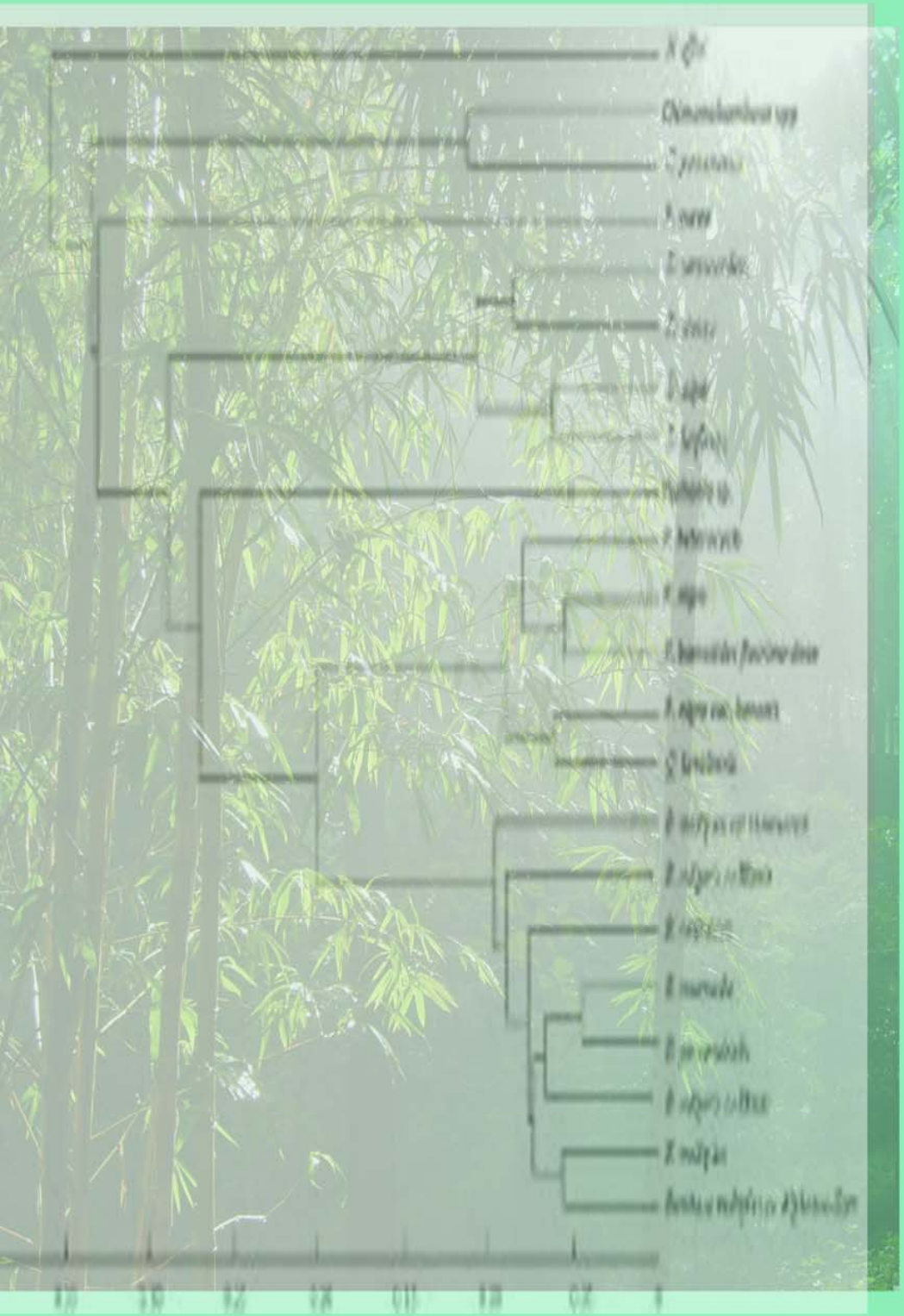

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PHYLOGENY OF SELECTED WOODY BAMBOOS

(Bamboo Phylogeny Group)

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June 2011

Project Proposal

Project Title : PHYLOGENY OF SELECTED WOODY BAMBOOS OF THE WORLD

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Objectives:

1. Generate a robust phylogeny for the woody bamboos (Bambuseae) using multiple plastid sequence data sets, AFLPs, structural characters, and a phylogenetic approach that reduces known sources of random and systematic error;

2. Examine selected aspects of morphological evolution within the tribe to test hypotheses regarding the origin and evolution of various features;

3. Construct predictive, more stable sub tribal and generic classifications for the woody bamboos based on the phylogeny and produce a Web-accessible, interactive identification resource for the recognized genera;

4. Establish an umbrella Web site for bamboo biodiversity to host the interactive identification key, provide links to relevant information, and make images and descriptive information on bamboos.

5. Project Period: 2008-2012

6. Funding agency : National Science Foundation,
Washington, USA

7. Budget (For KFRI) : Rs. 3,11,4000/- (=6920 US$) INR 45= 1US$

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Abstract

The Bamboo Phylogeny Project was undertaken by the Bamboo Phylogeny Group (BPG), an international collaboration of bamboo scientists. This project represents the first broadly based, collaborative attempt to produce a global evolutionary tree (phylogeny) for bamboos. An evolutionary tree for bamboos is essential to answer questions about the evolution of unique bamboo features, biogeography, and ecology, and to provide the basis for a stable and predictive classification system that accurately reflects relationships among bamboos. Survey of bamboos was done in Sri Lanka and the whole of South India for the distributional status of the species included in the present study.

The following four species of woody bamboos namely *Oclandra stridula* Moon ex Thwaites, *Oclandra travancorica* (Bedd.)Benth., *Davidsea attenuata* (Thwaites) Soderstrom & Ellis, *Pseudoxytenanthera monadelpha* (Thw.) Soderstrom & Ellis and one species of herbaceous grass *Streptogyna crinita* P. Beauv., were selected and used for molecular studies as well as morphological scorings. Morphological characters were analysed and some of the characters that cannot be coded or scored were excluded. Characterizations of species and OTUs have been developed. The Sequenced DNA of all the five selected species has been uploaded in the Bamboo Phylogeny Website and the homology obtained through NCBI-BLAST are also provided. The data matrix and character states selected are also given. The Phylogeny aspect is being carried out at the IOWA State University and hence, it is not included in this report.

INTRODUCTION

The Bamboo Phylogeny Project was undertaken by the Bamboo Phylogeny Group (BPG), an international collaboration of bamboo scientists. This project represents the first broadly based, collaborative attempt to produce a global evolutionary tree (phylogeny) for bamboos. An evolutionary tree for bamboos is essential to answer questions about the evolution of unique features, biogeography, ecology and to provide the basis for a stable and predictive classification system that accurately reflects relationships among bamboos. Even considering recent improvements in our understanding of grass evolution [Grass Phylogeny Working Group (GPWG) 2001; Posada and Buckley, 2004], bamboos remain less well understood than other major groups of grasses although like other grasses, bamboos are important both ecologically and economically. The lack of a stable classification and non-technical identification tools hampers development of bamboo as a resource and affects other fields of study including conservation (Bystriakova *et al*., 2003, 2004). Due to the lack of flowering material for woody bamboos, well-illustrated identification tools based primarily on vegetative characters, are necessary. The BPG aims to reconstruct the evolutionary tree of bamboos based on DNA sequence data, morphological features and use the tree as a springboard to explore the evolutionary history and create an improved classification system for bamboos. A computer-based, interactive identification resource for bamboos hosted on a Web site is intended to make information on the biodiversity of bamboos more readily accessible to all bamboo researchers.

Current Status

Bamboos are the only major lineage of grasses to diversify in forests. Our current understanding of bamboo evolution in relation to other grasses is largely based on recent molecular studies by the GPWG (2001), which helped to establish that true bamboos are most closely related to the rice and bluegrass lineages. This work also demonstrated that several groups of broad-leaved grasses long classified as bamboos are, in fact, distant relatives. Morphologically, a single origin for bamboos is indicated by the shared presence of well developed, asymmetrically lobed arm cells in the photosynthetic tissue of the leaves (Zhang and Clark, 2000) and molecular data support a single origin as well. The true bamboos (Poaceae subfamily Bambusoideae), with ca. 1,610 described species in 120 genera (Kumar, 2011) are usually classified into two major groups recognized as tribes (Soderstrom and Ellis, 1987; Judziewicz *et al*., 1999; Zhang and Clark, 2000). The woody bamboos (Bambuseae) with ca. 1,500 species are distributed worldwide (Kumar, 2011) while the herbaceous bamboos (Olyreae) with ca. 110 species (Ohrnburger, 1999) are restricted largely to the American continent. The woody bamboos are regarded as sharing a single common ancestor based on the presence of several apparently uniquely derived morphological features, including the presence of culm leaves (leaves modified for the protection and support of the tender young shoots), complex vegetative branching and gregarious monocarpy

(with flowering cycles ranging from a few years to 120 years), but so far, support for a single origin of the tribe from molecular sequence data is lacking (Zhang and Clark 2000). Conversely, sequence data strongly indicate that the herbaceous bamboos have a single common ancestor, but no unique shared morphological feature has yet been identified for this tribe.

The Bamboo Phylogeny Group

The Bamboo Phylogeny Group consists of an international team of bamboo taxonomists who have agreed to pool resources and expertise to achieve the stated goals. The Bamboo Phylogeny Group provides a means to facilitate communication among collaborators, coordinate species sampling and characters (both molecular and morphological) and exchange expertise. Current members of the Bamboo Phylogeny Group along with their institutional affiliations and their bamboo specialties are listed in Appendix 1.

The evolutionary tree will be reconstructed using state of the art methods and will be based on DNA sequence data sets that will be analyzed in conjunction with morphological features (or characters) for a representative subset of bamboo species. The emphasis is on some of the complicated genera like, *Arundinaria*, *Bambusa*, *Dendrocalamus*, *Gigantochloa*, and *Schizostachyum*, alliances. The morphological features selected are posted on the Bamboo Biodiversity Web site, with illustrations. The DNA sequences and the morphological data matrix will become available through the Bamboo Biodiversity Web site. Evolutionary tree will be used to explore the origin and evolution of unusual or complex structures in bamboos, such as pseudospikelets and vegetative branch complements (including the origin of multiple buds in certain lineages) as well as rhizomes and leaf anatomy. The earlier preliminary analyses suggest, that the ancestor of woody bamboos had clumping rhizomes and determinate (true) spikelets and that running rhizomes and pseudospikelets (indeterminately branching flowering units) arose independently multiple times. Careful analyses of morphological and anatomical features are needed as a foundation for the revised generic classification.

Plant molecular studies have brought about a revolution in plant taxonomy and a better understanding of the natural relationships among plants (and other outgroups). Consistent with this modern scientific revolution, subtribal and generic classifications of bamboo will be based explicitly on the evolutionary tree that is expected at the end of this study. The goal is to formally recognize units that appear as lineages in the evolutionary tree and that share a unique (common) ancestor as well as unique combinations of characters. Units that correspond to groups of species will be recognized as genera and units that correspond to groups of genera will be recognized as subtribes.

MATERIALS AND METHODS

The working methodology is common to all the collaborating partners of the BPG

Work Involvement of KFRI

The material of four woody bamboo species and one herbaceous relative was collected through fieldwork in the Western Ghats of India and Sri Lanka. Sampling of woody bamboos and outgroups, collection of materials of the selected species, characterization of species and development of OTUs were carried out in consultation with other International collaborators. Sequencing, approximately 32 kilobases of DNA for these five species was also done. Scoring of morphological characters for the four woody bamboo species and one herbaceous grass species was carried out. The sequence data and morphological data were stored in the project database. Sequence data was blasted and homology of the respective species were analysed through NCBI-BLAST. The following four species of woody bamboos *Ochlandra stridula, Ochlandra travancorica, Davidsea attenuata, Pseudoxytenanthera monadelpha* and one species of herbaceous relative *Streptogyna crinita* were selected and used for molecular studies and morphological scorings.

STUDY AREA

Survey and collection of the bamboo species selected were undertaken from throughout the Western Ghats, India and 13 Districts of Sri Lanka. In the Western Ghats, the areas covered were from the States of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. During the field survey in Sri Lanka thirteen districts namely, Badulla, Colombo, Galle ,Gampaha, Kalutara, Kandy , Kegalle , Kurunegala, Matale, Matara. Moneragala ,Nuwara Eliya and Ratnapura representing the Northern, Central, Western, Sabaragamuwa, Uva and Southern Provinces were covered.

