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Carbon Flux and Carbon Stock in a Bamboo Stand and their Relevance for Mitigating Climate Change

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ABSTRACT

In this report we describe the basics of biological carbon fixation in bamboo forests. Confusing carbon stock with carbon flux has led to false expectations on the significance of bamboo forests as carbon sinks. Furthermore, misunderstandings about the growth of bamboo culms can lead to highly exaggerated expectations on the productivity of bamboo.

RESUMO

O artigo explica as interrelações básicas que governam a fixação biológica de carbono em florestas de bambu. A confusão de conceitos entre fluxo de carbono e estocagem de carbono resulta em falsas expectativas sobre a capacidade de fixação de carbono em florestas de bambu. Além disso, idéias equivocadas acerca do crescimento de um colmo de bambu levam a expectativas exageradas sobre a produtividade de um bambuzal.

Carbon storage in the ecosystem of a bamboo stand

A number of recent publications raise high expectations on bamboo forests as a CO₂ sink and include misconceptions on their climatic effectiveness (Widenoja 2007, Henley *et al.* 2009, Lobovikov *et al.* 2009, Nath *et al.* 2009, Lou *et al.* 2009, INBAR Media Release 2010, Janssen and Lou 2010, Lou *et al.* 2010), due to an inadequate differentiation between carbon flux and carbon stock. In this report we outline the relationship between carbon flux and carbon stock of bamboo forests and their climatic significance.

Isagi *et al.* (1997a) quantitatively measured the relationship between carbon flux and carbon stock in an unused *Phyllostachys edulis* stand of at least 130 years in which dead culms and branches were removed once a year. The results are displayed in a flow diagram (Fig. 1).

In this diagram, Isagi *et al.* divided the total

carbon stock of the ecosystem of a bamboo forest into several compartments. These compartments have different carbon storage capacities, through which carbon fluxes occur to varying degrees. Above-ground storage compartments comprise the culms, branches, and leaves. Below-ground compartments comprise the rhizomes and the root system, the litter layer and the humus mineral soil. Similar studies were done for a *Phyllostachys bambusoides* forest (Isagi *et al.*, 1994).

Carbon enters the storage system by photosynthesis of the leaves and exits by respiration of the above-ground parts of the plant, the removal of dead culms and soil respiration. Of all the living biomass of the plant, culms have the highest capacity to store carbon. However, most of the carbon is stored in the decomposing biomass in the ground. Soil respiration consists of the respiration of heterotrophic organisms, which decompose the dead biomass and transform the stored carbon into CO₂, and of

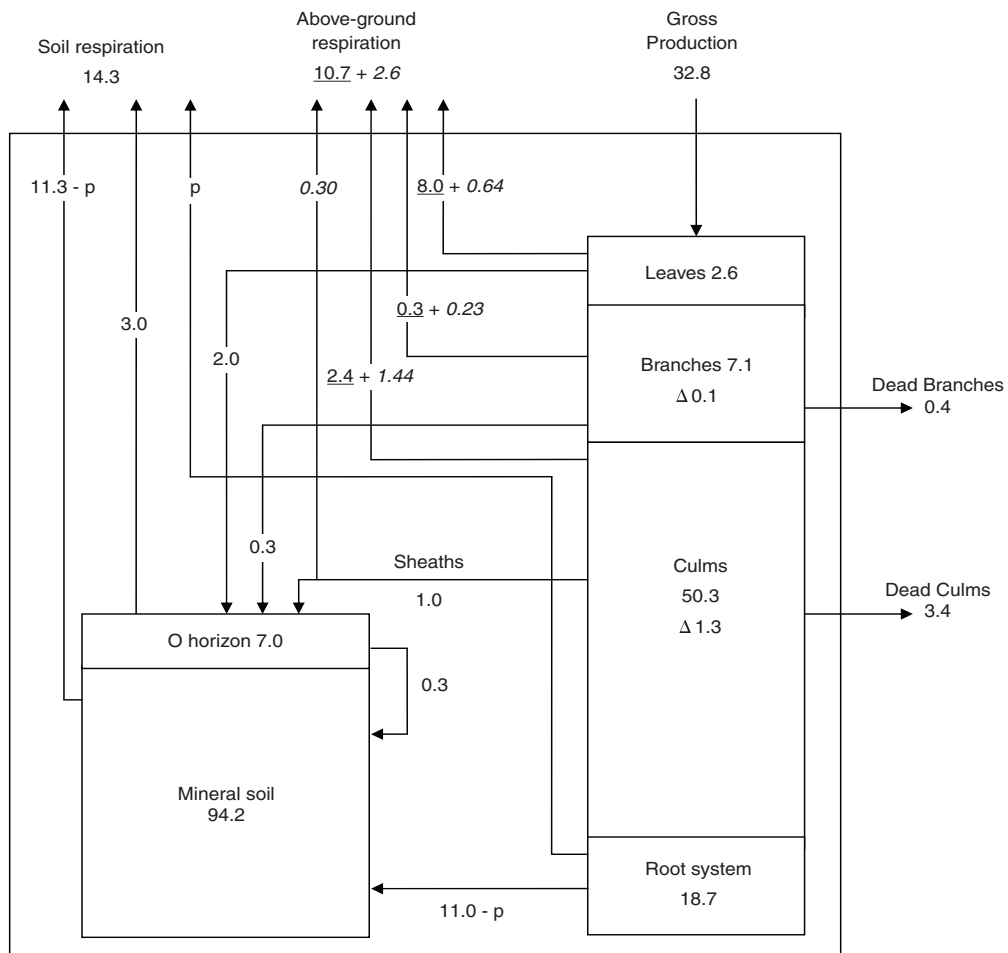


Figure 1. Compartmental representation of carbon stock and cycling in a *Phyllostachys edulis* stand. Figures in rectangles represent *carbon stocks* (t C ha⁻¹) and figures near arrows represent *carbon flux* between the compartments (t C ha⁻¹ yr⁻¹). Underlined and italic figures represent fluxes of maintenance and construction respiration of above-ground organs, respectively. From Isagi *et al.* (1997).

the respiration of the rhizome and root systems (in Figure 1 denoted by “p”). Moreover, the carbon stored in removed culms is also released as CO₂ into the atmosphere by decomposition or burning. Since individual culms have a lifespan of only 8 to 10 years, a bamboo forest always contains numerous old, dying culms.

In the mature bamboo forest studied by Isagi *et al.*, CO₂ intake and CO₂ release were roughly equal. When a newly planted bamboo forest reaches its final size after several years and no longer increases in height, culm thickness or density, this forest has reached a state of biological equilibrium. Statistically, for every new culm or leaf, an old culm or old leaf will

die and be decomposed, thereby releasing CO₂ from the stored biomass into the atmosphere. A bamboo forest that has passed into the steady-state stage is therefore CO₂ neutral (Figure 2).

The only time when in the eco-balance CO₂ is removed from the atmosphere, is when a woodless area is reforested with bamboo, and only until this plantation has reached its steady state. Indeed, as soon as the plantation has matured to a fully developed bamboo forest, the carbon stock of the above-ground living biomass and the rhizome and root system will not continue to increase. These conclusions are



Figure 2: A mature moso forest

the same for non-bamboo forests (Körner 2009). Trees have a longer lifespan than bamboo culms and unlike bamboo culms become taller and thicker throughout their lifetime, but in a forest ecosystem, carbon fluxes are also equalized by felling and tree die-back, as well as by storm and fire damage. If natural forests were truly effective CO₂ sinks, they would have – long before the era of industrialization occurred – reduced the atmospheric CO₂ content so far that plant growth would have become difficult.

The effect of bamboo forests on the climate is not determined by their productivity but instead by the sum of the above-ground living biomass and the below-ground carbon stock. Trunks in forest ecosystems generally accumulate a large amount of carbon (Isagi *et al.* 1994). Bamboo culms in contrast are hollow and do not carry out secondary growth. Hence a bamboo stand generally has a smaller carbon stock in the plant body than a comparable forest ecosystem. In the *Phyllostachys edulis* forest researched by Isagi *et al.* the total amount of carbon stock was 179.9 t C ha⁻¹, the sum of all the figures in the rectangles. Comparing the input and output of CO₂ and taking account of a slight increase of biomass in Isagi's flow diagram shows a balance of exactly zero.

The often forcefully advocated productivity of bamboo is irrelevant for the CO₂ storage of bamboo forests. For every type of vegetation in a steady state between growth and decomposition a high productivity also means a high rate of decomposition (Figure 3). Such an ecosystem has a high carbon flux and the mean residence time of carbon in the biomass is thus relatively short. An unused bamboo forest in a steady state is a CO₂ stock that has reached its maximum storage capacity of carbon.

It must also be mentioned that the monocarpic flowering in many bamboo species often results in the death of this species over large geographical areas sometimes worldwide (Figure 4). This leads to a temporary release of decade-long stored carbon in the form of CO₂ into the atmosphere. Areas with dead bamboos have a so-called CO₂ debt, until the forest has fully recovered. According to a model calculation for *Phyllostachys bambusoides* (Isagi *et al.* 1997b) the leaf biomass is saturated before the culm biomass, and the culm biomass is saturated about 20 years after the mass flowering. Extensive bamboo flowering may lead to a fluctuation of the CO₂ content in the atmosphere, but does not have a long-term effect on the CO₂ storage in the ecosystem.

Terms such as growth rate, net photosynthesis rate and net primary production pertain to different aspects of carbon flux. Using these terms when discussing the effectiveness of bamboo forests as carbon stock can lead to confusion and to the wrong conclusions. Also, quite often a negative correlation exists between growth rate and biomass in an ecosystem. For example, fast growing wood plantations with short rotation periods have very small CO₂ storage capacities (Körner 2009). A negative correlation is also observed in old bamboo plantations, in which the growth rate slowly declines, because the culms increasingly compete with each other and new culms begin to sprout to maximal thickness and height.



Figure 3. Old bamboo culms

In timber forests, the *growth rate* (i.e. the *carbon flux*) can be increased by continuing rejuvenation. The *biomass* (i.e. the *carbon stock*) in the ecosystem, however, can only be increased by an underutilization, not by an increase in productivity (Körner 2009). Such an underutilization of bamboo forests would contradict the numerous potential economic uses for the culms. Moreover, intensive management leads to increased soil respiration and to a lower carbon stock of the top soil (Zhou *et al.*, 2006).

According to the data of Isagi *et al.*, the biomass of the researched bamboo forest increased within 8 years, from November 1983 to November 1991, by $\Delta 1.3 \text{ t C ha}^{-1} \text{ year}^{-1}$ in culms and by $\Delta 0.1 \text{ t C ha}^{-1} \text{ year}^{-1}$ in branches. In mature bamboo stands in steady-state the amount of biomass will probably fluctuate around the equilibrium point depending on the varying ecological factors. After a phase of growth, a phase of decline may follow. From these data it cannot be concluded that a bamboo forest can unlimitedly increase its above ground biomass and therefore continue forever to act as an active CO_2 sink.

The above considerations apply only on the condition that a steady state also exists in the soil between humus formation and humus decomposition. But even without this condition, the increase of carbon stock in humus-bearing topsoil is so slow that this process could play no important role as a controllable CO_2 sink (Körner 2009).

The assumption that bamboo could reduce the CO_2 content in the atmosphere by developing long-living phytoliths that contain carbon (Parr *et al.* 2009) needs more comprehensive research (Köhl and Frühwald 2009). In accordance with this assumption, large depots of phytoliths would have to be found under century old bamboo stands. This assumed carbon stock would also have to show significant annual net increases to prove its effectiveness as an active carbon sink.

An anthropogenic CO_2 increase in the atmosphere could theoretically lead to an increase of the biomass in forests through an elevated equilibrium level. However there are no reliable data to back up the assumption that a potential increase in growth rate by CO_2 fertilization would significantly change the amount of biomass in an ecosystem (Körner 2006).



Figure 4. Monocarpic flowering

Carbon storage in bamboo products

A bamboo stand can only achieve a natural steady state between growth and decomposition if the culms are not constantly removed. However, a bamboo stand that is subject to regular harvesting will only become a true CO_2 sink if the carbon of the removed culms is stored in resulting bamboo products. There are about 1,500 kinds of products for manifold purposes. The commercial bamboo utilization is estimated to about 20 million tons/years, but much more is consumed by rural life (Scurlock *et al.* 2000). Main fields for bamboo utilization are construction, furniture, bamboo-based panels and boards. The pulp and paper industry is also a big consumer of bamboo biomass. Less than half of the harvested biomass is used for high quality products with a high durability. The climatic effectiveness of bamboo products is dependent on the quantity of products, that can be kept in circulation, from the initial production to the final decomposition, e.g. by incineration. There are a number of factors that influence the quantity of bamboo products, but the most important factor is the durability of the products. The lower the durability, the more frequently a bamboo product needs to be replaced in an existing pool of products.

Increased product durability could lead to a considerable increase in the willingness of consumers to use bamboo products and therefore increase the product stock. However, bamboo does not have any innate biological defense mechanism and is easily attacked and destroyed

by insects and fungi. The chemical protective measures that are frequently used to enhance durability often have environmental side effects (Liese and Kumar 2003, Liese and Düring 2009).

The storage of carbon in bamboo products corresponds to the storage of carbon in the ecosystem. The size of the product pool, resp. the carbon stock, is not determined by the rate of production, resp. the carbon flux, as long as the loss through decomposition or incineration is equal to the production rate. Only an increase in product quantity with the same or increased residence time of carbon in the products can enlarge the carbon sink (according to Körner 2009).

Suggestions to deposit bamboo coal as “biochar” into the soil and therefore decrease the CO₂ content in the atmosphere (Scholz and Hasse 2008, Köhl and Frühwald 2009) must be viewed with skepticism because of the order of magnitude and incalculable risks this kind of geo-engineering proposal would entail.

Sustainable bamboo stands as protection of old natural forests

The potential of bamboo as a CO₂ sink is often overestimated, especially at international congresses, e.g. recently in Cancun. It would be more effective to preserve old, carbon-rich forests and to meet the worldwide demand for wood with sustainable forestry (Körner 2009). In order to preserve forests and develop rural areas, suggestions to plant more bamboo stands for building material and fuel have been made (Lou *et al.* 2010, Lobovikov *et al.* 2009, Lou *et al.* 2009). If bamboo is competing with other fast growing wood plantations in this function, the factor productivity, resp. the carbon flux, becomes important, alongside other forestry factors. This is contrary to the CO₂ storage in the ecosystem.

Internet comments on the UN Climate Change Conference (COP 16) in Cancun show that misconceptions on culm growth and bamboo productivity still play a big role in the public discussion on bamboo (Nerenberg 2010). Under no circumstances can the much-cited fast development of a new bamboo culm (e.g. van der Lugt *et al.*, 2010) be used as a criterion for productivity. The growth of the leafless culm does not originate from its own ongoing photosynthesis, but from the allocation of organic material produced during the previous year and stored in the rhizome system and

older culms (Magel *et al.* 2005, Liese 2009; Figure 5). In contrast to trees, older bamboo culms do not get anymore thicker and higher, but use their annual yield largely for the growth of new culms.

To study the efficiency of the photosynthesis system in bamboo it is more useful to observe a bamboo seedling during its first period of growth instead of a fast growing culm. When the transfer of organic material from the old culms and the rhizome system is excluded a more accurate impression of photosynthesis activity is obtained.

Bamboo does not belong to the group of fast growing C₄ plants, such as maize or sugarcane (Hattersley, 1987). Therefore, since the type of CO₂ fixation in bamboo is the same as in trees (C₃), this provides no indication that bamboo is more productive than other fast growing trees (Scurlock *et al.* 2000).

While the preservation of old forests (including natural bamboo forests) is most effective (Körner, 2009), the high expectations and misconceptions of bamboo productivity will inevitably lead to overexploitation of natural resources and depletion of carbon stocks. In order to avoid overexploitation of bamboo stands and the inherent reduction of culms with a usable size, reports on the productivity of bamboo should rely on realistic data.



Figure 5. Growth of young moso shoots by allocation

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REFERENCES

- Hattersley, P.W. 1987. Variations in the Photosynthetic pathway. In: Soderstrom, T.R., Hilu, K.W., Campbell, C.S., Barkworth, M. (Eds.): Grass systematics and evolution. Smithsonian Institution Press, Washington DC & London.
- Henley, G., Lou, Y. 2009. The Climate Change Challenge and Bamboo – Mitigation and Adaptation. INBAR, 17 pp.
- INBAR Media Release, 2010. UNFCCC hears bamboo has a special niche to help climate and development objectives. Cancun 2010
- Isagi, Y. 1994. Carbon stock and cycling in a bamboo *Phyllostachys bambusoides* stand. *Ecological Research* 9, 47-55.
- Isagi, Y., Kawahara, T., Kamo, K. and Ito, H. 1997a. Net production and carbon cycling in a bamboo *Phyllostachys pubescens* stand. *Plant Ecology* 130: 41 – 52.
- Isagi, Y., Kawahara, T., Kamo, K. and Ito, H. 1997b. A computer-aided management system of *Phyllostachys* stands based on the ecological characteristics of carbon cycling. In: Chapman G.P. (Ed.) The Bamboos. Linnean Society Symposium Series Number 19.
- Janssen, J. and Lou, Y. 2010. Capturing carbon with bamboo. *BAMBOO* 31(3): 10-14.
- Köhl, M. and Fruhwald, A. 2009. Permanent wood sequestration: No solution to the global carbon dioxide problem. *Chem. Sus. Chem.* 2: 609-613.
- Körner, Ch. 2006. Plant CO₂ responses: an issue of definition, time and resource supply. *New Phytologist* 172: 393–411.
- Körner, Ch. 2009. Biologische Kohlenstoffsenken: Umsatz und Kapital nicht verwechseln! *GAI* 18,4 : 288 – 293.
- Liese, W. 2009. Bamboo as Carbon-Sink – Fact or Fiction? *Journal of Bamboo and Rattan* 8: 103-114.
- Liese, W. and Duking, R. 2009. Bambus als CO₂ Speicher? *Naturwissenschaftliche Rundschau* 62 (7):341-348.
- Liese, W. and Kumar, S. 2003. *Bamboo Preservation Compendium*. CIBART, ABS, INBAR, Techn. Rep. No 22, 231 pp.
- Lobovikov, M., Lou, Y., Schöne, D. and Widenoja, R. 2009. The poor man's carbon sink. Bamboo in climate change and poverty alleviation. FAO Non-Wood Forest Products Working Document N° 8.
- Lou, Y., Henley, G. and Li, Y. 2009. Capturing Carbon with Bamboo. Fast and effective in managed stands. INBAR Environment Factsheet No. 3, COP 15, 2 pp.
- Lou, Y., Yanxia, L., Buckingham, K., Henley, G. and Zhou, G. 2010. *Bamboo and Climate Change Mitigation*. INBAR Technical Report No. 32, 47 pp.
- Magel, E., Kruse, S., Lutje, G. and Liese, W. 2005. Soluble carbohydrates and acid invertases involved in the rapid growth of developing culms in *Sasa palmata* (Bean) Camus. *Bamboo Science and Culture* 19: 23-29.
- Nath, A. J., Das, G. and Das, A. K. 2009. Above ground standing biomass and carbon storage in village bamboos in North East India. *Biomass and Bioenergy* 33(9): 1188-1196
- Nerenberg, J. 2010. *Using Bamboo to Fight Climate Change*. Fast Company.
- Parr, J., Sullivan, L., Chen B., Ye, G. and Zheng, W. 2009. Carbon bio-sequestration within phytoliths of economic bamboo species. *Global Change Biology* 16(10): 2661-2667.
- Scholz, F. and Hasse, U. 2008. Permanent wood sequestration: The solution to the global carbon dioxide problem. *Chem.Sus. Chem* 1: 381-384.
- Scurlock, J.M.O., Dayton, D.C. and Hames, B. 2000. Bamboo: an overlooked biomass resource? *Biomass and Bioenergy* 19: 229–244.
- Van der Lugt, P., Vogtländer, J. and Brezet, H. 2009. *Bamboo, a Sustainable Solution for Western Europe – Design Cases, LCAs and Land-use*. INBAR Technical Report No. 30.
- Widenoja, R. 2007. *Sub-optimal equilibriums in the carbon forestry game: Why bamboo should win but will not*. Thesis. The Fletcher School of Law and Diplomacy, 104 pp.
- Zhou, G-M, Xu, J-M., Jiang, P-K. 2006. Effect of management practices on seasonal dynamics of organic carbon in soils under bamboo plantations. *Pedosphere* 16(4): 525-531.

