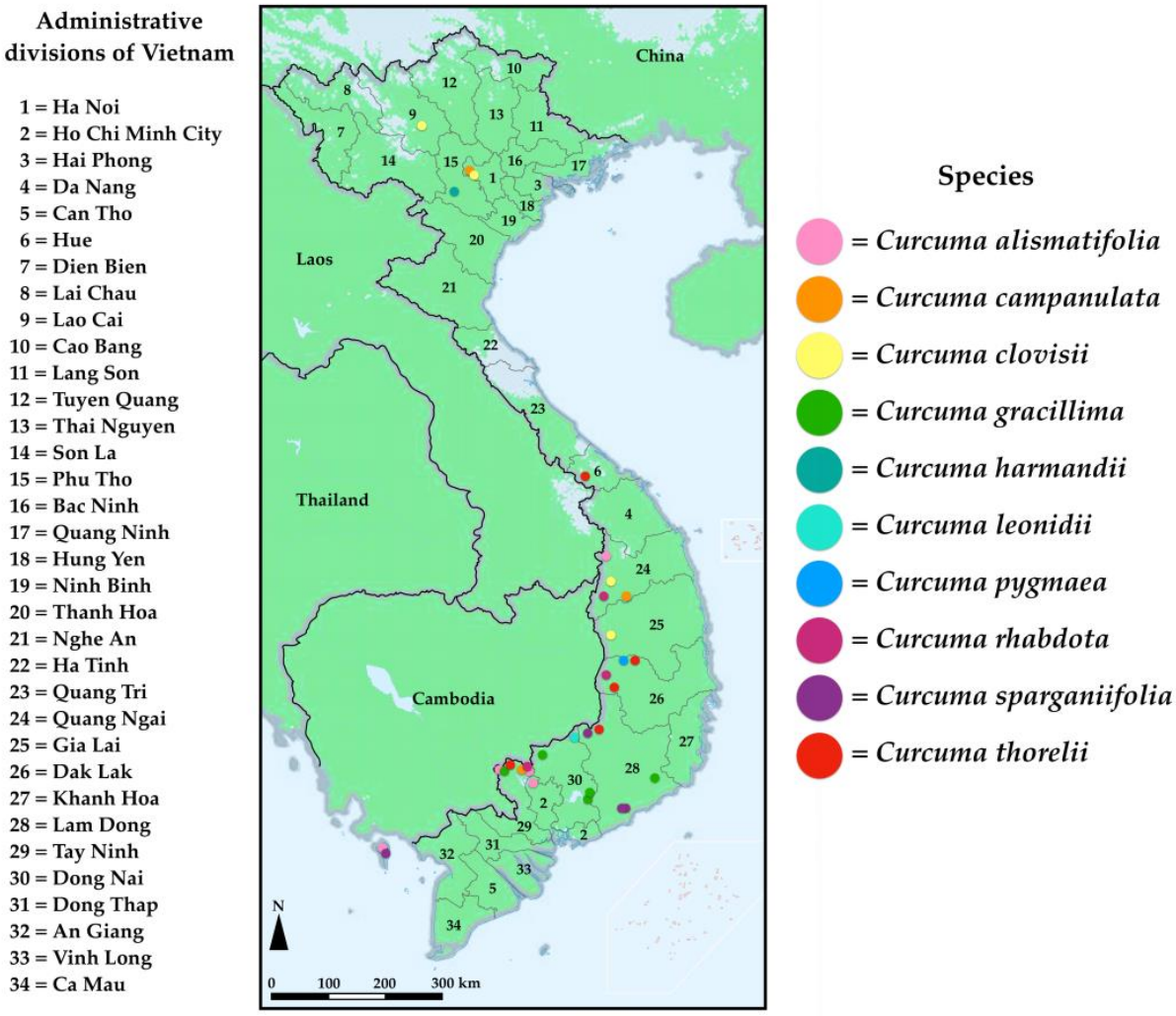

Figure 10. Distribution map of ten species of *Curcuma* subgenus *Hitcheniopsis* in Vietnam. Areas in green represent suitable habitats, whereas grey areas indicate unsuitable habitats.

The integration of predictive modelling with field data provides a more comprehensive perspective, but until further surveys are undertaken, the conservation status of each species should be assessed cautiously. Preliminary conservation categories for each taxon are summarized in Table 4.

