

BAMBOOS

Current Research

Proceedings of the
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from 14-18 November 1988

Editors

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FOREWORD

By far the single-most important item of forest produce used by rural communities of the tropics, from the cradle to the coffin, is the bamboo. Over 75 genera and 1250 species are reported to occur in the world. Of late, the demand for this material has increased far beyond the availability, causing serious problems of over-exploitation and depletion of resources.

Bamboos are aptly called the "poor man's timber". They are particularly important for the people of the East where they are found in greatest abundance and variety. Their strength, straightness, lightness combined with extra-ordinary hardness, range in size, abundance, easy propagation, and the short period in which they attain maturity, make them suitable for a variety of purposes and hundreds of different uses have been reported from times immemorial. Even today, the bamboo continues to find new uses, such as paper-making, rayon industry, construction, architecture, engineering, technology, handicrafts, food and medicine. No doubt, this amazing tree-grass has played a significant role in the life and activities of man and perhaps no growing thing on earth has so many and as varied uses as the bamboo.

Yet, we know very little about several aspects of this fascinating plant and these are receiving a high priority in the research activities of bamboo specialists. Thus, its biology, embryology, cytology, physiology of flowering, ecology, silviculture, utilisation are all under detailed investigation. Even the authentic identification of the different species of bamboos which is basic to all other studies has to be undertaken with a sense of purpose.

It is in this context that the third International Bamboo Workshop held at Cochin, is specially relevant. The workshop gave an opportunity for specialists in different aspects of bamboo to come together, discuss various problems under the same roof, evaluate the present state of knowledge on this very important resource and suggest measures for its effective propagation, scientific conservation, proper utilisation and management.

To a true scientist and scholar, work is its own reward. Workshops of this type facilitate exchange of ideas and provide an entirely new dimension in the pursuit of truth and knowledge. The deliberations of the workshop have furthered our knowledge on the subject and the papers contained in this volume will add to the information of all those who are interested in the different aspects of this wonderful grass.

N. BALAKRISHNAN NAIR
Chairman
State Committee on Science,
Technology & Environment
Government of Kerala
India

PREFACE

The bamboos which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely-used resource. Especially in Asia, where it is known variously as the “poor man’s timber”, the “cradle-to coffin plant” and “green- gold” bamboo has and still provides, the materials needed for existence. Bamboo is also an eminently renewable resource; under the right conditions they display prodigious rates of growth - some species can produce culms 40m high and 30 cm in diameter in just four months. The total lengths of culms produced by a giant bamboo clump over its lifetime can well exceed 15km!

And yet, over-exploitation associated with growing human populations, destruction of tropical forests and new demands on the resource for industrial uses, especially by the pulp and paper industry, has resulted in wide-scale decimation of bamboo stocks; from vast forests of bamboo in South and Southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban outright the harvesting and exporting of bamboos.

For many developing countries this translates into the loss of potentially great economic opportunities. The greatest losses though, are borne by the poor and especially the rural poor, as a once abundant and cheap material that provided sustenance, shelter and income has become scarce and expensive. Truly, the present crisis in the availability of bamboos is testament to its remarkable utility.

It is against this backdrop of conflicting industrial and social needs that at Cochin, India, the largest-ever meeting of bamboo scientists and technical experts was convened. The wide-ranging discussion topics reflect a growing interest in bamboo research - very gratifying to IDRC as a demonstration that our long interest in the topic has been well-placed.

The Cochin workshop saw 40 percent more papers than were presented at the last workshop in Hangzhou, China. Several newer areas of research, including work on the use of bamboo as geobam and mass-propagation through tissue culture were covered in sessions at the workshop. A satellite meeting, chaired by Dr Jules Janssen, was also held on the topic “Building and Engineering with Bamboo”.

The papers are reproduced in 14 sections of the book ranging from Country Reports, Bamboo Resources and Propagation to Physical Properties of Bamboo, Bamboo as a Construction/Housing Material, Bamboo Economics and Bamboo Information Systems. Not only does this reflect the varied interests of the participants, but also an enlarging scope of applications of bamboos which need further research and qualification.