Changes of Cell Wall Polysaccharides of Moso Bamboos of Four Different Ages

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ABSTRACT

The cell wall polysaccharides in moso bamboos of four different ages were extracted with cyclohexane-trans-1,2-diaminetetra-acetate (CDTA), Na_2CO_3 , $1\text{mol}\cdot\text{L}^{-1}$ KOH and $4\text{mol}\cdot\text{L}^{-1}$ KOH solutions. Gas chromatography (GC) was used to analyze the monomeric sugar residues after methylation and trimethylsilylation. The results show that the average yields of cell-wall polysaccharides in the cell wall material (CWM) residue fractions were the highest compared to other four fractions, while that in the Na_2CO_3 fractions were the lowest. Cell walls of moso bamboo consisted mainly of arabinose, galactose, glucose, xylose residues, while five other components were scarce, especially mannose residues. Galactose and arabinose had a significant influence on the changes in the pectic side chains of moso bamboo, and arabinose, glucose and xylose contributed to the growth of moso bamboo woods.

A list of abbreviations

CDTA – cyclohexane-trans-1,2-diaminetetra-acetate
GC – Gas chromatography
CWM – cell wall material
Ara – Arabinose;
Fuc – Fucose;
Gal – Galactose;
GalA – Galacturonic acid;
Glc – Glucose;
Man – Mannose;
Rha – Rhamnose;
Xyl--Xylose;

INTRODUCTION

Bamboo, a highly fibrous grass, is one of the most important forest resources, growing abundantly in many tropical and subtropical countries. The plant has a fast growing rate, a high strength and stiffness, can easily be used in many manufacturing processes and is available on many locations (Lu, 2006). Bamboo stands attain maturity within 3 years in controlled forests. The plant is considered as a short-term renewable resource, which has environmental advantages over long-cycle renewable resource extraction (Scurlock, *et al.* 2000; YaMashita *et al.*

2007). Moso bamboos (*Phyllostachys pubescens* Mazel ex H. de Lehaie), one of the most popular bamboos, is of high economic significance in China. Since this species is both lightweight and exceptionally durable, the treated moso bamboo is used extensively as building material for houses, construction scaffolding, flooring, bridges, etc. Also, the shoots are extensively used to make furniture, chopsticks, food steamers, paper pulp, etc (Sathitsuksanoh *et al.*, 2010).

The lignification of plant tissues is an extremely complicated process, which involves not only an increase in lignin content, but also the changes of cellulose, hemicellulose, lignins, pectins and insoluble proteins. The two major components in the cell wall, cellulose and hemicelluloses, consist mainly of polysaccharides. Therefore, deposition of cellulose and hemicellulose in plant cell walls is directly associated with changes in cell-wall polysaccharides (Cosgrove *et al.*, 1997; Selvendran & MacDougall, 1995; Edashige & Ishii, 1998). In our study, the relationship between the lignification of moso bamboo tissues and the changes in the composition of the cell-wall polysaccharides were revealed by isolating and analyzing the CWM from the cell walls of moso bamboo culms of different ages. Based on these results, the proper harvesting time will be determined for moso bamboo woods, for different industrial uses such as panel manufacture, paper pulping, biochemistry.

MATERIALS AND METHODS

Raw materials and Reagents. Fresh moso bamboos (*Phyllostachys pubescens* Mazel ex H. de Lehaie) of four different ages (1, 3, 5 and 7 years) were harvested from Fuyang (Zhejiang, China) in September 2007. Of all harvested moso bamboo stems, each time the middle parts were used in this paper. After being air-dried exhaustively at room temperature, moso bamboo stems were sliced to pieces and ground to powder. The samples were stored in dark place until the time of analysis.

Arabinose, galactose, galacturonic acid, glucose, fucose and rhamnose were purchased from Sigma Chem. Co. (St. Louis, MO, USA).

Mannose was from TCI Chem. Co. (Tokyo, Japan). Xylose was purchased from Sanland Chem. Co. (USA). Cyclohexane-trans-1,2-diaminetetra-acetate (CDTA) was purchased from Nacalai Chem. Co. (Kyoto, Japan). Hexamethyldisilazane and trimethylchlorosilane were purchased from Sinopharm Chem. Reag. Co. (Shanghai, China). Other reagents were bought from Kermel Chem. Reag. Co. (Tianjin, China).

Preparation of cell-wall materials and sequential chemical extraction of the polysaccharides. Cell-wall material CWM of moso bamboo was prepared by the method described by Rose (1998) with some modifications. The bamboo powders were ball milled at 400 RPM for 20h (QM-DK2, Instrument Factory of Nanjing University, China); afterwards, about 9 g of the outcomes were boiled in 120 mL of 95% ethanol for 40 min. After pouring off the liquid, the solid left was boiled in 100 mL of 80% ethanol for 20 min, and finally filtered with 5-15 μm sand core filter pore after the temperature of the mixture had dropped to room temperature. Insoluble residues were washed sequentially with 100 mL of mixture of chloroform and methanol (1:1, *V/V*), and 100 mL of acetone until a pale yellow material was obtained. The residue was dried at 30°C and stored in the dark for analysis.

The polysaccharides of cell walls were extracted sequentially as described previously (Selvendran & O'Neill, 1987; Konno, *et al.* 2010; Mateos-Aparicio, *et al.* 2010; Jin, *et al.* 2006) with some modifications. The CWM (500 mg dry weight) were sequentially extracted with 50 $\text{mmol}\cdot\text{L}^{-1}$ CDTA (pH 6.5, 100 mL) at 20°C for 9 h; 50 $\text{mmol}\cdot\text{L}^{-1}$ Na_2CO_3 (100 mL) containing 20 $\text{mmol}\cdot\text{L}^{-1}$ NaBH_4 at 1°C for 20 h; 1 $\text{mol}\cdot\text{L}^{-1}$ KOH (100 mL) containing 20 $\text{mmol}\cdot\text{L}^{-1}$ NaBH_4 at room temperature for 2 h, and 4 $\text{mol}\cdot\text{L}^{-1}$ KOH (100 mL) containing 20 $\text{mmol}\cdot\text{L}^{-1}$ NaBH_4 at room temperature for 2 h. The extractions with Na_2CO_3 and KOH were carried out under N_2 atmosphere. After each extraction step, the soluble polymers were separated from the insoluble residues by centrifugation (1000rpm/min, 10 min), and the supernatants were dialyzed exhaustively against distilled water at 5°C and concentrated by rotary evaporation at 65°C; Na_2CO_3 and

KOH-soluble fractions were neutralized with glacial acetic acid prior to dialysis. After 4 mol·L⁻¹ KOH extraction, the CWM residues were washed successively with distilled water and ethanol, and then dried at 50°C.

Analysis of the sugar composition from CWM. Each extracted fraction was pretreated for gas chromatography as described by Komalavilas and Mort (1989) and Albersheim *et al.* (1967) with some modifications. A methylating agent was prepared by adding acetyl chloride (140 µL) to anhydrous methanol (4 mL). Standards of monosaccharide or extracted polysaccharides (10 mg) were suspended in methylating agent (20 mL) with 5 mg of inositol, and kept hermetically under N₂ atmosphere for 16 h at 65°C. 4 mL of these cooled solutions were concentrated to dryness at 40°C under a stream of nitrogen gas. 2 mL of pyridine, 0.4 mL of hexamethyldisilazane and 0.2 mL of trimethylchlorosilane were added sequentially and the mixed solution was kept at 80°C for 20 min. The reagents were evaporated at 40°C under a continuous N₂ stream. The residues were extracted twice with hexane (1.5 mL×2), and after centrifugation, the supernatants were concentrated at 40°C using a stream of N₂. Finally, 1 mL of hexane was added to be used for GC analysis.

The samples were analyzed by gas chromatography on an Agilent 6890N (Agilent AG, USA). Pretreated aliquots of 5 mL were injected into an HP-1 capillary column (30 m×0.25 mm). The injector temperature and FID were kept at 250°C. The oven temperature was programmed starting at 150°C for 1 min, then increased at 10°C per min to 200°C, held there for 10 min;

then increased again at 10°C per min to 240°C, and was finally held there for 5 min (Jin *et al.*, 2006). Sugar residues were identified by comparison with authentic standards and quantified using inositol as the internal standard.

Statistical data treatment. All extractions were done in triplicate. Average values, standard deviation and statistical significance according to a LSD test ($p \leq 0.05$) were calculated and performed using the program of SPSS 17.0.

RESULTS AND DISCUSSION

Contents changes of cell-wall polysaccharides extracted from moso bamboo. In this paper, cell-wall polysaccharides were separately extracted from CWM of moso bamboo with 4 different ages using CDTA, Na₂CO₃, 1 mol·L⁻¹ KOH and 4 mol·L⁻¹ KOH solutions. Table 1 shows the yields of different fractions, in function of the extraction agents. The average contents of cell-wall polysaccharides in the CWM-residue fractions were the highest (33.58-35.89 mg/100 mg CWM) compared to other fractions, while that in the Na₂CO₃ fractions were the lowest (6.65-9.13 mg/100 mg CWM). Contents of the CDTA and 1 mol·L⁻¹ KOH fractions ascended in growth period (1-3 years) of moso bamboo, and then descended gradually in mature period (3-5 years) and senescent period (after 5 years). Contents of cell-wall polysaccharides in Na₂CO₃ fractions decreased with the age going up, finally tended to stabilization, while the opposite tendency was found in 4 mol·L⁻¹ KOH. In CWM-residue fractions, contents increased with growth period and mature period, and decreased in senescent period.

Table 1. Contents changes of cell-wall polysaccharides extracted from moso bamboo cell walls of four different ages using chelating reagent and alkaline solutions

Fraction	Contents of cell-wall polysaccharides (mg/100 mg CWM)			
	1-year	3-year	5-year	7-year
CDTA	14.44±0.85 ^a	14.61±0.93 ^a	13.52±0.76 ^a	14.47±0.71 ^a
Na ₂ CO ₃	9.13±0.41 ^a	7.33±0.56 ^b	6.68±0.64 ^b	6.65±0.39 ^b
1 mol·L ⁻¹ KOH	23.18±1.14 ^a	24.24±2.75 ^a	23.65±1.76 ^a	23.57±2.28 ^a
mol·L ⁻¹ KOH	12.23±0.45 ^a	12.67±1.44 ^a	12.41±1.07 ^a	13.14±0.78 ^a
CWM-residue	33.58±2.78 ^a	33.73±2.61 ^a	35.89±1.60 ^a	35.25±2.72 ^a
ΣFrac.	92.56	92.58	92.15	93.08

Different superscripts within the same line in every fraction represents significant differences according to a LSD test ($p \leq 0.05$).

Table 2. Contents of monomeric sugar in cell-wall polysaccharides extracted from four different bamboo ages

Fraction	Ages (Year)	Monomeric composition (mg/100 g CWM)									
		Ara	Fuc	Gal	GalA	Glc	Man	Rha	Xyl		
CDTA	1	153.46±8.42 ^a	5.12±0.13 ^b	13.61±4.63 ^c	8.19±1.21 ^b	392.74±10.76 ^c	-	4.77±0.86 ^b ^c	214.04±9.84 ^c		
	3	119.98±9.24 ^b	3.56±0.08 ^c	22.99±4.36 ^c	3.92±1.14 ^c	119.98±5.20 ^d	-	3.69±0.74 ^c	157.11±5.13 ^d		
	5	128.85±8.40 ^b	-	60.36±7.42 ^b	8.25±1.17 ^b	570.79±13.47 ^a	-	5.39±1.06 ^b	325.75±10.27 ^a		
Na ₂ CO ₃	7	103.52±8.53 ^c	10.19±1.12 ^a	83.92±7.26 ^a	15.39±2.38 ^a	454.96±12.85 ^b	-	12.80±0.91 ^a	247.01±10.39 ^b		
	1	94.86±7.18 ^a	-	49.57±4.29 ^a	9.53±0.11 ^a	329.72±10.96 ^a	6.40±0.99	5.87±0.27 ^a	179.97±9.62 ^a		
	3	60.83±4.15 ^b	5.45±0.19 ^a	38.29±2.94 ^b	7.59±0.30 ^b	312.90±24.41 ^a ^b	-	5.57±0.23 ^a	162.89±7.62 ^b		
1 mol•L ⁻¹ OH	5	45.22±3.04 ^c	3.48±0.13 ^b	28.28±4.20 ^c	7.42±0.19 ^b	237.33±14.13 ^c	-	3.64±0.18 ^c	144.88±6.40 ^c		
	7	43.85±2.53 ^c	3.09±2.22 ^c	17.49±2.27 ^d	9.38±0.34 ^b	283.65±15.26 ^b	-	4.64±0.13 ^b	155.87±5.50 ^b ^c		
	1	165.99±9.28 ^e	-	66.38±3.8 ^b	-	1431.89±62.63 ^b	-	-	782.32±19.25 ^b		
4 mol•L ⁻¹ OH	3	194.34±7.48 ^b	-	40.70±5.59 ^c	50.43±6.20 ^b	1046.98±54.66 ^c	58.98±2.77 ^b	25.03±3.97 ^b	524.30±28.80 ^c		
	5	270.45±13.24 ^a	-	178.09±8.27 ^a	82.24±3.05 ^a	2620.33±92.34 ^a	184.51±5.66 ^a	83.94±8.04 ^a	1405.50±56.85 ^a		
	7	168.44±7.28 ^c	9.69±0.12 ^a	43.71±3.57 ^c	15.92±0.70 ^c	573.41±18.92 ^d	19.20±1.09 ^c	12.97±3.39 ^c	323.24±20.79 ^d		
CWM-residue	1	106.77±7.48 ^e	-	39.73±2.26 ^b	-	560.90±11.57 ^a	-	-	269.11±10.99 ^a		
	3	157.76±3.80 ^a	7.25±0.63 ^a	13.12±1.09 ^d	8.12±0.44 ^b	501.84±8.53 ^b	21.16±0.74 ^a	-	212.45±8.10 ^b		
	5	142.28±6.69 ^b	6.88±0.36 ^a	49.12±3.04 ^a	11.61±0.81 ^a	387.02±8.66 ^c	9.16±0.41 ^b	6.92±0.83 ^a	198.85±9.37 ^b		
CWM-residue	7	80.17±2.41 ^d	3.43±0.05 ^b	20.70±1.48 ^c	4.35±0.12 ^c	185.97±6.50 ^d	-	3.41±0.14 ^b	102.35±4.02 ^c		
	1	386.68±8.84 ^a	-	36.91±1.43 ^b	-	1479.52±76.05 ^c	70.25±2.14 ^a	30.95±3.61 ^b	842.25±12.13 ^c		
	3	285.94±6.53 ^b	-	212.97±8.75 ^a	41.88±1.95 ^b	2104.81±195.18 ^b	-	29.60±3.41 ^b ^c	1242.56±91.76 ^b		
	5	375.89±15.34 ^a	34.09±0.97 ^a	222.51±8.97 ^a	49.82±7.01 ^a	2602.72±70.75 ^a	-	75.69±4.11 ^a	1410.28±30.95 ^a		
7	264.18±12.31 ^c	16.10±1.03 ^b	39.03±0.56 ^b	44.32±4.07 ^a ^b	1219.39±79.02 ^d	46.42±5.35 ^b	23.76±2.75 ^c	670.14±20.12 ^d			

* Ara: Arabinose; Fuc: Fucose; Gal: Galactose; GalA: Galacturonic acid; Glc: Glucose; Man: Mannose; Rha: Rhamnose; Xyl: Xylose; -: not detected.
 * Different superscripts within the same column in every fraction represents significant differences based on a LSD test ($p \leq 0.05$).

The water-soluble fraction is typically thought to include polymeric material that has been solubilized from the cell wall, whereas the CDTA and Na_2CO_3 fractions are generally considered to be enriched for ionically and covalently bound pectins, respectively. Polymers extracted with $1 \text{ mol}\cdot\text{L}^{-1}$ KOH usually contain a high proportion of hemicellulosic polysaccharides, whereas $4 \text{ mol}\cdot\text{L}^{-1}$ KOH is necessary to extract hemicellulose-rich polymers that are tightly bound to the cell walls, and to cellulose microfibrils in particular. The residual material following $4 \text{ mol}\cdot\text{L}^{-1}$ KOH extraction is mainly comprised of cellulose and a small quantity of associated polysaccharides (Rose, *et al.* 1998).

Content change of monomeric sugar in every fraction. After methylation and trimethylsilylation, monomeric sugar residues were obtained from cell wall polysaccharides of moso bamboo. As shown in Table 2, eight different kinds of standard sugars had been detected in this experiment in tremendously different quantities. The cell walls of moso bamboo consisted mainly of arabinose, galactose, glucose and xylose residues, while the contents of other four compositions were scarce, especially mannose residues.