The conservation assessment of *Curcuma* subgenus *Hitcheniopsis* in Vietnam shows varying levels of risk. *C. harmandii* and *C. thorelii* are Least Concern (LC), while *C. alismatifolia*, *C. campanulata*, *C. clovisii*, and *C. gracillima* are Near Threatened (NT) due to small, scattered populations and habitat disturbance. Endemic species *C. leonidii* and *C. pygmaea* are Critically Endangered (CR) with extremely limited ranges, whereas *C. rhabdota* is Vulnerable (VU) and *C. sparganiifolia* is Endangered (EN) owing to small population sizes and ongoing threats.

Table 4. Conservation Status Assessment of *Curcuma* subgenus *Hitcheniopsis* in Vietnam.

No.	Scientific Name	Distribution Status for Vietnam	IUCN Red List Status [1] in Website [52]	Propose Conservation Status Assessments [1]	Notes
1	*Curcuma alismatifolia* Gagnep.	Native	NT	NT	During field surveys in Vietnam, small populations of this species were observed at forest edges adjacent to agricultural land. Habitat clearance in these areas poses a direct threat. The species occurs in open deciduous forests and shallow sandy soils, and its limited and fragmented distribution supports a provisional assessment of Near Threatened, as ongoing habitat disturbance may lead to population declines.
2	*Curcuma campanulata* (Kuntze) Škorničk.	Native	NE	NT	Populations are small and scattered, typically growing in moist humus soils along field edges and under forest canopy in northern and central Vietnam, with potential threats from habitat clearance, forest degradation, and future local harvesting.
3	*Curcuma clovisii* Škorničk.	Native	NE	NT	Populations are limited and scattered, occurring near streams and in moist habitats in northern and central Vietnam. The rhizomes are used in traditional medicine, which poses a higher risk to the species than harvesting other parts of the plant and may contribute to population declines.
4	*Curcuma gracillima* Gagnep.	Native	LC	NT	It is widespread and occurs in open lowland semi-deciduous forests and moist sandy areas in Vietnam. Although the species is not used locally for food or medicine, its populations are potentially vulnerable to overharvesting and habitat disturbance, as observed in nearby Thailand, where wild plants have increasingly been collected for ornamental use. Its limited use in Vietnam, combined with potential threats from habitat alteration, supports monitoring and a precautionary assessment.
5	*Curcuma harmandii* Gagnep.	Native	LC	LC	Occurs under the canopy of open, moist forests, specifically in Hòa Bình province in southern Vietnam. Although detailed information on population size and trends is limited, it has been found to be occasionally cultivated as an ornamental plant, and there are no reports of other uses. The species is not highly popular among collectors and does not face significant threats. Its presence in suitable habitats and low collection pressure supports a provisional assessment of Least Concern in Vietnam.

Table 4. *Cont.*

No.	Scientific Name	Distribution Status for Vietnam	IUCN Red List Status [1] in Website [52]	Propose Conservation Status Assessments [1]	Notes
6	*Curcuma leonidii* Škorničk. & Luu	Endemic	CR	CR B2ab(iii)	Restricted to a single locality with an estimated area of occupancy (AOO) of 4 km^2 within a National Park but is threatened by increasing human pressures from surrounding areas. Due to its extremely limited range and ongoing threats, it qualifies as Critically Endangered (CR) under IUCN criterion B2.
7	*Curcuma pygmaea* Škorničk. & Šída f.	Endemic	CR	CR B2ab(iii)	This species is known only from the type locality at Ea H'Leo village, Ea H'Leo Dist., Dak Lak Province, Viet Nam, with an estimated area of occupancy (AOO) of 4 km^2. Although the area lacks formal protection, suitable dipterocarp habitat still exists, and surveys are urgently needed to determine whether any subpopulations persist.
8	*Curcuma rhabdota* Sirirugsa & M.F.Newman	Native	VU	VU B2ab(iii,v)	In this study, *Curcuma rhabdota* is confirmed for the first time in Vietnam, based on specimens collected from Tây Ninh Province, in forests close to the Cambodian border. The surrounding areas are being cleared for agriculture and other human activities, raising concerns that this newly documented population may be directly threatened. A similar situation has been observed in Thailand, where the species is harvested from the wild for ornamental trade. Although its popularity in Vietnam is not yet high, urgent conservation measures are needed to protect both the species and its habitat.
9	*Curcuma sparganiifolia* Gagnep.	Native	NT	EN B2ab(v),D	*Curcuma sparganiifolia* is known in Vietnam from a single population of fewer than 100 mature individuals within an area of occupancy of under 32 km^2 in Phú Quốc National Park. Although the site is legally protected, the species faces ongoing habitat loss and degradation due to tourism development. It is very small population size, restricted distribution, and continuing decline in habitat quality justify its assessment as Endangered (EN) under criteria B2ab(v) and D.
10	*Curcuma thorelii* Gagnep.	Native	NE	LC	*Curcuma thorelii* is widely distributed across southern, central, and Central Highlands regions of Vietnam, occurring in multiple provinces and locations. The species appears to have a relatively large area of occupancy and is not confined to a single population or heavily fragmented habitat. There are currently no reports of significant threats impacting its populations across its range. Based on this information, the species is considered Least Concern.