A note on the cover photograph: the woody bamboos typically flower infrequently and at long intervals (often measurable in decades). It is, therefore, nearly impossible to get simultaneous flowering in desired parents for hybridization. In vitro flowering is seen as a means of overcoming this barrier to germplasm improvement programs. The in vitro flowering bamboo featured on the cover

reflects the current, worldwide interest in this subject and that the first paper on this aspect was presented at the Cochin workshop (see paper by Ramanuja Rao and Usha Rao). Since then there has been further progress in this area. Notably, Nadgauda, Parasharami and Mascarenhas have obtained seed-set in vitro. Their findings, which received worldwide publicity, were reported in the March 1990 issue of Nature.

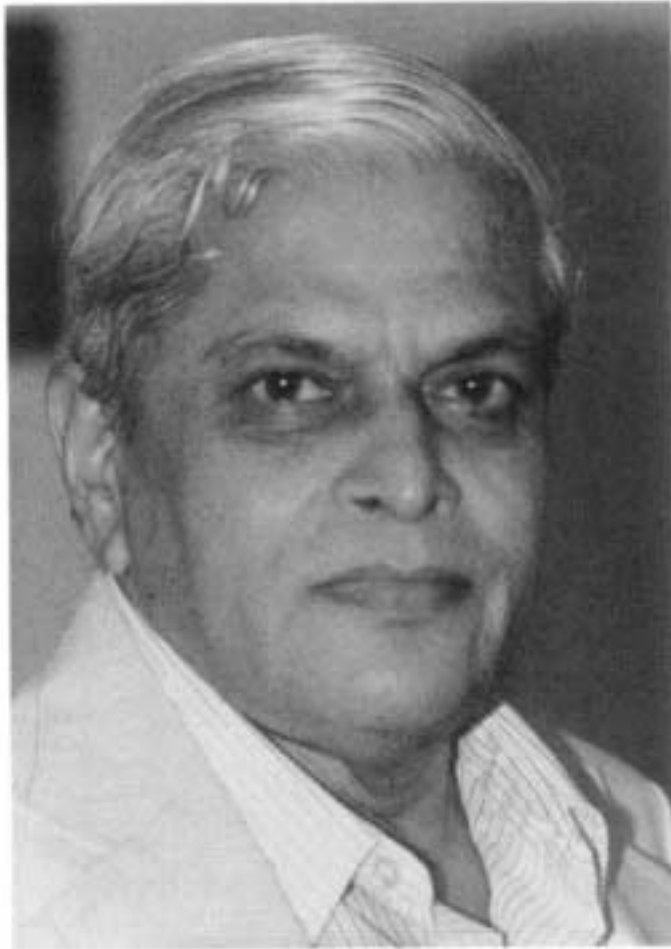
We wish to extend thanks to all the presenters, other workshop participants, the organisers and all those who helped in the preparation of the proceedings. Special thanks are in order for Dr. I. Usha Rao of the University of Delhi for her careful review of all the manuscripts. We hope these proceedings will be widely consulted as a useful reference to all bamboo researchers as have its predecessors, **Bamboo Research in Asia and Recent Research on Bamboos.**

To all those who participated at Cochin, and to fellow bamboo scientists who missed this exciting workshop - we hope to see you at the Fourth International Bamboo Workshop to be held in November 1991 in Chiangmai, Thailand.

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DEDICATION



It is with deep regret that we record the sad demise of Professor Y.M.L. Sharma who attained heavenly abode on 4 April 1988 after a brief illness. He was 72.

Professor Sharma was trained in forestry at the Indian Forest College at Dehradun, India. After a long career in the Indian Forest Service, he retired as Chief Conservator of Forests in Karnataka, India, in December 1973. He was Dean of the Indian Forest College at Dehradun and Principal of the Southern Forest Rangers College at Coimbatore for about 14 years. Professor Sharma was consultant to several national and international organisations and was widely travelled. 'Myforesr', a journal on forestry in Karnataka, was founded by him and he was its chief Editor for long.

The contribution of Professor Sharma to bamboo research in India was considerable. Many will also remember him from his widely quoted articles on 'Bambas in the Asia-Pacific Region' in Bamboo Research in Asia (Proceedings of the workshop held in Singapore in 1980) and 'Inventory and Resource of Bamboos' in Recent Research on Bamboos (Proceedings of the International Bamboo workshop held in Hangzhou, People's Republic of China in 1985).

We dedicate this volume to his memory.

