

**M.K. Alam*: A Note on the Taxonomic Problems,
Ecology and Distribution of Bamboos in Bangladesh**

Abstract

There are records of 22 bamboo species under 9 genera from Bangladesh. Presently the number of taxa is regarded to be more. In the present paper a list of bamboos occurring in Bangladesh with their vernacular names and distribution in Bangladesh has been given. Few taxonomic problems regarding *Bambusa tulda-longispiculata-nutans-teres* complex and "bethua"- "parua" problems have been discussed. A brief note on the ecology regarding the occurrence of bamboos in Bangladesh has been included.

Introduction

Bamboos are plants of enormous importance to the rural people in several regions of the world, but their usefulness is great in Bangladesh. In Bangladesh, bamboos are used for house construction, scaffolding, ladders, mats, baskets, fencing, tool-handles, pipes, toys, fishing rods, fishing traps, handicrafts, etc., and for several other articles of everyday use. In some parts of the country, the bamboo leaves are used as thatching materials and it is a good fodder. For tropical countries, bamboo is one of the important raw materials for paper industries. Bamboos are planted for hedges and landscaping. Bamboo groves also act as a wind break and prevent soil erosion. The young tender shoots of bamboos are eaten as delicious vegetables. These young shoots, locally known as "banskorol" are much eaten by the tribal people of Bangladesh during the rainy season. Considering the wide range of uses as construction material, it is called the "poor man's timber."

Bangladesh lies on both sides of the Tropic of Cancer and the 90° East Meridian. It belongs to a moist sub-humid megathermal climate having little or no moisture deficit period.

Bamboo research in Bangladesh was initiated in the early 1970s. Bangladesh Forest Research Institute (BFRI) has taken on the endeavor. The taxonomic studies of Bangladesh bamboo are very recent. In the present paper, a list of different bamboo species recorded from Bangladesh has been given with their vernacular names. The taxonomic problems of Bangladesh bamboos have been discussed. A note on their ecology and distribution has been given.

Bamboos of Bangladesh

Bamboos occurring in Bangladesh are represented by 22 species under 9 genera as recorded by Gamble (1896), Hooker (1897), Prain (1903), Brandis (1906) and Bor (1940). Presently the number of taxa is regarded to be more. Following is a list of the species recorded from Bangladesh (Table 1).

Taxonomic Status and Problems

The taxonomic accounts of Bangladesh bamboos are found in the works of Kurz (1877), Gamble (1896) and Bor (1940). Taxonomic research in Bangladesh bamboos is very recent and has been initiated at the BFRI, Chittagong. Though there are many problems in bamboo taxonomy, the need for a field guide was urgently felt. Based on the nomenclature and taxonomic concepts of existing literature, a field guide for 18 bamboo species of Bangladesh

*Senior Research Officer, Bangladesh Forest Research Institute, P.O. Box 273, Chittagong, Bangladesh.

Table 1. List of species recorded from Bangladesh

Scientific names	Vernacular names	Distribution in Bangladesh
1. <i>Bambusa arundinacea</i> (Retz.). Willd.	Kanta bans, berua-bans, kentua, bon-bans.	Cultivated in Sylhet, Dhaka, Mymensingh, Dinajpur.
2. <i>B. balcooa</i> Roxb.	Silbarua, hilbarua, tellibarua, barak, balku, boira, bara-bans, gita-bora, bora-bans.	Cultivated throughout the country. Abundant in northern, western and central districts.
3. <i>B. glaucescens</i> (Willd.) Sieb. ex Munro	Choi.	Cultivated as a hedge bamboo in many districts.
4. <i>B. longispiculata</i> Gamble ex Brandis	Mitinga, mahal, talla, bon, kalia makla, makla, sakua.	Cultivated in many districts, common in northern districts, Dhaka and Mymensingh.
5. <i>B. nutans</i> Wall. ex Munro	Peechle, keytta, mitinga.	Forests of Chittagong and Sylhet. Cultivated in Sylhet, Mymensingh, Tangail.
6. <i>B. pallida</i> Munro	Makla.	Sylhet.
7. <i>B. polymorpha</i> Munro	Pharua, burma-bans.	Forests of Sylhet. Also cultivated in Sylhet and Chittagong district.
8. <i>B. teres</i> Ham. ex Munro	Mitinga.	Forests of Chittagong, Chittagong Hill Tracts and Sylhet.
9. <i>B. tulda</i> Roxb.	Mirtinga, mitinga, mal, mahal, bon, talla.	Cultivated throughout Bangladesh; common in central and eastern districts. Also occurs in forests of Sylhet, Chittagong, and Hill Tracts.
10. <i>B. vulgaris</i> Schrd. ex Wendl.	Baijja, jai, jowa.	Cultivated in all the districts.
11. <i>Bambusa</i> sp. (unidentified)	Kanakkaich.	Comilla.
12. <i>Bambusa</i> sp. (unidentified)	Tetua, tengra, konko, tengal.	Cultivated in Moulvibazar, Sylhet and Gazipur districts.
13. <i>Bambusa</i> sp. (unidentified)	Bethua, moral.	Cultivated in Sylhet, Moulvibazar and Chittagong districts.

Table 1 (Continued). List of species recorded from Bangladesh

Scientific names	Vernacular names	Distribution in Bangladesh
14. <i>Bambusa</i> sp. (unidentified)	Kafajali, jeutha, jewa, kurajava, keskijawa, kalijawa.	Cultivated in Mymensingh, Thakurgaon, Dinajpur, Rangpur, and Khulna districts.
15. <i>Dendrocalamus</i> <i>giganteus</i> Munro	Budum.	Cultivated in Buddhist temples of Chittagong district and Cox's Bazar.
16. <i>D. hamiltonii</i> Nees et Arn. ex Munro	Pencha.	Sylhet forests.
17. <i>D. longispathus</i> (Kurz) Kurz	Ora, khang, rupai.	Chittagong, Chittagong Hill Tracts and Sylhet forests. Also cultivated in Chittagong Sylhet districts.
18. <i>D. strictu.</i> (Roxb.) Nees	Lathibans, karail.	Cultivated in many districts.
19. <i>Dinochloa maclel-</i> <i>landii</i> Gamble	—	Reported to occur in Chittagong and Cox's Bazar forests.
20. <i>Gigantochloa</i> <i>macrostachya</i> Kurz	Makla.	Reported to occur in the forests of Chittagong Hill Tracts.
21. <i>Melocalamus</i> <i>compactiflorus</i> (Kurz) Benth.	Lota bans.	Forests of Chittagong, Cox's Bazar, Chittagong Hill Tracts and Sylhet.
22. <i>Melocanna baccifera</i> (Roxb.) Kurz	Muli, paiyya, nali.	Forests of Sylhet, Chittagong and Chittagong Hill Tracts and Cox's Bazar. Also cultivated in many areas.
23. <i>Neohouzeaua dullooa</i> (Gamble) Camus	Dolu.	Forests of Sylhet, Chittagong and Chittagong Hill Tracts.
24. <i>Oxytenanthera</i> <i>albociliata</i> Munro	Kalia.	Reported to occur in Sylhet forests.
25. <i>O. nigrociliata</i> Munro	Kali, kaliseri.	Occurs in the forests of Sylhet, Chittagong and Chittagong Hill Tracts.
26. <i>Teinostachyum</i> <i>griffithii</i> Munro	Bajail.	Reported to occur in the forests of Chittagong Hill Tracts and Sylhet.
27. <i>Thyrsostachys</i> sp.	Rangoon bans.	Cultivated in bhawal tracts of Gazipur.

has been prepared by Alam (1982). The taxonomic studies of Bangladesh bamboos are in progress at BFRI, Chittagong. The taxonomic studies of Bangladesh bamboos pose some problems. Although 9 genera have been recorded from present Bangladesh, *Gigantochloa* and *Dinorchloa* may not occur. Occurrence of *T. griffithii* and *O. albociliata* are also doubtful. All genera occurring in Bangladesh excepting *Oxytenanthera* are well defined. The position of the species of the genus *Oxytenanthera* is doubtful as discussed by Holttum (1958). There are many taxonomic problems in recognizing Bangladesh species. The following are worthy to be mentioned:

i. *Bambusa tulda* - *longispiculata* - *nutans* - *teres* complex:

All these species were established from their floral characters. It is difficult to differentiate these species on vegetative characters. In the available literature (Gamble 1896), these have been delimited on the characters of anther tips such as tip apiculate for *B. nutans*, penicillate for *B. teres* and obtuse for *B. tulda* which are not always constant and some on the spikelet length (defined as spikelet long for *B. longispiculata* which have not been quantified). Our very common village bamboo viz. "talla," "mahal," "mitiaga," and forest bamboo "mitiga" belong to this complex.

ii. "Betua" - "Parua" problem:

Gamble (1896) has mentioned these two local names from Sylhet under *B. polymorpha*. "Parua" is a forest bamboo and "bethua" is grown in village groves. In 1982 "parua" flowered in Sylhet forest areas. It is evident from the flowering materials that the palea is ciliated on the keels, but the palea is naked in *B. polymorpha*. So "parua" is not *B. polymorpha* but is close to it. In 1984 a bamboo clump of "bethua" flowered in Sylhet. On examining the flowers, it seems that it is not *B. polymorpha* and also it is not "parua" either. The spikelet has similarities with *B. tulda* and allied species. It differs from *B. tulda* by having a pubescent culm and an absence of branches up to the upper mid-culm.

iii. Variations in *Dendrocalamus longispathus*:

Hasan (1979) reported that clumps raised from seeds of *D. longispathus* collected from two different localities showed differences in culm-sheath and branch bud morphology. One clump type showed similarities with *D. longispathus*, one clump type with *O. nigrociliata*, and one with *N. dulloa*. He ranked the differences at varietal level. This needs further investigation.

There are also some identification problems, SN nos. 11, 12, 13, 14, and 26 on the list (Table 1) and a few clumps at vegetative phase still could not be determined. From the taxonomic point of view, bamboos of Bangladesh present many interesting problems including identification and complex placement.

Distribution in Bangladesh and Ecological Notes

Bamboos have an extremely wide range of distribution, with some bamboos recorded from a latitude as far north as 46° and as far south as 47° (Soderstrom and Calderón, 1979). Bamboos of non-clump forming types grow in low mountain zones of 30-38° north latitudes, while clump forming bamboos grow in zones that straddle the equator, from latitudes 25° north to 25° south (Uchimura 1981). All the species growing in Bangladesh are of the clump-forming type.

Holttum (1958), in his discussion of Malayan bamboos, speaks of village (or cultivated) and native (or forest) bamboos. In Bangladesh also, there are two distinct bamboo production areas; one is the village groves where bamboo is cultivated by individuals mostly for domestic

consumption; the other is the forest where the entire stock is natural.

Village Bamboos: Although 10-12 species are cultivated in the village groves, the more common are *B. tulda*, *B. balcooa*, *B. vulgaris*, *B. longispiculata*, "tengra/tengal," "kanakkaich" and "bethua." *B. tulda*, *B. balcooa*, and *B. vulgaris* occur throughout the country. *B. balcooa* and *B. longispiculata* are fairly common in northern districts. *B. tulda* and *B. vulgaris* occur widely in eastern and central districts. "Kanakkaich" and "bethua" mostly occur in Sylhet and Comilla. "Tengra/tengal" is seen in cultivation in the districts of Moulvibazar, Sylhet and Gazipur. "Rangoon bans" is mostly distributed in the "bhawal" area of Gazipur district.

Forest Bamboo: Bamboo species growing in the forest areas include *Melocanna baccifera*, *B. tulda*, *B. nutans*, *B. teres*, *B. polymorpha*, *D. longispathus*, *D. hamiltonii*, *Melocalamus compactiflorus*, *N. dullooa*, and *O. nigrociliata*. Among the species growing in the forest, *Melocanna baccifera* grows in pure brakes but the others grow sporadically in small patches. Natural bamboos occur in the eastern hill forests of Chittagong, Chittagong Hill Tracts and north eastern hill forests of Sylhet. The major vegetation type of these hill forests are moist evergreen and moist semi-evergreen. Natural bamboos form a component of the vegetation of semi-evergreen forests. Except for *D. hamiltonii*, all the forest species are common in both the eastern and north eastern hilly forests. *D. hamiltonii* is confined only in the eastern side of the eastern Sylhet Forest and usually grows along streams.

Generally, if not always, bamboos are found in association with other woody plants (Soderstrom of Calderón, 1979). All the natural bamboos other than *M. baccifera* grow as an understory of the moist evergreen and semi-evergreen forests. Forests with an understory of bamboos are not different from those without an understory of bamboos. There are usually, but not always, scattered trees (typical of the evergreen and semi-evergreen climax) standing singly over the bamboo. Many species tend to be concentrated in separate patches, though with appreciable overlapping. Generally, *O. nigrociliata* and *D. hamiltonii* are found to grow separately. The former is found along the edges and fringes of the forest. *D. hamiltonii* grows along the streams and forest fringes.

B. polymorpha, *B. tulda*, *D. longispathus*, and *N. dullooa* are usually found to grow separately, except in the interior of the forests. *M. compactiflorus* is a clambering bamboo stretching on the canopy of the tall trees.

M. baccifera grows as pure brakes. Champion *et al* (1965) state that *Melocanna*, occurs as an undergrowth, it may come to form an almost pure stand as a result of shifting cultivation. When the area is vacated after taking 1-2 agricultural crops, dense bamboo regeneration appears and subsequent re-clearing on an 8-12 year cycle results in pure and denser crops of bamboo after each period of cultivation. The rhizome type of *Melocanna* is a factor in its ability to spread in clear areas.

Light might be an important factor with respect to the distribution of natural bamboos. *Melocanna baccifera* and *Melocalamus compactiflorus* seem to demand more light as the former grows in open brakes and the latter grows covering the tree canopy. Species growing in the interior of forests grow in diffused light but the species growing along the fringes and edges of the forests might need a little more light.