Taxon Sampling

All together, in this study, sequencing of 154 species of bamboos and five outgroups are included for all the collaborating countries. A minimum of an additional 16 species were also sampled for AFLP work for a total of 46 temperate species. Monotypic genera aside, two species per genus were included. From among the 154 species of bamboos five species were allotted to KFRI.

Fieldwork and Physical Collections

All specimens were collected in multiple sets, and the first set deposited in the national herbarium. Additional sets were distributed to the U.S. National Herbarium at the Smithsonian Institution

and the herbarium at the Royal Botanic Gardens, Kew.

Structural Data

Molecular Data For the structural analysis, 98-character list was prepared including the morphological characters (e.g., oral setae in the foliage and culm leaves) and characters that could not be coded or scored were excluded. Gross morphological characters were scored primarily from herbarium specimens and live plants. Whenever possible, leaf materials from the same vouchers were used for the molecular analyses and two samples per species were examined.

Nucleotide Sequence Data: For sequencing, three existing plastid data sets (*ndh*F, *rpl*16 intron, and *trn*L-*trn*F spacer) and two new ones (*rps*16 intron and *trn*D-*trn*T spacer) as the primary basis for phylogenetic estimation for the-woody bamboos were used. Amplified Fragment Length Polymorphisms: AFLP analyses was conducted to provide additional resolution within the NT Clade and to complement sequence and structural data. The protocol developed by the Wendel lab (2004), was followed utilizing fluorescent-labeled primers and data extraction with software programs Genotyper (Applied Biosystems) and Genographer (2004).

Extraction and amplification of the DNA for the selected species were carried out. The primer details were provided by the BPG. Plant DNA Samples were extracted using Sigma –Aldrich GenElute™ Plant Genomic DNA miniprep kit.
The samples were separated on 1.5 per cent agarose gel and then viewed after staining in an aqueous solution of ethidium bromide.

The following forward and reverse primers were used for amplifying plastid genes (ndhF, rpS16 and rpL16) from the isolated genomic DNA in all the four species of bamboos and in *Streptogyna crinita*.

1. FORWARD (ndhF) 5' ATGGAACAKACATATSAATATGC 3'
   REVERSE (1318R) 5' CGAAACATATAAAACGCAGTTAATCC 3'
2. FORWARD (rpS 16 F) 5' AAACGATGTGGTARAAAGCAAC 3'
   REVERSE (rpS16 R) 5' AACATCWATTGCAASGATTCGATA 3'
3. FORWARD (rpL 16 F) 5' GCTATGCTTAGTGTGTGACTCGTTG3'
   REVERSE (R1661) 5' CGTACCCATATTTTTCCACCACGAC 3'

Polymerase chain reaction

DNA samples were amplified using Phusion PCR kit for *Ochlandra stridula, Davidsea attenuata* and *Psedoxytenanthera monadelpha*. PCR master mix (25µl) was then added to each tube. Final concentrations of reagents were as follows: 200µM dNTPs, 0.2U/µl phusion DNA polymerase,

0.5µM of each primer and 1x HF buffer. Negative control contains all the chemicals except DNA.

PCR reactions were carried out with an initial denaturation at 98^0 C for 1 minute and 30 cycles of PCR reaction, each of denaturation (98^0 C -7 sec.). Primer annealing (58^0 C -20 sec. for primer set 1; 60^0 C -20 sec. for primer set 2 and 67^0 C -20 sec. for primer set 4) and extension (72^0 C -1 minute) were performed. A final extension at 72^0 C for 5 minutes was also given. The amplified samples were separated on 1.5 per cent agarose gel and then viewed after staining in an aqueous solution of ethidium bromide.PCR products were then sequenced. For *Streptogyna crinita* and *Ochlandra travancorica* PCR assay was carried out with specific primers in 20 µl reaction mix containing 2.5 µlof 10X Taq buffer, 0.625 µl of dNTPs (10 mM) (Genei, Bangalore), 10 picomoles each of forward primer and reverse primer, 50 ng of template DNA and 0.6µl of Taq polymerase (Sigma) (3U). PCR mixture was subjected to 35 cycles of amplification in a thermal cycler (MJ research) under the following conditions: initial denaturation at 94°C for 4minutes followed by 35 cycles each of cycle denaturation at 94°C for 1min., primer annealing (51°C for ndhF, 60°C for rpS16 and 57°C for rpL16) for 1min. and primer extension for 1.30 min. At the end of PCR, a final extension of 10min. was also given. Annealing temperatures were standardized for each primer pair. PCR products were visualized on 1% agarose gel with ethidium bromide staining and documented. PCR products were purified using silica DNA binding column (Qiagen) and sequencing of the purified products were performed (SciGenom, Cochin). The DNA sequences were edited and deposited into Genebank public domain.

Phylogenetic Analyses

This aspect is being done at the IOWA State University and other Institutions collaborating in this project. The phylogenetic details are excluded from this report.

Computational Resources and Web Site Development

The Bamboo Biodiversity Web site is developed as a primary repository for information on bamboo diversity with links to other relevant Web sites. It is organized to provide access to descriptions, classification and species lists, images, phylogenies, databases and matrices, and identification resources.

RESULTS AND DISCUSSION

Bamboo Resources

In the Western Ghats bamboos form a major component of the biodiversity. There are 21 species of bamboos known to occur in Western Ghats. Out of the 21 species, 20 are distributed in Kerala, 6 species in Karnataka, 5 species in Tamil Nadu and 2 species in Andhra Pradesh. Among these, 13 species are endemic to this phytogeographic region (Kumar, 2011). Bamboos show a high degree of endemism and most of the species have a restricted distribution. Some of the species known from Western Ghats are also distributed in Sri Lanka. This gives an indication of the affinities of the Sri Lankan flora with the flora of Western Ghats. The phytogeographical affinities of the forests of Sri Lanka and Western Ghats are best evidenced by the distribution of six species of bamboos common to both the phytogeographical regions.

Bamboo resources in Sri Lanka are not as abundant as in many South Asian countries and consequently, the importance of bamboo in the household economy, construction, and in cottage industry is comparatively less. The availability of indigenous bamboo species such as *Ochlandra stridula*, in forest areas, is decreasing because of deforestation and over-exploitation. However, they are found abundantly in a few areas, e.g. in Ratnapura and Kalutara Districts. Native Bamboo species (Table 1) are found in the natural forest areas while introduced species are found as plantations owned by the State, or on private lands as well as confined to Botanic Gardens and occasionally, as ornamental species. There is a high degree of endemism with one genus *Davidsea* (80%). *Bambusa bambos* and *Dendrocalamus cinctus* are confined to the dry zone of the country. Of these, *Dendrocalamus cinctus* is highly restricted in distribution and is known only from one

Table -1. Native bamboo species and their habitats

	Species	**Location**
1	*Bambusa bambos* (L.)Voss	Dry zone (wasgamuwa) Intermediate and dry forests in low hills
2	*Ochlandra stridula* Moon ex Thwaites	Wet lowlands and in the low hills in the western and southern parts of the country
3	*Arundinaria densifolia* Munro	High altitudinal montane areas
4	*A. debilis* Thwaites	High altitudinal montane areas
5	*A. scandens* Soderstrom & Ellis	High altitudinal montane areas
6	*A. floribunda* Thwaites	High altitudinal montane areas
7	*A. walkeriana* Soderstrom & Ellis	High altitudinal montane areas
8	*Pseudoxytenanthera monadelpha* (Thw.) Soderstrom & Ellis	Wet and intermediate zone, mountains of Badulla and Nuwara eliya districts
9	*Davidsea attenuata* (Thw.) Soderstrom & Ellis	Wet and intermediate zone, mountains of Badulla and Nuwara Eliya districts
10	*Dendrocalamus cinctus* R.B. Majumdar *ex* Soderstrom & Ellis	Dry zone North Central Region, restricted distribution.

Table-2. List of bamboo species introduced in Sri Lanka

Serial No.	**Species**
1	*Bambusa vulgaris* Schrad. ex Wendl.
2	*Bambusa multiplex* (Lour.)Raeush ex Schult. & Schult.f.
3	*Bambusa polymorpha* Munro
4	*Bambusa tulda* Roxb.
5	*Bambusa wamin* Camus
6	*Dendrocalamus asper*(J.H.Schultes)Backer ex K.Heyne
7	*Dendrocalamus giganteus* Munro
8	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro
9	*Dendrocalamus longispathus* Kurz
10	*Dendrocalamus membranaceus* Munro
11	*Dendrocalamus strictus* (Roxb.)Nees
12	*Gigantochloa atter* (Hassk.)Kurz
13	*Melaccana baccifera*(Roxb.)Kurz
14	*Pseudosasa hindsii* (Munro) C.D.Chu & C.S.Chao
15	*Thyrostachys siamensis* Gamble

or two isolated localities such as Ritigala, located in the North-central region of the country. *Ochlandra stridula*, is found extensively in the wet lowlands of the south-western region. The remaining species are found in the high altitudinal montane areas of the country. The natural habitat of most of the bamboo species is the forest under-storey. The exceptions are species confined to special habitats such as *Dendrocalamus cinctus*, and *Arundinaria scandens* which have been reported from windswept mountain tops and *A.densifolia* from low temperature swamps within the montane grasslands. The bamboo resource of the country is enriched with the introduction of many species, some of which are cultivated. Twenty two species of bamboos are found in the National botanical gardens. Many of the indigenous bamboos are shrubby montane type and are not well suited for utility purposes.

The larger diameter bamboos (*Bambusa vulagris* and *Dendracalamus giganteus*), are mostly introduced species and are cultivated in homegardens and along roadsides and riverbanks (Table 2). The bamboo handicraft industry uses *B. vulgaris* and *O. stridula* species and the construction industry uses *B. vulagris* and *D. giganteus*. Bamboo industry supports about 250 families and 690 workers. According to a survey by the Forest Department about 80 percent of people who collect bamboos process it for household consumption and rest 20 percent people either process it for domestic use as well as sell them to processors.

1. ***Davidsea attenuata*** (Thwaites) Soderstrom & Ellis, in Smithson.Contr.Bot. No.72: 59-66, 1988; *Bambusa attenuata* Thwaites in Thwaites & J.D.Hooker,Enum. Pl. Zeyl., 1864:375 [type: Sri Lanka, *CP. 3255,* (K lectotype, Selected by Soderstrom & Ellis, 1988:59); *Teinostachywn attenuatun* (Thwaites) Munro in Trans. Linn. Soc. London 26, 143-144,1868. **Fig.1.**

Description: Medium sized bamboo 8 - 9 m tall. ***Rhizome*** sympodial, pachymorph with a short neck 3-5 cm long, producing a dense clump with closely placed culms. ***Culms*** hard, light green with a white blush at the summit of the internode, whip-like terminally and strongly arching, 1.5-2.5 cm dia. ***Nodes*** with a single bud, the prophyllum glabrous, margins sparingly ciliolate, the base covered by the thick girdle, consisting of 26-30 nodes, internodes cylindrical, hollow, the longest 37-38 cm long. ***Branching*** intravaginal central dominant primary branch developing first, followed by two secondary branches later becoming elongate, thin and whip-like. ***Culm-sheath*** when young maroon toward the summit and pale green below, covered with scattered appressed white hairs, thick at the base and leaving a girdle upon abscission of the sheath, strongly tessellate on the inner surface; blade tardily deciduous, horizontal to slightly reflexed, as long as the sheath, linear-lanceolate, up to 8.5 cm long, 1 cm wide, the margins twisted toward the base, apex acuminate, inrolled, pointed, glabrous on the lower surface, the upper surface with sparse long hairs intermixed, the long hairs becoming dense toward the apex; inner sheath ligule truncate, membraneous 2 mm long with a denticulate margin, glabrous on both surfaces; lateral appendages small, with a few white oral setae; outer sheath ligule absent. ***Leaves*** in 9 or 10 leaved complements, 40 cm long, 30 cm wide; blade fully developed 10-20 cm long, 2-3 cm wide, lanceolate with an acuminate tip, the edges smooth or denticulate, paler green on the lower surface, glabrous on both surfaces, the mid- and lateral veins not manifest on the upper surface, mid-vein prominent on the lower surface and lateral veins clearly delimited, short-petiolate and at length abscissile from the sheath; leaf sheath glabrous except for a few appressed hairs toward the summit and cilia on the upper overlapping margin, the upper margin slightly elevated into an auricle and sometimes bearing a short lateral appendage with oral setae; inner ligule a minute truncate rim less than 1 mm long; outer ligule a hard glabrous rim less than 1 mm long.