Based on Obro *et al.* (2004), the changes of the galacturonic acid to rhamnose residue ratio are often reflecting modifications of the main pectic chains, while changes of the alactose to rhamnose and the arabinose to rhamnose residue ratio are reflecting the modifications of pectic side chains. As shown in Fig. 1A, in CDTA fractions, the galacturonic acid to

rhamnose residue ratio decreased during growth period from 1.72 to 1.06, but increased in mature period reaching to 1.53, finally decreased slightly to 1.20. The galactose to rhamnose residue ratio increased significantly within first 5 years from 2.85 to 11.20, but descended to 6.56 during senescent period. The ratio of arabinose to rhamnose residue was constant during the growth period (ratio: 32.17-32.51), but decreased rapidly in the mature and senescent period, eventually dropping to 8.09. This indicated that the constitution of pectic main chains in different bamboo ages was stable, but more changes happened in pectic side chains. This suggests that the modifications of side pectic chains contribute significantly to the growth of moso bamboo woods.

In Na_2CO_3 fractions, the ratios of the galacturonic acid to rhamnose residue at four ages were 1.62, 1.36, 2.04 and 2.02, separately (Fig. 1B). Galactose to rhamnose residue ratios decreased, on the whole, from 8.44 in 1 year to 6.87 in 3 years and to 3.77 in 7 years, however, with a little rebound during mature period (ratio: 7.77). The same tendency had been found in the ratio of arabinose to rhamnose residue, which dropped from 16.16 in 1 year to 10.92 in 3 years and to 9.45 in 7 years, with a rebound at 12.42 in 5 years. According to this, we can reveal that the pectic main chains in different bamboo ages were also stable as well as that in CDTA fractions. In the meantime, the side pectic chains degraded with the bamboo ages going up.

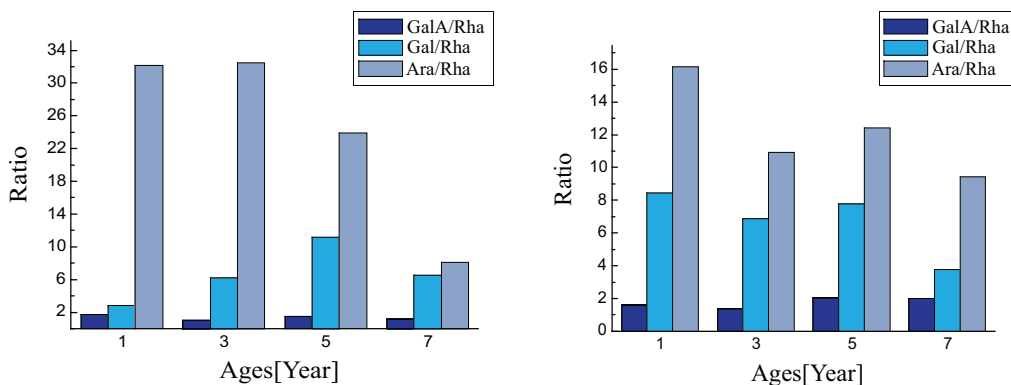


Fig. 1 Changes in galacturonic acid to rhamnose residue ratio (GalA/Rha), galactose to rhamnose residue ratio (Gal/Rha) and arabinose to rhamnose residue ratio (Ara/Rha) of pectic fractions of moso bamboo at different ages
A: CDTA fraction; B: Na_2CO_3 fraction

As described by Rose (1998), CWM extracted with 1 mol•L⁻¹ KOH and 4 mol•L⁻¹ KOH usually contain a high proportion of hemicellulosic polysaccharides that are bound to the cell walls. Table 2 shows indeed that the 1 mol•L⁻¹ KOH and 4 mol•L⁻¹ KOH fractions contain higher amounts of arabinose, glucose and xylose, which made up the hemicellulosic polysaccharides of moso bamboo, than the pectin-rich (CDTA and Na₂CO₃) fractions, separately. The contents of these three monomeric sugars all reached the maximum in 1 mol•L⁻¹ KOH at 5 years. However, galacturonic acid and rhamnose contents were low in these two fractions. This indicates that arabinose, glucose and xylose contents are also related with the growth of moso bamboo woods. Finally, the primary sugars in CWM-residue fractions were arabinose, galactose, glucose and xylose residues (Table 2).

CONCLUSION

First of all, the average contents of cell-wall polysaccharides in the CWM-residue fractions were the highest, while those in the Na₂CO₃ fractions were the lowest. Secondly, cell-walls of moso bamboo consisted mainly of arabinose, galactose, glucose and xylose residues, while the contents of other fucose, galacturonic acid, mannose and rhamnose were scarce, especially mannose residues. Finally, galactose and arabinose had a significant influence in changes in side pectic chains of moso bamboo, and arabinose, glucose and xylose were contributed to the growth of moso bamboo woods. Therefore, further work should be taken to study the specific relationship between growth of moso bamboo and these monomeric sugars.

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LITERATURE CITED

- Albersheim, P., Nevins, D.J., English, P.D., Karr, A. (1967). A method for the analysis of sugar in plant cell wall polysaccharides by gas-liquid chromatography. *Carbohydrate Research*. 5: 340-345
- Cosgrove, D.J., Bedinger, P., Durachko, D.M. (1997). Group I allergens of grass pollen as cell wall-loosening agents. *Proceedings of the National Academy of Sciences of the USA*. 94 (12): 6559-6564
- Edashige, Y., Ishii, T. (1998). Hemicellulosic polysaccharides from bamboo shoot cell-walls. *Phytochemistry*. 49 (6): 1675-1682
- Jin, C.H., Suo, B., Kan, J., Wang, H.M., Wang, Z.J. (2006). Changes in cell wall polysaccharide of harvested peach fruit during storage. *Journal of Plant Physiology and Molecular Biology*. 32 (6): 657-664
- Komalavilas, P., Mort, A.J. (1989). The acetylation at 0-3 of galacturonic acid in the rhamnose-rich portion of pectins. *Carbohydrate Research*. 189: 261-272
- Konno, H., Tsumuki, H., Nakshima, S. (2010). Characterization of the cell wall polysaccharides and glycosidehydrolyzing enzymes of *Distylium racemosum* callus. *Plant Science*. 178: 213-220
- Lu, K.T. (2006). Effects of hydrogen peroxide treatment on the surface properties and adhesion of ma bamboo (*Dendrocalamus latiflorus*). *Journal of Wood Science*. 52 (2): 173-178
- Mateos-Aparicio, I., Redondo-Cuenca, A., Villanueva-Suarez, M.J. (2010). Isolation and characterization of cell wall polysaccharides from legume by-products: Okara (soymilk residue), pea pod and broad bean pod. *Food Chemistry*. 122: 339-345
- Obro, J., Harholt, J., Scheller, H.V., Orfila, C. (2004). Rhamnogalacturonan I in *Solanum tuberosum* tubers contains complex arabinogalactan structures. *Phytochemistry*. 65 (10): 1429-1438
- Rose, J.K.C., Hadfield, K.A., Labavitch, J.M., Bennett, A.B. (1998). Temporal sequence of cell wall disassembly in rapidly ripening melon fruit. *Plant Physiology*. 117: 345-361

- Sathitsuksanoh, N., Zhu, Z.G., Ho, T.J. Bai, M.D., Zhang, Y.H.P. (2010). Bamboo saccharification through cellulose solvent-based biomass pretreatment followed by enzymatic hydrolysis at ultra-low cellulose loadings. *Bioresource Technology*. 101 (13): 4926-4929
- Scurlock, J.M.O., Dayton, D.C., Hames, B. (2000). Bamboo: an overlooked biomass resource. *Biomass and Bioenergy*. 19 (4): 229-244
- Selvendran, R.R., MacDougall, A.J. (1995). Cell-wall chemistry and architecture in relation to sources of dietary fibre. *European Journal of Clinical Nutrition*. 49 (3): 27-41
- Selvendran, R.R., O'Neill, M.A. (1987). Isolation and analysis of cell walls from plant material. *Method of Biochemical Analysis*. 32: 25-153
- Yamashita, O., Yokochi, H., Imanishi, H., Kanayama, K. (2007). Transfer molding of bamboo. *Journal of Materials Processing Technology*. 192-193: 259-264

***Chusquea mayrae* (Poaceae: Bambusoideae: Bambuseae), a new species of montane forest bamboo from Costa Rica**

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ABSTRACT

Chusquea mayrae is described as a new species of woody bamboo from the lowland montane forest in Provincia de San José, Costa Rica. *Chusquea mayrae* is distinct from all sympatric Costa Rican *Chusquea* species in that it exhibits a scandent, clambering habit, with delicate culms, and two sizes of subsidiary branches. The new species exhibits similarities with *Chusquea repens*, a species from southern Mexico, and their characteristics are contrasted here. We consider *Chusquea mayrae* to be endangered due to the unprotected status of the three known localities, the low numbers of individuals observed, and rapid habitat loss in the Tarrazú region.

RESUMEN

Se describe *Chusquea mayrae* como una especie nueva de bosque bajo montañoso de la Provincia de San José, Costa Rica. Se distingue *Chusquea mayrae* de las demás especies simpátricas de *Chusquea* por el hábito bejucoso, sus culmos finos, entrenudos largos, y yemas subsidiarias de dos tamaños. *Chusquea mayrae* es más afin a *Chusquea repens*, una especie del sur de México, y aquí se las comparan. Consideramos *Chusquea mayrae* estar en peligro de extinción debido a la situación sin protección de las tres localidades conocidas, el bajo número de individuos observados, y la rápida pérdida de hábitat en la región de Tarrazú.

With 14 endemic species, Costa Rica and western Panama are one of the biodiversity hotspots of the neotropical woody bamboo genus *Chusquea* Kunth, along with southeastern Brazil and the Andean forests of Ecuador and Peru (Judziewicz *et al.* 1999). Costa Rica alone is home to 22 species of *Chusquea*, where they are a major component of high elevation montane forests and subpáramo habitats (Montiel L. 1991). Although Costa Rica has had a long history of botanical exploration, several new species of *Chusquea* have been described from the Cordillera de Talamanca in the last 25 yrs (e.g., Clark and March 2000).

In contrast to the species diversity found at higher elevations, there are only six *Chusquea* species found in the lower montane forests and

cloud forests of Costa Rica (*C. coronalis* Soderstr. & C. Calderón, *C. liebmannii* Fourn., *C. scabra* Soderstr. & C. Calderón, *C. serpens* L. G. Clark, *C. simpliciflora* Munro, and *C. virgata* Hack.). These species are all members of *Chusquea* subgenus *Chusquea*, which occurs throughout the range of *Chusquea* and exhibits a wide variety of morphologies (Clark 1989; Fisher *et al.* 2009). Subgenus *Chusquea* is divided into five sections and two informal groups; Costa Rica contains species from sections Longifoliae, Serpentes, and Verticillatae.

The authors collected two specimens of a probable new species of *Chusquea* in Provincia de San José while making collections for a phylogenetic study of woody bamboo genera. Photographic images of its salient features and

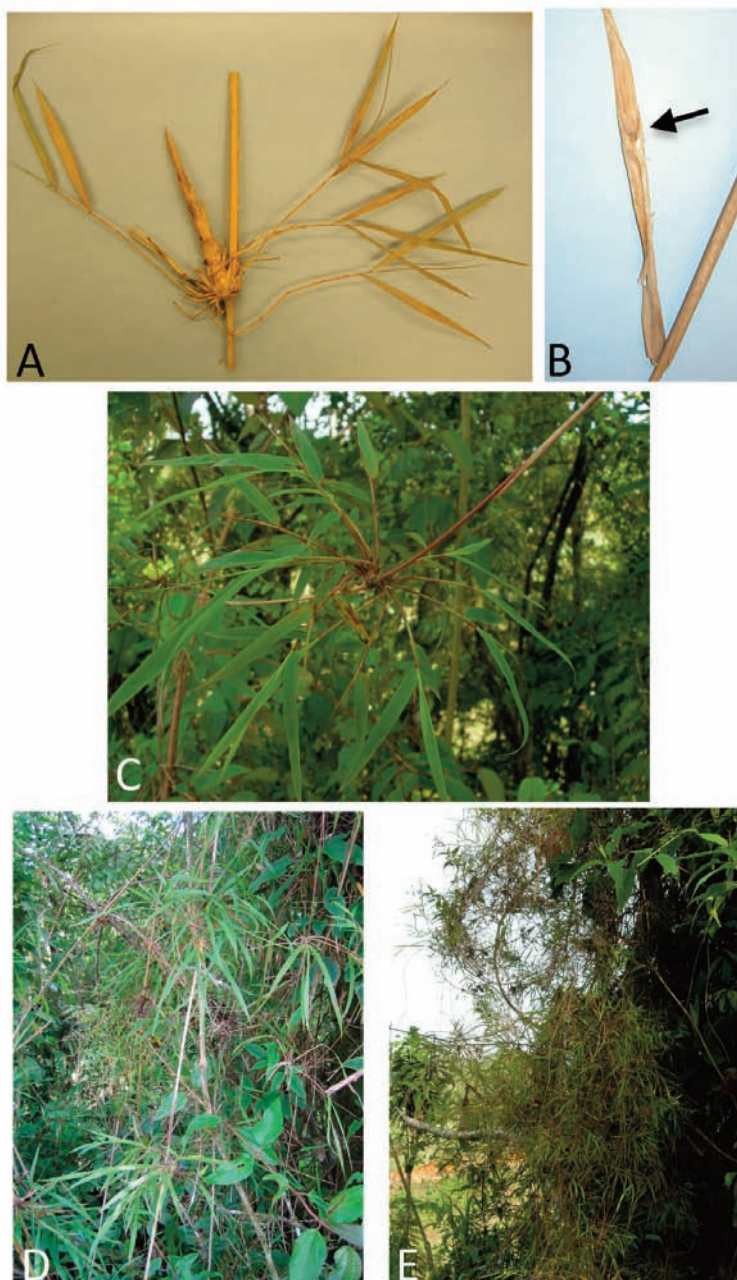


Fig. 1. *Chusquea mayrae* A. Mature branch complement and portions of two internodes showing a developed central branch and a few smaller leafy subsidiary branches. B. Arrow indicates the U-shaped junction between blade and sheath of the culm leaf. C. Mid-culm branch complement, with a persistent culm leaf blade. D. Internodes of hanging culms. E. Habit with many culms clambering onto surrounding foliage and hanging in a mat. (All photos from Fisher *et al.* 32.)

a map of its distribution are shown in Figs. 1 and 2. These specimens have a morphological affinity to *Chusquea repens* L. G. Clark and Londoño, but differ in several obvious characters. No flowering material of this species

was observed; however, the novelty of the vegetative characters found in these collections lead us to award it formal recognition as the new species *C. mayrae*. We describe this species and distinguish it from *C. repens* (Table 1).

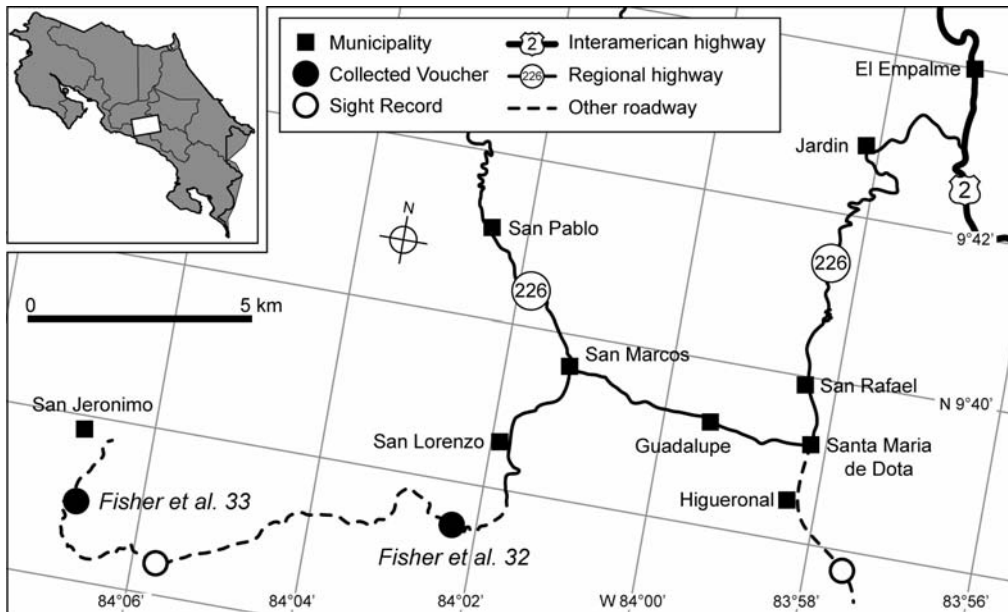


Fig. 2. Known locations of *Chusquea mayrae*.

TAXONOMIC TREATMENT

Chusquea mayrae A. E. Fisher, C. D. Tyrrell, and L. G. Clark sp. nov. TYPE: COSTA RICA. San José: Area de conservación Pacífico Central (ACOPAC), along road to Napoles, 7 km SW of San Lorenzo (9° 37' N, 84° 3' W), elev. 1898 m, 14 June 2008, A. E. Fisher; C. D. Tyrrell and L. G. Clark 32 (Holotype: INB; Isotypes: CR, ISC, US, USJ).

Gramen lignosum. Culmi 0.3-0.5 cm diametro, 5-10 m longi, scandentes. Internodia ad culmum medium 30-50 cm longa, scabrida. Folia culmorum 24-45 cm longa, persistentes;

vaginae adaxialiter pubescentes secus marginem superpositam versus apicem, abaxialiter scabridae; cingulum 0.2-0.5 cm latum, glabrum, junctura ad vaginam notata per cristam suberosam ad 0.2 cm. Nodi ad culmum medium gemma centrali singulari triangulari gemmis subsidiarii cujusquisque nodi 14-30 subtenta. Ramificatio infravaginalis. Vaginae foliorum glabrae; laminae 7.4-11.5 cm longae, 0.45-1.1 cm latae, long./lat. = 7-26, glabrae, non tessellatae. Synflorescentia ignota.

Woody bamboo. Rhizomes unknown. Culms 5-10 m long, 0.3-0.5 cm in diam, scandent, clambering and hanging. Internodes 30-50 cm

Table 1. Morphological comparison of *Chusquea mayrae* and *Chusquea repens*.