Distribution of the village bamboos depends on human factors such as utility, availability of propagules locally, and human migration. This is probably why *B. vulgaris*, *B. tulda*, and *B. balcooa* are very common all over the country. Biotic factors, mainly human, impact forest species also. Increased demographic pressure has resulted in the disappearance of bamboos in

the forests near human localities. Because of over-cutting, the dimension of bamboos has become smaller. Though soil is not a limiting factor (Hassan et al 1988), water logging may affect the cultivation of bamboos. As bamboo cannot tolerate water logging, it is not found in cultivation in areas which remain under-water for extended periods of the year.

Uchimura (1981) stated that the distribution and growth of bamboo are influenced by temperature: high temperature usually acts favorably on the growth of bamboos. The mean annual rainfall in the bamboo growing area is more than 1,000 mm. He also stated that the growth of bamboo is highly correlated with temperature when it is overlapped by annual rainfall of more than 1,000 mm. In Bangladesh, the rainfall is mainly monsoonal and the monsoon extends from June to October, followed by a delightfully cool and dry winter. The mean annual rainfall in hilly areas ranges from 2,200-5,000 mm. In January, the average temperature is 17.8° C. April is generally the hottest month with the temperature averaging 26.7° C but a secondary rise in temperature may occur in September. Humidity is one of the governing factors for bamboo growth (Kadambi 1949). In Bangladesh, humidity during the monsoon remains at more than 80 per cent. The shoots from the rhizomes develop during pre-monsoon, and grow during the rainy monsoon. Elongation of the culms takes place during the rainy season and it continues during the post rainy season.

Though the annual rainfall and temperature are favorable still (generally), bamboo does not grow in deciduous sal forests of the central and northwestern parts of the country. Bamboo also does not occur in the mangrove forests of the country. No systematic accounts are available about the absence of natural bamboos in these forests. As bamboo rhizomes need well drained and aerated soils, regular inundation and water logging might be responsible for absence of bamboos from mangroves. Uchimura (1981) stated that bamboo can not grow in soils which contain free salt. Lyall (1928) stated that geology is a factor in governing the distribution of "sal" and bamboos.

Conclusion

It is widely understood that correct botanical names are a point of reference. The *B. tulda* complex comprises our very common village bamboos. The taxonomic problems could be sorted out by systematic studies both in the field and in the herbarium. Most of the specimens of Indian species are preserved at the herbarium of Royal Botanical Gardens, Kew. The Forest Research Institute, Dehra Dun, India, has a good living collection. So regional and international cooperation is required to solve the taxonomic problems of bamboos.

For bamboo cultivation and management, the knowledge of ecology and distribution are two important factors to be studied systematically, individually or in association. Bamboo is also one of the important agroforestry component species in the context of the rural economies of south-asian countries. Knowledge about the autoecology and synecology of bamboos will govern the nursery management, crop combination pattern, and field management practices for maximization of yield. About a century back, Brandis (1899) rightly stated that "each species has its own peculiarities and its own requirements..."

References

- Alam, M. K. 1982. A Guide to Eighteen Species of Bamboos from Bangladesh. *Bull. 2, Plant Taxonomy Series*. Forest Research Institute, Chittagong, 29 pp.
- Bor, N. L. 1940. *Flora of Assam*. Vol. 4, 480 pp (Reprinted 1982).

- Brandis, D. 1899. Biological notes on Indian Bamboos. *Indian Forester*, 25: 1 - 25.
- Brandis, D. 1906. *Indian Trees*. International Book distributors, Dehra Dun, India, 767 pp.
- Champion, H. G., S.K. Seth, and G. M. Khattak 1965. *Forest Types of Pakistan*, 238 pp.
- Gamble, J. S. 1896. The Bambuseae of British India. *Annals of Royal Botanical Garden, Calcutta*, 7: 133 pp.
- Hasan, S.M. 1979. Observations on culms and culm-sheaths of Ora Bamboos raised from seeds. *Bano Biggyan Patrika*, 8(1&2): 13-26.
- Hassan, M.M., M.K. Alam, and A.H. Mazumder, 1988. Distribution of bamboos under the edaphic and climatic conditions of Bangladesh. *Indian Forester*, 114(9): 505-513.
- Holttum, R.E. 1958. The bamboos of Malay Peninsula. *The Garden's Bulletin*, 16: 1-135.
- Hooker, J.D. 1987. *Flora of British India*. Vol. 7, L. Reeve and Co. Ltd. Kent, 842 pp.
- Kadambi, K. 1949. On the ecology and silviculture of *Dendrocalamus strictus* in the bamboo forest of Bhadrawati Division, Mysore State and comparative notes on the species *Bambusa arundinacea*, *Ochlandra travancoria*, *Oxytenanthera monostigma* and *O. stocksii*. *Indian Forester*, 75: 289-299.
- Kurz, S. 1877. *Forest Flora of British Burma*. 2: 457-471.
- Lyll, J.H. 1928. The distribution of sal and bamboos in south Palamau Division, Bihar and Orissa. *Indian Forester*, 54(9): 486-490.
- Prain, D. 1903. *Bengal Plants*, 2: 663-1319, Calcutta.
- Soderstrom, T.R. and C.E. Calderón 1979. Ecology and phyto-sociology of bamboo vegetation. In *Ecology of Grasslands and Bamboolands in the World*. (ed. M. Makota). VEB Gustav Fischer Verlag Jena: 223-236.
- Uchimura, E. 1981. Site condition of growth and methods of multiplication of bamboo. *Bamboo Production and Utilization. Proceedings of the Congress Group 5-3A*. (ed. T. Higuchi). IUFRO World Congress, Kyoto, Japan, September 6-17, 1981: 23-26.

Qiu Fugeng and Ma Naixun*: **Selection of Cold Resistant Economic Bamboo Species in China**

Abstract

This article deals with the bamboo resources in China and also the methods for the determination of cold resistant bamboos. These are the method of freezing and the method of using a physical-biochemical index. Through environmentally controlled indoor experimentation, the introduction through planting, and the field investigation of candidate bamboo species in the Beijing district, the cold resistance of many bamboo species is investigated in this article.

Present Situation of Bamboo Resources in China

China has rich resources of bamboo which includes about 400 species belonging to 40 genera. Some are of the monopodial type (running bamboo), some are of the sympodial type (clumping bamboo), and some are of the amphipodial type (mixed). Most of them are erect with economic value, and only a few of them are climbing or dwarf types, but the culm of all of these bamboo species is woody. In Latin America, the grass type bamboos are distributed extensively, but not in China.

More than 90% of the bamboo species in China are distributed in the Yangzai River basin and southward. Yunan, Taiwan, Zhejiang and Sichuan are the regions which have the richest bamboo resources in and around China. In the Zhejiang province especially, some species of *Phyllostachys* form large-scale pure bamboo forests, of which *Ph. pubescens* has 443 thousand hectrares and grows well. Some small-scale, high-yield *Ph. pubescens* forests have a productivity of 30 T/ha./yr[†] and the large-scale medium-yield forests produce 10T/ha./yr. However, because of climate, the Yellow River basin has only a few bamboo species with a very small distribution. To the north of the basin, there are no natural bamboo forests in the Beijing district, with only some bamboo groves in gardens or yards.

The collection, storage, and introduction of bamboos has made great progress in China, and a lot of bamboo botanic gardens have been established. The Anji Bamboo Botanic Garden of Zhejiang in eastern China, has planted more than 200 bamboo species. The majority of these are the running type bamboo species of middle-subtropical and north-subtropical regions, having a complete range of species in *Phyllostachys*. The Bamboo Garden of the Guangxi Forestry Institute in southwestern China, has planted more than 100 bamboo species. Most of them are clump bamboos distributed in tropical and south-subtropical regions. The Beijing Botanic Garden, in the north of China, has introduced 36 bamboo species that are from north-subtropical and temperate regions. The three gardens have collected and planted almost all of the bamboo species found in China.

The Selection of Cold Resistant Bamboo Species

The selection of cold resistant bamboo species in China is of interest for the development of bamboo in the north of China, especially in the Beijing district, to beautify the environment of our capital. Therefore, these bamboos must be cold resistant species and also have a high economic value. Because the Beijing district is located on a big plain, those high mountain bamboo species which are distributed in the 3000m mountains of southwestern China cannot

*Research Institute of Subtropical Forestry, Chinese Academy of Forestry, Fuyang, Chekiang, China.

†Tons per hectare per year.

inhabit the plain. Although they have good cold resistant characteristics, they cannot survive the high temperatures in summer and the drought in winter in the Beijing district. Therefore, it is not suitable to select these high mountain species for introduction into Beijing. There are many clumping bamboo species in Yunnan, Guangdong, Guangxi and Taiwan, but these areas are unlike Beijing in latitude. The temperatures are too different to allow successful introduction. With this in mind, the suitable region for selecting cold resistant species is the region transitted from south to north. Through the determination of cold resistance, a lot of bamboo species have been selected as introductory species and then planted in the northern regions to observe their suitability.

The research of cold resistant bamboo species has received the help and support of the International Development Research Center (IDRC), in Canada. This research project is an important part of the bamboo research program funded by IDRC. The cold resistant bamboo species were primarily selected in the Anji Bamboo Garden of Zhejiang. Then, these species were planted outdoors in the Beijing Botanic Garden for observation. We have now obtained some results.

Determination of Cold Resistance by the Method of Freezing

A bamboo plant was treated by exposure to a series of low temperatures in a special, large refrigerator. Through investigation of the degree of freezing and recovery of the bamboo species and comparison with other bamboo species under the same conditions, the cold resistance of the species can be determined. The method includes:

a) The ages of treated bamboo:

One and three years old.

b) The preparation of tested bamboo:

In June, two culms with rhizomes from each tested bamboo species were selected. They were growing normally and not too tall. Each culm was transplanted into a big pot and given good care for normal growth.

c) The treatment at low temperatures:

In the middle of December, when the dormant season had arrived, these selected bamboo species were treated in 3 low-temperature stages in a large refrigerator.

The 1st stage: The tested bamboos were kept at -10°C for 17 hours in the refrigerator. Then, the electricity for the refrigerator was turned off. After the temperature in the refrigerator returned to normal, the bamboos were moved into a plastic shed and sprayed once every 1/2 to 1 hour. The next day, they were moved out and put into a shady, cool spot.

The 2nd stage: The bamboos which survived the first stage were moved into the refrigerator and kept at a temperature of -10°C for 7-8 hours. Then the temperature was lowered to -15°C for 12 hours. Following this, the electricity was turned off and when the temperature had returned to normal the bamboos were taken out, sprayed, and stored in a cool and shady spot. This is the same post-treatment care given in the first stage.

The 3rd stage: At 14:00, the bamboos which had completed the 2nd stage were moved into the refrigerator and maintained at -10°C again. The temperature was dropped to -15°C at 21:00, then at 08:00 the temperature was dropped to -20°C and held for 10 hours. Finally, the electricity to the refrigerator was switched off.

The refrigerator was opened at 08:00 on the 3rd day and the bamboos were taken to a shady and cool place at 14:00 on the same day. On the 4th day, they were moved into the plastic shed with a relative air moisture of 80%. Two days later, they were put into the field for observation. Finally, the results, i.e. the cold resistance of the tested bamboo species, were divided into five levels according to the criteria given in Table 1.

Table 1. Criteria for cold-resistance classification

Grades	Criteria
A	Both tested bamboos survived -15° C
B	One survived -15 degrees C, another survived -10° C
C	Both tested bamboos survived -10° C
D	Only one survived -10° C
E	Both tested bamboos died at -10° C

Cold Resistance Ranking

A total of 128 culms from 64 species were treated with low temperatures. We have placed these 128 culms into 5 groups:

- A. - 11 species that are the most cold resistant species
- B. - 13 species that are among the more cold resistant
- C. - 27 species that are cold resistant
- D. - 7 species that are less cold resistant
- E. - 6 species that are the least cold resistant.

The A and B grades are listed below:

- A. The most cold resistant species:
 - 1. *Ph. aurea* Carr ex A. et C. Rivière
 - 2. *Ph. atrovaginata* Chao et Chou
 - 3. *Ph. bambusoides* f. *Tanakae* Makino et Tsuboi
 - 4. *Ph. decora* McClure
 - 5. *Ph. elegans* McClure
 - 6. *Ph. flexuosa* A. et C. Rivière
 - 7. *Ph. praecox* Chu et Chao
 - 8. *Ph. rutila* Wen

- 9. *Ph. tanmuensis* Wang et Ma
- 10. *Pleioblastus oedogonatus* Wang et Ye
- 11. *In. decorus* Dai

B. The more cold resistant species:

- 1. *Ph. acuta* Chu et Chao
- 2. *Ph. bissetii* McClure
- 3. *Ph. hispida* Li Wu et Chen
- 4. *Ph. heteroclada* f. *solida* Wang et Ye
- 5. *Ph. glauca* McClure
- 6. *Ph. meyeri* McClure
- 7. *Ph. nigra* Munro
- 8. *Ph. nigra* var. *henonis* Stapf. et Rendle
- 9. *Ph. rubromarginata* McClure
- 10. *Brachystacyum densiflorum* Keng
- 11. *Shibataea chinensis* Nakai
- 12. *Pleioblastus solidus* Chen
- 13. *Sinobambusa orthotropa* Chen

To determine the cold resistance of bamboo using the method of freezing is not only more laborious and time consuming, but is also often disturbed by pathological changes during the experimental period. The physical-biochemical method of determination of the cold resistance of bamboo can help to overcome these problems. The soluble sugar content of 44 bamboo species in 8 genera was estimated. The results indicated that the soluble sugar content of bamboo leaves in winter is 3% - 12 % of the total dry weight; the content of soluble sugar in bamboo leaves is related to the cold resistance of bamboo — those with a high content of soluble sugar are more cold resistant while those with a low content are less resistant (Table 2).

