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Boesenbergia Kuntze (Zingiberaceae) in Cambodia: Four New Records with Notes on Their Potential Horticultural Significance, Cultivation Guidelines, and Lectotypification of *B. xiphostachya* (Gagnep.) Loes.

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Abstract: This study presents four new records of *Boesenbergia* species (Zingiberaceae) in Cambodia: *Boesenbergia parvula* (Wall. ex Baker) Kuntze, *B. petiolata* Sirirugsa, *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk., and *B. xiphostachya* (Gagnep.) Loes. Previously, only *B. rotunda* (L.) Mansf. was officially recognized in Cambodia. This research also confirms the occurrence of *B. rotunda* in natural habitats. and provides a new distribution report for this species within the country, and lectotypification of *B. xiphostachya* (Gagnep.) Loes. We studied plant specimens collected from Cambodia, using calipers and a stereomicroscope, and identified them based on protologue descriptions and herbarium records. We provide detailed morphological descriptions, complete synonymy, taxonomic diagnoses, and a comprehensive identification key. In addition, we present data on habitat, phenology, vernacular names, traditional uses, provisional conservation statuses, horticultural potential, and cultivation guidelines. These findings substantially expand the known species diversity of *Boesenbergia* in Cambodia, highlighting their ecological significance, cultural value, and ornamental potential. By advancing the understanding of regional flora, this study contributes to biodiversity conservation and emphasizes the importance of continued exploration and documentation in Southeast Asia to preserve ecological integrity and. traditional knowledge.

Keywords: fingerroot; ginger; horticulture; lectotypification; Taxonomy; Zingiberales

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1. Introduction

The genus *Boesenbergia* Kuntze, belonging to the family Zingiberaceae, order Zingiberales, is classified within the subfamily Zingiberoideae and the tribe Zingibereae [1]. It is a diverse and ecologically significant group of plants with widespread distribution across

Southeast Asia, India, and Indonesia [2], known for its distinct morphological features, cultural importance, and applications in traditional medicine [3–5]. The genus has undergone significant taxonomic revisions over the years [6–8]. These revisions. include the reclassification of species from *Caulokaempferia* K.Larsen and *Haplochorema* K.Schum. into *Boesenbergia*, as well as the synonymizing of *Jirawongsea* Picheans. with *Boesenbergia*. Approximately 100 species are currently recognized, though their distribution and diversity remain unevenly documented across regions [2,9–32].

In Cambodia, *Boesenbergia rotunda* (L.) Mansf. has been the only officially recognized species [2]. The genus *Boesenbergia* is discussed in the Gingers of Cambodia, Laos, and Vietnam book, which notes that about ten species across Indochina—a number likely to increase with further exploration [33]. Understanding *Boesenbergia* diversity is essential for conservation, particularly as the genus holds ecological importance, cultural significance, and promising horticultural potential. Despite its prominence, discrepancies remain in the documentation of *Boesenbergia* species within Cambodia's natural habitats, a gap that this study aims to address.

This study presents new records of the genus *Boesenbergia* in Cambodia. Through field surveys and morphological analyses, these findings provide taxonomic treatments, confirm the presence of *B. rotunda* in natural habitats, and offer insights into their ecological roles, including lectotypification of *B. xiphostachya* (Gagnep.) Loes. Moreover, notes on the potential horticultural significance of these species emphasize their broader value and cultivation guidelines. By advancing knowledge of *Boesenbergia* diversity, this study contributes to regional biodiversity conservation and underscores the need for. ongoing exploration and sustainable utilization of Cambodia's botanical resources.

2. Materials and Methods

2.1. Plant Materials and Study Area

Plant materials (whole plants) were collected from their natural habitats in various provinces of Cambodia, including Siem Reap, Preah Vihear, Ratanakiri, Pursat, Koh Kong, Mondulkiri, and Kampot, between 2019 and 2024. The ecology and phenology data was specific to plants from Cambodia.

2.2. Procedures

Morphological characteristics were assessed using 20 living specimens of each. species, collected from their natural habitats within Cambodia. Measurements were taken with a vernier caliper (Series 536–Moving Jaw Type, Mitutoyo Corporation, Kawasaki, Japan), while detailed observations of smaller parts were conducted using a stereoscopic microscope (Stemi 2000-C, ZEISS, Oberkochen, Germany). Dry specimens and spirit collections (preserved in 70% alcohol) were deposited at Mahasarakham University Herbarium (MSU), and some living plants were cultivated at Brio Botanical Research Garden (BBRG) in Nakhon Nayok Province, Thailand.

Species identification, we performed a thorough analysis of the morphological traits of our specimens and compared them with published descriptions of Zingiberaceae plants, focusing particularly on their distribution in Cambodia and other Southeast Asian countries, e.g., the works of Mood et al. [6,7,18–20], Holttum [9], Tong [10], Sirirugsa [11,12], Saensouk and Larsen [13], Sabu et al. [14], Mood et al. [16], Veldkamp [17], Aishwarya and Sabu [21,22], Aishwarya et al. [23,24], Tanaka et al. [26], Chen and Xia [27], Lam et al. [29,30], Saravanan and Kaliamoorthy [32], Chaveerach et al. [34,35], and Bongcheewin et al. [36,37]. Additional data were sourced from the Zingiberaceae Resource Center online database (ZRC) and Global Biodiversity Information Facility (GBIF). Visual inspections of digital images and data from various herbarium institution collections—including the Aarhus Uni-

versity Herbarium (AAU), Department of Agriculture (BK), Natural History Museum (BM), Department of National Parks, Wildlife and Plant Conservation (BKF), Botanical Survey of India (CAL), University of Calicut (CALI), Chiang Mai University (CMU), Chiang Mai University's Department of Biology (CMUB), Royal Botanic Garden Edinburgh (E), National University of Laos (FOF), South China Botanical Garden (IBSC), Royal Botanic Gardens (K), Khon Kaen University (KKU), Naturalis Biodiversity Center (L), Makino Botanical Garden (MBK), Tamil Nadu Agricultural University Campus at Coimbatore (MH), Muséum National d'Histoire Naturelle (P), Prince of Songkla University (PSU), Queen Sirikit Botanic Garden, Botanical Garden Organization (QBG), Forest Research Institute (RAF), Singapore Botanic Gardens, National Parks board (SING), National Museum of Nature and Science (TNS), Universiti Kebangsaan Malaysia (UKMB), and Smithsonian Institution (US)—were conducted to substantiate our findings. This comprehensive methodology ensured that our comparisons were based on accurate and reliable information.

3. Results

This study documented four new records of *Boesenbergia* species in Cambodia: *Boesenbergia parvula* (Wall. ex Baker) Kuntze from Koh Kong and Pursat Provinces, *B. petiolata* Sirirugsa from Siem Reap Province, *B. rotunda* (L.) Mansf. from Ratanakiri Province, *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk. from Mondulkiri Province, and *B. xiphostachya* (Gagnep.) Loes. from Preah Vihear Province [11,12,14,19,20] (Figure 1).