Fig.1. *Davidsea attenuata*

Inflorescence as pseudospikelets terminating in leafy branches or occurring on short leafless branches clustered at the nodes; internodes of the flowering branches flat below and becoming thickened upward. ***Pseudospikelets*** sessile, 1-2 cm long, subtended and at first covered by a firm, persistent, many nerved, glabrous bract, ciliate on the lower margins, otherwise glabrous; ***prophyllum*** gemmiferous, 8 mm long, obtuse at the apex, the 2 keels winged, ciliate, with the interkeels concave, nerveless, the lateral flanges each with 2 or 3-nerved and glabrous; gemmiferous bracts (glumes) 2 or 3; bracts ciliate on the margins, many-nerved, glabrous.

Spikelets consist of 1 empty glume and several florets, only the lowermost one develops fully, the other one or two depauperate, followed by an empty lemma and/or a terminal empty lemma, the rachilla extension short, 1-2 mm long, not disarticulating; glume single, 11 mm long, the margins ciliate, otherwise glabrous, apiculate, 13-nerved; *lemma* 14 mm long, glabrous, apiculate, firm, 16-nerved, with transverse veinlets, tighty convolute, enclosing the palea and flower; *palea* thin, shorter than the lemma, with an obtuse tip, ciliate on the 2- keeled, otherwise glabrous, with 1 nerve between the keels and 1 in each lateral flank; *lodicules* 3, 2.4 mm long, obovate and pointed at the tip, the two anterior broader than the single posterior, thin, many-nerved; ***Stamens*** 6, the filaments free, anthers yellow, 2 mm long, basifixed, shortly apiculate; ***Ovary*** tubular**,** glabrous, gradually narrowing upwards; style long flat divided into 3 shortly-plumose stigmas. ***Fruit*** unknown.

Distribution: so far known as endemic to Sri Lanka. However, the same species has been collected from the forests of Sultan Battery, Wayanad District and Kottiyoor, Kannur District of Kerala part of Western Ghats and therefore, the said species share their distributional range.

Specimenes examined.- SRI LANKA: Kandy District: Knuckles Mountain, *Gould* & *Balakrishnan 13898* (US); Rangala Hill, east of Kandy, *Soderstrom* & *Kulatunge I770* (PDA, US); Badulla District: between Horton Plains and Ohiya, *Soderstrom* & *Kulatunge I657* (PDA,US); Nuwara Eliya District-:6 miles [9 km] north west of Nuwara Eliya along the Gampola-Nuwara Eliya road, *Davidse* & *Sumithraarachchi 7968* (PDA, US); INDIA: Wersern Ghats, Wayanad District: Sultan Battery, 1100m alt. *Remesh & Kumar 20656* (KFRI); Kannur District: Iritty, *Remesh & Kumar 20624* (KFRI); KARNATAKA: Sampage *Remesh & Kumar 7531* (KFRI).

2. ***Ochlandra stridula*** Moon ex Thwaites, in Thwaites & J.D. Hooker, 376. 1864 [type: Sri Lanka, *C.P. 241*,lectotype, PDA selected by Soderstrom & Ellis 1988];Gamble, in Ann. Roy. Bot. Gard Calcutta 7, 123, pl.109, 1896; Hooker f. in Trimen, 318-1900;Camus, 181-182, pl. 99, 1913;Soderstrom & Ellis, in Smithson. Contr. Bot. No.72. 67, 1988; *Beesha stridula* (Moon ex Thwaites) Munro in Trans. Linn. Soc. London 26, 145, 1868. **Fig.2.**

Discription: Medium sized unicespitose gregarious shrubby bamboo. ***Rhizomes*** sympodial pachymorph with a short neck, forming a dense clump with closely placed culms. ***Branch complement*** at mid-culm nodes unrestricted, consisting of one strong, central axis and 3 slightly smaller ones on either side. ***Culms*** soft, when new light brown-maroon becoming dark green, self-supporting below and slightly arched above, 4-5 m tall, -1 cm in diameter, tip arched or drooping; Nodes swollen, sheath scar and nodal ridge conspicuous. The internodes cylindrical, hollow, 39-42 cm long, glabrous except in young culms in which the upper part is covered sparsely with appressed translucent hairs producing a whitish appearance and roughened surface.

Fig 2. *Ochlandra stridula*

Culm sheath laminiferous, abscissile upon branching, when new greenish brown below becoming orange-brown to maroon at summit, the blade strongly reflexed and appressed to the sheath, linear-lanceolate, 7.5 cm long, 1 cm wide, with a 2.5 mm long lateral extension, apex attentuate, upper surface green, glabrous except for the whitish short-hirsute base and summit; auricles on either side of insertion of the blade bearing antrorsely barbed oral setae 7.5 mm long; the ligule membraneous, 1 mm long with an entire margin. ***Leafy twigs*** 55-81 cm long containing 8-14 leaves; leaf blades lanceolate, tapering to an acuminate apex, the most fully developed 23-34 cm long, 2.5-5 cm wide, glabrous on both sides, one of the margins scabrous, midrib prominent, tip acuminate, scrabrous, truncate at base into a short petiole; leaf sheath overlapped, smooth striate; auricles small, falcate with stiff bristles, bristles deciduous; ligule very short, outer ligule absent. ***Inflorescence*** developing as pseudospikelets, arise terminally on the leafy branches. ***Spikelets*** ovate-lanceolate, 3 cm long, 5mm wide, comprising 3 transitional glumes, 1, lemma, 1 palea, 7 lodicules, 27 stamens, and 1 pistil; transitional glumes firm, ovate, 10-15 mm long with a mucro 2-2.5 mm long, many-nerved, glabrous except for a few appressed hairs on the upper third, the margins overlapping, ciliate along the edge; lemma membranous, about as long as the palea with the margins overlapping above, glabrous, 18-nerved with a slight sulcus in the middle without transverse veinlets; lodicules 7, in 2 alternating whorls, membranous throughout, lanceolate, 3-5-nerved, 10- 12 mm long, 1.9-2.5 mm wide. ***Stamens*** 27, yellow (brown with green tips when mature), with 1 or 2 spicules at the apex of the connective, the filaments filiform, free, basifixed. ***Ovary*** glabrous, rounded at the base becoming quadrangular above, with a glabrous quadrangular perigynium; style 1.2-2.8 cm long, dividing terminally into 3 plumose stigmas (one or two of them may further split to give 6 stigmas). ***Fruit*** a caryopsis, fleshy, oblong, 6-6.5 cm long, 0.7-1 cm across, supported by persistent glumes**.**

Distribution: Endemic to Sri Lanka. Detailled examination and comparision of *Ochlandra stridula*, so far endemic to Sri Lanka, with the Western Ghat endemic species *Ochlandra scriptoria* revealed that taxonomically both species are concpecific and it is proposed to synonymise *Ochlandra scriptoria* (Dennst.)CEC Fischer under *Ochlandra stridula* Moon ex Thwaites according to the rules of priority.

Specimens examined.-SRI LANKA. Colombo District: Abugama, *N. Balakrishnan 207*

(PDA,US). Kegalle District: Uwanwelle [ruanwelle], nov 1883, *Ferguson s.n.* (PDA; Arandara, near Galigamuwa, *Soderstrom* & *Kulatunge 1673* (PDA, US); road to Maliboda from Deraniyagala through Kosgahakanda, *Soderstrom* & *Kulatunge1674* (PDA, US); meenawata, between Deraniyagala and Kosgahakanda, *Soderstrom* & *Kulatunge 1676* (US); near Arandara, road to Udugama, [ll km] from Kegalle, [6 km] from Galigamuwa *Soderstrom 2563* (B, CANB, DD, K, LE, P, PRE, TNS, US). Kandy District:: Peradeniya, Royal Botanic Garden, cultivated, *Soderstrom* & *Kulatunge 1601* (PDA, US).

3. ***Ochlandra travancorica*** (Bedd.) Benth. in Benth. & Hook.f., Gen. Pl. 3: 1215. 1883; Gamble, Ann. Roy. Bot. Gard. Calcutta 7:125.t.111.1896 & in Hook. f., Fl. Brit. India 7:419.1897; Brandis, Indian Trees 684. 1906; Bourd., For. Trees Travancore 403. 1908; E. G. Camus, Les Bamb. 182. 1913; Rama Rao, For. Pl. Travancore 448. 1914; C.E.C. Fisch. in Gamble, Fl. Pres. Madras 3: 1863.1934; Varmah & Bahadur, Indian For. Rec. (n.s.) Bot. 6(1): 4. 1980; Tewari, Monogr. Bamb. 115. 1992; M. Kumar, Rheedea 5:82.1995; Seethalakshmi & M. Kumar, Bamb. India Comp.191. 1998; Ohrnberger, Bamb. World 328. 1999. **Fig.3.**

Fig 3. *Ochlandra travancorica*

Description: Medium sized, caespitose, gregarious bamboo, growing in tufts, culms very close and impenetrable. ***Rhizome***, sympodial, pachymorph, solid, short necked, covered with scales. ***Culms*** erect, self supporting, hollow, 4-10 m tall, tip slightly arched or sometimes whip- like. ***Node*** slightly swollen, sheath scar and nodal ridge prominent, a single nodal bud is present, enclosed by prophyllum; internodes 0.5-1.2 m long, 4-6 cm in diameter, dark green, smooth below and rough towards the tip. ***Culm sheath*** 15-26 cm long, 8-12 cm broad at base, coriaceous, covered with bulbous based golden brown hairs when young, smooth, or sparsely hirsute, deciduous and striate when old, truncate at the tip, inner side smooth and shining; sheath blade reflexed, glabrous, subulate, 5-12 cm long, 0.6-1.2 cm broad at base; auricle short, inconspicuous, ornamented with numerous stiff bristles; inner ligule 0.2-0.3 cm high, outer ligule not clear; branches arise from the fifth or sixth node, the young branches form just above the sheath scar, intravaginal eruption, the primary central branch develops first, numerous laterals arise from its basal buds, rebranches. ***Leaves*** arise on branches, linear-lanceolate, 19-40 cm long, 2-6 cm broad, glabrous on both sides, margins rough and scabrous, midrib prominent, clear on the lower side, tip acuminate, setaceous, scabrous and

sometimes twisted, truncate at the base into a short, thick petiole; leaf sheaths overlap, closely attached, smooth, striate, the sheaths have very short auricle and oral setae at the tip, oral setae deciduous when old, ligule short. ***Inflorescence*** a large compound spicate panicle on leafy branches, spikelets borne at all branches at successive nodes, also on the main culm nodes, composed of pseudo-spikelets, form semiverticillate clusters at the nodes, fertile and sterile flowers mixed. ***Spikelets*** single flowered, ovate-lanceolate, glabrous, 4-6 cm long, 0.7-1 cm broad, very short stalked, basal portion supported by 3-4 bracts, sterile glumes 3-4, the first glume ovate, 1.2-1.5 cm long, 0.6-0.8 cm broad, the second ovate-lanceolate, 1.8-2.3 cm long, 1-1.2 cm broad, the third ovate-lanceolate, 2.5-3 cm long, 1.7-2 cm broad, the fourth glume lanceolate, 4-4.5 cm long, 2-2.5 cm broad, stiff and coriaceous, ciliate along the margins, many nerved, acute, strongly mucronate, stiff hairs arise from the base of mucro in the lower glumes; fertile glumes, lemma long-lanceolate, mucronate, thin, many nerved, 4-5 cm long, 2.5-3.2 cm broad; palea ovate-oblong, thin, membranous, margins overlap, ciliate, tip retuse, slightly notched, ciliate, 4.3-4.5 cm long, 1.8-2.3 cm broad; lodicules 3, hyaline, almost of the same size, 1.3-1.8 long, 3-4 cm broad, narrow towards the base, 5-6 nerved, margins fimbriate, ciliate. ***Stamens*** 65-130, number not fixed, yellow, filaments free, long, filiform, basifixed, anthers about 1.6-2 cm long, apiculate, tip ciliate. ***Ovary*** glabrous, rounded at the base and gradually elongated into a, perigynium enclosing the style; style 3.8- 4.7 cm long, divides at the tip to form 6 plumose stigmas. ***Fruit*** a caryopsis, large, fleshy, ovate-oblong, about 8-9.5 cm long, 2.8-3 cm diameter, pericarp fleshy, caryopsis partially covered by persistent glumes.

Distribution: This is the most common reed bamboo throughout the Western Ghats and has a wider distribution in southern Western Ghats. It is found growing in Kerala, South Karnataka and Tamil Nadu from sea level to an elevation of 2000 m. It is a component of moist deciduous and semi-evergreen forests, and forms reed breaks. It also grows along river and stream sides. Sporadic flowering is very common in summer months. Gregarious flowering was observed during the present study at Goodrical Range, Pathanamthitta district in 1998.

