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REVIEW ARTICLE

Diversity and morphology of bamboo species in Nepal

Rajesh Tamang[1,3*] . Sanjeev Kumar Rai[2] . Sangeeta Rajbhandary[1]

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Abstract: This review article mainly focuses on the revision of bamboo diversity and morphological characters used for their identification in Nepal. Peer-reviewed research papers and grey literature on the diversity and morphology of bamboo species was reviewed for this study. A total of 77 bamboo taxa (74 species and 3 infraspecific taxa) has been recorded in Nepal, belonging to 21 genera. Among them, 37 species are native, including 7 endemic species; 5 species have been introduced for cultivation, and 35 are exotic ornamental species. Morphological characters of 33 native species were examined, revealing 778 distinct morphological traits in 20 broad categories, namely: habitat, habit, clumps, rhizome, culms, nodal ring, internodes, branches, culm sheaths, leaf sheath and blades, and flowering characters. The highest number of variations was observed in culm sheaths (183), followed by leaf sheaths (150), flowering and inflorescence characteristics (52), culms (47), branches, etc. Culm sheaths and leaves are particularly important morphological characters for bamboo identification.

Keywords: bamboo diversity, morphological character, culm sheath, Nepal

*Corresponding Authors

[1] Central Department of Botany, Kirtipur, Kathmandu

[2.] Department of Plant Resources Thapathali, Kathmandu

[3] Ministry of Tourism, Forest and Environment, Koshi Province, Nepal
✉ rajes_tmg@yahoo.com

Introduction

Bamboo plants, commonly called *Bans, Nigalo* and *Malingo* in Nepal, are described as “friend of the people”, “poor man’s timber”, “green gasoline”, “the cradle to coffin timber” and “green gold” (Das, 1988; Haridasan & Tewari, 2008). They belong to the subfamily Bambusoideae (family Poaceae), comprising 1698 species belonging to 136 genera (Soreng *et al.,* 2022). The latitudinal distribution of bamboo ranges from 47°S to 50°30’ N, while their altitudinal range extends from sea level is up to 4000 m (Tewari, 1992). Bamboos are evergreen, perennial dwarf to tall woody plants. Some species are the largest in the grass family reaching up to 40 meters in height, and can grow faster than 1 meter per day (Lobovikov *et al*., 2007; Kaminski *et al*., 2016; Canavan *et al*., 2017; Ahmad *et al*., 2021; Getachew *et al.,* 2021).

Nepal is a landlocked country, situated between two mega countries, India and China. The northern neighbor, China, is currently estimated to harbour 861 species (Liu *et al.,* 2018), whereas India harbours 151 species and 6 varieties (Tewari, 1992; Kumari

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et al., 2024). The physio-climatic condition of Nepal is very similar to the north-eastern regions of India, which comprise 90 species including 41 endemic bamboos (Tewari *et al.,* 2019). Similarly, Bhutan harbours 33 bamboo species belonging to 15 genera (Stapleton, 1994b; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Michael B.T. 2017).

The identification of bamboo species seems is problematic due to limited and peculiar morphological characters, in their flowers, as the flowering period varies between 15 to 120 years, and some species are never known to flower (Janzen, 1976). Bamboos are mainly identified based on their vegetative morphological characteristics, including rhizomes, culm, node, internode, buds, leaves, branching patterns, culm sheath, leaf sheath, auricle, bristles, ligule, blade, petiole, leaf blade as well as, at times, reproductive morphological characters such as inflorescence, spikelet, lodicules, glumes, bracts, lemmas, stamens, filament, anther, stigma, style, ovary and fruits (Stapleton, 1991; Noltie, 2000; Stapleton, 1994a; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Bor, 1940; DPR, 1986; Zhengyi, 2006; Hajra, 1996; Chowdhery, 1984; Chowdhery, 2009). The primary goal of this paper is to review and examine bamboo diversity in Nepal and to determine the best morphological characteristics for identifying bamboo species.

This review of bamboo species in Nepal was conducted using a systematic literature review method. All Nepalese bamboo related books, particularly those focused on taxonomy, as well as peer-reviewed articles, grey literature, theses and reports published to date, were reviewed. The scientific areas of focus were species diversity and morphology of bamboo species in Nepal. To identify search terms and phrases, a scoping study was conducted using Google Scholar. Following the finalization of the search terms, keywords, and inclusion criteria, pertinent papers were selected for the review. A preliminary scan of abstract and content was carried out to assess the suitability of the retrieved literature for inclusion in the in-depth review.

