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On the cover: Ximena Londoño, for whom the new species *Aulonemia ximenae* is named in the article by Clark, Judziewicz, and Tyrrell in this issue. She is standing at Cataratas Iguazu on the border between Argentina and Brazil. Photo provided by Ximena Londoño.

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Aulonemia ximenae (Poaceae: Bambusoideae), a new northern Andean species with fimbriate sheath margins

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A number of the estimated 60 species in *Aulonemia* have pectinately-fimbriate overlapping sheath margins on both culm and foliage leaves. A new species in this group, *Aulonemia ximenae*, from the Andes of Colombia and western Venezuela, is described and illustrated and its distribution is mapped. It is distinguished by the presence of pectinate fimbriae along the full length of the overlapping sheath margins. *Aulonemia ximenae* is compared with *A. subpectinata* and *A. trianae,* the two most similar species in the same region. A key to the species of *Aulonemia* with fimbriate sheath margins is also included.

Existen aproximadamente 60 especies en el género *Aulonemia*, y algunas poseen fimbrias pectinadas en las márgenes sobreponientes de las vainas en las hojas caulinares y las hojas del follaje. Se describe e ilustra una nueva especie de este grupo, *Aulonemia ximenae*, de los Andes de Colombia y el oeste de Venezuela, y se presenta un mapa de su distribución. La especie nueva se distingue por la presencia de fimbrias pectinadas a lo largo de toda la márgen sobreponiente. Se compara *Aulonemia ximenae* con *A. subpectinata* y *A. trianae*, las dos especies más parecidas en esta región. Una clave de las especies de *Aulonemia* con fimbrias marginales está incluida.

Aulonemia Goudot is an Andean-centered genus including 33 described species (plus one new species in press) (Clark & Londoño 1990; Clark . 1997; Judziewicz . 1999; Judziewicz 2004) and is classified within subtribe Arthrostylidiinae of the woody bamboos (Bambuseae). Work toward a revision of *Aulonemia* by Judziewicz has led to the discovery of a number of species new to science, raising the total diversity in *Aulonemia* to an estimated 60 species. This work has also confirmed the importance of fimbria morphology and distribution on the culm and foliage leaf sheaths in distinguishing among species in the genus. Using these and other characters, Judziewicz (unpubl.) has divided *Aulonemia* into several informal groups, including one group defined by the presence of fimbriate

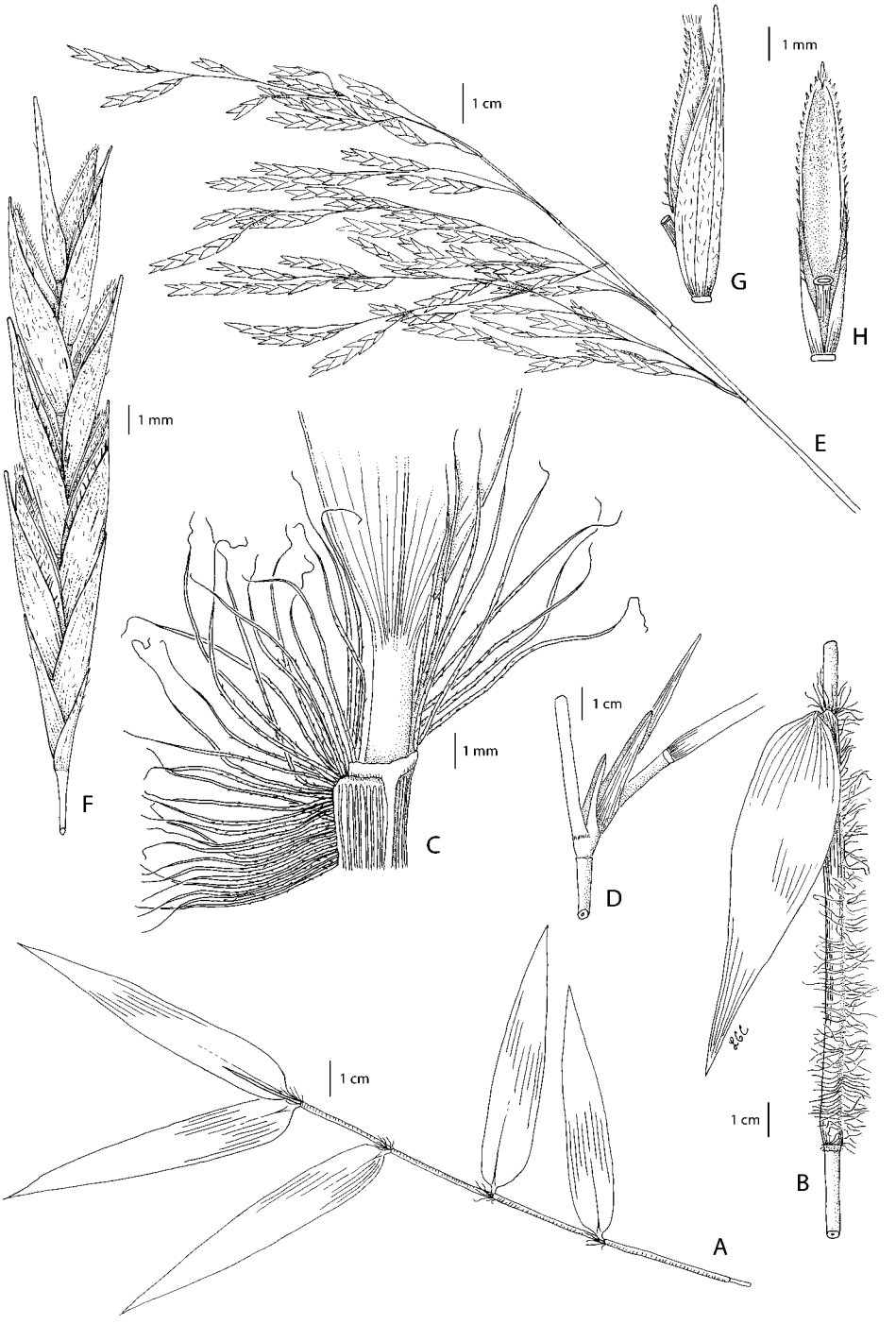

Figure 1. *Aulonemia ximenae*. A. Branch with foliage leaves. B. Culm leaf. C. Foliage leaf ligular area showing apical and marginal fimbriae. D. Branch complement showing one dominant branch and a developing secondary branch. E. Synflorescence. F. Spikelet. G. Floret, lateral view. H. Floret, adaxial view showing rachilla internode and broad sulcus of the palea. (A based on *Clark et al. 528*; B based on *Clark et al. 537*; C based on *Londoño & Clark 482*; D based on *Clark et al. 558;* E-H based on *Clark et al. 531*.) Illustration by Lynn G. Clark.

sheath margins. Among the members of this group is a new species from Colombia and Venezuela with pectinately fimbriate sheath margins that we describe and illustrate in this paper. We also present a key to the species of *Aulonemia* with fimbriate sheath margins.

Key to the species of *Aulonemia* with fimbriate sheath margins

1. Foliage leaf blades 4-13.5 cm wide.
   2. Spikelets 11-16 mm long; northeastern Colombia and northwestern Venezuela. .....*A. robusta* L.G. Clark & Londoño
   2. Spikelets (20-)24-38 mm long.
      3. Spikelets with florets 8-12 mm long, each lemma with an awn 1-4(-7) mm long; Colombia to Peru.....*A. patula* (Pilg.) McClure
      3. Spikelets with florets 5-6 mm long, lemmas awnless; Venezuelan coastal cordillera .....*A. subpectinata* (O. Kuntze) McClure
1. Foliage leaf blades 1-3.5 cm wide.
   4. Spikelets 8-15 mm long, 2-4(-5)-flowered; leaf blades linear-lanceolate; Peru.....*A. humillima* (Pilg.) McClure
   4. Spikelets 13-36 mm long, (4-)5-9-flowered; leaf blades lanceolate or ovate-lanceolate; Colombia and Venezuela.
      5. Foliage leaf blades 17-26 cm long, (2.7-) 3.5-5.7(-7.5) cm wide, broadly lanceolate to narrowly ovate; sheath summit fimbriae 15-20(-30) mm long; sheath margins with fimbriae extending about three-fourths of the length, with the basal fourth ciliate; spikelets with lemmas awnless; Venezuelan coastal range .....*A. subpectinata* (O. Kuntze) McClure
      5. Foliage leaf blades 8-15(-17) cm long, 1-2.5 (-2.8) cm wide, lanceolate; sheath summit fimbriae 7-15 mm long; sheath margins with fimbriae extending along the full length of the sheath; spikelets with lemmas awnless to awned; Colombia and western Venezuela .....*A. ximenae* L.G. Clark, Judz. & C.D. Tyrrell

Aulonemia ximenae* L.G. Clark, Judz. & C.D. Tyrrell *sp. nov. (Figure 1) TYPE. VENEZUELA. MÉRIDA: Dtto. Tovar, vía Las Colorados - Santa Cruz de Mora, Páramo de Los Colorados, 2690 m, 8°18.5'N, 71°35'W, 14 June 1989 (fl), L.G. Clark, J. Gaviria & G. Adamo 531 (holotype: MERC not seen, isotypes: ISC, K, MO, NY, US).

Figure 2. Distribution of *Aulonemia ximenae*.

Culmi usque ad 2(-5) m alti, 3-6(-10) mm diametro, erecti ad basim, scandentes ad apicem. Vaginae foliorum striatae, nonauriculatae, marginibus superpositis plene fimbriatis; fimbriae 3-5(-10) mm longae; laminae foliorum 8-15 (-17) cm longae, 1-2.5(-2.8) cm latae, reflexae. Synflorescentia paniculata 15-20 cm longa. Spiculae 13-36 mm longae, puberulentes, (4-) 5-9 flosculos continentes; glumae 2, acutae vel aristatae; gluma I 4-5.5(-12) mm longa, gluma II 6-8.5 mm longa; lemmata fertilia 8-12.5 mm longa, acuta vel aristata.