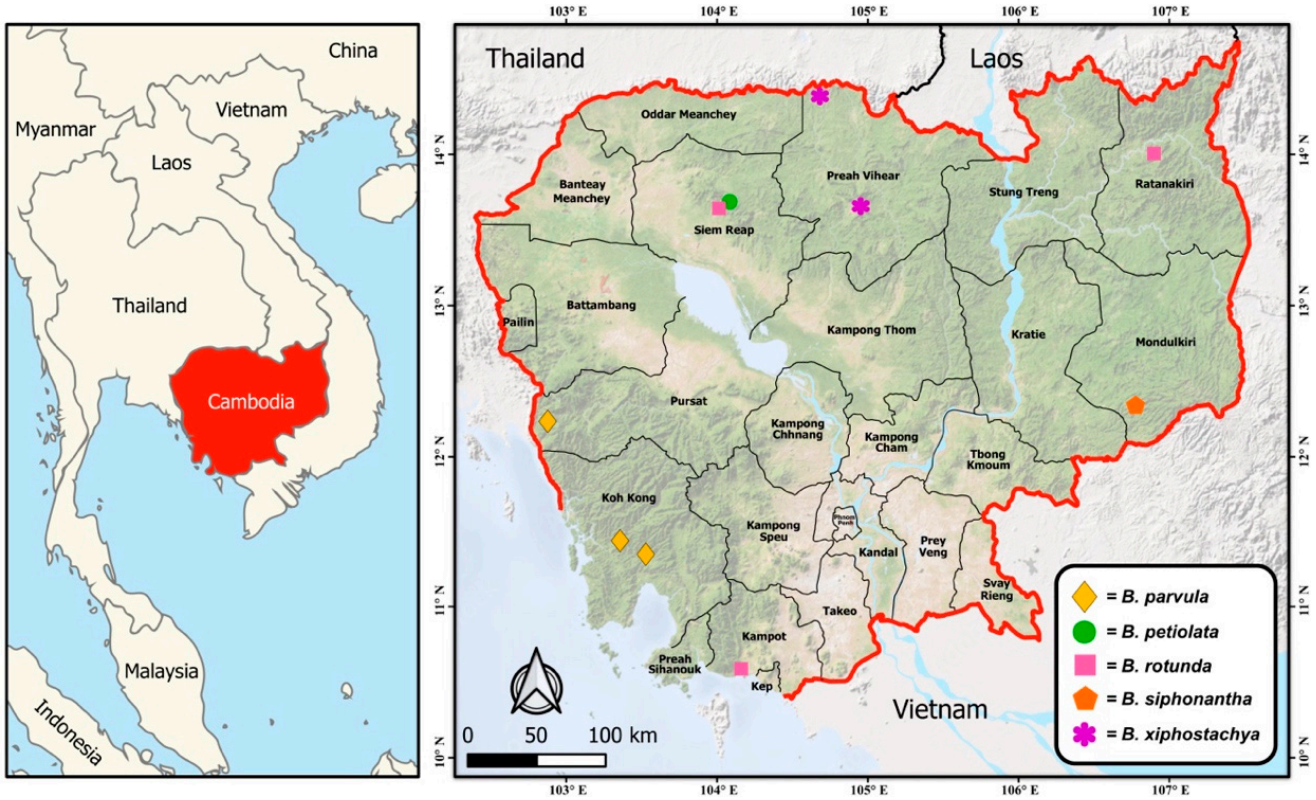

Figure 1. Distribution map of five species of *Boesenbergia* in Cambodia according to the locations from specimens examined, Designed in Pixelmator Pro Program Version 3.6.14 (Archipelago) by Thawatphong Boonma.

3.1. Taxonomic Treatment

The morphological characteristics of all specimens from the four *Boesenbergia* species collected in Cambodia generally align with their respective species descriptions. However, minor variations, such as slight differences in size and color, were observed. These variations, though not significant, are likely influenced by ecological factors, such as annual rainfall, light intensity, and humidity. The findings highlight the species' adaptability to diverse habitats and do not warrant taxonomic distinction. An identification key for the Cambodian species of *Boesenbergia* is provided (Table 1). Detailed morphological, ecological, and reference specimen information is provided in the respective sections for each species. Photographs of all species are provided (Figures 2 and 3).

Table 1. Identification key for *Boesenbergia* species Kuntze in Cambodia.

1a.	Staminodes pinkish; androecial cup absent	*B. rotunda*
1b.	Staminodes white to pale yellow; androecial cup present	2
2a.	Leaves base cordate	3
2b.	Leaves base attenuate	4
3a.	Floral tube 2–3 cm long; only terminal inflorescence	*B. petiolata*
3b.	Floral tube 7–9 cm long; both terminal and radical inflorescence	*B. siphonantha*
4a.	Spike fusiform, 4–5 cm long	*B. parvula*
4b.	Spike gladiate, 12–17 cm long	*B. xiphostachya*

Figure 2. *Boesenbergia* spp. in Cambodia: (**A**) *Boesenbergia parvula* (Wall. ex Baker) Kuntze, (**B**) *B. petiolata* Sirirugsa, (**C**) *B. rotunda* (L.) Mansf., (**D**) *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk., and (**E**) *B. xiphostachya* (Gagnep.) Loes. Photographs by Det Song and Thawatphong Boonma.