PROCEEDINGS OF
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COUNTRY REPORTS

Bamboo Research in Nepal

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Abstract

Bamboos, which are perennial woody grasses, are one of the most important forest resources of Nepal. These are also grown by farmers. The bamboos are extensively used by the rural people and are distributed from the terai (flat plains) to the high mountains. Work on the identification of the available bamboos, their distribution and uses is continuing in Nepal. The bamboos are traditionally propagated by vegetative means in which culms more than 2 m high with rhizomes are planted vertically. Research is currently underway at the Forest Research and Information Centre, Department of Forests, to develop alternative propagation techniques. Research is also going on to evaluate the potential of bamboos for the stabilization of roads in the hills. Work on the tissue culture of bamboo is being carried out by the Department of Medicinal Plants, Nepal, and also in collaboration, by the Department of Forestry, University of Aberdeen in Scotland. For propagating Bambusa balcoa, Bambusa sp. (Tharu bans), Dendrocalamus humiltonii, D. hookerii, and Dendrocalamus sp. (Dhungre bans), the single node culm cutting technique has proved very successful. Training courses on this technique have been held in several districts of the country, due to the importance of bamboos in community forestry.

Introduction

Bamboos are amongst the important plant species of Nepal. These are grown mostly in homesteads and unproductive land and are common in the natural forests. From the utilization point of view there is no other plant with as much importance to the rural people as bamboo. In the hills, bamboos are used for making furniture, agricultural implements, baskets, houses, bridges, for scaffolding and fencing and as fodder, fuelwood and even as water supply pipes. Besides, the new shoots are used as vegetable. The uses of bamboo vary from place to place depending upon the choice of the local people as well as on the availability of a particular species in that area. In the terai (flat plains), these are mostly used in house construction, fencing, as scaffolding for big buildings and in making baskets, etc.

The bamboos are abundant between the mid-hills and the terai with most of the species being found in the mid-hills. Here these are categorised into two types: bans and nigalo. Bans are big diameter bamboos whereas nigalo are of small diameter. The nigalo bamboos do not occur in the

terai. In the high mountains, bamboos are categorised into three types, namely, bans, nigalo and malingo. Malingo, the smallest diameter bamboos, produce the high quality weaving material, whereas that from nigalo is of medium quality with the lowest quality coming from bans. Bans are not found in abundance in the high mountains and malingo, the high altitudinal species, are rarely found in the mid-hills. Bamboos are abundant in the eastern, central and western hills and in the terai region, but not in the mid-western and far-western regions of Nepal. The land area occupied by bamboos in the country has not been estimated.

Bamboo Research Activities

At present there are two organizations working on bamboo research in Nepal. These are the Forestry Research Project (FRP), which is part of the Forest Survey and Research Office (FSRO) under the Department of Forests and is partly funded by the Overseas Development Administration (UK), and the Department of Medicinal Plants, FRP has many sections, one of which is the Bamboo Research Section. At present this Section is

carrying out work on identification, distribution, uses, and propagation; it also trains field staff and nursery foremen involved in the Community Forestry Development Program (Stapleton, 1986; Jackson, 1987). The Department of Medicinal Plants is working on the tissue culture of bamboos.

Survey for Identification, Distribution and Uses

Before the Forestry Research Project was established eight years ago, very little work had been done on the taxonomic classification of bamboos in Nepal. At that time only two genera and five species had been identified. At present five genera and more than 30 species have already been recorded (Das, 1988; Stapleton, 1982; Stapleton &

Tamrakar, 1983). In the past, surveys had been made in the eastern, central and western regions of Nepal but not extensively in the western and far-western regions. Since bamboos were not surveyed in the past for identification purposes and since flowering occurs after long intervals, the scientific identification of bamboos has been difficult. Local names of the same species sometimes vary from place to place and two different species may even have the same local name. This compounds the problem of identification. Often, people do not even have local names for the species growing in their locality. Table 1 gives the local and botanical names of useful bamboo species along with their distribution and uses.