Bamboo with culms up to 2(-5) m tall, 3-6 (-10) mm in diameter, erect at first then climbing or scandent, freely branching and often forming an intricate mass; internodes all approximately the same length, 10-26 cm long, greenish and maculate when young, with a small lumen, each glabrous below and sparingly appressed-hispid near the summit. Culm leaves tardily deciduous; sheaths 10-18 cm long, 1.2-2.2 cm wide, somewhat inflated near the base, abaxially sparsely hispid with glassy hairs 1-2 mm long or glabrous, overlapping margins bearing pectinate fimbriae 4-11 mm long for the full length, the summit bearing erect fimbriae 7-15 mm long, all fimbriae antrorsely scabrous; pseudopetioles 1-2 mm long, minutely pubescent on both sides; blades 3-10 cm long, 0.8-2.5 cm wide, lanceolate, pseudopetiolate, strongly reflexed, deciduous. Branching intravaginal; usually one branch per node, occasionally one or two smaller secondary branches developing from the base of the dominant branch; promontory

absent. Foliage leaves few per complement, widely spaced; leaf sheaths striate, glabrous below, glabrous to puberulent to sparingly appressed-hispid near the summit, the overlapping margins entirely fringed with spreading to upwardly arching, papillose-based pectinate fimbriae 3-5 (-10) mm long, fimbriae at sheath summit 7-15 mm long, abundant, erect, curly at their apices, all fimbriae antrorsely scabrous; auricles absent; outer ligule 0.3-0.5 mm long, ciliolate; inner ligule an inconspicuous rim to 0.5 mm long; pseudopetioles 2-5 mm long, usually minutely pubescent adaxially and abaxially, sometimes glabrous abaxially, often also with a coating of white wax adaxially and abaxially; blades 8-15(-17) cm long, 1-2.5(-2.8) cm wide, lanceolate, reflexed, adaxially glabrous, abaxially glabrous to puberulent, the margins antrorsely scabrous and slightly cartilaginous. Peduncles up to 7 cm long, usually exserted but sometimes retained within the subtending leaf sheath. Synflorescences paniculate, 15-20 cm long, 4-10 cm wide, with lax, capillary, smooth to scaberulous, triquetrous branches. Spikelets 13-36 mm long, 3-5.5 mm wide, greenish to stramineous to plumbeous or dull purplish-brown when mature, puberulent and antrorsely scabrous throughout or rarely glabrous, (4-)5-9-flowered; glumes lanceolate to rarely linear-subulate, acute to awned; lower glume 4-5.5 (-12) mm long, 1-3(-5)-nerved; upper glume 6-8.5 mm long, 3-5(-7)-nerved; lowermost floret lacking a palea, sterile, about as long as the lemmas; lemmas 8-12.5 mm long, lanceolate, acute or with an awn 1.5-3(-5) mm long, 7-11-nerved; palea slightly shorter than to slightly protruding from the lemma, apex rounded and bifid, bicarinate, the keels each with a cartilaginous, serrulate wing to 0.1 mm wide at the apex, the sulcus broad, 0.8-1 mm wide, scabrous-pubescent toward the apex; uppermost floret reduced and sterile. Flowers [based on *Pohl & Giraldo 15363*] with lodicules 3, 1-1.4 mm long, one oblanceolate and the other two obovate, acute, finely 2-4-nerved, tipped with erect ciliola 0.2-0.4 mm long; stamens 3, the anthers 3-4 mm long, purple-brown when dry; pistil with 2 hispid stigmas. Fruit not seen.

We take great pleasure in naming this bamboo after Ximena Londoño de la Pava of the Valle del Cauca Scientific Research Institute (INCIVA), Cali, Colombia, world expert on the genus *Guadua* Kunth and other bamboos, and collector of many of the specimens of this new species. *Aulonemia ximenae* grows at elevations from about 2400 to 3100 meters (the *Garcia-Barriga & Jaramillo 19708* elevation of 3700 to 3960 m seems to be an error) in the Andes of Colombia (Cordillera Occidental, Cordillera Central, Cordillera Oriental, and Sierra de Perijá) and adjacent Venezuela (Cordillera de Mérida) in upper montane forest and subpáramo, persisting in secondary vegetation. It is distinguished by the following combination of characters: pectinate fimbriae present all along the overlapping margins of the leaf sheaths; absence of auricles; foliage leaf blades 8-17 cm long and 1-2.8 cm wide; and spikelets 13-36 mm long with (4-)5-9 acute to short-aristate, scabrously puberulent florets. It most closely resembles *A. trianae* (Munro) McClure (Table 1), but that species completely lacks pectinate fimbriae all along the overlapping foliage leaf sheath margins. Among putatively related species of *Aulonemia* with fimbriate leaf sheath margins, *A. ximenae* differs from *A. subpectinata* (O. Kuntze) McClure in its narrower leaf blades, fully fimbriate overlapping sheath margins, and typically smaller spikelets (Table 1), and from *A. robusta* L.G. Clark & Londoño in its much smaller stature, leaf size, and fimbria length and density.

Two collections of *A. ximenae* exhibit some deviation from normal variation in spikelet size and awn development on the lemmas. *Londoño & Clark 470,* from the Serranía de Perijá, has significantly larger (30-36 mm long) spikelets than those of other flowering populations, with stramineous florets whose lemma apices are attenuated into erect, 1.5-3 mm long awns. *Wood 4527,* from the northern Cordillera Oriental, has plumbeous spikelets 25-30 mm long with noticeably recurved spikelet bracts including linear-subulate glumes and long-awned (5 mm) lemmas. For the present, we retain these two collections in *A. ximenae* but suggest that they deserve further study once additional collections are available from northern Colombia.

Additional collections examined: COLOMBIA. ANTIOQUÍA: Mun. Santa Rosa, Medellín-Yarumal-Caucasia road, above

Table 1. Morphological comparison of *A. ximenae*, *A. subpectinata* and *A. trianae*.

Character	***A. ximenae***	***A. subpectinata***	***A. trianae***
Plant height (m)	to 2(–5)	0.5–3	0.5–2(–5)
Culm diameter (mm)	3–6(–10)	5–10	5–10
Sheath marginal fimbriae presence and distribution	present along the full length	present along the upper three-fourths of the length	absent
Sheath summit fimbriae length (mm)	7–15	15–20(–30)	7–15
Foliage leaf blade length (cm)	8–15(–17)	17–26	8–15
Foliage leaf blade width (cm)	1–2.5(–2.8)	(2.7–)3.5–5.7 (–7.5)	1.1–2.5
Spikelet length (mm)	13–30(–36)	(20–)25–36	10–18(–22)
Spikelet width (mm)	3–5.5	2–3	3–5
Number of florets	(4-)5-9	6-9	5-7(-9)
Lemma length (mm)	8–12.5	7–9	6.5–8
Lemma awns	absent to present and 1.5–5 mm long	absent	absent
Distribution	Venezuela (southwestern Andean) and throughout Andean Colombia	Venezuela (coastal cordillera)	Venezuela (southwestern Andean); throughout Andean Colombia

Santa Rosa, Vereda Cimitarra, ca. 6°40'N, 75°30'W, 2670 m, 1 Mar. 1988, *Londoño & Clark 411* (ISC, MO, NY, TULV, US); Mun. Urrao, al faldo de la carretera que conduce a Caicedo, arriba de Quebrada Las Juntas, 2750 m, crece en arbustos debajo de la carretera en boque primario, 9 Sept. 1986, *Pohl & Betancur 15472* (ISC, MO, TULV); Prov. Medillín, Cerro de Padre Amaya, cerca de las torres de televisión, 2950 m, subpáramo, solamente una mata florecida, 5 Aug. 1986 (fl), *Pohl & Girardo 15363* (ISC, MO, TULV, US). BOYACÁ: Mun. Guacamayas/ San Mateo, vía Guacamayas-San Mateo, 6°27'N, 72°34'W, 2830 m, upper montane forest/subpáramo, culms erect to scandent and climbing, culms more or less erect and shorter in cut-over parts, 31 July 1989, *Londoño & Clark 483* (ISC, MO, NY, TULV, US). CAUCA: km 29 vía El Tambo-Cerro de Munchique, 2°30'N, 77°51'W [sic, for 76°51'W the given longitude is too far west and in a lowland habitat], 2770 m, 28 June 1989, *Londoño & Zuloaga 453* (MO, US). CESAR: Mun. Manaure, Serranía de Perijá, vía Manaure-Sabana Rubia near Venezuelan border, ca. 21 km from Manaure, between El Cinco and Sabana Rubia, 10°23'N, 72°56'W, 2720 m, one big patch with many new shoots found, some old inflorescences seen, one branch with fresh inflorescences, 24 July 1989 (fl), *Londoño & Clark 470* (COL, ISC, MO, NY, TULV). CUNDINAMARCA: Páramo de Une, 2480 m, 15 Feb. 1991, *Barbosa & Kobayashi 6808* (COL, ISC); ca. 1 km S of summit on the Ubaté-Zipaquirá Rd, 3000 m, 12 Apr. 1986 (fl), abundant and subdominant in a scrub-filled gully, gregarious, an intricate mass of wiry stems scrambling over vegetation, to 1 m, *Wood 5403* (K, US); Mun. Cabrera, vereda Nuñéz, 14 km por la vía Cabrera-Nuñéz, Quebrada Negra, 2380 m, 15 Mar. 1989, *Londoño 436* (MO, TULV, US). HUILA/ CAQUETÁ divide: 20 km SE of Gigante, Huila, 10,300 ft. [= 3140 m], paramillo, bamboo 1-2 m high, not the common bamboo of the páramo, 20 Sept. 1944, *Little 8682* (MO, US). NORTE DE SANTANDER: Páramo de Tamá, vertiente de Samaria, 2600-2900 m, 29 Oct. 1941 (fl), *Cuatrecasas et al. 12744* (COL, F); N border of Santander and Cesar, 20 km S of Abrego, Las Jurisdicciones (Cerro de Oroque), 3700-3960 m, 19-21 May 1969,