After removing duplicates and considering the study's time range, 36 peer-reviewed articles and books were selected for in-depth review. Ten pieces of literature were used to write the introduction, based on a checklist of quality criteria, including a clear purpose and reproducible methodology, accurate and consistently measured outcomes, and consistently reported findings with empirical data. Eleven pieces of literature focused on bamboo diversity, while fifteen focused on morphology (Bor, 1940; DPR, 1986; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Hajra& Verma, 1996; Zhengyi*et al.,* 2006; Kumari *et al.,* 2024).

After a thorough review of all the articles, a morphological character matrix was developed for different species. Bamboo species were then categorized into endemic, native, native to the Himalayan range, introduced for farming and exotic ornamental species. Morphological characters were analyzed for 33 native bamboo species, while other species were excluded due to limited literature. The morphological characters were broadly categorized into 20 groups: namely habitat, habit, clumps, rhizome, culms, nodal ring, internodes, branches, culm sheaths, leaf sheaths, flowering and inflorescence, floret, glumes, lemma, palea, lodicules, stamens, pistils and fruit. Based on these categories, 778 characters were identified (Bor, 1940; DPR, 1986; Stapleton, 1994a; Stapleton, 1994b; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Hajra & Verma, 1996; Zhengyi *et al.,* 2006; Kumari *et al.,* 2024).

Bamboo diversity in Nepal

A total of 77 bamboo taxa (74 species and 3 infraspecific taxa) have been recorded in Nepal (Table 1), belonging to 21 genera (Stapleton, 1994a; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Das, 1998; Press *et al*., 2000; Poudyal, 2006; Rajbhandari & Baral, 2010; Das and Thapa, 2011; Rajbhandari *et al*., 2020; Shrestha *et al*, 2022; and Ayer *et al*., 2023; Kumari *et al.,* 2024). Out of the total, 37 bamboo taxa (35 species and 2 infraspecific) are native, including endemic species, 5 are introduced species and 35 are exotic ornamental species (Stapleton, 1994; Poudel, 2006; Das and Thapa, 2011; Ayer *et al*., 2023; Shrestha *et al.,* 2022). Eight endemic bamboo taxa (seven species and one variety) have been identified in Nepal's Himalayan area (Table 2) (Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Rajbhandari *et al*., 2016, Shrestha *et al.,* 2022).

Table 1: Number of genera and species recorded in Nepal.

Sl. No.	Scientific name	Endemism /Nativeness	Ecological Range	Distribution in Nepal	References
1	*Ampelocalamus patellaris* (Gamble) Stapleton	Native	1200-1800 m	Central, Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
2	*Bambusa balcooa* Roxb.	Native	Up to 1800 m	Central and Eastern Nepal	ACFPN, 2000; Stapleton, 1994; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
3	*Bambusa jaintiana* R.B.Majumdar	Native	Up to 1000 m	Eastern Nepal	ACFPN, 2000; Stapleton, 1994; Barlow, 2002; Poudyal, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
4	*Bambusa multiplex* (Lour.) Raeusch. ex Schult.	Native	Cultivated		Stapleton, 1994; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
5	*Bambusa nepalensis* Stapleton	Endemic to Nepal	500-1700 m	Central and Eastern Nepal	ACFPN, 2000; Stapleton, 1994; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
6	*Bambusa nutans* subsp. *cupulata* Stapleton	Native	100-1600 m	Eastern Nepal	Stapleton, 1994; Barlow, 2002; Das and Thapa, 2011; Ayer *et al.,* 2023.
7	*Bambusa nutans* Wall. ex Munro	Native	1000-1700 m	Western and Central Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Chaudhary *et al.*, 2015; Chaudhary *et al.*, 2002; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
8	*Bambusa teres* Buch.-Ham. ex Munro	Native	Up to 1400 m		Stapleton, 1994; Barlow, 2002; Das and Thapa, 2011; Ayer *et al.,* 2023.
9	*Bambusa tulda* Roxb.	Native	Up to 1400 m		Poudyal, 2004, 2006; Ayer *et al.,* 2023.
10	*Cephalostachyum capitatum* Munro	Native	1600-3000 m	Western, Central and Eastern Nepal	Flora of Kathmandu, 1986.
11	*Cephalostachyum latifolium* Munro	Native	600-2000 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
12	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Native	600-2000 m	Central and Eastern Nepal	Stapleton, 1994; EFPN1, 1978; ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2002; Chaudhary *et al*, 2015; Ayer *et al.,* 2023.