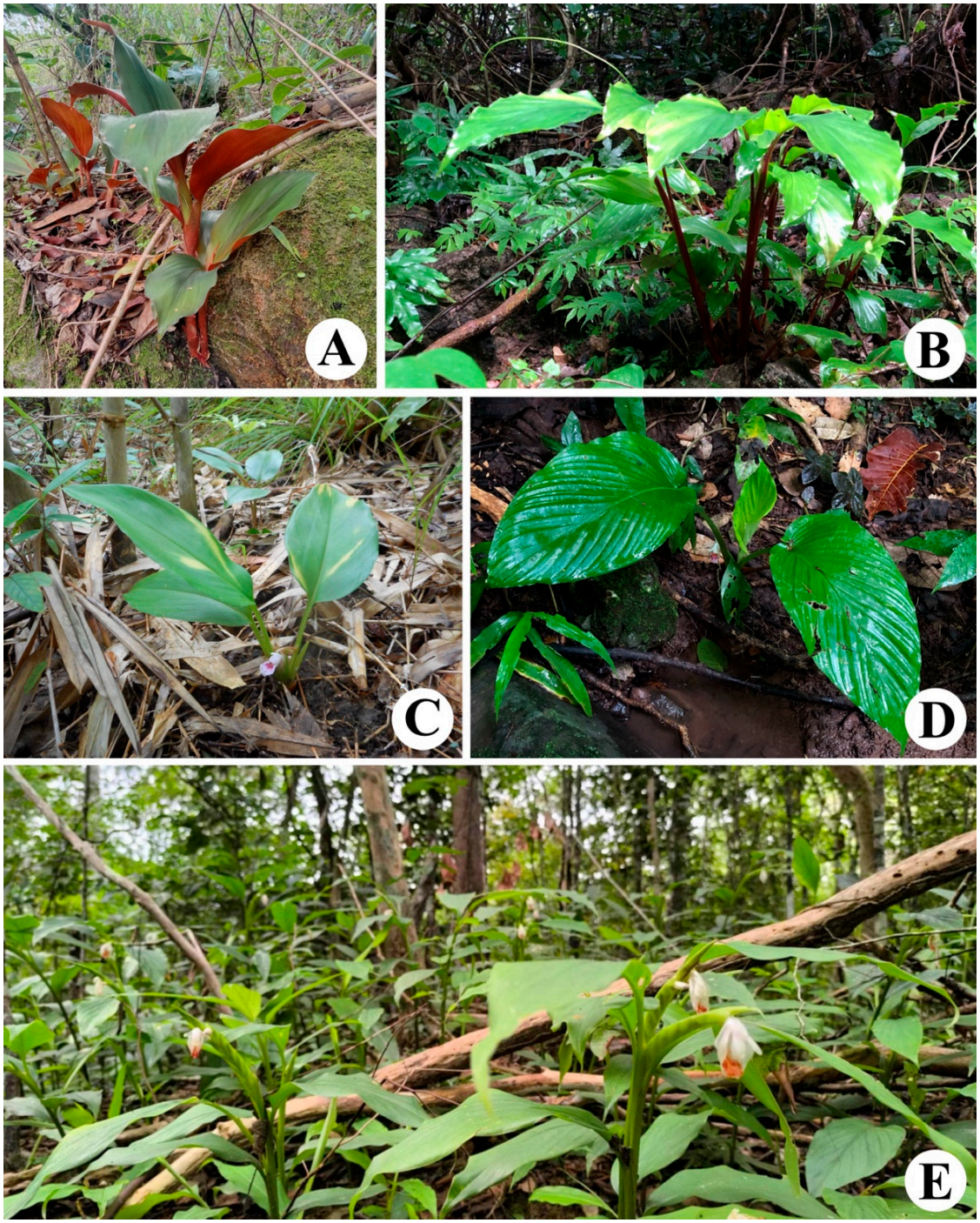

Figure 3. *Boesenbergia* spp. in their natural habitats in Cambodia: (**A**) *Boesenbergia parvula* (Wall. ex Baker) Kuntze, (**B**) *B. petiolata* Sirirugsa, (**C**) *B. rotunda* (L.) Mansf., (**D**) *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk., and (**E**) *B. xiphostachya* (Gagnep.) Loes. Photographs by Det Song and Thawatphong Boonma.

3.1.1. *Boesenbergia parvula* (Wall. ex Baker) Kuntze var. *parvula* [2,20]

Heterotypic synonyms:

- *Boesenbergia gelatinosa* K.Larsen [2]
- *Boesenbergia jahaiana* Meekiong and C.K.Lim [2]
- *Boesenbergia phyllostachya* (Gagnep.) K.Larsen ex Veldkamp [2]
- *Gastrochilus phyllostachyus* Gagnep. [2]

Type: Myanmar, Tavoy, 1827, Gomez, W. in Wallich, N. 6590 (K-W barcode K000795161 [digital image]!).

The following characteristics were observed from specimens observed in Cambodia (Figures 2 and 3): Perennial herb, leafy shoot 15–50 cm tall; perennating organ cylindrical, 1–10 cm long, 1–2 cm diam., usually in multiples attached together at the proximal end, internally and externally white; roots fibrous, short. The stems were succulent, with short internodes, and branching from the lower leaf axils. The leafless sheaths were corrugated and were either green or with reddish tinge. Leaf sheaths were 1–3 or 1.5–2 cm long; they were green or red; ligule bilobed, c. 5 mm, with green, triangular lobes that were semitranslucent at the margin, with a petiole subsessile to 2 cm long and ribbed. There were 5–7 distichous leaves; there were 8–12 lamina ovate that were 4–5 cm, with an attenuated base, acuminated apex, and they were adaxially green, with or without a darker pattern along the centre of the midrib, and silver margins that were glabrous, abaxially green or reddish, and glabrescent. The terminal inflorescence was on the main pseudostem, and the axillary stems, which were tightly clasped between the innermost leaf sheaths, but partially exserted and mucilaginous. The peduncle up to 1 cm and white, the spike was fusiform and 4–5 cm long. The bracts were distichous and lanceolate, 2–3 cm long, with an acuminated apex that was green or red and covered with whitish portions, glabrous, finely striated. The bracteoles lanceolate were 2–2.5 cm long, whitish or green, and glabrous. There were 4–8 flowers, c. 3 cm long, deflexed downward. Their calyx was c. 3 mm long, white, and translucent, with an irregular apex. The floral tube was 2–3 cm long, white, and glabrous; The dorsal corolla lobe was ovate and c. 1 × 0.5 cm, with a white, glabrous, cucullate apex. The lateral corolla lobes were ovate and 0.8–1 × 0.5 cm, with a white, glabrous, cucullate apex. The androecial cup was c. 5 mm long, and orientated c. 90° to the floral tube with the throat pubescent. The labellum saccate was almost orbicular and c. 2.5 × 2 cm. It was white or very pale yellowish white, with various red patterns. It was glabrous, and the entire apex had deflexed margins. The lateral staminodes were obovate, 7–8 × 5 mm, white, and glabrous. Stamen 1 was 0.8–1 cm long, white, and was glandularly hairy; the filament was c. 2 mm long, the anther was c. 6 × 3 mm and white. The anther crest was absent, the anther thecae were c. 5 × 1.5 mm and dehiscent along the length of anther. There were two epigynous glands, c. 2 mm long and pale green. The ovary was cylindrical, c. 3 × 2 mm, white, and glabrous. The style was filiform, c. 4 cm long and white; stigma orbicular, white, ostiole ciliate. Fruit cylindrical, 1–1.2 cm long; seed elongate, 5–6 × 2 mm, brown, with translucent white arils, c. 3 mm long. Bulbils cylindrical, 1–1.2 × 0.6–0.8 cm, green.

Vernacular name: ឆ្កាយថ្ម (Khcheay Thmor): In Khmer, ឆ្កាយ (Khcheay) refers to plants in the genus *Boesenbergia*, and "ថ្ម" (Thmor) means "rock"; this name refers to the plant's ecological habitat, as it is usually found growing on rocks.

Ecology: Found in evergreen forests with high humidity, primarily on soils derived from sandstone or granite, or in rock cracks in shady areas, often near watercourses.

Phenology: Flowering in June to October, fruiting in July to late October.

Distribution: Native to Cambodia, Laos, Malaysia, Myanmar, Thailand, and Vietnam [2].

Utilization: Auspicious ornamental pot plants.

Specimens examined from Cambodia: Koh Kong, Khum Chi Phat, nearby Chhay Kpous Waterfall, 10 July 2022, *D.Song BC002* (MSU!). Pursat, Veal Veng, Thmor Da Commune, 10 July 2022, *D.Song BC003* (MSU!). Koh Kong, Trapaeng Rung, 2 September 2023, *D.Song BC004* (MSU!).

Additional specimens examined: In Supplementary Materials.

3.1.2. *Boesenbergia petiolata* Sirirugsa [11]

Type: Thailand, Saraburi Province, Nam Tok Sam Lan National Park, Maxwell 74–631, 29 June 1974 (holotype BK!; isotypes AAU!, L!).