Garcia-Barriga & Jaramillo 19708 (US); Mun. Abrego, Hacienda La María, ca. 43 km sobre la vía Abrego-Jurisdicciones, 2490 m, 17 Apr. 1994, bosque nublado con robles, sietecuros, ericaceas, helechos y chusques, *Londoño et al. 870* (NY, TULV, US); Páramo de Las Jurisdicciones, SW of Ocaña, 8 July 1984 (fl), 2800-3100 m, enormously abundant at upper edges of cloud forest where it scrambles over bushes and trees, reaching 5 m in height, *Wood 4527* (K, MO, US). SANTANDER: Mun. San Andres, vía San Andres – Málaga, beyond Pangote, 6°45'N, 72°47'W, 2620 m, 30 July 1989, *Londoño & Clark 482* (ISC, MO, NY, TULV); Mun. Tona/Floridablanca, vía Bucaramanga-Berlin-Pamplona, between La Corcova and Berlin, 3.8 km from Bucaramanga, 7°07'N, 73°00'W, 2700 m, *Londoño & Clark 479* (ISC, MO, TULV); Gold mine valley above California, 2700 m, forming an intricate mass of low, scrambling stems, 14 Sept 1985, Wood 5064 (K). VENEZUELA. LARA/TRUJILLO: Páramo de Los Ñepes, ridge above La Peña, ca. 2740 m, 24-25 Dec. 1959, heavy low growth in open areas, *Barclay & Juajibioy 10308* (MO, US). MÉRIDA: Dtto. Pinto Salinas, Páramo de Las Coloradas, 2800 m, 27 Sep. 1985 (fl), *Briceño & Adamo 1380* (ISC, MERC); Dtto. Sucre, vía Estanquez-Las Coloradas, El Molino-Canaguá, past turnoff to Las Labranzas, 8°20'N, 71°35'W, 2470 m, 14 June 1989, 2460-2810 m, 8°13-21'N, 71°34-52'W, *Clark et al. 526* (ISC, MERC, MO, NY, US), *528* (ISC, MERC, MO); Dtto. Arzobispo Chacón, vía Canaguá-El Molino, 8°10.5'N, 71°29'45"W, 2510 m, 15 June 1989, tangled decumbent mats, *Clark et al. 537* (ISC, MERC, MO, NY); Dtto. Rivas Dávila, vía La Grita-Tovar, towards Bailadores, Páramo El Portachuelo, 8°12.5'N, 71°53'W, 2800 m, *Clark et al. 557* (ISC, K, MERC, MO, NY); Dtto. Rivas Dávila, vía La Grita-Tovar, towards Bailadores, Páramo El Portachuelo, 8°13'N, 71°52'W, 2790 m, 18 June 1989 (fl), *Clark et al. 558* (ISC, K, MERC, MO, NY). TÁCHIRA: Swampy meadow in paramito below Quebrada del Palmar and Quebrada de Palmito, base of Páramo de Tamá, 2 km above Betania and 7 km above Villapaez, 2500 m, 14 July 1944, *Steyermark 57207* (F). TRUJILLO: Mun. Boconó, Páramo del Pumar y alrededores [ca. 9°15'N, 70°15'W], 2700 m, 19 Nov. 2004 (fl), 90-120 cm, formando densas colonias y dominantes en el súbparamo y páramo, a orillas del bosque paramero se comparta como trepador decumbente, alcanzando hasta 4 m de altura, *Niño 1572* (MO, US); Mun. Boconó, Páramo del Pumar, Parque Nacional Guaramacal (UTM: 19-364614E; 1021651N), on Roberto's finca near Pozo Verde at 1950 m and páramo at 2600 m, on old mule trail to caserío de Guaramacal, in transition to páramo, scandent bamboo, 27 Dec. 2000, *Dorr et al. 8658* (US).

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Coloring bamboo slivers with natural dyes

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Value-addition of bamboo slivers by coloring using natural dyes for handicrafts, mat weaving and basketry work fetches improved income to traditional bamboo workers. Even though many natural dyes are available, lack of information on a standard treatment practice or schedule that can be followed is a bottleneck for the wide application of these dyes for coloring bamboo slivers. A study on this aspect revealed that dyeing in 5% weight/weight basis aqueous dye solution for three hours in boiling condition followed by the required post-treatment with 2% aqueous boiling metallic salt mordants (copper sulphate, potassium dichromate or ferrous sulphate, as the case may be) for an hour is found to be effective practice that needs to be followed for imparting satisfactory color and shades to bamboo slivers. The color development depends on the chemical nature of the dye and the mordants. Some natural dyes yield colors by direct dyeing and do not require any mordanting whereas some other dyes impart a different color after mordanting. Heartwood powder of the locally available plants such as *Acacia catechu* (cutch) and *Caesalpinia sappan* are found to be good dyes that can be used singly or with mordant post-treatments yielding different color and shades. Fruit powder of *Terminalia chebula* (myrobalan) yields a brownish yellow color before mordanting and a very dark gray color after mordanting in ferrous sulphate. Seed pulp of *Bixa orellana,* leaf powder of *Camellia thea* (commercial tea powder), rhizome powder of *Curcuma longa* (commercial turmeric powder), leaf pulp of *Lawsonia alba* and heartwood powder of *Pterocarpus santalinus* are found to offer color directly without mordanting. There was no special advantage in using metal salts post-treatment (mordanting) as far as the color development is concerned while using these dye sources. *Lawsonia alba* is found capable to impart a reddish gray color even at ambient temperature. The color developed is also characterized in comparison with a standard color assessment system.

Bamboo is a quickly growing, sustainable raw material, and much interest exists in the products from bamboo, especially in export market. The use of bamboo in sliver form is well known in basket ware, mats and mat-based products, handicrafts, etc. These products are as an important livelihood material for the rural communities in Kerala, India. The augmentation of quality and value in the above products will improve their marketability.

The love for color is a natural instinct, and coloration of bamboo slivers for eye-catching products is a prime concern for livelihood improvement. Because of the health risks associated with various synthetic dyes, today, there is a renewed interest in the use of natural dyes. The limitations of the natural dyes such as their availability, color yield, complexity of the dyeing process due to their inertness and reproducibility of color shade are responsible for their declined use. It is desirable to have a standard dyeing practice applicable for the different locally available natural dyes for the dyeing of bamboo slivers. This is very important, as in India, many of such units are being handled by traditional bamboo working communities. There are only very few studies reported on coloring of bamboo products with natural dyes

(IIT 2003, Gulrajani 2004) and they too have not attempted to evolve any uniform treatment condition applicable for the different natural dyes. The present study was oriented mainly to develop a standard treatment condition.

As visual perception of color may vary from person to person, precise characterization of the color developed in comparison to a standard color assessment system is another need. Since such an attempt was also not reported so far on bamboo slivers stained by natural dyes, we looked into this aspect also. The natural color and hue of a dye can be altered by treatment with metal salts. The possibility of retention of a desirable color on the slivers was examined by identifying effective mordants and their appropriate reaction conditions.

MATERIALS AND METHODS

Details of the different natural dyes used in the study are given in Table 1. Slivers of thickness 1-2 mm and width 15 mm were prepared manually by traditional bamboo workers using hand tools, from mature *Bambusa bambos* (L.) Voss, the major bamboo species of Kerala, India. Ten samples of 150 mm length were cut and used for each treatment. Dyeing trials were conducted on slivers in both green and air dried conditions. Efficacy of soaking in 5% aqueous dye solution for 12 hours in room temperature was tested in the preliminary trial. Soaking in a boiling solution of the dye with the same concentration for a period of 3 hours was also tested in all the cases and its efficacy was compared with the cold soak method.

The dye solution was prepared by extracting the estimated quantity of the powdered plant part in boiling water for an hour. The resultant solution was filtered and used as the dye solution. The colored samples were kept exposed to air for a period of two months in order to stabilize the color and to account for the slight color changes caused by oxidation or light. Then the developed color was assessed in terms of its hue, chroma and lightness value using standard Munsell color charts (Munsell Color Company 1975) and accordingly the color names were given.

Two percent aqueous solutions of copper sulphate, potassium dichromate and ferrous sulphate were used as standard mordants in cases where appreciable coloration was not obtained by simple dyeing. Mordants were added after dyeing when necessary. Soaking the dyed samples in the mordant solution for 12 hours in room temperature as well as a boiling treatment for an hour were tested. The treated samples were washed in water; air dried under shade and the color development was assessed. The selection of the concentration of the dye and mordant solutions and duration of the cold and boiling soak treatments are arbitrary, for convenience, and are not based on any earlier works.

Table 1. Details of the natural dyes used

Dye source Plant name	**Common name & Local name**	**Plant part used as dye**	**Type of Dye present**
Acacia catechu	Cutch, karingali	Heartwood powder extract	Condensed tannins (Catechin)
Bixa orellana	Annatto, kuppamanjal,	Green seed pulp extract	Carotenoid dyes (Bixin)
Caesalpinia sappan	Pathimugham, chappangam	Heartwood powder extract	Brazilin
Camellia thea	Tea, theila	Commercial tea leaves powder	Ploy phenolic tannins
Curcuma longa	Turmeric, manjal	Commercial turmeric powder extract)	Curcuminoid dyes (Curcumin)
Lawsonia alba	Henna, mylanchi	Green leaves extract	Alpha naphthaquinones (Lawsone)
Pterocarpus santalinus	Red sandal, rakthachandanam	Heartwood powder extract	Santalin
Terminalia chebula	Myrobalan, kadukka	Dry fruit pod extract	Tannins (Pyrogallol type)

Table 2. Colors developed by the use of different natural dyes and mordants in bamboo slivers

Dye source	With/Without	Color developed	Hue	Chroma	Lightness value
Acacia catechu	Without mordant	Reddish gray	10R*	1	6
	Boiling $K_2Cr_2O_7$ solution as mordant	Reddish brown	2.5YR**	4	4
	Boiling $CuSO_4$ solution as mordant	Dark reddish brown	2.5YR	4	3
Caesalpinia sappan	Without mordant	Pale red	10R	4	6
	Boiling $CuSO_4$ solution as mordant	Red	10R	6	4
	Boiling $K_2Cr_2O_7$ solution as mordant	Dark reddish brown	2.5YR	4	3
Terminalia chebula	Without mordant	Brownish yellow	10YR	6	6
	Boiling Fe SO_4 solution as mordant	Very dark gray	2.5Y	0	3
Bixa orellana	Without mordants No advantage by using mordants	Reddish yellow	7.5YR	8	7
Camellia thea	Without mordants No advantage by using mordants	Light brown	7.5YR	4	6
Curcuma longa	Without mordants No advantage by using mordants	Yellow	2.5Y***	8	7
Lawsonia alba	Without mordants No advantage by using mordants	Reddish gray	5YR	2	5
Pterocarpus *santalinus*	Without mordants No advantage by using mordants	Light red	2.5YR	6	6
Control	Not dyed	White	10YR	2	8

(*R – Red; **YR – Yellow-Red; ***Y – Yellow)

RESULTS AND DISCUSSION

Attractive colors were developed by the use of natural dyes. The different colors developed in the treatments (simple dyeing or dyeing followed by use of a mordant) are given in Table 2. Generally, dyeing in boiling aqueous dye solutions was found more effective than prolonged soaking (12 hours) at room temperature in imparting dark shades to the color developed, and hence suggested. Similar was the result in use of mordants, and boiling in an aqueous solution for an hour is suggested. Some dye sources such as *Bixa orellana, Camellia thea, Curcuma longa, Lawsonia alba* and *Pterocarpus santalinus* were found nonresponsive to mordants, indicating that there is no special advantage in using mordants while dyeing with these dyes. *Lawsonia alba* was found capable of imparting a reddish gray color even at ambient temperature. The nature of the mordant was also found to have a significant role in determining the color development. Use of mordants resulted in drastically contrasting color. Dyeing bamboo slivers with *Terminalia chebula* offered a brownish yellow color which turned very dark gray with the addition of ferrous sulphate. This indicates the potential of

mordants to generate different color shades while dyeing bamboo slivers with natural dyes.