13	*Dendrocalamus hamiltonii* var. *undulatus* Stapleton	Endemic to Nepal	1300-1500 m	Central and Eastern Nepal	Stapleton, 1994; Shrestha *et al.,* 2022
14	*Dendrocalamus hookeri* Munro.	Native	1200-2000 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2015; Ayer *et al.,* 2023.
15	*Dendrocalamus parishii* Munro	Native to West Himalaya			Kumari *et al*., 2024.
16	*Dendrocalamus strictus* (Roxb.) Nees	Native	100- 1800 m	Western, Central and Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
17	*Drepanostachyum falcatum* (Nees) Keng f..	Native	1000-2200 m	Western, Central and Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004; Poudyal, 2006; Chaudhary *et al.,* 2015; Ayer *et al.,* 2023.
18	*Drepanostachyum intermedium* (Munro) Keng f..	Native	1000-2400 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000;Poudyal, 2004, 2006; Chaudhary *et al.*, 2015; Ayer *et al.,* 2023.
19	*Drepanostachyum khasianum* (Munro) Keng f.	Native	1900-2000 m	Central and Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2015; Ayer *et al.,* 2023.
20	*Himalayacalamus asper* Stapleton	Endemic to Nepal	1200-2500 m	Central Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al.,* 2023
21	*Himalayacalamus brevinodus* Stapleton.	Native	1500-2500 m	Eastern Nepal	Stapleton, 1994; 2006; ACFPN, 2000; Poudyal, 2004,
22	*Himalayacalamus collaris* (T.P.Yi) Ohrnb.	Native			Flora of China 22:99
23	*Himalayacalamus cupreus* Stapleton	Endemic to Nepal	2300-2800 m	Central Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al* ,2023.
24	*Himalayacalamus falconeri* (Munro) Keng f.	Native	2000-2500 m	Central and Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
25	*Himalayacalamus fimbriatus* Stapleton	Endemic to Nepal	1100-1400 m	Central Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al*., 2023.
26	*Himalayacalamus hookerianus* (Munro) Stapleton.	Native	2000-2500 m	Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2015; Ayer *et al.,* 2023.
27	*Himalayacalamus planatus* Stapleton	Endemic to Nepal	1400-2500m	Central Nepal	Rajbhandari *et al.,* 2016.
28	*Himalayacalamus porcatus* Stapleton	Endemic to Nepal	2000-2300 m	Central Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al.,* 2023.

29	*Melocanna baccifera* (Roxb.) Kurz	Native	upto 1400 m	Central, Eastern Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
30	*Sarocalamus racemosus* (Munro) Stapleton	Native	2600-3600 m	Eastern Nepal	Stapleton, 1994; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023
31	*Thamnocalamus chigar* (Stapleton)	Endemic to Nepal	2600-3100 m	Central Nepal	Stapleton, 1994; Poudyal, 2004; Poudyal, 2006; Ayer *et al.,* 2023.
32	*Thamnocalamus crassinodus* (T.P.Yi) Demoly	Native	2800-3500 m	Central Nepal	Stapleton, 1994; Poudyal, 2004, 2006; Rajbhandari *et al.,* 2016; Ayer *et al.,* 2023.
33	*Thamnocalamus spathiflorus* (Trin.) Munro	Native	2800-3700 m	Central and Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Limbu *et al.*, 2012; Ayer *et al.,* 2023.
34	*Yushania emeryi* (Stapleton) Demoly	Native	2000-4100 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Rajbhandari *et al.*, 2016; Rajbhandari & Rai, 2017; Ayer *et al.,* 2023.
35	*Yushania maling* (Gamble) R.B.Majumdar & Karthik.	Native	2000-3200 m	Eastern Nepal	EFPN1, 1978; Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2002, 2015; Limbu *et al.*, 2012; Ayer *et al.,* 2023.
36	*Yushania microphylla* (Munro) R.B. Majumdar	Native	2300-2500 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
37	*Yushania pantlingii* (Gamble) R.B.Majumdar	Native	2300-3800 m	Eastern Nepal	Stapleton, 1994; ACFPN, 2000; Poudyal, 2004, 2006; Ayer *et al.,* 2023.
38	*Bambusa bambos* (L.) Voss.	Native to SA Asia	Up to 3000m	Eastern Nepal (introduced)	ACFPN, 2000; Limbu & Rai, 2013; Stapleton, 1994; Barlow, 2002; Poudyal, 2004, 2006; Das and Thapa, 2011; Ayer *et al.,* 2023.
39	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	Native to Cambodia, China, Laos, Myanmar, Thailand, Vietnam	Up to 1400 m		Poudyal, 2004, 2006; Ayer *et al.,* 2023.
40	*Dendrocalamus asper* (Schult. & Schult.f.) Backer	Native to SA Asia; as cultivated species in India	Up to 1400 m		Stapleton, 1994; Ayer *et al.,* 2023.
41	*Dendrocalamus giganteus* Munro	Native to China South-Central, East Himalaya, India, Laos, Myanmar	Up to 1000 m		Stapleton, 1994; Poudyal, 2004, 2006; Ayer *et al.,* 2023

