BAMBOO SCIENCE & CULTURE

The Journal of the American Bamboo Society

Volume 23

BAMBOO SCIENCE
&
CULTURE
The Journal of the American Bamboo Society

is published by the
American Bamboo Society

ISSN 0197– 3789

Bamboo Science and Culture: The Journal of the American Bamboo Society
is the continuation of *The Journal of the American Bamboo Society*

Membership Information

Membership in the American Bamboo Society and one ABS chapter is for the calendar year and includes a subscription to the bimonthly Newsletter and annual Journal.

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Bamboo Science and Culture:
The Journal of the American Bamboo Society 23(1): 1-28

Bamboo based agroforestry systems to reclaim degraded hilly tracts (jhum) land in North Eastern India: study on uses, species diversity, distribution, and growth performance of *Melocanna baccifera, Dendrocalamus hamiltonii, D. longispathus* and *Bambusa tulda* in natural stands and in stands managed on a sustainable basis

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ABSTRACT

The present study reports on bamboo species diversity and their distribution; growth performance of major bamboo species at different altitudes, aspect and slope percent in its natural habitat in order to recommend the suitable range of altitude, aspect and slope percent for future plantation of desired species; yearly consumption of young bamboo shoots for vegetables; felling intensities need to be applied to maintain sustain supply of young culms for vegetables and mature culms for other uses, and feasibility of introduction of bamboo based agro forestry system to reclaim degraded shifting cultivation land or hill slopes in north eastern states of India.

INTRODUCTION

Bamboo, the fastest growing woody plant, has been the choice of millions. Sharma (1980) and Soderstrom (1985) have reported about 75 genera and 1250 species, distributed in different parts of the world whereas Ohrnberger and Goerrings (1985) mention approximately 110 genera and 1010-1400 species. However, Sarker (1983) mentions about 51 genera and over 1000 species of bamboo in the world. In the north-eastern region of India, bamboo diversity is quite rich, with about 63 species belonging to 15 genera (Biswas 1998).

Bamboo area of Mizoram state is highest in India (49.1 percent to the forest cover of the state). Out of which, 98 percent is contributed by non-clump forming species (*Melocanna baccifera*), and the remaining 2 percent are different clump forming bamboo species. Bamboo forms an indispensable resource base for the rural population of northeastern states in general and Mizoram in particular. Overexploitation of bamboo resources and the destruction of natural habitat due to shifting cultivation, have resulted in a decrease of growing stock, especially the clump forming species in Mizoram state of India (Anon. 1997 and Jha & Laha 2002). The growing stocks of *Melocanna baccifera*, *Dendrocalamus hamiltonii* and *D. longispathus* vary greatly at different fallow periods in Mizoram (Jha and Laha, 2002). In olden times, the bamboo dominated Village Supply Reserves were managed and conserved for the sustained extractive use of forest-based resources. With increased acreage under shifting cultivation, population pressure and erosion of the psychology of fear that damage to the Village Supply Reserves is severely punishable, has resulted in overexploitations of the Village Supply Reserves.

This tendency had resulted in excessive biotic pressure on virgin forests particularly in Mizoram. The rampant clearing of forests in the past has created favorable conditions for colonization by the non-clump forming bamboo species *Melocanna baccifera* in northeastern states of India.

Growing stock of bamboo resource has come under tremendous biotic pressure since the last three to four decades. Immature culms are being extensively consumed as vegetables, whereas mature culms are in great demand for household purposes and for cottage industries. The biotic pressure, fire and unscientific management have remarkably reduced the bamboo's growing stocks (Jha 2003).

In this study we report on 1) bamboo species diversity and distribution, 2) grwoth performance of bamboo at different altitude, aspect and slope, 3) the estimation of total consumption of young culms for vegetables, 4) the optimal felling intensity to maintain sustainability of the growing stock of major bamboo species, and 5) the feasibility of the introduction of bamboo based agroforestry systems to boost up socio-economical conditions of rural people and to rehabilitate degraded hill slopes in Mizoram and seven sister hilly states of northeast India.

METHODOLOGY

1. Bamboo species diversity and distribution

In the first phase basic information on bamboo species diversity was collected from the Govt. Departments and specialists. A questionnaire was prepared and circulated to each Village Council of Mizoram State in order to catalogue the bamboo species growing in their villages and adjoining forests. On the basis of response to the questionnaire, the study area was divided into eight parts to cover almost all representative areas to complete the survey and identify the range/ place of distribution. The collected specimens were preserved with proper labeling in the Dept. of Forestry, Mizoram University, India. The work was completed in two and half years.

2. Growth performance of major bamboo species at different altitudes, aspect and slope percent in its natural habitat

The correlation between topographical variables, distribution and growth performance of bamboos, would help the concerned Govt. Depts. and farmers to determine the most appropriate slope range, altitude and aspect for plantation of major clump forming bamboo species. Forest areas with east, west, north and south facing slopes were selected for the study. The least count quadrant method was used to determine density of the bamboo species (Phillips 1959). Correlations were developed between topographical features and various growth attributes. Mean and standard deviations of various growth measures of bamboo were calculated. Significance tests were performed and correlation coefficients were calculated using Pearson's Product moment correlation coefficient formula.

$$r = \frac{Cov(X,Y)}{\sigma_x \sigma_y}$$

where Cov = Covariance, X and Y = Variables, and σ_x and σ_y the standard deviations of X and Y respectively.

3. Market survey to estimate total consumption of edible bamboo shoots

On the basis of preliminary information a "Stratified Three-Stage Sampling Design" with a variable sampling fraction was planned. Based on the "Block Statistics Report of 1997" of households, the state of Mizoram is stratified into three strata – 1) Aizawl Town, 2) 21 other towns of the state and 3) Villages of the state. The other 21 towns of the state were clustered into 5 clusters of nearly equal sizes and the 755 villages were clustered into 64 clusters of nearly equal sizes. These clusters constituted the first state sampling units. Markets, clustered into nearly equal sizes, constituted the second stage units, and the vendors selling bamboo shoots in the markets constituted the third stage sampling units.

The frequency of vendors in the markets varied from daily to fortnightly. For simplicity, the amount brought by each selected vendor was converted into its weekly equivalent, in case it was not weekly. The estimated weekly total is obtained using the formula.

$$T = \Sigma_h W_h (N_h M_h R_h) y_h$$

Here T is the total number of bamboo shoots available weekly in the markets of Mizoram; h is the stratum (h =1, 2, 3); N_h is the population number of first stage units in the h^{th} stratum; M_h is the population number of second stage

units in the h[th] stratum and finally, R_h is the population number of third stage units in the h-th stratum.

Y_h is the sample mean amount (in numbers) per vendor per market per town/village of the hth stratum.

The estimated variance of T is obtained using the formula.

$$V(T) = \Sigma W_h^2 (N_h M_h R_h)^2 [(1-f_{1h})s^2_{1h}+f_{1h}(1-f_{2h})s^2_{2h}+f_{1h}f_{2h}(1-f_{3h})s^2_{3h}]$$

Here, f_{ih} is the sampling fraction of the i^{th} stage units (i = 1,2,3) in the h[th] stratum s_{ih}^2 is the sampling fraction of the ith stage units (i = 1, 2, 3) in the h[th] stratum, and n_h, m_h, r_h are respectively the first stage, second stage and third stage sample size in the h[th] stratum.

The survey was conducted during the months of July and August of the year 2000 to 2002. Attempts were made to visit all the randomly selected markets during the months of July and August. After the survey, altogether 102 samples were included in the analysis.

The sampling scheme followed is as follows:

Station No.	h	(1) Aizawl Town	(2) The other 21 towns of Mizoram	(3) The 755 villages of Mizoram
First stage units	Population	1	5*	64*
	Sample	1	2	3
Second stage units	Population	5*	2*	1*
	Sample	3	2	1
Third stage units	Population	78	46	10
	Sample	14	9	8

Note: *Number of Clusters of nearly equal sizes in which the respective Stage units were clustered within stratum

4. Management of edible bamboo species *(Melocanna baccifera, Dendrocalamus hamiltonii, Dendrocalamus longispathus* and *Bambusa tulda)* in natural habitat

The experimental plots were laid at Sakawrtuichhun village which is located 15 km northwest of Aizawl, the capital of Mizoram. The study site is located at 23°45'N latitude and 92°41'E longitude at an elevation of 850 m above sea level. Randomized Block design was applied with five replications for each species and in each replication three clumps were kept. The harvesting of young shoots were harvested at 25, 50, and 75 percent and compared with control. The numbers of new shoots emerged and harvested were recorded twice (within 15 days).

5. Growth performance of edible bamboo species grown with crops (bamboo based agro forestry) to rehabilitate degraded Jhum (shifting cultivation) land or hills

The study was conducted at Luangmual Village, which is located at the outskirt of Aizawl, the capital city of Mizoram, during 1998-2003. The experimental site was a degraded jhum fallow land. It enjoys an average annual rainfall of 250 cm with temperatures ranging from 10-27°C in winter and 20-35°C in summer. From 1998 onwards, three bamboo species (*Dendrocalamus hamiltonii*, *Dendrocalamus longispathus* and *Bambusa tulda*) were grown along with soybeans under asymmetrical factorial design with three replicates in 36 sub-plots. Rhizomes were planted at spacing of 2.5 m x 2.5 m and 3 m x 3 m. Soybean seeds were sown in the interspaces as intercrops. NPK was applied in the form of urea (80kg/ha), superphosphate (50 kg/ha) and muriate of potash (45kg/ha) in two split doses at an interval of two months. Six subplots in each replicate were kept as control (without fertilizer).

RESULT AND DISCUSSION

1. Bamboo species diversity and distribution

The state of Mizoram is rich in bamboo resources. Bamboo occurs in the lower storey of tropical evergreen and moist deciduous forests

along the banks of rivers in the riverine forests and in the valleys with humid conditions. On the basis of preliminary survey, Jha and Lalramnghinglova (1995) reported the presence of 15 bamboo species in Mizoram and emphasized the adoption of scientific management practice to maintain sustainability of growing stock of bamboo in Mizoram. Bamboos are found from 40 meters to 1500 meters elevation, and are less common in the eastern region of the state, particularly in Champhai District, due to the high altitude. Bamboos are rare in eastern and southeastern part of state. In the present survey 20 bamboo species were collected and identified. Out of 20 species *D. hamiltonii, D. longispathus, B. tulda* and *M. baccifera* are edible bamboos.

The bamboo species growing naturally in Mizoram are presented in Table 1 and description of species, notes on habitats and photographs are presented thereafter.

Table 1. Diversity of Bamboo Species and its Distribrution in Mizoram

DISTRICT	BLOCK	VILLAGE	Code Number of bamboo species (1-20)																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
AIZAWL**	AIBAWK	Lungsei	-	+	+	+	-	-	+	-	-	+	-	-	-	+	+	+	+	+	-	-
		Hmuifang	+	-	-	-	-	-	+	+	-	+	-	-	-	+	-	-	+	+	-	-
		Sumsuih	+	+	+	+	-	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-
		Phulpui	-	-	-	+	-	-	+	-	-	+	+	-	-	+	+	+	+	+	-	-
	DARLAWN	Khanpui	+	+	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	-
		Zohmun	-	+	-	+	-	+	+	-	-	+	-	+	-	+	+	+	+	+	-	-
		Khawpuar	-	+	+	+	-	+	+	-	-	+	+	-	-	+	+	+	+	+	-	-
		Hmunnghak	-	-	+	+	+	+	+	+	-	+	+	+	-	+	+	-	-	-	+	-
		Sailutar	+	-	+	+	+	-	+	-	-	+	+	+	+	+	+	+	+	+	-	-
		Palsang	-	-	+	+	-	-	+	-	+	+	+	+	+	+	+	+	+	+	-	-
		Ratu	-	-	+	+	+	+	+	-	-	+	+	-	-	+	+	+	-	+	-	-
		Mauchar	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
		Kepran	-	-	+	+	+	-	+	+	-	+	-	-	-	+	+	+	-	+	-	-
		Vaitin	-	-	-	+	-	-	+	-	-	+	-	-	-	+	+	+	+	+	-	-
	REIEK	Reiek	-	-	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	-
KOLASIB**	THINGDAWL	Buhchangpui	-	+	-	+	-	+	+	-	-	+	-	-	-	+	+	+	-	+	-	-
		Thingdawl	-	-	-	+	-	-	+	-	-	+	-	-	-	+	+	+	+	+	-	-
		North Chhimluang	-	-	-	-	-	-	+	-	-	+	-	-	-	+	+	+	-	+	-	-
		North Chawnpui	-	-	-	-	-	+	+	-	-	+	-	-	-	+	+	+	+	+	-	-
		Phainuam	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	-
		Saiphai	-	-	-	-	-	-	+	+	-	+	-	-	-	+	+	+	-	-	-	-
		Saipum	-	-	-	+	+	+	+	-	-	+	+	-	-	+	+	+	+	+	-	-
		South Chhimluang	-	+	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-
		North Hlimen	-	+	+	+	-	+	+	-	-	+	+	-	-	+	+	+	+	+	-	-
		Bairabi	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-
		Bilkhawthlir	-	-	-	+	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-
		Bualpui	-	-	-	+	-	+	+	-	-	+	+	-	-	+	+	-	+	-	-	-
		Kawnpui	-	-	-	+	-	+	+	-	-	+	+	-	-	+	+	-	-	-	-	-
		Kolasib	-	-	-	+	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	-
		Serkhan	-	-	-	+	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	-
		Vairengte	-	-	-	+	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-
		Zawlnuam	-	-	-	+	-	-	+	-	-	+	-	-	+	+	-	-	+	-	-	-
		Saiphai	-	-	-	+	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	-

Table 1. Diversity of Bamboo Species and its Distribrution in Mizoram (continued)

DISTRICT	BLOCK	VILLAGE	Code Number of bamboo species (1-20)																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
MAMIT**	W. PHAILENG	Phuldungsei	-	-	-	+	-	-	+	-	-	-	-	-	-	+	+	+	+	+	-	-
		Saithah	-	-	+	+	-	-	+	-	-	+	-	+	-	+	+	+	+	+	-	-
		Lengpui	-	-	-	+	-	-	+	+	-	+	-	-	+	+	+	-	-	-	-	+
		Parvatui	-	-	-	+	-	-	-	-	-	+	-	-	-	+	+	+	+	-	-	-
		Dampa Rengpui	-	+	+	-	-	-	+	-	+	+	-	-	-	+	+	+	+	+	-	-
	ZAWLNUAM	Bungthuam	-	-	-	+	-	+	+	-	-	-	-	-	-	+	+	+	-	-	-	-
		Saikhawthlir	-	-	-	+	-	-	+	-	-	+	+	-	-	+	-	+	-	-	-	-
		West Bunghmun	-	-	-	+	-	-	+	-	-	+	-	-	-	+	+	-	-	-	-	-
CHAMPHAI**	KHAW ZAWL	Champhai	-	+	-	-	-	-	+	-	-	+	-	-	-	+	+	-	+	+	-	-
	THINGSUL THLIAH	Buhban	+	+	+	+	-	-	+	+	-	+	+	+	-	+	+	+	-	+	-	-
		Sialhawk	-	-	+	+	-	-	+	-	+	+	-	+	-	+	-	-	+	-	-	-
SERCHHIP**	SERCHHIP	Keitum	-	+	-	+	-	+	+	-	-	+	-	-	-	+	+	-	+	+	-	-
		Hriangtlang	-	+	-	+	-	-	+	-	-	+	-	-	-	+	-	-	+	+	-	-
		Buangpui	-	-	-	+	-	-	+	-	-	+	-	-	+	+	+	+	+	+	-	-
		Thinglian	-	-	-	+	-	-	+	+	-	+	+	+	-	+	+	-	+	+	+	-
		New Vervek	-	+	+	+	-	+	+	-	-	+	+	-	-	+	+	+	+	-	-	-

Note: (-) indicates absence and (+) indicates presence [1. Phar *(Arundinaria callosa),* 2. Rua *(Bambusa arundinacea),* 3. Rawte/Chalte *(Bambusa khasiana),* 4. Rawthing *(Bambusa tulda),* 5. Talan *(Bambusa oliveriana)*, 6. Vairua/Vaimau *(Bambusa vulgaris)*, 7. Rawnal *(Dendrocalamus longispathus)*, 8. Rawngal *(Cephalostachyum fuchsianum)*, 9. Rawpui *(Dendrocalamus giganteus)*, 10. Phulrua *(Dendrocalamus hamiltonii)*, 11. Rawlak *(Dendrocalamus hookeri)*, 12. Rawmi *(Dendrocalamus sikkimensis)*, 13. Tursing *(Dendrocalamus strictus)*, 14. Mautak *(Melocanna baccifera)*, 15 Sairil *(Melocalamus compactiflorus)*, 16. Rawthla *(Neohouzeaua dullooa)*, 17. Chal *(Pseudostachyum polymorphum)*, 18. Lik *(Chimonobambusa khasiana)*, 19. Rawthing Chi *(Bambusa longispiculata)* and 20. Rawnal *(Cephalostachyum capitatum)*]
**Latitude and Longitude : AIZAWL (23°20'0"-24°25'0" N, 93°15'0"- 92°35'0" E); KOLASIB (23°50'0"-24°30'0" N, 92°30'0"-93°55'0" E); MAMIT (23°15'0"-24°10'0" N, 92°10'0"- 93°45'0" E); CHAMPHAI (3°00'0-24°05'0" N, 92°55'0"-93°35'0" E); and SERCHHIP (22°55'0"-23°40'0" N, 92°40'0"-93°10'0" E).

(1) **Mizo name: Phar** (Photoplate 1)
Arundinaria callosa Munro, Trans. Linn. Soc. Lond. 26:30, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:11, 1896; Blatter J. Bombay Nat. His. Soc. 33:900, 1930; *Chimonobambusa callosa* (Munro) Nakai, J. Arn. Arb. 6:151, 1925; Bor, Fl. Assam, 5:46, 1940 & Bahadur, Ind. J. For. 2:237, 1979.

Distribution: Native to northeastern states of India distributed (maximum growing stock) in Aibawk & Darlawn Block of Aizawl district and Thigsul & Thliah block of Champhai district.

Habitat: Prefers northern and western aspects, moist localities, light demander.

Taxonomic notes: Small (up to 7 m tall and 2.5 cm diameter) thorny culm, nodes swollen, subtended by a ring formed by the base of the fallen sheaths, fringed with soft brown hairs and studded with short thick conical spines. Culm-sheaths (15 by 7 cm), striate, thin, yellowish covered with bulbous based hairs on the surface especially dense towards the base, imperfect blade (2 cm long), striate, subulate, decurrent on the sheath, ligule short up to 2 mm, fimbriate. Leaves (20 by 3 cm), oblong-lanceolate, scabrous on the ventral surface, tip acute, leaf sheath striate, scabrous ciliate on the edge, ending into a callus with short ciliae and a few long bristles, ligule short, hairy, fimbriate. Flowers and fruit not seen during study period.

Uses: Small farm implements, tying and thatch making.

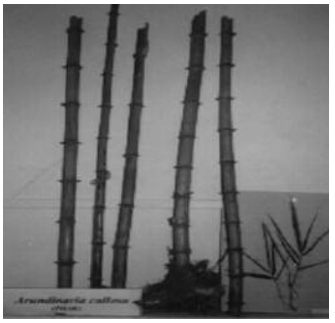
(2) **Mizo name: Rua** (Photoplate 1)
Bambusa arundinacea (Retz) Gamble, Ann. Roy. Bot. Gard. Cal. 7:51, pl.48,1896; Munro, Trans. Linn. Soc. Lond. 26:103, 1868; Hooker, Fl. Brit. India. 7:395, 1897 and Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6 1(2), 1980 (New name: *Bambusa bambos*)
Distribution: all districts.
Habitat: Prefers lower altitude, northern aspect most preferred, light demander.
Taxonomic Notes: Deciduous, culm 15-18m tall, 12-14 cm diameter, shiny green, thick walled, branches arranged alternately in dense clusters with spines. Culm-sheath: rounded top, coriaceous, covered with dark-brown hairs margin with white cilia. Leaves lanceolate, a few long hairs at the base. 13-15 x 15-25 cm in size. Flowers and fruit not seen during study period.
Uses: Commercial species in plains of India, used for construction, household goods, paper industry.