Between the green and air dried bamboo slivers, in general, for all the treatments, intensity of the color developed was not found very significantly different, as assessed visually. Hence, bamboo slivers can be dyed conveniently at any moisture level.

CONCLUSIONS

Seed pulp of *Bixa orellana,* leaf powder of *Camellia thea* (commercial tea powder), rhizome powder of *Curcuma longa* (commercial turmeric powder), leaf pulp of *Lawsonia alba* and heartwood powder of *Pterocarpus santalinus* were found to yield reddish yellow, light brown, yellow, reddish gray and light red colors respectively in bamboo slivers directly on dyeing. There was no special advantage in using metal salts post-treatment (mordants) as far as the color development is concerned while using these dye sources.

The chemical nature of mordant is also found to have a deciding role in color development while dyeing bamboo slivers with natural dyes. *Acacia catechu* and *Caesalpinia sappan* heartwood powder yields reddish gray and pale red color respectively on direct dyeing. Use of potassium dichromate or copper sulphate mordants improved the darkness of the shade of the color while using *Acacia catechu.* In the use of *Caesalpinia sappan dye,* copper sulphate post-treatment yielded red color whereas potassium dichromate post-treatment imparted a different color, dark reddish brown, to the dyed bamboo slivers. Certain dyes such as *Terminalia chebula* fruit powder, will offer contrasting color after treatment with metal salts (ferrous sulphate, in this case; very dark gray color).

Dyeing and the use of mordants at elevated temperatures was found more effective. Dyeing in 5% aqueous boiling dye solution for 3 hours followed by post-treatment with 2% aqueous boiling metallic salt mordants (copper sulphate, potassium dichromate or ferrous sulphate as the case may be) for an hour was found to be effective. Between green and air dried slivers, there was not significant difference in color development while dyeing; indicating that moisture content of slivers need not be a limiting factor in color development.

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Sporadic flowering in six introduced woody bamboos (Poaceae: Bambusoideae) in Brazil

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The sporadic flowering of six introduced woody bamboos in Brazil (*Bambusa tuldoides, B. vulgaris, Phyllostachys aurea, P. bambusoides, Sinarundinaria falcata*) is reported. In a single case of these flowering episodes caryopsis formation was documented (in *Bambusa tuldoides*). The reasons for such sporadic seed formation is discussed and suggestions for future research is made.

Flowering in bamboos is a peculiar event. Normally, herbaceous bamboos are polycarpic, i.e., most species flower within a certain timeframe or even continuously. Conversely, their woody counterparts, as a rule, will flower cyclically (Jansen, 1976). The flowering cycle of the woody bamboos vary a great deal, from just a few to as many as 120 years. There are exceptions to these rules, especially in the woody group. To complicate the matter further, some species will also flower sporadically and erratically (Filgueiras, 1988; Nadgauda, 1997).

Artificial induction of flowering in seedlings of several species of woody bamboos was first reported almost simultaneously by Rao & Rao (1990) and Nadgauda . (1990), and a bit later by Chambers . (1991), Rout & Das (1994), and, Redgauda . (1997). In all these cases, a medium pH close to 5.8 or lower, plus treatment of the seedlings with 6-Benzylaminopurine (BAP) was considered essential for *in vitro* induction of flowering (for details of the techniques used and the complete list of the species tested, see the literature cited on this topic, above).

More than 20 woody bamboos species are grown in Brazil (Filgueiras & Santos-Gonçalves, 2004). The flowering behavior of these species has not yet been studied but a few field observations have recently come to our attention. Field data and the study of herbarium material have revealed a few interesting facts that are reported herein.

MATERIALS AND METHODS

Herbarium and fieldwork by the authors were the basis of the results presented here. Herbarium acronyms follow Holmgren. (1992). Abbreviations of the names of the Brazilian states are the following: DF – Distrito Federal, GO – Goiás, MA – Maranhão, SP – São Paulo, SC – Santa Catarina

RESULTS AND DISCUSSION

Examples of flowering plants are shown in Figure 1. Table 1 shows a summary of the data on flowering episodes of six woody Asian bamboo species under cultivation in Brazil: *Bambusa multiplex* (Lourd.) Raueusch. ex Schult. & Schult. f., *B. tuldoides* Munro, *B. vulgaris* Schrad. ex J.C. Wendl., *Phyllostachys aurea* Rivière & C. Rivière, *P. bambusoides* Siebold & Zucc., and, *Sinarundinaria falcata* (Nees) C.S. Chao & Renv.

Four flowering episodes of *P. aurea* have been recorded, in the years 1963, 1969, 1972, 1987. Except for the first (1963), all the subsequent episodes were recorded in the Distrito Federal. In fact, the two Heringer collections

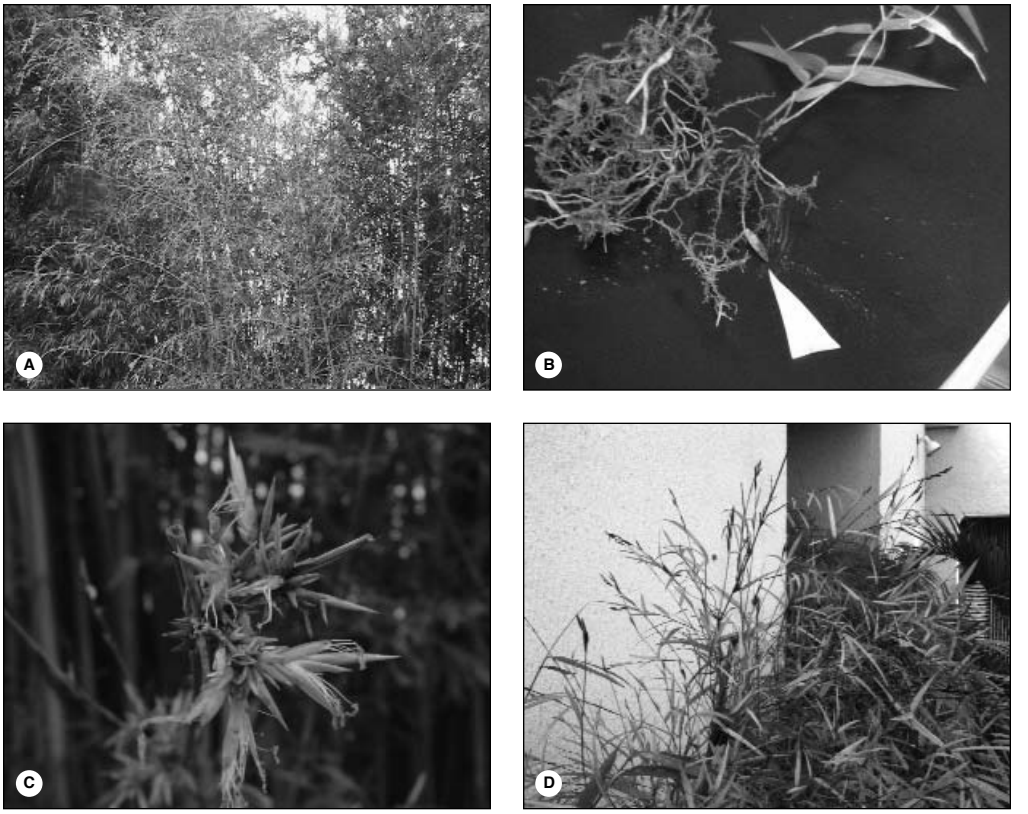

Figure 1: A: Flowering culms of *Bambusa tuldoides;* seedling of *B. tuldoides,* the white arrrow indicates a germinating seed; C: detail of spikelts of *B. tuldoides;* D: flowering culms of *Sinarundinaria falcata* (Photos by R.M.C. Silva).

(*Heringer 11839, 12117*) apparently were taken from the same population, i.e., Av. W-3 Sul, in the city of Brasilia.

Several culms in a sizable plantation of *P. bambusoides* located in a suburban area of Brasilia flowered in 1984, and, in1996. Most flowering culms in this plantation flowered from the lowermost branches to the top ones. This flowering lasted for several months. According to Kawamura (1927), the flowering cycle of this bamboo in Japan is 120 years! The two flowerings reported here, only a few years apart, seem to suggest that the clones grown in Brazil behave differently than plants grown in Japan. According to Bennet & Gaur (1990), in *Dendrocalamus strictus* there are different strains which differ in the length of their intermast periods and incidence of flowering (20, 30, 34, 45, and 60 years intervals) besides also exhibiting sporadic flowering.

Two flowering episodes of *Bambusa vulgaris* are reported here, one in the Distrito Federal and the other in the state of Maranhão. Flowering of this bamboo, the most commonly grown in Brazil (both green and striped forms) is not such a rare event, as once thought (McClure, 1966). Ahmed & Das (1986) reported flowering episodes of this species in India, whereas Judziewicz (1990) reported that the species bloomed in the Guianas in the years 1827-1828, 1842-1843, 1845, 1850, 1892, 1903, 1921, and, 1949-1950.