Character	<i>C. mayrae</i>	<i>C. repens</i>
Culm length (m)	5-10	1-6
Internode length (cm)	30-50	6-14
Culm leaf blade	persistent, erect	caducous, reflexed
Culm leaf length (cm)	24-45	4.7-6.6
Branching pattern	infravaginal	extravaginal
Subsidiary branch # per node	14-30	10-25
Subsidiary branch size classes	2	1
Inner ligule (mm)	0.8-2	0.5-8
Culm leaf blade-sheath junction (adaxial)	“U” to curvi-linear dark mark	linear mark
Distribution	Costa Rica	Mexico

long on mature culms, solid, terete, scabrid where exposed. Culm leaves 24-45 cm long, persistent, extending one half to one full internode length at midculm; juncture of sheath and blade U-shaped or curvi-linear, adaxially distinct, abaxially indistinct; sheaths 17-34 cm long, 3-5 times as long as the blade, abaxially scabrous, adaxially pubescent just inside the overlapping margin, otherwise smooth and shiny, margins entire; girdle 0.2-0.5 cm wide, corky, brown, glabrous, a corky flange up to 0.2 cm wide present at the juncture with the sheath base; blades 4-11 cm long, erect, persistent, glabrous, adaxially and abaxially scabrid, apex subulate; inner ligule ca. 1 mm long, glabrous. Nodes at mid-culm with a triangular central bud subtended by 14-30 subsidiary buds in 1-2 constellate rows, subsidiary buds of two sizes, usually 2 larger buds directly subtending the central bud and 12-28 smaller buds; nodal line dipping below central bud; supranodal ridge present as a pale line; nodal region glabrous. Branching infravaginal; central branch sometimes developing, 0.2-0.5 cm in diam; subsidiary branches of two sizes, the larger two developing into robust branches extending beyond the smaller branches and often rebranching; the smaller subsidiaries developing into leafy branches 10-25 cm long. Foliage leaves 3-5 per complement; sheath glabrous, margins ciliate toward the sheath summit, the cilia 0.05-0.1 cm long; blades 7.4-11.5 cm long, 0.45-1.1 cm wide, L:W = 7-26, linear to lanceolate, glabrous, venation not tessellate; midrib centric; base attenuate, apex aristulate to subulate; pseudopetiole 1-3 mm long, glabrous, pulvinate at the base; pulvinus yellow; inner ligule 0.8-2 mm, glabrous, truncate to irregular; outer ligule 0.1-0.3 mm, glabrous. Synflorescence unknown.

Distribution and Habitat. *Chusquea mayrae* is known only from a few populations south of San José, Costa Rica, between 1600-1900 m elevation (Fig. 2). Fisher *et al.* 32 was collected in a roadside montane forest remnant and Fisher *et al.* 33 was found in secondary growth forest. Both collection sites were in areas heavily impacted by grazing and farming. This species may have previously been widespread in the area.

Phenology. No flowering collections of this species are known.

Etymology. *Chusquea mayrae* is named for Costa Rican agrostologist Mayra Montiel Longhi, who has taught courses on agrostology and forage grasses at the Universidad de Costa Rica since 1965. She has published several papers on the ultrastructure of species in the Bambusoideae and the Ehrhartoideae and has generously facilitated agrostology field work in Costa Rica.

Placement in *Chusquea*. *Chusquea mayrae* exhibits the novel combination (within *Chusquea*) of small culm diameters (0.3-0.5 cm), long internodes (30-50 cm), infravaginal branching, a corky flange (or “skirt”) present at the juncture of the sheath and girdle, and two sizes of subsidiary branches. In addition to the 12-28 smaller subsidiary buds, two larger subsidiary buds subtend the central bud directly. These sometimes develop into branches that may rebranch and develop foliage leaves on the secondary branches, but they consistently extend beyond the smaller leafy subsidiary branches that develop from the smaller subsidiary buds. With this combination of characters we classify *C. mayrae* in *Chusquea* subg. *Chusquea*, and note that preliminary molecular evidence resolves *C. mayrae* in a clade with other Costa Rican subgenus *Chusquea* taxa (Fisher 2011). However, we are unable to place it in any of the recognized sections or informal groups within that subgenus, so we put it in *Incertae Sedis* along with *C. repens* and a number of other species (Fisher *et al.* 2009).

C. mayrae is most similar to *C. repens*, a species known only from southern Mexico. Both *C. repens* and *C. mayrae* have long, narrow culms that clamber into surrounding trees and hang down (Clark and Londoño 1991). However, *C. mayrae* has longer culms and internodes, persistent and erect culm leaf blades (in contrast to the caducous and reflexed culm blades of *C. repens*), longer culm leaves, infravaginal branching, two sizes of subsidiary branches, and short inner ligules on the foliage leaves instead of the usually longer, often ciliate, inner ligules in *C. repens* (Table 1). There is also a slight distinction between the two species in the markings on the adaxial juncture between the culm blade and sheath. The inner

ligule is marked by a dark “U” to tilda shaped curve in *C. mayrae*, while it is marked by a light line in *C. repens*. No molecular work has yet been conducted on *C. repens*.

Conservation Status. The species appears to be narrowly endemic to the low elevation montane forests of Costa Rica. The few known populations of *C. mayrae* are located in unprotected areas and are in jeopardy due to habitat loss and fragmentation. As in other agricultural areas in Costa Rica, the Tarrazú region in San José Province has undergone rapid development and land clearing for both coffee plantations and cattle grazing in the last 70 yrs (FAO 2007). *C. mayrae* can be classified as endangered (EN) according to the International Union for Conservation of Nature (IUCN) criterion A2: observed or suspected population size reduction of $\geq 50\%$ over the last 10 yrs where the reduction or its causes may not have ceased or may not be understood or may not be reversible, based on (a) direct observation and (b) a decline in area of occupancy, extent of occurrence and/or quality of habitat. In addition, *C. mayrae* may meet IUCN endangered criteria B1&2: extent of occurrence estimated to be less than 500 km², and known to exist at no more than five locations and continuing observed decline in (i) area of occupancy, (ii) area, extent and/or quality of habitat, and (iii) number of locations or subpopulations (IUCN 2001).

Representative specimens examined: Costa Rica. San José: less than 1 km W of Alto San Juan on the roadside, near San Carlos, 9°37' N, 84°7' W, elev. 1619 m, 14 June 2008, Fisher, Tyrrell and Clark 33 (CR, ISC, US, USJ).

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LITERATURE CITED

- Clark, L.G. 1989. Systematics of *Chusquea* Section *Swallenochloa*, Section *Verticillatae*, Section *Serpentes*, and Section *Longifoliae* (Poaceae-Bambusoideae). *Systematic Botany Monographs* 27: 1-127.
- Clark, L.G. and R.H. March. 2000. *Chusquea costaricensis*, A New Species of *Chusquea* sect. *Swallenochloa* (Poaceae: Bambusoideae). *Bamboo Science and Culture* 14(1): 4-9.
- Clark, L.G. and X. Londoño. 1991. Miscellaneous new taxa of bamboo (Poaceae: Bambuseae) from Colombia, Ecuador and Mexico. *Nordic Journal of Botany* 11(3): 323-331.
- (FAO) Food and Agriculture Organization of the United Nations. 2007. State of the World's Forests. Rome.
- Fisher, A. E. 2011. Phylogenetic Studies of Plastid Evolution in the Neotropical Woody Bamboo Genus *Chusquea* (Poaceae: Bambusoideae: Bambuseae). Biological Sciences. Pocatello, Idaho, Idaho State University. Ph.D.
- Fisher A.E., Triplett J.K., Ho C.S., Schiller A.D., Oltrogge K.A., Schroder E.S., Kelchner S.A., Clark L.G. 2009. Paraphyly in the Bamboo Subtribe *Chusqueinae* (Poaceae: Bambusoideae) and a Revised Infrageneric Classification for *Chusquea*. *Systematic Botany*, 34: 673-683.
- (IUCN) International Union for Conservation of Nature and Natural Resources. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp.
- Judziewicz, E.J., L.G. Clark, X. Londoño and M.J. Stern. 1999. American Bamboos. Smithsonian Institution Press, Washington and London.
- Montiel Longhi, M. 1991. Introducción a La Flora de Costa Rica. San José de Costa Rica: Editorial de la Universidad de Costa Rica.

Antioxidant and pharmaceutical potential of bamboo leaves

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ABSTRACT

Bamboos (Poaceae: Bambusoideae: Bambuseae) form a unique group of giant arborescent grasses. Bamboo leaves form an important diet of pandas and are much valued as fodder. Literature on the nutritional value of bamboo leaves is scarce. Anti-oxidant of bamboo leaves (AOB) is used as a novel food anti-oxidant in many food items for which the safety has also been evaluated by a few researchers. Bamboo leaves have been found to contain flavonoids. With this background, this paper reviews the different compounds present in the leaves of different species of bamboo. Several studies have shown positive correlation between consumption of bamboo extract and prevention of diseases like cancer, diabetes, heart problems, aging, fatigue etc. Bamboo leaves being rich in flavonoids have been found to have a great pharmaceutical potential which has not been fully explored.

Keywords: bamboo leaves, flavonoids, antioxidant, pharmaceutical

Abbreviations: FAO: Food and Agriculture Organization, OM: Organic Matter, CP: Crude Protein, EE: Ether extract, CF: Crude Fat, NFE: Nitrogen Free Extract, NDF: Neutral Detergent Fiber, ADF: Acid Detergent fiber, NBT/XO: Nitroblue Tetrazolium Chloride/Xanthine Oxidase, ROS: Reactive Oxygen Species, MSH: Melanocyte Stimulating Hormone, DPPH: 2,2-Diphenyl-1-Picrylhydrazyl, AOB: Antioxidant of bamboo leaves, BLE: Bamboo Leaf Extract, NADPH: nicotinamide adenine dinucleotide phosphate.

INTRODUCTION

Non-timber forest products (NTFPs) are products of biological origin other than wood derived from forests. NTFP's have long been an important component of the livelihood strategies of forest-dwelling people including tribal. Several million households world-wide depend heavily on NTFP for sustenance as well as for meeting family nutritional needs. As per FAO estimates, approximately 80 percent of the population of the developing world use NTFP for health care and fulfilling nutritional needs. In addition to providing subsistence and income, commercial value of NTFP has been increasing. Important products traded from the tropics include rattan, brazil nuts, gum arabic, lac, bamboo and spices (Arinana *et al.* 2009).

Bamboos are group of giant arborescent grasses and are mainly found in the Mixed Deciduous and Tropical Evergreen forests and partly found in the dry Dipterocarps forest. More than 1250 species belonging to 75 genera have been reported to be distributed world-wide. In India 125 species are found spreading over an area of 9.57 million hectare (Sharma 1980). India has the richest bamboo resources after China. The North Eastern states are endowed with more than 50% of the Indian bamboo genetic resources. Besides its several uses to human life, it prevents soil erosion and conserves soil moisture and thus can prove to be of immense significance in environmental protection. Along with its wide usage in the structural and building materials, it also forms an essential component in cottage and rural industry (Sharma *et al.* 1992). It constitutes one of the most important renewable natural resources of India. Recently, some biologically active components in bamboo leaves and their potential health benefits have been reported in

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literature. This paper gives an overview of the investigated bio-activities and pharmaceutical potential of bamboo leaves.

Uses and nutritional composition

Bamboo leaves are much valued as fodder for ruminants particularly when there is scarcity of pasture. In some district bamboo foliage forms the favorite food of elephants & giant pandas (Raizada and Chatterji 1956). Bamboo fodder had been reported to promote high milk production as well as high ghee content. All species of bamboos and species given as fodder were considered to have positive effects on animals, particularly young calves (Thapa *et al.* 1997).

Leaves of 27 species of bamboo plants analyzed for their nutrient content were found to be rich in crude protein (9-19%) and low in crude fiber (18-34%). Seventy percent of the total ash content was silica and other insoluble mineral matters. Leaves were poor in P, K and Na, normal to rich in Zn and Ca and rich in Ca, Mg, Cu and Mn contents. Cu content was very high (17ppm) in *B. arundinacea* leaves (Singh 1999). Seven species of bamboo leaves of Tripura studied for their nutritional composition were found to contain 83.89±0.51, 12.42±0.51, 1.39±0.06, 25.28±0.59, 44.79±0.50, 16.11±0.52, 73.01±0.46, 41.61±1.11, 31.40±0.84, 32.15±0.74 and 5.59±0.32% of OM, CP, EE, CF, NFE, total ash, NDF, ADF, hemicellulose, cellulose and acid detergent lignin, respectively. They were also found to be deficient in P but rich in Ca, Fe & Mn. (Datt *et al.* 2006).

In another study, conducted in the south of Hubei Province of China, on the nutritional status of bamboo leaves (*Phyllostachys pubescens*) concentrations of N, P, K, Ca, Mg and S were found to be 24.3, 1.34, 5.44, 4.08, 1.41, 112.2 mg/kg dry matter basis respectively. The concentration of micronutrients namely Fe, Mn, Cu, Zn, B and Mo was 144.3, 269.5, 4.2, 27.1, 5.6 and 9.6 mg/kg dry matter basis respectively. As the bamboo yield increases macronutrients, except Mn, Cu and Zn, and micronutrient concentration also increased (Chen *et al.* 2004).

CP, CF, Ca and P content in 2 species of Bamboo, namely *D. strictus* and *B. arundinacea* was found to be 14.2-15.1, 23.5-25.6, 1.1-1.6, 0.2-0.3% in *D. strictus* and 18.6, 24.1,

0.6 and 0.2% for *B. arundinacea* respectively (Gulati *et al.* 1984)

Antioxidant of bamboo leaves (AOB)

The antioxidant of bamboo leaves, abbreviated to AOB, is a pale brown powder extracted from bamboo leaves of the *Phyllostachys* Sieb. et Zucc. genus, represented by *Phyllostachys nigra* var. *henonis*. The main functional components in AOB are flavonoids, lactones and phenolic acids. As Flavone C-glucosides are a group of representative flavonoids in AOB. The chemical structures of four flavone C-glucosides, including orientin, homoorientin, vitexin and isovitexin found in AOB, are shown in Fig. 1. Other polyphenols present in AOB are naringenin-7-rhamnoglucoside, quercetin, luteolin, rutin, tricrin, caffeic acid, chlorogenic acid and *p*-coumaric acid (Zhang *et al.* 2002b). AOB is used as a food antioxidant, which not only blocks the chain reaction of spontaneous oxidization of lipids, but also chelates transition metals, acting as a primary and secondary antioxidant simultaneously. On the basis of initial research, AOB was approved by the Food Additive Standardization Committee of People's Republic of China on December 28, 2003 as a novel food anti-oxidant, which can be used in edible oil, meat products, aquatic products and other foods with maximum dosage of 0.50 g/kg, and has been listed in the state standard GB-2760 (Hygienic Standards for Food Additives in Use) since April, 2004 (Hu *et al.* 2000; Lu *et al.* 2005; Lu *et al.* 2006). Studies done in fried bread sticks (Zhang and Zhang 2007), potato crisps and french fries (Zhang *et al.* 2007b) revealed the efficiency of using AOB to reduce acrylamide content by 82.9%, 74.1% and 76.1% in fried bread sticks, potato crisps & french fries respectively.

Table 1: Characteristics of antioxidant of bamboo leaves (*Phyllostachys nigra* var *henonis*)

Parameters	Specification
Total flavonoids	32.4%
Total lactone	15.6%
Phenolic acids	7.9%
Ash	1.24%
Protein	2.3%
Total heavy metals	<0.001
Moisture	4.9%

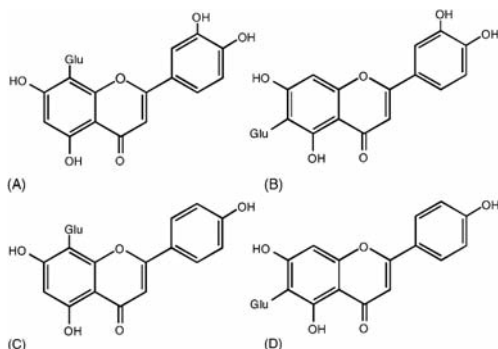


Figure 1: Chemical structure of the studied flavone C-glycosides in antioxidant of bamboo leaves (AOB): (A) orientin; (B) homoorientin; (C) vitexin; (D) isovitexin.

Safety evaluation of AOB

Animal models

For safely using AOB in food systems safety evaluation studies were conducted on animal models. The safety of AOB was examined by evaluating acute oral toxicity using Kun-Ming mice and Sprague-Dawley rats. A 90-day oral toxicity study showed that the maximum tolerated dose (MTD) of AOB was >10 g/kg body weight in both rats and in mice and there was no evidence for mutagenic effects. Administration at levels of 1.43, 2.87 and 4.30 g/kg per day to the rats for 90 days did not induce significant hematological, clinic, chemical and histopathological changes (Lu *et al.* 2005). Moreover when tested for teratogenicity, mortality did not occur. Weight gain during gestation, food consumption, and food efficiency were similar in all groups; reproductive performance was not affected and examination of the fetuses for external, visceral, and skeletal alterations did not reveal any fetotoxic, embryotoxic, or teratogenic effects of AOB. These safety studies suggested a no-observed-adverse-effect level (NOAEL) of 4.30 g/kg per day indicating safe use as food additive (Lu *et al.* 2006).

Sensory evaluation studies

AOB has recently been used in many food systems to reduce the carcinogenic agents formed during thermal processing of the food product. AOB with a total flavanoid content of 32% at an antioxidant ratio of 0.1 and 0.5% reduced acrylamide formation in fried chickens wings by 57.8 & 59% without affecting the original flavor & odour (Zhang *et al.* 2007a).

Secondary metabolites in Bamboo leaves and their antioxidative role

Secondary metabolites including flavanoids and polyphenols are widely distributed in medicinal plants, fruit juices, teas and health beverages, resulting in high human consumption (Walle 2004). Flavonoids generally occur in plants as glycosylated derivatives, and they contribute to the brilliant shades of blue, scarlet, and orange colours in leaves, flowers, and fruits. In recent years the health effects of flavonoids present in human diet have attracted much attention. Several studies suggested that they act as antioxidants (Burns *et al.* 2000; Kaneko and Baba 1999), and epidemiological studies indicate an inverse association between the intake of flavonoids and the risk of cardiovascular diseases (Hertog *et al.* 1995; Knekt *et al.* 1996; Yochum *et al.* 1999) and different types of cancer (Marchand *et al.* 2000).

Flavonoid content was found to be on average 3.44% in different bamboo leaves species. Bamboo leaf flavonoids content varied in different parts of bamboo and was found highest up to 3.35% in shady spot of leaves (Li 2009). In another study the total flavonoid (TF) of bamboo leaf varied in the range of 0.67%-1.71% (on dry basis of leaf) (Zhang *et al.* 2002a).

Four flavone C-glycosides, i.e. orientin (49 mg), homoorientin (142 mg), vitexin (15 mg) and isovitexin (62 mg) were isolated from an ethanol aqueous extract of AOB by AB-8 resin-based column chromatography and preparative high-performance liquid chromatography (HPLC) (Zhang *et al.* 2008). These four flavone C-glycosides were determined for the first time in several food systems fortified by the antioxidant of bamboo leaves (AOB), such as high temperature sterilized milk, sunflower seed oil and extruded rice cake. The total amounts of these four flavone C-glycosides were 12.56 $\mu\text{g}/100$ mL, 881.08 $\mu\text{g}/100\text{mL}$ and 1420.83 $\mu\text{g}/100$ g dry weight in AOB-fortified sterilized milk, sunflower seed oil and extruded rice cake, respectively (Zhang *et al.* 2005).