Table 2. The Soluble Sugar Content of Bamboo Leaves in Winter and Cold-Resistance

Species	Soluble sugar content (% of dry weight)	Cold resistance
<i>Ph. glauca</i> McClure	11.055	More resistant
<i>Ph. flexuosa</i> A. et C. Rivière	10.402	
<i>Ph. rutila</i> Wen	9.705	
<i>Ps. amabilis</i> Keng f.	4.618	Less resistant
<i>Ph. bissetii</i> McClure	4.742	
<i>Ph. bambusoides</i> f. Tanakae Makino et Tsuboi	4.388	

The relative electroconductive ratio of 4 known cold resistant bamboo species was

estimated at a temperature of -20°C by the electroconductive method, and the regression coefficients at -20°C have been calculated. The variable X is increasing time and Y is the relative electroconductive ratio (Table 3).

Table 3. Relative Electroconductive Ratios

Species	Cold-resistance	Linear regression equation	Regression coefficient
<i>Ph. angusta</i> McClure	more	$Y=18.05+0.337X$	0.337*
<i>Ph. nigra</i> Munro	more	$Y=14.36+0.380X$	0.380*
<i>Ph. arcana</i> f. arcana	middle	$Y=14.23+0.432X$	0.432*
<i>Ph. pubescens</i>	less	$Y=21.57+0.435X$	0.435*

* statistically significant t-test at the 5% level

The results show that their sensitivity to low temperature and sustained -20° temperature could be indicated by the linear regression coefficient $|b|$ of treated temperature, continuing time and relative electroconductive ratio. Those with a high $|b|$ value have more cold resistance and those with a low $|b|$ value are less (Table 3).

Determination of the cold resistance of bamboos by the method of soluble sugar content in winter bamboo leaves and by the method of relative electroconductive ratios offer the advantages of convenience and speed. Because many factors contribute to the cold resistance of bamboo, it is difficult to attribute it to one single factor. Also, because it is not easy to control strict uniformity in collection and preparation of the samples during the experiment, there will be occasional errors in the results.

Until now, the results of these methods have not been as accurate as the results of the freezing method. But further study may indicate that if some corrections were to be made to these two methods, they would be optimum for selection in the early stages.

Estimation of Cold Resistance of Bamboo by Field Planting

These cold resistant bamboo species (selected by means of freezing and physical-biochemical index) were introduced into geographically cold districts for observation of their cold resistance under natural conditions. Then, a corrective estimation of cold resistance was made.

Thirty-four species from A, B, and a few from C, which have rather high economic value, have been introduced into the Beijing Botanic Garden for observation of their cold resistance levels. The status of introduction is shown in Table 4.

In 1987, an investigation of these planted bamboo species was taken. Most of the bamboos died and the surviving bamboo species or varieties are:

Ph. hispida Li Wu et Chen
Ph. arcana f. *luteosulcata*
Ph. nuda f. *localis*
Ph. nuda
Ph. vivax

Table 4. The status of 34 Bamboo Species Surviving the Winter

Species	Old culms before winter	Old culms after winter	New culms in 1983	New culms in 1984
<i>Pl. sp.</i>	31	23	11	26
<i>Pl. amarus</i>	3	0	1	0
<i>Pl. sp.</i>	7	0	0	1
<i>Pl. solidus</i>	6	0	1	3
<i>In. sp.</i>	2	0	1	1
<i>Pl. gozadakensis</i>	10	23	8	9
<i>Br. densiflorum</i>	8	10	few clumps	7
<i>S. edulis</i>	7	0	0	2
<i>S. tootsik</i>	0	0	0	0
<i>Ps. japonica</i>	8	0	2 clumps	0
<i>Ps. cantori</i>	4	0	2 clumps	0
<i>In. decorus</i>	6	0	0	0
<i>S. sichuanensis</i>	6	0	1 clump	0
<i>Ph. heterocycla</i> var. <i>pubescens</i> f. <i>gracilis</i>	4	2	0	2
<i>Ph. heterocycla</i> var. <i>pubescens</i> f. <i>obliquinoda</i>	5	2	0	0
<i>In. latifolius</i>	5	4	0	0
<i>Ph. rutila</i>	5	5	2 clumps	4
<i>Ph. acuta</i>	5	2	3	4
<i>Ph. arcana</i> f. <i>luteosulcata</i>	7	7	0	7
<i>Ph. vivax</i>	4	4	0	3
<i>Ph. heterocycla</i> var. <i>pubescens</i> f. <i>luteosulcata</i>	2	1	0	0
<i>Ph. hispida</i>	3 clumps	6	0	3
<i>Ph. nuda</i> f. <i>localis</i>	8 clumps	10	0	8
<i>Ph. heterocycla</i> f. <i>solida</i>	4	0	3	3
<i>Ph. nidularia</i>	5	0	0	0
<i>Ph. platyglossa</i>	5	0	1	0
<i>Ph. concava</i>	8	0	4	3
<i>Ph. nuda</i>	20	20	10	10
<i>Ph. atrovaginata</i>	4	0	3	0
<i>Ph. rubromarginata</i>	4	1	3	0
<i>Ph. bissetii</i>	6	5	3	5
<i>O. sulcatum</i>	6	0	0	0
<i>Ph. viridi-glaucescens</i>	0	0	1	0
<i>Pl. oedogonatus</i>	0	0	0	0

Ph. rutila Wen
Brachystachum densiflorum (Rendle) Keng
Pl. gozadakensis

The management of the plants was not the cause of death and they were not disturbed by animals. Therefore, it was determined that these 8 species or varieties were the most cold resistant species which can be planted in the Beijing district.

Introduction of Bamboo into the Beijing District

Beijing is located approximately at Latitude 40° North and Longitude 116° East, with the north Chinese great plain in the east and the Yanshan mountains in the northwest. The climate is cold and dry and the absolute lowest temperature is -18.3°C, the absolute highest temperature is 39.1°C, and the annual average rainfall is .516m according to the calculations for the period during 1983-1986. Because of the extreme cold and dryness, there are not any bamboo species naturally distributed in that district. For a long time people introduced bamboo species from the south to Beijing and planted them in wind-free and sunny places in gardens. Some small scale bamboo forests have been established by means of irrigation, wind-proofing, and cold proofing. The Beijing Botanic Garden located at the south of the Yanshan mountains of the Beijing Western suburbs, has introduced bamboo species from the south for several years. Thirty-six species remained in that garden, some of which have grown well. None have frozen and the bamboo forests are vigorous. Some of them have more or less frozen, but they can recover from this hazard in the spring. We conducted two studies at that garden during the winter of 1987 and spring of 1988, and divided the cold resistant bamboo species into 5 grades according to the criteria below (Table 5)

Table 5. Criteria of Cold Resistance Grade

Grades	Position			
	Leaf	Branch	Culm	Rhizome
I	Δ	Δ	Δ	Δ
II	X	Δ	Δ	Δ
III	X	X	Δ	Δ
IV	X	X	X	Δ
V	X	X	X	X

X: froze
Δ: didn't freeze

The bamboo species belonging to Grade I are:

- 1. *Ph. aureosulcata f. spectabilis* Chu et Chao
- 2. *Ph. propinqua* McClure
- 3. *Ph. aureosulcata f. aureosulcata*
- 4. *Ph. decora* McClure
- 5. *Ph. dulcis* McClure
- 6. *Ph. iridenscens* Yao et Chen

7. *Ph. nuda f. nuda*
8. *Ph. nuda f. localis* Wang et Yu
9. *Ph. parvifolia* Chu et Chao
10. *Ph. arcana f. arcana*
11. *Ph. aureosulcata f. aureocaulis* Wang et Ma
12. *Ph. glauca f. glauca*
13. *Ph. aureosulcata f. pekinsensis* Lu
14. *Ph. glauca var. variabilis* Lu
15. *Ph. nidularia* Munro
16. *Ph. praecox f. praecox*
17. *Ph. angusta* McClure
18. *Bashania fargesii* Keng f. et Yi
19. *Pleioblastus amarus* (Keng) Keng f.
20. *Indocalamus latifolius* McClure

The bamboo species belonging to Grade II are:

1. *Ph. nigra var. henonis* Stapf ex Rendle
2. *Ph. robustiramea* Chen et Yao
3. *Ph. gozodakensis* Nakai
4. *Ph. pubescens f. pubescens*
5. *Ph. flexuosa* A. et C. Rivière
6. *Ph. glauca f. Yunshu* Lu

The bamboo species belonging to Grade III are:

1. *Ph. bambusoides f. Tanakae* Makino et Tsuboi
2. *Ph. aurea* Carr. ex A. et C. Rivière

The bamboo species belonging to Grade IV are:

1. *Ph. viridis f. Houzeauana* Chu et Chao
2. *Ph. viridis f. Youngii* Chu et Chao
3. *Ph. bambusoides f. bambusoides*

The bamboo species belonging to Grade V had died and were thrown away and are not listed here.

Conclusion

It has been proved by the long-standing practice of introduction and the selection of cold resistant bamboo species recently that the Beijing district (having no naturally occurring bamboo species) can support the introduction of these more cold resistant bamboo species. They can be planted and will survive in the warm, irrigable lands which have been wind-proofed.

The cold resistant bamboos can be acquired by expanding the propagation of those cold resistant species already introduced, and also by introducing selected cold resistant species from the south.

The best method of determining the cold resistant bamboo species is a combination of

freezing and planting experiments. The method of the physical-biochemical index has some inherent error and should be corrected and refined before it is applied in general practice.

Using the above methods, out of 64 species provided for the test, we have determined 20 species to be the most cold resistant, and 6 species that are more cold resistant. The 20 most cold resistant species currently growing in the Beijing Botanic Garden are doing very well at the time of this writing.

References

- Cai Weigo & Zhang Jihe, 1989. Cold-resistant bamboo species in Beijing Botanic garden. *Journal of Bamboo Research* 8(2): 66-71.
- Cen Yangping & Ma Naixun, 1987. Study on determination of cold hardiness of bamboo by electroductive method. *Journal of Subtropical Forestry Research* 6(2): 47-52.

A. Sood[†], O.P. Sharma*, & L.M.S. Palni[†]: **Improved Methods of Propagation of Maggar Bamboo (*Dendrocalamus hamiltonii* Nees et Arn. ex Munro) Using Single Node Cuttings Taken from Juvenile Culms of Elite Seedlings**

Abstract

Among the bamboos, Maggar (*D. hamiltonii*) fits very well in social forestry programs in the hills. It gives good performance up to an altitude of 1,500 m, especially in valleys with high rainfall. Besides checking soil erosion, this fast growing bamboo provides nutritious green fodder for the cattle in winter, raw material for the farm-oriented cottage industry, and a much needed cheap substitute for small timber. The existing Maggar plantations in Himachal Pradesh, India, are of uncertain age and have been exclusively propagated by vegetative methods. They are bound to flower and die. To rejuvenate these on a long-term basis, it is imperative to start from seed. Thus, seedling in nurseries were raised and based on general vigor, number of culms produced per year and size, and thickness of individual culms, ten elites have been selected over a period of seven years for further mass and clonal multiplication. Over and above traditional methods of propagation, two innovative methods have been developed: a) macropropagation using single node cuttings from juvenile branches and b) micropropagation using tissue culture techniques.

Introduction

Forests represent a renewable source of energy in the form of firewood and fodder and provide raw material for the paper, fiber and timber industry. These are vital for climatic stability, soil and water conservation, and for the maintenance of biological diversity. The need of the hour is to undertake massive afforestation programs to protect our environment, and to meet the demand of forest based products. This is particularly relevant in states like Himachal Pradesh (H.P.) in Northern India where resources are meager and people look to the "forest Gods" for their sustenance. There has been a growing awareness of the use of bamboos in the social forestry programs because of their multiple uses. *Dendrocalamus hamiltonii* Nees et Arn. ex Munro, a native of tropical eastern Himalaya and Nepal, is popularly known as "Maggar" in H.P., and is particularly suited because of its fast growing and high yielding culms. It has entered into the very culture of hill folks and a tribe of wicker workers called "Doomnas" owe their livelihood to this one species of bamboo. It provides literally a true "tree grass" from October-February, a lean period for greens in the hills. The yield is 50-125 kg of fresh leaves per clump; one year old culms start yielding fodder and can be harvested until their 4th year. A detailed study on important winter tree fodders (*Grewia optiva*, *Bauhinia variegata*, *Artocarpus lakoocha* and *D. hamiltonii*) in Western Himalaya showed it to be a favorite with the farming community because of high crude protein and fiber content, and digestibility ratio (Pal *et al.*, 1979). Further studies by this group revealed *D. hamiltonii* to have higher digestibility and nutritive value during November-December (winter months) as compared to March-April (Negi *et al.*, 1980).

Mature culms (4th year onwards) are extensively used for rural housing, as fence, tent and poles, for making bridges, gates, handlooms, toys, and as shuttering, scaffolding and ceilings. The young, one year old culms, are used for basket making and in allied cottage industry. The tender sprouts are also eaten, cooked or pickled.

[†]Division of Biotechnology, CSIR Complex, Palampur-176 061, H.P., India.

*College of Basic Sciences, H.P. Agricultural University, Palampur-176 062, H.P., India.

Materials and Methods

Seeds were collected from different localities of Kangra district and seedlings were raised at H.P. Agricultural University, Palampur. Screening of over ten thousand seedlings over a period of seven years for general vigor, number of culms produced per year (a minimum of 12-14 in this case) and the size and thickness of individual culms, has resulted in the selection of 10 high performance seedlings (elites) for further clonal multiplication. Single node cuttings with precocious branchlets were taken from plants derived from three season old elites. After surface sterilizations with an aqueous solution of HgCl_2 (0.04%; 6 min.), the explants were transplanted vertically on the surface of variously modified Murashige and Skoog media (MS, 1962) and incubated under fluorescent light at $25 \pm 2^\circ \text{C}$ with a 12 hour light/dark cycle. Details of the sterilization procedure are given elsewhere (Sood *et al*, 1991).