Specimens examined: KERALA: Ernakulam Dist. Pooyankutty, *AG Pandurangan* 79243 (MH); Edamalayar, *N Unnikrishnan 74025* (CALI). Idukki Dist. Adimali, *N Unnikrishnan 74024* (CALI); Vallakkadavu, *BD Sharma* 43940 (MH); Pambanar *MY Ansai* 51549 (BSI); Kallar, *N Unnikrishnan 74018* (CALI); Vagamon, *N Unnikrishnan 74002* (CALI). Kollam Dist. Shenduruny, *Punalur Paper Mill* 140613 (DD); Shenduruny, *KJ Joseph* 130257 (DD); Kulathupuzha, *N Unnikrishnan 74017* (CALI). Kottayam Dist. Mundakkayam, *N Unnikrishnan 74015* (CALI). Malappuram Dist. Nilambur, *N Unnikrishnan 74027* (CALI); Nilambur, Thalichola, *Philip Mathew 33922* (CALI). Pathanamthitta Dist. Plapilly, *M. Kumar* 6429 (KFRI); Goodrical, *N Unnikrishnan 74005* (CALI). Thrissur Dist. Kollethirumudi, *M. Kumar* 6412 (KFRI); Poringal *GS Puri* 15905 (BSI). Thiruvananthapuram Dist. Agasthyarmalai, *M Kumar* 6481 (KFRI); Agasthyarmalai, *N Mohanan 11463* (CALI); Bonnaccord, *M Mohanan* 61719 (MH);

Nedumangad, *CA Barber* 7178 (MH); Kottur RF, *J Joseph* 44088 (MH); Travancore hills, *Beddome* s.n. (MH). TAMIL NADU: Kanyakumari Dist. Muthukuzhivayal, *AN Henry* 4945 (MH). Thirunelveli Dist. Thirunelveli, *EAC Forests* 39687 (DD); Nangunery Range, *Forest Ranger* 40541 (DD).

4. ***Pseudoxytenanthera monadelpha*** (Thwaites) Soderstr. & R.P. Ellis, Smith.Contr. Bot. 72: 52.1988; *Oxytenanthera monadelpha* (Thwaites) Alston in Trim., Fl. Ceylon 6 (Suppl.) 342.1931; C.E.C. Fisch. in Gamble, Fl. Pres. Madras 1861.1934; Varmah & Bahadur, Indian For. Rec. (n.s.) Bot. 6(1): 4. 1980; Tewari, Monogr. Bamb. 124. 1992. *Dendrocalamus monadelphus* Thwaites, Enum. Pl. Zeyl. 376.1864. Seethalakshmi & M. Kumar, Bamb. India Comp.224. 1998. *Pseudotenanthera monadelpha* (Thwaites) R.B. Majumdar in Karthikeyan *et al*., Fl. Ind. Enum. Monocotyl. 280. 1989.*Oxytenanthera thwaitesii* Munro, Trans. Linn. Soc. London 26: 129. 1868; Gamble, Ann. Roy. Bot. Gard. Calcutta 7: 72, t. 63.1896 & in Hook. f., Fl. Brit. India 7: 402. 1897; Brandis, Indian Trees 673. 1906; Bourd., For. Trees Travancore 400. 1908; E. G. Camus, Les Bamb. 147. 1913; Rama Rao, For. Pl. Travancore 447. 1914. **Fig.4.**

Type: Sri Lanka, Ambagamuwa, *Thwaites* s.n. (lectotype PDA. selected by Soderstrom & Ellis, 1988; isotype MH !).

Fig 4. *Pseudoxytenanthera monadelpha*

Description: Medium sized, caespitose, gregarious bamboo, forming loose clumps. ***Rhizome*** sympodial, pachymorph, solid, neck slightly long, covered with scale leaves. ***Culms*** erect, self supporting, hollow, 7-10 m tall, tip gradually become curved and whip like; node slightly swollen; sheath scar is very prominent forming a girdle, supranodal ridge not clear, a single dormant branch bud is present at each node enclosed inside a prophyllum; internodes 30-35 cm long, 1.5-2.5 cm diameter, dull green, hirsute, scabrous. ***Branches*** start form the lower nodes, arise just above the sheath scar, extravaginal, branches numerous, forming semiverticillate clusters on the nodes, the primary buds remain dormant and numerous laterals, develop from its sides, sometimes the central axis becomes prominent, whip like similar to the main culm. ***Culm sheath*** 15-25 cm long, 7-11 cm broad at base, purplish-green, coriaceous, margins ciliate, covered with bulbous based brown hairs, yellowish orange when young, striate, brittle, abscissle, straw coloured, hirsute towards the base when old, tip truncate; ***sheath blade*** reflexed, foliose, upper

surface glabrous, lower side slightly hirsute, broad, acuminate, 7-12 cm long, 1.2-3 cm broad at base, base truncate, spreading and decurrent along the top of the sheath, deciduous when old; auricles very prominent, ear-shaped, falcate, with stiff bristles, oral setae numerous, persistent; inner ligule large, prominent in large sheaths, 0.5-1 cm high, short in smaller sheaths, erose, outer ligule not clear. ***Leaves*** size highly variable, 4-32 cm long, 0.5-3.2 cm broad, linear-lanceolate, glabrous on both sides, margins rough and scabrous, tip acuminate, midrib prominent, base attenuate, narrows into a short petiole, leaf sheaths closely attached, overlapping, smooth, striate, straminous, keeled, tip ends in a callus; auricle prominent, falcate with stiff bristles, bristles deciduous; inner ligule prominent in mature branches, 0.4-0.5 cm high, erose, membranous, outer ligule short. ***Inflorescence*** a large compound spicate panicle on leafy branches, later shed all leaves and the whole plant is converted to a huge inflorescence. ***Spikelets*** arise on the nodes of all branches, composed of pseudospikelets form semiverticillate clusters or as very large globose heads, those at the ends of the branchlets are small; spikelets 1-3-flowered, ovate-lanceolate, acute, 1-1.4 cm long, 0.2-0.3 cm across, supported by two bracts, hirsute along the margins of glumes, the lowermost develop first and dominate with reduction upwards; sterile glumes 2, stiff, coriaceous, many nerved, mucronate, hirsute along the sides, first glume 0.4-0.5 cm, ovate, second glume 0.6-0.8 cm long, ovate-lanceolate; fertile glumes, lemma ovate-lanceolate, thin, 1-1.2 cm, many nerved, strongly mucronate, ciliate along the sides and also the tip; palea thin, membranous, concave, 0.8-1 cm long, two keeled, ciliate on the keels, convolute, slightly bifid, tip ciliate; lodicules absent. ***Stamens*** 6, monadelphous, yellowish, exserted; anthers 0.5-0.6 cm long, short, apiculate, ciliate at the tip. ***Ovary*** glabrous, fusiform, style long, 0.8-1 cm long, hairy; stigma 3, plumose. ***Fruit*** a caryopsis, 0.4-0.5 cm long, thin, fusiform, scabrous, sulcate along one side, tip mucronate, hairy, pericarp dry.

Distribution: This species is distributed in southern Peninsular India and Sri Lanka. It is a component of moist deciduous and semi-evergreen forests and found growing from 600-2000 m altitude. Sporadic flowering is common in summer months. In South India, it is distributed in Kerala, Karnataka and some parts of Tamil Nadu.

Specimens examined: INDIA: Andhra Pradesh-Kurnool Dist. Kurnool Forest, *RH Beddome* s.n. (MH). Karnataka: Chickmangalore Dist. Bababudan, *NS Adakoli* 156635 (DD). Kerala: Idukki Dist. Vellimala, *Jomy Augustine 13334* (CALI); Munnar, *N Unnikrishnan 74022* (CALI); Munnar, Chokkanad, *N Unnikrishnan 74206* (CALI). Palakkad Dist. Mutthikulam, *Stephen Sequiera & Michiale 8821* (KFRI); Sispara, *M Remesh & Stephen 20712* (KFRI). Wayanad Dist. Manantoddy, *Rodes Morgen* s.n. (MH); Mundakai, *Stephen Sequiera & Michiale 8162* (KFRI). TAMIL NADU: Madura Dist. Highway Mountains, *Cheriyan Jacob 17614* (MH). Nilgiri Dist. Nilgiris, *Perrottet 1344*:*773* (DD); Nilgiris, *JS Gamble 20642* (DD); Nilgiris, *JS Gamble 21450* (MH); Ochterlomy valley, *JS Gamble 20531* (DD); Coonoor, *JS Gamble 12155* (DD); Coonoor, *JS Gamble 12165* (MH). Thirunelveli Dist. Thirunelveli, *Forest Ranger 40544* (DD).

5. ***Streptogyna crinita*** Palisot de Beauvois, *Ess. Agrostogr. 80:* + pl. 16, fig. 8. 1812 [Type *yide* Hubbard, 1956): Nigeria, *Palisot de Beauvois s.n.* Holotype: P, not seen.] Thwaites, 1864:374; Bor, 1960:649.*Streptogym gerontogaea* Hook.f., Trimen, Handb. Fl. Ceyl.5: 301.1900. [Type *yide* Hubbard,1956): Sri Lanka, *without locality or collector, C.P.* 922. Holotype, K,not seen.] Senaratna, 1956:34. Soderstr. & R.P. Ellis, Smith.Contr. Bot. 65: 13.1987; Sasidharan Flowering plants for Kerala 593.2004. **Fig.5.**

Fig 5. *Streptogyna crinita*

Description: ***Culms*** errect 75-100 cm tall, each representing the aerial extension of an upturned sympodial rhizome, the culm itself producing at its base 1-3 additional rhizomes to 25 cm long, these with short internodes about 1 cm long covered by the overlapping sheaths. ***Leaves*** evenly distributed along the culm, the sheaths not overlapping; sheaths glabrous, strongly ribbed, extending upward along both sides of the blade pseudopetiole and contiguous with the inner ligule; blades up to 26 cm long, 2.5 cm wide, broadly lanceolate and tapering at both ends, acute at the tip, narrowed below to a pseudopetiolate base, narrower than the summit of the sheath, 6 primary nerves present on either side of the midrib; upper blade surface pale green, with scattered spine like hairs, lacking manifest transverse veinlets, the midrib not pronounced; lower surface darker green than the upper, glabrous, transverse veinlets manifest,the midvein conspicuous, thick, shiny; outer ligule about 0.5 mm long, indurate; inner ligule about 1.2 mm long, the upper margin erose, ciliate on the abaxial (outer) surface, glabrous on the adaxial surface. ***Inflorescence*** terminating the culm, racemiform, 20-22 cm long, secund,containing 20-25 overlapping spikelets; axis appressed-pubescent, rounded on the back, with the outer surface flat or grooved; rachis slightly twisted, bringing all spikelets into alignment. ***Spikelets*** pale green, 4- or 5-flowered, slightly laterally compressed, the first floret most developed, with reduction upwards; 1st glume about 12 mm long, linearlanceolate, glabrous, 3-nerved, transversely veined, attached to the side of the thickened pedicel that supports the second glume; 2nd glume about 26 mm long, elliptic-lanceolate, glabrous, 17-nerved, the nerves of various thicknesses, not all extending the length of the glume, with numerous transverse veinlets and an antrorsely scabrous awn 1-2 mm long; lemma of lowest floret about 19 mm long, lanceolate, firm and thick except for the broad scarious margins, 9-nerved, the two halves tightly folded, sparingly appressed-pubescent on the lower half, the base extended beyond the attachment of the lemma and palea into a pubescent stipe (glabrous in the upper reduced florets), the midnerve

thickening above into an antrorsely scabrous awn about 15 mm long, this becoming elongated and coiled at maturity; palea about 13 mm long, glabrous and bowedout below, narrowed above and puberulent, strongly 2-keeled, the keels close together and grooved between them; rachilla internodes elongated, glabrous, curved, with an oblique apex and base; lodicules 3, thin, narrowly obovate, glabrous, with a few tiny hairs at the tip, the anterior pair 1.6-2.4 mm long, 1-5-nerved, the posterior one a little shorter, 1.6-1.8 mm long, 1-3-nerved. ***Stamens*** 2, the filament weak and ribbon-like, the anthers yellow, basifixed. ***Ovary*** fusiform, long-ciliate on the upper third and lower part of the style; style long, flattened, with sparse appressed hairs; stigmas 2, strongly retrorsely barbed above, the barbed portions elongating and coiling with age, eventually becoming entangled with each other and with the awns of the lemmas. ***Fruit*** a caryopsis about 15 mm long, narrow, elongated, slightly tapering, the ciliate summit of the ovary persistent at its apex; hilum narrow, linear, extending the full length of the fruit.