The following describes the specimens observed in Cambodia (Figures 2 and 3). This perennial herb had a leafy shoot 25–50 cm tall and multiple stems that were 2–5 cm apart. The perennating organ was a rhizome, branched, expanding linearly, with variable length, c. 1 cm diameter. It was externally brownish and internally yellowish, with numerous tuberous roots that were 4–10 cm long, 0.5–0.7 cm diameter, externally and internally white, and with a tapered apex. There were 7–12 stems per clump; they were 18–24 cm long, 0.8–1 cm in diameter, green and glabrous. The leafless sheaths were 3–4 cm long, green and glabrous, and their apex was acute to rounded. The leaf sheaths were 6–12 cm long, green and glabrous. The ligule bilobed; each lobe was 1–1.5 cm long, translucent white or with a reddish tinge, glabrous, and with an obtuse apex. The petiole was 3–9 cm long, green, and glabrous. There were 4–5 distichous leaves; they were lamina asymmetrical ovate to lanceolate shaped, 7–25 × 4–7 cm, with a cordate base. Some were oblique, with an acuminate apex. They were adaxially green to dark green, glossy, and glabrous, with embossed primary veins; they were abaxially pale silvery green and glabrous. The terminal inflorescence was distichous; the peduncle was 1–1.5 cm long, green, and glabrous, with a spike 7–12 cm long, 7–14 bracts, and at the base, the lanceolate was 3–4 × 0.8 cm wide, pale green with white, and glabrous. It was compressed together in two ranks on one side, with the rachis exposed on the non-flowering side. It had bracteole lanceolate, 3–4 × 0.7–0.8 cm, green with white toward the base, and glabrous. The flowers were c. 4 cm long, facing outward from the bract, and tilted slightly downward. The calyx was tubular, c. 0.5 cm long, c. 0.3 cm in diameter, with a trifid apex. It was translucent white and glabrous; the floral tube was 2–3 cm long, whitish and glabrous; the dorsal corolla lobe was oblong to obovate, 1.2–1.3 × 0.5 cm, white, and glabrous. The apex was slightly cucullate; the lateral corolla lobes were oblong, c. 1 × 0.3 cm, white, and glabrous, with the apex slightly cucullate. The Androecial cup was c. 2 × 2 mm, orientated c. 90° to the floral tube, with a glabrous throat; the labellum saccate was nearly orbicular, 2.5–2.8 × 2–2.5 cm, and white. The throat was marked with two red spots, and more red spots continued along all the veins outward, with longitudinal red stripes or spots in a broad patch reaching almost to the margins, very pale yellow, becoming darker yellow with age, externally covered with a few of short glandular hairs. The lateral staminodes were obovate, 1.2–1.3 × 0.8–0.9 cm, white, glabrous, and the apex was slightly revolute. Stamen 1 was c. 1 cm long; the filament was c. 4 × 2 mm and very pale yellow to white. The anther was c. 8 mm long and white, the anther thecae was dehiscent over the full length and dorsally covered with glandular hairs, and the apex was slightly indented; the pollen was white. There were two epigynous glands, c. 2 × 1 mm and yellowish. The ovary was trilocular, its style was filiform, and it was 3.8–4 cm long and white. The stigma were funnel-shaped, white, ostiole, and rounded with few cilia. The fruit was cylindrical, 1.5–2 cm long; the seed was 5–6 × 1.8–2 mm, brown, with white arils.

Vernacular name: ខ្ចាយផ្កាតូច (Khcheay Pka Toch): In Khmer, ខ្ចាយ (Khcheay). refers to the genus *Boesenbergia*, and ផ្កាតូច (Pka Toch) means "small flower". This name highlights the distinguishing characteristic of this plant within the *Boesenbergia* genus, referring to its relatively small flowers.

Ecology: Found in dry evergreen or deciduous forests on soils derived from sandstone or granite, in semi-shady areas near watercourses.

Phenology: Flowering in June to October, fruiting in July to November.

Distribution: Native to Cambodia, Laos, Thailand and Vietnam [2].

Utilization: Auspicious ornamental pot plants.

Specimens examined from Cambodia: Siem Reap, nearby watercourse, 14 August 2022, T.Boonma BC002 (MSU!).

Additional specimens examined: In Supplementary Materials.

3.1.3. *Boesenbergia rotunda* (L.) Mansf. [2]

Homotypic synonyms:

- *Curcuma rotunda* L. [2]
- *Gastrochilus rotundus* (L.) Alston in H.Trimen [2]

Heterotypic synonyms:

- *Boesenbergia cochinchinensis* (Gagnep.) Loes. [2]
- *Boesenbergia pandurata* (Roxb.) Schltr. [2]
- *Gastrochilus panduratus* (Roxb.) Ridl. [2]
- *Kaempferia cochinchinensis* Gagnep. [2]
- *Kaempferia ovata* Roscoe [2]
- *Kaempferia pandurata* Roxb. [2]

Lectotype: Rheede, Hort. Malab. 11: t.10. 1690. Designated by Burtt & R.M. Smith (1972).

Description from specimens observed in Cambodia are as follows (Figures 2 and 3). These were perennial herbs, with a leafy shoot 70−100 cm tall and pseudostem 15–18 cm long; they were green with a reddish tinge. The perennating organ was a rhizome thick, 1−2 cm diameter, that was strongly aromatic. It was externally brown and internally yellow. The leafless sheaths were red or green with an acute, glabrous apex. The leaf sheath was (10–)30−40(–50) cm long and glabrescent. The ligule was bilobed, 3−6 mm, with oblong that were translucent, pale green, and ciliate. The petiole was (2–)5−12 cm, green and glabrous. There were 3−5(–7) leaves per shoot; they were distichous, lamina (15–)28−50 × 6−12 cm, elliptic, adaxially green, glabrous, abaxially pale green, and villous, with an acute tip, a cuneate base, and the entire margin. The terminal inflorescence was enclosed by the innermost leaf sheath. The peduncle was cylindrical and 1–2 cm long. The spike was oblong, 5−9 cm long, pale green, and glabrous. The rachis was crowded with bracts, not elongate. Between eight and twelve flowers had flowered; they were 9−10 cm long, pink, and one or two opened per day. The bracts were 4−5.5 × 0.6−0.7 cm, oblong, translucent, and membranous; they were white with a pale green tinge, slightly hairy on the outer surface, with the entire margin and an acute apex. The bracteoles were 4−5.5 × 0.4−0.5 cm, oblong-lanceolate, membranous; they were white with a reddish or orange tinge, an entire margin, and a sparsely hairy surface. The calyx was 1.5−1.9 × 0.3−0.4 cm, tubular, truncate, and white, with a reddish tinge towards the upper half. It was membranous, glabrous, split on one side up to c. 0.7 cm depth, unsplit side bilobed, and its lobes were c. 2 mm long. The floral tube was 6.0−7.5 cm long, white, and sparsely hairy towards the base. The dorsal corolla lobe was 2.3 × 0.6 cm, oblong, incurved, reticulate, translucent, white with pink tinge, and glabrous, with an acute apex. The lateral corolla lobes were 2 × 0.4 cm, oblong, incurved, reticulate, translucent, white with pink tinge, and glabrous, with an acute apex. The androecial cup was absent. The labellum was ovate-elliptic, saccate, and 3.0−3.2 × 1.5−1.6 cm, with a rounded apex that was slightly trilobed. The middle lobe was notched and reflexed, deep pink towards the tip, and white with crimson spots and bands radiating laterally in the throat. It was glabrous (hairy along median), and the margin was wavy towards the apex. There were two lateral staminodes, 1.5–2 × 0.5−0.6 cm; they were obovate, membranous, and pink, with an entire margin. There was one stamen, 8−10 mm long, either white or pinkish. The filament was 2–4 × 1–3 mm, and the anther was 4–6 × 1–3 mm. The crest was connected, 2 × 1 mm, recurved, and emarginated. There were two epigynous glands, 6−8 mm long, linear and

pale yellow. The ovary was 6−7 × 1.5 mm, tricarpellary, and trilocular, with ovules on axile placenta; it was glabrous or had very few hairs only at apex. Its style was 7.6−9.3 cm long, filiform, and white with minute golden spots towards tip; the stigma was cup-shaped with a slightly ciliate opening. The fruit and seed were not seen.

Vernacular name: ខ្ចាយ (Khcheay).

Ecology: In deciduous or dry evergreen forests.

Phenology: Flowering in late June to October, fruiting in July to November.

Distribution: Native to Andaman Is., Cambodia, China (South-Central), India (Assam), Indonesia (Jawa, Lesser Sunda Is., Sumatera), Malaysia, Thailand, and Vietnam [2].

Utilization: Rhizomes and roots are used as spices; the young pseudostem is eaten fresh or boiled and served with chili paste.