[1] Conservation status: NE = Not evaluated; LC = Least Concern; NT = Near threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered.

3.6. Tips for Cultivating Curcuma Subgenus Hitcheniopsis as Pot Plants

Based on the ecological preferences, flowering periods, and dormancy patterns observed for the species in Vietnam, the following guidelines are recommended for successful pot cultivation:

- Potting and soil: Use well-drained, sandy-loamy or peat-based substrates in pots with adequate drainage holes to prevent rhizome rot.
- Light: During the active growing phase, most species of *Curcuma* subgenus *Hitcheniopsis* thrive in partial sunlight. *Curcuma alismatifolia*, *C. campanulata*, *C. clovisii*, *C. gracillima*, *C. pygmaea*, *C. sparganiifolia*, and *C. thorelii* generally tolerate bright, filtered light. *Curcuma harmandii* and *C. rhabdota* prefer moderately shaded conditions, while *C. leonidii* grows best under low to moderate light levels.
- Watering: Provide consistent moisture while plants are actively growing, avoiding waterlogging. Reduce watering during dormancy to prevent rhizome decay.
- Fertilization: Apply a balanced liquid or slow-release fertilizer every 3–4 weeks during the growing season to enhance leaf and inflorescence development.
- Temperature: Maintain warm conditions during growth and avoid prolonged exposure to cold, as tropical species may become stressed.
- Dormancy management: Allow foliage to naturally senesce in winter. Rhizomes can remain in the pot or be lifted and stored in slightly moist substrate in a cool, shaded location until the next growth cycle.

Propagation: The most practical method for pot cultivation is rhizome or new shoot division. For large-scale propagation or hybrid production, tissue culture can be employed. These approaches help maximize flowering and ornamental display, while respecting the plants' natural seasonal cycles and promoting sustainable cultivation practices.

4. Discussion

In Vietnam, ten species of *Curcuma* subgenus *Hitcheniopsis* were identified, including two endemics (*C. leonidii* and *C. pygmaea*) [30,31]. Notably, *C. rhabdota* was recorded for the first time in the country, extending its known range and suggesting the possibility of other undocumented populations [4,49]. Most species were observed in deciduous dipterocarp and dry evergreen forests [4], highlighting clear habitat preferences and the importance of these forest types for regional biodiversity. Most species, including *C. alismatifolia*, *C. gracillima*, *C. harmandii*, *C. pygmaea*, *C. rhabdota*, *C. sparganiifolia*, and *C. thorelii*, flower from July to September, coinciding with the peak of the rainy season. Early flowering species, such as *C. campanulata* and *C. clovisii* [4], which produce lateral inflorescences, flower from April to May, likely reflecting inflorescence position and habitat effects. In contrast, *C. leonidii* [31], which produces a terminal inflorescence and occurs in dry evergreen forests, flowers earlier, from April to June, likely due to microclimatic differences such as light and soil moisture. This temporal separation highlights phenological niche differentiation, reducing interspecific competition and supporting species coexistence. These patterns are valuable for conservation planning, targeted surveys, and ornamental utilization.