Distribution: This species is distributed in southern India and Sri Lanka. It is a component of moist deciduous and semi-evergreen forests and found growing from 600-2000 m altitude. Sporadic flowering is common in summer months. In South India, it is distributed in Kerala: Idukki, Kollam and Trivandrum District. In Sri Lanka it is restricted to very few localities. This species is so far known endemic to South India.

Specimenes examined.- SRI LANKA: Kurunegala District*:* Dolukanda, *Senaratna 2700* (PDA). Matale District: Matale, Dec 1846, *Gardner s.n., C.P. 922* (PDA). Colombo District: Henaratgoda, 3 Jan 1881, *Ferguson s.n.* (PDA). Moneragala District: Buttala to Sirigala, 3 Mar 1907, *Rock s.n.* (PDA); INDIA: Trivandrum District: Arippa Forest Floor, *Muktesh Kumar 26442* (KFRI).

Structural Data

Based on the morphological observations the character states (OTUs) were selected for structural analysis**.** Characters for the Bamboo Phylogeny Group morphological phylogenetic analysis are organized into the groups listed below:

Each character set is numbered sequentially within the set, each set with its own prefix. Coding is according to the character state numbers. When a character is not observable, then '?' is entered in the data matrix. If the character is inapplicable, then '–' is entered in the data matrix. In the event of polymorphisms, the following coding are used: A = states 0 and 1 present; B = states 1 and 2 present; C = states 2 and 3 present; D = states 1, 2 and 3 present; E = states 0, 1, 2 and 3 present; F = states 0 and 4 present; G = states 0 and 2 present; H = states 0, 1 and 2 present. The data matrix has been prepared (Appendix 2).

Life Span and Rhizomes

Life Span

R-1. Life span: 0 = perennial; 1 = annual. (It is considered that the perennials are less advanced than the annuals).

Rhizomes / Culm Bases (in adult / mature plants)

R-2. Leptomorph rhizomes: 0 = present; 1 = absent.

R-3. Culm base morphology: 0 = slender (all internodes more or less equal in diameter) and more or less vertical; 1 = at least some proximal internodes thicker than the distal internode(s) emerging from the soil and more or less horizontal (pachymorph).

R-4. Culm base branching (tillering): 0 = tillering absent; 1 = 1 tiller per culm base present; 2 = 2 or more tillers per culm base present.

R-5. Culm neck development: 0 = short (neck < the length of the culm base section with relatively short, bud-bearing internodes); 1 = at least some culm necks long (neck > the length of the culm base section with relatively short, bud-bearing internodes).

Culms

C-1. Habit: 0 = erect; 1 = apically arching/pendulous; 2 = clambering/scandent; 3 = twining; 4 = decumbent.

C-2. Culm internodes: 0 = all solid (at least when young); 1 = all hollow; 2 = some proximal internodes (including the basalmost ones) solid, distal internodes hollow.

C-3. Wall thickness (ratio of 2X wall thickness: culm diameter): 0 = walls very thin (ratio up to 0.15); 1 = walls thin (ratio 0.16-0.30); state 2 = walls moderately thick (ratio 0.31-0.45); 3 = walls thick (ratio 0.46-0.60); 4 = walls very thick (ratio 0.61-0.99).

C-4. Lacuna size: 0 = lacuna large, > 1/3 the diameter of the culm; 1 = lacuna small, < 1/3 the diameter of the culm.

C-5. Vegetative culm branching: 0 = present; 1 = absent.

C-6. Branch initiation/development: 0 = acropetal (toward the apex, i.e., branching begins at the base and proceeds toward the apex); 1 = basipetal (toward the base, i.e., branching begins at the apex and proceeds toward the base; 2 = bidirectional (starting at mid-culm and proceeding toward the base and toward the apex simultaneously).

C-7. Internode length (relative): 0 = all internodes more or less equally elongated along the culm (excluding the normal variation in size between basal/apical internodes and those of the mid-culm); 1 = one elongated internode regularly alternating with 1 to 4 very shortened internodes; 2 = the first internode greatly elongated (up to 5 m long) with additional apical internodes (if present) very shortened.

C-8. Nodal line position: 0 = horizontal; 1 = dipping slightly below the bud(s); 2 = dipping markedly below the bud(s).

C-9. Nodal line diameter: 0 = more or less the same diameter as the adjacent internodes; 1 = borne on a flange-like extension (patella), its diameter greater than the adjacent internodes.

C-10. Supranodal ridge: 0 = inconspicuous (a line, diameter less than at the nodal line); 1 =

conspicuous (a ridge, diameter equal to or greater than at the nodal line).

C-11. Aerial roots: 0 = absent; 1 = present on the lower nodes only; 2 = present on lower and upper nodes.

C-12. Aerial root morphology: 0 = root-like (more or less elongated, firm, and rounded at the apices); 1 = spine-like (short, hardened, and pointed).

Buds and Branching

Hypothesis I proposed by McClure (1966, 1973) regarded the multiple buds of *Chusquea* as all primary. Presumably the dominant bud is homologous to the single primary bud typical of bamboos, while the two to many additional smaller subsidiary buds are derived separately from meristematic tissue of the nodal region (in the more general morphology literature these would be called supernumerary buds). **Hypothesis II** proposed by Stapleton (1997) maintained that the extensive loss or reduction of prophylls was consistent with condensation of a single primary axis as a pathway for the evolution of the bud complement in *Chusquea*. Although, the main example here is *Chusquea*, there are other taxa with multiple buds as in *Filgueirasia* or *Holttumochloa*.

Hypothesis I

B-1. Primary buds per mid-culm node: 0 = 1; 1 = 2 or more; 2 = none.

B-2. Multiple primary buds, relative size: 0 = all buds subequal; 1 = central primary bud at least 2 times the diameter of the other primary buds (i.e., subsidiary buds). [Inapplicable for taxa with a single primary bud or with no buds.]

B-3. Central (or sole) primary bud shape: 0 = triangular; 1 = circular (dome-shaped).

B-4. Central (or sole) primary bud prophyll: 0 = prophyll unitary, margins free (open); 1 = prophyll unitary, margins fused (closed); 2 = prophyll binary (divided), margins free (open).

B-5. Compression of the proximal internodes of the axis developing from the central (or sole) primary bud: 0 = no compressed internodes present; 1 = one compressed proximal internode present at the very base; 2 = two to several compressed proximal internodes at the base; 3 = all internodes compressed.

B-6. Relative sizes of secondary branches developing from the central (or sole) primary axis: 0 = secondary axes subequal to the central (or sole) primary axis; 1 = at least some of the secondary axes no more than one-half the diameter of the central (or sole) primary axis.

B-7. Central (or sole) primary branch size relative to the main culm: 0 = more or less equal in diameter; 1 = smaller in diameter than the main culm.

Hypothesis II

B-8. Primary bud prophyll: 0 = present; 1 = absent.

B-9. Primary bud shape: 0 = triangular; 1 = circular (dome-shaped). [Inapplicable for taxa with multiple buds, unless one wishes to assume that the shape of the central bud reflects the shape of the primary bud.]

B-10. Primary bud prophyll: 0 = prophyll unitary, margins free (open); 1 = prophyll unitary, margins fused (closed); 2 = binary (divided), margins free (open).

B-11. Compression of the proximal internodes of the primary axis: 0 = no compressed internodes present; 1 = one compressed proximal internode present at the very base; 2 = two to several compressed proximal internodes at the base; 3 = all internodes compressed.

B-12. Relative sizes of secondary branches developing from the primary axis: 0 = secondary axes subequal to the primary axis; 1 = at least some of the secondary axes no more than one-half the diameter of the central axis. [Under this hypothesis, the secondary branches include both the ones flanking the dominant bud/branch in *Chusquea* and the ones that grow from the nodes of the dominant branch once it develops.]

B-13. Primary axis size relative to the main culm: 0 = more or less equal in diameter; 1 = primary axis smaller in diameter than the main culm.

General

B-14. Branching pattern: 0 = intravaginal; 1 = extravaginal; 2 = infravaginal.

B-15. Thorns developing from the primary axis (or central primary axis): 0 = absent; 1 = present.

B-16. Thorn morphology: 0 = relatively short, stout, stiff and usually curved; 1 = relatively elongated, slender, more or less flexible and at most slightly curved.

B-17. Bud/branch complement base: 0 = indistinguishable from the adjacent nodal region (promontory absent); 1 = swollen, forming a promontory that bears the bud/branch complement.

Culm Leaves

CL-1. Girdle: 0 = absent or poorly developed; 1 = present as a band at least 1 mm wide, no flap, prominent or not; 2 = prominent, with or without a flap covering the bud complement.

CL-2. Abaxial sheath surface: 0 = stiff, dark, irritating hairs present; 1 = only soft hairs present; 2 = glabrous, no hairs present; 3 = scabrous.

CL-3. Adaxial sheath surface: 0 = glabrous, shiny; 1 = scabrous-pubescent toward the apex.

CL-4. Sheath apex: 0 = more or less horizontal; 1 = symmetrically convex; 2 = symmetrically concave; 3 = asymmetrical/irregular.

CL-5. Sheath apex (or summit or shoulders) indument: 0 = glabrous; 1 = fimbriate

CL-6. Sheath summit extension: 0 = absent; 1 = present on one or both sides.

CL-7. Oral setae: 0 = absent; 1 = present, whether adnate to the inner ligule or not.

CL-8. Culm leaf blade position: 0 = erect to slightly spreading; 1 = reflexed.

CL-9. Culm leaf blade shape: 0 = broadly triangular; 1 = more or less narrowly triangular; 2 = cordate, some constriction at the base; 3 = pseudopetiolate, lanceolate.

CL-10. Culm leaf blade midrib abaxial development: 0 = indistinguishable; 1 = visible or even prominent toward the apex.

CL-11. Auricle (blade-derived appendage) development: 0 = absent; 1 = present and contiguous with the base of the blade; 2 = present on the sheath apex but not contiguous with the blade.

CL-12. Auricle size: 0 = auricles more or less equal on both sides of the blade base; 1 = strongly unequal, at least 2 times as large (or long) on one side as on the other side.

CL-13: Auricle indument: 0 = glabrous or ciliate; 1 = fimbriate.

CL-14. Auricle position: 0 = erect; 1 = strongly spreading or reflexed.

Foliage Leaves

FL-1. Sheath summit extension: 0 = absent; 1 = present on one or both sides.

FL-2. Sheath summit indument: 0 = glabrous; 1 = ciliate; 2 = fimbriate.

FL-3. Sheath: 0 = rounded on the back; 1 = strongly keeled at least near the summit.

FL-4. Outer ligule (contraligule): 0 = present; 1 = absent.

FL-5. Oral setae: 0 = absent; 1 = present wether adnate to the inner ligule or not.

FL-6. Auricle (blade-derived appendage) development: 0 = absent; 1 = present.

FL-7. Auricle size: 0 = auricles more or less equal on both sides of the blade base; 1 = strongly unequal, at least 2 times as large (or long) on one side as on the other side.

FL-8. Auricle indument: 0 = glabrous; 1 = ciliate; 2 = fimbriate.

FL-9. Foliage leaf blade, abaxial marginal green stripe (best seen in living material): 0 = absent; 1 = present.

FL-10. Foliage leaf blade, pseudopetiole absent: 0 = pseudopetiole distinct (leaf blade base constricted); 1 = pseudopetiole absent (leaf blade not constricted).

FL-11. Foliage leaf blade/pseudopetiole position: 0 = pseudopetiole (if present) and blade upwardly directed, blade fully erect or arching over; 1 = pseudopetiole (and therefore the blade) reflexed.

FL-12. Midrib placement: 0 = centric; 1 = excentric (wider side of blade 1.3 times or more as wide as the narrower side).

FL-13. Midrib development (abaxial surface): 0 = visible (distinct) for the full length (or nearly so) of the blade; 1 = visible (distinct) only in the basal one-third or so if the blade; 2 = not distinguishable from the primary veins in the leaf blade.

Inflorescences

Stapleton (1997) and others have interpreted the spikelet (i.e., little spike) as representing the basic inflorescence type within the grass family; this interpretation is accepted here. An aggregation of spikelets becomes a compound structure, which we refer to as the synflorescence. Synflorescences in grasses are traditionally described as spikes, racemes, or panicles or some variation on one of these themes. It should be noted, however, that in addition to the compound nature of grass synflorescences, they mature in a determinate pattern so that grasses, including bamboos, do not have true spikes, racemes, or panicles, except for the spikelets themselves, which are bracteate spikes. In bamboos, there is also the additional challenge of interpreting the pseudospikelet, which contains bud-bearing (gemmiparous) bracts that usually continue to develop additional orders of pseudospikelets but in a cymose fashion. Inferring homology among the synflorescences of bamboos must await a deeper understanding of bamboo evolution derived from other sources of data, so the characters in this section are focused primarily on structures that differentiate spikelets and pseudospikelets.