Likewise, four flowering episodes of *B. tuldoides* were recorded: 1954, 1984, and, 2005 (three different localities). It is interesting to note that in 2005, two widely separated populations (c. 300 km apart) of this bamboo flowered at the same time, i.e., in Santa Teresinha (S 14°29'46", W49°38'42", Alt. 384 m), Turvânia, state of Goiás, and in the Reserva Ecológica do IBGE (15°57'S; 47°52'W).

The case of *Sinarundinaria falcata* (known in the nursery trade in Brazil as *Bambusa gracilis* Hort. (cf. Lorenzi & Souza, 1994) is interesting. This bamboo is widely grown in Brazil as an ornamental but, apparently, rarely blooms. Three clumps were observed with a few flowering culms, one in the state of Goiás (*Filgueiras & Silva 36700)* and the other two in the city of Brasilia (*Filgueiras 3673, 3674*). They all grew in private gardens as ornamentals or hedges. A forth flowering specimen was collected in Curitiba, state of Paraná. So far as is known, none of these flowering episodes resulted in caryopsis formation.

Apparently, caryopsis formation in all these five bamboos species in Brazil seems to be the exception, rather than the rule. Caryopsis formation was only observed in a single instance, in a population of *Bambusa tuldoides* in the State of Goiás (Table 1, Fig. 1B). Subsequently after falling to the ground, some caryopses germinated and produced healthy seedlings. Each seedling was somewhat morphologically distinct from each other, which suggests sexual origin of the caryopses rather than apomixis. However, the flowering culms of the same species in the Federal District (Brasilia area) did not produce caryopses.

Likewise, no caryopses resulted from the four sporadic flowering episodes of *P. aurea* recorded in the cities of Brasilia, and, São Paulo (Table 1), nor from the two flowering episodes of *P. bambusoides,* in the Distrito Federal, nor from the two flowerings of *Bambusa vulgaris* in the DF or from the several flowerings of the same species reported by Judziewicz (1990) in the Guianas. The early statement by McClure (1966; 1993) that *Bambusa vulgaris* has never produced caryopses since it is known to science remains, apparently, true.

We offer here no satisfactory explanation for the fact that caryopsis formation in these

Table1. List of six species of flowering woody bamboos studied in Brazil.

Species	**Locality**	**Year (s) of flowering**	**Caryopsis formation**	**Death after flowering**	**Voucher & Herbarium**
Bambusa multiplex	Silvânia, Goiás	1988	No	No	S.col.,s.n. (IBGE 20323)
B. tuldoides	1. Santa Teresinha, GO 2. Campinas, SP 3.RECOR, DF 4. Paraopeda, MG 5. Turvânia	1. 2005 2. 1984 3. 2005 4. 1954 5. 2005	1. Yes 2. No 3. No 4. No 5. Yes	1. No 2. No 3. No 4. No 5. No	1. Filgueiras & e Silva 2. Aranha s.n. (IAC 25237; UB s.n.). 3. Filgueiras 3666(IBGE) 4. Heringer 3612 (UB) 5. Filgueiras & Silva 36700
Bambusa vulgaris	Brasília, DF Rod. Belém-Brasilia, MA	2001 1960	No No	No No	Filgueiras 3412 (IIBGE) E. Oliveira 1058 (UB)
Phyllostachys áurea	1. Brasília, DF 2. Brasília, DF 3. Brasília, DF 4. São Paulo, SP	1. 1987 2. 1969 3. 1972 4. 1963	1.No 2. No 3. No 4. No	1.No 2. No 3. No 4. No	1. Filgueiras 1276 (IBGE) 2. Heringer 11839 (UB) 3. Heringer 12117 4. Skvortzov 158-B (SP, UB)
B. tuldoides	1. Santa Teresinha, GO 2. Campinas, SP 3.RECOR,DF 4. Paraopeda, MG 5. Turvânia	1. 2005 2. 1984 3. 2005 4. 1954 5. 2005	1. Yes 2. No 3. No 4. No 5. Yes	1. No 2. No 3. No 4. No 5. No	1.Filgueiras & e Silva 2. Aranha s.n. (IAC 25237; UB s.n.). 3. Filgueiras 3666(IBGE) 4. Heringer 3612 (UB) 5. Filgueiras & Silva 36700
Sinarundinaria falcata	Brasília, DF Brasilia, DF Itauçú, GO	1. 2005 2.2005 3.2005	No No No	No No No	1. Filgueiras 3673 (IBGE) 2. Filgueiras 3674 (IBGE) 3. Filgueiras & e Silva s.n.

bamboos is so rare. However, we speculate that this critical phenophase requires a suit of finely tuned (but not yet determined) ecological conditions that results in such erratic fruit formation. It has been determined that seed setting in bamboos is dependent upon pollen availability and dispersal, and the absence of barrier for self-pollination (Redgauda ., 1997). To these we add that pollen viability should be investigated as yet another possible explanation. Another possibility is that these species are obligate outcrossers. As rarely more than one population of a given species blooms at the same time, opportunity for cross-pollination is indeed rare. Stigma receptivity should also be investigated as a possible explanation for such low seed setting.

In all the cases where the flowering episodes reported by us could be followed at irregular intervals, one fact became evident: some individual flowering culms died after flowering, but others did not. In all cases, neither the clump, nor the population died after the flowering of a few culms.

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Culm characteristics and population structure of dolu bamboo (*Schizostachyum dullooa* (Gamble) Majumder) in Barak Valley, Northeast India, the need for conservation and implications for management

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The conventional management system, consequences of bamboo extraction on culm characteristics and culm population structure of dolu bamboo (*Schizostachyum dullooa*), a prioritized forest bamboo species were studied in a forest patch of Cachar district, Barak Valley, Assam, North-East India. The resource extraction exhibited unscientific management strategies being practiced that exert greater pressure on the sustainable productivity of the stand. Average culm growth parameters such as culm height, culm DBH, culm internode length, and culm wall thickness were 6.63 m, 2.99 cm, 19.6 cm, 0.42 cm respectively. Harvesting of culms was practiced throughout the year with a greater intensity during May 2004-August 2004 (38% of the total). A loss of 28 percent of total number of culms per clump was observed during the period May 2004 to May 2005. Culm population structure showed a preponderance of younger culm ages over older ones with the culm ages of current, one and two year old culms. We argue the urgent need of an integrated approach for the conservation of the species from the characterization of culm characteristics and culm population structure studied. Management strategies for the restoration of the bamboo stand are proposed.

Holttum (1958) in his discussion on the Malayan bamboo speaks of village bamboo (cultivated) and native (forest) bamboo. Forest bamboos have been harvested by human populations for subsistence use and trade over thousands of years. In India bamboo occupy 8.96 million hectares of forests and exist as sporadic clumps in agricultural lands and homesteads. About 66% of the growing stock is concentrated in the Northeastern states of the country (Hore 1998; Adkoli 2002). *Schizostachyum spp*. Nees are the priority species of bamboo for international action (Rao *et al.* 1998). *Schizostachyum dullooa* is a dominant bamboo species in the successional fallows of Northeast India regenerating after slash and burn agriculture (Rao *et al.* 1990). This species is one of the most commercially important sympodial forest bamboo species growing naturally in the hilly tracts of Barak Valley and

also in other parts of the North-East India and Bangladesh (Banik 2000). Internodes of the green culm are used for preparation of a traditional food during the religious harvest festival in addition to its wide range of uses in house construction, fencing and craft making.

The growing commercial trade of natural products has generated concern about over-exploitation (Rebelo and Holmes 1988; Clay 1997; Rawat 1997; Tiwari 2000). The indiscriminate extraction from natural populations coupled with large-scale habitat loss has seriously endangered bamboo genetic resources. A number of investigations with emphasis on the traditional as well scientific management of natural bamboo stands has been carried out (Huberman 1959; Upreti and Sundriyal 2001) but the effect of bamboo extraction on culm characteristics and culm population structure has seldom been made for any species. Management of the natural bamboo forests in the tropics should aim to alleviate the prevalent shortages of forest products and to safeguard their potential for sustainable production (Embaye *et al.* 2005). Information on population structure of bamboos subject to different management system is scarce (Lodhiyal *et al.* 1998, Embaye *et al.* 2005, Nath *et al.* 2006). Knowledge of population structure of bamboo is important for development of a management approach to increase the production efficiency (Nath *et al.* 2006). In view of greater exploitation of forest bamboo resources, the present study aims at acquiring information on the consequences of overexploitation on culm characteristics and culm population structure.

MATERIALS AND METHODS

The Barak Valley region, which forms the southern part of Assam, covers an area of 6922 sq.km. The region shares its border with North-Cachar Hills district and the state of Meghalaya in the north, the state of Manipur in the east; the state of Mizoram in the south and the state of Tripura and the Sylhet district of Bangladesh in the west (Roy and Bezbaruah 2002). The climate of the study site is sub tropical warm and humid with average rainfall of 2660 mm most of which is received during the southwest monsoon season (May to September). The mean maximum temperature ranges from 25.1°C (January) to 32.6°C (August). The mean minimum temperature ranges from 11°C (January) to 25°C (August).

The Barak Valley region has about 34.39% forest cover of the total geographical area of the region in contrast to 25.80% for Assam as a whole (Govt. of Assam 2000). Cachar is the largest district of Barak Valley with a total geographical area of 3786 sq. km. The present study was carried out in a natural forest patch of 49 ha in the Cachar district of Assam situated between longitude 92°45'24.6" East and latitude 24°40'53.2" North.

Schizostachyum dullooa is the most dominant plant species in the forest understory of the large tree species of *Artocarpus chama* Buch-Hum. and *Tetrameles nudiflora* R.Br. According to local villagers approximately 40-50 years ago, larger woody trees dominated the forest stand. Subsequent felling due to population upsurge and construction activities rapidly dwindled the forest trees, shifting resource use of local villagers from timber products to the non-timber forest products.