Phloroglucinol (PG), hydrocaffeic acid (HCA) & phloretic acid (PA) were identified as metabolites of these flavone C-glycosides. The fate of metabolism of flavone C-glycosides studied in rats revealed its poor absorption in the GI Tract, but prolonged retention time in

the colon suggested its ability to exert antioxidant activity and scavenge free radicals. More than 50% recovery of flavone C-glucosides was determined 12h after ingestion. Faeces contained 21.23 ± 1.92 % of these four analytes (Zhang *et al.* 2007c)

Six phenolic acids viz., chlorogenic, ferulic, coumeric, protocatechuic, vanillic and caffeic acids were identified in the fallen leaf water extract of *Bambusa arundinacea* according to another study (Eyini *et al.* 1989).

Sasa borealis is considered as a medicinal plant and a major source of bamboo leaves in Korea. Butanol extract of *S. borealis* leaves were found to have two antioxidative flavonoid C-glycoside derivatives, isoorientin (2) and isoorientin 2-O- α -L-rhamnoside (4) along with tricetin 7-O- β -D-glucopyranoside (1) and apigenin 6-C- β -D-xylopyranosyl-8-C- β -D-glucopyranoside (3). Flavonoids (2) and (4) showed potent free radical scavenging activity in DPPH assay with IC_{50} values of 9.5 and 34.5 μ M, respectively, and strong cytoprotective effects against oxidative damage in HepG2 cells, at significantly low concentrations of 1.1 μ M isoorientin and 0.8 μ M isoorientin 2-O- α -L-rhamnoside (Park *et al.* 2007). Ethanol extracts of 17 species of bamboo leaves belonging to 6 genera were found to contain flavonoids and phenolic acids and had strong antioxidative and free radical scavenging activity. The extraction rate, total flavonoid and total phenol content were 16.08 ± 3.59 %, 1.97 ± 0.57 % and 4.21 ± 1.05 % of dry leaves respectively and IC_{50} on $O_2^{\cdot-}$ and $\cdot OH$ scavenging were 4.93 ± 2.36 μ g/ml and 1.48 ± 0.91 mg/ml (on dry weight basis) (Zhang and Ding 1996). Tricetin (5,7,4'-trihydroxy-3',5'-dimethoxyflavone) occurring in its glycosidic form in rice bran and other grass species such as wheat, barley, and maize is considered safe for cancer prevention (Jiao *et al.* 2007). Tricetin (3.09 g) was prepared from 174 g of a crude column chromatography fraction obtained from 5 L of AOB (Jiao *et al.* 2007).

Three chlorogenic acid derivatives, one known and two novel, namely, 3-O-(3'-methylcaffeoyl)quinic acid (1), 5-O-caffeoyl-4-methylquinic acid (2), and 3-O-caffeoyl-1-methylquinic acid (3) were isolated from bamboo (*Phyllostachys pubescens*). The butanol extract of the bamboo leaves was found to have a significant antioxidant

activity. Compounds 2 (IC_{50} = 8.8 and 19.2 μ M) and 3 (IC_{50} = 6.9 and 14.6 μ M) showed ~2–4 times higher antioxidant activity than did chlorogenic acid (IC_{50} = 12.3 and 28.3 μ M), caffeic acid (IC_{50} = 13.7 and 25.5 μ M) and ferulic acid (IC_{50} = 36.5 and 56.9 μ M). Compound 1 yielded the weakest antioxidant activity (IC_{50} = 16.0 and 29.8 μ M). All three compounds exhibited stronger superoxide anion ($O_2^{\cdot-}$) scavenging activities (IC_{50} = 1, 4.3 μ M; 2, 2.8 μ M; and 3, 1.2 μ M) than ascorbic acid (IC_{50} = 56.0 μ M), α -tocopherol (IC_{50} > 100 μ M), and other test compounds (Kweon *et al.* 2001). Solvent-extracted bamboo leaf extract (BLE) of the species (*Phyllostachys nigra* var. henonis) containing chlorogenic acid, caffeic acid, and luteolin 7-glucoside exhibited a concentration-dependent scavenging activity of DPPH radical, suppressed the rate of propagation of liposome peroxidation, prevented human low-density lipoprotein oxidation, mediated by Cu^{2+} and finally protected supercoiled DNA strand against scission. Prooxidant activity of BLE was seen in a Cu^{2+} -induced peroxidation of structured phosphatidylcholine liposome, indicating catalytic peroxidation due to a relatively high reducing power of BLE (Hu *et al.* 2000).

The antioxidant capacities of essential oils from leaves of the 15 bamboo species was evaluated using the DPPH assay. The antioxidant capacity of essential oil obtained from *Bambusa multiplex* (IC_{50} = 3.605 mg/mL) was greater than that from *Brachystachyum densiflorum* (IC_{50} = 12.128 mg/mL). The IC_{50} value of *Dendrocalamopsis oldhami* was 4.464 mg/mL. A positive correlation between antioxidant capacity and the concentration of essential oils is indicative for their antioxidative activity (Yue-jun *et al.* 2010).

The bamboo leaf extract of *Phyllostachys praecox* could scavenge the DPPH free radical with an IC_{50} value of 7.02 mg /l of the leaf extract and could significantly protect DNA from damage when the concentration is higher than 400 mg/L (Liu *et al.* 2009). Bamboo leaf extract had a strong antioxidative activity and was found to be as good as that of vitamin C (Yao *et al.* 2000). Bamboo extracts (*Phyllostachys nigra* var. henonis) had dose-dependently antioxidant activity in DPPH, NBT/XO and intracellular ROS assay. Bamboo extracts of *Phyllostachys* species inhibited xanthine oxidase (XO) directly. Bamboo extracts inhibited not

only purified tyrosinase activity but also inhibited melanin production in B16 melanoma cells stimulated by 1 μ M α -MSH. Bamboo extracts may thus be useful for the development as whitening agents reducing cytotoxicity (Song *et al.* 2007)

Absolutely Hemicellulose *Senanensis* (AHSS), a novel extract from *Sasa senanensis* showed antioxidative activity and inhibited the intestinal rat ischemia and subsequent reperfusion I/R induced production of lipid peroxide. Thus, AHSS could be an important source of ingredients for use in functional foods and other applications in protecting against oxidation as in cancer, heart diseases, stroke etc. (Kurokawa *et al.* 2006).

Pharmaceutical potential

Bamboo leaves and cancer

Bamboo leaves of different *Sasa* species have been widely used in food and medicine in Eastern Asia for hundreds of years. Of special interest are Kumai-zasa (*Sasa senanensis* Rehder) leaves used to prepare an alkaline extract known as Sasa Health. Chronic treatment for 12 days with Sasa Health, in drinking water at the concentration of 0.044%-0.088% Fe-Chlorophyllin Na resulted in the significant inhibition of both development and growth of spontaneous mammary tumours in a high mammary tumour strain of SHN virgin mice. Results indicated that Sasa Health could be a promising agent for the protection and therapy of breast and other types of tumours (Tsunoda *et al.* 1998). In another study the efficacy of Sasa Health (in hot water at 100, 121 and 196°C) was tested in mouse tumor models (S-180, C38 and Meth-A) for anti-tumor activity. Oral administration of the extracts at concentrations of 0.05% or higher significantly suppressed tumor growth in S-180 and C38 tumor models. Overall survival was significantly prolonged in the treatment group than that of control. The extracts resolved into three major fractions (F-I, F-II and F-III) out of which Fraction F-I consists of 1,3-beta-glucan and stimulated both macrophages and NK cells suggesting that it may be the primary immunopotentiating factor in suppressing cancer. Fraction F-III has potent free radical scavenging effects and may play an important role in cancer prevention. (Seki *et al.* 2008).

Two cohorts of Her2/NeuN female mice of different age (eleven-week-old and twenty-four-week-old) chronically treated with Sasa Health in drinking water showed both a delay in the development of tumors and reduced tumor multiplicity. Sasa Health also induced inhibition of mammary duct branching and side bud development in association with reduced angiogenesis indicating that it contains phytochemicals which retard spontaneous mammary tumorigenesis (Ren *et al.* 2004). Methanol extract of bamboo leaves induced rapid apoptosis in the human leukemia CMK-7 cell line. The active compounds are 201-hydroxypurpurin-7 delta-lactone ethyl methyl diester (1) and the corresponding methyl phytyl diester (2). The apoptosis by compound 1 (0.3 to 0.1 μ M for CMK-7 cells) was enhanced when the culture was briefly irradiated with a fluorescent lamp suggesting it to be a promising compound as photosensitizers for photodynamic therapy in cancer treatment. Compound 2 was a weaker inducer of apoptosis than compound 1. The apoptosis occurred after light irradiation (Kim *et al.* 2003).

Plasmic malondialdehyde (MDA) content was found to decrease whereas superoxide dismutase (SOD) activity increased in rats consuming BLE (bamboo leaf extract) indicating its free-radical scavenging activity in mice bearing carcinoma (Li *et al.* 2010). Possibility of bamboo in the treatment of leukemia became clear when treatment of human myeloid leukemia HL-60 cells with 50-400 μ g/mL acetone fraction of bamboo leaf for 72 hr significantly inhibited cell proliferation and induced a little increase in cell differentiation and nitroblue tetrazolium reduction assay. Synergistic induction of HL-60 cell differentiation was also observed when the acetone fraction of bamboo leaf was combined with either 5 nM 1,25-dihydroxyvitamin D (1,25-(OH)(2)D(3)) or 50 nM all-trans retinoic acid (RA). These results suggest that the acetone fraction of bamboo leaf enhanced leukemia cell differentiation and suggest a possibility of bamboo in the treatment of leukemia (Kim *et al.* 2007)

Bamboo and diabetes

Diabetes mellitus (DM), a global public health problem, is now emerging as an epidemic world over. According to a widely accepted estimation, the prevalence of diabetes for all

age-groups was 2.8% in 2000 and the number of diabetic patients is expected to reach 4.4% i.e. 366 million by the year 2030 (Wild *et al.* 2004). Diabetes is a metabolic disease which affects not only the glucose metabolism but also lipid and protein metabolism. There are mainly two types of diabetes – Type 1 and Type 2. In Type 1 or Insulin Dependent diabetes, the hormone insulin is not produced in the absence of pancreatic β -cells while Type 2 diabetes mellitus (T2DM) is characterized by a progressive impairment of insulin secretion by pancreatic β -cells and by a relative decreased sensitivity of target tissues to the action of this hormone (Kaushik *et al.* 2010).

When 50 diabetic mice were given different doses of polysaccharide from hairy bamboo, moso bamboo leaves (PMBL), it was found to possess a good hypoglycemic effect and it reduced significantly water and food intake and alleviate the weight loss of diabetic mice (Ding *et al.* 2007). Patty prepared with 2.5% of the water extract of bamboo leaf (*Sasa borealis*) substituted for the meat in ten healthy adult women significantly lowered plasma glucose concentrations indicating bamboo leaf or powder may improve blood glucose (Hyun and Hyeon-Sook 2009). *Sasa borealis* water-extract (SBwE) modulated the high glucose-triggered mitogen-activated protein kinase-dependent upregulation of heat-shock proteins. Moreover SBwE suppressed these detrimental effects caused by PKC-dependent peroxynitrite formation via activation of NADPH oxidase and induction of nitric oxide synthase and heat-shock protein family that may be essential mechanisms responsible for increased apoptotic oxidative stress in diabetic vascular complications (Choi *et al.* 2008). A flavone, luteolin 6-C-(6"-O-trans-caffeoylglucoside) isolated from black bamboo leaves (*Phyllostachys nigra*) was found to show a strong aldose reductase, advanced glycation endproducts inhibition and showed antioxidative activity and thus can be thought as a new natural drug for diabetic complications (Jung *et al.* 2007)

Bamboo leaves and cardiovascular disease

With industrialization, the major causes of death and disability, in the more advanced societies, have shifted from a predominance of nutritional deficiencies and infectious diseases, to those classified as degenerative (chronic dis-

eases such as cardiovascular disease (CVD), cancer, and diabetes). This shift has been termed “the epidemiologic transition” (Yusuf *et al.* 2001).

Reduction in blood viscosity, plasma viscosity and increase in the speed of electrophoresis time in blood adhesion model occurred in sixty rats when given different doses of Bamboo Leaf extract BLE (15 mg/kg, 30 mg/kg and 60 mg/kg). BLE at different concentrations of 22.5 mg/kg, 45 mg/kg, and 90 mg/kg could significantly reduce serum cholesterol of the high cholesterol's mice (Fu *et al.* 2005a). Extract from bamboo *Phyllostachys pubescens* showed protective effect against palmitic acid (PA)-induced lipoapoptosis (Panee *et al.* 2008). Tests done on rats showed that Bamboo beer, produced by fortifying BLE, rich in flavanoids lowered concentration of blood triglyceride and cholesterol significantly. Furthermore, it also elevated HDL-cholesterol and decreased LDL-cholesterol depending on dosage level (Zhang *et al.* 2000).

Orientin (0.5, 1.0 and 2.0 mg /kg) from bamboo leaves (*Phyllostachys nigra*), exerts a potent cardioprotective effect on ischemia/reperfusion (I/R), and hypoxia/reoxygenation (H/R) treated myocardium and cardiomyocytes, and inhibits apoptosis by preventing activation of the mitochondrial apoptotic pathway (cytochrome c - caspase-3 pathway) (Fu *et al.* 2006). Orientin, also relaxed phenylephrine-induced contractions with an IC₅₀ value of 2.28 μ M in the endothelium intact and with an IC₅₀ value around 7.27 μ M in the endothelium removed aortic rings of rabbit. Furthermore, Orientin inhibited norepinephrine (NE), CaCl₂ and KCl-induced vasoconstriction, concentration dependently in, and also reduced both the initial fast release and the sustained phases of phenylephrine-induced contractions. Orientin also increased cyclic guanosine 3',5'-cyclic monophosphate (cGMP) levels without changing in adenosine-3',5'-cyclic phosphoric acid (cAMP) in rabbit aorta. The inhibition of both intracellular Ca²⁺ release and extracellular Ca²⁺ influx may be one of the main vasorelaxant mechanisms of Orientin (Fu *et al.* 2005b).

Bamboo and aging

A number of evaluations done on bamboo-leaf-flavonoids (comparable to the tea polyphenols and the *Ginkgo biloba* extract) was found to be

anti-free radicals, anti-oxidative, and anti-radiation and anti-inflammatory. It significantly accelerated the proliferation of two kinds of rat skin cells and inhibited the pigment synthesis at a concentration of 0.005% to 0.05%. Hence bamboo-leaf-flavonoids have potential as anti-aging product to protect skin in cosmetics (Zhang et al 2004). Bamboo leaf-extract of *Phyllostachys nigra* var. henonis showed anti-aging effect by inhibiting the post-oxidation of lipid and scavenge post-oxidated products of aged mice (Zhang and Tang 1997).

Bamboo leaves and fatigue

Administration of an 80% ethanol extract (PJE) of the leaves of *Pseudosasa japonica*, one of the major bamboo species in Korea, lead to a 1.5-fold increase in swimming time of mice, compared to the control group. The blood lactate level, an important indicator of fatigue was significantly lower (28%, $P < 0.05$) in PJE group than in the control group suggesting that PJE possesses stimulatory effects that can enhance exercise endurance and reduce fatigue (Yanghee et al. 2006). Effect of the bamboo leaf-extract of the species *Phyllostachys nigra* var. henonis showed that it could enhance the capacity of anti-fatigue and resistance to nonspecific irritation in mice (Zhang and Tang 1997).

Bamboo leaves and Anti-inflammatory activity

Inflammation is a protective reaction against a variety of exogenous (microbial, chemical, physical) or endogenous (immunological, neurological) disturbances, which is characterized by the accumulation and activation of leukocytes in the affected tissue (Baggiolini and Dahinde 1994).

Methanol extract of the leaves of *Bambusa arundinacea* have been shown to possess anti-inflammatory effect on carrageen induced as well as immunologically induced paw oedema and antiulcer activity in albino rats (Muniappan and Sundararaj 2003).

Conclusion and Future Scope

Bamboo being the fastest growing grass has a potential to become man's favorite plant in view of its contribution to the environment, construction, food and fodder sectors. Bamboo leaves contribute as a source of fodder for ruminants in scarcity of pasture. Toxicity tests on animal models and sensory evaluation studies

done on AOB indicate its safe use within specified limits as a food additive. Mainly four flavonoids namely orientin, homoorientin, vitexin and isovitexin have been isolated from bamboo leaves.

A number of studies done by various investigators on the antioxidant potential of alcoholic extract of bamboo leaves reflect its huge potential in scavenging free radicals, although a lot needs to be explored through scientific validation and experimentation. Bioactivity of bamboo leaves and their potential health benefits have been widely studied by various researchers. Studies showing positive correlation between flavonoids present in bamboo leaves and prevention of cancer, diabetes, heart diseases etc. are still scarce. Bamboo leaves thus exhibit a great potential as a raw material to the nutraceutical and pharmaceutical industry for future investigations.

REFERENCES

- Arinana, Hinsui, J., Ignatius, B., Kronseder, K., Kärkkäinen, J., Pingoud, P., and Sandra, E. (2008). Non Timber Forest products in Northern Thailand. http://www.mm.helsinki.fi/MMEKO/VITRI/forrsa/RE_2_Course%20and%20workshop%20proceedings/report/Group5_Report.pdf. Accessed on 4/07/09.
- Baggiolini M. and Dahinden CA. 1994. CC chemokines in allergic inflammation. *Immunology Today*, 15 (3):127-13.
- Burns J, Gardner PT, O'Neil J, Crawford S, Morecroft I et al. 2000. Relationship among Antioxidant Activity, Vasodilation Capacity, and Phenolic Content of Red Wines. *J. Agric. Food Chem.* 48 (2): 220-230.
- Chen, WW, Luo, ZJ, Chen, F., Lu, JW, Ding, CP, 2004. The nutrition status and nutrition diagnosis of bamboo leaves in the South of Hubei. *Journal of Northeast Forestry University.* 32(2):41-44.
- Choi YJ, Lim HS, Choi JS, Shin SY, Bae JY, Kang SW, Kang IJ and Kang YH. 2008. Blockade of Chronic High Glucose-Induced Endothelial Apoptosis by *Sasa borealis* Bamboo Extract. *Experimental Biology and Medicine* 233:580-591.
- Datt C, Niranjana M, Chhabra A and Dhiman KR. 2006. Nutritional evaluation of different Bamboo leaves of Tripura. *Indian journal of dairy science.* 59 (6):376-379.