42	*Drepanostachyum annulatum* Stapleton	Native to East Himalaya	1000-2000 m	Central and Eastern Nepal	ACFPN, 2000; Poudyal, 2004, 2006; Chaudhary *et al.*, 2015; Ayer *et al.,* 2023.
43	*Dendrocalamus sikkimensis* Gamble ex Oliv.	Native to Assam, China South-Central, East Himalaya	1400-2000 m		Stapleton, 1994; Poudyal, 2004; Poudyal, 2006; Ayer et *al.,* 2023.
44	*Phyllostachys nigra* (Lodd. ex Lindl.) Munro.	Ornamental, cultivated in India	Cultivated		Stapleton, 1994, Poudyal, 2004; Poudyal, 2006; Ayer *et al.,* 2023
45	*Bambusa pallida* Munro	Native to Assam, Bangladesh, China, South-Central, East Himalaya, Laos, Malaya, Myanmar, Thailand, Vietnam			Poudyal, 2004, 2006.
46	*Dendrocalamus longispathus* (Kurz) Kurz	Native to Bangladesh, Myanmar, Thailand			Poudyal, 2004, 2006.
47	*Dendrocalamus pendulus* Ridl.	Native to Peninsula Malaysia	1400-2000 m		Ayer *et al.,* 2023
48	*Phyllostachys reticulata* (Rupr.) K.Koch	Ornamental	Cultivated		Poudyal, 2006; Ayer *et al.,* 2023
49	*Pleioblastus viridi-striatus* (Regel) Makino	Ornamental, cultivated in India	Cultivated		Poudyal, 2004; Poudyal, 2006. (as Sasaella auricoma)
50	*Thyrsostachys siamensis* Gamble	Native to Cambodia, China South-Central, Laos, Myanmar, Thailand, Vietnam	Up to 1000 m		Ayer *et al.,* 2023.
51	*Bambusa tuldoides* Munro.	Ornamental	Cultivated		Poudyal, 2004, 2006.
52	*Chimonobambusa marmorea* (Mitford) Makino	Ornamental	Cultivated		Poudyal, 2004, 2006.
53	*Chimonobambusa tumidissinoda* Ohrnb.	Ornamental			Poudyal, 2006.
54	*Phyllostachys nidularia* Munro.	Ornamental			Poudyal, 2006; (as Phyllosatchys nudillaris)
55	*Pleioblastus japonica vartsutsumiana* Yanagita	Ornamental	Cultivated		Poudyal, 2004, 2006.
56	*Pleioblastus variegatus* (J.Dix) Makino	Ornamental	Cultivated		Poudyal, 2004, 2006.
57	*Sasa palmata* (Burb.) .G.Camus	Ornamental			Poudyal, 2006.

58	*Sasaella ramosa* (Makino) Makino	Ornamental	Cultivated	Poudyal, 2004, 2006.
59	*Tongpeia fungosa* (T.P.Yi) Stapleton	Ornamental		Poudyal, 2006.
60	*Bambusa lako* Widjaja	Ornamental	Cultivated	Poudyal, 2004, 2006.
61	*Bambusa sinospinosa* McClure	Ornamental		Poudyal, 2006.
62	*Cephalostachyum latifolium* var. variegata	Ornamental		Poudyal, 2006.
63	*Chimonobambusa marmorea* var. *variegata* Makino	Ornamental		Poudyal, 2006.
64	*Chimonobambusa quadrangularis* (Franceschi) Makino	Ornamental, as naturalized in India	Cultivated	Poudyal, 2004, 2006.
65	*Dendrocalamus minor var. amoenus* McClure	Ornamental		Poudyal, 2006.
66	*Fargesia dracocephala* T.P.Yi.	Ornamental		Poudyal, 2006.
67	*Fargesia murielae* (Gamble) T.P.Yi	Ornamental		Poudyal, 2006.
68	*Otatea acuminata* (Munro) C.E.Calderón ex Soderstr.	Ornamental		Poudyal, 2006.
69	*Phyllostachys aurea* (André) Rivière & C.Rivière	Ornamental, cultivated in India	Cultivated	Poudyal, 2004, 2006.
70	*Phyllostachys aureosulcata* McClure	Ornamental		Poudyal, 2006.
71	*Phyllostachys bissetii* McClure	Ornamental		Poudyal, 2006.
72	*Phyllostachys dulcis* McClure	Ornamental		Poudyal, 2006.
73	*Phyllostachys edulis* (Carrière) J.Houz.	Ornamental	Cultivated	Stapleton, 1994; Poudyal, 2004, 2006
74	*Phyllostachys heteroclada* Oliv.	Ornamental		Poudyal, 2006.
75	*Pseudosasa japonica* Makino	Ornamental, cultivated in India	Cultivated	Poudyal, 2004, 2006.
76	*Shibataea kumasasa* (Zoll. ex Steud.) Makino	Ornamental, cultivated in India	Cultivated	Poudyal, 2004, 2006.
77	*Pleioblastus argente-ostriatus* (Regel) Nakai	Ornamental	Cultivated	Poudyal, 2004, 2006.