Information on the conventional management system of the villagers was gathered through a modified questionnaire survey (Chambers *et al.* 1989). In addition to questionnaire survey with 100 villagers, periodic field observation was undertaken. Parameters like total number of villagers collecting bamboo resources daily, number of green/dead bamboo culms extracted, pattern of bamboo extraction by male, female and children and pattern of utilization were also enumerated during the study. Depending on the culm sizes 4 (four) different girth classes were recognized representing the whole diameter range and from each girth class fifty (50) culms were harvested for studying the culm height, culm DBH, culm internode length and culm wall thickness from fifty (50) different randomly marked clumps. The values of different culm characteristics presented in the present paper are the mean of different size classes of the current, one and two year culm ages, as we did not observe any statistically significant

relationship between culm characteristics with culm ages. For culm population structure, thirty (30) clumps each having the total culm number between 15-22 were selected randomly and marked with paint. The marked clumps were monitored at three-month intervals from May 2004 to May 2005. Bamboo culms were categorized into three ages depending on their maturity (i) current year (ii) one year old (iii) two year old (Banik 1993, Nath *et al.* 2004). Current year culms were identified by the presence of sheath on the nodes of whole culm, few branches at the apex and light green culm color. One-year culms were characterized by the presence of few or no sheath, presence of branches on the whole culm and dark green culm. Two-year-old culms were distinguished by the rough pale green culm and by the presence of dark patches of mosses and lichens on the culm.

RESULTS AND DISCUSSION

Conventional management system of the villagers

Villagers harvest the bamboo culms throughout the year irrespective of culm ages and harvesting season. Culms are harvested at the height of 50-85 cm from the ground level. A total of 65 villagers visit the forest stand daily, of which 34% are male, 29% are female and 37% are children. Male members mainly collect the green culms for household purpose (76%) and for selling in the market (24%). Household use includes split and whole culms in construction of new houses and repairing of old houses, fencing of homegardens and farms. Female members collect the dead one for fuel wood. Children collect the green culms and sell it to the nearby bamboo based industry. There is a growing commercial trade of dolu bamboo in the present study site for the production of musical instruments. A similar pattern of various traditional use of bamboos by the local people from natural bamboo stands has been reported by Laha (2000), Upreti and Sundriyal (2001) and Singh *et al.* (2003) from different parts of North East India.

Culm characteristics

The detailed culm characteristics are described in Table 1. Comparison of culm characteristics of the present study with the corresponding reported values of culm height (6-9 m), culm diameter (2.5-7.5 cm) and internode length (0.4-.075 m) of Seethalakshmi and Muktesh Kumar (1998) shows consistency with lower values of the range. Average number of total culms per clump across the study period was 19, which was similar with the 5 year old fallow in the secondary successional vegetation dominated by *S. dullooa* in North eastern India after shifting cultivation (Rao *et al.* 1990) but much lower than 15, 25 and 60 year old fallows of the same study, although the present bamboo stand dates back to about 45 years and developed following gregarious flowering during 1962 (Nath 1962). Total number of culms per clump during May 2004 was 17 (Figure 1), which increased to 26 during August 2004. Such increase corresponds to new culm emergence during the period of June-August (rainy season). Culm emergence during rainy season was also reported in *Melocanna baccifera* (Roxb.) Kurz, an early colonizer in the succes-

Table 1. Culm characteristics of S. dullooa

Culm characteristics	Values	Range
Culm height (m)	6.63	4.50-8.60
Culm DBH (cm)	2.99	2.01-3.57
Ave. internode length (cm)	19.6	10.20-40.0
Culm wall thickness (cm)	0.42	0.20-0.65

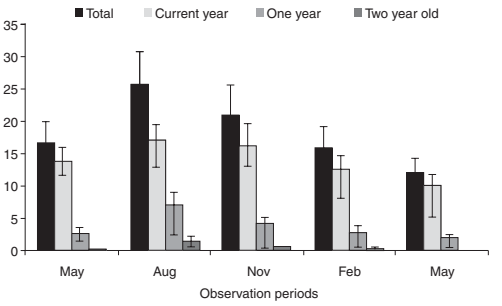

Figure 1. Total number of culms per clump with different culm ages during one year study period in *Schizostachyum dullooa.* Error bar represents standard error.

sional vegetation of Barak Valley (Nandy *et al.* 2004) and in *Bambusa cacharensis* Mazumder, a priority village bamboo of Barak Valley (Nath *et al.* 2004). The total number of culms per clump declined by August 2004 and was 12 in May 2005. A total of 22 culms were harvested during the one-year period from a clump with a greater intensity during May 2004-August 2004 (38% of the total). During this period fencing of the farm lands especially rice seedling beds require a substantial amount of bamboo leading to higher extraction. In the one year study period total number of culms per clump experienced a loss of 28%. Annually 42% and 54% of the current and one year old culms are harvested from each clump. However, Seth (1954), Huberman (1959), Sharma (1987) and Cusak (2002) emphasized the need of retaining all the current year culms along with a portion of old culms to maintain the rhizomes in full vigour and to provide stability to the new culms. Higher new culm production and greater culm height and diameter can result from selective felling of mature culms each year. It is necessary to evaluate the stock of culms per clump and to harvest 30-35 percent of total culms per clump annually by removing the mature culms. Harvesting mature culms maintains a continuous harvesting cycle that enables maximum sustainable yield (Nath *et al.* 2006). Thus under the present management system with its high intensity of harvest, rhizomes cannot maintain full vigor which in turn affects the culm height, culm DBH, internode length and culm wall thickness.

Culm population structure

Culm population structure exhibited the preponderance of younger culm ages than older ones. Only three culm ages: current year, one year and two year old culms represented the culm population structure in the present study. A stand culm age class structure with preponderance of current year culm was observed in all the five observation dates (Figure 2). Proportion of two-year culm ages to the total number of culms per clump was very low and was absent during the May 2005. Culm population structure of five different

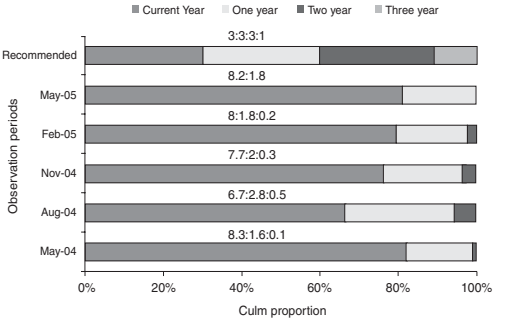

Figure 2. Culm population structure of *Schizostachyum dullooa* during one year study period.

culm ages preponderant towards younger culms for three *Bambusa sp.* was reported by Nath *et al.* 2006. A stand age structure of *Yushania alpine* (K. Schum.) W.C. Lin heavily skewed towards older culms was reported by Embaye *et al.* (2005) in a highland bamboo forest in southwest Ethiopia. However, Yuming *et al.* (2001) recommended an age class structure of 3:3:3:1 for 1-4 year old culms for optimum culm production. Huberman (1959) reported that cutting should be conducted so as to cause a minimum of disturbance and it is essential to retain a portion of old culms for mechanical support of new shoots. Thus the present stand population structure differs greatly from the recommended culm population structure for optimum yield. This reflects the poor management strategies adopted by the local villagers that exerts greater pressure on sustainable productivity of the bamboo stand.

Management implications

Excessive harvest of bamboo irrespective of culm age and harvesting season has resulted in the poor regeneration of the stand. The high percentage of current year culms along with low percentage of older culm ages reflects the lack of a sustainable management system in practice. The growing commercial trade of dolu bamboo for the production of musical instruments has resulted in excessive harvest and therefore generated concern about overexploitation. The consequences of overexploitation have a direct effect on the culm characteristics and culm population structure. Higher intensity of

exploitation in a low productivity area can further degrade the stands, which can lead to the elimination of the species from a given area. Overexploitation can lead to the extermination of species with limited distribution, endangering bamboos existence in the long term (Banik 2000, Adkoli 2002). Therefore, urgent conservation action is needed to protect and manage this internationally prioritized bamboo species for the restoration of the habitat as well for the conservation of the species in the forest. Moreover the restricted distribution of the species in the moist semi evergreen forests of North East India to Sylhet in Bangladesh and in small patches in Nepal, Bhutan and Myanmar (Banik 2000) reflects the great need of conservation in the species. The proposed management strategies for the conservation of the species include:

1. Mass cultivation of the species in the home gardens so as to diversify the supply base of the species.
2. A complete restriction on the harvesting of bamboo culms during rainy season (May-October). Seth (1954), Huberman (1959) and Sharma (1987)
3. Harvesting of mature culm ages leaving all the current year culms. Huberman (1959), Sharma (1987) and Cusak (2002)
4. Harvesting should be done at the base of the culm (up to 30 cm from the ground level). Huberman (1959)
5. The present effort to conserve the bamboo would also benefit from mass education of the villager's regarding the problems that may arise with ecologically unsustainable harvesting practices.

CONCLUSION

Information on culm characteristics and population structure as affected by the conventional management system reflect the need of an integrated approach for the conservation of the species. There is an urgent need to device means and ways to conserve and to maintain this socioeconomically and ecologically valuable forest resource under its natural habitat. Strategies should ensure development of bamboo resources inside the forest to maximize the ecological benefits and to halt the trend of degradation. A combined and controlled effort for the regeneration of bamboo by concerned authorities and local villagers can enhance the sustainable productivity of the stand.

ACKNOWLEDGEMENTS

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Preservation of the *Guadua angustifolia* Kunth by submersion in aqueous boron solutions: the influence of temperature, concentration and duration of submersion in aqueous boron solutions on the effectiveness of the preservation of Colombian bamboo (*Guadua angustifolia* Kunth)

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In the Colombian Coffee Region, the effectiveness of the chemical preservation of *Guadua angustifolia* Kunth using the submersion in a boron solution was investigated. Samples between 50 and 60 cm of length with different diameters and wall thickness were used with and without clump-curing. They were submerged in three different boron concentrations with a relation of borax:boric acid of 1:2, using different submersion times (3 to 5 days) and different temperatures (20 to 80 C). The quality of the preservation is controlled significantly by the initial moisture content of a sample, the specific weight, the concentration of the solution, the submersion time, and the temperature of the solution. Mathematical models were created to control the concentration of the solution and for the determination of the retention and the penetration of boron compounds into guadua using the submersion technique.