Results

A) Macropropagation: Since its introduction (prior to 1868), Maggar bamboo has been exclusively propagated by vegetative means ("offset" planting) where the entire rhizome along with a part of culm is planted during monsoon (July-August). The success rate by this method is <50 percent. An improvement in the method of propagation led to a large number of rooted plants from single node culm cuttings (up to 16 nodes from the base) from mature culms. These single node cuttings were planted horizontally in 5"-8" deep furrows containing well rotten farm yard manure (FYM) during March and irrigated twice a week initially. The buds sprouted with

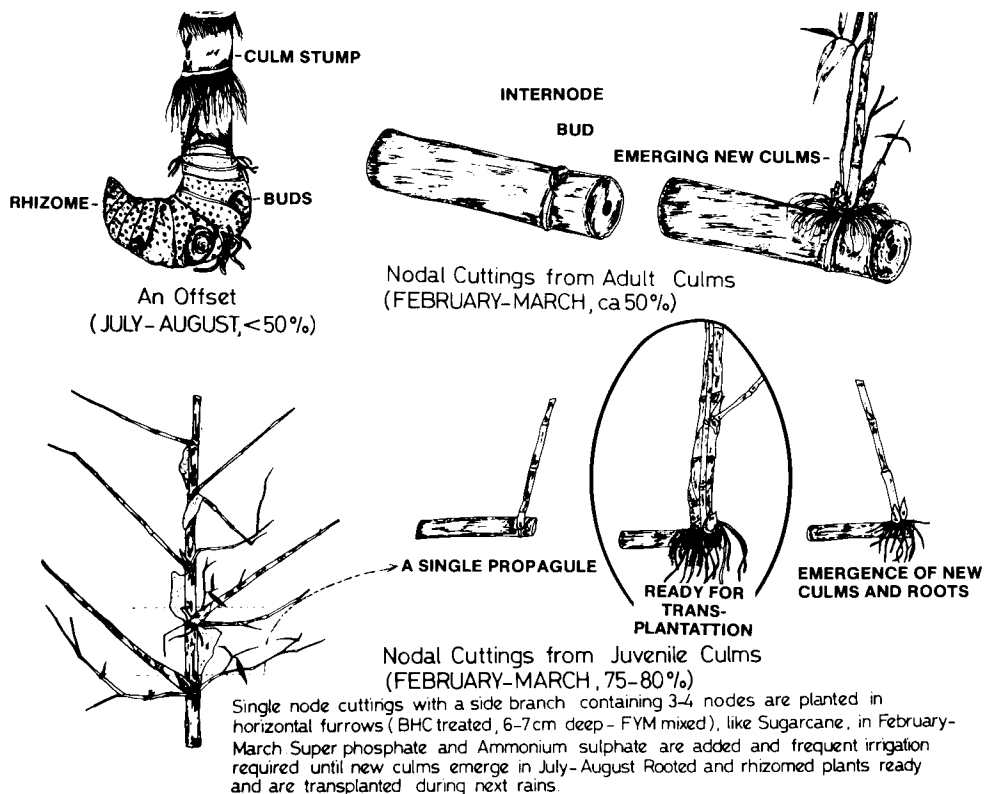


Figure 1.

the onset of monsoon and well formed roots developed in a further 2-3 months (Figure 1). These rooted plants were transplanted during the next rainy season. The success rate by this method is over 50 percent. Further refinement in this method using primary, secondary and even tertiary branches from one season old, cutting raised plants has led to 80 percent survival (Sharma, 1989), and is now the method of choice.

B) Micropropagation: Generally the buds from nodal explants (Figure 2) of precocious branchlets sprouted on half strength MS medium (sucrose, 3%; agar, 0.8%, w/v) within 10 days and grew to 3-4 cm in about three weeks. Occasionally 3-4 buds also sprouted from a single



Figure 2. Sprouted buds from nodal explants of precocious branches (8 days old).

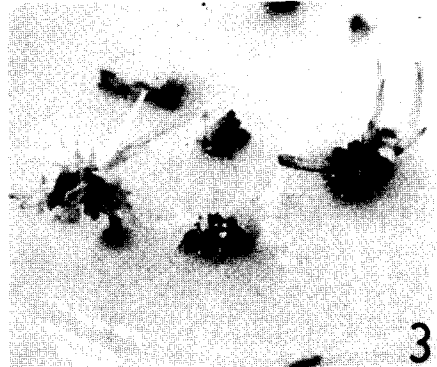


Figure 3. Direct regeneration of short buds from the cut segments of the sprouted buds in MS+BAP+2,4-D (1.0mg/l each).

node. These axillary shoots were excised and small segments (4-5mm) of these were used for further multiplication. Three types of responses were observed:

1) **Direct shoot bud differentiation:** Direct shoot bud regeneration was noticed (Figure 3) in cultures when MS medium was supplemented with 6-benzylaminopurine (BAP, 1.0 mg/l) and 2,4-dichlorophenoxyacetic acid (2,4-D, 1.0 mg/l). Liquid cultures kept over a gyratory shaker (80 rpm) further increased the rate of shoot multiplication (Figure 4). Rooting and subsequent rhizome formation (Figure 5) was accomplished within 6 weeks of transfer of these "rootless" shoots to a half strength liquid MS medium containing indole-3-butyric acid (IBA, 0.5 or 1.0 mg/l) or an α -naphthalene acetic acid (NAA, 0.5 mg/l) and sucrose (3%, w/v) but no cytokinins.

2) **Callus initiation and shoot bud differentiation:** Occasionally slightly compact, nodular, pale yellow and slow growing callus was formed on medium containing BAP and 2,4-D (1.0 mg/l each). Repeated sub-culturing at 15 day intervals on the same medium with additional gibberellic acid (GA_3 , 0.5 mg/l) induced shoot bud differentiation (Figures 6 and 7). These grew to form shoots which upon transfer to rooting medium (MS+IBA or NAA, 0.5-1.0 mg/l) produced rooted plants. Roots were readily formed in the presence of coumarin (9 mg/l) or choline chloride (3-9 mg/l) with IBA (0.5 mg/l), IAA or NAA (0.1 mg/l) or on half strength MS medium containing activated charcoal (0.3%).



Figure 4. Prolific shoot formation in liquid cultures [half strength MS+IBA(8.5 mg/l)+sucrose(3%)] kept over gyratory shakers (80 rpm).

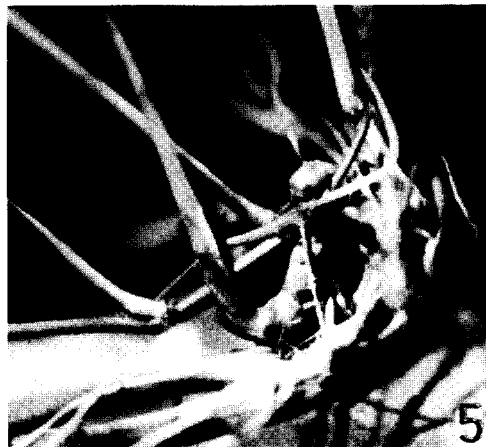


Figure 5. Same showing rooting and rhizome formation after 40 days.



Figure 6. Shows nodular, slow growing callus differentiating shoot buds.



Figure 7. Same as Figure 6 with additional supplementation of GA_3 (0.05 mg/l) in the medium.

3) **Callus initiation and root differentiation:** When nodular and compact callus lumps growing on MS medium supplemented with BAP and 2,4-D (1.0 mg/l each), were transferred to medium containing additional NAA (0.5-1.0 mg/l), a large number of thick, pale yellow and generally unbranched roots (Figure 8) were produced within 3-4 weeks, without shoot differentiation. When friable callus (Figure 10) from stem and leaf bases on MS medium, supplemented with 2,4-D (1.0-10.0 mg/l), was grown on MS medium containing BAP and 2,4-D (1.0 mg/l each), well organized greenish, densely packed structures (Figure 9) with trichomes at the base were differentiated. These looked like "embryoids" and their further growth is being monitored.

C) Transfer to Soil: Rooted and rhizomed plants were transplanted directly in the soil; these pots were initially kept in the growth chamber at 28° C with 80% RH for 2 weeks. Ten



Figure 8. Differentiation of roots from similar compact, nodular callus tissue in the presence of NAA (1.0 mg/l).



Figure 9. Shows a well organized greenish structure (embryoid?) being formed in highly friable callus.

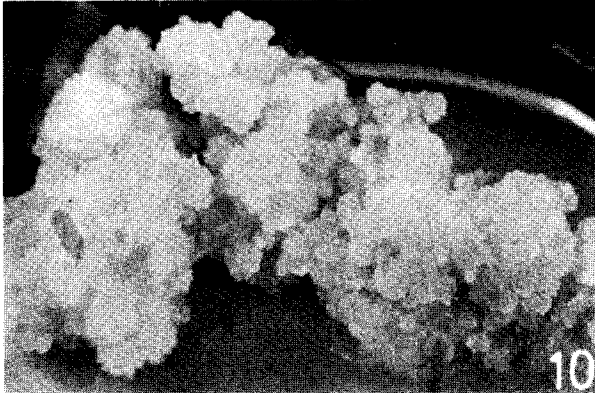


Figure 10. Highly friable callus formed at higher concentrations (1.0-10.0 mg/l) of 2,4-D when incorporated into MS medium.

plants, after a period of six months (Figure 11) in the pots kept under unprotected conditions, have been transferred to the field.

Discussion

Although superior genotypes, selected for faster growth, culm girth, leaf canopy etc. are being propagated routinely by culm cuttings and offset planting methods, its wide scale implementation is limited on two accounts. First, it is labor intensive and slow and second, plants propagated through cuttings taken from established culms of uncertain age, retain physiological age of the mother plant. This is a matter of considerable concern for Himachal Pradesh where bamboos have been exclusively propagated through “offsets” during the rainy season (July-August). By advancing the time of planting of single node culm cuttings to March in well irrigated land, we could increase the number of rooted plants quite substantially and such plants were ready for transplantation during the next monsoon in rain fed areas. However, these plants are likely to flower terminally and perish. Unfortunately, the process has already begun. Blissful ignorance of the impending calamity has resulted in a complete lack of revamping of bamboo plantations through seeds. But the entire seedling population is not suitable for

economic planting because it is extremely heterogeneous.

Micropropagation using tissue culture technique offers substantial advantage over other methods. The plant material can be multiplied readily on a mass scale, using explants from physiologically young and field tested elites. This would appear to be a novel approach for the propagation of *D. hamiltonii*. Earlier, Nadgir *et al.*, (1984) have used single node cuttings for shoot multiplication of *in vitro* raised seedlings of *D. strictus*. Dekkers and Rao (1987) also obtained multiple shoots in this species, however, the rooting was inconsistent; similar observations have been recorded by others (Rao *et al.*, 1990). Banik (1987) reported growth and proliferation of dormant culm buds on MS medium supplemented with BAP and NAA and extensive rooting was noticed with NAA (1.0 mg/l) and activated charcoal (0.3%) in three and a half months. A similar approach has recently been adopted for *Bambusa tulda* and *B. vulgaris* (Paranjothy *et al.*, 1990). Our strategy has been slightly different in that small segments were cut from proliferating buds (axillary shoots) and used as explants for further multiplication.

In the present study, friable callus was obtained from stem segments in medium supplemented with 2,4-D (1.0-10.0 mg/l) where densely packed cells of various shapes and sizes were seen. These appear to be involved in the formation of multicellular, well organized structures (embryoids?) with trichomes. Embryoid formation has been reported from leaf explants of *Phyllostachys viridis* (cf. Rao *et al.*, 1990) and from culm sheaths in *Schizostachyum* and *Thyrsostachys*. Root differentiation from stem callus was also achieved on MS medium containing BAP, 2,4-D and NAA. Our observations on differentiation of shoots from compact, nodular callus support earlier findings of Huang *et al.* (1989). The observed formation of roots in callus cultures is in conformity with earlier reports in *B. beecheyana* (Yeh and Chang, 1986a) and *B. oldhamii* (Yeh and Chang, 1986b).

Although rooting and rhizome formation is frequently observed in liquid media, the



Figure 11. A six month old plant growing in the community pot before transplantation to the field.

success rate is not entirely satisfactory. Coumarin has been used for root induction in *B. tulda* (cf. Paranjothy *et al.*, 1990; Saxena, 1990) but the effective use of choline chloride would appear to be for the first time in bamboos.

A close scrutiny of the literature reveals that most of the research groups engaged in tissue culture of bamboo initiate cultures from seeds (caryopses) of indeterminate genetic potential. The variation in seed progeny is so remarkable that it is impossible to predict the end product. The present approach of direct shoot regeneration from explants taken from already screened, selected and physiologically young seedlings, and their subsequent rooting has obvious added advantages for clonal and mass multiplication of bamboo plants. Such physiologically young and superior plants, raised initially from seed, should be harvestable for the next 50-60 years.

Acknowledgements

The authors gratefully acknowledge financial assistance from the Department of Environment, Government of India, New Delhi.