- Ding H-X, Gao Y-Y, Chao H-J, Xia D-H. 2007. Study on Hypoglycemic Effect of Polysaccharide from Moso Bamboo Leaves. *Shipin Kexue* (Beijing, China). 28(12), 446-449.
- Eyini M, Jayakumar M, Pannirselvam S. 1989. Allelopathic effect of bamboo leaf extract on the seedling of groundnut. *Tropical Ecology Trop. Ecol.* 30 (1): 138-141.
- Fu XC, Wang MW, Li SP, Wang HL. 2006. Anti-apoptotic effect and the mechanism of orientin on ischaemic/reperfused myocardium. *J Asian Nat Prod Res.* 8(3):265-72.
- Fu XC, Wang MW, Li SP, Zhang Y, Wang HL. 2005b. Vasodilatation produced by orientin and its mechanism study. *Biol Pharm Bull.* 28(1):37-41.
- Fu, -X; Wang, -M; Li, -S; Li, -Y. 2005a. The effect of bamboo leaves extract on hemorheology of normal rats. *Zhong-Yao-Cai.* 28(2): 130-2.
- Gulati NK, Chaudhari DC and Suri RK. 1984. In: *Recent trends in forest utilization*, ed. Suri RK and Mathur KC. pp: 85-86. India.
- Helper C.D and Strand L.M. 1990. Opportunities and responsibilities in pharmaceutical care. *Am J Hosp Pharm* 47:533-43.
- Hertog MG, Kromhout D, Aravanis C, Blackburn H, Buzina R et al. 1995. Flavonoid Intake and Long-term Risk of Coronary Heart Disease and Cancer in the Seven Countries Study. *Arch. Intern. Med.* 155 (4): 381-386.
- Hu C, Zhang Y and Kitts D.D. 2000. Evaluation of Antioxidant and Prooxidant Activities of Bamboo *Phyllostachys nigra* var. henonis Leaf Extract in Vitro. *J. Agric. Food Chem.* 48 (8):3170-3176.
- Hu C, Zhang Y, and Kitts DD. 2000. Evaluation of Antioxidant and Prooxidant Activities of Bamboo *Phyllostachys nigra* var. henonis Leaf Extract in Vitro. *J. Agric. Food Chem.*, 48 (8):3170-3176.
- Hyun KO and Hyeon-Sook L. 2009. Effects of hamburger patties with bamboo leaf (*Sasa borealis*) extract or sea tangle (*Laminaria japonica*) powder on plasma glucose and lipid profiles. FASEB J, 2009. Meeting Abstract Supplement 563.17.
- Jiao J, Zhang Y, Liu C, Liu J, Wu X and Zhang Y. 2007. Separation and Purification of Tricin from an Antioxidant Product Derived from Bamboo Leaves. *J. Agric. Food Chem.* 55 (25):10086-10092.
- Jung SH, Lee JM, Lee HJ, Kim CY, Lee EH, Um BH. 2007. Aldose reductase and advanced glycation endproducts inhibitory effect of *Phyllostachys nigra*. *Biol Pharm Bull.* 30(8):1569-72.
- Kaneko T, Baba N. 1999. Protective Effect of Flavonoids on Endothelial Cells against Linoleic Acid Hydroperoxide-induced Toxicity. *Biosci. Biotechnol. Biochem.* 63:323-328.
- Kaushik G, Satya S, Khandelwal RK, Naik SN. 2010. Commonly consumed Indian plant food materials in the management of diabetes mellitus. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews;* 4 (1): 21-40.
- Kim K-K; Kawano Y; Yamazaki Y. 2003. A novel porphyrin photosensitizer from bamboo leaves that induces apoptosis in cancer cell lines. *Anticancer-Res.* 23(3B): 2355-61.
- Kim SH, Kim TS, Lee HJ, Yoo JC. 2007. Enhancement of 1,25-dihydroxyvitamin D3- and all-trans retinoic acid-induced differentiation of human leukemia HL-60 cells by *Phyllostachys nigra* var. henonis. *Immunopharmacol Immunotoxicol.* 29(1):119-29.
- Knekt P, Jarvinen R, Reunanen A, Maatela J. 1996. Flavonoid intake and coronary mortality in Finland: a cohort study. *Br. Med. J.* 312 (1996) 478-481.
- Kurokawa T, Itagaki S, Yamaji T, Nakata C, Noda T, Hirano T and Iseki K. 2006. Antioxidant Activity of a Novel Extract from Bamboo Grass (AHSS) against Ischemia-Reperfusion Injury in Rat Small Intestine. *Biological & Pharmaceutical Bulletin.* 29 (11): 2301.
- Kweon M-H, Hwang H-J and Sung H-C. 2001. Identification and Antioxidant Activity of Novel Chlorogenic Acid Derivatives from Bamboo (*Phyllostachys edulis*). *J. Agric. Food Chem.* 49 (10):4646-4655.

- Li Y-F. 2009. Comparison of Bamboo Leaf Flavone and Vc Content in Different Species Bamboo. *Human Agricultural Sciences*. Catalog 2009-02. http://en.cnki.com.cn/Article_en/CJFDTotal-HNNK200902014.htm. Accessed on 20th April 2010.
- Li Y-H, Liu H-M, Luo D-S, et al. Effect of BLE on Changes of Plasmic MDA and SOD Activity in Mice Bearing Carcinoma. *Journal of Xianning Medical College*. http://en.cnki.com.cn/Article_en/CJFD-TOTAL-XNYB200203000.htm. Accessed on 20th April 2010.
- Liu X, Mi S-Q, Zhang Y-X et al. 2009. Anti-oxidative Activity of Extract of North Ph. Praecox Leaves. *Journal of Environment and Health*. Catalog 2009-03. http://en.cnki.com.cn/Article_en/CJFD-TOTAL-HJYJ200903024.htm. Accessed on 20th April 2010.
- Lu B, Wu X, Shi J, Dong Y, Zhang Y. 2006. Toxicology and safety of antioxidant of bamboo leaves. Part 2: Developmental toxicity test in rats with antioxidant of bamboo leaves. *Food and Chemical Toxicology* 44:1739-1743.
- Lu B, Wu X, Tie X, Zhang Y and Zhang Y. 2005. Toxicology and safety of antioxidant of bamboo leaves. Part 1: Acute and subchronic toxicity studies on anti-oxidant of bamboo leaves. *Food and Chemical Toxicology* 43:783-792.
- Marchand LL, Murphy SP, Hankin JH, Wilkens LR, Kolonel LN. 2000. Intake of Flavonoids and Lung Cancer. *J. Natl. Cancer Inst.* 92: 154-160.
- Muniappan M, Sundararaj T. 2003. Anti-inflammatory and antiulcer activities of *Bambusa arundinacea*. *J Ethnopharmacol.* 88(2-3):161-7.
- Panee J, Liu W, Lin Y, Gilman C, Berry MJ. 2008. A novel function of bamboo extract in relieving lipotoxicity. *Phytotherapy Research.* 22 (5):675-680.
- Park H-S, Lim JH, Kim HJ, Choi HJ and Lee I-S. 2007. Antioxidant flavone glycosides from the leaves of *Sasa borealis*. *Pharmaceutical Society of Korea.* 30 (2): 161-166.
- Pietta P-G. 2000. Flavonoids as Antioxidants. *J. Nat. Prod.* 63: 1035-1042
- Raizada, M.B., and Chatterji, R.N. (1956). World Distribution of Bamboos with Special references to The Indian species and their more important uses. *Ind Forester.* 82(5):215-218.
- Ren M, Reilly RT, Sacchi N. 2004. Sasa health exerts a protective effect on Her2/NeuN mammary tumorigenesis. *Anticancer Res.* 24(5A):2879-84.
- Seki T, Kida K, Maeda H. 2008. Immunostimulation-Mediated Anti-tumor Activity of Bamboo (*Sasa senanensis*) Leaf Extracts Obtained Under 'Vigorous' Condition. *Evid Based Complement Alternat Med.* eCAM:1-11.
- Sharma, B.D., Hore, D.K, and Pandey, G. (1992) Genetic Resources of Bamboo in the North-Eastern Region of India. *Indian Journal of Forestry.* 15(1):44-51.
- Sharma, Y.M.L. (1980). Bamboos in the Asia-Pacific Region. In: *Bamboo Research in Asia*. Proceedings of a Workshop held in Singapore, G. Lessard and A. Chouniard Eds. pp:99-120. World Publications, Singapore.
- Singh K.A. 1999. Nutrient contents in tree fodders and bamboo leaves of Eastern Himalayas. *Indian J. Anim. Nutr.* 16 (2):178-182.
- Song H.S, Moon H.J, Park B.E, Choi B.S, Lee D.J, Lee J.Y, Kim C.J. and Sim S.S. 2007. Anti-oxidant Activity and Whitening Activity of Bamboo Extracts. *Yakhak Hoeji.* 51: 500-507.
- Thapa B., Walker D.H. and Sinclair F.L.. 1997. Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science Technology* 68: 37-54.
- Tsunoda S, Yamamoto K, Sakamoto S, Inoue H, Nagasawa H. 1998. Effects of Sasa Health, extract of bamboo grass leaves, on spontaneous mammary tumorigenesis in SHN mice. *Anticancer Res.* 18(1A):153-8.
- Walle T. 2004. Absorption and metabolism of flavonoids. *Free Redic. Biol. Med.* 36(7): 829-837.
- Wild S, Roglic G, Green A, Sicree R, King H. 2004. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care.* 27:1047-53.

- Yanghee Y, Kyungmi K, Hojin H, Kwangwon L, Jeongmin L, Sangin S and Woojin J. 2006. Stimulatory Effects of *Pseudosasa japonica* Leaves on Exercise Performance. *Bioscience, Biotechnology, and Biochemistry*. 70(10):2532-2535.
- Yao Z-X, Su H, Wei J P, Qin W Y. 2000. A study of conditions of effective extraction from bamboo leaf and its anti-oxidative activity. *Journal of Guangxi Institute of Technology*. Catalog 2000-01.
- Yochum L, Kushi LH, Meyer K, Folsom AR. 1999. Dietary flavonoid intake and risk of cardiovascular disease in postmenopausal women. *Am. J. Epidemiol.* 149: 943-949.
- Yue-jun H, Yong-de Y, Feng T. Detection of antioxidative capacity of essential oils from the bamboo leaves by scavenging organic free radical DPPH. *Journal of Anhui Agricultural University*. Catalog 2009-03. http://en.cnki.com.cn/Article_en/CJFDTOTAL-ANHU200903022.htm. Accessed on 20th April 2010.
- Yusuf S, Reddy S, Öunpuu S, Anand S. 2001. Global Burden of Cardiovascular Diseases Part I: General Considerations, the Epidemiologic Transition, Risk Factors, and Impact of Urbanization. *Circulation*; 104:2746-2753.
- Zhang Y and Ding X. 1996. Studies on antioxidative fraction in Bamboo leaves and its capacity to scavenge active oxygen radicals. *Journal of Bamboo Research*. Catalog 1996-03. http://en.cnki.com.cn/Article_en/CJFDTOTAL-ZZYJ603.003.htm. Accessed on 20th April 2010.
- Zhang Y and Tang L. 1997. Experimental studies on anti-aging effect of the leaf-extract of *Ph. nigra* var. *henonis*. *Journal of Bamboo Research*. Catalog 1997-04. http://en.cnki.com.cn/Article_en/CJFDTOTAL-ZZYJ199704015.htm. Accessed on 20th April 2010.
- Zhang Y, Fen L, Chen X, Wu X and Sheng J. 2000. Bamboo beer-a new kind of healthy beer. *Journal of Bamboo Research*. 19(1): 33-37.
- Zhang, -Y; Wu, -X-Q; Yu, -Z-Y. 2002a. Comparison study on total flavonoid content and anti-free radical activity of the leaves of bamboo, *Phyllostachys nigra*, and *Ginkgo biloba*. *Zhongguo-Zhong-Yao-Za-Zhi*. 27(4): 254-7.
- Zhang Y, Wu X.Q. and Yu Z.Y. 2002b. Activity of the leaves of bamboo, *Phyllostachys nigra*, and *Ginkgo biloba*, *China Journal of Chinese Meteria Medica* 27 (4): 254-257.
- Zhang Y, Shen J-F, Yu Z-Y, Lu B-Y, Lou D-D. 2004. Primary studies on Bamboo leaf flavanoids used as anti-aging factor for skin protection. *Linchan Huaxue Yu Gongye*. 24(1): 95-100.
- Zhang Y, Bao B, Lu B, Ren Y, Tie X, Zhang Y. 2005. Determination of flavone C-glucosides in antioxidant of bamboo leaves (AOB) fortified foods by reversed-phase high-performance liquid chromatography with ultraviolet diode array detection. *Journal of Chromatography A*. 1065:177-185.
- Zhang Y and Zhang Y. 2007. Study on reduction of acrylamide in fried bread sticks by addition of antioxidant of bamboo leaves and extract of green tea. *Asia Pac J Clin Nutr*. 16 (Suppl 1):131-136.
- Zhang Y, Chen J, Zhang X, Wu X, Zhang Y. 2007b. Addition of antioxidant of bamboo leaves (AOB) effectively reduces acrylamide formation in potato crisps and French fries. *J. Agric. Food Chem*. 55 (2): 523-528.
- Zhang Y, Tie X, Bao B, Wu X and Zhang Y. 2007c. Metabolism of flavone C-glucosides and p-coumaric acid from antioxidant of bamboo leaves (AOB) in rats. *British Journal of Nutrition*. 97: 484-494.
- Zhang Y, Xu W, Wu X, Zhang X, Zhang Y . 2007a. Addition of antioxidant from bamboo leaves as an effective way to reduce the formation of acrylamide in fried chicken wings. *Food Additives & Contaminants: Part A*. 24(3):242 - 251.
- Zhang Y, Jiao J, Liu C, Wua X, Zhang Y. 2008. Isolation and purification of four flavone C-glycosides from antioxidant of bamboo leaves by macroporous resin column chromatography and preparative high-performance liquid chromatography. *Food Chemistry*. 107:1326-1336.

Aphids as major pests of Bamboos in nurseries of South India and association of potential biocontrol agents

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ABSTRACT

The nurseries of different economically important species of bamboos raised under various programmes in south India face problems associated with pests and diseases. Aphids (Hemiptera) were observed as major pests in seedlings and young plants of some important bamboo species viz., *Dendrocalamus stocksii*, *Dendrocalamus strictus* and *Bambusa pallida*. Aphid species, *Hysteroneura setariae* (Thomas) on *D. stocksii*, *Astegopteryx bambusae* (Buckton) on *D. strictus*, *Pseudoregma bambusicola* (Takahashi) on *B. pallida* and *Melanaphis bambusae* on *B. bambos* were recorded as sap sucking pests affecting the growth of plants. 20-80% of leaves were found infested and the intensity of infestation was estimated. The coccinellid beetles, *Coccinella septempunctata*, *Menochilus sexmaculatus* and the lacewing bug, *Micromus timidus* were found associated with the aphids playing a major role in the biological regulation of the aphid pests. The predatory potential of *Coccinella septempunctata* on *A. bambusae* and *M. timidus* on *A. bambusae* and *P. bambusicola* was assessed and reported in this paper.

Keywords: Aphids, Bamboo, *Dendrocalamus*, *Bambusa*, Biocontrol agents.

INTRODUCTION

Bamboos are associated with the mainstay of rural life all over India. Its versatility and usage as a poor man's timber has led to the wide spread cultivation of plantation. Nearly 113 species occur in India with a wide range of distribution, covering on an estimated 9.57 million hectares of the forest area in deciduous and semi ever green regions of north eastern, north and south India, except Jammu and Kashmir (Thakur, 1988). Bamboo in India suffer assiduously from insect damage, right from the seed to the finished products, many insect pests including borers, defoliators, culm and shoot borers and sap-suckers attack the plants and hamper the growth and production. About 40 species of Aphids are recorded from the genus *Bambusa* all over the world (Blackman and Eastop, 1994). In India, 66 species of sap-suckers are found, of which two species, *Oregma bambusae* Buckton (on *Bambusa* sp. and *Dendrocalamus* sp.) and *Asterolecanium bambusae* Peal (on

Bambusa vulgaris) are major pests (Kazmi and Husen, 1999). Numerous species of coccinellids are predators and major biological control agents of Hemipteran pests such as aphids, mealy bugs and scale insects, as well as thrips (Thysanoptera) and mites (Acarina) in all parts of the world (Prakash *et al.*, 2008). Seven spotted lady bird beetle, *Coccinella septempunctata* is one of the potential predators of aphids in India (Ali and Rizvi, 2007) and both larvae (grubs) and adult *C. septempunctata* feeds on aphids. Four species of aphids, *Hysteroneura setariae* (Thomas) on *Dendrocalamus stocksii*, *Astegopteryx bambusae* (Buckton) on *D. strictus*, *Pseudoregma bambusicola* (Takahashi) on *Bambusa pallida* and *Melanaphis bambusae* Fullaway on *B. bambos* (first report from Karnataka) were collected from different bamboo species and the present investigation was designed to study the predatory potential of larva and adult of *C. septempunctata* on *A. bambusae* and that of the lace wing, *Micromus timidus* on *A. bambusae* and *P. bambusicola*.

MATERIALS AND METHODS

To study the pest problems of Bamboos, surveys were conducted in nurseries and plantations of different bamboo species raised in different south Indian states. Colonies of the aphid, *A. bambusae* from *D. strictus* and *P. bambusicola* from *B. pallida* were collected from different forest nurseries in Karnataka (Yelwala, Hoskote and Bangalore) and were used for detailed studies on Biocontrol. Different stages of the aphids and their predators were collected and brought to laboratory and identified. Infestation levels were observed and counts of aphids on randomly selected branches was taken. Infestation per branch and per leaf was assessed. Predatory potential of *C. septumpunctata* on *A. bambusae* and *M. timidus* on *A. bambusae* and *P. bambusicola* was assessed by laboratory studies. 1st instar larva of the predator, *C. septumpunctata* and *M. timidus* were kept in mesh boxes and adults of *A. bambusae* and *P. bambusicola* were introduced as food daily. The daily consumption of aphids was recorded during the different instars and total and per day consumption in each instar was calculated. The test was repeated thrice.

Observations were made in the laboratory till the larvae became adult. Predation was recorded till the adult died and per day consumption was calculated.

RESULT AND DISCUSSION

During the field survey, sap sucking aphids, *H. setariae* (Thomas) *A. bambusae* (Buckton) *P. bambusicola* (Takahashi) and *M. bambusae* were observed as major pests on *D. stocksii*, *D. strictus*, *B. pallida* and *B. bambos* respectively (Fig. 1). 20-80% of leaves in the different species were found infested. The predators, *Menochilus sexmaculatus*, *Coccinella septempunctata* and *Micromus timidus* were associated with these aphids. *A. bambusae* was found infesting *Dendrocalamus strictus* throughout the growing season, and several aphidophagous predatory insects, mainly the lady bird beetles, *C. septumpunctata* were observed attacking this aphid species. The intensity of infestation of *A. bambusae* on the host plant was estimated. The branch-wise (mean 7 leaves) count of different stages of *A. bambusae* varied from 91 to 227 and the leaf-wise count varied from 11 to 28 with a branch mean of 131 and leaf mean of 19.