S-1. One or more gemmiparous bracts subtending the spikelet proper: 0 = absent; 1 = present, buds developing subsequently or not.

S-2. Subtending bract at the base of the axis bearing the spikelet or spikelet proper: 0 = absent; 1 = present.

S-3. Subtending bract morphology: 0 = scalelike or present as a scar or rim, no more than a few mm long, blade absent; 1 = well developed with both a sheath and a blade (this often modified).

S-4. Prophyll at the base of the axis bearing the spikelet or spikelet proper: 0 = absent; 1 = present.

S-5. Prophylls: 0 = whole; 1 = at least some deeply cleft to split lengthwise into two halves.

S-6. One or more spatheate bracts associated with clusters of spikelets or spikelets proper: 0 = absent; 1 = present.

Spikelets

As noted under Synflorescence characters, it is interpreted that the spikelet (or spikelet proper of a pseudospikelet) as a bracteate spike, which thus represents the true inflorescence in grasses (Stapleton 1997). Based on this interpretation, the main axis (rachilla) of the spikelet becomes a rachis and the pedicel becomes a peduncle, this terminology is used here.

SP-1. Compression of florets: 0 = terete; 1 = lateral; 2 = dorsal.

SP-2. Number of glumes (in female-fertile spikelets or spikelets proper): 0 = absent; 1 = one; 2 = two; 3 = three; 4 = four; 5 = five or six.

SP-3. Lowermost glume (glume I) development: 0 = well developed; 1 = strongly reduced, scalelike.

SP-4. Apex of lowermost glume: 0 = obtuse/truncate; 1 = acute; 2 = mucronate; 3 = awned.

SP-5. Next higher glume (glume II) development: 0 = well developed; 1 = strongly reduced, scalelike.

SP-6. Apex of next higher glume: 0 = obtuse/truncate; 1 = acute; 2 = mucronate; 3 = awned.

SP-7. Number of female-fertile florets per spikelet or spikelet proper: 0 = one; 1 = two; 2 = three or more.

SP-8. Floret sexuality: 0 = bisexual; 1 = unisexual.

SP-9. Rachis extension (internode only, with or without rudimentary floret): 0 = absent; 1 = present.

SP-10. Relative length of the rachis extension (internode only, with or without rudimentary floret) when present: 0 = short (shorter than or equal to about half the length of the floret); 1 = long (approximately equal to or longer than the floret).

SP-11. Rachis extension (internode only): 0 = glabrous; 1 = hairy.

SP-12. Rudimentary floret on the rachis extension: 0 = absent; 1 = present.

SP-13. Female-fertile lemma nerve number: 0 = 1; 1 = 3; 2 = 5 or more.

SP-14. Female-fertile lemma shape: 0 = navicular; 1 = spindle-shaped; 2 = ellipsoid; 3 = helmet-shaped.

SP-15. Female-fertile lemma apex shape: 0 = obtuse; 1 = acute; 2 = mucronate; 3 = awned.

SP-16. Female-fertile lemma apex fusion (exclusive of the awn or mucro if present): 0 = margins free; 1 = margins fused (connate).

SP-17. Female-fertile lemma texture: 0 = chartaceous (membrano-chartaceous); 1 = rigid, hardened.

SP-18. Palea keels: 0 = bicarinate (2-keeled); 1 = 1-keeled; 2 = rounded (keels not evident).

SP-19. Palea keel wings: 0 = absent; 1 = present.

SP-20. Palea apex: 0 = biapiculate (sinus shallow); 1 = tips long-divided (sinus deep); 2 = acute, not divided.

SP-21. Palea sulcus: 0 = well developed for full length of palea; 1 = well developed only toward the apex; 2 = absent.

Flowers and Fruits

FF-1. Lodicule number: 0 = absent; 1 = three; 2 = two.

FF-2. Lodicule margin pubescence: 0 = ciliate (l) or ciliolate (r); 1 = glabrous (entire).

FF-3. Stamen number: 0 = two; 1 = three; 2 = six; 3 = > 6.

FF-4. Stamen filaments: 0 = free; 1 = monadelphous.

FF-5. Anther apex: 0 = lobes rounded; 1 = lobes apiculate.

FF-6. Anther connective: 0 = lower than apical anther lobes, not extended; 1 = narrow and slightly (l) to greatly (r) elongated; 2 = as wide as anther apex and shortly elongated.

FF-7. Style base/ovary apex: 0 = ovary apex narrow and continuous with the style base (normal); 1 = ovary apex blunt, the style base forming an expanded cap (or hood) on top; 2 = ovary apex blunt, hood absent.

FF-8. Style proper length: 0 = absent (including extremely short, less than 0.1 mm); 1 = elongated by over 0.1 mm up to the length of the ovary; 2 = elongated and greater than the length of the ovary.

FF-9. Style proper pubescence: 0 = glabrous; 1 = pubescent.

FF-10. Style proper core: 0 = hollow; 1 = solid.

FF-11 Stigma number: 0 = three; 1 = two; 2 = one.

FF-12. Stigma branching: 0 = very branched and plumose (2 or more orders of branching); 1 = limited branching/simple, hispid (1 order of branching).

FF-13. Caryopsis/ovary base: 0 = sessile; 1 = stalked (stipitate).

FF-14. Caryopsis apex: 0 = acute, no additional persistent structures; 1 = short style, style base (if style elongated) or short style plus stigma bases persistent; 2 = thickened style base persistent, often a slight constriction between the caryopsis apex and the style base evident or a distinct line or ridge present in this position; 3 = elongated style persistent; 4 = hood (cap) persistent.

FF-15. Pericarp adnation (in mature fruit): 0 = strongly adnate to the seed coat (separates only with great difficulty or not at all through cutting, scraping or rubbing); 1 = not adnate to the seed coat (separates easily through cutting, scraping or rubbing).

FF-16. Pericarp texture: 0 = thin, papery and dull; 1 = thin, hardened and shiny; 2 = thickened, fleshy.

FF-17. Embryo position (caryopsis in longitudinal side view): 0 = lateral at the base; 1 = central at the base.

Molecular Data

DNA sequencing of the five species selected have been completed and all the sequences have been uploaded in the Bamboo Phylogeny database hosted at the IOWA State University,USA. The sequences of the species and their homology is given below:

- ***Ochlandra travancorica*** **(rpL16)** (1145bp)

AAAATTGACTGAACCCTACTATAAATAGAAAAAGAAAAAAACTTAGTAATTATAGA
AAATTAACTAATAACCAACCTATTGCTTCGTATTGTCGAGATCCTAACTAAGAAACA
GTCACTATATGAATAAATACATCTATCATAAATGAGTAGATCTATCATATAGTTGTAGC

AACTGCAATTTTTTCTCTAAAAAAGAAAACGGATTCTAGGTTGTGAAGCAAAACTA
AAGGGATGTGGATAAAAGGAGGGATGATAGAAAGAAAGAAGAGGAATAAGAAAG
ATATAGGATTCCAATATGTATGGTCTATGAGTTACATCATAAAAGGCAATGTGATAAA
GCATCAATATAATAAAAATAACAGAGAATTCGAAATCGTAACTTGAAACAAGAAATA
CAAATTTAAAACAATAATAAAGAGCGGCCCGGGTTAATAAAACTGAGAAAATTGAC
TCGGAAAGAAATTTTTTGGAAGCTCCATTGTGGGATTCAGACCTAACCATTAAAGG
AGAAGTAGTGGGAACGACAGAACCTATGACTGCATAGGATTTTATTGAAAAGAATC
CTAATACTTTTATTTGGTAAGGTTATAATATAAATTAACAAATAAGACAGGAAAGAGT
AAATATTCGCCCGCGAAATCTTTATTGAATTAGAATACTTTACCGCGATTCAATAAGA
GTAAAAATAAGGAGATTTTTTGTTAAGAAAGATTACATTATCTATAAATATAGAATATA
GATAAATAGACACACACATCTAGATATATTCTAGATCTTCTTTCTTTACTATATATTTTT
CTATTTTAACAAATTCAATATTCAATATTAAAAAAACCCTAACTTTTTCTATTATCTATT
AATGTGCATCTATCCGTAATATTTTGGAATATTATGGAATTAGAGAAATTTGCACGCTT
TCTCATTTCATTCGCGAGGAGCTGGATGAGAAGAAACTCTCATGTCCAGTTTTGCA
GTAGAGATGGAACTAAGAAAGAACCATCGACTATAACCCCAAAAGAACCAGATTTC
GTAAACAACATAGAAGAAGAATGAAGGGAAAATCCTGCCGAGGCAATCGTATTTGT
TTTGGTAGATATGCTCTTCAAGCACTTGAACCCGCTTGGATCACGTCGAGACAGATAG

Homology search made through NCBI-BLAST with (rpL16) gene sequence has shown the following homologies (*Schizostachyum brachycladum* 99%, *Nastus elatus* 99%, *Bambusa vulgaris* 98%, *Bambusa longispiculata* 98% and *Dendrocalamus latiflorus* 98%).

- ***Ochlandra travancorica* ndh F** (1054bp)

TTCGTCGCATATGGGCTTTTCCTAGTGTTTTACTCTTAAGTATAGCTATGGTATTCTCA
GTTCACCTATCTATTCAACAAATAAATGGAAGTTCTATCTATCAATATCTATGGTCTT
GGACCGTCAATAATGATTTTTCCTTAAAATTTGGATACTTGATCGACCCGCTTACTT
CTATTATGTTAATACTAATTACTACTGTAGGAATCCTCGTTCTTATTTATAGTGACGA
TTATATGTCTCACGATGAAGGATATTTGAAATTTTTTGTTTATATAAGTTTTTTCAATA
CTTCCATGTTGGGATTGGTTACTAGTTCCAATTTGATACAAATTTATTTTTTTTGGGAA
CTTGTGGGAATGTGTTCCTATTTATTGATAGGCTTTTGGTTTACACGGCCAATTGCAG
CGAGTGCTTGTCAAAAAGCTTTTGTAACTAATCGTGTAAGGGATTTTGGTCTGTTATTA
GGAATTTTATTGGTGCAGTTGCGAAATCTGCACAATTCCCTCTTCACGTATGGTTACC
CGATGCTATGGAAGGACCCACTCCCATTTCGGCTCTTATACACGCAGCAACTATGGT
TGCTGCGGGGATTTTTCTTCTAGCTCGACTTCTTCCTCTTTTCATATCCCTACCTTTA
ATAATGAGTTTCATTTCTTTAGTAGGTACAATAACACTCTTCTTAGGAGCTACTTTAG
CTCTTGCTCAGAGAGATATTAAAAGAAGCTTAGCCTATTCTACAATGTCTCAATTGG
GTTATATGATGTTAGCTCTAGGTATAGGTTCTTATCAAGCTGCTTTATTCCATTTGATC
ACTCATGCTTATTCGAAAGCTTTATTGTTCTTGGGATCCGGATCCGTTATTCATTCAAT

GGAACCTCTTGTTGGATATTCACCAGATAAAAGTCAGAATATGGTTCTTATGGGTGG
TTTAAGAAAATACGTTCCAATTACAAGAACTACTTTTTTATGGGGTACGCTTTCTCTT
TGTGGTATTCCACCTCTTGCTTGCTTCTGGTCCAAAGATGAAATCCTTAGTAATAGTT
GGTTGTATCAACC

Homology search made through NCBI-BLAST with (ndhF) gene sequence has shown the following homologies (*Bambusa vulgaris* 99%*Arundinaria gigantea* 99%, *Dendrocalamus latiflorus* 99%, *Bambusa oldhamii* 99% and *Streptogyna americana* 99%).