References

- Banik, R., 1987. Techniques of bamboo propagation with special reference to pre-rooted and pre-rhizomed branch cuttings and tissue culture. In: *Recent Research on Bamboos* (eds. Rao, A. N., G. Dhanarajan, and C. B. Sastry), The Chinese Academy of Forestry and IDRC, Canada, pp. 160-169.
- Dekkers, A.J. and A. N. Rao, 1987. Tissue culture of four bamboo genera. In: *Proceedings of the Seminar on Tissue Culture of Forest Species*, (eds. A.N. Rao, and Aziah Mohd Yusoff), Forest Research Institute of Malaysia and IDRC, Singapore, pp. 83-90.
- Huang, L.C., B.L. Huang, and W.L. Chen, 1989. Tissue culture investigations of Bamboo. IV. Organogenesis leading to adventitious shoots and plants in excised shoot apices. *Environ. Exptl. Bot.* 29: 307-315.
- Murashige, Y. and F. Skoog, 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* 15: 473-497.
- Nadgir, A.L., C.H. Phadke, P.K. Gupta, V.A. Parsharami, S. Nair, and A.F. Mascarenhas, 1984. Rapid multiplication of bamboo by tissue culture. *Silvae Genet.* 33: 219-223.
- Negi, S.S., R.N. Pal, and C. Ehrich, 1980. *Tree Fodders in Himachal Pradesh*. German Agency for Technical Co-operation (GT7). Eschborn (FRG).
- Pal, R.N., K.K. Dogra, L.N. Singh, S.S. Negi, 1979. Chemical composition of some fodder trees in Himachal Pradesh. *Forage Res.* 5: 109-115.
- Paranjothy, K., S. Saxena, M. Banerjee, V.S. Jaiswal, and S.S. Bhojwani, 1990. Clonal multiplication of woody perennials. In: *Plant Tissue Culture: Applications and Limitations*. (ed. Bhojwani, S.S.), Elsevier, New York, pp. 190-219.
- Rao, I.V.R., A.M. Yusoff, A.N. Rao, and C.B. Sastry, 1990. *Propagation of bamboo and rattan through tissue culture*. The IDRC Bamboo and Rattan Research Network.

- Saxena, S., 1990. *In vitro* propagation of the bamboo (*Bambusa tulda* Roxb.) through shoot proliferation. *Plant Cell Rep.* 9: 431-434.
- Sharma, O.P., 1989. *Dendrocalamus hamiltonii* Munro, The Himalayan Miracle Bamboo. In: *Plant Science Research in India*. (eds. Trivedi, M.L., B.S. Gill, and S.S. Saini). Today and Tomorrow's Printers and Publishers, New Delhi, pp. 189-195.
- Sood, A., L.M.S. Palni, M. Sharma, and O.P. Sharma, 1991. Micropropagation of *Dendrocalamus hamiltonii* Munro using single node cuttings taken from elite seedling plants. Abstract in *IV. International Bamboo Workshop*, 27-30 Nov., 1991, Chiang Mai, Thailand, p. 65.
- Yeh, M.L., and W.C. Chang, 1986a. Plant regeneration through somatic embryogenesis in callus culture of green bamboo (*Bambusa oldhamii* Munro). *Theor. Appl. Genet.* 73: 161-163.
- Yeh, M.L., and W.C. Chang, 1986b. Somatic embryogenesis and subsequent plant regeneration from inflorescence callus of *Bambusa beecheyana* Munro var. *beecheyana*. *Plant Cell Rep.* 5: 409-411.

Zhang Weiping*: The Classification of Bambusoideae (Poaceae) in China

Abstract

The diversity of Bambusoideae (Poaceae) in China consists entirely of woody bamboos, including an estimated 37 genera and about 500 species. Prior to 1940, the Chinese Bambusoideae was studied mainly by foreigners, for example, H. F. Hance, W. Munro, A. and C. Rivière, A. B. Rendle, E. G. Camus, J. S. Gamble, A. Camus and F. A. McClure, and most of their work was limited to the description of new species and several genera. Beginning in the 1930's, the first Chinese botanist to study the Chinese bamboos was Keng Yi-Li. Since 1940, Chinese taxonomists, especially Keng and his son Keng P. C., have done a great deal of work on the classification of Chinese bamboos. The publication of *Flora Illustralis Plantarum Primarum Sinicarum — Gramineae* in 1959 marked the full emergence of the systematic study of the Chinese Bambusoideae. From 1940 to the present, Chinese taxonomists have described 26 new genera and hundreds of new species, but some of the new genera are obviously problematic. In this paper, I review the major contributions to Chinese bamboo systematics, discuss the questionable genera, and propose a modified classification system (which is mainly based on that of Keng P. C.) for Bambusoideae in China. The Chinese bamboos are classified into two supertribes and five tribes, and a key to the supertribes and tribes is also provided. My conclusion is that: *Oreocalamus* Keng = *Chimonobambusa* Makino; *Brachystachyum* Keng = *Semiarundinaria* Makino; *Chimonobambusa* Makino and *Qiongzhusa* Hsueh et Yi should be recognized separately; *Dendrocalamopsis* (Chia et Fung) Keng f. = *Bambusa* Retz.; *Neosinocalamus* Keng f. is acceptable; *Microcalamus* Gamble is an invalid name and *Neomicrocalamus* Keng f. should be accepted; *Oligostachyum* Z.P.Wang et G.H.Ye and probably *Metasasa* W.T. Lin = *Acidosasa* C.D.Chu et C.S.Chao; *Bashania* Keng f. et Yi, *Clavinodum* Wen, *Polyanthus* Y.C. Hu, and *Menstruocalamus* Yi = *Arundinaria* Michaux; *Pseudosasa* Makino in part = *Arundinaria*, and the other part = *Pleioblastus* Nakai; *Sellulocalamus* W.T. Lin and *Patellocalamus* W.T. Lin = *Dendrocalamus* Nees; *Sasamorpha* Nakai = *Sasa* Makino et Shibata.

Early Work

Prior to 1940, most of the work on Chinese Bambusoideae was done by non-Chinese botanists who mainly described new species and several genera. The first worker to study Chinese bamboos was Hance (1862, 1876), who described some Chinese bamboo species. Others who studied Chinese bamboos include Munro (1868), A. and C. Rivière (1878), Gamble (1890, 1896), Rendle (1903), E. G. Camus (1912, 1913), A. Camus (1924, 1935), and McClure (1925, 1931, 1935, 1940), who did much on the Chinese Bambusoideae.

Of the botanists listed above, McClure contributed the most to the early knowledge of Chinese bamboos. Dr. McClure lived and worked in China from 1924 to 1940. During his tenure at Lingnan University (now called Zhongshan University), Dr. McClure spent most of his energy and time on researching the Chinese Bambusoideae. He described three new genera and many species, and published papers on bamboo utilization and even discussed bamboo culture (1925, 1931, 1938). Dr. McClure made such a great contribution that he can be

* Department of Forestry, Southwestern Forestry College, Kunming, Yunnan 650224, China. Current Address: Department of Botany, Iowa State University, Ames, Iowa 50011, U.S.A.

considered as a pioneer of the classification of Chinese Bambusoideae.

The first Chinese botanist to work on Chinese Bambusoideae was Keng Yi-Li (1935, 1936a, 1936b), and since then, Chinese botanists, led by Prof. Keng and his son Keng Pai-chieh (or Geng Bojie) have worked extensively on the Chinese Bambusoideae. Because of his many contributions to bamboo systematics, Keng is generally regarded as the father of Chinese bamboo classification. His publication, in 1959, of the *Flora Illustralis Plantarum Primarum Sinicarum—Gramineae*, an illustrated grass flora of all Chinese grasses, signaled that the study of Chinese bamboos by Chinese taxonomists was well underway. Before that time, Keng Yi-Li had published papers on new bamboo species (1935, 1936a, 1936b, 1940a, 1940b) and two new genera (1940a). Meanwhile, his son, Keng P. C. (1948) had listed the genera and the species of the Chinese bamboos and arranged them systematically (1948). By the end of the 1960s, the classification of Bambusoideae in China was thoroughly underway on a large scale. Especially during the editing of the Bambusoideae for the *Flora Republicae Popularis Sinicae* and for the flora of the provinces, Chinese taxonomists made a great effort and completed unprecedented work on the collection and the classification of Chinese Bambusoideae. Many valuable papers were published, and more than 200 new species and 26 new genera of Bambusoideae were described, although some of these genera are problematic and need further study.

The following is a detailed review of the classification of Bambusoideae in China from 1940 to the present. Some of the questionable or problematic genera will be discussed, and at the end, a modified classification for the Chinese bamboos, based mainly on that of Keng P. C. (1982–1984), is proposed.

1940–1959

A new era for the study of bamboo systematics in China began with Keng's description (1940a) of two new genera, *Oreocalamus* and *Brachystachyum*. This was the first time that a Chinese taxonomist had described new genera of Chinese bamboos. Keng P. C. (1948) listed the known genera and species of Bambusoideae in China and arranged them systematically for the first time. In the same year that his father made such a significant contribution to the knowledge of Chinese grasses, Keng P. C. (1957) described another new bamboo genus — *Yushania*.

In 1959, the first flora of Chinese grasses was published. This great work was edited by Keng Y. L., who began this project in 1954. This flora presented in detail the morphological characters of five tribes of bamboos, including 20 genera and 71 species, and many accurate and exquisite plates were appended. The publication of this book signified that the classification of Bambusoideae in China had reached a new level and represented one of the most important events in the history of Chinese bamboo classification.

1960–1978

It is well known that during the Cultural Revolution, many Chinese scientists were persecuted, and scientific research virtually came a halt. During that time, some excellent scientists died, including Keng Yi-Li.

The only "achievement" with regard to the Bambusoideae during that time was the publication of Volume 5 of *Iconographia Cormophytorum Sinicorum* (Beijing Botanical In-

stitute, 1976), but only 18 genera and 38 species of Bambusoideae were included, many fewer than appeared in Keng's publication completed in 1959.

1979 – Present

Chu and Chao (1979) described another new genus of bamboo, *Acidosasa*, and in the same year, Hsueh and Yi (1979, 1980) described two additional new genera, *Chimonocalamus* and *Qiongzhusa*.

At the start of the 1980s, in order to lay the groundwork for the Bambusoideae volume of *Flora Republicae Popularis Sinecae* as well as the flora of every province, Chinese botanists devoted much effort to the classification of Bambusoideae, and with satisfactory results.

Chao *et al.* (1980) revised several genera and some species of Chinese Bambusoideae. They modified the concepts and the limits of *Sinarundinaria*, *Thamnocalamus*, *Indocalamus*, *Arundinaria*, *Sasa* and some other genera. Wang and Ye (1980b) studied the systematics of *Phyllostachys* in China. *Phyllostachys* is one of the most diverse genera of bamboos in China, with approximately 50 species, and it is taxonomically difficult. This marks the first time that Chinese taxonomists focused on one large genus. In another paper, Wang and Ye (1980a) discussed some taxonomic problems and the concepts of several other genera with leptomorph rhizomes. One thing that is quite interesting and unmatched in the history of bamboo classification in China is the controversy between Chia Liangchi and Fung Hoklam (1980, 1982) and Keng P. C. (1981) over the validity of *Sinocalamus* and *Lingnania*. This struggle focusing on one taxonomic problem signaled that bamboo systematics in China was becoming more and more mature.

Wang and Ye (1981) discussed the concepts and the scope of *Fargesia* and *Yushania* further. Chia and Fung (1981) erected a new genus, *Leptocanna*, to accommodate a species that had previously been placed in *Schizostachyum*. They thought it differed from *Schizostachyum* in some characters, such as the spikelet disarticulation, the glumes and lodicules, and thus elevated it to a genus. Cheng *et al.* (1981) described *Ampelocalamus*, a genus of vining bamboos from southern China.

Another milestone in Chinese bamboo research was achieved in 1982 when two publications, the *Journal of Bamboo Research* and *Bamboo Research* were initiated. Based on his long term studies, Keng P. C. (1982–1984) discussed the genera of Bambusoideae worldwide. He focused mainly on their diagnostic features, the number of species, their distribution, the meaning of generic nomenclature, a brief history of some genera, and he also presented a new system for Chinese Bambusoideae. At the same time, he described seven new genera: *Neosinocalamus*, *Neomicrocalamus*, *Himalayacalamus*, *Butania*, *Drepanostachyum*, *Dendrocalamopsis* and *Burmabambusa*. Wen (1982) described one new genus, *Gelidocalamus*, and at the same time he revised *Sinobambusa* from China. Wang and Ye (1982) described *Oligostachyum*, and Keng P. C. collaborated with Hsueh (1982) to describe *Ferrocalamus*. In the same year, Keng P. C. and Yi (Geng Bojie and Yi, 1982) erected *Bashania*. The year 1982 was a very remarkable one as 11 new genera of Bambusoideae were described in China.

Chao and Chu (1983) did a systematic study of *Indosasa*. They discussed the systematic position of the genus in the Bambusoideae and its relationship with several other genera. Hu

and Yang (1983) carried out a study of *Sasamorpha* in China. They argued that this taxon should be treated as a genus because it differed from *Sasa* in rhizome type and vegetative characters; they also discussed the differences among *Sasa*, *Sasamorpha* and *Indocalamus*. Hsueh and Sun (Xue, Jiru and Sun, Jiliang, 1983) discussed the distribution of *Cephalostachyum* and *Thyrsostachys* in China. Cheng and Cheng (1983) made an emendation to the subtribe Pleioblastinae. Wen (1984a) described *Clavinodum*, and discussed the relationship of his new genus with *Pleioblastus* and *Oligostachyum* in detail, but only referred to *Arundinaria* briefly. Hsueh and Yi (Xue, Jiru, and Yi, 1985) revised *Ampelocalamus*, and enlarged the scope of the genus.

Yi (1986) presented a thorough systematic study of *Yushania*, in which he described many new species, including those from Tibet. Wen (1986) provided proposals to resolve some taxonomic problems of Bambusoideae in China, including the problems of genera with pachymorph rhizomes, such as *Sinocalamus*, *Neosinocalamus*, *Racemobambos* (*Microcalamus* and *Neomicrocalamus*), *Bambusa* and *Dendrocalamopsis*. He accepted *Neosinocalamus* but did not explain why. *Neomicrocalamus* and *Racemobambos* possess the same type of inflorescence, so Wen considered *Neomicrocalamus* to be a synonym of *Racemobambos*, and he concurred that *Microcalamus* should be abandoned because Gamble abandoned it. He also regarded *Dendrocalamopsis* as an unacceptable genus but did not explain why. As for the genera with leptomorph or amphotomorph rhizomes, such as *Arundinaria*, *Chimonobambusa* and *Qiongzhusa*, he agreed that some species of *Pseudosasa* and *Pleioblastus* belonged to *Arundinaria*. He also maintained the separation of *Chimonobambusa* and *Qiongzhusa* because the fruit of the former was a caryopsis and that of the latter a nut. Keng P. C. (1986) supplemented the description of *Drepanostachyum* and compared it with Chusqueae; later he cooperated with Hu (Keng P.C. and Hu, 1986) to further revise the Shibataeae from China. They outlined the traits of 10 genera of the tribe, discussed the systematic relationships among the genera, and diagrammed the evolutionary lines of this tribe.