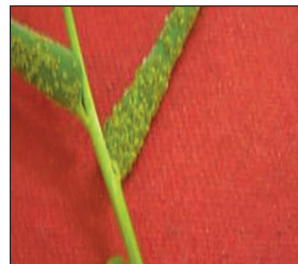
Fig. 1. Different types of aphids and predators



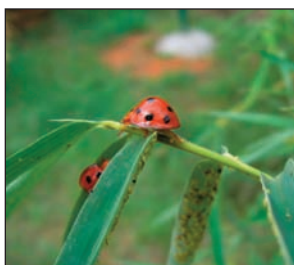
Hysteroneura setariae
(Thomas)



Pseudoregma bambusicola
(Takahashi)



Astegopteryx bambusae
(Buckton)



A. bambusae
predated by *C. septumpunctata*



Micromus timidus
Predator

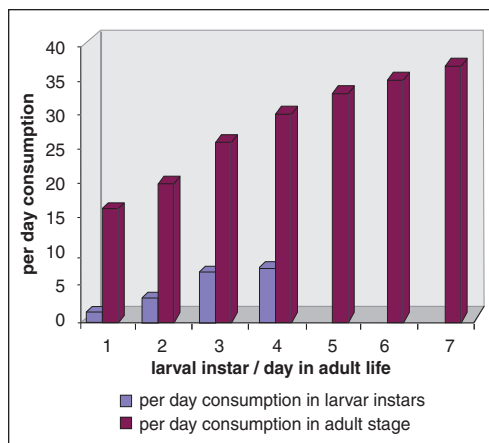


Fig. 2. Per day consumption of aphids, *A. bambusae* by the larval/adult stage of the predator, *C. septumpunctata*

The predatory behaviour of *C. septumpunctata*

The predatory behaviour of *C. septumpunctata* was studied in detail. Different larval instars and adult of *C. septumpunctata* were found to vary in their predation rate of the prey, *A. bambusae* (Fig.2.) The number of aphids consumed per day by an individual predator increased with the development of its age. The results revealed that the predator larva from first instar to fourth instar consumed an average of 2, 4.25, 8, and 8.58 aphids /day/ instar,

respectively, and adult from 1-7 days old consumed an average of 17, 21, 27, 31, 34, 36 and 38 aphids /day. Two way ANOVA was conducted to know the variation in the stage wise and day wise consumption in 1, 2, 3 and 4 instars and 2nd, 4th and 6th day of adult life. There was highly significant variation in consumption in the different stages and on the different days (d1, d2 and d3) and also stage vs day (Table 1). Radke *et al.* (2006) reported that average predation rate of both larvae and adult increased with prey density. Khan and Mir (2008) reported that the large predator, *C. septumpunctata* was seen to eat more aphids due to its greater voracity as compared to the smaller species, *Calvia punctata*, *Hippodamia variegata* and *Adalia tetraspilota*. Behra *et al.* (2006) reported that the feeding potential of first, second, third, and fourth instar grubs and adult of *C. septumpunctata* was 9.17 ± 1.5 , 20.8 ± 3.3 , 34.1 ± 3.5 , 37.5 ± 4.7 and 55.3 ± 6.7 aphids/day/ individual, respectively. Omkar and Srivastava (2003) mentioned that highest percent (92.80%) prey consumption was observed at initial prey density and lowest percent (40.86%) prey consumption at highest prey density by the fourth instar, though the total prey consumption increased with increase in either prey or predator densities. Ali and Rizvi (2007) investigated predatory potential

Table 1. Stagewise and daywise predation of *A. bambusae* by *C. septumpunctata*

	d1	d2	d3	MEAN/stage	
s1	1.7500	2.2500	2.0000	2.0000	
s2	3.7500	4.5000	4.5000	4.2500	
s3	8.0000	7.5000	8.5000	8.0000	
s4	7.7500	8.7500	9.2500	8.5833	
s5	21.0000	31.0000	36.0000	29.3333	
MEAN/day	8.4500	10.8000	12.0500		
ANOVA					
	df	SS	MS	F	PROB
s	4	5710.900000	1427.725000	1370.0941	0.000**
d	2	133.633333	66.816667	64.1196	0.000**
sd	8	341.700000	42.712500	40.9884	0.000**
Err	42	43.766667	1.042063	1.0000	
CV = 9.48%					
	SED	CD (0.05)	CD (0.01)		
s	0.41675	0.84122	1.12448		
d	0.32281	0.65161	0.87102		
sd	0.72183	1.45704	1.94766		

of *C. septumpunctata* on five aphids species. The overall predation by *C. septumpunctata* was significantly higher on *Lipaphis erysimi* than other species.

The predatory behaviour of the lacewing, *M. timidus*

During the course of development from the 1st instar to the adult stage of *M. timidus*, the per day consumption of *A. bambusae* was 11.5, 14.08, 41.41 in first, second and third instar respectively and 9.5, 12.5, 15.25, 17.25, 19 and 22 during the adult life (Fig 3). Two way ANOVA was conducted to know the variation in the stagewise and day wise consumption in 1, 2 and 3 instars and 2nd, 4th and 6th day of adult life. There was highly significant variation in the stages and on the different days (d1, d2 and d3) (Table 2). Feeding potential of *M. timidus* was also observed on other bamboo aphid, *P. bambusicola*. 1st instar, 2nd instar, 3rd instar larva and adult of *M. timidus* (1st day, 2nd day, 3rd day, 4th day and 5th day) consumed an average of 8.75, 10.5 and 37 in larval stages and 6, 9, 13, 11 and 15 during adult life (Fig 4). Two way ANOVA was conducted to know the variation in the stage wise and day wise consumption in 1, 2 and 3 instars and 2nd, 4th and 6th day of adult life. There was highly significant variation in the stages and on the different days (d1, d2 and d3) and also stage vs

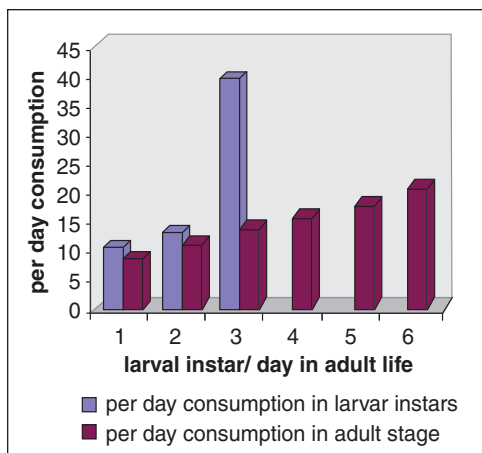


Fig. 3. Per day consumption of aphids, *A. bambusae* by the larval/adult stage of the predator, *M. timidus*.

day (Table 3). *M. timidus* consumed more number of *A. bambusae* than *P. bambusicola*. The body length and width of *P. bambusicola* is more than that of *A. bambusae*. Length of body of *A. bambusae* is 0.40 to 1.80 mm and width 0.30 to 0.94mm and length of *P. bambusicola* is 1.0 to 2.76 mm and width 0.60 to 1.32mm. This might be one of the reasons for the higher consumption of *A. bambusae*.

M. timidus Hagen has been recorded as a predator of many aphid species viz., *Aphis gossypii* G., *A. craccivora* Koch, *A. spiraeicola* Pagenstecher, *Lipaphis erysimi* (Kalt), *Myzus*

Table 2. Stage wise and day wise predation of *A. bambusae* by *M. timidus*

	d1	d2	d3	MEAN/stage	
s1	8.2500	9.2500	17.0000	11.5000	
s2	11.0000	14.0000	20.2500	15.0833	
s3	34.0000	43.0000	47.2500	41.4167	
s4	12.5000	17.2500	22.0000	17.2500	
MEAN/day	16.4375	20.8750	26.6250		
ANOVA					
	df	SS	MS	F	PROB
s	3	6669.229167	2223.076389	405.2656	0.000 **
d	2	834.875000	417.437500	76.0986	0.000 **
sd	6	73.458333	12.243056	2.2319	0.064 NS
Err	33	181.020833	5.485480	1.0000	
CV = 9.17%					
	SED	CD (0.05)	CD (0.01)		
s	0.95616	1.94536	2.61357		
d	0.82806	1.68473	2.26342		
sd	1.65612	3.36946	4.52684		

Table 3. Stage wise and day wise predation of *P. bambusicola* by *M. timidus*

	d1	d2	d3	MEAN/stage	
s1	7.5000	9.0000	9.7500	8.7500	
s2	8.0000	10.7500	12.7500	10.5000	
s3	29.5000	37.2500	44.2500	37.0000	
s4	6.0000	9.0000	13.0000	9.3333	
MEAN/day	12.7500	16.5000	19.9375		
ANOVA					
	df	SS	MS	F	PROB
s	3	6811.562500	2270.520833	402.7892	0.000 **
d	2	413.541667	206.770833	36.6810	0.000 **
sd	6	176.625000	29.437500	5.2222	0.001 **
Err	33	186.020833	5.636995	1.0000	
CV = 15.17%					
	SED	CD (0.05)	CD (0.01)		
s	0.96928	1.97204	2.64942		
d	0.83942	1.70784	2.29447		
sd	1.67884	3.41567	4.58893		

persicae (Sulzre) (Rao, 1969) (Radhakrishnan and Muraleedharan, 1989), *Longiunguis sacchari* (Zehntner) (Patnaik *et al.*, 1977), *C. lanigera* (Arakaki, 1992), *Myzus nicotianae* Blackman (Singh *et al.*, 1994 and Rao *et al.*, 1990) and *Cervahis quercus* Takahashi (Shantibala *et al.*, 1994). *M. timidus* larva consumed 10-16, 31-40 and 99-123 *L. erysimi* during 1st, 2nd, 3rd instar, respectively (Raychaudhuri *et al.*, 1981) whereas *M. posticus* consumed 4-16, 3-21 and 3-28 cabbage aphids during I, II and III instar respectively (Cutright, 1923). Vidya *et al.* (2010) observed feeding potential of I, II and III instar of *M. timidus* on sugarcane wooly aphid, *Ceratovacuna lanigera*

(49.42±16.84, 89.85±30.80 and 104.65±32.43 respectively). The first instar larva was observed to consume less number of aphids, with advancement of larval age, the aphid consumption increased gradually. The third instar larva was found to feed voraciously. Similar conclusion was drawn by Raychaudhuri *et al.* (1981) for *M. timidus*, Patro and Behera (2002) for *Chrysoperla carnea* (Stephens) and Vidya *et al.* (2010) for *Ceratovacuna lanigera* Zehntner. High prospect of utilization of predatory insects for management of Bamboo aphids is evidenced from this study.

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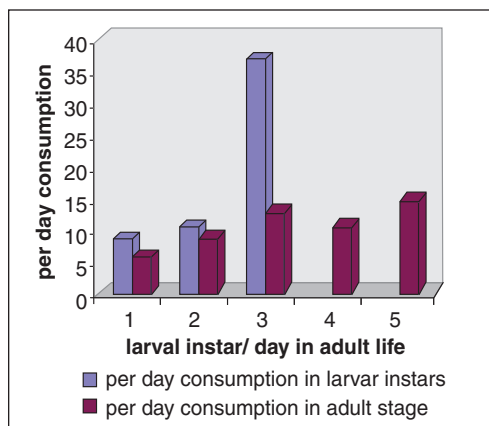


Fig. 4. Per day consumption of aphids, *P. bambusicola* by the larval/adult stage of the predator, *M. timidus*.

REFERENCES

- Arakaki, N., 1992. Seasonal occurrence of the sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) and its predators in sugarcane fields of Okinawa Island. *Appl. Entomol. Zool.*, 27: 99-105.
- Arshad Ali and Parvez Qamer Rizvi (2007) Development and Predatory performance *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on Different Aphids Species. *J. Biol. Sciences* 7 (8): 1478-1483.
- Behera, M. K., Behera, R., Patro, B. (2006). Biology and feeding Potential of *Coccinella septempunctata* Linnaeus (Coleoptera: Coccinellidae) on the Chrysanthemum aphid, *Macrosiphoniella sanborni* (Gillette).
- Blackman, R.L. and Eastop, U.F. 1994. Aphids on the world's trees. An identification and information guide. 82-87.
- Cutright, C.R., 1923. Life history of *Micromus posticus* Walker. *J. Econ. Entomol.*, 16: 448-456.
- Khan A.A and Mir R.A (2008). Functional response of four predaceous Coccinellids, *Adalia tetraspilota* (Hope), *Coccinella septempunctata* L., *Calvia punctata* (Mulsant) and *Hippodamia variegata* (Goeze) feeding on the green apple aphid, *Aphis pomi* De Geer (Homoptera: Aphididae). *J. Biol. Control*, 22(2): 291-298.
- Omkar and Shefali Srivastava (2003). Predation and searching efficiency of a ladybird beetle, *Coccinella septempunctata* Linnaeus in laboratory environment. *Indian Journal of Experimental Biology*, Vol. 41. pp. 85-87.
- Patnaik, N.C., Satpathy, J. M. and Bhagat, K.C., 1977. Note on the occurrence of aphidophagous insect predators in Puri district (Orissa) and their predation on the sorghum aphid, *Longiunguis sacchari* (Zhtn.). *Indian J. Agric. Sci.*, 47: 585-586.
- Patro, B. and Behera, M. K., 2002. Biology and feeding potential of *Chrysoperla carnae* (Stephens) (Neuroptera: Chrysopidae) on the bean aphid, *Aphis craccivora* Koch. *J. Bio. Control*, 16: 77-79.
- Prakash C. Joshi and Pushpendra K. Sharma (2008). First Records of Coccinellid Beetles (Coccinellidae) from the Haridwar, (Uttarakhand), India. *The Natural History Journal of Chulalongkorn University* 8(2): 157-167.
- Radhakrishnan, B. and Muraleedharan, N., 1989. Life history and population dynamics of *Micromus timidus* Hagen a predator of the tea aphid, *Toxoptera aurantii* (Boyer De Fonscolombe). *J. Plant. Crops*, 16 (Supplement) 189-194.
- Radke, S.G, Barwad, W.C. and Mundiwala, S.K. (2006). Influence of age of predator *Coccinella septempunctata* L. and population density of the host *Rhopalosiphum maids* (Fitch) (Homoptera: Aphidae) on the rate of predation. *Indian journal of Agricultural Sciences*.
- Rao, V.P., 1969. Common Wealth Institute of Biocontrol, United States, PL 480 Project Final Tech. Rep., pp. 1-93.
- Rao, R.S. N., Chari, M.S. and Rao, S.G., 1990. Further record of natural enemies on the insect pests of tobacco in Andhra Pradesh. *J. Bio. Control*, 4: 65-66.
- Raychaudhuri, D.N., Ghosh, D., Poddar, S.C. and Ghosh, S.K., 1981. Notes on an aphidophagous insect, *Micromus timidus* Hagen (Neuroptera: Hemerobiidae). *Sci. Cul.*, 47: 223-224.
- Sarfrazul Islam Kazmi and Azamal Husen (1999). Record of Anisolemnia (Caria) Dialatata Fab (Coleoptera: Coccinellidae) as a Predator on *Oregma bambusae* Buckton (Homoptera: Aphididae) Infesting Bamboo. *Ann. For.*, 7 (2) 301-302.
- Shantibala, K., Somen, L., Debaraj, Y. and Singh, T.K. 1994. Development and predatory efficiency of the larvae of *Micromus timidus* Hagen (Neuroptera: Hemerobiidae) on an oak aphid, *Cervaphis querus* Takahashi. *Indian. J. Hill Farm.*, 7: 212-214.
- Singh, L.S., Devjani, P., Debaraj, Y. and Singh, T.K. 1994. Studies on the seasonal incidence of *Myzuys persicae* (Sulzer) (Homoptera: Aphididae) on cabbage in relation to abiotic and biotic factors. *Proc. Nation. Acad. Sci.*, India, Section B. *Biol. Sci.*, 64: 95-98.
- Thakur, M.L. (1988) Current status of termites as pest of Bamboo and their control *Indian Forester*. 114 (7-12) 720-725.
- Vidya, M, Lingappa, S, Patil, R. K., and Ramegowda G.K. 2010. Biology and feeding potential of *Micromus timidus* Hagen (Neuroptera: Hemeobiidae) on sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner. *J. Agri. Sci.*, 23 (2):246-248.

Traditional utilization of village bamboos among the tea tribes of Barak Valley, northeast India

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Traditional utilization of bamboo has been an extremely practical source of material for the rural lives of northeast India. A number of investigations with emphasis on the traditional utilization of natural bamboo stand have been carried out while the knowledge of village bamboo utilization is scarce. Present study was carried out to document the traditional utilization of village bamboos among the tea tribes of Barak valley, Assam. Pattern of village bamboo utilization includes commercial, household and product making sector. Tea tribes were substantially dependent on village bamboo resources for their house construction technology. A total of 40 different farm, fishing and other related products were prepared, used and traded by the rural artisans in the study villages. Traditional product making is not the primary source of livelihood to the crafts person rather it is practiced along with their primary occupation. Preparation of traditional products using the traditional instrument reflects their skill and knowledge. Commercialization of these traditional knowledge through product quality upgradation, design input and innovative marketing may promote the livelihood security of the tea tribes of Barak Valley in northeast India and may result in overall regional development.

Assam's commercial tea industry is dependent on about two million artisans, almost all of whom were brought to Assam as

slaves by the East India Company from 1830s through 1920s. The descendents of these slaves are now called tea tribes. They are mainly present in Middle Assam; Eastern Assam and North Cachar, Karbi Anglong and Barak valley of Southern Assam (Bhadra 2005). The labourers in tea garden of Assam mostly belong to tribal belts of Chota Nagpur, Orissa, Madhya Pradesh and Andhra Pradesh. Along with them, labourers from some plain districts of Bihar and Eastern Uttar Pradesh who belonged to schedule caste and other backward class community also joined the team (Singh *et al.* 2006). With time the tea tribes settled as cultivators around besides working as labourer in tea garden. Tea tribes evolved as a subsistence agriculturist and maintained agrobiodiversity to fulfill their diverse household need (Das Gupta 1990).