Historically, bamboo has been used in Northern South America, and especially in some regions of Colombia, as an essential material for construction. The so called "bahereque" technique combined timber and the local bamboo (*Guadua angustifolia* Kunth, in the following "guadua") as structural elements for buildings.

Traditionally, the preservation of the guadua is made by special cutting and harvest methods. Especially in the Colombian Coffee Region, the bamboo is cut during the wane of the moon and before sunrise. The culms are left in vertical position at their sites for some weeks (clump-curing). On one side, the ongoing photosynthesis processes of the leaves reduces water and carbohydrates which are stored in the culms, and on the other side, a part of the sugars is fermented within the culms (Spanish: *"vinagrado"*), reducing the attractiveness for later borer attack. After two or three weeks, the leaves are dried and the guadua culms can be harvested and prepared for their final use (Moran 2003). Montoya (2002) showed that this method, indeed, reduces significantly the later attack by borers.

However, for modern construction and long term use, this technique is not sufficient and an additional preservation with chemicals is required (Liese 2004, Liese and Kumar 2003). Modern preservation methods for timber offer a wide range of techniques and technical requirements (JUNAC 1988, Vaca de Fuentes 1998). After the 1999 disastrous earthquake in the Colombian Coffee Region, reconstruction caused an increasing demand of preserved guadua and the necessity of a practical and environmentally friendly preservation method. Nowadays, and based on very good empirical results, the majority of the Colombian bamboo producers submerge the culms, after clump-curing, in an aqueous boron solution, generally applying a combination of boric acid and borax in a relation of 1:1 and in concentrations of 4 to 5%. To permit the diffusion of the protecting

boron compounds, all nodal walls are axially perforated and the culms are submerged in the aqueous boron solution for five days (soaking). In Colombia, this method has shown good preservation results and easy applicability in rural areas. The increasing export of bamboo poles to markets in USA and EU during the last few years makes a controlled quality of preservation necessary.

The focus of this study is to demonstrate the diffusion effectiveness, to quantify the penetration of the boron solution as function of temperature, concentration of the solution and duration of submersion, and to quantify the effective retention of boron salts within the timber as an indicator of preservation quality.

MATERIALS AND METHODS

A factorial experiment with two factors and tree levels (design 3^2) was designed with two blocs called "site 1" (Nápoles Farm, Montenegro, Quindío) and "site 2" (Botanical Garden, Universidad Tecnológica de Pereira), where samples with average diameters of 8.3 and 14.5 cm were taken.

The concentration of the solution (0.45, 0.90 and 1.35 wt. % of boron, calculated on the base of a mixture of borax and boric acid 1:2) and the duration of submersion (3, 4 and 5 days) were defined as factors. As response variables, the penetration and the retention of boron were measured and as co-variables, the moisture content before submersion as well as the specific weight of the samples. Experimental guadua samples consisted of the basal (*basa*) and the middle part (middle) of adult guadua of more than three years of age, 50-60 cm in length with at least two internodal sections.

To observe the influence of temperature of the preservative solution, a unifactorial experiment with four levels was designed (20°, 30°, 40° & 80° C). As response variables, the penetration and the retention of boron were measured and as co-variables, the moisture content before submersion as well as the specific weight of the samples. The experimental unity corresponds to samples of the basal part of adult guadua of more than three years, 60 cm in length with at least two internodal sections (from site 2).

The samples for the evaluation of penetration and retention of boron salts were taken in the middle of the nodes. The curcuma staining method was then used, and quantitative analysis was done by the azometina H-method at the Technical University of Pereira.

RESULTS AND DISCUSION

Effects of boron compounds in aqueous solutions

Borax and boric acid are available commercially as water-soluble salts. Increasing borax content changes the pH of an aqueous solution toward alkaline values, the addition of boric acid shifts the pH toward acidic values (Figure 1). This explains the necessity of both compounds to maintain pH neutral.

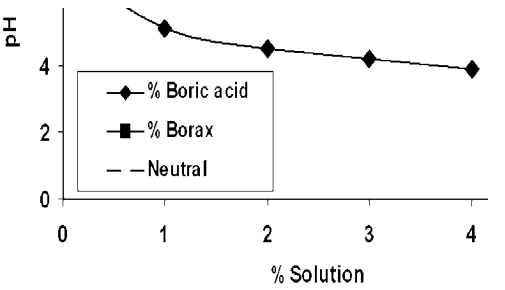

Figure 1. Influence of borax and boric acid concetration on the pH of an aqueous solution.

The solubility of both salts increases drastically with increasing temperature (Figure 2). However, the increase of solubility of borax at up to 60° C is low compared to the temperature interval 60°-100° C. Higher solubility in the lower temperature range would have been more favorable for practical uses. The dissociation of borax is at 100° C nearly 2.000 g/l compared to 250 g/l boric acid. The higher solubility of borax as compared to boric acid means that the preservation effect is caused principally by dissolved borax.

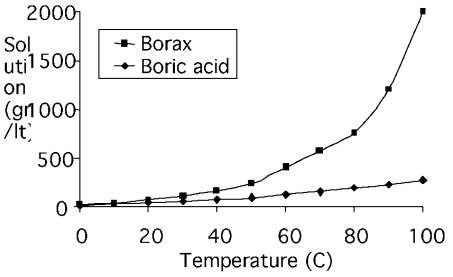

Figure 2. Solubility of borax and boric acid in function of the temperature of an aqueous solution.

To control the salinity, and therefore the quality of the preservation solution, it is possible to measure the conductivity of the solution at neutral pH as the conductivity is a linear function of the dissolved ions (Figure 3). A 2% borax solution is characterized by a mean conductibility of 6800 µS/cm meanwhile a 4% solution is 11500 µS/cm (at 23° ± 1° C). These differences are great enough to utilize the conductivity as a practical indicator for the borax content or quality of the solution as described by the formulas:

1.) % Borax = (Conductivity-315)/2929 or
2.) Conductivity (µS/cm) = 315+2929 x Borax (%)
3.) % Solution (relation 1:2) = % Borax + % Boric Acid

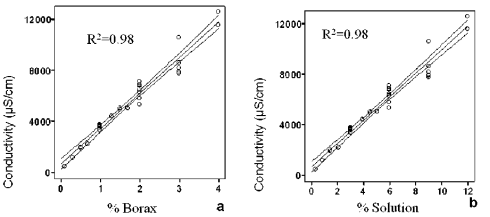

Figure 3. Conductivity of an aqueous solution in function of its boron concentration as described by formula 2 (a) and its solution concentration as described by formula 3 (b) at 23° ± 1° C.

Penetration and retention of boron salts

The concentration of the preservation solution and the submersion time are two of the most important variables with strong influence on the final retention of boron salts of a sample. Most of the samples showed a total penetration of boron compounds with a stronger boron concentration in the inner wall side. The concentration of the boron solution shows a significant influence on the diffusion and retention with 3.3 kg/m^3 BAE (boric acid equivalent) in a 3% solution and 6.9 kg/m^3 BAE in a 9% concentration (Table 1).

Due to the anatomic heterogeneity of guadua (Gritsch *et al.* 2004), with different moisture contents and different densities (both depend on the relative amount of parenchyma tissue), the penetration and retention of boron compounds is heterogeneous as well. Londoño *et al.* (2002) report a range of parenchyma tissue of 63% in basal and 36% in apical parts of *Guadua angustifolia* that corresponds to a range of specific weight from 0.36-0.99 g/cm^3 (Camargo 2006). Parenchyma tissue permits better diffusion of the preservative solution. On

Table 1. Boron content of preserved guadua as a function of different concentrations of the solution and different submersion times.

	Submersion time (days)			
Concentration (% of boron)	3	4	5	Total
0.5	1.6±0.4	3.7±1.1	4.7±2.2	3.3±0.8 (c)
0.9	4.9±1.4	6.1±2.0	6.1±1.7	5.7±0.9 (b)
1.4	6.6±1.7	6.9±2.1	7.1±1.8	6.9±1.0 (a)
Total	4.4±0.9	5.6±1.0	6.0±1.1	

Mean±standard error of the mean, based in 6 samples per treatment (n=54). Different letters mean significant differences in concentration (Tukey-test $p<0.05$).

the other hand, borers preferably attack parenchyma rich parts of the bamboo as they serve as storage for starch grains (Liese 2004). Therefore, the preservation reaches the parts where it is precisely required.

Penetration acts at the ends of a guadua pole along the metaxylem vessels of the vascular bundles, while, in the interior of a pole, diffusion processes through the inner wall-layer dominate. Guaduas without perforated inner nodal walls showed clearly lower retention values of 0.3 BAE at 20° C and 1,1 BAE at 80° C while samples with perforated nodal walls show retention values of 3.9 BAE and 15.2 BAE at the respective temperatures (Table 2).

Table 2. Boron concentration of preserved guadua with and without ruptured nodal walls at different temperatures.

Treatment	20° C	80° C
With ruptured	3.9±1.2 (b)	15.2±1.7 (a)
Without ruptured	0.3±0.1 (d)	1.1±0.4 (c)

Mean±standard error of the mean, based in 4 samples per treatment (n=16). Different letters mean significant differences in concentration (Tukey-test $p<0.05$).

The outer wall, with its watertight, silica rich layer (cortex), is practically not penetrated by the boron compounds. Our investigations showed that there exists longitudinal penetration, but it is negligible as compared to the penetration through the inner wall. Therefore, the perforation of the inner nodal walls or two perforations at each node are fundamental for a good preservation without using pressure techniques like "Boucherie".

Mature guadua, as harvested at an age of 5-7 years and used for the present investigation, has moister contents of 80-120%. After three weeks of clump-curing, the moisture content is still about 40-80%. Under this condition, the culms are submerged in the preservation solution. In samples with more than 80% moisture content, penetration of the boron solution was not complete, while in samples with a moisture content of less than 80%, the penetration was complete. However, in the present study, we did not investigate the lower limits of moisture content. Liese (2004) notes that with further drying, the bamboo tissue becomes quite refractory and penetration will depend mainly on the limited internal capillary forces.

In our linear regression model, 46% of the variability in retention of boron salts may be explained by moisture content and specific weight, while individual effects show 17% and 25% of variability (Figure 4).