- ***Ochlandra travancorica*** **(rpS16 gene)** (762bp)

TTTTCCATAGTAATGAAAATGCTCTTGGCTCGACATAGTCTGTTCTATTCGTCCCGAA
CCAAATTTGCGCTGGGTTGTTTGTAAGTAAATAGTACACGATGGAGCTCGAGAGGAC
AGAATTTCTTTTTTATCAAGGGAAAGAATCTAGGGTTAGTGAAAACTAATAAATTAGG
CCAACTTTGTCAGTCTATCCTTAATATAGAAGTCGAAAGGTTAAAATAAGAAGAAAG
TCCAATTTTGGAAGATTGGAAAAACTCTTTCAATTAAAAGTCTATCAAAATCAATCGC
TCATATTCGATTTCTATAGAAGAGGGAAATGCTTTATCGAAGGAAATAAGAAAAAAAG
GGTATGTTGCTACTCTTTTGAAAGAAAAAAGAATAGGAATTCCCGAAGTAATGTCTAA
ACCCAAGGATTTCACAAATCAAAGATAAAGAATTCCGGAACAAGTAAACGCGATTTT
CAACTGTCTCAACAATAAAATTGTCTCAACAATTGAATTGGATCAGAATAAGGAATAA
AAGTAAATTCGTTCGAGATGAGACAAAGAAAAGAGTTTAGAGACGACTAAAAAATTT
CGAAGGATTTTTCCTTTTAAGTCTGTTAGTCAAAATTAGCCAACTTGAGTCATGAGTAT
AAATGAAATTTGTTTTTTCTGTAAGGAAATTAATGCAAGTCATAGTCGAATTTCTATCTA
CTTGTATTATGGACAGAAATTCGAATCATTTTCTCGAGCCGTATGAGGAGAAAACCTCC
TATACGTT

Homology search made through NCBI-BLAST with (**rpS16**) gene sequence has shown the following homologies (*Schisostachyum jaculans* 99%, *Bambusa grandis* 99%, *Pseudostachyum polmorphorum* 99%,*Bambusa tulda* 99%, *Bambusa bambos* 99%, *Dendrocalamus strictus* 99% and *Dendrocalamus brandisii* 99%).

- ***Streptogyna crenata*** **(rpL16 gene)** (1112bp)

CTACTATAAATAGAAAAAGAAAAAAACTTAGTAATTATAGAAAATTAACTAATAACCAA
CCTATTGCTTCGTATTGTCGAAATCCTAACTAAGAAACAGTCACTATATGAATAAATA
CATCTATCATAAATGAGTAGATCTATCATATAGTTGTAGCAACTGCAATTTTTTCTCTA
AAAAAGAAATAGGATTCTAAGTTGTGAAGCAAAACTAAAGGGATGTGGATAAAAGG
AGGGATGATAGAAAGAAAGAAGAGGAATAAGAAAGATATAGGATTCCAATATGTATG
GTCTATGAATTACATCATAAAAGGCAATGTGATAAAGCATCAATATAATAAAAATAACA

GAGAATTCGAAATCGTAACTTGAAACAAGAAAGACAAATTTTAAGCAATAATAAAGA
GCGGCCCGGGTTAATAAAACTGAGAAAATTGACTCGGAAAGAAATTTTTTGGAAGCT
CCATTGCGGGATTCAAACCTAACCATTAAAGGAGAAGCAGTGGGAACGACAGAACC
TATGACTGCATAGGATTTTATTGAAAAGAATTCTATATTTGGTAAGGTTATGAATTAACA
AATAAGACAGGAAAGAGTAAATATTCGCCCGCGAAATCTTTATTGAATTAGAATACTTT
ACCGCGATTCAATAAGAGTAAAATAAAAATAAGGAGATTTTTTTTAAGAAAGATTACAT
TATCTATAAATATAGAATATAGATAAATAAACACACACATCTAGATATATTCTAGATCCTC
TTTCTTGACTATATCTTTTTCTATTTTAACAAATTCAATATTAAAAAAACCCTAACTTTTT
CTATTATCTATTAATGTGTATCTATCCGTAATATTTTTGAATATTATGGAATTAGAGAAATTT
GCACGCTTTCTCATTTCATTCGCGAGGAGCTGGATGAGAAGAAACTCTCATGTCCAGTT
TTGCAGTAGAGATGGAACTAAGAAAGAACCATCGACTATAACCCCAAAAGAACCAGAT
TTCGTAAACAACATAGAGGAAGAATGAAGGGAAAATCCTGCCGAGGCAATCGTATTTG
TTTTGGTAGATATGCTCTTCAAGCACTTGAACCCGCTTGGATCACGGCGAGACAGA

Homology search made through NCBI-BLAST with (rpL16) gene sequence has shown the following homologies (*Streptogyna americana* 98%, *Schizostachyum brachycladum* 98%, *Nastus elatus* 97%,*Cephalostachyum pergracile* 97%, *Bambusa oldhamii* 96% and *Bambusa vulgaris* 96%).

- ***Streptogyna crenata*** (**rpS16F & rpS16R**) (732 bp)

TAGTAATGAAAATGCTCTTGGCTCGACATAGTCTGTTCTATTCGTCCCGAACCGAAT
TTGCGCTGGGTTGTTTGTAAGTAAATAGTACACGATGGAGCTCGAGAGGACAGAAT
TGCTTTTTTATCAAGGGAAAGAATCTAGGGTTAGTGAAAACTAATAAATTAGGCCAA
CTTTGTCAGTCTATCCTTAATATAGAAATCGAAAGGTTAAAATAAGAAGAAAGTCCA
ATTTTGGAAGATTGGGAAAACTCTTTCGATTAAAAGTCTATCAGAATCAATCGCTCAT
ATTCGATTTCTATAGAAGAGGGAAATGCTTTATCGAAGGAAATAAGAAAAAAAGGGT
ATGTTGCTACTCTTTTGAAAGAAAAAAGAATAGGAATTCCCGAAGTAATGTCTAAAC
CCAAGGATTTCACAAATCAAAGATAAAGGATTCCGGAACAAGTAAACACGATTTTCA
ATTGTCTCAACAATAGAATTGGATCAGAATAAGGAATAAAAGTCAATTCGTTCGAGAT
GAGACAAAGAAAAGAGTTTAGAGACGACTCAAAAAATTTCGAAGGATTTTTCCTTT
GAAGTCTGTCAGTCAAAATTAGCCAACTTGAGTCATGAGTATAAGTGAAATTTGTTT
TTTCTGTAAGGAAATTAATGCAAGTCATAGTCTAATTTCTATCTACTTGTATTATAGAC
AGAAATTCGAATCATTTTCTCGAGCCGTATGAGGAGAAAACCTCCT

Homology search made through NCBI-BLAST with rps16 gene sequence has shown the following homologies(*Pseudosasa cantorii* 98%, *Phyllostachys edulis* 98%, *Phyllostachys nigra* 98%, *Chimonobambusa quandrangularis* 98% and *Bambusa grandis* 95%).

- ***Streptogyna crenata*** (**ndh F & 1318R)** (1112bp)

TTATTATGTCATGGGGTTTGGACTTATTCTTATTCCGACAGCAACAAAAAATCTTCGT
CGCATATGGGCTTTTCCTAGTGTTTGATTTTTAAGTATAACTATGGTATGCTCAGTTCA
CCTGTCTATTCAACAAATAAATGGAAGTTCTATCTATCAATATCTATGGTCTTGGACCA
TCAATAATGATTTTTCCTTAAAATTTGGATACTTGATCGACCCGCTTACTTCTATTATG
TTAATACTAATTACTACTGTAGGAATCCTGGTTCGTATTTATAGTGACGATTATATGTC
TCACGATGAAGGATATTTGAAATTTTTTGTTTATATAAGTTTTCTCTATACTTCCCTGTT
GGGATTGGTTACTAGTTCCAATTTGATACAAATTTATTTTTTTTGGGAACTTGTGGGGA
TGTGATCCTATGTATTGATAGGCTTTTGGTTTACACGGCCAATTGCAGCGAGCGCTTGT
CACAAAGCTTTTTGAAGTATGCGTGAGAGGCATTTTGGGTCTGTTATTTTATTATTCCTT
GGTGCAGTTGCGAAATCCGCACAATTCCCTCTTCACGTATGGTTACCCGATGCTATG
GAAGGACCCACTCCCATTTCGGCTCTTATACACGCAGCAACTATGGTTGCTGCGGGG
GTTTTTCTTCTAGCTCGACTTCTTCCTCTTTTCATATGCCTACCTTTGATAATGAGTTT
CATTTCTTTAGTAGGTACAATAACACTCTTCTTAGGAGCTACTTTAGCTCTTGCTCAG
AGAGATATTAAAAGAAGCTTAGCCTATTCTACAATGTCTCAATTGGGTTATATGATGTTA
GCTCTAGGTATAGGTTCTTATCAAGCTGCTTTATTCCATTTGATCACTCATGCTTATTCG
AAAGCTTTATTGTTCTTGGGATCCGGATCCGTTATTCATTCAATGGAACCTCTTGTTG
GATATTCACCAGATAAAAGTCAGAATATGGTTCTTATGGGTGGTTTAAGAAAATACGT
TCCAATTACAAGAACTACTTTTTTATGGGGTACACTTTCTCTTTGTGGTATTCCACCT
CTTGCTTGCTTTTGGTCCAAAGATGAAATCCTTAGTAATAGTTGGTTGTATTCAC

Homology search made through NCBI-BLAST with ndhF gene sequence has shown the following homologies (*Streptogyna americana* 99%, *Arundo donax* 98%, *Arundinaria teota* 98%, *Bambusa vulgaris* 98% and *Phyllostachys aurea* 98%).

- ***Ochlandra stridula*** **- (ndh F & 1318R)** (645bp)

ATGGAAGTTCTATCTATCAATATCTATGGTCTTGGACCGTCAATAAGGATTTTTCCTTA
AAATTTGGATACTTGATCGACCCGCTAACTTCTATTATGTTAATACTAATTACTACGGT
AGGAATCCTCGTTCTTATTTATAGTGACGATAATTTGTCTCACGATGAAGGATATTTG
AAATTTTTTGTTTATATAAATTTTTTCAATACTTCCATGTTGGGATTGGTTACTAGTTCC
AATTTGATACAAATTTATTTTTTTTGGGAACTTGTGGGAATGTGTTCCTATATATTGATA
GGCTTTTGGTTTACACGGCCAATTGCAGCGAGTGCTTGTCAAAAAGCTTTTGTAACT
AATCGTGTAGGGGATTTTGGTCTGTTATTAGGAATTTTAGGTTTTTTTTGGATAACAGG
TAGTTTAGAGTTTCGGGATTTGTTCAAATTAGCTAATAACTGGATTCCTAATAATGGGA
TTAATTCCTTACTTACTACTTTGTGTGCTTTTTTATTATTCCTTGGTGCAGTTGCGAAAT
CTGCACAATTCCCTCTTCACGTATGGTTACCCGATGCTATGGAAGGACCCACTCCCAT
TTCGGCTCTAATACACGCAGCACTATGGTTGCTGCGGGGATTTTTCTTCTAGCTCG

Homology search made through NCBI-BLAST with ndhF gene sequence has shown the following homologies (*Pseudosasa japonica 98*%, *Arundinaria gigantea* 98%, *Semirundinaria fustuosa* 98%, *Sasa veitchii* 98% , *Pleioblastus simonii* 98%, *Phyllostachys aurea* 97% and *Bambusa vulgaris* 97%).

- ***Ochlandra stridula* - (rpL16F & R1661) (**340bp)

ATCATTATTAACAAAAATTCTCCTTATTTTTACTTTTTGGAAGCTCCGTTGTGGGATTC
TAATTTAATCAATATTTGACGGGCGTGGTAACCACTTTACCTACTACTGCATTGATTTT
ATTNTAACCTTCCCAAATACTTCCAATGGGTGTTGGGGCGTNCCACCCCACCACCAT
TGGCAGTATTAGGATTGTTTTCAATAAAATCCTATGCAGTCATAGGTAGAGTAAATACC
CCCCCTTCTCCTCTTTTGGAATGTCTGTACNTCACCGCGGAGCTACCAGAGTAATTCT
ATCCGATTCTTTTTTCTCAGTGATATCATCCCGGGCCGCTNTATATTA

Homology search made through NCBI-BLAST with rpL16F gene sequence has shown the following homologies (*Dendrocalamus latiflorus 72*%, *Valiha diffusa*73%, *Bambusa oldhamii* 72%, *Bambusa vulgaris* 72% and *Sirochloa parviflora*72%).

- ***Davidsea attenuata* – (ndh F & 1318R)** (578bp)

ATGGAATAAAGCAGCTTGATAAGAACCTATACCTAGAGCTAACATCATATAACCCAA
TTGAGACATTGTAGAATAGGCTAAGCTTCTTTTAATATCTCTGTGAGCAAGAGCTAA
AGTAGCTCCTAAGAAGAGTGTTATTGTACCTACTNAAGAAATGAAACTCATTATTAA
AGGTAGGGATATGAAAAGAGGAAGAAGTCGAGCTAGAAGAAAAATCCCCGCAGCA
ACCATAGTTGCTGCGTGTATGAGAGGCGAAATGGGAGTGGGTCCTTCCATAGCATCG
GGTAACCATACGTGAAGAGGGAATTGTGCAGATGTCTCAACTGCACCAAGGAATAAT
AAAAAAGCACACAAAGTAGTAAGTAAGGAATTAATCCCATTATTAGGAATCCAGTTAT
TAGCTATTTTGAACAAATCCCGAAACTCTAAACTACCTGTTATCCAANNAAACCTAA
AATTCCTAATAACAGACCAAAATCCCCTACACGATTAGTTACAANAGCTTTTTGACG
AGGCTCGCTGCAATTGGCCGTGTGACCAAAAGCCTATCAATAAATAGGAACACATTC
CCACAAGTT

Homology search made through NCBI-BLAST with ndh gene sequence has shown the following homologies (*Pseudosasa japonica 97*%, *Arundinaria gigantea* 97%, *Semirundinaria fustuosa* 97%, *Sasa veitchii* 97% , *Shibatea kamasaca*97%, *Dendrocalamus latiflorus* 97% and *Bambusa vulgaris* 97%).