(3) **Mizo name: Rawte/ Chalte** (Photoplate 1)
Bambusa khasiana Munro, Trans. Linn. Soc. Lond. 26:97, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:39.1896; Hooker; Fl. Brit. India. 7:390, 1897; Bor., Fl. Assam 5:31, 1940 and Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980.
Distribution: Native to northeastern states of India, sporadic presence recorded in all districts.
Habitat: Prefers gentle slope, moderate light demander, grows even on degraded land.
Taxonomic Notes: Evergreen, culm small 6-8 m tall, culm emerges from creeping rhizomes, thin walled, internodes up to 15-25 cm. Culm sheath striate, covered with dense hairs, 10-12 x 8-12 cm in size, short lingual. Leaves lanceolate, rounded at the base in to a short petiole, leaf sheath shiny. Flowers and fruit not seen during study period.
Uses: Thatching purpose, household goods and basket making.

(4) **Mizo name: Rawthing** (Photoplate 1)
Bambusa tulda Roxb., Fl. Ind. 2: 103, 1832; Munro, Trans. Linn. Soc. Lond. 26:91, 1868; Kurz, For. Fl. Brit. Burma, 2:552, 1877; Gamble, Ann. Roy. Bot. Gard. Cal. 7:30, 1896; Hooker, Fl. Brit. India. 7:387, 1897; Brandis, Indian Trees, 668, 1906; Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980; Bennet and Gaur, Thirty Seven Bamboos, 41, 1990.
Distribution: Native in northeastern states of India and neighbouring countries Myanmar, Thailand and Bangladesh; common in almost all blocks of Mizoram.
Habitat: Prefers northern aspect over eastern aspect on moderate slopes (50-70%), growing up to 1200 m elevation.
Taxonomic Notes: A large evergreen or deciduous bamboo with green (young culm) to grayish-green (mature culm), usually 15-20 m tall and 7-12 cm in diameter, nodes with fibrous roots, internodes 30-60 cm, thin walled. Culm sheaths about 20-25 cm long, broad, adaxial surface with whitish powder and abaxial surface covered with oppressed light brown hairs, top rounded, blade triangular remiform, cuspidate with hair. Leaves 15-22 by 1-3 cm, lanceolate, apex acuminate, obliquely rounded base into a short hairy petiole; leaf-sheath, striate, shining, small ligule, auricle round in shape, border fringed with long white hairs. Flowers and fruit not seen during the study period.
Uses: Young shoots as vegetables & pickles, toys, mats, furniture and paper industry.

(5) **Mizo name: Talan** (Photoplate 1)
Bambusa oliveriana Gamble, Ann. Roy. Bot. Gard. Cal. 7:130, 1896; Brandis, Indian Trees 670, 1906; Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6 (1):2, 1980; Bennet and Gaur, Thirty Seven Bamboos, 31, 1990.
Distribution: Native to Myanmar and Mizoram (India), presence recorded only in Aizawl district, a few clumps in Kolasib districts.
Habitat: Prefers higher altitude, light demander, poor fire resistance.

Photoplate 1

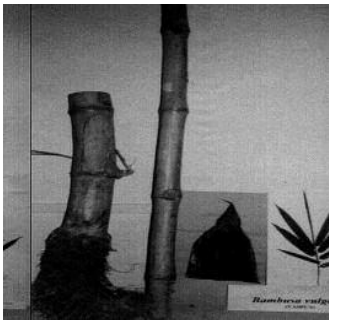


1. Phar *(Arundinaria callosa)*

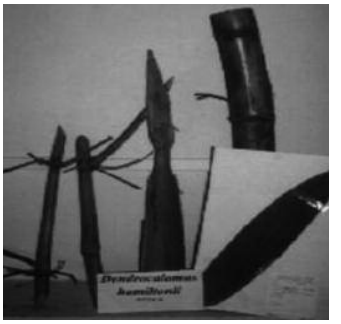
5. Talan *(Bambusa oliveriana)*

9. Rawpui
(Dendrocalamus giganteus)

2. Rua *(Bambusa arundinacea)*



6. Vairua *(Bambusa vulgaris)*



10. Phulrua
(Dendrocalamus hamiltonii)

3.Rawte/Chalte
(Bambusa khasiana)

7. Rawnal
(Dendrocalamus longispathus)

11. Rawlak
(Dendrocalamus hookeri)

4. Rawthing *(Bambusa tulda)*

8. Rawngal
(Cephalostachyum fuchsianum)

12. Rawmi
(Dendrocalamus sikkimensis)

Taxonomic Notes: Culm 12-18 m high, up to 6 cm in diameter, bright shining green, very thick walled, internodes 25-40 cm long, branches appear from the base and upwards. Culm-sheaths 20-27 x 8-15 cm, hairy in the young stage, both sides glabrous, ligule up to 4mm high, serrate, blade 12-20 x 6-9 cm, triangular-lanceolate, cordate at the base, brown hair scarred on both sides. Leaves – linear, 8-16 x 1-1.5 cm, with twisted long needle at the end point, rounded at the base in to a short (1.5-2 mm) petiole, leaf sheath glabrous, striate. Flowers and fruit not seen during the study period.

Uses: Thatching of houses, toys, furniture farm implements, mats etc.

(6) **Mizo name: Vairua /Vaimau** (Photoplate 1)
Bambusa vulgaris Schrader ex Wendl. Munro, Trans. Linn. Soc. Lond. 26:106, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:43, 1896; Brandis, Indian Trees 670,1906; Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980; Bennet and Gaur, Thirty Seven Bamboos, 43, 1990.

Distribution: Common in northeastern states of India, sporadically distributed in Aizawl and Kolasib districts.

Habitat: Prefers shady pockets, rare in southern aspect at higher altitude.

Taxonomic Notes: Culm of moderate size, 10-15 m tall, 4-9 cm in diameter, young culm green and matured yellowish, thick walled, branches appear from the mid culm and upward, nodes very prominent, covered with brown hairs; lower nodes with a ring of roots, internodes up to 40 cm long. Culm sheath 15-30 x 15-40 cm rounded and truncate at top, adaxial surface covered with dense thick oppressed brownish-black hairs, edge ciliate, ligule 5-8 mm, continuous with the top of the sheath, dentate, margin with cilia, auricle-2 subequal continuous with the blade, leaves lanceolate, 12-22 x 1.5-3 cm, rounded at the back, shining surface, hairs on the lower surface of young leaves. Flowers and fruits not seen during study period.

Uses: Basket, mat, etc.

(7) Mizo name: Rawnal (Photoplate 1)
Dendrocalamus longispathus Kurz, For. Fl. Brit. Burma 2:561, 1877; Gamble, Ann. Roy. Bot. Gard. Cal. 7:89, 1896 and Bennet and Gaur, Thirty Seven Bamboos, 57, 1990.

Distribution: Native to Mizoram, presence recorded in all districts of Mizoram.

Habitat: 40-70 percent slope is most preferred. Prefers northern and western aspects.

Taxonomic Notes: A large, tufted bamboo with culms 12-20 m tall, shining green (young culm) to grayish-green (mature culm), roots on the lower nodes, internodes 20-55 cm long, 5-12 cm in diameter, thick walled. Culm-sheaths 30-45 x 10-25 cm, outer surface covered with stiff-dark brown hairs in patches and inner surface glabrous, ligule broad, serrate, auricle abscent,blade lanceolate-acuminate. Leaves 8-30 x 1.5- 4 cm, linear-lanceolate, acuminate, rough margin, ciliate, covered with brownish pubescence. Flower and fruit not seen during the study period.

Uses: Young shoots as vegetables, basket making and paper industry.

(8) **Mizo name: Rawngal** (Photoplate 1)
Cephalostachyum fuchsianum Gamble, Syn. *Schizostachyum fuchsianum* Gamble, Ann. Roy. Bot. Gard. Cal. 7:107, 1896; Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980.

Distribution: Native to northeastern states, sporadic presence recorded in seven villages of Aizawl district and one village each in Serchip, Mamit and Kolasib district of Mizoram.

Habitat: Prefers open condition, can withstand fire and degraded edaphic conditions.

Taxonomic Notes: Culm 4-6 m, palish-green, thin walled, internodes grayish, vertical branching, internodes up to 1m and diameter 4-8 cm. Culm sheaths 25 x 10 cm, rounded at the top, edge reticulately veined, long-bristly fringed sinus, covered on the back with appressed light brown pubescence, ligule small. Leaves 10-34 x

Photoplate 2

13. Tursing
(Dendrocalamus strictus)

17. Chal
(Pseudostachyum polymorphum)

21. Bamboo shoots in the Kolasiv market (Mizoram)

14. Mautak
(Melocanna baccifera)

18. Lik
(Chimonobambusa khasiana)

22. Young shoots of *Melocanna baccifera* for vegetable

15 Sairil
(Melocalamus compactiflorus)

19. Rawthing Chi
(Bambusa longispiculata)

23 Shoots of *Dendrocalamus hamiltonii* for vegetable

16. Rawthla
(Neohouzeaua dullooa)

20. Rawnal
(Cephalostachyum capitatum)

4-10 cm, ovate-lanceolate, long petiole angled at the base, cuspidately acuminate, ending in a scabrous twisted point; shining surfaces, margin scabrous, sheath dark green, ciliate edge, ending in a round callus and produced at top in to an elongated auricle, covered with white bristles, ligule long. Flower and fruit not seen during study period.

Uses: Basket making and household goods.

(9) **Mizo name:Rawpui** (Photoplate 1)

Dendrocalamus giganteus Munro, Trans. Linn. Soc. Lond. 26:150, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:87, 1896; Brandis, Indian Trees 678, 1906; Bennet and Gaur, Thirty Seven Bamboos, 53, 1990.

Distribution: It is native to Myanmar, recorded sporadic distribution in Palsang and Mauchar villages of Aizawl district and in the Myanmar border of Mizoram.

Habitat: light demander, need moist edaphic condition for luxurious growth.

Taxonomic Notes: Largest sized, generally deciduous, usually thick walled, culm dull green, covered with white waxy crust in young stage. The culm sheaths are 30-50 cm long and broad, ligule 8-13 mm high, dark, serrate, auricles prominent brown, blade 13-38 cm long and up to 8 cm broad, acuminate. Leaves vary in size, oblique, oblong, acuminate, smooth above and hairy beneath, petiole 3-5 mm long, ligule 2-3 mm high, auricle small glabrous. Flowers and fruit not seen during study period.

Uses: Decorative pots, house construction, young shoots as vegetables,

(10) **Mizo name: Phulrua** (Photoplate 1)

Dendrocalamus hamiltonii Nees & Arn. ex Munro, Trans. Linn. Soc. Lond. 26:151, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:84, 1896; Hooker, Fl. Brit. India.7:40, 1897 and Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1): 3, 1980.

Distribution: Native to the northeastern states, common in Mizoram.

Habitat: Northern aspect most preferred, maximum density noted in slope range 70-100 percent, preferred altitudinal range of distribution 200 to 900 m, light demander. It is an early succession species in Jhum land.

Taxonomic Notes: A large tufted bamboo with erect culms or curved downwards, thin walled, culms large up to 20-22 m tall, 10-20 cm in diameter, thick branches in the upper portion of culm, grayish-white with dense appressed pubescence in young and dull green when mature, internodes 30-50 cm. Culm sheaths variable in size, glabrous, shining within with scanty patches of stiff brown hairs on outer side, truncate at the top, imperfect blade about 3/4 the length of the sheath, often 30 cm long, ovate-lanceolate, sides incurved, glabrous on outer surface closely covered with black hairs at he base of the inner surface, ligule smooth, entire. Leaves small on side branches, but on new shoots reaching 37.5 x 3.75 cm, rounded at the base into a short thick petiole, broadly lanceolate, ending in an acuminate scabrous twisted point, smooth above, rough beneath, serrate on the margin, leaf sheaths covered with white oppressed stiff hairs on outer surface glabrous inside, shining on the callus, ligule long, oblique, truncate. Flower and fruit not seen during the study period.

Uses: Young shoots as vegetables, basket making, house construction etc.

(11) **Mizo name: Rawlak** (Photoplate 1)

Dendrocalamus hookeri Munro, Trans. Linn. Soc. Lond. 26:151, 1868; Gamble, Ann. Roy. Bot. Gard. Cal.7:83, 1896; Brandis, Indian Trees, 677, 1906; and Bennet and Gaur, Thirty Seven Bamboos, 55, 1990.

Distribution: Sporadic distribution in Darlawn Block of Aizawl district and Saiphum and North Hlimen villages of Kolasib district.

Habitat: Moderate light demander, prefers moist locality with gentle slope.

Taxonomic Notes: Culm 12-18 m tall, 10-15 cm in diameter, internodes 35-50 cm long, rough hairy, thick walled, dark green, young shoots covered with black tomentose. Culm sheaths 20-30 cm long,

broad at the base, sheath of upper nodes narrower, clothed with blackish-brown hairs outside, glabrous inside, ligule 5-8 mm high, glabrous, seriate, auricles 2, small rounded with long stiff ciliae, blade 8-18 cm long. Leaves large, oblong-lanceolate, with a long acuminate tip, smooth above and rough below, hairs scattered near the base, scabrous on the margin, base oblique and rounded, short stalked, leaf-sheath striate. Flowers and fruit not seen during study period.

Uses: House construction, basket, rhizome to make toys/decorative pieces.

(12) **Mizo name: Rawmi** (Photoplate 1)

Dendrocalamus sikkimensis Gamble ex Oliver, Ann. Roy. Bot. Gard. Cal. 7:82, 1896; Hooker, Fl. Brit, India 7:405, 1897 and Varmah and Bahadur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980.

Distribution: Maximum sporadic distribution in Aizawl district of Mizoram. Also present in other north-eastern states.

Habitat: Light demander, prefers gentle slopes, fire resistant.

Taxonomic Notes: A large bamboo, culms 17-20 m high, 12-20 cm in diameter. Culm dark green, internodes up to 55 cm long, rough. Culm sheaths 36 x 30 cm covered with golden brown hairs, imperfect blade lanceolate, as long as the sheath, recurved, decurrent into two auricles fringed with pale bristles, ligule 5 mm wide, sharply serrate. Leaves 15-25 x 3-5 cm, oblong-lanceolate, unequal at the base, tapering into twisted point, smooth above, hirsute and rough below. Leaf sheaths smooth, auricle fringed with stiff bristles, ligule short, fimbriate. Flowers and fruit not seen during study period.

Uses: House construction, fencing.

(13) **Mizo name:** Tursing (Photoplate 2)

Dendrocalamus strictus (Roxb.) Nees, Linnaea 9:476, 1834; Munro, Trans. Linn. Soc. Lond. 26:147, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:78, 1896; Hooker., Fl. Brit.India.7: 404, 1897; Camus, Les Bambusees 152, 1913; Bennet and Gauar, Thirty Seven Bamboos, 61, 1990.

Distribution: Sporadic distribution in Darlawn, Aibawk and Reiek Block of Aizawl district. Very rare in other districts of Mizoram.

Habitat: Light demander, prefers nutrients and moisture, rich edaphic conditions, in moist localities tends to be evergreen.

Taxonomic Notes: It is a medium sized, densely tufted bamboo with strong thick walled culms varying in size according to the edaphic and climatic conditions. Solid culms are not recorded in Mizoram. The culm varies in size (8-15m tall and 2 to 8 cm in diameter), greenish blue when young and turn yellow at the time of maturity. Culm sheaths variable, lower ones shorter with golden-brown stiff hairs on the back, rounded at the tip, margin hairy, ligule 2-3 mm high, toothed, auricle small blade triangular, hairy on both sides. Leaves linear-lanceolate, rounded at the base in to a short petiole, tip sharply acuminate with twisted point, ligule very short. Flowers and fruit not seen during study period.

Uses: Construction purposes, raw materials for paper industry. The rhizomes are used for making decorative pieces.

(14) **Mizo name: Mautak** (Photoplate 2)

Melocanna baccifera (Roxb.) Kurz, Prelim. Report Fl. Pegu, Append, B. 1875; Tiwari, 104:1992.

Distribution: Abundant throughout Mizoram and other northeastern states of India.

Habitat: The rhizome spreads and colonizes areas easily in the barren degraded hills; maximum density in eastern aspect; prefers slopes ranging 50-80 percent; maximum diversity in height at altitudinal range 300 to 600 m; fire resistant.

Taxonomic Notes: An arborescent bamboo (culms up to 21 m tall and 10 cm diameter) arising singly from horizontal creeping rhizomes at intervals of 25 to 75 cm. Culms are straight, thin walled and strong, branches arise from the top 1/3rd of the culm. Culm sheaths 10-15cm long, yellowish green when young and yellowish-

brown when old, truncate at top, glabrous, ligule very short with undulated or toothed margin, auricles small, subequal, membranaceous, fringed with silvery bristles, blade deciduous, usually 15-30 cm long and 2-3 cm broad. Leaves 15-30 cm long, 2-5 cm broad, oblong-lanceolate, apex acuminate, base oblique, adaxial surface glabrous, abaxial surface glabrous or sparsely pubescent, margin ciliate; leaf-sheath thick, ligulate, auricles very small, with silvery bristles. Flowers in large panicles of drooping branches with clustered spikelets, fruits (caryopsis) pyriform, fleshy edible. The periodic flowering and fruiting recorded at the interval of 48 years in Mizoram. The sporadic flowering and fruiting is recorded in 2001 in the month of May-June near Mizoram University (Aizawl), Kolasib and Sihphir village of Kolasib districts. Gregarious flowering recorded in 2007.

Uses: Young shoots are largely eaten as vegetable or food- curry cooked with preserved fat (Sah-bawl); mature culms for building houses, paper pulp, mature rhizomes for tool handles and decoration of drawing room. Secretes siliceous secretion used as medicine known as tabashir.

(15) **Mizo name: Sairil** (Photoplate 2)

Dinochloa compactiflora (Kurz) Mc Clure, Kew Bull. 253, 1937; Bennet & Van Vigyan 27, 2:120, 1989. Syn. *Melocalamus compactiflorus* (Kurz) Benth. and Hook., F. Gen. Pl. 3, 1212, 1883; Gamble, Ann.Roy. Bot. Gard. Cal. 7:94, 1896 and Bahadur and Naithani, Ind. For. 109:266, 1983.

Distribution: Assam and Mizoram state of India

Habitat: Shade lover; also grows along with cane; prefers moist locality.

Taxonomic Notes: A handsome climbing bamboo, arching over tall trees. Culms solid, grayish green, rough scandent, 10-33 m long and 1.2-2.5 cm in diameter, nodes very thick (swollen), internodes up to 60 cm long. Culm sheaths about 15 cm long and 8 cm broad, cylindrical, covered with white appressed hairs, blade more or less equal to the length of the sheath, long-acuminate, rounded at the base auricle narrow, dark, crescent-shaped. Ligule narrow. Leaves 15-25 x 2-5cm oblong-lanceolate, subulate towards apex ending into twisted point, base rounded, petiole 3-5 mm long and hairy, leaf sheath striate with appressed white hairs when young, glabrous with maturity, ligule very small, entire, auricle lunate, fringed with stiff bristles. Flowers and fruit not seen during the study period.

Uses: Fibers used in furniture works, culm skin is scraped off and applied externally on cuts, sap of cut stem to cure cough and chest complains.

(16) **Mizo name: Rawthla** (Photoplate 2)

Neohouzeoua dullooa (Gamble) A. Camus. [*Schizostachyum dulloa* (Gamble) Gamble], Ann. Roy. Bot. Gard. Cal. 7:101. Pl. 89, 1896 and Kanjilal, Flora of Assam, Del., 5:21, 1997.

Distribution: Native to North-eastern states of India. Sparse distribution in all districts of Mizoram.

Habitat: Moderate light demander; can be grown on degraded soil.

Taxonomic Notes: Moderate to large sized bamboo (6-10 m tall and 3-8 cm in diameter), dark green with a few white hairs, node prominent, internodes 40-75 cm or even more, thin walled. Culm sheaths 10-30 x 10-25 cm, striate with white oppressed hairs, rounded at the top and then concavely truncate and loosely fringed with bristles, imperfect blade, recurve, hairy within, edge convolute 7-16 x 7 -2 cm, ligule long fimbriate. Leaves oblong-lanceolate, acuminate, rounded unequally at the base, petiole 5-10 mm long, rough on the upper surface and glabrous beneath, edge scabrous, sheath striate, ciliate on the edges, ligule broad, long-fimbriate. Flowers and fruit not seen during study period..