Specimens examined from Cambodia: Siem Reap, Angkor Wat, 30 June 2006, Long C., Cheng S.K., and Leti M. CL237 (P!). Kampot, Km180, road to Sre Umbell, 19 August 1919, Poilane E. 418 (P!). Ratanakiri, nearby Srer Pok river, 13 August 2020, *D.Song BC001* (MSU!).

Additional specimens examined: In Supplementary Materials.

3.1.4. *Boesenbergia siphonantha* (King ex Baker) M.Sabu, Prasanthk., & Škorničk [14]

Homotypic synonyms:

- *Kaempferia siphonantha* King ex Baker in J.D.Hooker [2,14,19]

Type: India, Andaman Islands, 1884, King's Collector 372 (lectotype: CAL! [CAL0000000916]; isolectotypes: CAL! [CAL0000000912, CAL0000000913], K! [K000640517].

Boesenbergia siphonantha was previously described as *Kaempferia siphonantha* by Baker [2,14,19], based on King's Collector 372 (K). This specimen and three similar specimens (King's Collector 372) in CAL (CAL0000000912, CAL0000000913, and CAL0000000916) were collected by Kunstler from the Andaman Islands. Later, *Kaempferia siphonantha* was combined into *Boesenbergia siphonantha* (Baker) M. Sabu, Prasanthkumar & Škorničková by Sabu et al. [14] with notes on the type "Andamans, 1884, King's Collector 372 (CAL)" but without choosing a lectotype. Subsequently, Mood et al. [19] designated them as follows: lectotype: CAL! [CAL0000000916]; isolectotypes: CAL! [CAL0000000912, CAL0000000913], K! [K000640517].

The following describes the specimens observed in Cambodia (Figures 2 and 3). This was a perennial herb with a leafy shoot 30−65 cm tall, that was clumping. The rhizome was globular, 0.8–1.5 cm in diameter, internally cream-yellow, and slightly aromatic. The roots were fibrous, with many elongate root tubers. The pseudostem was 5–cm long. There were 1–2 leafless sheaths, green or reddish tinged. There were 3−7 leaves per pseudostem; the leaf sheaths were 10–19 cm long, and the ligule was bilobed, 3−5 mm long, with a rounded apex, that was pale green, translucent, and either glabrous or with few hairs. The petiole was 4−11 cm long, green, and glabrous. The lamina was ovate to oblong-lanceolate, 13−32 × 5−11 cm; the base was cordate or sometimes oblique, with an apex that was acute to acuminate, the adaxial was dark green and glabrous, the abaxial was pale green, glabrous or slightly pubescent, and had an undulate margin. The terminal inflorescence was radical. The peduncle was 1–3 cm long, branched or unbranched. The spike was 5–6 cm long, c. 0.5 cm in diameter, with a white base, a dark reddish-brown or greenish tinged apex, and ribbed. There were 3–8 bracts that were distichous, ovate-lanceolate to linear and 3−5 × 0.5–1 cm. They were white, green, or green with reddish tinge at the distal part and glabrous. The bracteoles were tubular, 1−3 × 0.1–0.2 cm, whitish or cream, glabrous or pubescent, with a 2–3 toothed apex that had a unilateral incision of 2–3 mm. There were between three and eight flowers per spike, one flower per bract, and they were 8−12 cm long. The calyx was tubular, 6–7 × 1.5 mm, and the apex was

trifid, white or white with reddish dots, and had a unilateral slit up to 3 mm long. The floral tube was cylindrical, 7−9 cm long, white, and glabrous. The dorsal corolla lobe was triangular-lanceolate, 1.2–1.4 × 0.4–0.6 cm, with an acute, hooded, cream, and glabrous apex. The lateral corolla lobes were linear, c. 1.3 × 0.4–0.5 cm, with an acute, slightly hooded, cream, and glabrous apex. There were two lateral staminodes that were obovate, 0.8−3 × 0.4−1 cm, cream-white, with a rounded and revolute apex. The labellum was deeply saccate, ovate to obovate, 2 × 0.5−1.7 cm; the apex was rounded or emarginate and cream-white (more yellowish with age), and the throat and mib-lobe were bright red that broadening outward to dark pink. They were externally covered with short glandular hairs, and had a slightly undulate margin. There was one stamen, 7−8 mm long; the filament was 1–4 mm long, white, and glabrous. The anther was 5–6 × 3–4 mm, pale yellow, darker towards the tip, and glabrous; the anther crest was absent. There were two epigynous glands, 0.8−0.9 cm long, linear, and cream coloured. The ovary was cylindrical, trilocular, and 5−6 × 1.5–2 mm, with axile placentation. The apex was glabrous or with sparse hairs; it had a filiform style and was 7−8 cm long and white. The stigma was white with an ostiole ciliate. Fruit was not seen.

Vernacular name: ខ្ចាយផ្កាវែង (Khcheay Pka Veng): In Khmer, ខ្ចាយ (Khcheay) denotes the genus *Boesenbergia*, while ផ្កាវែង (Pka Veng) means "long flower". This name describes a key characteristic of this *Boesenbergia* species, known for its notably elongated flowers.

Ecology: dry evergreen to evergreen forest, moist, under the shade of the trees, near the watercourse.

Phenology: Flowering in June to September. This species could produce both terminal and radical inflorescences.

Distribution: Andaman Is., Cambodia, Myanmar, Nicobar Is., Thailand, and Vietnam [2].

Utilization: Ornamental plant.

Specimens examined from Cambodia: Mondulkiri, nearby Keo Seima, 8 August 2023, *T.Boonma BC003* (MSU!).

Additional specimens examined: In Supplementary Materials.

3.1.5. *Boesenbergia xiphostachya* (Gagnep.) Loes. [2,12]

Homotypic synonyms:

- *Gastrochilus xiphostachyus* Gagnep. [2,12].

Type: Laos, Ri-Hao, Pierre s.n., September 1865, (lectotype P!, P00686544, designated here (Figure 4); isolectotypes P!, P00686545, P00686546).

In 1906, Gagnepain described *Gastrochilus xiphostachyus* Gagnep. (as *G. xiphostachyum*) based on materials collected by Pierre in Indochina, without a collection number, specific locality, or date provided. Three sheets (P00686544, P00686545, P00686546) collected by Pierre in Indochina and identified as *G. xiphostachyus* in Gagnepain's handwriting are present at P!. Among these, P00686544 is designated here as the lectotype as it is the best-preserved specimen, in accordance with Articles 9.3 and 9.4 of the ICN [38].

Figure 4. Lectotype of *Gastrochilus xiphostachyus* Gagnep. (P!, P00686544) Photographs from https://www.gbif.org/occurrence/437997108 (accessed on 5 February 2025).