Table 1 Useful bamboo species*

Botanical name	Occurrence and uses
<i>Arundinaria maling</i> (Malingo)	Common high altitude species widespread above 2800 m in eastern Nepal. Produces best quality weaving material. Most highly valued bamboo for basket and furniture-making.
<i>A. racemosa</i>	Found above the altitudinal range of <i>A. maling</i> (Blatter, 1929).
<i>Bambusa arundinacea</i> (Kante bans)	Large exotic bamboo species found in far-western Nepal. Cultivated by farmers for house construction.
<i>Bambusa balcoa</i> (Dhanu/Bhalu/ Harouti Bolka bans)	Large-sized, big diameter, strong bamboo species occurring from terai to mid-hills. Uses same as for Tharu bans.
<i>Bambusa nutans</i> (Mal bans)	Large-sized, important species of eastern Nepal. Occurs from terai to 1600 m. Used for house construction, scaffolding, bridges, etc.
<i>Bambusa</i> sp. (Tharu bans)	Large-sized, important bamboo species of central Nepal. Found in Kathmandu and Pokhara valley, inner plains and foothills. Used for house construction, scaffolding, low quality woven products, etc.
<i>Bambusa</i> sp. (Mokhla bans)	Common in the terai regions of eastern and central Nepal. Used for house construction and woven products such as mats, baskets, etc.
<i>Bambusa vulgaris</i>	This species is planted for ornamental purposes.
<i>Bambusa / Uxytenanthera</i> sp. (Koraincho bans)	Yellow striped, sometimes erect, having strong branches and solid culms. The branches are used for weaving into baskets, and culms in construction and as fencing posts. Commonly found in the inner plains and Chure hills of central Nepal both in the natural forest and farmlands.
<i>Dendrocalamus hamiltonii</i> (Tama/Choya bans)	Commonly found in the hills mainly between 300 and 2000m. Produces better quality weaving materials than any <i>Bambusa</i> species; new shoots used as vegetable, leaves as fodder, and culms for house construction when other harder bamboo species are unavailable.
<i>D. hookerii</i> (Kalobans/Balu bans)	Common in the eastern hills between 1500 and 2000 m. Used for weaving and house construction. Leaves form good fodder.
<i>D. patellaris</i> (Nibha/Leyas/Murali/ Gopi bans)	Frequently found in the Mechi hills of eastern Nepal between 1900 and 2600 m; also found in Palpa district and in high rainfall areas around Pokhara valley in the western region. Used for making flutes and also produces good quality weaving materials.
<i>D. stricrus</i> (Kath/Laathi bans)	Found in the terai region below 1000 m in farmlands and also reported to occur in the natural forest of the mid- and far-western terai. Introduced in plantations due to easy availability of seed from India. Used for making sticks and in house construction. Less preference for this species by people due to its small size.

Table 1 Useful bamboo species* (continued)

Botanical name	Occurrence and uses
<i>Dendrocalamus</i> sp. (Choya bans/Khosre/ Tama/Phosre bans)	This species is quite similar to <i>D. hamiltonii</i> and is found between 1500 and 2000 m on a large scale. Used for weaving and leaves as fodder.
<i>Dendrocalamus</i> sp. (Dhungre bans)	This is the biggest diameter bamboo of Nepal. Commonly found between 1500 and 2000 m in central Nepal and less commonly in the eastern hills. Used for house construction, weaving, leaves as fodder during dry season, for making containers, etc.
<i>Drepanostachyum</i> <i>intermedium</i> (Tite nigalo)	Found from 1200 to 2400 m both on cultivated land and in natural forests of eastern Nepal. Used mainly for weaving into baskets, mats, etc. and leaves as fodder during the dry season.
<i>D. khasianum</i> (Tite nigalo)	A species of central and western Nepal, it is found in the natural forests as well as on cultivated land. Used for weaving.
<i>Drepanostachyum</i> sp. (Malinge nigalo)	Eastern species found between 1800 and 2200 m. Produces better quality weaving material than the previous two <i>Drepanostachyum</i> spp.
<i>Drepanostachyum</i> sp. (Malinge nigalo)	Occurs in central Nepal from 1800 to 2800 m in the natural forest, Not widely cultivated though it produces superior quality weaving material.
<i>Drepanostachyum</i> sp. (Malinge nigalo)	Occurs in western Nepal and looks similar to the previous two species. Produces superior quality weaving material and is managed intensively at 2500-3000 m in the forest around Pokhara valley for edible shoots.
<i>Thanocalamus</i> <i>spathiflorus</i> (Ringal)	Found above 2000 m under deodar and fir forest of far-western and mid-western Nepal.
<i>Thamnocalamus</i> sp. (Ghoonre nigalo)	Central Nepal species found between 2000 and 2500 m. Not good for weaving.
<i>Thamnocalamus</i> sp. (Chigar)	High mountainous, western Nepal species. Important food source for black bear and Nepalese national bird Impeyan pheasant.
<i>Thamnocalamus</i> (Jarubuto)	Western Nepal species of high mountains. Same uses as previous one.