Uses: Mats and basket making.

(17) **Mizo name: Chal** (Photoplate 2)
Pseudostachyum polymorphum Munro, Trans. Linn. Soc. Lond. 26: 142, 1868 and Gamble, Ann. Roy. Bot. Gard. Cal. 7: 96, 1896.
Distribution: Native to northeastern states, Myanmar and Bhutan. Presence noted in all districts of Mizoram.
Habitat: Prefers shady and moderate slope; grows better in northern aspect.
Taxonomic Notes: Bamboo with single culms from a long creeping, jointed rhizome. Culms 10-20 m tall, thickwalled, 3-4 cm in diameter, internodes 20-25 cm long, glaucous in the beginning, afterwards dark green. Culm sheaths smaller than internodes, triangular, truncate in outline, auricle with a tuft of short bristles, imperfect blade long-acuminate on the young culms, striate, ligule short, dentate. Leaves 10-20 x 2-6 cm, oblong-lanceolate, unequally rounded at the base into a short petiole, alternate at the top into a long twisted point, smooth on both surfaces, scabrid on one margin, sheaths faintly white-pubescent, ligule short. Flower and fruit not seen during study period.
Uses: Basket and mat making.

(18) **Mizo name: Lik** (Photoplate 2)
Chimonobambusa khasiana (Munro) Nakai, J. Arn., Arb. 6:151, 1925; Varmah and Bahadhur, Ind. For. Rec. 6 (i): 1, 1980 and Varmah and Pant, Ind. For. 107: 672, 1981.
Distribution: Native to north eastern states of India; recorded sporadic presence in all districts of Mizoram
Habitat: Moderate light demander, prefers moderate slope and moist locality.
Taxonomic Notes: A slender bushy bamboo. Culms up to 4 m tall and 2-4 cm in diameter, smooth dark green in young and blackish in mature culms, internodes up to 20 cm long, striate, node prominent, having a ring formed by the persistent base of the fallen sheath, branchlets many, fasciculate. Culm-sheaths up to 20 cm long papery, straw colored, striate, tapering concavely upwards into a narrow tip, imperfect blade 2- 2.5cm long, subulate, recurved, ligule up to 0.5 cm dentate. Leaves 8-10 x 1-1.4 cm, linear-lanceolate, alternate at the base into a very short petiole, tip acuminate. Flower and fruit not seen during study period.
Uses: Fuel wood, thatching, small tools.

(19) **Mizo name: Rawthing Chi** (Photoplate 2)
Bambusa longispiculata Gamble ex Brandis, Indian trees: 668, 1906; Camus, Les Bambusées: 116, 1913; Varmah and Bahadhur, Ind. For. Rec. (n.s.) Bot. (1):2, 1980. Bennet and Gaur, Thirty Seven Bamboos, 25, 1990.
Distribution: Native to Mizoram in India, Myanmar and Bangladesh. Rare, sporadic presence in all districts of Mizoram.
Habitat: Prefers well drained soil; light demander.
Taxonomic Notes: Moderate sized green culms, 12-15 m tall and 7-12 cm in diameter; nodes slightly thickened with a circular band of white pubescence above, internodes 25 to 60 cm long. Culm-sheaths deciduous, 16-25 x 16-30cm, covered with brownish-black appressed hairs, blade broadly triangular, cordate, erect and hairy within. Ligule 4 mm high, entire or lacerate, ciliate; auricles unequal falcate, with bristles. Leaves 18-30 x 2.5-6.5 cm, linear-oblong, glabrous above, whitish below. Flower and fruit not seen during study period.
Uses: Baskets making, thatching purpose, fence etc.

(20) **Mizo name: Rawnal** (Photoplate 2)
Cephalostachyum capitatum Munro, Syn. *Schizostachyum capitatum* Munro, Trans. Linn. Soc. Lond. 26: 139, 1868; Gamble, Ann. Roy. Bot. Gard. Cal. 7:104. Pl. 91. 1896; Camus, Les Bambusées, 165, 1913; Varmah and Bahadhur, Indian For. Rec. (n.s.) Bot. 6(1):2, 1980.
Distribution: Very rare, recorded presence in Saithah village of Mamit district of Mizoram.
Habitat: Moderate light demander, prefers moderate slope and well-drained soil.

Taxonomic Notes: A shrubby of sub-arborescent, semi-scandent bamboo. Green or yellowish green culms 4-7 m long, nodes not prominent, internodes up to 1m long and 2-3 cm in diameter, thin walled (5-8mm). Culm sheaths 15-30 x 5-8 cm, papyraceous towards the top on young culms covered on the back with pale brown pubescence, imperfect blade long, erect or recurved, covered with white hairs, ligule narrow and serrate. Leaves 10-20 x 2.5 to 5 cm, pale-green, whitish beneath, glabrous on both surfaces, margin scabrid, sheaths glabrous, shining, fimbriate in the throat with long cadacous hairs, ligule short. Flower and fruit not seen during study period.
Uses: Fencing, rhizome to make decorative pieces.

2. Impact of altitude, slope percent and aspect on density and growth performance of *Melocanna baccifera, Dendrocalamus hamiltonii, Dendrocalamus longispathus* and *Bambusa tulda* in natural habitat

Earlier Jha and Laha (2002) have studied population change of *Melocanna baccifera*, *Dendrocalamus hamiltonii*, and *Dendrocalamus longispathus* under different fallow periods in Mizoram. In the present findings growth performance of four major bamboo species at different topographical variables are presented in Tables 2 to 5.

Average height, diameter and length of internodes are recorded highest on the northern aspect followed by western slope and least on the southern slope. *Melocanna baccifera* shows maximum density on the eastern aspect and *Dendrocalamus hamiltonii*, *Dendrocalamus longispathus* and *Bambusa tulda* on the northern aspect (Table 2). Impact of slope on the various growth attributes is presented in Table 3. The maximum density of *Melocanna baccifera*, *D. longispathus* and *B. tulda* was recorded on a slope range of 50-70 percent whereas in case of *D. hamiltonii* maximum density was recorded at a slope range 70-120 percent. Growth performance of *D. hamiltonii* was minimum at a slope range of 25-50 percent whereas in case of *M. baccifera, D. longispathus* and *B. tulda* slope range of 70-120 percent shows minimum average height of culm.

Table 2. Effect of aspects on density, height, diameter and length of internodes

Attributes	Species	Aspects				Overall Mean
		West	East	North	South	
Average no. of culms (density)	*M. baccifera*	09.7(2.6)	17(2.24)	09.8(3.18)	09.68(3.07)	10.23(2.98)
	D. hamiltonii	21.7(3.6)	18.5(3.2)	22.8(3.8)	16.6(3.1)	20.7(3.6)
	D. longispathus	30.7(4.1)	32.7(4.2)	36.6(4.1)	21.03(3.12)	30.5(4.1)
	B. tulda	27.3(3.9)	20.3(3.4)	32.6(4.1)	16.6(2.8)	24.13(3.6)
Average Height of culms (cm)	*M. baccifera*	09.0(2.5)	08.86(2.6)	10.2(3.1)	08.85(2.4)	09.26(3.1)
	D. hamiltonii	19.6(3.2)	19.5(3.1)	19.9(3.4)	19.06(3.1)	19.5(3.3)
	D. longispathus	11.07(3.1)	11.07(3.1)	10.8(2.9)	10.6(2.1)	10.84(2.8)
	B. tulda	11.13(2.6)	10.9(2.5)	11.8(2.6)	09.8(2.3)	10.9(2.3)
Average Diameter of culms (cm)	*M. baccifera*	04.2(0.5)	04.2(1.1)	04.7(0.9)	03.9(o.5)	04.25(0.9)
	D. hamiltonii	09.1(2.1)	09.4(2.5)	09.6(2.01)	08.82(2.1)	09.2(2.2)
	D. longispathus	05.17(1.3)	05.2(1.2)	05.42(1.7)	05.0(1.09)	05.2(1.3)
	B. tulda	05.0(1.2)	04.8(1.1)	05.4(1.2)	04.8(1.02)	05.0(1.1)
Average Length of Internodes (cm)	*M. baccifera*	32.3(4.1)	31.4(3.8)	32.9(4.1)	31.2(3.1)	32.0(3.1)
	D. hamiltonii	33.8(3.1)	33.7(4.3)	33.9(4.3)	33.2(4.3)	33.7(3.1)
	D. longispathus	31.7(3.1)	30.4(4.1)	33.1(4.1)	30.6(3.4)	31.4(3.2)
	B. tulda	32.6(4.1)	31.6(4.3)	34.6(4.2)	31.2(3.1)	32.6(4.1)

Note: 1. Figure without brackets are mean. 2. Figures within brackets are standard deviation

Table 3. Effect of slope percent on density, height, diameter and length of internodes

Attributes	Species	Slope percent			Overall Mean
		25-50	50-70	70-120	
Average no. of culms (density)	*M. baccifera*	09.42(2.6)	10.76(2.01)	09.67(2.62)	09.93(2.51)
	D. hamiltonii	29.5(3.51)	30.02(3.75)	32.6(4.03)	30.7(4.23)
	D. longispathus	32.43(4.02)	34.4(4.6)	33.71(4.01)	33.5(4.12)
	B. tulda	30.05(3.92)	34.21(4.71)	23.3(4.04)	29.18(4.1)
Average Height of culms (cm)	*M. baccifera*	08.7(2.02)	10.46(2.9)	08.2(2.1)	09.1(2.24)
	D. hamiltonii	18.9(3.12)	19.45(3.41)	19.32(3.7)	19.23(3.5)
	D. longispathus	11.24(3.34)	11.34(2.4)	10.91(3.1)	11.16(2.91)
	B. tulda	11.43(2.31)	11.6(2.2)	10.6(2.1)	11.21(2.03)
Average Diameter of culms (cm)	*M. baccifera*	04.34(1.2)	04.6(0.9)	04.1(0.4)	04.34(0.9)
	D. hamiltonii	09.3(2.5)	09.7(2.6)	09.6(3.1)	09.54(3.02)
	D. longispathus	05.1(1.2)	05.2(0.9)	04.9(0.5)	05.06(0.63)
	B. tulda	05.1(1.3)	05.4(0.8)	05.0(0.6)	05.16(0.7)
Average Length of Internodes (cm)	*M. baccifera*	30.1(3.91)	34.2(4.3)	31.5(4.2)	31.9(4.3)
	D. hamiltonii	33.7(4.2)	34.1(4.4)	33.9(4.48)	33.9(4.4)
	D. longispathus	33.6(4.14)	33.01(4.6)	30.5(3.5)	32.03(4.09)
	B. tulda	32.5(4.1)	32.7(4.3)	31.4(3.9)	32.2(4.1)

Table 4. Effect of altitude on density, height, diameter and length of internodes

Attributes	Species	Slope percent			Overall Mean
		300-600	600-900	900-1200	
Average no. of culms (density)	*M. baccifera*	10.9(2.3)	11.03(2.5)	8.7(2.1)	10.2(2.1)
	D. hamiltonii	21.14(3.4)	25.72(3.7)	18.5(3.0)	21.78(3.3)
	D. longispathus	29.85(3.8)	31.9(3.9)	28.0(3.4)	29.9(3.7)
	B. tulda	27.4 (3.6)	30.5(3.8)	20.6(3.1)	26.16(3.3)
Average Height of culms (m)	*M. baccifera*	10.09(2.2)	10.12(2.2)	09.4(2.0)	09.87(2.0)
	D. hamiltonii	18.39(2.9)	19.25(2.9)	18.2(2.8)	18.61(2.8)
	D. longispathus	11.07(2.5)	11.29(2.5)	10.6(2.6)	10.98(2.6)
	B. tulda	11.4(2.6)	11.51(2.7)	08.9(1.9)	10.61(2.6)
Average Diameter of culms (cm)	*M. baccifera*	04.94(1.0)	04.9(1.0)	04.1(1.0)	04.6(1.0)
	D. hamiltonii	09.6(1.9)	09.6(1.9)	08.82(1.6)	09.2(1.8)
	D. longispathus	05.4(1.2)	05.3(1.1)	05.0(1.1)	05.24(1.2)
	B. tulda	05.3(1.2)	05.4(1.1)	05.0(1.1)	05.24(1.2)
Average Length of Internodes (cm)	*M. baccifera*	33.1(3.9)	32.5(3.7)	29.4(3.5)	31.67(3.8)
	D. hamiltonii	32.05(3.8)	33.5(3.8)	30.5(3.7)	32.01(3.6)
	D. longispathus	32.9(3.9)	33.1(3.9)	30.7(3.7)	33.23(3.9)
	B. tulda	32.6(3.9)	34.2(4.0)	31.2(3.8)	32.6(3.8)

Maximum density, height and diameter of culms were recorded at an elevation of 600-900 m for all the four species whereas minimum density, height and diameter are observed at an elevation of 900-1200 m. The average length of internodes was maximum at an elevation of 600-900 for *D. hamiltonii, D. longispathus* and *B. tulda* whereas in case of *M. baccifera* average length of internodes was highest at low attitude (300-600 m). The average length of internodes is minimum at higher altitude (900-1200 m: Table-4).

All the values of correlation were found to be negative. This indicates that with increasing values of altitude as well as the increasing values of slope inclinations the various measures of growth parameters decreases. In case of altitude except the length of internodes of *D. hamiltonii,*

Table 5. Correlation values between topographical features and growth attributes

Growth attributes	Altitude				Slope inclination			
	1	2	3	4	1	2	3	4
Density	-0.31*	-0.25*	-0.34	-0.41*	-0.24*	-0.15*	-0.28*	0.29*
Height	-0.32*	-0.36*	-0.29*	-0.43*	-0.19*	-0.24*	-0.18*	-0.14
Diameter of culms	-0.34*	-0.33*	-0.31*	-0.36*	-0.23*	-0.26*	-0.21*	-0.23*
Length of Internodes	-0.21*	-0.09	-0.19*	-0.22*	-0.07	-0.12	-0.19*	-0.19*

Note: 1 = *M. baccifera*, 2 = *D. hamiltonii*, 3 = *D. longispathus*, and 4 = *B. tulda*
*indicates significant at $\alpha = 0.05$ level

all other correlations are significant at 0.05 level and in case of slope inclination the length of internodes for *M. baccifera* and *D. hamiltonii* and also the height of *B. tulda* were non-significant and all others significant (Table 5).

The effect of variations in altitude has a more pronounced effect on growth parameters, in general, than the effect of slope variation. The effect of altitude variation on the growth parameter of *B. tulda* is the highest of all species.

The findings suggest appropriate altitudinal ranges, aspect and slope ranges for plantation of major bamboo species by the farmers. The study would be of great help to the extension workers in recommending most appropriate altitude, aspect and slope range for large scale plantation of important bamboo species in Mizoram.

3. Market survey of edible bamboo shoots in Mizoram

The finding highlights the consumption pattern of edible bamboo species and percent contribution of different species in the vegetable markets (Photoplate 2: 21-23). Also social aspects like distance covered by the villagers in collection of bamboo shoots, number of families involved in respondents' village in the trade of bamboo shoots (collection and marketing), frequency of collection of bamboo shoots from the adjoining forest area etc. is taken into account.

The weekly average availability of bamboo shoots in the markets of the state is 291436 in numbers (pieces) with a standard deveiation of 8772 pieces recorded in 2000. With 95 percent confidence it can be said that the weekly average availability of bamboo shoots in the market is between 254702 and 328170.

On an average two pieces are made from a single bamboo shoot and the shoots are available in the market for about ten weeks in a year. Considering this fact the total number of bamboo shoots available in the market in the year, 2000 becomes 1457180. The consumption in Aizawl town alone is of 419535 bamboo shoots in a year.

Bamboo shoots are offered in large quantities on the markets from late June to early September every year. Prior to June and after September its availability in the markets remains much lower.

The following five bamboo species are recorded as edible bamboo species: *Melocanna baccifera* (Mautak), *Dendrocalamus longispathus* (Rawnal), *Dendrocalamus hamiltonii* (Phulrua), *Bambusa tulda* (Rawthing) and *Dendrocalamus gigantens* (Rawpui) (Table 6).

In the state of Mizoram about 1,500 vendors sell bamboo shoots in the markets, out of these about 400 come to Aizawl markets alone.

Table 6. Availability of bamboo species in village market (%)

Sl No.	Species	Percent	
		2000	2002
i	*M. baccifera*	50	54
ii	*D. longispathus*	33	32
iii	*D. hamiltonii*	15	12
iv	*B. tulda*	02	02
v	*D. giganteus*	negligible	

Table 7. Frequency of visit paid by the respondents in forests to collect young bamboo shoots for vegetables

Sl No.	Frequency	% Vendors	
		2000	2002
1	Daily	06	04
2	Twice a week	16	33
3	Thrice a week	44	21
4	Weekly	34	42
5	Total	100	100

The 2000 data indicates that 97 percent of the vendors selling bamboo shoot in the market collect it by themselves. Only 3 percent buy it from villagers and sell. However, the 2002 survey differs from the 2000 in that 88 percent vendors collect it themselves from the forests and 12 percent buy bamboo shoots from villagers and sell in the market. Thus a 9 percent increase is recorded in the supply of bamboo shoots to the venders by the villagers.

The percentage availability of species is presented in Table 6. The bamboo shoots can be preserved 3-4 days without removal of culms sheath and after removal of culms sheath immature shoots can be consumed as vegetable up to 2 -3 days.

The frequencies of visit paid by the respondents are presented in Table 7. The visits paid by the respondents in the forests in the year 2000 and 2002 to collect bamboo young shoots shows pressure over natural forests. This can be reduced by large scale plantation of edible bamboo species in the community or private land.

Distance covered in collection of bamboo shoots in comparison to the last year is presented in Table 8. Numbers of families involved in respondent villages are presented in Table 9. Mode of collection of bamboo shoots is presented in Table 10. Earlier most of the villagers used to collect shoots from the forest and the same day

Table 8. Distance covered by respondents in collection of young bamboo shoots for vegetables

Sl No.	Distance change	% Respondents	
		2000	2002
1	Less	06	08
2	Almost the same	72	68
3	More	22	27
4	Total	100	100

Table 9. Number of families involved in respondents villages in Bamboo shoots collection and marketing

Sl No.	No. of families	Frequency (%)	
		2000	2002
1	Up to 5	01	13
2	6-10	25	26
3	11-20	32	38
4	21-50	27	17
5	51-100	09	04
6	100 and more	06	02
10	Total	100	100

or next day bamboo shoots were sold in the market. The survey indicates involvement of middle men in the marketing of the shoots. This may be treated as a new trend in marketing business.

Out of the reported 20 species of bamboo, *Melocanna baccifera* (mautak) alone constitutes about 98 percent of the growing stock. As a vegetable, *M. baccifera* constitutes about 50 percent of the total bamboo shoots consumption. The consumption of the remaining 50 percent is shared by four other edible clump forming species (Table 6) which altogether constitute less than 2 percent of the bamboo growing stock in the state. Thus clump forming edible bamboo species is under great pressure. Thus, to meet the requirements of edible bamboo shoots *Dendrocalamus longispathus* (Rawnal), *Dendrocalamus hamiltonii* (Phulrua), *Bambusa tulda* (Rawthing), *Dendrocalamus giganteus* (Rawpui) should be introduced in a large scale in agro forestry or farm forestry systems on degraded Jhum land or hills.

4. Management of edible bamboo species (*Melocanna baccifera, Dendrocalamus hamiltonii, Dendrocalamus longispathus* and *Bambusa tulda*) to ensure sustain supply of mature culms as well as young culms for vegetables and eco-restoration of degraded hills

Jha & Lalramnghinglova (1995) and Jha & Lalnundanga (1998) have reported problems related to management of bamboos growing stock in Northeast India. Impact of various harvesting intensities are presented herewith (Photoplate 3-4).

Table 10. Mode of collection of bamboo shoots

Sl No.	Distance change	% Vendors	
		2000	2002
1	Buy from others	03	12
2	Bring themselves from the forests.	97	88
3	Total	100	100

(i) *Dendrocalamus longispathus (Table 11A)*

In the first year, maximum percent increase in the number of culms was observed at 50% harvesting of young culms for vegetables (49.7%) followed by 25% (45.08%) and 75% (42.1%) harvest over the control. Whereas in the second year maximum increase in number of culms was recorded at 75% harvesting intensity (54.6%) followed by 50% (37.6%) and 25% (24.6%) harvest over the control. Third year shows maximum increase in number of new culms over the control at 50% harvesting intensity (38.1%) followed by 25% (31.7%) and 75% (24.5%).