The following describes the specimens observed in Cambodia (Figures 2 and 3). The perennial herb had a leafy shoot to 70 cm height. The perennating organ was a bud-crowned tuberous root. It was initially cylindrical, 2–3 cm long, and became fusiform over several seasons. It was 8–10 cm long and 2 cm in diameter, with a tapered apex. It was externally and internally white. The stems were erect, 1 cm in diameter, and the nodes were 9 cm apart. There were 1–2 leafless sheaths which were green with a reddish tinge or reddish and

glabrous. The leaf sheaths were 12–17 cm long and green or reddish; the ligule was bilobed, 0.8–1.2 cm long, green, and becoming papery, with the petiole subsessile to 3 cm long. There were 3–8 distichous leaves, with an elliptic lamina, 20–25 × 5–8 cm; adaxially, they were green with raised veins; abaxially, they were pale green, reddish purple, or dark red-purple, and glabrous. The base was thick and attenuate, and the apex was acuminate. The terminal inflorescence exserted 12–17 flowers from the innermost leaf sheaths. The peduncle was 5 mm and green; the spike was gladiate, 12–17 × 2.5 cm, and curved longitudinally. The bracts were distichous, lanceolate, 2–4 × 2 cm, dark green, and glabrous; the bracteoles lanceolate were 2–3 × 1 cm, light green, and glabrous, completely enclosing the floral tube. The flowers were 2.5–2.7 cm long and orientated 90° to floral tube; the calyx was c. 6 mm with an irregular, entire apex, that was light green or white, translucent, and glabrous. The floral tube was c. 1.5 cm long, white, and glabrous. The dorsal corolla lobe was ovate, c. 1.5 × 0.4 cm; the apex was slightly cucullate, white, translucent, and glabrous. The lateral corolla lobes were ovate, ca 1.5 by 0.4 cm, with a slightly cucullate, white, translucent, and glabrous apex. The androecial cup was c. 4 mm long, orientated 135° to floral tube, with a haired throat. The labellum saccate was broadly obovate, c. 3 × 2 cm, and white with an orange-red throat that broadened to the apex; it was glabrous, and its entire apex was slightly crisped with deflexed margins. The lateral staminodes were obovate, c. 1.2 × 0.5 cm, white, and glabrous. There was one stamen, c. 1.1 cm long, white, and glandular hair throughout. The filament was 3.5–4 mm long, the anther was c. 7 × 5 mm, the apex was emarginate, and the anther thecae was c. 5 × 1 mm, with dehiscent the full length and divergent towards the apex; the anther crest was absent. There were two epigynous glands that were linear, 4 mm, and white. The ovary was cylindrical, 3 by 2 mm, light green, and glabrous; it was a filiform style, 2.8 cm long. Its stigma was spherical, white, ostiole irregular, and sparsely ciliate. No fruit was seen.

Vernacular name: ខ្ចាយបាយសី (Khcheay Bay Sei): In Khmer, ខ្ចាយ (Khcheay) refers to the genus *Boesenbergia*, while បាយសី (Bay Sei) reflects the name given to this species because its inflorescence spike resembles the layered structure of Bay Sei, which is a traditional offering used in religious ceremonies that is crafted from banana leaves and flowers arranged in multiple tiers.

Ecology: Deciduous forests on shallow soils formed from sandstone.

Phenology: Flowering in late June to October.

Distribution: Native to Cambodia, Laos, Thailand and Vietnam [2].

Utilization: Cultivated as auspicious ornamental pot plant.

Specimens examined from Cambodia: Preah Vihear, near the road to Preah Vihear Mt., 20 August 2019, *T.Boonma BC001* (MSU!). Preah Vihear, Phnom Tbeng Meanchey, 3 August 2024, *D.Song BC005* (MSU!).

Additional specimens are examined in the Supplementary Materials.

3.2. Proposal for Conservation Status of Five Boesenbergia Species in Cambodia

In our study, we identified five species of *Boesenbergia* within Cambodia; however, information regarding their distribution, population size, and specific habitat requirements remains limited. Based on the available data, we proposed their conservation status according to the IUCN Red List Criteria [39], classifying *Boesenbergia parvula* (Wall. ex Baker) Kuntze as Endangered [EN B2ab(ii,iv)], *B. petiolata* Sirirugsa as Critically Endangered [CR B2ab(ii,iv,v)], *B. rotunda* (L.) Mansf. as Endangered [EN B2ab(ii,iv)], *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk. as Critically Endangered [CR B2ab(ii,iv,v)], and *B. xiphostachya* (Gagnep.) Loes. as Endangered [EN B2ab(ii,iv)], until further research is available to provide a more suitable conservation status.

To advance understanding and protect these species, we recommend implementing targeted field surveys across Cambodia to better define their distribution, habitat range, and population dynamics. Detailed ecological studies on aspects like reproductive biology, pollination, and habitat dependencies are essential for identifying each species' specific needs and vulnerabilities. We further suggest working with Cambodian conservation authorities to prioritize and protect critical habitats, including potential areas identified through surveys. Additionally, engaging local communities and stakeholders in awareness and educational programs will help build capacity for sustainable land-use practices, supporting *Boesenbergia* conservation. This proactive approach aims to safeguard the natural populations of these species while compiling the necessary data for a conclusive assessment, promoting the long-term preservation of *Boesenbergia* biodiversity within Cambodia.

3.3. Potential Horticultural Significance

The five *Boesenbergia* species confirmed in Cambodia represent a rich diversity that offers considerable horticultural potential. These species are not only valuable for their ornamental purposes [4,5], they also hold promise due to their culinary and medicinal applications, particularly in the case of *Boesenbergia rotunda* [3–5]. Moreover, other species in the genus may share similar beneficial properties, further enhancing their potential for horticultural use.

3.3.1. Ornamental and Aesthetic Value

The visually striking features of *Boesenbergia* species make them highly desirable for ornamental purposes. The brightly coloured and delicate flowers contribute to the aesthetic appeal of these plants. For instance, *B. rotunda* is celebrated for its vivid pink or red labellum, which provide an attractive contrast to its lush, tropical foliage. These species are ideal for tropical and subtropical gardens, where they can be used in beds, borders, or containers [4,5]. Due to their compact growth habits [12], they are also well-suited for small urban spaces, and their ability to thrive in shaded environments makes them versatile for a variety of garden designs.

3.3.2. Medicinal and Culinary Significance

Boesenbergia rotunda, in particular, is widely recognized for its culinary and medicinal uses [3–5,15,27,33]. The rhizomes of *B. rotunda* are commonly used as a spice in Southeast Asian cuisines, imparting a unique flavour to dishes [15,33], while also serving as a key ingredient in traditional medicine for their anti-inflammatory, digestive, and antimicrobial properties. It is highly possible that other species in the genus *Boesenbergia* may share similar phytochemicals, bioactive compounds, antioxidant properties and anticancer investigations [39], offering additional medicinal value. Research into the chemical composition and pharmacological properties of these species could reveal their potential for treating a variety of ailments, including gastrointestinal disorders, infections, and inflammation, enhancing the genus's appeal in both the culinary and herbal medicine markets [3–5,40,41].

3.3.3. Functional Roles in Landscaping and Gardening

Beyond their ornamental and medicinal properties, *Boesenbergia* species are also well-suited for functional roles in horticulture. Their tolerance of shade and ability to thrive in a range of soil types make them ideal candidates for use as groundcovers or underplanting in tropical and subtropical landscapes. The dense foliage and compact growth of these species allow them to effectively fill space in low-light areas, where other plants might struggle. Furthermore, the edible rhizomes, offers the potential for incorporation into herb gardens or permaculture systems, where functional plants that provide both aesthetic and practical value are highly sought after.

3.3.4. Low Maintenance and Adaptability

Boesenbergia species, particularly *B. petiolata*, *B. rotunda*, and *B. xiphostachya*, demonstrate notable adaptability to diverse environmental conditions, making them relatively low-maintenance choices for cultivation. These species thrive in various forest types and soil conditions, reflecting their resilience. For instance, *B. petiolata* is found in dry evergreen and deciduous forests, often on soils derived from sandstone or granite, and semi-shady areas near watercourses, indicating its ability to grow in moderately challenging environments. Similarly, *B. rotunda* is common in deciduous and dry evergreen forests, showcasing its adaptability to a broader range of habitats. *Boesenbergia xiphostachya* thrives in deciduous forests on shallow soils formed from sandstone, further highlighting its suitability for landscapes with limited soil depth or fertility.