Yang (1987) revised *Indocalamus* on a worldwide basis, and examined all those species previously attributed to *Indocalamus*. Keng P. C. (1987a) classified the Bambusoideae of China and neighboring areas into two supertribes with six tribes and three subtribes.

Hu (1988) revised *Shibataea*. He discussed the concept of this genus, its systematic position in the Bambusoideae and its relationships with other genera. Lin (1988) erected a new genus, *Metasasa*, and Chia *et al.* (1988) described another new genus, *Monocladus*. Hsueh and Zhang (1988) completed a systematic study of *Chimonobambusa*, in which they discussed the concept of the genus and its relationships with other genera. Hsueh and Li (Li, 1986; Li and Hsueh, 1988) studied *Qiongzhusa* and *Dendrocalamus*. Wang and Ye (1988) inquired into the relationships between *Racemobambos* and *Neomicrocalamus*; in contrast to Wen (1986), they concluded that these two genera had very different inflorescence types, one being semelaucant and the other iterlaucant, so they recognized the two genera as separate. In his revision of *Fargesia*, Yi (1988) described many new species, and discussed the concept of the genus and its relationships with other genera.

Lin (1989a) described two new genera, *Sellulocalamus* and *Patellocalamus*. These two taxa were separated from *Dendrocalamus*; later, Lin (1989b) expressing some of his views about the classification of *Dendrocalamus*, said that he thought the recent classification of

Dendrocalamus was in total disarray, and that the genus needed further studies. Li (1989) applied isozyme analysis to the classification of *Arundinaria*. Yao (1990) applied scanning electron microscopy to the observation of the epidermal microstructures of bamboo leaves and culms, and related their results to bamboo classification. Hu *et al.* (1990) used the anatomical structure of bamboo roots to provide new characters for Chinese bamboo classification.

Wen (1991) discussed the taxonomic problems concerning *Neohouzeaua*, *Sasa*, *Sasamorpha*, *Sasaella*, *Chimonobambusa* and *Qiongzhusa*. He discussed the distribution of *Neohouzeaua* in China and combined several species from other genera into it. He also proposed to put *Sasa*, *Sasamorpha* and *Sasaella* together but did not explain why, and he put *Qiongzhusa* and *Chimonobambusa* together because most of their species have nutlike fruits. Chao and Chu (1991) revised *Acidosasa*, and also discussed its relationships with other genera. Hu *et al.* (1991) described one new genus, *Polyanthus*. Yi (1992) erected *Menstruocalamus*, another new genus. Keng P. C. (1992) revised his system of Chinese Bambusoideae. Hui and Hsueh (1992) revised *Melocalamus*.

Up to the present, Chinese taxonomists have named 26 new genera in the Bambusoideae. As our data accumulate and our practical and theoretical abilities improve, we realize clearly that some genera need further revision and some may not be valid. Next, I will present some of my views on some of the questionable genera, and I hope that this will stimulate further discussion of the classification of Bambusoideae in China.

Although *Oreocalamus* and *Brachystachyum* are the first two genera described by a Chinese taxonomist, both are questionable. *Oreocalamus* is very similar to *Chimonobambusa*. From the original description (Keng Y. L., 1940a), we find that only the characters "leptomorph rhizome" and "nutlike fruit" differ from those of *Chimonobambusa*. After making a trip to the type localities of *O. szechuanensis* (Rendle) Keng and *O. utilis* Keng, I found that the rhizomes of both species are amphimorph, the same as in *Chimonobambusa*. As to the fruit, all of the species of *Oreocalamus* and *Chimonobambusa* possess a caryopsis, and although some of them exhibit a thickened pericarp, they are definitely not nuts. From cross sections of the fruits, I found that two or three layers of the seed coat cells were relatively larger and had denser cytoplasm, and these cells were arranged regularly and adhered to the pericarp cells, such that they could not be separated from the pericarp, so the fruits were caryopses. Obviously, there is no difference between *Oreocalamus* and *Chimonobambusa*. Therefore, *Oreocalamus* is a synonym of *Chimonobambusa*. *Brachystachyum* is rather close to *Semiarundinaria* not only in the vegetative appearance but also in the morphology of spikelets and florets. The only difference is that the inflorescence of *Brachystachyum* is shortened and contracted, but essentially, there is no difference in the basic structure of the inflorescences of these two genera. Therefore, it is more reasonable and objective to combine *Brachystachyum* with *Semiarundinaria*.

Qiongzhusa and *Chimonobambusa* share a very similar inflorescence, spikelet and floret morphology. Some workers (Keng, unpublished manuscript, 1984; Wen, 1991) advocate combining these two genera. However, the vegetative characters, biological traits, such as the initiation of new culms (*Qiongzhusa* shoots in April and May, *Chimonobambusa* in October and November), the altitudinal distribution, and the chromosome morphology and isozymes of these two genera are quite different (Hsueh and Zhang, 1988), so I prefer to maintain them as separate genera.

The vegetative characters of *Neomicrocalamus* are the same as those of *Raceobambos*. Keng P. C. (1982) mistook the itercautant inflorescence of *Neomicrocalamus* for semelauctant, and he erected this new genus. Later, Wen (1986) reexamined the type specimen and found that the inflorescence of *N. prainii* Gamble Keng f. (= *Arundinaria prainii* Gamble = *Microcalamus prainii* Gamble), the type species of *Neomicrocalamus*, has an itercautant inflorescence. This means that both the reproductive and vegetative characters of *Neomicrocalamus* are concordant with those of *Raceobambos*, so Wen proposed placing *Neomicrocalamus* in synonymy. However, Wang and Ye (1988) further studied *N. prainii* and *R. gibbsae* Holttum, the type species of *Raceobambos*, and found that the inflorescence of *R. gibbsae* was in fact semelauctant (determinate or restricted) and that of *N. prainii* itercautant (indeterminate or unrestricted). Thus, Wang and Ye (1988) proposed and explained the separation of *Neomicrocalamus* from *Racemobambos*, but they mentioned that it is impossible to distinguish them without inflorescences, and that even with the inflorescences it is still difficult because they are so similar. From the explanation and the drawing of the inflorescences, I found that the main difference was in the prophyll and buds at the base of the spikelets. *Neomicrocalamus* has a distinctive prophyll and buds whereas *Racemobambos* does not. For this reason, I agree with the decision to recognize both *Neomicrocalamus* and *Racemobambos*. Another question I would like to mention here is about *Microcalamus*. Gamble (1890) described it but soon abandoned it without explanation, so some (Keng, 1982a; Wen, 1986) therefore regarded *Microcalamus* as invalid, and Keng (1982) erected *Neomicrocalamus*. In fact, *Microcalamus* is invalid because Franchet (1889) used this name for another genus of Poaceae one year earlier than Gamble.

During the last decade, Chinese botanists have been involved in a controversy over the concept of *Dendrocalamus*. Some think this genus should be circumscribed in the narrow sense (Keng 1981, 1982a, 1987a; Lin 1989a,b), and others in the broad sense (Chia et Fung, 1980, 1982; Wen, 1986; Li et Hsueh, 1988). Lin (1989a), for example, regarded it as essential to segregate *Sellulocalamus* and *Patellocalamus* from *Dendrocalamus*. Sometimes it is very difficult to identify taxa suitably without inflorescences. So *Dendrocalamus* in the broad sense probably includes species belonging to other genera, such as *Gigantochloa* and even *Oxytenanthera*, although some agree this genus does not occur in Asia (Keng, 1987a). The views of Lin (1989b) on the classification of *Dendrocalamus* are valuable, but further study of *Dendrocalamus* and related genera is needed. For now, I recommend dividing *Dendrocalamus* into four subgenera: subg. *Dendrocalamus*, subg. *Patellaris* Hsueh et D.Z. Li, subg. *Sellulocalamus* and subg. *Sinocalamus* Hsueh et D.Z. Li. Lin (1989a) showed the divergence of these four subgenera at nearly the same level in his evolutionary diagram.

Similar problems exist with respect to the delimitation of *Bambusa*. *Dendrocalamopsis* and *Leleba* have the same inflorescences, spikelets, and florets as *Bambusa*, but differ vegetatively somewhat in the thorny short branches and smooth culm sheaths. I think that these differences are not enough to separate *Leleba* and *Dendrocalamopsis* from *Bambusa* at the generic level. Therefore, it is better to recognize a broad concept of *Bambusa*, and to divide it into four subgenera: subg. *Bambusa*, subg. *Leleba* Chia et Fung, subg. *Dendrocalamopsis* Chia et Fung and subg. *Lingnania* Chia et Fung.

As to *Neosinocalamus*, the main confusion is how to treat the species *N. affinis* (Rendle) Keng f. which the rachilla of spikelets is not broken down at the nodes, and the florets do not fall away from the spikelets, each floret has 3–4 lodicules and 2–3 stigmas, and is therefore

intermediate between *Bambusa* and *Dendrocalamus*. The spikelet rachilla of *Bambusa* is broken down easily at its nodes, the florets usually fall away from the rachilla, each floret has three lodicules; on the other hand, the spikelet rachilla of *Dendrocalamus* is not broken down at the nodes, the floret lacks lodicules or occasionally has reduced ones. So some workers (Chia and Fung, 1980, 1982; Li and Hsueh, 1988; Lin, 1988) synonymized *Neosinocalamus* with *Dendrocalamus*. I do not agree with that treatment. It seems clear that *N. affinis* is closer to *Dendrocalamus* than to *Bambusa*, but I do not think it is convincing to attribute this taxon to either *Bambusa* or *Dendrocalamus* at present. Currently, we accept *Neosinocalamus* as a valid genus, with two species: *N. affinis* and *N. yunnanensis* Hsueh f. As far as *Sinocalamus* McClure is concerned, this nomenclature can not be used any longer at the generic level, because the type species of *Sinocalamus* clearly belongs to *Dendrocalamus* (Chia and Fung, 1980, 1982). The species once attributed to *Sinocalamus* now are transferred to other genera, one to *Neosinocalamus*, some to *Bambusa* and the other to *Dendrocalamus*.

The vegetative characters and the structure of the inflorescences, spikelets and florets of *Oligostachyum* (Wang and Ye, 1982) are rather similar to those of *Acidosasa*, and especially vegetatively, it is difficult to distinguish the two genera. The only difference, from the description, is that *Oligostachyum* has 3, 4, or 5 stamens, and *Acidosasa* has 6 stamens. Most bamboo genera in China have 3 or 6 stamens, but a few species of *Arundinaria* occasionally have 4 or 5 stamens. Sometimes, the number of stamens is not counted correctly due to poor development or loss during their developmental period. Therefore, it is possible that *Oligostachyum* has 3 or 6 stamens as the normal condition. Furthermore, some species of *Acidosasa* do not consistently have 6 stamens. For example, *A. chienouensis* (Wen) Chao et Wen has 6 stamens but sometimes 4 or 5, and *A. longiligula* (Wen) Chao et Chu can have 6 or 4 stamens. Therefore, if we accept a slightly broader concept of *Acidosasa*, it includes *Oligostachyum* completely, and thus, *Oligostachyum* becomes a synonym of *Acidosasa*.

From the description (Lin 1988), I find *Metasasa* Lin to be rather distinct, especially in the character of two branches per node, but the inflorescence, culm leaves and the foliage leaves are very similar to those of *Acidosasa*. The main differences between *Metasasa* and *Acidosasa* are that the former has two branches per node and two glumes in each spikelet, and the latter has three branches per node and four glumes. As for the stigma, I do not observe any essential difference between the two genera. However, not all of the species of *Acidosasa* have four glumes, for example, *A. hirtinoda* Chu et Chao and *A. longiligula* both have two glumes, and *A. chienouensis* has three glumes. Thus, we know that *Acidosasa* has two to four glumes per spikelet, rather than consistently four glumes. So, with respect to the glumes, the two genera are alike. The unusual feature of *Metasasa* is the presence of two branches per node. I think that further investigation and study of *Metasasa* is necessary, and that *Metasasa* may not be distinct from *Acidosasa*.

Keng P. C. and Yi (Geng, Bojie and Yi, 1982) insisted that *Arundinaria* should be defined in the narrow sense, which means that *Arundinaria* includes only the one species and three subspecies distributed in North America. They argued that it is necessary to erect a new genus, *Bashania*, to accommodate the Chinese species of this alliance. I do not think that it is correct to define a genus based only on its geographic distribution. The best method to resolve generic problems in the *Arundinaria* complex is to review the original concepts, and revise the genera, analyze characters and character distribution, and critically examine their relationship. I stress

here that I do not think that it is suitable to enlarge the concept of *Arundinaria* without limitation, as has often been done historically, but we should not go to the other extreme and necessarily restrict it very narrowly. I am currently studying *Arundinaria* and related genera to resolve these questions, but for now *Bashania* is included in *Arundinaria*.

Wen (1984a) compared his new genus, *Clavinodum*, with *Oligostachyum* and *Pleiblastus* in detail, but unfortunately he did not compare *Clavinodum* with *Arundinaria*. If Wen had compared these two genera, he would not have erected his new genus, because all the characters of *Clavinodum*, such as rhizome type and the structure of the inflorescence, spikelets and florets are found in *Arundinaria*. Furthermore, *Arundinaria* as defined by Wen himself, has few differences from *Clavinodum*, and I therefore, submerged it into *Arundinaria*.