Accurate species identification is essential for reliable taxonomic studies, as it ensures that morphological data, distribution records, and evolutionary relationships are correctly interpreted. Careful verification of herbarium specimens strengthens the foundation of systematic research and supports consistent biodiversity assessments. For example, specimen LX-VN028 from Son La was previously identified as *Curcuma thorelii* [4], but detailed morphological examination revealed traits characteristic of subgenus *Curcuma* rather than subgenus *Hitcheniopsis*. Correctly recognizing this specimen as *Curcuma* aff. *plicata* not only clarifies its true taxonomic placement but also highlights the value of revisiting historical collections to improve the accuracy of floristic and evolutionary studies.

The confirmation of *Curcuma rhabdota* in Vietnam provides a significant contribution to botanical knowledge. While the species has been mentioned in broader Indochinese records, no verified specimens from Vietnam existed until this study. The specimen from Tây Ninh Province now establishes its presence in the national flora and strengthens the accuracy of regional inventories. Verified specimens serve as essential references for future taxonomic, ecological, and ethnobotanical research, ensuring that conservation measures and sustainable management plans rely on correctly identified populations. Furthermore, authentic plant material can support ornamental cultivation, breeding programs, and studies of bioactive compounds, effectively connecting field taxonomy to applied research.

Species distribution modeling revealed that suitable habitats for *Curcuma* subgenus *Hitcheniopsis* extend beyond the currently documented locations in Vietnam [4], covering parts of Southeast Asia and southern China [38,49]. These predictions indicate areas where undiscovered populations may occur and highlight landscapes that could be prioritized for conservation or ex situ cultivation. Habitat modeling thus provides practical guidance for targeted field surveys and planning sustainable use [46–48].

All documented species showed moderate to high decorative value. *Curcuma rhabdota*, *C. alismatifolia*, and *C. thorelii* scored the highest in the Ornamental Value Index (OVI). Statistical tests (Kruskal–Wallis and Mann–Whitney U) confirmed significant differences in OVI among most species, while some closely related taxa had similar values, reflecting shared morphological traits. Species with high OVI have already been used as parents in hybrid production in Thailand, including *Curcuma* hybrid 'Chocolate' (*C. harmandii* × (*C. alismatifolia* × *C. rhabdota*), 'Maejo Elite' (*C. rhabdota* × *C. alismatifolia*), and 'Chiang Rai CF3' (*C. alismatifolia* × *C. thorelii*) [53]. These examples illustrate the practical potential of high-OVI species for horticultural breeding, commercial propagation, and ornamental landscaping.

The Ornamental Value Index of *Curcuma* species was strongly influenced by floral and inflorescence characteristics. Species with high OVI values, such as *C. alismatifolia*, *C. rhabdota*, and *C. thorelii*, consistently exhibited large and showy flowers with prominent color contrast, high flower abundance, and well-developed coma and fertile bracts. Additionally, these species displayed tall peduncles and moderately long thyrses, which elevated the inflorescence above the foliage and enhanced visual prominence. Leaf size and color contributed to overall aesthetic balance, but the primary drivers of high OVI were floral traits and the distinctive appearance of the inflorescence. In particular, the combination of floral display, structural balance, and unique or rare visual features rendered these species most attractive, indicating that aesthetic and rarity-related traits play a central role in shaping the ornamental potential of *Curcuma* species.

However, this study is limited by the small sample size per species. Consequently, the current Ornamental Value Index (OVI) results should be considered preliminary and require further verification through larger-scale cultivation experiments with more individuals per species.

Although most species are cultivated primarily for ornamental purposes, some, such as *C. clovisii*, are known for traditional medicinal uses. Additionally, several species in Vietnam have been investigated for bioactive compounds and pharmacological activities, including volatile constituents of *C. harmandii* [54]; antioxidant and antidiarrheal properties of *C. alismatifolia* leaves [55]; antimicrobial compounds from rhizomes of *C. rhabdota*, *C. thorelii*, and *C. petiolata* [40]; essential oil components and antibacterial activity of *C. pygmaea* [56]; volatile leaf oils of *C. thorelii* [57]; and acetone extracts of *C. thorelii* [58]. These findings indicate that even species without documented traditional medicinal uses may possess valuable bioactive properties, emphasizing the subgenus' significance for both pharmacological and horticultural applications.