Among the 21 genera, *Bambusa* is the largest, comprising 14 taxa and, is commonly referred to as Maal, Makla, Sete, or Buddha bans in Nepali. The genera *Dendrocalamus, Cephalostachyum, Drepano stachyum, Himalayacalamus, Melocanna, Saro-calamus, Thamnocalamus, Ampelocalamus* and *Yushania* are native and include some endemic species. The genera *Chimonobambusa, Otatea, Phyllostachys, Pleioblastus, Pseudosasa, Sasa, Sasaella, Shibataea, Thyrsostachys* and *Tongpeia* are exotic ornamental species. Among the ornamental species 32 bamboo species were recorded by Poudyal (2004; 2006) and 15 ornamental bamboo species were introduced by Poudyal (2002). The Himalayan bamboo species *Himalayacalamus collaris* (T.P.Yi) Ohrnb was recorded only in Flora of China vol. 22 (Zhengyi*et al.,* 2006), while the subtropical species *Dendrocalamus parishii* Munro was recorded in Flora of India vol. 30 (Kumari *et al.,* 2024).

Endemic Bamboo in Nepal

In Nepal, eight taxa (seven species and one variety) of bamboo are endemic belonging to the genera *Bambusa*, *Dendrocalamus*, *Himalayacalamus*, and *Thamnocalamus* genera (Table 2) (Stapleton, 1994a; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Rajbhandari *et al* 2016; Rajbhandari *et al.,* 2020; Shrestha *et al.,* 2022). Most of these endemic species have been recorded from central part of Nepal, including the Piper area of the Annapurna Conservation Area and Langtang National Park in Rasuwa district.

Table 2: Endemic bamboo species in Nepal

Sl. No.	Scientific name	Nepali name	Herbarium records of Endemic species in literatures
1	*Bambusa nepalensis* Stapleton	Tama Bans (Kathmandu), Khosre Bans, Phusre Bans (East Nepal)	Kathmandu district, Bansbari, 1987.12.20, C. Stapleton 719 (E, holotype).
2	*Dendrocalamus hamiltonii* var. *undulatus* Stapleton	Tama Bans	Kathmandu, Balaju, 27°46 N 85°18 E, 1400 m, Stapleton 456; Holotype: E)
3	*Himalayacalamus asper* Stapleton	Ghode nigalo (Kaski), Malinge Nigalo, Baa ma (Tamang)	Kaski district, Karuwa, Pipar, 28°26'N 83°57'E, 2000m, 16 xi 1983, Stapleton 314(holo. E).
4	*Himalayacalamus cupreus* Stapleton	Malinge Nigalo	Kaski district, Karuwa, Pipar, 1983.09.12, C. Stapleton 306 (E, holotype).
5	*Himalayacalamus fimbriatus* Stapleton	Tite Nigalo	Kathmandu district, Kathmandu, 1200 m, 1990.01.16, C. Stapleton 910 (E, holotype).
6	*Himalayacalamus planatus* Stapleton	Malinge nigalo, Bar Ma (Tamang)	Rasuwa district, Syabru, ca. 2440 m, 1984.10.7, C. M. A. Stapleton 328 (K, holotype).
7	*Himalayacalamus porcatus* Stapleton	Seto Nigalo, Bra ma (Tamang)	Rasuwa district, Syabru, 2290 m, 1984.10.8, C. Stapleton 332 (E, holotype. KATH, isotype).; Rasuwa dist., Syabru, 28°08'N 85" 21'E, 7500ft, 8 x 1984, Stapleton 331.
8	*Thamnocalamus chigar* (Stapleton) Stapleton	Chigar	Kaski district, Karuwa – Pipar, 3000 m, 1983.09.16, C. Stapleton 315 (E, holotype of *Borinda chigar*).