Conversely, species like *B. parvula* and *B. siphonantha* exhibit more specific ecological requirements, which may make them less adaptable to a variety of settings. *B. parvula* is typically found in evergreen forests with high humidity, growing in rock cracks or on soils derived from sandstone or granite, often in shady areas near watercourses. This preference for high-humidity environments suggests a need for consistent moisture levels. Similarly, *B. siphonantha* thrives in moist, shaded conditions within dry evergreen and evergreen forests, usually near watercourses, emphasizing its reliance on stable, humid microhabitats.

The natural habitat preferences of these species offer insights into their potential as low-maintenance plants. While species like *B. petiolata*, *B. rotunda*, and *B. xiphostachya* can adapt to a range of garden settings with varying moisture levels and soil types, *B. parvula* and *B. siphonantha* are better suited for specialized gardens where their ecological needs, such as consistent moisture and shade, can be met. These contrasting requirements highlight the diversity within the genus and underscore the importance of understanding their natural habitats to optimize their horticultural use.

3.3.5. Economic Opportunities in Cultivation

The commercial potential for *Boesenbergia* species, particularly *B. rotunda*, is significant. As both an ornamental and a functional plant, *B. rotunda* could be cultivated for its aesthetic qualities in gardens, as well as for its edible rhizomes, which are highly valued in culinary and medicinal applications.

The potential for other *Boesenbergia* species to offer similar medicinal and culinary benefits broadens the opportunities for commercial cultivation. With increasing global demand for herbal remedies and edible plants, agricultural enterprises could focus on scaling up the production of *Boesenbergia* species, while commercial nurseries could develop cultivars with enhanced ornamental traits, such as unique foliage or vibrant flower colours.

This dual-purpose utility, combined with relatively low-cost cultivation practices, positions *Boesenbergia* species as attractive candidates for both domestic and international markets. By leveraging their adaptability to various environments and their potential as a source of natural health products, growers and businesses could tap into the expanding market for multifunctional plants, creating sustainable economic opportunities.

3.3.6. Planting Between Rows in Fruit Orchards

Boesenbergia species, especially *B. rotunda*, have the potential for cultivation between rows in fruit orchards, offering an additional income stream with low investment. These species are easy to maintain and thrive in shaded environments, making them well-suited for intercropping with fruit trees, such as mango, durian, and other tropical fruits. By planting *Boesenbergia* between orchard rows, farmers can maximize the use of their land, contributing to soil health while benefiting from the ornamental, culinary, and medicinal properties of these plants. The edible rhizomes of *B. rotunda* can be harvested for both local

markets and culinary use, offering a sustainable and low-maintenance crop. Moreover, *Boesenbergia* adaptability to various soil types and moisture levels allows it to coexist harmoniously with fruit trees, requiring minimal resources for care.

3.3.7. Future Prospects for Research and Development

The potential for *Boesenbergia* species to be developed into high-value horticultural crops extends beyond their current uses. Ongoing research into the genetic diversity, bioactive compounds, and environmental adaptability of these species could lead to the development of cultivars with enhanced medicinal properties or ornamental traits. By exploring the pharmacological potential of different *Boesenbergia* species, researchers may uncover additional species within the genus with similar or unique health benefits. Furthermore, the identification and promotion of sustainable cultivation methods for *Boesenbergia* species would support efforts to integrate these plants into functional and ecologically sustainable landscapes.

3.4. Cultivation Guidelines for Boesenbergia Species

The cultivation of *Boesenbergia* species presents promising opportunities for ornamental horticulture and sustainable agriculture. By addressing their ecological requirements and practical management, these plants can be successfully integrated into diverse environments.

3.4.1. Site Preferences and Growth Conditions

Boesenbergia species are well-adapted to warm, humid tropical environments, thriving in temperatures between 20 and 30 °C. They prefer shaded environments, such as garden understories or forest edges, where direct sunlight is limited. Exposure to intense sunlight can cause foliage damage, reducing their ornamental appeal.

For optimal growth, the plants require well-drained, nutrient-rich, loamy soil. They can tolerate sandy or slightly clayey substrates if proper drainage is maintained to avoid waterlogging. Consistent soil moisture is crucial during the growing season, whereas reduced watering during dormancy minimizes the risk of rhizome rot.

3.4.2. Effective Propagation Methods

Propagation of *Boesenbergia* is typically done through rhizome division, a straightforward and reliable technique. Divisions should contain at least one active growth bud along with sufficient rhizome mass to ensure establishment. The early rainy season is an ideal time for this process, as natural moisture supports vigorous growth.

Seed propagation, though less common, is an option for breeding programs aimed at developing new cultivars. Successful germination requires warm, consistently moist conditions to support early growth stages.

3.4.3. Watering and Nutrient Management

Regular watering is essential, particularly during the active growth phase, to maintain soil moisture and support flowering. However, overwatering should be avoided, as it can lead to rhizome decay.

The use of balanced fertilizers, such as NPK 16-16-16, applied during the growing season, promotes strong foliage and inflorescence development. Organic soil amendments, including compost or well-aged manure, further enrich the soil while supporting sustainable growing practices.

3.4.4. Maintenance and Pest Control

Routine maintenance ensures healthy and aesthetically pleasing plants. Removing spent flowers and aging leaves encourages robust growth. Applying a layer of organic

mulch, such as wood chips or straw, helps retain soil moisture, suppress weeds, and regulate temperature. While *Boesenbergia* species are generally resilient, pests such as aphids, snails, and mealybugs may occur. Integrated pest management practices, including the use of neem-based sprays or manual removal, are effective for control. Proper spacing and air circulation help minimize fungal issues, such as leaf spot and rhizome rot.

3.4.5. Applications in Landscaping and Agriculture

The compact form and striking flowers of *Boesenbergia* species make them highly suitable for shaded gardens, border plantings, and container cultivation. These plants also adapt well to urban landscaping, including vertical gardens and indoor arrangements.

In agricultural systems, their compatibility with intercropping is particularly noteworthy. Incorporating *Boesenbergia* into agroforestry systems, such as planting alongside fruit trees, optimizes land use and enhances soil health. This approach offers smallholder farmers additional income opportunities while promoting sustainable cultivation practices.

3.4.6. Potential for Cultivar Development

Selective breeding holds the potential for the development of specialized cultivars with enhanced ornamental traits, such as unique bract colours or prolonged blooming periods. Similarly, cultivars with higher concentrations of bioactive compounds could expand their applications in pharmaceutical and nutraceutical industries.

3.4.7. Rhizome Storage and Dormancy

During dormancy, rhizomes can be carefully harvested, cleaned, and stored in cool, dry conditions to ensure their viability. Proper storage practices are particularly important in regions with harsh winters or prolonged dry periods. Protecting stored rhizomes from pests is critical to maintaining their quality.

By adhering to these cultivation practices, *Boesenbergia* species can be successfully grown and utilized for both ornamental and functional purposes. Their adaptability, ease of propagation, and potential for specialized applications highlight their significant horticultural value. Future research on breeding techniques and innovative cultivation methods will further enhance their utility and promote broader adoption in horticulture and agriculture.

4. Discussion

The confirmation of five *Boesenbergia* species in Cambodia substantially advances our understanding of the genus within the country. Previously, only *B. rotunda* had been officially documented, but this study highlights Cambodia as home to a richer species diversity of *Boesenbergia* species than previously recognized. The discovery of additional species underscores the importance of comprehensive botanical surveys, which can reveal hidden biodiversity within understudied regions, and suggests that the genus may be more widespread throughout Southeast Asia than current records indicate.