Based on its terminal inflorescence and many florets per spikelet, Hu (1991) considered his new genus, *Polyanthus*, to be distinct from *Pleiblastus*, which he regarded as having lateral inflorescences and few florets per spikelet. If we examine *Arundinaria*, we will find that the inflorescence of *A. gigantea* Nutt is both terminal and lateral according to the different definitions and the spikelet sometimes has more than 20 florets. From this I conclude that we can not distinguish *Polyanthus* from *Arundinaria*, and so I propose to combine *Polyanthus* with *Arundinaria*.

As to another new genus, *Menstruocalamus*, the main problem is still concerned with the status of the concept of *Arundinaria*. Yi (1992) does not think there is *Arundinaria* distributed in Asia, so he did not compare his new genus with *Arundinaria*. *Menstruocalamus* differs from *Chimonobambusa*, *Sinobambusa*, and even any Asian bamboo genus by its semelauctant inflorescence, one to three branches per node, and amphimorph rhizome. If we were to regard *Arundinaria* in the narrow sense as Keng P. C. and Yi (1982) defined, then of course we should accept the nomenclature of *Menstruocalamus*. But according to the characters of the taxon and my understanding of the concept of *Arundinaria*, I think it is better to combine *Menstruocalamus* with *Arundinaria* because no significant character differs between them.

In discussing the delimitation of new genera, we encounter some problems with concepts of previously described genera, especially *Arundinaria*. *Arundinaria* is one of the first described genera in the Bambusoideae, and it has become one of the most problematical due to confusion regarding its delimitation. At one time, nearly all species of bamboos were placed in *Arundinaria*, which made *Arundinaria* the largest genus, but now this is clearly unreasonable and unacceptable. I think we need to do a great deal of study on this genus using all characters available and analyzing them using cladistic methodology, so that a more stable classification can be achieved.

Pleiblastus also needs further revision, as some of its species probably belong to *Arundinaria*. As to *Pseudosasa*, the type, *P. japonica* (Makino) Sieb. et Zucc. ex Steud. (= *A. japonica*), is very similar to *A. gigantea* not only in its vegetative characters, but also in the structure of inflorescences, which means some species of *Pseudosasa* should be classified in *Arundinaria*, while others differ from *Pleiblastus* only in the branching, and thus should be placed into *Pleiblastus*.

Nakai (1931) mistook the rhizome of *Sasamorpha* for leptomorph, so he separated it from

Sasa. But after further study, others (Wang and Ye, 1980a; Chao *et al.* 1980) found that the rhizomes of both *Sasa* and *Sasamorpha* were neither leptomorph nor pachymorph, but amphimorph. It is easy to make this mistake if one fails to pay enough attention to the rhizomes. When the soil is good, the bamboos with amphimorph rhizomes grow well, and can look like those with strictly leptomorph rhizomes. On the contrary, if soil conditions are bad, the bamboos do not grow well, the bamboos are gregarious and the rhizomes appear to be pachymorphic. Sometimes mistakes may be made because only a part of the rhizome is dug up. There are no differences in the structure of the inflorescences, spikelets and florets of *Sasa* and *Sasamorpha*, and vegetatively the two genera are also similar, so *Sasamorpha* should be submerged into *Sasa*.

The biggest disagreement in the classification of the bamboos with iterant inflorescences, here recognized as the supertribe Bambusatae, arises in the treatments of *Bambusa* and *Dendrocalamus*. Both Munro (1868) and Bentham (1883) placed *Bambusa* and *Dendrocalamus* in two different tribes. Holttum (1956) and Grosser & Liese (1973) put them in one tribe. I think that Holttum's and Grosser's treatments are more reasonable. We know that one main difference between *Bambusa* and *Dendrocalamus* is that the former has lodicules in the florets and the latter lacks lodicules. From our inspection, we find that some species of *Dendrocalamus* have rudimentary lodicules or reduced ones, such as *D. membranaceous* Munro and *D. bambusoides* Hsueh et D. Z. Li. So *Bambusa* and *Dendrocalamus* cannot be distinguished so clearly only by the lodicules. The other main difference between two genera is that the spikelet rachilla of *Bambusa* is easily broken at the nodes, and the spikelet rachilla of *Dendrocalamus* cannot be broken easily. But there is an intermediate existing, that is, *Neosinocalamus*, which has lodicules in the florets and whose spikelet rachilla cannot be broken easily at the nodes; this leads to confusion in that the relationship between *Bambusa* and *Dendrocalamus* is not so distinct as people once thought. I think that it is better to merge these two genera into one tribe. Soderstrom and Ellis (1987) put *Bambusa* and *Dendrocalamus* into one subtribe, the Bambusinae. At the same time, they combined both *Sinocalamus* and *Neosinocalamus* with *Bambusa*, and they mentioned that the distinction between *Bambusa* and *Dendrocalamus* was not so clear.

As to the classification of the bamboos with semelauctant inflorescences, here recognized as the supertribe Arundinariatae, I want to emphasize the importance of the vegetative characters, especially rhizome type. Most confusion at the generic level arose mainly from the misunderstanding of the rhizome types.

One main reason why the classification of Bambusoideae is so difficult and so debatable is that woody bamboos flower rarely. There are few chances for us to get flowering bamboo specimens, but classification of Bambusoideae is mainly based on the structures of the flower, (inflorescence, spikelets and florets). This contradiction causes many disagreements on the classification.

The person who first thought of bamboos as a group was Rumphius (1750), although now it appears that his concept of bamboos was not very clear, because he put all the species under one genus, *Arundo*. Kunth (1815) regarded the bamboos as a separate group of grasses, and is thought to be the first person to formally define bamboo (Calderón and Soderstrom, 1980). Munro (1868) presented a relatively complete system of Bambusoideae, although before that time some botanists (Kunth, 1822; Nees, 1835) had discussed the classification of bamboos in part. Before long, Bentham (1883) modified Munro's system. Hackel, Gamble and E. C. Camus

used Bentham's system, and even now, some taxonomists still carry on Bentham's system. A. Camus (1935) amended Bentham's system by putting all the genera with the filaments united into a tube into one group. Subsequently, the system of bamboo classification did not vary basically until the appearance of Holttum's system (1956). Based on the ovary types, Holttum's system differed widely from any other former system; he arranged the Bambusoideae into four groups. Grosser and Liese (1973) confirmed Holttum's system by anatomical observations on the bamboo vascular strands. Soderstrom and Ellis (1987) presented another system based primarily on leaf anatomy. They divided Bambuseae (woody bamboos) into nine subtribes, among them the Arundinarinae, Bambusinae, Schizostachydinae and Shibataeinae, the four subtribes containing the Chinese bamboos. In China, Keng Yi-Li presented a classification system of the Bambusoideae in 1959; it was also primarily derived from Bentham's system, but it has been revised extensively by Keng P. C. (1982).

I think that the views of Holttum (1946, 1956, 1958) regarding the classification of bamboos are very valuable. Holttum paid more attention to the ovaries rather than fruits. Bamboos rarely flower, and even if a species flowers, it does not always produce fruits, but ovaries can often be found. Therefore, it is more difficult to get fruits than ovaries. Because of the deficiency of fruits, Munro could not arrange his system more objectively, and that is one reason why his system had limited use.

Based on my opinion of the treatment of the tribes and the genera, I propose to classify Chinese Bambusoideae into two supertribes: 1) Bambusatae, including three tribes, Melocanneae, Bambuseae and Shibataeae, and twenty-three genera, all of them with iterant inflorescences; and 2) Arundinariatae, including two tribes, Chimonocalamuseae and Arundinarieae, and fourteen genera, all with semelant inflorescences. Chimonocalamuseae contains all the taxa with pachymorph rhizomes; while Arundinarieae includes all the taxa with leptomorph and amphimorph rhizomes. I think the treatment of *Chimonocalamus* and *Fargesia* as two tribes (Keng P.C., 1982, 1987a) is wrong, because recently I found a natural hybrid between *Chimonocalamus* and *Fargesia*, which means these two genera are quite close. I present a modified system of Chinese bamboos which is mainly based on Keng's system (Keng P. C., 1982–1984), and also a key to the supertribes and the tribes based on characters of inflorescences, the spikelets, the ovaries and rhizome types. As to a key to the genera, it is not so stable because several genera still need further studies, so I will not present a key to genera now.

A Key to the Supertribes and Tribes

1a. Inflorescence iterant, branching unlimited; rhachis jointed with clear nodes and hollow internodes; spikelets sessile or the terminal one with a very short pedicel; prophylls and buds present at the base of the spikelet (pseudospikelet)._____

_____supertribe I. Bambusatae.

2a. Rhizomes pachymorph, short and stout, occasionally elongate, solid and with inconspicuous nodes, the elongated neck without buds and roots.

3a. Ovary narrowed gradually into a stiff, angled style, which is hollow at flowering; fruit large or small, the pericarp free from the seed; one to a few florets per spikelet._____

_____tribe I. Melocanneae.

3b. Ovary narrowed abruptly to a slender style which is solid at

flowering; fruit small, the pericarp free or adherant to seed; many florets per spikelet.

tribe 2. Bambuseae.

2b. Rhizomes amphimorph or leptomorph, long and slender, hollow and with clear nodes, every node has one bud and roots.

tribe 3. Shibataeae.

1b. Inflorescences semelautant, branching limited; rhachis unjointed, solid and without conspicuous nodes and internodes; spikelets pedicellate; prophyll and buds absent at the base of spikelets.

supertribe II. Arundinariatae.

4a. Rhizomes pachymorph, short and stout, occasionally elongated, solid and with inconspicuous nodes; the elongated neck without buds and roots.

tribe 4 Chimonocalamuseae.

4b. Rhizomes amphimorph or leptomorph, long and slender, hollowed and with conspicuous nodes, every node has one bud and roots.

tribe 5. Arundinarieae.

The Classification System of Bambusoideae from China

Supertribe I. Bambusatae Keng and Keng f.

Tribe 1. Melocanneae Benth.

1. *Melocanna* Trin.
2. *Leptocanna* Chia et Fung
3. *Schizostachyum* Nees
4. *Neohouzeaua* A. Camus
5. *Monocladus* Chia, Fung et Y.L. Yan
6. *Pseudostachyum* Munro
7. *Cephalostachyum* Munro
8. *Thyrsostachys* Gamble
9. *Melocalamus* Benth.
10. *Dinochloa* Buse

Tribe 2. Bambuseae Kunth.

11. *Teinostachyum* Munro
12. *Neomicrocalamus* Keng f.
13. *Bambusa* Retz. [*Leleba* Rumph. ex Teijsm & Binn.; *Dendrocalamopsis* (Chia et Fung) Keng f.; *Lingnania* McClure and *Sinocalamus* McClure in part]
14. *Neosinocalamus* Keng f.
15. *Dendrocalamus* Nees (*Sellulocalamus* Lin; *Patellocalamus* Lin and *Sinocalamus* in part)
16. *Gigantochloa* Kurz. ex Munro

Tribe 3. Shibataeae Nakai

17. *Indosasa* McClure
18. *Sinobambusa* Makino
19. *Semiarundinaria* Makino (*Brachystachyum* Keng)

20. *Chimonobambusa* Makino (*Oreocalamus* Keng; *Tetragonocalamus* Nakai)
21. *Qiongzhusa* Hsueh et Yi
22. *Shibataea* Makino
23. *Phyllostachys* Sieb. et Zucc.

Supertribe II. Arundinariatae Keng et Keng f.

Tribe. 4. Chimonocalamuseae Keng f.

24. *Drepanostachyum* Keng f.
25. *Racemobambos* Holttum
26. *Chimonocalamus* Hsueh et Yi
27. *Fargesia* Franch.
28. *Yushania* Keng f.
29. *Ampelocalamus* Chen, Wen et Sheng
30. *Thamnocalamus* Munro

Tribe. 5. Arundinarieae Steud.

31. *Arundinaria* Michaux (*Bashania* Keng f. et Yi; *Clavinodum* Wen; *Menstruocalamus* Yi; *Polyanthus* H.C.Hu; *Pseudosasa* Makino in part and *Pleioblastus* Nakai in part)
32. *Pleioblastus* Nakai (*Pseudosasa* in part)
33. *Gelidocalamus* Wen
34. *Sasa* Makino et Shibata (*Sasamorpha* Nakai; *Sasaella* Makino and *Neosasamorpha* Tatew.)
35. *Indocalamus* Nakai
36. *Ferrocalthamus* Hsueh et Keng f.
37. *Acidosasa* Chu et Chao (*Oligostachyum* Wang et Ye; probably *Metasasa* Lin)

Acknowledgements

I am very grateful to Lynn Clark, my academic advisor, for revising my manuscript again and again, and correcting not only the grammatical problems, but also some mistakes in the content of my manuscript. Also, I am grateful to Prof. Hsueh Chiru (Southwestern Forestry College, P. R. China) for his advising my bamboo studies during the past years. I would like to thank Dr. G. Davis for his carefully reviewing my manuscript and giving me lots of suggestions.

References

- Beijing Botanical Institute, 1976. *Iconographia Cormophytorum Sinicorum*. V. Science Press. Beijing.
- Bentham, G., 1883. Gramineae in *Genera Plantarum* 3. London.
- Calderón, C. and T. R. Soderstrom, 1980. The genera of Bambusoideae (Poaceae) of the American continent: Key and comments. *Smithsonian Contr. Bot.* 44: 6.
- Camus, A., 1924. Especies nouvelles d'Arundinaria malgaches. *Bull. Mus. National d'His.*

Natural (Paris) 3: 394 - 396.

——, 1935. Classification des Bambusees. *Arch. du Mus. d'His. Nat. (Paris)* 12: 601 - 603.

Camus E.G., 1912. Bambusees nouvelles. *Notulae Systematicae* 2(8): 244 - 246.

——, 1913. *Les Bambusees*. Paris.

Chao, Chison, Chengde Chu and Wenyi Xiong, 1980. A revision of some genera and species of Chinese bamboos. *Acta Phytotax. Sin.* 18(2): 20-36.