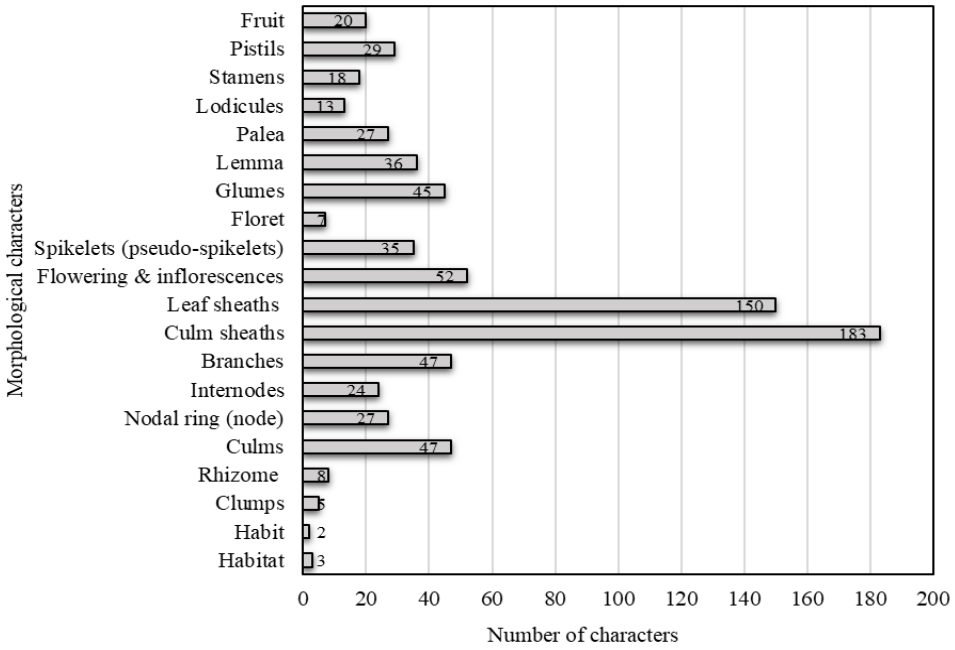

Fig 1: Morphological characters bamboo species in Nepal

Morphology of Bamboo

Out of the 778 morphological characters recorded, the highest diverwsity was found in the culm sheath (183), followed by leaf sheaths (150), flowering and inflorescences (52), culms (47), branches (47), glumes (45), lemma (36), spikelet (35), etc. (Fig.1).

The highest number of culm sheath character (183) was further divided into five subcategories. These are characterized by the overall culm sheaths form, size, type, and texture of the culm sheath (74), followed by the culm sheath blade (36), ligule (32), oral setae (23) and auricle (18) (Fig. 2).

Comparably, the leaf blade has the highest number of characteristics (55), followed by the leaf sheaths in terms of size, shape, kinds, and texture (23), the leaf sheath auricle (24), the leaf sheath oral setae (23) and the leaf sheath ligule (25) (Fig. 3).