The lectotypification of *Gastrochilus xiphostachyus* Gagnep. addresses a long-standing taxonomic ambiguity within the Zingiberaceae. While the original description by Gagnepain in Notulae Systematicae provided a detailed morphological account of the species, the absence of a designated type specimen has led to confusion in its application. This is particularly critical given the historical misidentifications and the subsequent transfer of the species to the genus *Boesenbergia* as *Boesenbergia xiphostachya* (Gagnep.) Loes.

Previous taxonomic studies [7,8,11,14,16,17,20,22,27] have emphasized the importance of lectotypification in clarifying historical plant names, especially within genera like *Boesenbergia*, where species delimitation is often challenging due to overlapping morphological traits. The designation of the specimen P00686544 from P! herbarium as the lectotype

ensures the nomenclatural stability of this species. This specimen, collected by L. Pierre in 1865 from "Cochinchine, Laos, Ri-hao", aligns closely with Gagnepain's protologue, particularly in its distinct floral morphology and bract characteristics. These traits not only distinguish it from Zingiber but also highlight its affinities within *Boesenbergia*, a genus characterized by diverse floral adaptations. This lectotypification provides a critical foundation for resolving taxonomic uncertainties in *Boesenbergia*, a genus that has undergone significant revisions in recent years. Many studies [11,13,24] have documented the discovery of new species and records within the genus, underscoring its floristic significance in Southeast Asia. By stabilizing the application of *Boesenbergia xiphostachya*, this study contributes to a more accurate understanding of species diversity and distribution within the region.

Beyond nomenclatural stabilization, this work has implications for conservation biology and ecological studies. Southeast Asia's Zingiberaceae, including *Boesenbergia*, face threats from habitat loss and climate change [42]. Accurate taxonomic identification is essential for assessing conservation priorities and understanding species' ecological roles. The clear delimitation of *Boesenbergia* species enhances the ability to evaluate its distribution, habitat specificity, and potential conservation status, particularly in regions like Southeast Asia, where it may hold ecological and cultural significance.

The morphological similarities observed among *Boesenbergia* species in Cambodia and those documented in neighbouring countries, such as Thailand, Laos, Vietnam, and Myanmar, point to possible evolutionary relationships [4,5,12,19,23,26]. These similarities could indicate not only common ancestry but also shared ecological adaptations that may have arisen in response to similar environmental pressures across these regions. Such traits might include adaptations to seasonal rainfall patterns, soil types, and interactions with local fauna [5]. Studying these adaptations could provide valuable insights into the ecological strategies that *Boesenbergia* species employ to thrive in Southeast Asia's diverse habitats, from lowland forests to more arid or disturbed areas.

The conservation status of the five *Boesenbergia* species identified in our study is of significant concern, particularly given the major gaps in knowledge regarding their distribution, population size, and specific habitat requirements. Many areas of Cambodia remain unexplored and undocumented in terms of *Boesenbergia* distribution, highlighting the urgent need for further field research. We classified *Boesenbergia petiolata* Sirirugsa and *B. siphonantha* (King ex Baker) M.Sabu, Prasanthk. & Škorničk. as Critically Endangered species [CR B2ab(ii,iv,v)], while *Boesenbergia parvula* (Wall. ex Baker) Kuntze, *B. rotunda* (L.) Mansf., and *B. xiphostachya* (Gagnep.) Loes. as Endangered species [EN B2ab(ii,iv)]. However, the lack of data underscores the pressing need to explore more areas and gather comprehensive ecological information to better assess the vulnerability of these species. While *Boesenbergia petiolata* has not yet been assessed globally, *B. siphonantha* is listed as Vulnerable (VU), and the other three species are classified as Least Concern (LC) [39].

The limited knowledge of their distribution is a key challenge for conservation efforts, as habitat loss due to agricultural expansion, urbanization, and infrastructure development continues to threaten many plant species in Cambodia. Furthermore, climate change, with its potential to alter rainfall patterns and increase drought frequency, adds another layer of risk to these species. Without further research and more comprehensive data, it is difficult to predict how resilient these *Boesenbergia* species are to environmental changes. Given these uncertainties, it is crucial to conduct targeted field surveys across Cambodia to expand our understanding of the species' distribution and ecology. This will be a crucial step in refining their conservation status and ensuring that effective protective measures are put in place to safeguard these species for the future.

To address these knowledge gaps, further research is essential. Detailed studies on the habitat preferences and ecological interactions of *Boesenbergia* species would help clarify

the specific environmental conditions necessary for their survival and reproduction. Investigating their reproductive biology, including flowering and fruiting cycles, pollination mechanisms, and seed dispersal methods, could also provide important insights into how these species reproduce and establish new populations. Such studies are especially relevant in the face of climate change, as understanding how *Boesenbergia* species respond to temperature and moisture fluctuations can inform predictions about their future distribution and potential resilience to changing climates [42].

The horticultural potential of *Boesenbergia* species, as highlighted in this study, opens a wide range of applications that blend ornamental, culinary, medicinal, and functional uses. Their vibrant flowers, compact growth forms, and adaptability to diverse environmental conditions make them ideal candidates for enhancing both urban and rural landscapes. Species like *B. rotunda*, already recognized for its culinary and medicinal uses, exemplify the multi-faceted value of the genus. Expanding their use as ornamental plants could further increase their popularity in the global market, while their adaptability to shaded environments and intercropping systems aligns with sustainable agriculture practices.

In particular, integrating *Boesenbergia* species into agroforestry systems, such as intercropping with fruit orchards, could offer economic and ecological benefits by maximizing land use efficiency and contributing to soil health. This approach is especially promising for smallholder farmers in tropical regions, who could benefit from an additional income stream while maintaining sustainable cultivation practices. Additionally, the potential for developing specialized cultivars with enhanced ornamental traits or increased bioactive compound content could further broaden their appeal in both horticultural and pharmaceutical industries.

Future research on the genetic diversity, ecological requirements, and propagation methods of *Boesenbergia* species will be instrumental in unlocking their full horticultural potential. By integrating traditional knowledge with modern cultivation techniques, it is possible to promote the sustainable use of these plants while conserving their natural populations. This dual approach not only ensures the preservation of biodiversity but also fosters economic opportunities, emphasizing the significant role *Boesenbergia* species can play in horticulture and beyond.

Finally, elevating the conservation priority of these *Boesenbergia* species in Cambodia could contribute to broader regional biodiversity goals. Given that *Boesenbergia* species play roles in their ecosystems—possibly as food sources or habitat for certain insects and animals, or by contributing to soil health and structure—protecting them could help support the resilience of entire ecosystems. Enhanced protection measures, such as habitat conservation and legal protection, could mitigate some of the immediate threats posed by human activities. Additionally, community involvement in conservation initiatives, including the promotion of sustainable harvesting practices for species with known medicinal or culinary uses, may foster local stewardship and ensure sustainable resource use.

5. Conclusions

The findings of this study highlight both the richness of *Boesenbergia* species diversity in Cambodia and the urgent need for targeted research and conservation action. Documenting the distribution, ecological roles, and conservation requirements of these species is essential to protect them from potential threats and to preserve the biodiversity and ecological stability of Cambodia ecosystems. Such efforts will ultimately contribute to the resilience of Southeast Asia's natural landscapes, ensuring that future generations can benefit from and appreciate these valuable native plants.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae11020178/s1. Additional specimens examined of *Boesenbergia* in Cambodia.

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