Maximum percent increase of height over control was recorded 6.09% at 25% harvesting intensity followed by, 5.9% at 50% and 4.5% at 75% harvesting intensities in the first year. In the second year maximum percent increase of height was recorded 11.5% at 25% harvesting intensity, followed by 10.1% at 50% and 9.4% at 75% harvesting intensities over control. The maximum percent increase of height was recorded 7.7% at 50% followed by 5.5% at 25% and 2.2% at 75% harvesting intensities over the control in third year.

The percent increase in diameter over the control in the first year was recorded maximum 15.7% at 50% harvesting intensity, followed by 10.5% at 75% and 5.5% at 25% harvesting intensities. In the second year diameter was recorded maximum 17.4% at 50% followed by 7.6% at 75% and 0.0% at 25% harvesting intensities over the control. The percent increase in diameter was recorded maximum 15.0% at 50% harvesting intensity followed by 10.0% at 75% and 5.0% at 25% harvesting intensities over the control in the third year

Harvesting intensities at the rate of 25, 50, and 75% have resulted 31.7, 38.1 and 24.5 percent increase in number of culms; 5.5, 7.7 and 2.2 percent increase in average height and 5.0, 15.0 and 10.0 percent increase in average diameter as compared to control (Table 11A).

Harvesting of immature shoots at 50 percent intensity produces maximum percent increase in number (38.1%), average height (7.7%) and average diameter (15.0%) of the culms. Thus, sustained production of immature shoots for vegetables and mature culms for other uses would be possible if clumps are managed at 50 percent harvesting of young culms (shoots). The culms which are left on yearly basis (50%) should be harvested 4th year onwards. Each clump will have culms of different age gradation. The adoption of above mentioned harvesting pattern for immature shoots (vegetables) and four year felling cycle for mature culms (50%

Table 11. Effect of different harvesting intensities on the number, height and diameter of bamboo. (Figures in the parenthesis indicate changes over control)

Table 11A. Species: *Dendrocalamus longispathus*

% Harvesting	% increase in no. of culms			Average Height (m)			Average Diameter (cm)		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
25%	49.3 (45.08)	50.6 (24.6)	46.4 (31.7)	8.7 (6.09)	9.2 (9.5)	9.5 (5.5)	4.01 (5.5)	3.9 (0)	4.2 (5.0)
50%	50.9 (49.7)	55.9 (37.6)	48.8 (38.1)	8.69 (5.9)	9.1 (8.3)	9.7 (7.7)	4.4 (15.7)	4.4 (12.8)	4.6 (15.0)
75%	48.3 (42.1)	62.8 (54.6)	44.1 (24.5)	8.57 (4.5)	8.9 (5.0)	9.2 (5.9)	4.2 (10.5)	4.2 (7.6)	4.4 (10.0)
Control	33.98	40.6	35.4	8.2	8.4	9.0	3.8	3.9	4.0

Photoplate 3. Few selected photos from different treatment (felling intensity) plots

[A] ***Melocanna baccifera***

Control Replication 1 (3rd year)

Replication 1 (50 % harvesting of Culms)
3rd year: Plot C-2

[B] ***D. hamiltonii***

Replication 1 (50 % harvesting of Culms)
3rd year: Plot A-6

Control Replication 1 (3rd year)
Clump No. A1

Replcation 1 (25% harvesting of Culms)
3rd year: Plot A-2

Replication 1 (50 % harvesting of Culms)
3rd year: Clump No. A3

Photoplate 4

Replication 1 (75 % harvesting of Culms)
3rd year: Clump No. A6

Replication 3 (25 % percent harvest)
3rd year: Clump No. D-4

[C] ***D. longispathus***

[D] ***Bambusa tulda***

Replication 3 (Control)
3rd year: Clump No. D-2

Replication 1 (Control)
3rd year: Clump No. A1

Replication 3 (50 % percent harvest)
3rd year: Clump No. D-6

Replication 1 (25 % percent harvest)
3rd year: Clump No. D-3

Table 11B. Species: *Dendrocalamus hamiltonii*

% Harvesting	% increase in no. of culms			Average Height (m)			Average Diameter (cm)		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
25%	45.23 (22.5)	46.8 (18.18)	39.5 (10.3)	13.3 (10.8)	12.9 (9.3)	14.5 (8.2)	9.7 (16.8)	8.1 (10.9)	9.0 (5.8)
50%	46.5 (25.9)	48.4 (22.2)	42.3 (18.1)	13.92 (15.8)	13.2 (11.5)	14.9 (11.9)	10.5 (26.5)	8.5 (16.4)	9.2 (8.2)
75%	45.7 (23.7)	48.1 (21.4)	40.5 (13.1)	14.0 (16.4)	13.6 (11.9)	15.1 (12.6)	10.6 (27.7)	8.1 (10.9)	9.1 (7.0)
Control	36.92	39.6	35.8	12.02	12.5	13.4	8.3	7.3	8.5

left out) would help in getting immature culms for vegetables and mature culms for other purposes on sustained basis. The clump would act as cover crop and will protect the steep slope from degradation.

(ii) *Dendrocalamus hamiltonii (Table 11B)*

The maximum percent increase in number of culms in the first year was observed at 50% harvesting intensity followed by 75% and 25% harvesting intensities over the control. In the second year maximum increase in number of culms was recorded at harvest intensity 50% (22.2%) followed by 75% (21.4%) and 25% (18.08%) harvesting intensities over the control.

In the third year maximum percent increase of new culms (18.1%) was recorded at 50% harvest of new culms for vegetables, followed by 75% (13.1%) and 25% (10.3%).

The maximum percent increase of height was recorded 16.4% at 75% harvesting intensity followed by 15.8% at 50% and 10.8% at 25% harvesting intensities over the control in the first year. In the second year maximum percent increase of height was recorded 11.9% at 75% harvesting intensity followed by 11.5% at 50% and 9.3% at 25% harvesting intensities over the control. Whereas, maximum percent increase of height over the control was recorded 12.6% at 75% harvesting intensity followed by 11.9% at 50% and 8.2% at 25% harvesting intensities. In the first year diameter was recorded maximum 27.7% at 75% harvest intensity followed by 26.5% at 50% and 16.8% at 25% harvest intensities over the control. In the second year maximum diameter 16.4% recorded at 50% harvest intensity followed by 10.9% at 75% and 25% harvest intensities over the control. In the third year maximum diameter was recorded 8.2% at 50% harvest intensity followed by 7.0% at 75% and 5.8% at 25% harvest intensities over the control. Maximum percent increase in number of culms and average diameter of the culms were recorded at 50 percent harvesting intensity. Maximum average height was observed at 75% harvesting intensity (Table 11B).

Table 11C. Species: *Bambusa tulda*

% Harvesting	% increase in no. of culms			Average Height (m)			Average Diameter (cm)		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
25%	48.5 (42.7)	50.6 (18.7)	46.2 (30.5)	9.12 (8.5)	8.7 (7.8)	9.1 (1.1)	4.1 (5.1)	4.5 (4.6)	4.6 (15)
50%	51.1 (50.3)	57.7 (35.4)	49.7 (40.3)	9.25 (10.5)	8.7 (8.9)	9.1 (3.3)	4.1 (10.2)	4.5 (17.4)	4.6 (27.5)
75%	51.1 (50.3)	59.4 (39.4)	48.4 (36.7)	9.06 (7.8)	8.5 (7.3)	9.3 (3.3)	4.2 (7.6)	4.6 (6.9)	4.4 (10)
Control	33.98	42.6	35.4	8.2	8.4	9.0	3.8	3.9	4.0

Thus, to maintain the sustainability of the clumps and also to get culms of greater diameter, harvesting of 50 percent young shoots (culms) for vegetables is recommended and rest (50%) need to be retained to maintain sustain supply of mature culms of the clumps. The culms left each year (50%) may be harvested at four year rotation period or cycle to maintain age gradation and sustainability of each clump.

(iii) ***Bambusa tulda (Table 11C)***

The maximum percent increase in number of culms in the first year was observed 50.3% at 50 and 75% harvest intensities followed by 42.7% at 25% harvest over the control. Whereas maximum increase in number of culms (39.4%) was recorded at 75% harvest intensity followed by 35.4% at 50% and 18.7% at 25% harvest over the control in the second year. In the third year, maximum increase (40.3%) was recorded at 50% harvest intensity, followed by 36.7% at 75% and 30.5% at 25% harvesting intensities over the control.

The maximum percent increase of height over the control was recorded 10.5% at 50% harvesting intensity, followed by 8.5% at 25% and 7.8% at 75% harvesting intensities in the first year. In the second year maximum percent increase of height was recorded 8.9% at 50% harvesting intensity followed by 7.8% at 25% and 7.3% at 75% harvesting intensities over the control. In the third year maximum percent increase of height was recorded 3.3% at 50% and 75% harvesting intensities followed by 1.1% at 25% harvesting intensity over the control.

In the first year diameter was recorded maximum 10.2% at 50% harvesting intensity followed by 7.6% at 75% and 5.1% at 25% harvesting intensities over the control. In the second year diameter of bamboo was recorded maximum17.4% at 50% harvesting intensity followed by 6.9% at 75% and 4.6% at 25% harvest intensities over the control. In the third year percent increase in diameter was recorded maximum 27.5% at 50% harvesting intensity followed by 15.0% at 25% and 10.0% at 25% harvest intensities over the control (Table 11C). The maximum percent increase in number of culms (40.3%) and average diameter of the culms (27.5%) over the control were recorded at 50 percent harvesting intensity. Harvesting of immature shoots at 75 and 25 percent intensities gave 36.7 and 30.5 percent increase in number of culms over the control. The percent increase in average diameter at 75 and 25% harvesting intensities were recorded as 10 and 15 percent over the control. The percent increase in height over the control was recorded same at 50 and 75% harvesting intensities.

Thus, to maintain the sustainability of the clumps and also to get culms of greater diameter harvesting of 50 to 75 percent young shoots for vegetables is recommended and the rest (25 to 50 percent) need to be retained to produce mature culms on sustainable basis. The culms left each year (25 to 50%) may be harvested by introducing four year felling cycle. This pattern will help in maintaining age class in each clump.

(iv) ***Melocanna baccifera (Table 11D)***

The maximum percent increase in number of culms over the control in the first year was observed 64.6% at 50% harvesting intensity followed by 53.3% at 25% and 47.2% at 75% harvesting intensities. In the second year maximum percent increase in no. of culms (20.05%) was recorded at 50% harvest intensity followed by 18.2% at 75% and 16.4% at 25% harvesting intensities over the control. Third year showed maximum percent increase in new culms (27.4%) at 50% harvest intensity followed by 24.8% at 75% and 22.5% at 25% harvests over the control.

In the first year maximum percent increase of height was recorded 13.2% at 50% followed by 12.4% at 75% and 9.6% at 25% harvesting intensities over the control. Second year showed maximum percent increase in height 8.2% at 50% harvesting intensity followed by 8.1% at 25% and 7.5% at 75% harvesting intensities over the control. In the third year percent increase of height was recorded maximum 4.4% at 50% harvesting intensity, followed by 3.3% at 25% and 2.2% at 75% harvesting intensities over the control.

Increase in diameter was recorded maximum 4.8% at 50% followed by 2.4% at 75% and 25% harvesting intensities over the control. in the first year. In the second year diameter

increase in percent of bamboo was recorded maximum 6.4% at 75% followed by 3.8% at 50% and 2.5% at 25% harvest intensities over the control. Whereas diameter increase in percent was recorded maximum12.5% at 50% followed by 10.0% at 25% and 8.5% at 75% harvesting intensities over the control. The maximum percent increase in number of culms (27.4%) and average diameter of the culms (12.5%) over the control were recorded at 50 percent harvesting intensity. Harvesting of immature shoots (culms) at 75 and 25 percent intensities gave 18.2 and 16.4 percent increase in number of culms over the control. The percent increase in average diameter at 75 and 25% harvesting intensities was recorded 8.0 and 10.0 percent over the control. The maximum percent increase in average height (4.4%) was recorded at 50 percent harvesting intensity (Table 11D).

In order to maintain the sustainability of the stand and also to get culms of greater diameter harvesting of 50 percent young shoots (culms) for vegetables is recommended and the rest (50 percent) new culms need to be retained to produce mature culms. The culms which are left each year (50%) may be harvested in 4th year of maturity. This pattern will help in maintaining age gradation in each stand. The farmers can harvest the culms on completion of its rotation period i.e. minimum three years for selling or self consumption. *Melocanna baccifera* is a non clump forming bamboo species but contributes 50 percent share in the vegetable markets of Mizoram. Thus to maintain sustainability of the *Melocanna baccifera* stand adoption of above mentioned felling cycle and harvesting of immature shoots for vegetables at 50 percent felling intensity is suggested. However, above suggested harvesting pattern to manage *Melocanna baccifera* may not be suitable in the forest area where Mahal system is in operation to harvest only mature culms.

5. Growth performance of edible bamboo species along with crop (Bamboo based agro forestry system) to rehabilitate degraded Jhum (shifting cultivation) *land*

Earlier agro forestry systems, having bamboo as woody component along with intercrops in northeastern India are reported by Jha and Lalnunmawia (2003) and Jha et. al (2004). The results on bamboo based agro forestry system, introduced to reclaimed degraded Shifting cultivation (Jhum) land are presented herewith (Photoplate 5).

Effect of spacing on culms height and diameter of all three bamboo species were significant in the third year. It was observed that growth in height and diameter in *Dendrocalamus longispathus* was found to be the best, followed by *Dendrocalamus hamiltonii* and the least in *Bambusa tulda* (Tables 12 and 13).

Effect of spacing on the number of new culms was significant in the third year. It was observed that the numbers of culms emerged was more in 2.5 m x 2.5 m spacing. The number of new culms was more in *Bambusa tulda* followed by *Dendrocalamus longispathus* and least in *Dendrocalamus hamiltonii* (Table 14).

Effect of fertilizer (NPK) on height and diameter of bamboo was significant in the three years of the study. It was observed that

Table 11D. Species: *Melocanna baccifera*

% Harvesting	% increase in no. of culms			Average Height (m)			Average Diameter (cm)		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
25%	38.4 (53.3)	44.7 (16.4)	43.4 (22.5)	9.01 (9.6)	9.2 (8.1)	9.3 (3.3)	4.2 (2.4)	4.0 (2.5)	4.4 (10)
50%	41.5 (64.6)	46.1 (20.05)	45.1 (27.4)	9.31 (13.2)	9.25 (8.2)	9.4 (4.4)	4.3 (4.8)	4.05 (3.8)	4.5 (12.5)
75%	37.11 (47.2)	45.4 (18.2)	44.2 (24.8)	9.24 (12.4)	9.01 (7.5)	9.2 (2.2)	4.2 (2.4)	4.15 (6.4)	4.34 (8.5)
Control	25.26	38.4	35.4	8.22	8.3	8.6	4.1	3.9	4.0

Photoplate 5. Bamboo based On-farm Agroforestry Experimental Farm *(Village-Luangmual)* Mizram (India)

B. tulda grown with soyabean, 3 year, four months old (Spacing: 3m x 3m with NPK)

D. hamiltonii grown with soyabean, 3 years, six month sold (Spacing: 2.5m x 2.5m with NPK)

D. longispathus grown with soyabean, 3 years, six months old (Spacing: 2.5m x 2.5m with NPK)

D. longispathus grown with soyabean (Spacing: 3m x 3m with NPK)

the height was more in fertilized plot than in the control plot. The growth in terms of height was best in *Dendrocalamus longispathus* followed by *Dendrocalamus hamiltonii* and least in *Bambusa tulda* (Tables 12 and 14).

Effects of fertilizer on the emergence of number of new culms were significant. The number of new culms was more in fertilized plot than in unfertilized plot. The increase in number of new culms was highest in *Bambusa tulda* followed by *Dendrocalamus longispathus* and least in *Dendrocalamus hamiltonii* (Table 14).

Effect of fertilizer (NPK) was significant on the yield of soyabean (*Glycine max*) in the three years of the study. However, the effect of species and spacing on the yield of soybean was not significant in the first two years but become significant in the third year (Table 15).

The yield of soybean grown along with the bamboo was higher in the fertilized plot as compared with the control. Soybean grown

Table 12. ANOVA Table for height of bamboo under different treatments

SV	Df	1st year		2nd year		3rd year	
		MS	F-ratio	MS	F-ratio	MS	F-ratio
BLOCK	5	0.189	0.208	0.276	3.450	0.054	3.66
SPECIES	2	0.635	0.701	1.505	18.812*	2.703	182.67*
SPACING	1	0.8762	0.967	0.65	8.125	0.95	64.22*
FERTILIZER	1	7.412	8.186*	0.77	9.625*	3.509	237.11*
SPECIES x SPACING	2	0	0	1.085	13.562*	0.176	11.89*
SPECIES x FERTILIZER	2	4.87	5.378*	1.315	16.437*	0.113	7.67*
SPACING X FERTILIZER	1	0.1575	0.173	0.19	2.375	0.073	4.93
SPECIES X SPACING X FERTILIZER	2	0	0	0.49	6.125*	0.12	8.11*
ERROR	19	0.9053	-	0.08		0.014	
TOTAL	35			-			

along with *Dendrocalamus longispathus* showed the highest yield (Tables 16-18).

The results of these experiments allow us to select the optimal agroforestry systems with clump forming bamboo species as woody component and soybean as intercrops, to be introduced successfully to reclaim the degraded jhum (shifting cultivation) lands in hills of northeastern India. Farmers can stop growing intercrops after establishment of clumps. Clumps of *Dendrocalamus hamiltonii* can be managed on sustained basis by introduction of 4 year felling cycle with 50 percent felling intensity and 45 cm felling height. Similarly *Dendrocalamus longispathus* can be managed on sustainable basis in four year felling cycle by introducing felling intensities at the rate of 5 0 to 75 percent with 45 cm felling height (Laha and Jha 2008). All three bamboo species tested as woody component in agro forestry system can also be managed with the dual objective of a sustainable supply of 1) young culms for vegetables, and 2) mature culms for other purposes by introducing the harvesting and felling intensities resulting from experiment 4 in this paper.