Village bamboos form an important component in the home garden systems that have been traditionally used in northeast India for variety of purposes. The rural lives in Barak Valley are intricately linked with the village bamboos (Nath and Das 2008). Occurrence of seven bamboo species in the home gardens of Barak Valley and its role in socioeconomy of the villagers has been reported (Nath and Das 2008). The association of men with bamboo in India also is as old as human civilization (Chandrashekara 1997a). Home gardens in villages of India often possess bamboo clump as like Bangladesh, Malaysia and Indonesia (Randhawa 1980; Widjaja 1991; Aminuddin 1995) that had been in use for a variety of purposes since time immemorial. Various traditional utilization patterns of bamboo were reported (Rao and Ramakrishnan 1987; Laha 2000; Sundriyal *et al.* 2002; Singh *et al.* 2003;) from various parts of northeast India. Traditional

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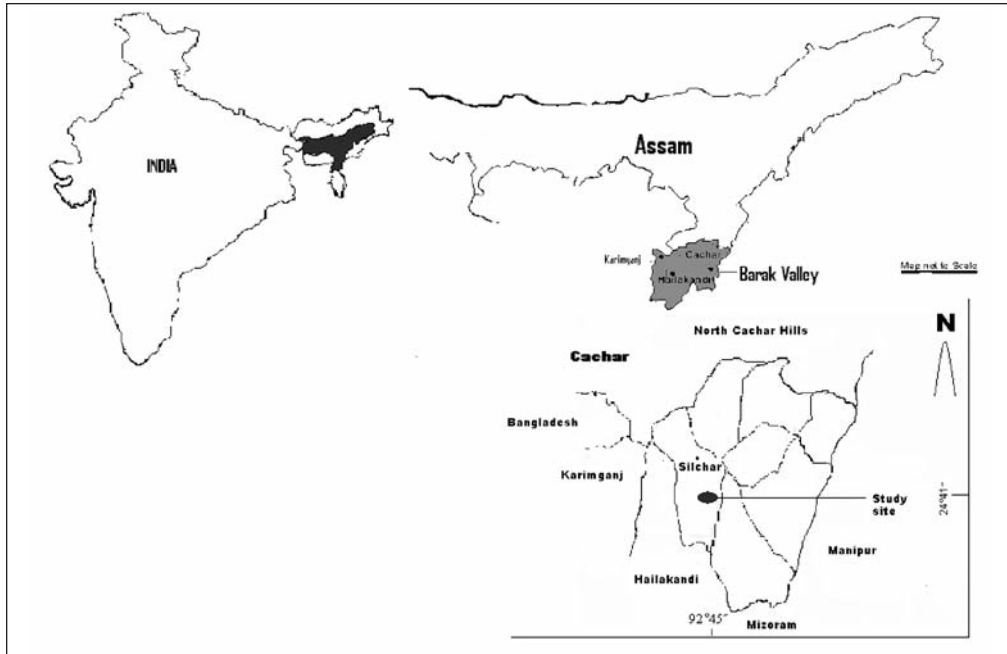


Figure 1. Map of the study area

systems of resource use are often being recognized as sophisticated and appropriate as they are socially well based (Chandrashekara 1997b). The present study is an attempt to assess the traditional knowledge base system of village bamboo utilization by the tea tribes of Barak valley, Assam in northeast India.

MATERIALS AND METHODS

The study was conducted in Irongmara and Dargakona village, in Cachar district of Barak valley of North East India and is situated between latitude 24°41' North and longitude 92°45' East. Map of the study area is provided in Figure 1. Bamboo was found to occur in all the homegarden of focal villages. Villagers grew seven bamboo species in the study area but higher frequency of occurrence was observed for *Bambusa cacharensis* R. Majumder (*Betua*), followed by *B. vulgaris* Schrad. ex Wendl. (*Jai borua*) and *B. balcooa* Roxb. (*Sil borua*) (Nath and Das 2008). Around 85-90% of the total growing stock of bamboo in homegarden was contributed by the three species. The study villages dates back from the British colonial rule and most of the inhabitant of villages are tea garden labourers.

The plantation labour population was a heterogeneous society consisting of multi-language, multi-caste, tribe and ethnicity (Pakem 1990). The labourers in the area, like any other tea plantation site in Assam, were brought in from West Bengal, Orissa, Madhya Pradesh, Andhra Pradesh and Tamil Nadu during the early 19th century with the rise in tea industry in the state (Sengupta 1996). Prior to immigration to plantation industry in the Barak valley the labourers practiced traditional occupation. Most of the tribes were agriculturists (Sengupta 1996). Socioeconomically the villagers are smallholders with paddy land as the major land use system. Community like Mala, Maal, and Pashi dominates the study villages.

Traditional utilization of village bamboo was studied by surveying hundred selected homegardens representing 10% of the total household of the focal villages. Information regarding bamboo species used, average life span of bamboo crafts, cost of bamboo crafts etc. were gathered through field visits and interaction with bamboo growers through detailed and structured questionnaire. Periodic visits were made to the local village market for assessing the commercial importance of traditional bamboo products.

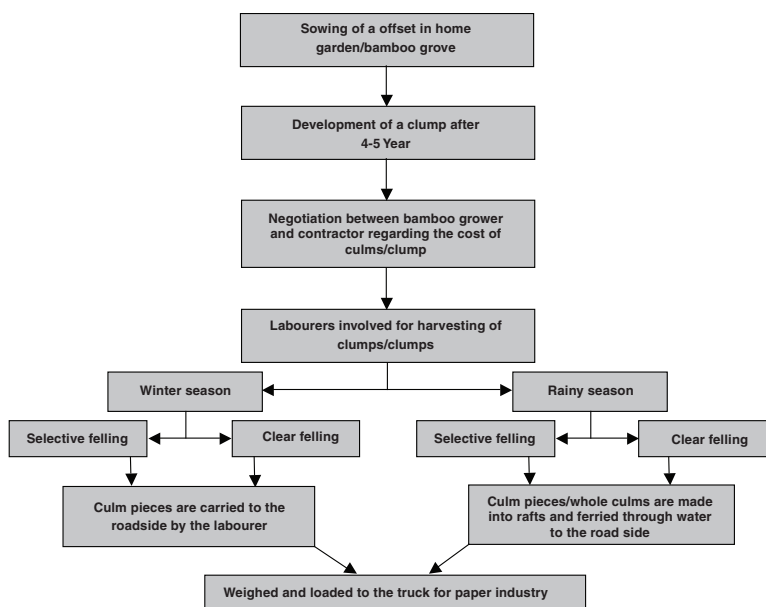


Figure 2. Detailed steps involved in industrial utilization of village bamboo resources.

RESULTS AND DISCUSSION

Traditionally bamboo resources of home-garden of Barak Valley have assumed great economic importance both commercially and locally. Traditional utilization pattern of village bamboo resources includes commercial, household and product making sector. In commercial utilization of village bamboo, bamboo contractor is a major linkage between bamboo grower and the commercial unit. A detailed steps involved in the commercial utilization of village bamboos are described in Figure 2. Villagers are required to depend substantially on village bamboo resources as building material for construction of their new houses as well as repairing of old houses. Bamboo provides the major framework of traditional houses in the study villages. Different components used for construction of rural houses include pillars, walls, ceiling and roof. Bamboo need for housing material is mainly met from the villagers' own bamboo grove. For construction of new houses about 25-40 bamboo culms are required while repairing of old houses require 10-25 bamboo culms. *B. balcooa* and *B. vulgaris* are mainly used for providing pillars of houses while *B. cacharensis* for walls, ceiling and structure of roofs. Culms of

B. cacharensis are split and woven into mat walls. Some of the villagers use mud plaster over bamboo mat wall. Pattern of traditional housing and construction technology in the study villages are entirely dependent on village bamboo resources. *B. cacharensis*, *B. balcooa* and *B. vulgaris* are the primary material for house construction. Thus the role of bamboo as building materials in the study villages is extremely important. Bamboo has wide acceptance for construction of houses due to its desired structural properties of size, shape, flexibility and strength (Laha 2000). According to the villagers houses constructed using bamboo as raw material are comfortable in hot and humid climate. Bamboo in traditional house construction in northeast India has been reported (Laha 2000; Sundriyal *et al.* 2002; Singh *et al.* 2003) by many workers. It was observed that villagers do not apply any preservative treatment in bamboo components of their traditional houses and the result is degradation of bamboo by insect attack within a short lifespan. Therefore, the introduction of preservative treatment facilities may greatly enhance the durability of bamboo and change its current perception as a material of temporary quality.

Table 1. Traditional bamboo products, their local name, local uses, life span and market cost

A. Farm devices

Sl. No	Product description	Local name used	Bamboo sp with regular use	Average life span (yrs)	Local use	Cost of items (Rs)	Prepared by	
							M	F
1.	Ladder	Moi	B.V	2-3	For leveling the earth during ploughing	100-125	M	—
2.	Ploughing device	Jak	B.V	2-3	Used during ploughing	50-80	M	—
3.	Open basket	Tukri	B.C	1-2	To store rice	30-50	M	F
4.	Long cylindrical container	Jungi	B.C	1-2	To store rice	80-150	M	F
5.	Carrying device	Huja	B.B	2-4	To carry the bunches of rice	25-40	M	—
6.	Carrying device	Bang	B.B	2-4	To carry rice in basket	25-40	M	—
7.	Reshuffling rice straw device	Ukon	B.B	3-5	To reshuffle the rice straw during and after reaping	10-15	M	—
8.	Mat	Chatai	B.C	1-2	To dry paddy	35-50	M	F
9.	Porous tray/sieve	Chaiyn	B.C	2-4	To remove husk from rice	20-30	M	F
10.	Winnowing tray	Jani	B.C	2-4	To clean rice	20-25	M	F
11.	Ploughing related	Joal	B.C	3-4	Used during ploughing	70-80	M	—

B. Fishing device

Sl. No	Product description	Local name used	Bamboo sp with regular use	Average life span (yrs)	Local use	Cost of items (Rs)	Prepared by	
							M	F
1.	Cylindrical fishing device	Hogra	B.C	3-5	To catch fishes from running water	60-100	M	—
2.	Fishing device	Dori	B.C	2-3	To catch fishes from running water	30-60	M	F
3.	Fishing device	Parang	B.C	1-2	To catch fishes from standing water	15-40	M	—
4.	Bigger sized cylindrical fishing device	Runga	B.C	3-5	To catch bigger sized fishes from running water	150-200	M	—
5.	Box shaped fishing device	Gui	B.C	3-5	To catch bigger sized fishes from running water	100-200	M	—
6.	Fishing device	Polo	B.C	2-3	To catch fishes from both standing and running water	150-200	M	—
7.	Fishing device	Chepa	B.C	1-2	To catch fishes from running water	40-60	M	F
8.	Carrying basket	Changa	B.C	1-2	To store fishes after catching or during selling	80-120	M	—

Table 1. Traditional bamboo products, their local name, local uses, life span and market cost (cont'd)

B. Fishing device (cont'd)

Sl. No	Product description	Local name used	Bamboo sp with regular use	Average life span (yrs)	Local use	Cost of items (Rs)	Prepared by	
							M	F
9.	Small carrying conical container	Kholoi	B.C	1-2	To store fish	15-30	M	F
10.	Small carrying basket	Potangi	B.C	1-2	To wash fish	15-30	M	F
11.	Flat container	Dala	B.C	1-2	To keep fish while selling	25-40	M	F
12.	Fish rearing device	Jungra	B.C	3-5	To rear small sized fishes after catching	35-50	M	—

C. Other related products

Sl. No	Product description	Local name used	Bamboo sp with regular use	Average life span (yrs)	Local use	Cost of items (Rs)	Prepared by	
							M	F
1.	Container	Japi	B.C	2-3	Mainly used in rituals to keep fruits	20-30	M	F
2.	Hen cop	Jhaka	B.C	1-2	To keep domestic chicken	35-50	M	F
3.	Porous	Khara	B.C	1-2	To store fodder for livestock	30-40	M	F
4.	Broom	Jharu	B.C	2-3	For cleaning purposes	10-15	M	F
5.	Flower pot	Khari	B.C	2-3	To keep flower	15-20	M	F
6.	Hat	Chhata	B.C	1-2	Used while working in agricultural field	25-30	M	—
7.	Carrying basket	Uri	B.C	1-2	To carry soil while digging	15-20	M	—
8.	Hand fan	Pakha	B.C	1-2	For the purpose of aeration	5-10	M	F
9.	Stool	Mura	B.C/B.B	2-3	For sitting purpose	30-40	M	—
10.	Reck	Thak	B.C	2-3	To keep the materials organized	70-100	M	—
11.	Pen	Kolom	B.B	1-3	For writing purposes	5-10	M	—
12.	Rickshaw hood	Hood	B.B/B.V	2-3	To provide shade	70-100	M	—
13.	Boat cover	Chaya	B.C	2-3	To provide shade	60-80	M	—

B.C – *B. cacharensis*, B.V – *B. vulgaris*, B.B – *B. balcooa*

Traditional craftsperson in the study villages prepare a total of about 40 different products to fulfill their own needs and to sell in the local market throughout the year. Depending on the mode of utilization of products, these were categorized in three main heads: farm devices, fishing devices and other devices. Detailed description of the traditional products, their uses, average life span, and costs at local market are described in Table 1 (A, B & C) and Figure 3, 4 & 5. Fishing devices are seasonal and are

prepared, used and sold in the local market during the rainy season of the year while agriculture related and miscellaneous products are prepared, used and sold in the local market throughout the year. In the study villages 60% of the craftsperson sell the traditional product in the market and rest 40% to the local village shops. Male members of the family can prepare all the products, whereas certain products like mat, open basket etc. are prepared by females also. Maximum of the fishing related and

Figure 3. (A-F) Farm related products: preparation, use and trade at the local market.



A. Preparation of open basket (khara)



B. Preparation porous tray (chayin)



C. Preparation of rice storing device (jungji)



D. Ploughing device (jak) and ladder (moi) in use in agricultural field



E. Carrying basket under preparation



F. Farm related crafts in local market

Figure 4. (A-F) Fishing related products: preparation, use and trade at the local market.



A. Fishing device (jungra) in use



B. Conical container used to store fish after catching



C. Fish storing device (changa) under preparation



D. Changa after preparation



E. Fishing device (dori) in use



F. Fishing device (paloin) in use

Figure 4. (G-J) Fishing related products: preparation, use and trade at the local market.



G. Box shaped fishing device (gui) in use



H. Fishing device (hogra) in use



I. Fishing related products in the local market



J. Fishing related products in the local market

miscellaneous products are prepared from *B. cacharensis* while almost all the agriculture related products are prepared from *B. balcooa* and *B. vulgaris*. Village bamboo resources are also used in construction of bridges, fencing and for making structural device for growing vegetables. Village bamboos are also utilized in various traditional rituals. Dead and distorted culms in the clump are utilized as a source of fuel. Handicrafts are valued as art objects and souvenirs of the traditional skills of a country; they have special appeal when made from indigenous, natural materials (Wong 1988). In the study villages traditional product making is not the primary source of livelihood to the craftsman rather it is done side by side with

their primary occupation. Craftsmen are daily labourers and farmer in occupation and in their free time they prepare the products. Preparation of traditional products using the traditional instrument reflects their skill and knowledge. Participation of female member of the family in the preparation of traditional products enable them to contribute to their household income. Traditional craftspeople of the study site never get any organizational or institutional support to convert their skill and knowledge into commercial production. Design and quality of the traditional products are also not up to the desired level.

The rural lives in Barak Valley are intricately related with the village bamboos, as this important

Figure 5. (A-F) Other uses of village bamboos.



A. Bamboo use as scaffolders



B. Ceiling and wall construction using bamboo



C. Boat cover made from bamboo



D. Traditional bamboo houses



E. Bamboo bridge in the study site



F. Preparation of broom (jharu) in the study site

rural resource fulfill various basic needs. Utilization of village bamboos provide direct and indirect economic benefit through employment generation that is accessible to low income and socially disadvantaged groups (Nath *et al.* 2009). There is also an urgent need of commercialization of the bamboo products through skill upgradation, quality improvement, design input and innovative marketing. Sustainable management protocols with emphasis to utilize the village bamboo resource locally may promote the livelihood security (Nath and Das 2008) of the tea tribes in Barak Valley and may result in overall regional development.

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LITERATURE CITED

- Aminuddin, M. 1995. Bamboo in Malaysia: conservation status, biodiversity base and strategic programme for improvement, In *Bamboo and Rattan Genetic Resources and Use*, Edited by Rao, V.R. and Rao, A.N., IPGRI, 35-38.
- Bhadra, R.K. 2005. Sociological dimensions of tea plantation workers of northeast India, In *Identity of Adivasis in Assam*, Edited by Pulloppillil, T., Don Bosco Publications.
- Chandrashekara, U.M. 1997a. How culture influences the uses and management of bamboo in India, *INBAR Newsletter*, 10.
- Chandrashekara, U.M.; Sankar, S. and Gnanaharan, R. 1997b. Socioeconomic and ecological aspects of developing bamboo resources in homesteads of Kerala, Kerala Forest Research Institute Report No 125.
- Das Gupta, R. 1990. From peasants and tribesmen to plantation workers, In *Tea Garden Labourers of North East India*, Edited by Karotemperel, S. and Roy, B. R., Vendrame Institute, Shillong.
- Laha, R. 2000. Bamboo uses for housing by the different tribes of Northeast India. *Journal of the American Bamboo Society*, 14:10-14.
- Nath, A.J. and Das, A.K. 2008. Bamboo resources in the homegardens of Assam: A case study from Barak valley. *Journal of Tropical Agriculture*, 46: 46-49.
- Nath, A.J.; Das, G. and Das, A.K. 2009. Traditional knowledge base in the management of village bamboos- A case study in Barak Valley, Assam, Northeast India. *Indian Journal of Traditional Knowledge*, 8(2):163-168.
- Pakem, B. (Ed.) 1990. Nationality, ethnicity and cultural identity in North East India. Omsons Publications, New Delhi, 388 pp.
- Randhawa, M.S. 1980. A history of agriculture in India, Vol 1, Indian Council of Agricultural Research, New Delhi.
- Rao, K.S. and Ramakrishnan, P.S. 1987. Socioeconomic analysis of bamboo resources in east khasi hills of district of Meghalaya. *Man in India*, 67: 221-231.
- Sundriyal, R.C.; Upreti, T.C. and Varuni, R. 2002. Bamboo and cane resource utilization and conservation in the Apatani plateau, Arunachal Pradesh, India: implications for management. *Journal of Bamboo and Rattan*, 1:205-246.
- Singh, H.B.; Kumar, B. and Singh, R.S. 2003. Bamboo resources of Manipur: an overview for management and conservation, *Journal of Bamboo and Rattan*, 2 (1): 43-55.
- Singh, S.N.; Narain, A. and Kumar, P. (2006) Socio-economic and political problems of tea garden workers: a study of Assam. Mittal Publications.
- Sengupta, S. (ed.). 1996. Peoples of North East. Gyan Publishing Home, 91-94.
- Wong, K.M. 1988. Current and potential uses of bamboos in Peninsular Malaysia. *Journal of the American Bamboo Society*, 7:1-14.
- Widjaja, E.A. 1991. Socio-ecological observations of bamboo forests in Indonesia. *Journal of the American Bamboo Society*, 8:125-135.

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