Flowering periods among *Hitcheniopsis* species in Vietnam range from April to September (Table 1), with each species exhibiting distinct timing. For example, *C. campanulata* and *C. clovisii* flower in April–May, while *C. alismatifolia*, *C. gracillima*, *C. harmandii*, *C. pygmaea*, *C. rhabdota*, *C. sparganiifolia*, and *C. thorelii* flower from July to September, and *C. leonidii* blooms from April to June. All species enter a pronounced dormancy during cooler winter months, when above-ground shoots senesce and rhizomes remain inactive. Recognizing these dormancy patterns is critical for successful ornamental cultivation, as it guides watering, fertilization, and propagation schedules. Proper management of light and temperature during dormancy ensures rhizome health and supports vigorous regrowth, enabling synchronized flowering and optimal display in pots.

To prevent overexploitation, all species of *Curcuma* subgenus *Hitcheniopsis* require sustainable management. Conservation measures should include ex situ cultivation, reduced collection from natural habitats, and promotion of sustainable use practices. Unprotected areas could be designated as Other Effective area-based Conservation Measures (OECMs) [28,59,60] to maintain long-term population stability and support horticultural use. By integrating field surveys, species distribution modeling, ornamental assessment, and ethnobotanical data, this study provides a practical framework for conservation, sustainable horticulture, and the broader biological understanding of *Curcuma* subgenus *Hitcheniopsis* in Vietnam and Southeast Asia.

5. Conclusions

This study provides a comprehensive assessment of the diversity, traditional uses, ornamental potential, distribution, and conservation status of *Curcuma* subgenus *Hitcheniopsis* in Vietnam. A total of ten species were documented, including two endemic species (*C. leonidii* and *C. pygmaea*), and one species (*C. rhabdota*) newly recorded for the Vietnamese flora, expanding knowledge of its regional distribution. Species-specific flowering periods and dormancy patterns were characterized, which are crucial for successful ornamental cultivation, particularly in potted settings. Ornamental Value Index (OVI) analysis revealed significant variation among species, with *C. rhabdota*, *C. alismatifolia*, and *C. thorelii* demonstrating the highest ornamental potential. These high-value species have already been utilized in hybridization programs in Thailand to produce new *Curcuma* cultivars. Although most species are primarily cultivated for ornamental purposes, several have been investigated for bioactive compounds and pharmacological properties, highlighting their potential for ethnomedicinal and biotechnological applications. Distribution modeling identified extensive suitable habitats across Southeast Asia, indicating the possibility of undiscovered populations. However, many species remain vulnerable due to habitat loss, limited range, and potential overharvesting. Sustainable cultivation practices, including pot cultivation, propagation, and dormancy management, are essential to minimize pressure on wild populations. The findings underscore the importance of integrating field surveys, ecological modeling, and horticultural practices to support both conservation and sustainable utilization of *Curcuma* subgenus *Hitcheniopsis* in Vietnam.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d17110778/s1. Table S1: Evaluation traits and subtraits used for the preliminary assessment of ornamental value; Table S2: Ornamental Value Index of each individual and species of *Curcuma* subgen. *Hitcheniopsis* in Vietnam.

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Abbreviations

The following abbreviations are used in this manuscript:

BK	Bangkok Herbarium, Department of Agriculture, Thailand
BKF	Department of National Parks, Wildlife and Plant Conservation, Thailand
E	Royal Botanic Garden Edinburgh, Edinburgh, United Kingdom
HN	Vietnam Academy of Science and Technology (VAST), Hanoi, Vietnam
HNPM	National Institute of Medicinal Materials, Vietnam
HNU	VNU University of Science, Hanoi, Vietnam
IBK	Guangxi Institute of Botany, China
IMDY	Chinese Academy of Medical Sciences, China
K	Royal Botanic Gardens, United Kingdom
KKU	Khon Khan University Herbarium, Thailand
P	Muséum National d'Histoire Naturelle, Paris, France
QBG	Queen Sirikit Botanic Garden, The Botanical Garden Organization, Thailand
SGN	Southern Institute of Ecology, Ho Chi Minh City, Vietnam
SING	National Parks Board, Singapore
VMSU	Vascular Plant Herbarium, Mahasarakham University, Thailand
VNM	Institute of Tropical Biology, Ho Chi Minh City, Vietnam
VNMN	Vietnam National Museum of Nature, Hanoi, Vietnam

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