Table 13. ANOVA Table for diameter of bamboo under different treatments

SV	Df	1st year		2nd year		3rd year	
		MS	F-ratio	MS	F-ratio	MS	F-ratio
BLOCK	5	0.95	3.812	0.8762	3.812	0.03	4.12
SPECIES	2	3.509	2.151*	7.412	8.125*	2.068	134.9*
SPACING	1	0.176	1. 252	1.23	5.625	1.065	43.8*
FERTILIZER	1	0.113	15.09*	4.87	13.562*	2.495	176.9*
SPECIES x SPACING	2	0.073	1.76	0.1575	2.437	0.201	12.21*
SPECIES x FERTILIZER	2	0.12	1.23	0.701	2.375	0.187	8.43*
SPACING X FERTILIZER	1	1.505	2.125	0.967	3.125	0.054	3.87
SPECIES X SPACING X FERTILIZER	2	0.65	3.823	1.065	2.014	0.177	9.24*
ERROR	19	0.77	0.014	2.495	0.98	0.013	-
TOTAL	35					-	-

Table 14. ANOVA Table for number of culms

SV	Df	1st year		2nd year		3rd year	
		MS	F-ratio	MS	F-ratio	MS	F-ratio
BLOCK	5	1.122	3.42	0.298	2.733	0.0397	2.06
SPECIES	2	3.452	12.37*	1.56	14.311*	1.8377	145.6*
SPACING	1	0.531	3.132	1.38	12.66*	0.763	54.73*
FERTILIZER	1	2.32	20.34*	2.03	18.623*	3.6509	199.64*
SPECIES x SPACING	2	2.049	5.43	2.36	10.825	0.1435	12.12*
SPECIES x FERTILIZER	2	2.109	2.341*	2.65	12.155*	0.1538	8.34*
SPACING X FERTILIZER	1	0.241	1.02	0.36	3.302	0.0509	4.65
SPECIES X SPACING X FERTILIZER	2	2.34	2.04	1.30	5.963	0.1283	9.092*
ERROR	19	-	-	2.08	-	0.0112	-
TOTAL	35			-			

Table 15. ANOVA Table for yield of Soyabean grown along with bamboo

SV	Df	1st year		2nd year		3rd year	
		MS	F-ratio	MS	F-ratio	MS	F-ratio
BLOCK	5	1.122	3.42	0.945	0.208	0.125	0.131
SPECIES	2	3.452	1.37	1.270	0.701	1.342	3.651*
SPACING	1	0.531	3.132	0.876	0.967	0.876	2.967*
FERTILIZER	1	2.32	4.312*	7.412	8.186*	5.412	6.111*
SPECIES x SPACING	2	2.049	1.43	0	0	0.112	0.123
SPECIES x FERTILIZER	2	2.109	2.341	4.87	5.37*	3.87	4.127*
SPACING X FERTILIZER	1	0.241	1.02	0.157	0.173	0.132	0.211
SPECIES X SPACING X FERTILIZER	2	2.34	2.04	0	0	0.122	0.323
ERROR	19	-	-	17.202	0.905		
TOTAL	35			-			

Table 16. Mean yield of soyabean grown with bamboo in the first year

Species	Treatments	Yield Kg/plot	SE+
D. hamiltonii	NPK Control	17.45 15.12	3.18
D. longispathus	NPK Control	21.60 19.3	3.76
B. tulda	NPK Control	23.50 20.22	3.92

Table 17. Yield of soyabean grown with bamboo in the second year

Species	Treatments	Yield Kg/plot	SE+
D. hamiltonii	NPK Control	15.07 11.31	3.5
D. longispathus	NPK Control	16.85 10.2	3.1
B. tulda	NPK Control	14.88 11.57	3.9

Table 18. Yield of soyabean grown with bamboo in the third year

Species	Treatments	Yield Kg/plot	SE+
D. hamiltonii	NPK Control	15.12 8.55	2.73
D. longispathus	NPK Control	18.85 11.66	2.96
B. tulda	NPK Control	153.65 9.77	2.48

ACKNOWLEDGEMENTS

Financial assistance provided by the Ministry of Environment and Forests, Government of India, to take up the project is duly acknowledged. The author thanks authorities of NEHU, Shillong and MZU, Aizawl, Mizoram (India) for providing facilities to complete the research project. The author also thanks the farmers of Mizoram state for their enthusiasm and support. Thanks to Dr. F. lalnunmawia, J.R.F and Lecturer, Dept. of Forestry, MU, Aizawl and Mrs. P. Roy, T.A and Mr. Lalhmachhuana, F.A. for their assistance in completion of research project and Prof L.N. Singh and Dr. S. Jha for their help in lay out of experimental plots and analysis of results. The author also expresses his special thanks to Prof. H. Lalramanlinghlova, Taxonomist, Mizoram University for sparing his valuable time to match the Taxonomic notes to confirm the identification of bamboo species.

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Bamboo Diversity and Utilization in Balinese Rituals at Angsri Village-Bali, Indonesia.

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ABSTRACT

Bamboo is an important resource that is abundant on the island of Bali. Bamboo is always required as an offering tool **(banten)** in Balinese rituals and is utilized in unique ways, making it difficult to identify or generalize the types of bamboo used in these ceremonies.

In order to identify and catalogue bamboo diversity, an inventory was conducted at Angsri village in 2005 through an exploration of all bamboo growth in the village. Investigation of ethno-botanical utilization of bamboos in Balinese rituals was conducted by an interview method.

Two species of bamboos, *Gigantochloa apus* **(tiing tali)** and *Dendrocalamus asper* **(tiing petung)**, were the dominant species among the seventeen identified. Thirteen were used for Balinese ethno-botany rituals, and the study identified at least fifty-five uses in Balinese ritual. Beyond its ceremonial uses, bamboo plays an important role in local economies.

Key words: Bamboo diversity, ethno-botany, Angsri village-Bali.

INTRODUCTION

The population of Bali is more than three million and about 93% are Hindu. Balinese Hinduism requires rituals in several cycles: daily, and every three , five, seven and fifteen days, monthly, six months, annually, etc. Thus, every day has an associated ritual. The Balinese rituals employ several instruments, such as **tirtha** (holy water), fire, incense, animals and plants (Suparta, 1998). Three kinds of plants used in the main Balinese rituals – coconut *(Cocos nucifera)*, banana *(Musa paradisiaca)* and bamboos. These plants are called the three pillars of Balinese culture (Eisman, 1992).

Coconut symbolizes a tree of life because all of parts can be used. Banana represents welfare. Bamboo also symbolizes welfare, with the additional meaning of safety.

Bamboo is the most important plant and is an essential offering tool **(banten)** in Balinese rituals (Arinasa and Peneng, 2006) ranging from simple to sophisticated. Its uses include simply sewing together of an offering (**semat** and **katikan**), temporary temple construction **(sanggah)**, and symbolizing the mountain **(penjor)**. It is a part of the more complex instrumental rituals (**pancak, sokasi, tempeh, katik sate** etc.), and is a central part of the most sophisticated cremation ceremony **(ngaben)**. The beautiful voice of bamboo is called **sunari** (flute-like) and is believed to connect with the God blessing the ceremony.

Photo 1. A mask dancer explaining the procession a ritual ceremony.

Photo 2. Procession a of ritual ceremony. It uses several instruments such as holy water, fire, incense, animals and plants. Three kinds of plants used in the main Balinese rituals are coconut, banana and bamboos. Bamboos are an important offering tool.

The yellow bamboos are the most important because of their use in the teeth filing **(bale gading)** and cremation (**tumpang salu** or **pengabenan**) ceremonies. Balinese Hinduism, from cutting the umbilical cord at birth to the cremation ceremony after death, revolves around bamboo (photos 3 and 9).

Bale gading is a special building made of *Bambusa vulgaris* var. striata for the teeth filing ceremony. Afterwards the structure is taken down. Every Balinese Hindu girl and boy at adolescence is obligated to have the teeth filing ceremony. This ceremony is meant to decrease carnal desire.

In the **Tumpang salu** or **Ngaben** ceremony, a human corpse is placed in a bed or divan-like building. **Tiing ampel gading** (*Bambusa vulgaris var.* striata) is always used for the main pole of **tumpang salu**. The Balinese Hindu ceremony of human corpse cremation is called **Ngaben**, while the beautiful building that carries the human corpse is called **bade** or **wadah**.

The Angsri village of Tabanan Regency has large and sacred bamboo forests (Sumantera and Peneng, 2005). The bamboos have been partially inventoried and identified. Widjaja (1994) reported that the diversity of bamboo in Indonesia is concentrated in Sumatra at the West end of the Archipelago (56 species) and becoming fewer in Sulawesi (14 species). At least 36 species of bamboos have been discovered in Bali (Arinasa and Widjaja, 2005), including 5 that are newly described (Widjaja *et al,* 2004).

The Angsri village manages its bamboo forests in a unique way: no one can cut bamboo without permission and each person follows the **adat** (traditional rules) in order to perpetuate the resource. The Angsri bamboo forest preserves the water resources essential for traditional agriculture. **Subak** is the traditional irrigation system organization in Bali that guarantees

Photo 3. Left. **A Bade (wadah)** with its bridge **(trajang wadah)** in front. Right. **Tumpang salu**, the main axis, uses yellow bamboo.

even water distribution to the paddy fields. With good management, the water resources from the 12 hectare bamboo forest can irrigate more than 25 hectares of paddy fields.

Manufacture of bamboo ethno-botanical items for Balinese rituals forms the basis for the traditional religious community's trade and can substantially augment its income.

RESEARCH METHODOLOGY

In 2005, a study to catalogue bamboo and its use in Balinese ritual was conducted in the Angsri village. The researchers explored and inventoried the village bamboo growths in both community bamboo forest and private properties. Investigations of the ethno-botanical utilization of bamboos as an offering tool were conducted through interviews.

RESULT AND DISCUSSION

A. Bamboo Inventory.

Angsri village has about 12 ha of bamboo forest and almost every family plants some kind of bamboos on a small scale. Based on this inventory, the two species of bamboos having the largest population are **tiing tali** *(Gigantochloa apus)* and **tiing petung** *(Dendrocalamus asper)*. These species are dominant among the seventeen species found in the forest and private properties. The Angsri village's bamboo diversity is much greater than that of Tegallalang village of Gianyar Regency-Bali, which has just 4 kinds of bamboo (Arinasa, 2005). *Gigantochloa* comprises the most numerous genus, (8 species), followed by *Bambusa* (4 species), *Dendrocalamus* and *Schizostachyum* (each 2 species) and *Thyrsostachys*, one species (Table 1).

Table 1. Bamboos Inventory in Angsri - Tabanan Regency

No	Latin Name	Local Name	Population	Utilization
1	*Bambusa blumeana* (J.A. & J.H. Schult.) Kurz	Tiing ori, gesing	Rare	Rare
2	*Bambusa multiplex* (Lour.) Raeusch.ex J.A. & J.H. Schult.	Tiing sudamala	Rare	Rare
3	*Bambusa vulgaris* Schrad. ex Wendl. var. striata	Tiing ampel gading	Rare	Frequent
4	*Bambusa vulgaris* Schrad. ex Wendl. var. vulgaris	Tiing ampel gadang	Frequent	Frequent
5	*Dendrocalamus asper* (Schult.) Backer ex Heyne	Tiing petung manis	Abundant	Abundant
6	*Dendrocalamus sp.*	Tiing petung abu	Frequent	Frequent
7	*Gigantochloa apus* (J.A. & J.H. Schult.) Kurz	Tiing tali	Abundant	Abundant
8	*Gigantochloa atroviolacea* Widjaja	Tiing selem	Rare	Frequent
9	*Gigantochloa hasskarliana* (Kurz) Backer ex Heyne	Tiing petung taluh	Frequent	Frequent
10	*Gigantochloa nigrociliata* (Buse) Kurz	Tiing tabah	Rare	Frequent
11	*Gigantochloa* sp. 1	Tiing jajang saru	Rare	Rare
12	*Gigantochloa* sp. 2	Tiing jajang swat	Frequent	Frequent
13	*Gigantochloa* sp. 3	Tiing jajang pusut	Rare	Rare
14	*Gigantochloa* sp. 4	Tiing jajang	Frequent	Frequent
15	*Schizostachyum brachycladum* Kurz	Buluh gading, Buluh tamblang gading	Rare	Frequent
16	*Schizostachyum lima* (Blanco) Merr.	Buluh	Frequent	Frequent
17	*Thyrsostachys siamensis* Gamble	Tiing siam	Frequent	Rare

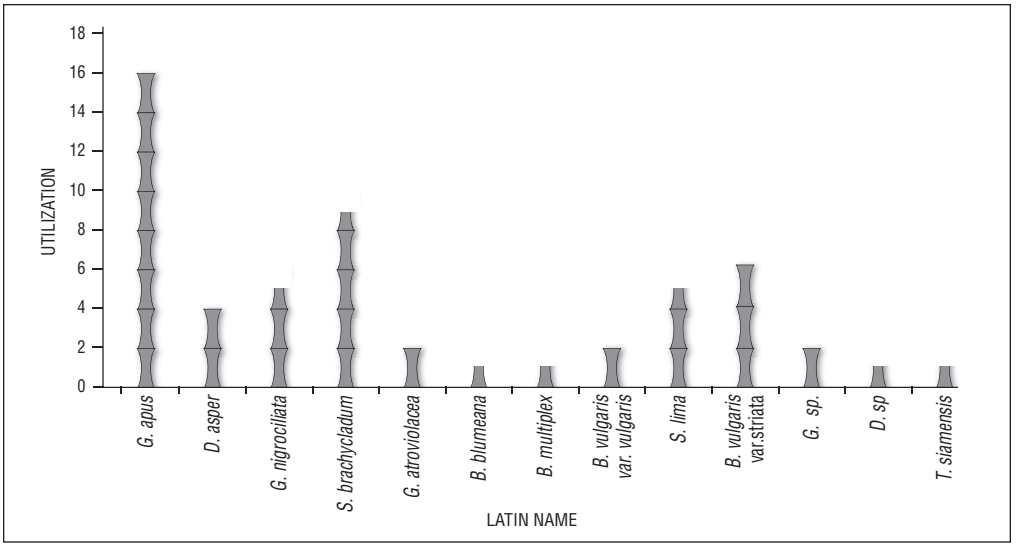

Figure 1. Bamboos utilization in Balinese rituals at Angsri Village

Tiing jajang pusut *(Gigantochloa sp. no 3)* and *tiing* **jajang saru** *(Gigantochloa sp. no 1)* populations are rare and sparingly used by local community as raw material for offerings. **Tiing tabah** *(Gigantochloa nigrociliata)* is similarly uncommon but is extensively harvested for its edible shoots and its culms, which are used both for traditional musical instruments and offering. If these rare species do not get enough attention they may become extinct.

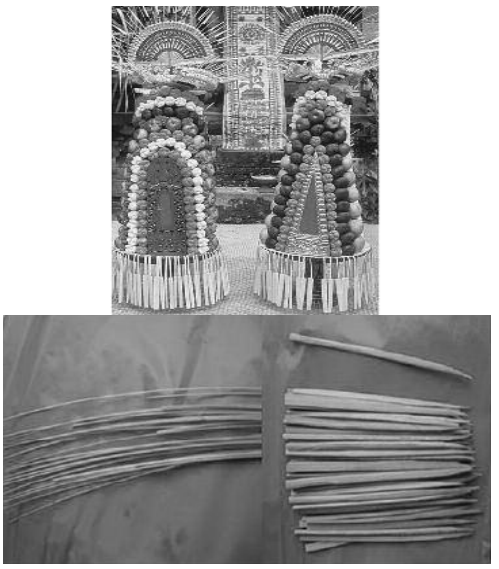

Photo 4. Top: An offering **(banten)**. Bottom left: **Semat.** Bottom right: **Katikan.** Their function is to arrange the **banten** to look beautiful.

Tiing selem *(Gigantochloa atroviolacea)*, **buluh** *(Schizostachyum lima)* and **tiing siam** *(Thyrsostachys siamensis)* are three bamboo species that were recently introduced and are only planted on private properties. These species can also be used to manufacture offerings. **Tiing selem's** black culms are also used for furniture and handicrafts. **Buluh tamblang gading's** yellow culms are employed ornamentally. The farmers have planted these intensively.

B. Utilization of Bamboos in Balinese Rituals.

Based on an interview with **Kelian Adat** (head of custom) and **tokoh masyarakat** (communities figure), thirteen of seventeen species of bamboo that grow in Angsri village are used for Balinese rituals. **Tiing tali** *(Gigantochloa apus)* is employed most extensively, with 16 distinct uses. This species is followed by **buluh tamblang gading** *(Schizostachyum brachycladum)*, **tiing ampel gading** *(Bambusa vulgaris* var. striata), **tiing tabah** *(Gigantochloa nigrociliata)* and **buluh** *(Schizostachyum lima)* with nine, six, five, and five uses, respectively. (Figure 1 and Table 2).

Semat (thread) made from smallest splitable culms of *Gigantochloa apus, Schizostachyum brachycladum* and *S. lima.* **Semat** is essential for sewing up the offerings and thus it – and the bamboos it is made from – are very important to Balinese culture.

Sanggah cucuk and **sanggah surya** are most frequently built of *Gigantochloa apus*,

Table 2. Utilization of Bamboos in Balinese Rituals at Angsri village

No.	Latin Name	Local Name	Name of artifacts	Part used
1	*Gigantochloa apus*	Tiing tali	Kuskusan Pancak Sanan bade Katik sate (asem,lilit,lembat,tusuk) Sokasi Keranjang suci Asagan Penjor Semat culm Sanggah (cucuk,surya) Katik umbul-umbul/ lelontek Ngiu/nyiru Sidi Kulit entil/pesor Bade/wadah Penimpug/kekeplugan	Split culm Split culm Culm Split culm Split culm Split culm Culm All culm Smallest split Culm tip Small culm Split culm Split culm Leaf Culm and or split culm Small culm
2	*Dendrocalamus asper*	Tiing petung	Tiang sanggah surya Tinjeh bade/wadah Trajang (jembatan bade) Bale pawedaan	Culm Culm Culm Culm
3	*Gigantochloa nigrociliata*	Tiing tabah	Katik umbul-umbul/lelontek Penjor Penjor caru mancaklud Sanggah cucuk Penimpug/kekeplugan	Culm Culm Culm tip+ leaves Culm Small culm
4	*Schizostachyum brachycladum*	Tiing tamlbang gading	Sunari Tumpang salu Katik kekenjer Penolak merana Penjor pecaruan Ngad pengerik tanah pecaruan Rsigana Penimpug/kekeplugan Semat/biting Tempat tirta	All culm Culm Twig+leaves Twig+leaves Culm tip+leaves Sharp split Culm Small culm Smallest split culm Culm
5	*Gigantochloa atroviolacea*	Tiing selem	Katik umbul-umbul/lelontek Penjor	Small culm All culm
6	*Bambusa blumeana*	Tiing ori/ ge sing	Tinjeh bade	Culm
7	*Bambusa* multiplex	Tiing sudamala	Penjor caru manca sanak	Culm tip+leaves
8	*Bambusa vulgarisvar.vulgaris*	Tiing ampel gadang	Tinjeh bade Sanan	Culm Culm
9	*Schizostachyum lima*	Tiing buluh	Suling Katik umbul-umbul/lelontek Sawen pengasih merana Tiang leluwur Semat/biting	Culm Culm Culm tip+ leaves Culm Smallest splitting culm

Table 2. Continued

No.	Latin Name	Local Name	Name of artifacts	Part used
10	*Bambusa striata*	Tiing ampel gading	Tumpang salu Bale gading Lante pangringkesan Damar kurung Tiang damar kurung Tempat tirta	Culm Culm Split culm Split culm Culm Culm
11	*Gigantochloa sp.*	Tiing jajang saru	Tinjeh bade Penjor pecaruan	Culm Culm tip+leaves
12	*Dendrocalamus sp.*	Tiing petung abu	Tinjeh bade	Culm
13	*Thyrsostachys siamensis*	Tiing siam	Umbul-umbul/lelontek	All culm

although other types of bamboo can be used as well. **Sanggah cucuk** is a temporary temple constructed to make an offering for **bhuta-kala** and is built of a single culm-tip. **Sanggah surya** is also a temporary temple symbolizing the Sun God's palace and is made of four culms.

For making a **bade** or **wadah** (beautiful place of cremation), on the other hand, most people use **tiing tali**. *Gigantochloa apus* is one of the most important bamboos in this village because it has many functions. It can be used as a **keranjang suci** (basket tool for offering), **penjor** (a symbol of mountain or prosperity), **katik sate banten** (offering sate stalk), etc. Besides its regular use as an offering tool, **tiing tali** is often used in building, handicrafts, as an agriculture tool and in traditional music.

Tiing petung *(Dendrocalamus asper)* is a crucial part of some of the holy buildings such as **bale pewedaan** (special building for priest), **salon** (some buildings for preparing a ceremony), **penjor agung** (exalted or majestic penjor).

Buluh tmablang gading *(Schizostachyum brachycladum)* is one of bamboos that is never replaced with another variety, especially in the production of **sunari** (flute) and the ceremony **Ngad pengerik tanah pecaruan Rsigana** where a sharp blade of bamboo is used to clean the earth for the **Bhuta-kala** (a creature of lower degree than human being) ritual.

Bale gading (special bed for tooth filing ceremony), **lante pengringkesan** (woven bamboo for binding a human corpse for cremation), and **tumpang salu** (holy bed for

Photo 5. Left. In front is **Sanggah cucuk** made of **tiing tali.** Right. **Keranjang** made of **tiing tali** to present an offering.

Photo 6. The Majestic penjor for Balinese ceremony.

human corpse) must be made from the yellow bamboos like *Bambusa vulgaris* var.striata or *Schizostachyum brachycladum* (Sumantera, 1995). **Penimpug** or **kekeplugan** is a flute like sound made when culms of *Gigantochloa apus* or *Schizostachyum lima* are burned in a fire. The sound is an invitation to evil spirits to come to a ceremony so they will not be jealous and ceremony will run smoothly (Surayin, 2004).

Thyrsostachys siamensis is one of the exotic bamboos that can used as the **umbul-umbul** or **lelontek** (the holy flag symbol) because it has uniform culms. Further information on bamboo utilization can read in detail in Table 2.