Chao, Chison and Chengde Chu, 1983. A study on the bamboo genus *Indosasa* of China. *Acta Phytotax. Sin.* 21 (1): 60-75.

——, 1991. A study of the genus *Acidosasa* of Bambusoideae. *Act. Phytotax. Sin.* 29(6): 517-524.

Chen, Shouliang, Taihui Wen and Gueying Sheng, 1981. *Ampelocalamus* — A new genus of Chinese bamboo. *Act. Phytotax. Sin.* 19(3): 332-334.

Cheng, Shouliang and Caoying Cheng, 1983. A revision on subtrib. Pleioblastinae Keng et Keng f. *Acta Phytotax. Sin.* 21(4): 404-414.

Chia, Liangchi and Hoklam Fung, 1980. On the validity of the genera *Sinocalamus* McClure and *Lingnania* McClure. *Act. Phytotax. Sin.* 18(2): 211-216.

——, 1981. *Leptocanna*, A new genus of Bambusoideae from China. *Act. Phytotax. Sin.* 19(2): 211-216.

——, 1982. Critical remarks against "Further comments on the 'On the validity of the genera *Sinocalamus* McClure and *Lingnania* McClure'". *Acta Phytotax. Sin.* 20(4): 510-512.

Chia, Liangchi, Hoklam Fung, and Yaling Yang, 1988. *Monocladus*, Genus novum Bambusoidarum (Poaceae). *Act. Phytotax. Sin.* 26(3): 211-216.

Chu, Chengde and Chison Chao, 1979. *Acidosasa* - A new genus of Chinese Bambusoideae. *Journ. Nan. For. Prod. Tech. Coll.* 1979(1-2): 142-145.

Franchet, R., 1889. Sur deux nouveaux genres de Bambusees. *Journ. de Bot.* 3: 282 -284.

Gamble, J. S., 1890. *Journ. As. Soc. Beng.*, lix. II. 207.

——, 1896. The Bambuseae of British India, *Ann. Bot. Gard. Calcutta* 7: 1-133.

Geng, Bojie (Keng P. C.) and Tongpei.Yi, 1982. *Bashania*, A new genus from western China. *Journ. Nan. Uni. (Nat.Sci.)* 1982(3): 722-732.

- Grosser, D. and F. Liese, 1973. Present status and problems of bamboo classification. *Journ. Arn. Arb.* 54(4): 293-308.
- Hance, H.F., 1862. "Manipulus Plantarum Novarum, Potissime Chinensium." *Annales des Sciences Naturelles*, 235.
- , 1876. A new Chinese *Arundinaria*. *Journ. Bot.* 14: 339 - 340.
- Holttum, R. E., 1946. The classification of Malayan bamboos. *Journ. Arnold Arb.* 27(4): 340-346.
- , 1956. The classification of bamboos. *Phytomorphology* 6: 73 - 90.
- , 1958. The Bamboos of the Malay Peninsula. *Gard. Bull. Singapore* 16: 1-135.
- Hsueh, Chiju (Xue, Jiru) and Tongpei Yi, 1979. Two new genera of Bambusoideae from S.W. China. 1. *Chimonocalamus* Hsueh et Yi. *Act. Bot. Yunnan* 1(2): 74-92.
- , 1980. Two new genera of Bambusoideae from S. W. China. 2. *Qiongzhuia* Hsueh et Yi. *Acta Bot. Yunnan* 2(1): 91 - 99.
- Hsueh, Chiju and Weiping Zhang, 1988. A study on *Chimonobambusa* Makino in China. *Bamb. Res.* 1988(3): 1-14.
- Hu, Chenghua and Yaling Yang, 1983. A taxonomical study of the genus *Sasamorpha* from China. *Journ. Bamb. Res.* 2(1): 47-56.
- Hu, Chenghua, 1988. A taxonomical study on the genus *Shibataea* Makino. *Act. Phytotax. Sin.* 26(2): 130-138.
- , 1990. A preliminary study on the anatomical structure on roots of bamboos. *Journ. Bamb. Res.* 9(2): 11-21.
- Hu, Chenghua, 1991. *Polyanthus*, A new genus of the bamboo from Hunan Province. *Journ. Bamb. Res.* 10(3): 28-30.
- Hui, Chaomao and Chiju Hsueh, 1992. A study on the genus *Melocalamus* Benth. (Bambusoideae) from China. *Act. Phytotax. Sin.* 30(2): 163-168.
- Keng, Pai-chieh, 1948. Preliminary study on the Chinese bamboos. *Techn. Bull. Nat. For. Res. Bur. China* No. 8: 1 - 14.
- , 1957. One New Genus and Two New Species of Chinese Bamboos. *Acta Phytotax. Sin.* 6: 355 - 360.
- , 1981. Further comments on the "On the validity of the genera *Sinocalamus* McClure and *Lingnania* McClure". *Act. Phytotax. Sin.* 19(1): 140-142.

- , 1982 - 1984. A revision on the genera of bamboos from the world. *Journ. Bamb. Res.* 1(1): 1-19, 1982; l.c. 1(2): 31-46, 1982; l.c. 2(1): 11-27, 1983; l.c. 2(2): 11-27, 1983; l.c. 3(1): 22-42, 1984; l.c. 3(2): 1-22, 1984.
- , 1986. A new discovery of bamboo genus *Drepanostachyum* Keng f. in China. *Journ. Bamb. Res.* 5(2): 28-40.
- , 1987a. A systematic key to the tribes and genera of subfam. Bambusoideae (Gramineae) occurrence in China and its neighborhoods. *Journ. Bamb. Res.* 6(3): 13-28.
- , 1987b. On the nomenclature of the high-alpine bamboos from China. *Journ. Bamb. Res.* 6(4): 11-17.
- , 1991. New taxa of Bambusoideae in the Flora of P.R. China. *Journal of Bamboo Res.* 11(1): 21-26.
- Keng, P. C. and Chenghua Hu, 1986. An emendation in the tribe Shibataeeae Bambusoideae. *Journ. Nan. Uni. (Nat. Sci.)* 22(3): 408-430.
- Keng, P. C. and Jiru Xue (Chiju Hsueh), 1982. *Ferocalamus* Hsueh et Keng f., A new bamboo genus in China. *Journ. Bamb. Res.* 2(1): 1-5.
- Keng, Yi-Li, 1935. New bamboos and grasses from Chekiang and Kiangsi Provinces. *Sinensia* 6(2): 147 - 154.
- , 1936a. New species of *Arundinaria* from Southwestern China. *J. Wash. Acad. Sci.* 26 (10): 396 - 397.
- , 1936b. Two New *Arundinaria* from Yunnan. *Kew Bulletin , Misc. Inf.* 1936: 106-107.
- , 1940a. Two new generic names and one new species of Chinese bamboos. *Sunyatsenia* 4(4): 146-153.
- , 1940b. *Oxytenanthera felix*, a new species of bamboo from Yunnan, China. *J. Wash. Acad. Sci.* 30 (10): 426 - 428.
- , 1957. *Claves Generum et Specierum Graminearum Primarum Sinicarum, Appendice nomenckarion systematica.*
- , 1959. *Flora Illustralis Plantarum Primarum Sinicarum - Gramineae.* Peking.
- Kunth, C. S., 1815. Considerations generales sur les Gramineeen. *Memoires du Museum d'Histoire Naturelle* 25 (3): 421 - 489.
- Li, Dezhu and Chiju Hsueh, 1988. *Materiae ad floram Qiongzhuearum Graminearum*

- sinensium. *Act. Bot. Yunnan* 10(1): 49-54.
- Li, Shengfeng, 1989. Application of isozymes in *Arundinaria* classification. *Journ. Bamb. Res.* 8(4): 2-21.
- Lin, Wantao, 1988. New taxa and combinations of Bambusoideae from China. *Act. Phytotax. Sin.* 26(2): 144-149.
- , 1989a. The genus *Dendrocalamus* Nees and its neighbouring two new genera from China. *Journ. South. China Agr. Uni.* 10(2): 40-47.
- , 1989b. Comments on the genus *Dendrocalamus* Nees from China. *Journ. Bamb. Res.* 8(4): 30-35.
- McClure, F.A., 1925. Some observations on the bamboos of Kwangtung (China). *Lingnan Agr. Rev.* 3: 40-47.
- , 1931. Studies of Chinese bamboos. A new species of *Arundinaria* from southern China. *J. Lingnan. Sci.* 10(5-10): 295 - 305.
- , 1935. Bamboo, a taxonomic problem and an economic opportunity. *Sci. Monthly* 41: 193 - 204.
- , 1938. Notes on bamboo culture with special reference to South China. *Hong Kong Nat.* 9: 4 - 18.
- , 1940. New genera and species of Bambusoideae from Eastern Asia. *Lingnan Uni. Sci. Bull.* (9): 34-39.
- Munro, W., 1868. A monograph of the Bambusaceae. *Trans. Linn. Soc. London* 26: 1-156.
- Nakai, T., 1931. Bambuseae in Miyabe, K. et Y. Kudo, Flora of Hokkaido and Saghalien. *Journ. Fac. Agr. Hokkaido Univ.* 26: 180.
- Nees, C. G. D., 1835. *Bambusa Brasiliensis*: Recensuit, et Alias in India Orientali Provenientes Adjecit. *Linnaea* 9: 461 - 494.
- Rendle, A. B., 1903. “Enumeration of all the plants known from China proper, Formosa, Hainan, The Corea, The Luchu Archipelago, and the Island of Hongkong”, Gramineae. *Journ. Linn. Soc.* 36: 434-449.
- Rivière, C. and A. Rivière, 1878. Les Bambous, *Bulletin de la Societe D'Acclimatation. Ser. III.* v. 758-828.
- Rumphius, E. S., 1750. *Het Amboinsch Kruid-boek (Herbarium Amboinense)*, 6 vols. Amsterdam.
- Soderstrom, T.R. and Calderón, 1980. The genera of Bambusoideae (Poaceae) of the American

continent: Key and comments. *Smithson. Contrib. Bot.* 44: 4-9.

Soderstrom, T. R. and Ellis, P. R., 1987. The position of bamboo genera and allies in a system of grass classification. *Grass Systematics and Evolution*, Smithsonian Institution Press, 225-238.

Wang, Zhengping and Guanghan Ye, 1980a. On the problems of the classification of Chinese bamboos with creeping rhizomes. *Act. Phytotax. Sic.* 18(3): 283-291.

——, 1980b. A taxonomical study of *Phyllostachys*, China. *Act. Phytotax. Sin.* 18(1): 15-19 and 18(2): 168-193.

——, 1981. Miscellaneous notes on Chinese Bambusoideae. *Journ. Nan. Uni. (Nat. Sci.)* 1981(1): 91-108.

——, 1982. *Oligostachyum* - A new genus of Chinese Bambusoideae. *Journ. Nan. Uni. (Nat. Sci.)* 1982(1): 95-100.

——, 1988. The separation of *Neomicrocalamus* from *Racemobambos* and their systematic position in Bambusoideae. *Act. Bot. Yunnan.* 10(2): 212-214.

Wen, Taihui, 1982. A new genus and some new species of Bambusoideae from China. *Journ. Bamb. Res.* 1(1): 20-45.

——, 1982, 1983. Study on bamboo genus *Sinobambusa* from China and some other species. *Journ. Bamb. Res.* 1(2): 6-30 and 2(1): 57-86.

——, 1984a. New taxa of Bambusoideae in China. *Journ. Bamb. Res.* 3(2): 23-47.

——, 1984b. Some issues of taxa of Bambusoideae in China. *Journ. Bamb. Res.* 3(2): 23-47.

——, 1986. Some issues of taxa of Bambusoideae in China. *Journal of Bamb. Res.* 5(2): 10-17.

——, 1991. Some ideas on the taxonomy of several Bambusoideae taxa. *Journ. Bamb. Res.* 10(1): 11-25.

Xue, Jiru (Hsueh, Chiju) and Jiliang Sun, 1983. A new record of *Thyrsostachys* Gamble and *Cephalostachyum* Munro from China. *Bamb. Res.* 1983(3): 40-49.

Xue, Juru (Hsueh, Chiju) and Tongpei Yi, 1985. New taxa of the genus *Ampelocalamus* (Gramineae). *Journ. Bamb. Res.* 4(2): 1-8.

Yang, Yanling, 1987. A revision of the genus *Indocalamus* of Bambusoideae from the world. *Journ. Nan. Uni. (Nat. Sci.)* 23(3): 453-462.

Yao, Xishen, 1990. SEM observation on superficial microstructure of bamboo. *Journ. Bamb.*

Res. 9(1): 13-26.

Yi, Tongpei, 1986. Studies on the genus *Yushania*. *Journ. Bamb. Res. 5(1): 8-66.*

——, 1988. A study on the genus *Fargesia* Franch from China. *Journ. Bamb. Res. 7(2): 1-119.*

——, 1992. A new genus of Chinese bamboo - *Menstruocalamus*. *Journ. Bamb. Res. 11(1): 38-44.*

DIRECTORS

Gerald Bol President	David King Vice-President	Kenneth Brennecke Coeditor
Richard Haubrich Treasurer	Elizabeth Haverfield Secretary	Rick Valley
Gilbert Voss	Michael Bartholomew	William Teague

CONTENTS

M.K. Alam: A Note on the Taxonomic Problems, Ecology, and Distribution of Bamboos in Bangladesh.....	1
Qiu Fugeng & Ma Naixun: Selection of Cold Resistant Economic Bamboo Species in China.....	8
A. Sood, O.P. Sharma, & L.M.S. Palni: Improved Methods of Propagation of Maggar Bamboo (<i>Dendrocalamus hamiltonii</i> Nees et Arn. ex Munro) Using Single Node Cuttings Taken from Juvenile Culms of Elite Seedlings	17
Zhang Weiping: The Classification of Bambusoideae (Poaceae) in China	25