- ***Pseudoxytenanthera monadelpha* - (ndh F & 1318R)** (735bp)

GAAGCCCTATTCTTGACTTATCTCTGGTCAAGGACCAACAATAGGGACCTTTCATTG
AATTACGGATCCTGATCCCACCAGCATACTTGTTTTCTGATAATACTGATTGATCCAA
TGGGAATAAGCGGCTTGATTAGAACCTATACCTAGATGTCTATGATGAACGAAATTGA
AGATTTGTAGAATAGGCTAAGCTTCTTTTACATCCCTCTGAGCAAGGGTTACAGNAT
CCCCTATGAAGCGAGTTATTGTACCTTCTAAACAAGTGGGAACAGTTCCTATTTAGG
GATATGAAAAGGGTAAGAACGCCCNATTGAAGAAAAAGCCCCGCANCAACCATTT
TGCTGCATGTATAAGGGGATTTTGGGAGTGGGTCCTTAATTTTCAGCGTGTATCCATT
CATGGGGAGGTAATAGTGCCGATTTTGCAACTGCACCAAGGAATAATAAAATACCAC
ACAATGTGGTAAGTTCGGAACTAATCCCATTATTAGGAATCCAGTTATTAGCTAGGTG
GAACAAATCCCGAAGCTCTATTCTACCTGTTATCTAAGGAAAACCTAAGATTCCTAAG
GACCGACCACAATCCCCTACACGANTACTTACAGAAGCTTTGTGAGAGCACTCGCT
GTTATTGGCCGTGTAAATCAAAAGCCTATCCATAAATAGGAACACACTCCCACANGT
TCCCAAANAAAATAAGTTGTACAATTGGAACTGGAACCAATCCCAACAT

Homology search made through NCBI-BLAST with ndhF gene sequence has shown the following homologies (*Chusqea serpens 80%, Arundo donax* 80%, *Sinochasea trigyna* 80%, *Streptogyna americana* 80%, *Dendrocalamus latiflorus*80%, *Bambusa oldhamii* 80% and *Bambusa vulgaris* 80%).

The Bamboo Biodiversity Website

http://www.eeob.iastate.edu/research/bamboo/index.html) has been developed as the primary accessible repository for information on bamboo diversity resulting from this project. The work is in progress and is being updated periodically by the collaborating Institutions. It will be organized to provide access to descriptions, classifications, character and species lists, maps, images, evolutionary trees, and identification resources and other data as well as links to other relevant Web sites. The information will initially be focused on the subtribal and generic levels, but data for species will be incorporated as and when it becomes available, either directly on this Web site or through links. Descriptions will be augmented by images of diagnostic features as appropriate. A bibliography is available in pdf format and will be updated on a regular basis, as the current version is not complete and new scientific papers are published frequently.

One of the major goals of the Bamboo Phylogeny Project is to create a well-illustrated interactive identification resource that will allow non-specialists to identify bamboos at least to the level of the genus. Interactive keys will allow the user to start with any character or any combination of characters visible from material on hand and get the specimen identified. Two preliminary interactive keys using SLIKS (Guala 2004) have already been developed. An interactive key to

the woody bamboo genera included in our classification will be prepared at the end of the study.

Project output/ impacts

- The work will contribute to an improved understanding of bamboo and grass evolution and biology through a robust phylogeny, which will form the basis for a stable, predictive generic classification for bamboos as well as a Web-accessible, interactive identification resource.
- The project will establish a worldwide network of bamboo systematists, thus improving communication and collaboration with international colleagues and providing with internet-based access to optimized phylogenetic and bioinformatic tools.
- Along with the interactive identification tools, phylogenetic results, images, and descriptive material will also be disseminated broadly through the Bamboo Biodiversity Web site.

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Appendix-1.

List of collaborators in the Bamboo Phylogeny Group.

Name	**Institution**	**Bamboo Speciality**
Lynn G. Clark lgclark@iastate.edu	Iowa State University, U.S.A.	Chusqueinae; Neotropical bamboos; *Arundinaria*
Gilberto Cortés gcortesbambumex@hotmail.com	Instituto Tecnologico de Chetumal, Mexico	Guaduinae; bamboos of Mexico
Soejatmi Dransfield s.dransfield@rbgkew.org.uk	Royal Botanic Gardens, Kew, England	Paleotropical bamboos
Tarciso Filgueiras tfilg@uol.com.br	Reserva Ecológica do IBGE, Brazil	Bamboos of Brazil
Gerald F. Guala gerald.guala@la.usda.gov	U.S.D.A. Plants Database, Baton Rouge, LA, U.S.A.	Bioinformatics; Arthros tylidiinae + Guaduinae Clade
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Emmet Judziewicz Emmet.Judziewicz@uwsp.edu	University of Wisconsin, Stevens Point, U.S.A.	Arthrostylidiinae; Neotropical bamboos
Scot Kelchner kelchner@isu.edu	Idaho State University, U.S.A.	Molecular phylogenetics of bamboos; bioinformatics
Muktesh Kumar muktesh@kfri.org (off); muktesh.kumar@gmail.com	Kerala Forest Research Institute, India	Taxonomy of Indian bamboos
De-Zhu Li dzl@mail.kib.ac.cn	Kunming Institute of Botany, China	North Temperate Clade; molecular phylogenetics of bamboos
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Chris Stapleton c.stapleton@rbgkew.org.uk	Royal Botanic Gardens, Kew, England	North Temperate Clade; bamboo morphology
Jimmy Triplett triplett@iastate.edu	Iowa State University, U.S.A.	*Pleioblastus*; North Temperate Clade
Elizabeth Widjaja ewidjaja@indo.net.id	Indonesian Institute of Sciences, Indonesia	Paleotropical Bambuseae
Khoon Meng Wong wong@um.edu.my	University of Malaya, Malaysia	Bamboos of SE Asia; bamboo morphology
Nian-He Xia nhxia@scib.ac.cn	South China Institute of Botany, China	Bambusinae

Appendix-2
Data Matrix as per the Character List (BPG)

Name of the species	Character States (OTUs)												
	R 1	R 2	R 3	R 4	R 5	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8
Davidsea attenuata (Thw.) Soderstrom & Ellis	0	1	1	2	1	1	1	1	1	0	0	0	0
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	0	1	1	2	1	1	1	1	0	0	0	0	0
Ochlandra stridula Moon ex Thwaites	0	1	1	2	1	0	1	1	0	0	0	0	0
Ochlandra travancorica (Bedd.)Benth.	0	1	1	2	1	0	1	1	0	0	0	0	0
Streptogyna crinita P. Beauv.	1	0	0	0	0	0	1	1	1	1	0	0	1
Name of the species	**Character States (OTUs)**												
	C 9	C 10	C 11	C 12	B 1	B 2	B 3	B 4	B 5	B 6	B 7	B 8	B 9
Davidsea attenuata (Thw.) Soderstrom & Ellis	0	1	0	-	0	-	0	0	0	1	1	0	0
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	0	1	0	-	0	-	0	0	0	1	1	0	0
Ochlandra stridula Moon ex Thwaites	0	1	0	-	1	1	0	2	1	1	1	0	0
Ochlandra travancorica (Bedd.)Benth.	0	1	0	-	0	-	0	0	1	1	1	0	0
Streptogyna crinita P. Beauv.	0	0	0	-	-	-	-	-	0	-	-	-	-
Name of the species	**Character States (OTUs)**												
	B 10	B 11	B 12	B 13	B 14	B 15	B 16	B 17	CL 1	CL 2	CL 3	CL 4	CL 5
Davidsea attenuata (Thw.) Soderstrom & Ellis	0	0	1	1	0	0	-	1	2	1	0	0	1
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	0	0	1	1	0	0	-	1	2	2	0	0	1
Ochlandra stridula Moon ex Thwaites	1	1	1	1	0	0	-	1	2	0	0	0	1
Ochlandra travancorica (Bedd.)Benth.	0	1	1	1	0	0	-	1	2	0	0	0	1
Streptogyna crinita P. Beauv.	-	-	-	-	-	0	0	-	0	-	-	-	-
Name of the species	**Character States (OTUs)**												
	CL 6	CL 7	CL 8	CL 9	CL 10	CL 11	CL 12	CL 13	CL 14	FL 1	FL 2	FL 3	FL 4
Davidsea attenuata (Thw.) Soderstrom & Ellis	1	1	1	1	0	2	0	0	0	1	0	0	1
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	1	1	1	1	0	2	0	0	1	1	0	0	1
Ochlandra stridula Moon ex Thwaites	1	1	1	1	0	2	0	0	0	1	1	1	1
Ochlandra travancorica (Bedd.)Benth.	1	1	1	1	0	2	0	0	0	1	0	0	1
Streptogyna crinita P. Beauv.	-	-	-	-	-	-	-	-	-	1	0	0	0
Name of the species	**Character States (OTUs)**												
	FL 5	FL 6	FL 7	FL 8	FL 9	FL 10	FL 11	FL 12	FL 13	S 1	S 2	S 3	S 4
Davidsea attenuata (Thw.) Soderstrom & Ellis	0	1	0	0	1	0	0	0	1	1	1	1	1
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	0	1	1	1	1	0	0	0	1	1	1	1	1
Ochlandra stridula Moon ex Thwaites	1	1	0	1	1	0	0	0	1	1	1	1	1
Ochlandra travancorica (Bedd.)Benth.	0	1	0	1	1	0	0	0	1	1	1	1	1
Streptogyna crinita P. Beauv.	0	0	-	-	1	0	0	0	1	1	0	0	0

Name of the species	Character States (OTUs)												
	S 5	S 6	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	SP 7	SP 8	SP 9	SP 10	SP 11
Davidsea attenuata (Thw.) Soderstrom & Ellis	1	1	2	2,3	0	1,3	1	1,3	0,1	0	1	0	0
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	0	1	2	2,3	0	1,3	0	1,3	0,1	0	1	0	0
Ochlandra stridula Moon ex Thwaites	0	1	2	3	0	1,3	0	1,3	0,1	0	1	0	0
Ochlandra travancorica (Bedd.)Benth.	0	1	2	3,4	0	1,3	0	1,3	0,1	0	1	0	0
Streptogyna crinita P. Beauv.	0	0	0	0	0	1	0	1	2	0	1	1	0

Name of the species	Character States (OTUs)												
	SP 12	SP 13	SP 14	SP 15	SP 16	SP 17	SP 18	SP 19	SP 20	SP 21	FF 1	FF 2	FF 3
Davidsea attenuata (Thw.)Soderstrom & Ellis	1	2	2	3	0	0	0	1	1	1	1	1	2
Pseudoxytenanthera monadelpha (Thw.) Soderstrom & Ellis	1	2	2	3	0	0	0	1	2	1	0	-	2
Ochlandra stridula Moon ex Thwaites	1	2	2	3	0	0	2	0	1	1	3	0	3
Ochlandra travancorica (Bedd.)Benth.	1	2	2	3	0	0	2	0	1	1	1	0	3
Streptogyna crinita P. Beauv.	0	2	3	3	0	0	0	0	2	1	1	0	0

Name of the species	Character States (OTUs)													
	FF 4	FF 5	FF 6	FF 7	FF 8	FF 9	FF 10	FF 11	FF 12	FF 13	FF 14	FF 15	FF 16	FF 17
Davidsea attenuata (Thw.) Soderstrom & Ellis	0	1	0	2	2	0	1	0	0	1	3	0	-	-
Pseudoxytenanthera monadelpha (Thw.) Soderstr. & Ellis	1	1	0	2	2	1	1	0,1	0	0	-	0	1,2	1
Ochlandra stridula Moon ex Thwaites	0	1	0	2	2	0	1	0	0	1	3	0	2	1
Ochlandra travancorica (Bedd.)Benth.	0	1	0	2	2	0	1	0	0	1	3	0	2	1
Streptogyna crinita P. Beauv.	0	1	0	0	2	1	0	1	1	0	3	0	0	1

PHYLOGENY OF SELECTED WOODY BAMBOOS OF THE WORLD

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