Tiing selem *(Gigantochloa atroviolacea)* is mainly used for furniture and handicraft. **Tiing tabah** *(Gigantochloa nigrociliata)* produces young shoots for food and culms used in traditional music. **Buluh tamblang gading** *(Schizostachyum brachycladum)* is predominately employed ornamentally, but lately the farmers have planted them intensively with an eye on developing further uses. Beyond their importance in Balinese rituals, all of these varieties can used for other purposes, such as agriculture, ethno-botany, raw material industry, as kitchen utensils, and as musical instruments.

Photo 7. Penimpung or kekeplugan made of tiing tali or buluh.

Balinese Ethnobotanical Terms

Angklung = bamboo musical instrument shaken to produce a note.
Lante pengringkesan = woven bamboo for binding a human corpse.
Asagan = special square table for an offering.
Bade/wadah = cremation tower, the beautiful building that used to carry the human corpse.
Bale gading = special bed for teeth filing, made of yellow bamboo.
Bale pewedaan = special place for priest in religious ceremonies.
Caru manca klud, manca sanak, rsigana = step or kind of offering to Bhutakala (creature with lower degree than human being).
Damar kurung = A basket of tiing gading (yellow bamboo) with a lamp of coconut oil inside.
Lelontek = holy flag symbol.
Gerantang/rindik = bamboo music.
Katikan = stick of bamboo, with one sharp edge, usually used to arrange an offering.
Katik kekenjer = stalk sign showing way to cemetery.
Katik sate = stalk of brochettes.
Katik umbul-umbul/lelontek = stalk of holy flag.
Keranjang suci = offering basket.
Kulit entil/pesor = rice wrapper made from bamboo leaf.
Kuskusan = rice steamer.
Ngad pengerik tanah = sharp blade of bamboo used to clean the earth for offering.
Ngiu/nyiru = winnowing basket for offering.
Pancak = square of split culms of bamboo where some offerings are placed.
Penimpug/keplugan = voice of bamboo when burned in the fire as a symbol and believed to invite the bhuta-kala to observe the ceremony so it will run smoothly.

Penjor = a symbol of mountain or prosperity, uses entire culms of bamboo in ritual ceremonies.
Penjor agung = exalted or majestic penjor.
Penolak merana = insect repellent.
Sanan bade = bamboo stalk to carry the cremation building (wadah).
Sanggah cucuk/caru = temporary temple for evil ceremony.
Sanggah surya = temporary temple for the Sun God.
Sawen pengasih merana = sign of insect protection.
Semat = the smallest piece of bamboo thread /split culms to sew together an offering.
Sidi = offering sifter.
Sokasi = woven box.
Suling = flute.
Sunari = beautiful flute like sound made from bamboo culms when burned.
Tempat tirta = a place of holy water.
Tiang damar kurung = a pole for damar kurung.
Tiang leluwur = a roof made from four poles and white cotton cloth.
Trajang bade = special bridge for entering the cremation building (wadah or bade).
Tumpang salu = holy bed for human corpse in ngaben ceremony.
Umbul-umbul/lelontek = holy flag symbol.

C. The Role of Bamboo in Local Economy.

Bamboo plays an important role in the local economy when it is processed into handicrafts by semi or highly skilled craftsmen. These are are noted in Table 2. One raw culm of **tiing tali** *(Gigantochloa apus)* brings ten thousand rupiahs. If it is made into penjor, it brings fifty thousand rupiahs. If it is made into sokasi, one culm can produce three boxes bringing one hundred fifty thousand rupiahs. Moreover, a finely-made offering utensil such as a wadah can bring ten million rupiahs to the craftsman.

CONCLUSION

The Angsri village belonging to Tabanan Regency-Bali, Indonesia has about 12 ha of bamboo forest and almost every family plants some kind of bamboos. Two species of bamboos, tiing tali *(Gigantochloa apus)* and tiing petung *(Dendrocalamus asper)*, are the most widespread. Thirteen of these seventeen identified species are used for Balinese ethno-botanical rituals; there are at least fifty-five different types of ritual uses documented. Tiing tali has the highest utility with sixteen ceremonial uses. Beyond its ritual important, bamboo also plays an important role in the local economy.

ACKNOWLEDGEMENT

We would like to thank Dr. Cliff Sussman from the American Bamboo Society who gave much information about the journal. He has also kindly and critically read this manuscript.

Photo 8. Some types of sokasi made of tiing tali used to prepare an offering.

Photo 9. Some types of sokasi made of tiing tali used to prepare an offering.

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Bamboo Science and Culture:
The Journal of the American Bamboo Society 23(1):38-48

Notes on *Melocanna baccifera* and bamboo brakes in the Rakhine Hills of western Myanmar

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ABSTRACT

Melocanna baccifera (Roxburgh) Kurz ex Skeels is a large monopodial bamboo that forms extensive monotypic stands (known as brakes) throughout the Rakhine Hills of western Myanmar. Despite the ecological and cultural importance of bamboos in Southeast Asia, little is known about *M. baccifera* in Myanmar. We report characteristics of a representative stand, describe recent mast fruiting and fire ecology, and comment on the ethnobotanical importance of *M. baccifera*. Additionally, we provide a preliminary assessment of bamboo brakes as wildlife habitat. Fieldwork was conducted in the Rakhine Hills during 2000, 2003, and 2009 in conjunction with studies of *Heosemys depressa*, a critically endangered turtle endemic to the region. The mean (±1SE) density of living and dead culms in a representative stand of *M. baccifera* was 32,000 ± 2000 and 22,000 ± 2000 culms/ha, respectively. The mean (±1SE) diameter breast height (DBH) of living and dead culms was 4.1 ± 0.05 cm and 2.6 ± 0.05 cm, respectively. The mean basal area of living culms 455 ± 35 m^2/ha. Flowering and fruiting of *M. baccifera* in the Rakhine Hills began in May 2007, and by May-June 2009 widespread culm die-back was underway. Our data and historic accounts suggest an intermast period of 45-50 years. Dry season fires occur frequently in *M. baccifera* brakes as a result of lightning strikes, dried culms rubbing together, and human ignition. A post-fruiting fuel load of 59,400 kg/ha was estimated for a representative brake. Cursory observations suggest that ethnic Chin inhabiting the Rakhine Hills have a multitude of uses for *M. baccifera*. Bamboo brakes in the Rakhine Hills appear to support a diverse assemblage of wildlife, many of which are species of conservation concern. Henceforth bamboo brakes should not be regarded as degraded ecosystems of minimal conservation value, but instead recognized as important human and wildlife habitats.

INTRODUCTION

Melocanna baccifera is a large monopodial bamboo with erect culms (diameter = 3.8 to 7.5 cm) arising from rhizomes and growing to a height of 15 to 21 m (McClure 1966). The geographic distribution of *M. baccifera* encompasses parts of northeastern India (Assam), eastern Bangladesh, and western Myanmar (Chatterjee 1960; McClure 1966). Throughout its distribution, *M. baccifera* forms dense, monotypic stands referred to as "brakes" (Stamp 1924; Terra 1944) or "bamboo jungle" (Kurz 1877; Evans 1911; Smart 1917). Extensive *M. baccifera* brakes are found throughout the Rakhine (formerly "Arakan") Hills of western Myanmar

(Stamp 1924, 1930; Terra 1944; Smythies 1953), where this bamboo is known in Burmese as *khayin wa* (=bamboo of the Khayin People). According to Smart (1917), "bamboo [*M. baccifera*] covers the greater part of the hill masses of Arakan", and more recently the Myanmar Forest Department estimated that >75% of the Rakhine Hills are characterized by *M. baccifera* brakes (Win Ko Ko 2003). *Melocanna baccifera* brakes are thought to represent an anthropogenic climax community that develops in response to long-term shifting cultivation, frequent fires, or both (Stamp 1924; Terra 1944; McClure 1966; Salter 1983). Once established, dense brakes appear to inhibit the regeneration of most tree species (Stamp 1924; Salter 1983; Blower *et al.* 1991).

Melocanna baccifera is a monocarpic bamboo exhibiting prolonged vegetative growth followed by mast seeding (synchronized production of seeds within a population; Janzen 1976) and subsequent culm die-off over a wide geographic region (Stapf 1904; Thom 1935; Chatterjee 1960). Intermast periods ranging from 7 to 60 years have been reported (reviewed by Janzen 1976). *Melocanna baccifera* produces the largest fruit of any bamboo, which unlike other species contains a liquid endosperm that hardens as the fruit matures (Stapf 1904; Chatterjee 1960). *Melocanna baccifera* is said to be viviparous as seeds often germinate while still hanging from the parent plant (Stapf 1904; Smart 1917; Vaid 1962; McClure 1966).

Despite the areal extent and ubiquity of bamboo brakes in the Rakhine Hills (Smart 1917; Thom 1935; Terra 1944; Salter 1983; Blower *et al.* 1991), frequent mention of this ecosystem in historic accounts (Kurz 1877; Bryce 1886; Evans 1911; Smart 1917; Thom 1935), and the cultural and commercial importance of bamboo both within Myanmar and throughout the region (Rodger 1963; Anderson 1993; FAO 2005), little is known about the ecology of *M. baccifera* in Myanmar; even basic descriptions and floristic studies of bamboo brakes are lacking. Furthermore, while bamboo communities in Southeast Asia and elsewhere support diverse and often specialized assemblages of wildlife (Ridley 1908; Stanford 1946; Wiles 1979, 1981; Mogi and Suzuki 1983; Schaller *et al.* 1985, 1990; Yu 1994; Louton *et al.* 1996; Kratter 1997; Silveira 1999; Platt *et al.* 2001), there is a notable paucity of information on the fauna inhabiting *M. baccifera* brakes.

Herein we report ecological observations of *M. baccifera* in the Rakhine Hills, including characteristics of a representative stand and an account of recent mast fruiting. Field observations of bamboo flowering and fruiting are especially noteworthy given the often lengthy intermast periods, and essential for understanding the reproductive biology of bamboos (Soderstrom and Calderón 1979; Pohl 1991; Judziewicz *et al.* 1999). Additionally, we comment on the fire ecology and ethnobotanical importance of *M. baccifera*, and provide a preliminary assessment of *M. baccifera* brakes as wildlife habitat.

STUDY AREA AND METHODS

We collected data on *M. baccifera* in conjunction with population surveys and ecological studies of the critically endangered Arakan forest turtle (*Heosemys depressa*, Anderson), a terrestrial turtle endemic to the Rakhine Hills of western Myanmar (Platt *et al.* 2003a, 2003b; Platt and Khin Myo Myo 2009). The Rakhine Hills are the southern-most extension of the Himalaya Mountains, and one of the most rugged and sparsely inhabited regions of Southeast Asia (Henderson *et al.* 1971). These hills extend over 500 km along the western coast of Myanmar, and consist of steep, parallel north-south ridges separated by streams flowing through deep, restricted valleys (Stamp 1930; Henderson *et al.* 1971). Maximum elevation ranges from 915 to 1200 m above sea level (asl), while valley floors are often <100 m asl (Salter 1983). Mean annual precipitation ranges from 4,500 to 5,300 mm with a pronounced wet season extending from late May through late October (Smythies 1953). The Rakhine Hills are populated by scattered groups of ethnic Chin who grow upland rice (*Oryza* sp. L.), under a system of shifting cultivation known as taungya agriculture (Stamp 1924).

We conducted fieldwork in the Rakhine Hills during January-February and November

2000, May-June 2003, and May-June 2009. During January-February 2000 we worked in the vicinity of An and Mae *chaungs* (=rivers) in the central Rakhine Hills; subsequent visits in November 2000, and May-June 2003 and 2009 were made to the Rakhine Yoma Elephant Range (RYER) in the southern Rakhine Hills (Fig. 1). The latter is a 175,644 ha wildlife sanctuary established for the protection of Asian elephants (*Elephas maximus* Linnaeus) and administered by the Nature Conservation Division of the Myanmar Forest Department (Platt *et al.* 2003a). The dominant vegetation type in RYER is *M. baccifera* brake (Win Ko Ko 2003; Platt and Khin Myo Myo 2009).

During visits to remote villages and encampments we conducted open-ended interviews (*sensu* Martin 1995) with hunters, farmers, and other knowledgeable individuals regarding previous mast fruiting events, local uses of bamboo, and fauna associated with bamboo brakes. In accordance with the format of an open-ended interview, we asked each person a series of questions that included standard questions prepared in advance and others which arose during the course of conversation (Martin 1995). Ethnoecological knowledge is particularly useful in studies of bamboo reproduction as it allows researchers to draw on the life-long experience of forest dwellers to recount past flowering events (Silveira 1999).

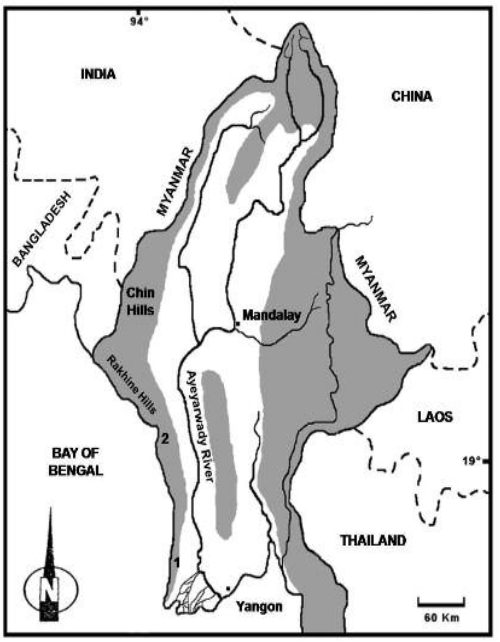

Figure 1. Map of Myanmar showing approximate location of (1) Rakhine Yoma Elephant Range, and (2) region in central Rakhine State where fieldwork was conducted in 2000. Shading denotes hill ranges and mountains.

To estimate culm density we established six 100 m transects in a representative natural stand of *M. baccifera* near Pyaung Chaung Village (19°32.650'N; 94°06.700'E; elevation ca. 90 m asl) in February 2000. Transects were established perpendicular to terrain contours and spaced at 20 m intervals. Along each transect we positioned 1 m^2 quadrats at 5 m intervals. Within each quadrat all living and dead culms were counted. The diameter breast height (ca. 1.3 m; DBH) of each living and dead culm was measured to the nearest 0.1 cm using tree calipers. We used a Student's t-test to test the one-tailed hypothesis that the DBH of living culms was greater than that of dead culms. The basal area of living culms in each plot was calculated as $\sum \pi r^2$ where r is the radius of each culm (Avery and Burkhart 1983). Statistical references are from Zar (1996). Mean values are presented as ±1 SE and results considered significant at $p \leq 0.05$.

Observations of wildlife and wildlife sign, such as scats and tracks were made opportunistically as we searched for *H. depressa* or traveled through the region. Local hunters supplied a great deal of information regarding the fauna of bamboo brakes, and we often relied on these individuals to identify and interpret wildlife sign. Additionally, we reviewed historic accounts of the region, especially those of Colonial-era big game hunters, for information on the large mammal fauna of bamboo brakes. Historic accounts are a rich, yet frequently over-looked source of biological data (Kay *et al.* 2000), and many big game hunters were also astute naturalists who recorded behavioral and ecological aspects of their quarry, such as habitat associations, food habits, seed dispersal, reproduction, and predation (Brander 1971). Importantly, historic accounts are now the only source of information available on locally extinct species (e.g., Sumatran rhinoceros; *Dicerorhinus sumatrensis* Fischer) that once inhabited bamboo brakes.

RESULTS AND DISCUSSION

Stand characteristics

We found the mean density of living culms in a representative stand of *M. baccifera* near Pyaung Chaung Village was 3.2 ± 0.2/m^2 (range = 0 to 13; n = 120) or 32,000 ± 2000 living culms/ha. Our estimate exceeds the range of 17,411 to 26,860 living culms/ha reported for *M. baccifera* brakes in the Arakan Hills of East Bengal (Bangladesh) by Troup (1921). We are unaware of any other quantitative assessments of culm density for natural stands of *M. baccifera*. The mean density of dead culms in our representative stand was 2.2 ± 0.2/m^2 (range = 0 to 9; n = 120) or 22,000 ± 2000 dead culms/ha. The mean DBH of living and dead culms was 4.1 ± 0.05 cm (range = 1.1 to 6.5 cm; n = 367) and 2.6 ± 0.05 cm (range = 1.0 to 5.6 cm; n = 252), respectively. The DBH of living culms was significantly greater than dead culms (t = 19.3, df = 550; p<0.001). These data suggest that dead culms represent smaller and probably younger culms that fail to reach maturity, rather than older culms that have died. Although often neglected in descriptive studies of bamboo stands, dead culms constitute a significant proportion of the biomass in the *M. baccifera* stand we examined, and make a substantial contribution to the fuel load available following reproduction (Keeley and Bond 1999). Additionally, dead culms provide habitat for insects, amphibians, reptiles, and small mammals living in bamboo stands (Mogi and Suzuki 1983; Louton *et al.* 1996; Platt *et al.* 2001). The mean basal area of living culms in our representative stand was 45.5 ± 3.5 cm^2/m^2 (range = 0 to 211.2 cm^2; n = 120) or 455 ± 35 m^2/ha.

Mast fruiting

Observations by one of us (AM) and statements of local informants indicate that *M. baccifera* began flowering in the southern Rakhine Hills during 2007. By May-June 2009, widespread culm die-back had occurred (Fig. 2) and an abundance of seeds and seedlings (to 30 cm in height) was noted beneath the standing dead culms (Fig. 3). This was a regional rather than a localized event that occurred throughout the southern Rakhine Hills. According to our informants, *M. baccifera* last produced seed in the southern and central Rakhine Hills from 1958 to 1960. Prior to that, fruiting reportedly occurred in 1864 and again during 1909-1913 (Smart 1917). Collectively our data and those of Smart (1917) suggest an intermast period of 45 to 50 years for *M. baccifera* in western Myanmar. Intermast periods ranging from 7 to 60 years have been given for *M. baccifera* (Chatterjee 1960; McClure 1966; Janzen 1976), although Farrelly (1984) noted the basis of many reports is unclear, and Janzen (1976) regarded relatively brief intermast periods as suspect because most bamboos cannot accumulate sufficient energy reserves for mast seeding in less than 15 years.

Fire ecology

Observations made during our fieldwork suggest that fires occur frequently in *M. baccifera* brakes. In 2000, we traversed a brake (ca. 40 ha) that local informants stated was burned two years earlier. This site was characterized by a tangle of standing and fallen dead culms with a near-impenetrable understory of young culms sprouting from rhizomes. In 2009, we found numerous widely scattered areas (<1 to ca. 70 ha) in RYER that had burned subsequent to mast fruiting. Fire intensity appeared to have varied greatly at these sites; most burned areas had been swept by light ground fires that removed only surface litter leaving dead standing culms intact. However, at some sites intense fires consumed entire stands of dead culms leaving only bare mineral soil. Germinating bamboo seeds were found throughout burned areas in May-June 2009.

Many bamboo communities in the wet-dry tropics are pyrogenic ecosystems maintained by fire (Keeley and Bond 1999). Mass mortality among post-fruiting bamboo synchronously produces a large fuel load that increases the potential for wildfire disturbance. Once ignited, heavy fuel loads generate intense fires that eliminate competing woody vegetation and increase the chance of successful seedling establishment (Keeley and Bond 1999). We used our estimates of culm density and data from McClure (1966) to calculate the potential fuel load in a representative stand of *M. baccifera* subsequent to mast fruiting. Because living

Figure 2. Dead *Melocanna baccifera* after mast fruiting event in the Rakhine Hills of Myanmar. Note scattered deciduous trees among bamboo. Photographed in Rakhine Yoma Elephant Range (May 2009).

Figure 3. *Melocanna baccifera* seeds (left) and seeds germinating beneath standing dead culms (b). Photographed in Rakhine Yoma Elephant Range (June 2009).

culms perish after fruiting, we summed the estimated number of living and dead culms in our plots yielding a total of 54,000 culms/ha. Assuming the average mass of an air dried *M. baccifera* culm is 1.1 kg (calculated from McClure 1966), the potential fuel load in our representative stand is 59,400 kg/ha. Fuel loads ranging from 10 to 100,000 kg/ha have been reported in stands of other bamboos (Keeley and Bond 1999), and the high caloric content of dried culms often results in extremely intense "explosive" fires (Stott 1988; Silveira 1999). Moreover, because of their great height (to 21 m), dead *M. baccifera* culms may act as ladder fuels that spread fire into adjacent canopy trees (Keeley and Bond 1999).