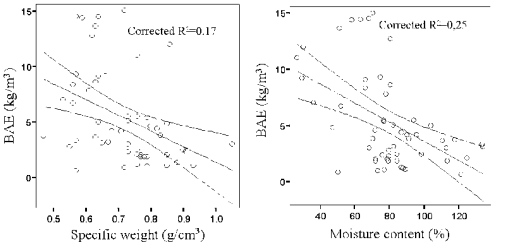

Figure 4. Relation between specific weight, moisture content and penetration.

As the conductivity is a direct function of the dissociated ions of borax, the concentration of the preservating solution can be measured easily by the conductivity and the pH of the solution. For practical uses it is recommended to maintain the pH neutral. The retention of boron compounds depends strongly on the concentration of the solution, on the specific weight of the guadua, on the moisture content of the guadua and on the duration of submersion. Each of the four parameters may strongly influence the quality of protection in soaking treatment.

The concentration of the boron solution showed good results in the range of 3-9% but a 4-5% solution seems sufficient for a good preservation. In practical application, higher concentrations may produce a thin crystal film on the pole´s surface during drying (pers. comm. Joerg Stamm). At increased temperature, the solution dissolves significantly more borax and favors the penetration of the boron compounds. Shorter submersion times could be the consequence, but the higher costs for heating up the solution has to be compared with the advantage of shorter submersion times.

The specific weight of the guadua is a natural parameter that may depend on growing conditions or site quality but it is present also within a single guadua pole. A good selection of the material before submersion is required to achieve a uniform preservation. The moisture content of the guadua at the time of submersion

should be less than 80%. For a uniform preservation, groups of culms from one site and with the same harvesting and drying history should be treated. Submersion time depends strongly on the other three parameters. According to the variables studies here, submersion for four to five days is recommended.

The retention of boron compounds is not uniform because it depends strongly on the specific weight of the guadua. The natural heterogeneity from lower dense inner walls to higher dense outer walls and from lower dense lower parts to higher dense upper parts makes the homogeneous retention of salts impossible. Therefore, a minimum limit of BAE should be defined to guarantee the preservation quality. Control sampling should be made at the parts with lowest parenchyma content i.e. highest specific weight. However, all analysis done in this study have shown that the retention of 1-4 kg BAE, which is reached by the applied soaking method, is sufficient to guarantee good protection of the guadua.

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***Bamboo Notes*[1]**

Fruit production in *Melocanna baccifera* (Roxb.) Kurz under two contrasting conditions

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A study was conducted on the fruit production after gregarious flowering of muli bamboo (*Melocanna baccifera* (Roxb.) Kurz.) in 2005-2006 under two different conditions viz. undisturbed natural bamboo forest and burned bamboo area for shifting cultivation. The regular once-every-48-year flowering in Mizoram is well recorded in this species (Banik, 1998; Lalramnghinglova, 2003). It was observed that the density of culms differ significantly in the two study sites. Higher density was observed in the burned area with the number of culms recorded as 25 culms /9m^2, whereas in case of natural bamboo forest the density was 21 culms /9m^2. Obviously culms height was very low in burnt area. It was interesting to note that the number of fruits produced per culm in burned area was higher (37 fruits /culm) as compared to that of natural bamboo forest (17 fruits /culm. This variation in production of fruits may be due to high level of protogyny in natural forest as compared to the burnt bamboo area, which we have observed during flowering period. Contrary to this, the size and weight of fruits was observed significantly greater under natural bamboo forest. The details are presented in Table 1. Troup (1921) has also observed very low fruit setting in *M. baccifera*. The low fruit to flower ratio can be inferred to be a sequence of selection to over produce flowers (Wilson and Price, 1977; Lee, 1988; Stephenson, 1981; Udovic, 1981; Cohen and Ducas, 1990; Erhlem, 1991) and might be due to strong protogyny. The fruits remain viable for about 30 days in normal condition and the rates of seed germination in the nursery vary between 60 and 80 percent. However, vivipary (germination before release from the plant) is a common phenomenon observed in this species.

This study was carried out in the Thentlang bamboo forest of Serchhip District of Mizoram, India, which is located at an altitude of 1000-1086 m asl. The temperature of the study area ranges from 18-34°C during summer (April to August) and 4-28°C during winter (October to February). The average annual rainfall ranges between 250 and 300 cm. The production of fruits of *M. baccifera* was studied under two contrasting conditions: (i) felled and burned bamboo forest (ii) undisturbed bamboo forest. Three study plots of 0.1 ha were laid out for the purpose in each site. Within each study plot, 5 quadrats of 3m x 3m were laid randomly to study the density of culms and production of fruits. Estimation of fruit production per culm was made by felling 10 culms in each quadrat and a total of 50 culms per study plot and counting was done manually. The harvested fruits were brought to the laboratory for qualitative measurements i.e., fruit weight, length and diameter, and viability tests.

Table 1: Culm density and production of fruits and their physical characteristics under two different conditions.

Sites	Culm density / 9m^2	Number of fruits/culm	Average production of fruits	Average diameter of fruits (cm)	Average length of fruits (cm)	Average weight of fruits (gm)
Undisturbed natural forest	21	17±10.24	390±154.21	6.13±1.23	12.92±1.89	166.28±25.62
Burned forest	25	37±15.36	1030±150.20	2.58±0.68	9.14±0.98	80.91±14.48

[1]***Bamboo Notes*** are communications of brief and generally self-evident data not requring extensive discussion or explanation.

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Historical bamboo images

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Figure 1: Flowering *Chusquea scandens,* growing along the Quito-Saloya road at Km 23 just beyond the San Juan pass, Pichincha, Ecuador (McClure 21414, collected in August, 1945). Photo by F. A. McClure from the research archives of the U.S. National Herbarium, Smithsonian Institution, Department of Botany.

Figure 2: Francisco Tiosciuro and family (Otavalo Indians, village of Pingyaro, near Otavalo, Ecuador), makers of hats and baskets from the culms of suro (*Chusquea scandens* and related species). Photo by F. A. McClure, September 1945: from the research archives of the U.S. National Herbarium, Smithsonian Institution, Department of Botany.

Figure 3: *Chusquea subtessellata,* Cerro de la Muerte, Costa Rica. Photo by L. G. Clark, 1982.

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Errata

Republished here are two illustrations of species published in Volume 19 of Bamboo Science And Culture.

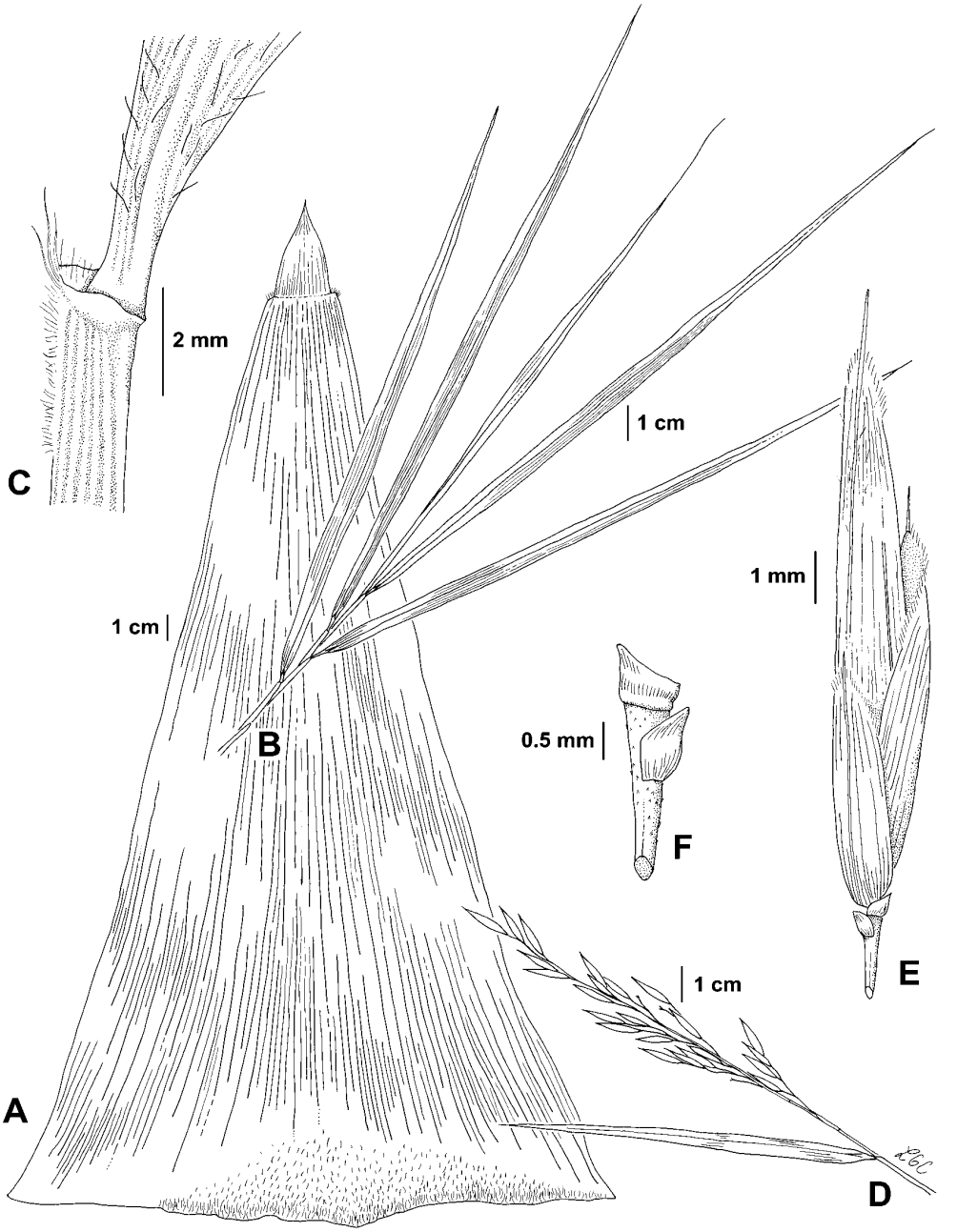

Figure 1. *Chusquea robusta* L.G. Clark & Losure
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Figure 2. *Aulonemia dinirensis* Judz. & Riina Bamboo Science and Culture: The Journal of the American Bamboo Society. 19(1): 11 (-15; figs. 1-2). 2005

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