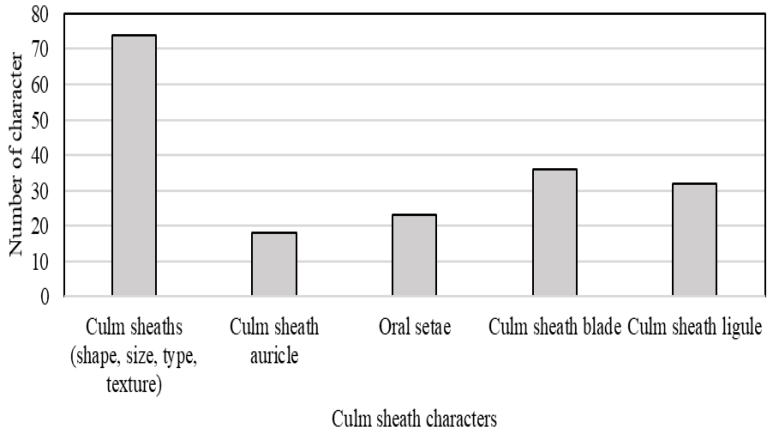

Fig 2: Morphological characters on culm sheath and blade

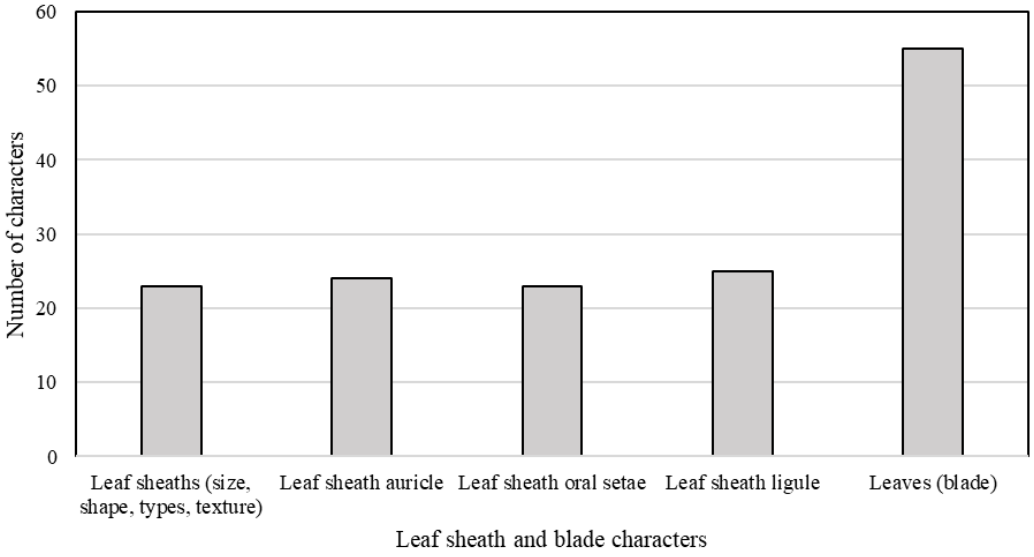

Fig 3. Morphological characters on leaf sheath and blade

Discussion

Nepal is a mountainous country with elevation ranges from 60 meters above mean sea level (m asl) to the top of the world Mt. Everest with 8848.86 m asl. It comprises five vegetation zones, 35 forest types and 118 ecosystem types. Due to the high degree of variations in physio-climatic conditions, Nepal is rich in plant biodiversity including bamboo species. Nepal harbours 77 taxa (74 species and 3 infra-specific taxa) of bamboo including endemic, native, introduced and ornamental species. Among all these 38 bamboo species are also found in India, particularly in the north-eastern regions (Tewari, 1992; Negi, 2009; Kumari & Singh, 2014; Sharma & Borthakur, 2018; Tewari *et al.,* 2019; Kumari *et al.,* 2024). Stapleton (1994) published three research articles on the bamboos of Nepal and Bhutan (Part I, II and III) which are considered fundamental and pioneering works on the bamboo sector in both countries. In these research articles, similarity in bamboo species found in Nepal and Bhutan is also highlighted (Stapleton, 1994b; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e; Michael B.T. 2017). This review found 34 taxa (32 species and 2 infra-specific taxa) recorded in Nepal with proper herbarium specimen (Rajbhandari *et al*., 2020, Shrestha *et al.,* 2022) while two taxa are recorded in Flora of China and Flora of India; Ayer *et al.* (2023) listed 53 species using the PRISMA method, whereas Poudyal (2004 & 2006) listed 82 bamboo species including introduced and ornamental exotic species.

In Nepal, bamboo species are found from the lowest elevation (60 m) up to approximately 3500 m above sea level (Stapleton 1996a). Among the 33 native species studied and analysed, 12 are found in Nepal's tropical ecological zone, which includes the Tarai, Churiya range, Bhabar, and lower foothills twenty species are occour in the Himalayan and upper mountain regions, ranging from temperate to sub-alpine ecological zones, and 26 species are found in the hilly regions of Nepal. Since the mountainous areas of Nepal serve as a transitional zone between the tropical and temperate ecological zones, they harbour a high diversity of bamboo species (Stapleton, 1994a; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e).

Of the 33 native species reported in Nepal, 9 are arborescent, while the remaining 24 are shrubby. Additionally, there are 9 caespitose species, 4 pluri-caespitose species, and 15 uni-caespitose species. Three species form open clumps, while 19 species form dense clumps. One species, *Sarocalamus racemosus* (Munro) Stapleton, has monopodial branching (leptomorph), while the remaining 32 species exhibit sympodal (pachymorph) rhizome morphology.

Similarly two species lack expanded necks, ten species have long necks, and thirteen species have short necks (Stapleton, 1994a; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e).

The height of the bamboo culms ranges from two meters to thirty meters. Nine of the native species in Nepal are shorter than five meters, thirteen range from five to ten meters, eight range from ten to twenty meters, and the remaining three exceed more than twenty meters in height.

Bamboo species can exhibit various culm textures, including glabrous, hairy, rough, glaucous, scabrous, silvery, softly, persistent, and shiny. In *Thamnocalamus spathiflorus* (Trin.) Munro, the culm wax turns red or yellow and isusually referred to as Rato nigalo. In *Yushania emeryi* (Stapleton) Demoly, the wax turns black, which is referred to as Kalo Nigalo.

The nodal ring is also an important morphological character for bamboo identification . A prominent, corky collar is found in *Ampelocalamus patellaris* (Gamble) Stapleton. Rings of red colour can be seen above and below the nodes in *Himalayacalamus falconeri* (Munro) Keng f. While most bamboo species have fistular internodes, *Dendrocalamus strictus* (Roxb.) Nees develops solid internodes when grown in dry areas. Internode lenght varies from less than 5 cm to 100 cm, with *Cephalostachyum latifolium* Munro having the longest internodes, measuring up to 100 cm. The shape of the bud is also important for the identification of shrubby bamboos. Lanceolate (chilli shaped) buds are found in *Thamnocalamus* species, whereas ovate (onion shaped) buds are found in *Ampelocalamus, Himalayacalamus* and *Drepanostachyum* species.