Lightning strikes at the end of the dry season are thought to be the primary source of ignition for fires in pyrogenic tropical bamboo communities (Stott *et al.* 1990; Keeley and Bond 1999). Our informants also maintained that wildfires are ignited when winds cause dead culms to rub together, eventually producing hot embers that fall onto dry surface litter. However, our informants believed the majority of fires are deliberately set by humans, primarily *taungya* farmers clearing land and hunters seeking to drive game from bamboo brakes.

Fire hunting is widely practiced during the dry season in the Rakhine Hills; hunters set fires along ridges, which burn slowly downslope. Animals moving ahead of the flames are intercepted by hunters waiting in streambeds below. According to villagers, fire hunting is an extremely effective technique for capturing turtles (*Indotestudo elongata* Blyth and *H. depressa*) and red muntjac (*Muntiacus vaginalis* Boddaert).

Ethnobotany

Although we did not attempt an exhaustive ethnobotanical survey, cursory observations suggest ethnic Chin inhabiting the Rakhine Hills have a multitude of uses for *M. baccifera*. Thom (1935) observed that tribes in the Rakhine Hills "suffered greatly" when flowering and subsequent culm die-off of *M. baccifera* deprived them of building materials. Owing to their dependence on bamboo, Anderson (1993) regarded the hill tribes of northern Thailand as "bamboo cultures", an appellation we consider equally fitting to describe the Rakhine Hills Chin.

Chin villagers construct houses almost entirely of bamboo (except for roof thatching), and bamboo fences surround houses and garden plots to exclude free-ranging domestic pigs (*Sus scrofa* Linnaeus). According to McClure (1966), the resistance of *M. baccifera* to termite damage makes it a preferred material for domestic construction in Bangladesh. Chin villagers use culm segments for containers, and split culms are burned as cooking fuel, fashioned into various implements (e.g., cutlery, fish hooks, etc.), and woven into mats, baskets, and fish traps. Chairs, tables, and beds are made from bamboo culms and woven bamboo matting. Villagers stated that during the wet season *M. baccifera* shoots are harvested for food and incorporated into a variety of dishes. When available, fruits are occasionally collected and consumed raw, boiled, or roasted; however, none of our informants seemed particularly fond of eating bamboo seeds. To us, uncooked *M. baccifera* seeds tasted very similar to raw or lightly boiled peanuts (*Arachis hypogaea* L.). Although *M. baccifera* is rich in tabasheer, a silicaceous compound widely used in traditional Asian medicine as an antidote for poisons, love potion, and to treat respiratory ailments (Farrelly 1984), the villagers we interviewed were unaware of any medicinal uses for this bamboo.

Chin farmers consider *M. baccifera* brakes desirable sites for *taungya* fields. Those we interviewed described a system in which brakes are clearcut during the early to mid-dry season, and felled culms are left in place and allowed to dry. Fields are then burned late in the dry season, and upland rice is sown immediately prior to the first rains (late May to early June). During the clearing phase culms are cut and burned, but farmers make no attempt to grub out rhizomes from the fields. Farmers cultivate fields from one to four years depending on soil fertility. When rice yields begin to decline, fields are abandoned, and farmers move to another site and repeat the cycle. Because human population density is low and uncultivated land widely available, abandoned *taungya* fields remain fallow for 15 to 20 years before being returned to cultivation. Our inspection of recently abandoned *taungya* sites suggests reestablishment of *M. baccifera* is rapid owing to rhizomes remaining in the fields. According to our informants, brakes mature 8 to 10 years after *taungya* fields are abandoned. Similarly, McClure (1966) observed that the "rate of recovery of *M. baccifera* after clear-cutting" in Bangladesh was "phenomenal" and in large part due to persistence of the rhizomes, which are "remarkably tenacious of life, and survive the burning *in situ* of the felled culms, leaves, and branches".

Wildlife habitat

Our field observations, reports of local hunters, and historic accounts collectively suggest that *M. baccifera* brakes in the Rakhine Hills provide habitat for a diverse assemblage of large mammals, many of which are classified as globally threatened or endangered (Table 1). In contrast, the smaller fauna (small mammals, birds, reptiles, amphibians, and invertebrates) of *M. baccifera* brakes remains poorly known. Bamboo associations in neighboring Thailand support diverse communities of small mammals (Wiles 1981) and birds (Wiles 1979), but comparative data sets from *M. baccifera* brakes are lacking. Squirrels and other rodents reportedly consume *M. baccifera* seeds (Thom 1935; Chatterjee 1960), and we observed numerous squirrels (*Callosciuris* sp. Gray) in bamboo

brakes and found abundant evidence of rodent predation on seeds. Rodent plagues in the wake of mast events are well documented (Janzen 1976; Judziewicz *et al.* 1999), and occurred following mast fruiting by *M. baccifera* in 1910-13 (Smart, 1917) and 1960 (Chatterjee 1960); however, we are unaware of any recent rodent population irruptions in the Rakhine Hills. Such events may go unnoticed in this sparsely populated region or have yet to occur given the time lag between fruit availability and increased rodent fecundity. Red junglefowl (*Gallus gallus* Linnaeus) are said to consume *M. baccifera* flowers (Thom 1935), although seeds are probably too large for these birds to swallow (SGP, pers. obs.). Red junglefowl were abundant in *M. baccifera* brakes of RYER, and we found three active nests consisting of dried bamboo leaves among thick clusters of dead culms in June 2009.

Virtually nothing is known regarding the herpetofauna of *M. baccifera* brakes. Blue-throated lizards (*Ptyctolaemus gularis* Peters) reportedly inhabit *M. baccifera* brakes in Bangladesh (Ahsan *et al.* 2008). In Myanmar, we found *H. depressa* in the bamboo brakes of central and southern Rakhine Hills (Platt *et al.* 2003a, 2003b; Platt and Khin Myo Myo 2009). Hunters contend that *H. depressa* consumes *M. baccifera* seeds and we recovered undigested spikelets from their feces (Platt and Khin Myo Myo 2009); undoubtedly these were consumed after falling from the parent plant. We also encountered *I. elongata* and Burmese python (*Python molurus* Linnaeus) in *M. baccifera* brakes (Platt *et al.* 2003b; Platt and Khin Myo Myo 2009). Hunters provided vernacular names for numerous snakes, lizards, and frogs inhabiting bamboo brakes, but we were unable to confidently equate these folk species (*sensu* Berlin *et al.* 1966) with scientifically recognized taxa.

Because species inventories of particular habitats are essential data sets for conservation and resource management (Oliver and Beattie 1993), and acquiring baseline data on the occurrence of even common species is a necessary prerequisite for conservation planning (Dodd and Franz 1993), we recommend that rigorous, systematic faunal surveys be conducted in *M. baccifera* brakes of western Myanmar. Future investigation of bamboo brake fauna should concentrate on small mammals, birds, herpetofauna, and invertebrates, groups for which there is an almost complete lack of data. Such data are urgently needed in Myanmar where surprisingly little is known about the biodiversity of many regions and basic faunal inventories are lacking for most protected areas (Platt *et al.* 2007). This general lack of biodiversity knowledge makes conservation planning difficult and hampers effective management.

Whereas Blower *et al.* (1991) regard the extensive *M. baccifera* brakes in western Myanmar as degraded ecosystems of minimal conservation value, our findings suggest otherwise; this habitat supports a diverse assemblage of wildlife, many of which are species of conservation concern. Admittedly, *M. baccifera* brakes are at least partially the result of long-term anthropogenic disturbance. Nonetheless bamboo brakes constitute an important wildlife habitat that should not be over-looked in conservation planning. As noted by Heinimann *et al.* (2007), anthropogenically disturbed habitats are an underrated component of tropical landscapes that are often tainted with a reputation of being degraded and therefore considered less valuable than undisturbed primary forests. However, disturbed habitats can play a significant role in delivering ecosystem services and contributing to rural livelihoods, and are often critical in maintaining high levels of local biodiversity (Finegan and Nasi 2004).

ACKNOWLEDGEMENTS

The Myanmar Ministry of Forestry is thanked for granting us permission to conduct fieldwork in the Rakhine Hills. We are especially grateful to U Tin Tun (Director of the Nature and Wildlife Conservation Division) for continuing support of our field work. We also thank Colin Poole, U Than Myint and the Wildlife Conservation Society Myanmar Program for logistical support, and Linda Epps and the interlibrary loan staff at the Bryan Wildenthal Memorial Library, Sul Ross State University, for locating many obscure references. Fieldwork in Myanmar was funded by Andy Sabin, the Turtle Conservation Fund, and Walt Disney Company Foundation. Finally, we are indebted to the many villagers who shared their knowledge,

Table 1. Large mammals known to inhabit *Melocanna baccifera* brakes in the Rakhine Hills of western Myanmar. Conservation status according to IUCN Red List categories (IUCN 2009): Least concern (LC), Near threatened (NT), Vulnerable (VU), Endangered (EN), Critically endangered (CR). RYER = Rakhine Yoma Elephant Range

Species	Notes and conservation status
Primates	
Phayre's langur (*Trachypithecus phayrei* Blyth)	We commonly encountered small groups (3 to 5) of langurs in bamboo brakes of RYER; langurs consume *M. baccifera* shoots leaving behind small piles of culm sheaths. *M. baccifera* foliage was found to be an important food source for this folivorous species in India (Gupta and Kumar, 1994); (EN).
Hoolock Gibbon *(Hoolock hoolock* Harlan*)*	Frequently heard vocalizing in bamboo brakes of southern RYER; (EN).
Carnivora	
Dhole *(Cuon alpinus* Pallas*)*	Local informants maintained dhole are present in bamboo brakes of RYER. We found the skeletal remains of a female sambar *(Rusa unicolor)* and her calf killed by dholes in RYER. Camera trap photographs of dholes in bamboo brakes of RYER obtained by National Tiger Survey Team (2001); (EN).
Asian black bear *(Ursus thibetanus* G. Cuvier)	Hunters attributed scrapings found on trees growing in bamboo brakes to black bears. Camera trap photographs of black bears and sun bears (Helarctos malayanus Raffles) in bamboo habitats obtained during tiger survey of RYER (National Tiger Survey Team 2001). *Ursus thibetanus* and *Helarctos malayanus* listed as VU.
Tiger *(Panthera tigris* Mazak)	Prior to World War II tigers were abundant in bamboo brakes of Rakhine State, and the region was a favored destination of Colonial-era big game hunters seeking these cats (Thom 1934a; Marshall 1947). As recently as the early 1980s tigers remained common in the Rakhine Hills, and the region was considered one of the major remaining strongholds for tigers in Southeast Asia (Salter 1983). We speculate that the dense cover afforded by bamboo and the abundance of prey species, such as *Bos gaurus, Rusa unicolor,* and *Sus scrofa* (see below) made *M. baccifera* brakes particularly important habitat for tigers. Tigers have since been largely extirpated throughout Myanmar with the exception of the Hukawng Valley and perhaps forests in extreme southern Myanmar (Lynam *et al.* 2006). Viable populations apparently no longer remain in Rakhine State, although our informants reported finding *Bos gaurus* killed by tigers, encountering tiger tracks, and hearing vocalizations as recently as 2007-08; (EN).
Proboscidea	
Asian elephant *(Elephas maximus* Linnaeus)	*M. baccifera* culms, foliage, and when available, seeds are consumed, and brakes are important cover (Thom 1933). Elephants remain common in RYER; informants indicated that as a result of culm die-back associated with the recent mast event, elephants have switched from eating bamboo to a variety of other plants including wild banana (*Musa* sp. L.); (EN).
Perissodactyla	
Sumatran rhinoceros *(Dicerorhinus sumatrensis* Fischer)	Once common in the Rakhine Hills, but now locally extirpated (Platt and Khin Myo Myo 2009) as a result of chronic over-hunting for their commercially valuable horn, blood, and feces which were widely used in traditional Chinese medicine (Smart 1917). Dense *M. baccifera* brakes afforded important cover (Smart 1917), and rhinoceros consumed bamboo foliage, shoots, flowers, and seeds, being especially fond of the latter (Thom 1935; Christison 1945; Ansell 1947); (CR).

Species	Notes and conservation status
Artiodactyla	
Wild pigs *(Sus scrofa* Linnaeus*)*	We noted abundant tracks, feeding signs, and wallows in bamboo brakes. Wild pigs reportedly consume *M. baccifera* seeds (Thom 1935), and we found numbers of crushed seeds in pig wallows. Numerous camera trap records are available for *S. scrofa* in bamboo brakes (National Tiger Survey Team 2001); (LC).
Sambar *(Rusa unicolor* Kerr*)*	We encountered abundant sign (tracks, feces, shed antlers) in bamboo brakes and flushed two adults while searching for turtles. Sambar reportedly consume bamboo shoots (Tun Yin 1993); (VU).
Red muntjac *(Muntiacus vaginalis* Boddaert*)*	Tracks commonly encountered in sandbanks along small streams in bamboo brakes. Numerous photorecords from bamboo brakes of RYER (National Tiger Survey Team 2001); (LC).
Gaur (*Bos gaurus* H. Smith)	The bamboo brakes of the Rakhine Hills have long been recognized as important gaur habitat (Thom 1934b). Salter (1983) found gaur "common and widespread" in bamboo brakes of southern Rakhine State and concluded the region provided important habitat. We noted abundant well-worn gaur trails through bamboo brakes in RYER and found numerous fresh tracks and feces; some of the latter contained crushed *M. baccifera* seeds. We also noted extensive browsing of regenerating *M. baccifera* in abandoned *taungya* fields in the central Rakhine Hills; (VU).

provided accommodation, and assisted with fieldwork. An early draft of this manuscript benefited from the review of Lewis Medlock.

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Bamboo Science and Culture:
The Journal of the American Bamboo Society 23(1): 49-56

Floristic composition and phytosociology of a temperate bamboo stand in Eastern Himalayas, India

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ABSTRACT

Arundinaria maling forest in Jang area of Arunachal Pradesh of Eastern Himalayas, India is a temperate secondary successional forest which harbored 29 species of herbaceous and 28 shrubby species. Fourteen species each of the total herbs and shrubs had broad ecological amplitude and were distributed throughout the *A. maling* forest (2400-3600 m). Most of the herb and shrub species were distributed in clumps inside the bamboo forest. Distribution of *Rhododendron arboreum, R. thomsonii, R. fulgens* and *R. tawangensis* were restricted between 2800-3600 m. *Eleocharis atropurpurea* dominated between 2400-2800 m and *Eragrostis ciliaris* has dominated between the elevation of 2800-3200 m, whereas *Gnaphalium apiculatum* was the dominant species between 3200-3600 m in the forest. Species composition between 3200-3600 m and 2800-3200 m resembled greatest similarity. Density of herbaceous species decreased with the decrease in elevation, whereas density of shrubs was highest between 2800-3200 m. Species richness and Shannon Wiener Index was also highest between 2800-3200 m.

Key words: *Arundinaria*, Biodiversity, *Rhododendron*, Tawang, Vegetation.

INTRODUCTION

Bamboos have a wide range of ecological amplitude and are distributed throughout the tropical, sub tropical and cold temperate regions except in Europe, from sea level to 4000 m (Soderstrom and Calderon 1979). Diversity and natural distribution of bamboo is governed mainly by geographical location and physiographical features like altitudinal variations. Bamboo generally forms an under storey or it grows mixed with other tree species where herbs and shrubs are associated as its undergrowth. Few species of *Phyllostachys* and *Arundinaria* form pure bamboo forests in temperate and sub alpine regions. Few species of the genus *Melocanna* and *Dendrocalamus* in the Eastern Himalaya of India form pure bamboo patches as a result of clear felling of natural mixed forests or in areas abandoned after shifting cultivation (Rao 1986). In India, bamboos form an important component of the dry and moist deciduous, wet evergreen or tropical evergreen rainforests as an under storey, or they occur as pure bamboo brakes (Qureshi and Deshmukh 1962). It spreads from tropical to temperate and alpine regions. *Arundinaria maling* forest of Tawang district of Arunachal Pradesh in Eastern Himalaya is a secondary successional forest which has replaced the earlier existing *Taxus baccata* mixed forest. During the Indo-China war, large area of this mixed forest was destroyed due to temporary constructions of concrete bunkers inside the forest. Mass harvest of *Taxus baccata* for commercial purpose also resulted in sudden denudation of its natural forest

stands. Villagers of the Jang area harvest the bark of *Taxus baccata* for medicinal use and leaves as major fodder for the domestic animals such as yak and cattle. It has also accelerated the mortality rate due to the non-systematic removal of bark and lopping of this precious species. Bamboos due to their fast growth and strong competitiveness for nutrients, generally do not allow other plant species to grow in association. Therefore, the original mixed *Taxus* forest was converted into a secondary bamboo brake of *Arundinaria maling* following human disturbances.

Present study emphasizes on the distribution, diversity and density of herbs and shrubs which are associated with *Arundinaria maling* in a temperate bamboo brake of Eastern Himalaya, which is located in the Indo-China border at Tawang District of Arunachal Pradesh, India.

MATERIALS AND METHODS

The study was carried out at three different elevation zones (2400-2800 m, 2800-3200 m and 3200-3600 m.) in *Arundinaria maling* forest growing in Jang area of Tawang district of Arunachal Pradesh. It is located at the extreme east of Tawang district (27°30'-27° 35'N latitude and 91°55'-92°E longitude) which lies in the western part of Arunachal Pradesh. Figure 1 represents the location of the study site showing the *A. maling* forest in Jang area of Tawang district of Arunachal Pradesh. The area is a hilly terrain with very steep slopes. The three elevation zones have been designated in this study as the low elevation (2400-2800 m), medium elevation (2800-3200 m) and high elevation (3200-3600 m.) sites. Beyond the high elevation site, there were barren lands with few perennial deciduous shrubs. As the study was carried out in a secondary pure bamboo forest of *Arundinaria maling*, it allowed few herbs and shrubs to grow as undergrowth. Vegetation analysis was done during July as this month represents the period of peak vegetative growth. Herb and shrub specimens were collected and identified consulting the Flora of Arunachal Pradesh (Hajra *et al.* 1996), Flora of Assam (Kanjilal *et al.* 1934-1940) and Flora of British India (Hooker 1872-1897). Wherever necessary, the herbaria of State Forest Research Institute and Botanical Survey of India (BSI), Itanagar and Botanical Survey of India and Forest Research Institute, Dehra Dun were consulted for correct identification. For determining phytosociological attributes, belt transect method was employed (Misra 1968). Three belts of 30 m width and 300 m length were laid along the altitudinal gradient (2400-3600 m.) at each of the elevation sites. Within each belt, 10 quadrats of 1m x 1m were laid randomly for herbs and 10 quadrats of 5 m x 5 m for shrubs at each of the three elevation sites. Other community indices such as Shannon-Wiener diversity index, Whitford's index and Sorensen's similarity index were computed as follows:

Whitford's index (Whitford 1948) = Abundance / Frequency
(A / F ratio < 0.025 = Regular distribution; 0.025-0.05 = Random distribution; > 0.05 = Clump distribution)

Similarity index (Sorensen 1948) = 2c/ (a + b); where, a = Number of species in stand a, b = Number of species in stand b, c = Number of species common to both stands a and b.

Species richness index (Magurran 1988) = $(S-1)/\log_e N$; where, S = Number of species, N = Number of individuals.

Shannon and Wiener index of diversity (Shannon and Wiener 1963) = $\overline{H} = -\sum (p_i \text{ in } p_i)$; where, p_i = proportion of number of i^{th} species in the number of all the species.

RESULTS

Population analysis of *Arundinaria maling* at the three elevation sites during the study period revealed that the low elevation site (2400-2800 m) had highest clump as well as culm density and it gradually decreased with the increase in elevation (Table 1).

Floristic composition, their distribution pattern and dominance

A total of 29 species of herb and 28 species of shrub were recorded from the *Arundinaria maling* forest of Jang area (Table 2). Most of the herbaceous species were annual and were

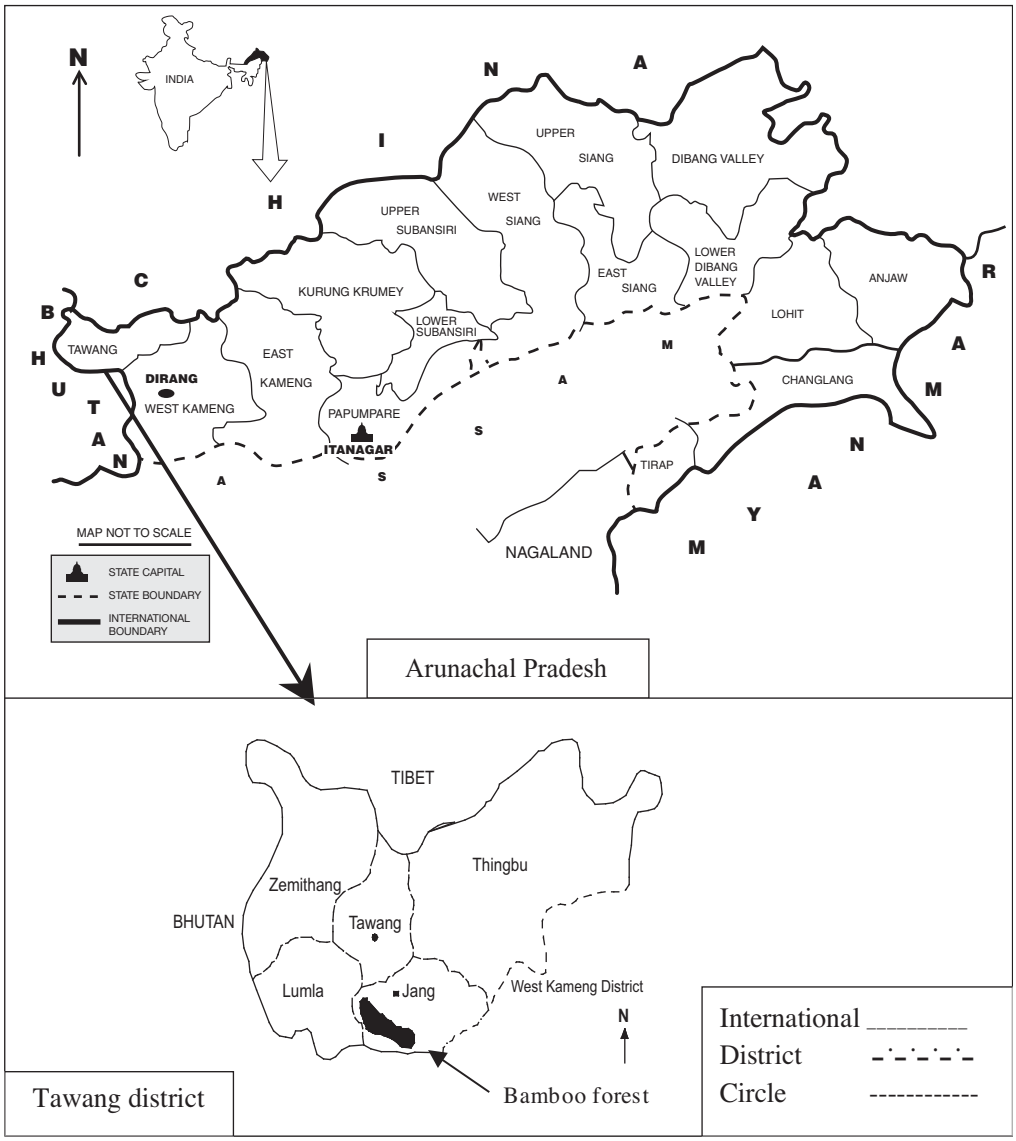

Figure 1. Location map of the study site showing the Arundinaria maling forest in Jang area of Arunachal Pradesh, India.

mostly absent during winter months at all the three elevation sites. However at the low and medium elevation sites, few species of Cyperaceae and Poaceae family were observed to grow even during the winter. Amongst the 29 species of herb, 14 had broad ecological amplitude and were distributed to all the three elevation sites. They included *Anthopogon lanceolatus, Carex condensata, Cyanotis vaga, Dicrocephala latifolia, Echinochloa crus-galli, Eleocharis atropurpurea, Galium asperifolium, Juncus lampocarpus, Polygonum berbatum, P. capitatum, P. filicaule, Potentilla atrosanguinea* and *Psilocarya scirpoides.* Amongst the 28 species of shrub, 14 species were observed to occur to all the three elevation sites. The distribution of the four *Rhododendron* species namely *Rhododendron arboreum, R. thomsonii, R. fulgens* and *R. tawangensis* were restricted to the high and medium elevation sites, whereas they were

absent from the low elevation site. Except *R. fulgens,* the other three species were observed to be highly dominant at the medium elevation site. Whitford's index showed the horizontal distribution pattern of the entire herb and shrub species at the three elevation sites, where most of the species were distributed in clumps. At all the three elevation sites, not a single species was found to show regular distribution. Twenty species of herb and shrub showed random distribution. Among the three elevation sites, medium and high elevation sites had greater number of species as compared to the low elevation site. Among the herbs and shrubs, *Eleocharis atropurpurea* of Cyperaceae was the most dominant species at the low elevation site, whereas *Eragrostis ciliaris* of Poaceae was dominant at the medium elevation site and *Gnaphalium apiculatum* of Asteraceae at the high elevation site (Table 3). Sorensen's similarity index revealed that the medium and high elevation sites had greater similarity (90.4%) followed by the similarity between the medium and the low elevation sites (78.6%), whereas least similarity was recorded between the high and the low elevation sites (65.9%).

Density, species richness and diversity

Density of the herbaceous species was highest at the high elevation site (53.21 per m^2), and it decreased with the decrease in elevation. In case of shrubs, the density was highest at the medium elevation site (29.2 per 25 m^2), followed by the high elevation site (23.9 per 25 m^2) and lowest at the low elevation site (17.3 per 25 m^2). Highest number of herb and shrub species was observed at the medium elevation site followed by the high and low elevation sites. Species richness and Shannon-Wiener indices also showed highest value at the medium elevation site followed by the high and low elevation sites (Table 4).

DISCUSSION AND CONCLUSION

Importance Value Index (IVI)

Importance value is a reasonable and a perfect measure to assess the overall significance of a species. It takes into account several ecological parameters of the species in the vegetation such as, density, dominance and frequency. Importance value index was calculated by summing relative density, relative dominance and relative frequency of respective plant species (Curtes and Mc Intosh 1950). The study also revealed that Eragrostis ciliaris had highest IVI followed by *Anthopogon lanceolatus* and *Rumex nepalensis*, while *Juncus elegans* and *Launaea acaulis* had least IVI (Table 3).

Most of the herb and shrub species in Jang bamboo forest were distributed in clumps, which might be due to the limited space to distribute/disperse inside the bamboo forest accompanied by allelopathic effect and competitive inhibition for nutrients by *Arundinaria maling*. Among the study sites located at different elevations, the highest herb and shrub diversity was recorded at the medium elevation site, which may be due to the suitable climatic and soil condition. Martins (2004) has reported a similar trend of colonization of herbs and shrubs in the gaps between bamboo clumps while studying influence of clump density and light intensity on herb and shrub diversity and density. Higher species diversity of herbs and shrubs at the medium elevation site may also be attributed to the transitional habitat, which supports the growth of species of both low and high elevation sites. Species richness and Shannon-Wiener indices also showed highest value at the medium elevation site followed by the high and low elevation sites. Density of the herbaceous species was highest at the high

Table 1. Clump characteristics and culm density of *Arundinaria maling* at the three elevation sites in the Jang bamboo forest (Mean ± SE).

Parameters	Low elevation	Medium elevation	High elevation
No. of clumps/ quadrat*	28.0 ± 0.6	18.0 ± 0.7	14.1 ± 0.5
No. of clumps/ ha	311± 6.3	200 ± 7.9	156 ± 5.8
No. of individuals/ ha	43851 ± 746	37600 ± 540	7800 ± 746

**Quadrat size = 30m x 30m*

Table 2. Herb and shrub diversity at low, medium and high elevation sites (species are arranged in alphabetical order)

Name of the species	Family	Occurrence of species at different elevation sites		
		Low	Medium	High
Herbaceous species				
Anaphalis cinnamomea C.B. Clarke	Asteraceae	-	+	+
Anthopogon lanceolatus (Roxb.) Hochst.	Poaceae	+	+	+
Brunella vulgaris L.	Lamiaceae	-	+	+
Calamogrostis sp.	Poaceae	-	-	+
Calanthe sp.	Orchidaceae	-	-	+
Carex condensata Nees.	Cyperaceae	+	+	+
Cyanotis vaga (Lour) Schult. f	Commelinaceae	+	+	+
Cynoglossum zeylanicum (Vahl) Thumb	Boraginaceae	-	+	+
Cyperus difformis	Cyperaceae	-	+	+
Dicrocephala latifolia DC.	Asteraceae	+	+	+
Echinochloa crus-galli Beauv.	Poaceae	+	+	+
Eleocharis atropurpurea Kunth.	Cyperaceae	+	+	+
Eragrostis ciliaris Trin.	Poaceae	-	+	+
Galium asperifolium Wall.	Rubiaceae	+	+	
Geranium aconitifolium L. Herit	Geraniaceae	-	+	+
Gnaphalium apiculatum	Asteraceae	-	+	+
Impatiens thomsoni Hook f.	Geraniaceae	-	+	+
Juncus elegans Samuls	Juncaceae	-	+	+
Juncus lampocarpus Ehrh.	Juncaceae	+	+	+
Launaea acaulis Roxb. Babe	Asteraceae	-	+	+
Osmunda claytoniona	Osmundaceae	-	-	+
Polygonum berbatum	Polygonaceae	+	+	+
Polygonum capitatum Ham.	Polygonaceae	+	+	+
Polygonum filicaule Wall.	Polygonaceae	+	+	+
Potentilla atrosanguinea Lodd.	Rosaceae	+	+	+
Psilocarya scirpoides Torrey	Cyperaceae	+	+	+
Swertia chirayita (Roxb. Ex Fleming) Karsten	Gentianae	-	+	+
Veronica sp.	Asteraceae	+	+	+
Viola sp.	Violaceae	-	+	+
Shrub species				
Acer palmatum Thumb	Aceraceae	+	+	-
Anemone sp.	Ranunculaceae	+	+	+
Aster salsuginosus Richardson	Asteraceae	+	+	+
Berberis wallichiana DC.	Berberidaceae	+	+	+
Cnicus sp.	Asteraceae	+	+	+
Daphne papyracae	Thymaleaceae	+	+	+
Dipsacus inermis Wall.	Dipsaceae	+	+	+
Elaegnus	Elaegnaceae	+	+	+
Euphorbia wallichii	Euphorbiaceae	+	+	+
Gentiana sp.	Gentianae	-	+	+
Litsea citrata Bl.	Laurinae	+	+	-
Lyonia ovalifolia	Ericaceae	+	+	+
Lyonia sp.	Ericaceae	+	+	+
Mahonia leschenaultic Tak.	Berberideae	+	+	+
Meliosma dilleniaefolia Wall.	Sabiaceae	+	+	+
Prunus bukhariensis	Rosaceae	+	+	+
Rhododendron arboreum	Ericaceae	-	+	+
Rhododendron thomsonii	Ericaceae	-	+	+

Table 2. Continued

Name of the species	Family	Occurrence of species at different elevation sites		
		Low	Medium	High
Rhododendron fulgens	Ericaceae	-	+	+
Rhododendron tawangensis	Ericaceae	-	+	+
Rubus alpestris Blume	Rosaceae	+	+	-
Rubus paniculata Smith	Rosaceae	+	+	-
Rumex nepalensis Spreng	Polygonaceae	+	+	+
Sambucus ebulus Linn.	Caprifoliaceae	-	+	+
Sarcococca saligna Muell.Arg.	Buxaceae	+	+	-
Schefflera sp.	Araliaceae	+	+	-
Senecio chrysanthemoides DC.	Asteraceae	-	+	+
Viburnum stellulatum Wall.	Caprifoliaceae	+	+	-

+, - Indicates presence and absence of the species, respectively

Table 3. Density, IVI and Whitford's index of herbs & shrubs at three elevation sites

Name of the species	Density			IVI			Whitford's index		
	L	M	H	L	M	H	L	M	H
Herbaceous species									
Anaphalis cinnamomea C.B. Clarke	NA	0.53	3.20	NA	1.419	6.907	NA	0.300	0.113
Anthopogon lanceolatus (Roxb.) Hochst	7.00	5.33	2.67	17.314	9.998	5.181	0.321	0.188	0.240
Brunella vulgaris L.	NA	2.67	3.60	NA	5.349	6.736	NA	0.240	0.225
Calamogrostis sp.	NA	NA	0.67	NA	NA	1.554	NA	NA	0.375
Calanthe sp.	NA	NA	2.40	NA	NA	6.215	NA	NA	0.067
Carex condensata Nees.	2.00	2.33	1.87	6.671	4.899	3.799	0.180	0.210	0.263
Cyanotis vaga (Lour) Schult. f	0.67	2.13	3.33	2.415	5.328	7.425	0.375	0.098	0.093
Cynoglossum zeylanicum (Vahl) Thumb	NA	0.80	1.33	NA	2.479	3.798	NA	0.113	0.083
Cyperus difformis	NA	0.13	0.33	NA	0.530	1.467	NA	0.300	0.083
Dicrocephala latifolia DC.	3.33	2.33	2.00	10.927	4.899	4.317	0.117	0.210	0.180
Echinochloa crus-galli Beauv.	0.20	0.33	0.73	0.954	2.198	4.399	0.450	0.030#	0.017#
Eleocharis atropurpurea Kunth.	11.00	4.53	3.47	27.208†	8.918	6.908	0.205	0.159	0.159
Eragrostis ciliaris Trin.	2.00	7.67	2.00	5.522	13.148†	4.662	0.500	0.270	0.125
Galium asperifolium Wall.	3.00	2.00	1.60	11.443	4.449	4.833	0.068	0.180	0.056
Geranium aconitifolium L. Herit	NA	1.67	2.67	NA	3.998	6.905	NA	0.150	0.060
Gnaphalium apiculatum	NA	0.47	5.67	NA	1.679	10.795†	NA	0.117	0.128
Impatiens thomsoni Hook f.	NA	2.40	3.00	NA	4.639	6.993	NA	0.338	0.083
Juncus elegans Samuls	NA	0.07	0.47	NA	0.440	1.639	NA	0.150	0.117
Juncus lampocarpus Ehrh.	0.33	0.67	1.00	2.357	2.998	4.055	0.083	0.042#	0.035#
Launaea acaulis Roxb. Babe	NA	0.07	0.27	NA	0.440	1.380	NA	0.150	0.067

L – low elevation site, M – medium elevation site, H- high elevation site

Table 3. Continued

Name of the species	Density			IVI			Whitford's index		
	L	M	H	L	M	H	L	M	H
Herbaceous species (cont.)									
Osmunda claytoniona	NA	NA	0.33	NA	NA	1.811	NA	NA	0.047#
Polygonum berbatum	0.60	0.67	1.20	3.438	3.348	5.004	0.084	0.031#	0.027#
Polygonum capitatum Ham.	0.67	1.00	0.53	2.990	4.147	2.760	0.167	0.035#	0.033#
Polygonum filicaule Wall.	0.40	0.67	0.47	1.909	3.697	2.329	0.225	0.023#	0.042#
Potentilla atrosanguinea Lodd.	0.20	0.53	0.40	1.529	2.468	1.898	0.113	0.048#	0.056
Psilocarya scirpoides Torrey	3.40	2.13	1.33	12.203	5.677	3.453	0.077	0.075	0.120
Swertia chirayita (Roxb. Ex Fleming) Karsten	NA	0.67	1.20	NA	2.998	5.004	NA	0.042#	0.027#
Veronica sp.	0.33	0.80	1.80	2.357	2.828	5.782	0.083	0.072	0.041#
Viola sp.	NA	2.20	3.67	NA	5.068	8.547	NA	0.138	0.068
Shrub species									
Acer palmatum Thumb	1.87	1.00	NA	7.567	3.098	NA	0.086	0.090	NA
Anemone sp.	0.27	1.33	2.67	1.656	3.548	6.216	0.150	0.120	0.094
Aster salsuginosus Richardson	1.20	2.67	3.00	5.727	6.398	5.614	0.075	0.094	0.270
Berberis wallichiana DC.	0.60	1.33	1.87	2.863	3.548	4.834	0.150	0.120	0.086
Cnicus sp.	0.40	1.00	1.20	2.484	3.098	3.280	0.100	0.090	0.108
Daphne papyracae	0.67	1.20	0.20	2.415	3.718	0.604	0.375	0.075	0.450
Dipsacus inermis Wall.	0.13	0.33	0.67	0.828	1.149	1.899	0.300	0.188	0.167
Elaegnus sp.	0.40	0.13	NA	2.484	0.879	NA	0.100	0.075	NA
Euphorbia wallichii	NA	0.80	1.20	NA	2.828	3.970	NA	0.072	0.055
Gentiana sp.	NA	0.80	2.67	NA	1.779	5.181	NA	0.450	0.240
Litsea citrata Bl.	0.60	0.13	NA	2.863	0.530	NA	0.150	0.300	NA
Lyonia ovalifolia	0.40	1.20	0.13	2.484	4.417	0.518	0.100	0.042#	0.300
Lyonia sp.	1.20	0.47	0.20	5.727	2.029	0.949	0.075	0.066	0.113
Mahonia leschenaultic Tak.	1.80	1.60	0.07	8.590	4.608	0.431	0.050#	0.073	0.150
Meliosma dilleniaefolia Wall.	1.40	1.13	0.07	7.256	3.628	0.431	0.049#	0.071	0.150
Prunus bukhariensis	0.80	0.47	0.07	6.117	2.378	0.431	0.028#	0.042#	0.150
Rhododendron arboreum	NA	1.80	1.33	NA	5.577	3.798	NA	0.050#	0.083
Rhododendron thomsonii	NA	2.07	1.40	NA	5.937	4.574	NA	0.057	0.049#
Rhododendron fulgens	NA	1.27	2.20	NA	3.808	6.300	NA	0.079	0.050#
Rhododendron tawangensis	NA	2.33	1.20	NA	6.647	2.935	NA	0.053	0.169
Rubus alpestris Blume	0.60	0.40	NA	4.588	1.939	NA	0.038#	0.056	NA
Rubus paniculata Smith	0.53	0.40	NA	5.610	2.288	NA	0.019#	0.036#	NA
Rumex nepalensis Spreng	2.40	1.80	1.00	9.729	5.227	3.021	0.067	0.063	0.090
Sambucus ebulus Linn.	NA	0.87	0.60	NA	3.268	2.157	NA	0.054	0.084
Sarcococca saligna Muell.Arg.	0.60	1.33	NA	2.863	3.898	NA	0.150	0.083	NA
Schefflera sp.	0.67	0.13	NA	2.990	0.530	NA	0.167	0.300	NA
Senecio chrysanthemoides DC.	NA	0.80	2.20	NA	2.828	6.300	NA	0.072	0.050#
Viburnum stellulatum Wall.	1.00	0.47	NA	5.922	2.378	NA	0.046#	0.042#	NA

L – low elevation site, M – medium elevation site, H – high elevation site

†Species having highest IVI, #Species in random distribution, NA – Not applicable

Table 4. Number of family, genera and species of herbs and shrubs; species richness and diversity indices at the three elevation sites (m.)

Elevation sites	Family	Genera	Herb species	Shrub species	Total species	Species richness index (D)	Species diversity index (H)
Low (2400-2800)	20	26	14	21	35	12.079	1.285
Medium (2800-3200)	25	45	26	28	54	17.730	1.570
High (3200-3600)	23	43	28	21	49	16.322	1.558

elevation site, and it decreased with the decrease in elevation, which may be due to the increase in bamboo clump density at the lower elevations with competitive exclusion of herbs and shrubs by *A. maling*.

This study revealed that in temperate zone, the distribution and colonization of other plant species in bamboo forests is highly influenced by the density of bamboo. The higher the bamboo density the lower is the diversity and density of other plant species. Soil and climatic condition pertaining to the habitat as well as the allelopathic effects of bamboos on other plant species might also have influenced on the diversity, distribution and density of other plant species in this temperate bamboo forest of Eastern Himalaya, India.

Finally, plants such as *Eragrostis ciliaris, Anthopogon lanceolatus* and *Rumex nepalensis* etc. showed high Importance Value Index, which may be due to their adaptive nature to extreme environments in all the three elevation sites including inbuilt defense mechanism against allelopathic effects of *Arundinaria maling.*

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Volume 23 2010

BAMBOO SCIENCE & CULTURE

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