Bamboo's branching pattern is also helpful for the identification at the generic level. In *Dendrocalamus*, branches are absent near the base and three central branches are dominant. In *Drepanostachyum*, the number of branches ranges from 25 to 70, while in *Melocanna baccifera* species, the branching pattern is similar.

Similarly, the culm sheath is reported to have 183 types characters, the highest among all structures, while the leaf sheath has 150 characters, the second highest. This indicates that culm sheath and leaf morphology play a significant role in the identification of various bamboo species (Sarma and Pathak, 2004). The culm sheath auricle is absent in *Bambusa balcooa, Bambusa multiplex, Drepanostachyum, Himalayacalamus, Thamnocalsmus* and *Yushania* sp. (Bor, 1940; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e).

Leaf morphology is also important for species identification. An unequal leaf base is found in *Ampelocalamus patellaris* (Gamble) Stapleton, a sub-cordate base in *Bambusa balcooa* Roxb., and a distinctly tessellate (cross-veins) pattern is found in *Thamnocalamus* species.

Bamboo identification also relies heavily on reproductive traits, particularly floral structures. According to this review, flowering and inflorescences (synflorescences) exhibit the highest number of morphological features (52), followed by glumes (45), lemma (36), spikelet (pseudospikelet) (35), pistils (29), palea (27), stamens, and fruit (20).

Like the other grasses, bamboo is monocarpic, i.e., it flowers and sets seeds only once before dying. Most bamboo species exhibit gregarious flowering (21 species), while *Dendrocalamus hamiltonii* Nees & Arn. ex Munro floweres sporadically. The inflorescence of *Dendrocalamus giganteus* Munro bears lax heads with few spikelets and may sometimes be leafy at the top. In *Cephalostachyum capitatum* Munro, *Cephalostachyum latifolium* Munro and *Melocanna baccifera* (Roxb.) Kurz., the branches (paraclades) are unilateral, subtended by long, narrow, projecting bracts, with a short awn arising from midrib or keel. Many of these bracteate inflorescences have also been reported to bear further axes or viable buds in the axils of the bracts and prophylls, including in basal bracts of the pseudo-spikelets. This allows for indeterminate (iterauctant) growth, potentially leading to the formation of dense spherical clusters. A total of 14 species with iterauctant inflorescences, such as *Bambusa, Cephalostachyum, Dendrocalamus,* and *Melocanna* species have been identified. In temperate bamboos the bracteate inflorescences seen in 19 species including *Ampelocalamsu, Drepanostachyum, Himalayacalamus, Sarocalamus, Thamnocalamus,* and *Yushania,* generally produce viable buds, and those that do form are not capable of indeterminate growth.

Similarly, flower prophyll is useful for identifingy bamboo at the generic level: *Dendrocalamus* has a single-keeled prophyll, while *Bambusa* haa a rwo-keeled prophyll. The number of stamens also helps in identification, three stamens are found in *Ampelocalamus, Drepanostachyum, Himalayacalamus,* and *Sarocalamus,* whereas six stamens are found in *Bambusa, Dendrocalamus,* and *Melocanna* species. Most bamboo species have yellow-colored anthers, though some have purple anthers; *Dendrocalamus hamiltonii* Nees & Arn. ex Munro has honey-colored anthers. Small caryopsis fruit are found in most bamboo species, while *Melocanna baccifera* (Roxb.) Kurz produces pea- or pear-shaped fruits up to 13 cm in length (Bor, 1940; Stapleton, 1994c; Stapleton, 1994d; Stapleton, 1994e).

Conclusion

Nepal is rich in bamboo diversity, with 77 taxa, including eight endemic species. The subtropical zone of Nepal is particularly rich in bamboo diversity, with both large and shrubby species present. Culm sheaths and leaf characters are especially important for bamboo species identification, as bamboo has long flowering cycles, ranging from 40 to 130 years. Therefore, both macro-morphological and micro-morphological characters, including culms, branches, node and internodes, flowering, and inflorescences, are essential for accurate identification. This review work has helped to highlight the morphological characters useful for identifying bamboo species. Molecular systematics tools including DNA barcoding, are modern approaches to bamboo identification, especially given the rarity of flowering. However, very few studies have employed molecular markers in Nepal for solving taxonomic complexities. Thus, comprehensive taxonomic treatment combined with molecular systematics is necessary for delimiting the species boundaries in Nepal and for exploring bamboo species for bio-prospecting.

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