* local name in parenthesis

Propagation Trials

The raising of bamboos by seed is restricted since bamboos flower after long intervals (*Dendrocalamus hamiltonii* (Tama bans) flowers after 30-40 years and *Bambusa nutans* (Mal bans) after 50-60 years). Even when seed is available, it generally has a very low germination percentage. Besides, it takes a long time to establish bamboo clumps from seed.

The traditional method of propagation (raising bamboos from offsets by vertically planting the rhizomes which is commonly practised by rural people in Nepal) is not feasible in afforestation programmes due to its high purchasing and transportation costs. In comparison, the single-node culm cutting method has several advantages over the above propagation techniques. It is easy,

cheap and reliable. Besides, culm cuttings are easy to transport and have a high rate of success in propagation.

A high success rate of propagation from single node culm cuttings can be achieved in the bamboo species that characteristically produce strong branches. Single node culm cutting propagation trials have been established for *B. balcoa*, *B. nutans*, *Bambusa* sp. (Koraincho bans), *Bambusa* sp. (Tharu bans), *D. hamiltonii*, *D. hookerii*, *Dendrocalamus* sp., and *Oxytenanthera* sp. in different parts of the country. Sixty to 80 percent survival was obtained in *B. balcoa*, *Bambusa* sp. (Tharu bans), *D. hamiltonii* and *D. hookerii*. The success rate was low in *B. nutans* (30%). In Koraincho bans only 20 percent survival was obtained.

In the terai, cuttings are taken from early February to late March whereas in the hills it is from March to April. The cuttings are taken from culms in their second year of growth having strong branches and large dormant buds at the nodes. Shading and irrigation are provided to the culm cuttings throughout the year.

On Dharan-Dhankuta hill roadsides, which is in the eastern region of Nepal, bamboos were introduced in 1987 and 1988 on sites prone to erosion and landslides. Bamboos were established on these sites by the traditional method of propagation, using single node culm cuttings, whole culms with rhizomes planted horizontally and a small modification of Dai's Chinese technique of horizontal planting. In Dai's technique, whole culms with rhizomes are used and notches two-thirds deep are made in internodes at the upper portion of culms. On Dharan-Dhankuta hill roadsides, the notches were made at the bottom portion of internodes. The final assessment of these experiments will be made in January 1989.

A comparative study of the two techniques of propagation was made on *D. hamiltonii* in April 1988 using whole culms with rhizomes planted horizontally and whole culms with rhizomes having notches at the bottom of the internode planted horizontally. The final result will be available by February 1989.

Training and Extension

Training on bamboo propagation from single node culm cuttings has been provided to the field staff and nursery foremen involved in community forestry programmes.

Information about recent research on bamboos is being provided regularly to the district forest offices.

Work on Tissue Culture

Work on tissue culture of bamboos is being carried out in the Department of Medicinal Plants. Dr S.B. Rajbhandari is working on *D. hamiltonii* and *D. strictus* for which seeds are readily available. It has been found that tissue culture propagation can be carried out successfully on these bamboos.

Future Research Activities

The future research activities on the bamboos will be mainly on the following aspects:

- surveys for determining distribution, identification and local uses,
- research work on propagation techniques,

- management,
- utilization, and
- socio-economic surveys.

The work on surveys of bamboos for identification, distribution and uses will be continued next year with visits to the mid-western region of Nepal for this purpose. Research on propagation of bamboo species will be continued next year and the single node culm cuttings propagation trials repeated on those species in which success rates have been low. Different treatments will be tried. Promising species on which propagation trials were not made in the past will be included next year. More trial plots will be established in the terai region. Whole culms with rhizomes (horizontal planting) will be introduced in *D. hamiltonii* to establish this species on the Dharan-Dhankuta hill roadsides. Since the Community Forestry Development Program (CFDP) has already been launched all over Nepal with monetary assistance from different international agencies, the highest priority is being given to those species which are most wanted by people. The experience gained from research on the best techniques of propagation for individual species will be disseminated to the district forest officers, field staff and nursery foremen involved in the CFDP. Training to the nursery foremen and field staff in the forestry sector on bamboo propagation will be provided as in the past.

In most parts of Nepal, bamboos are not managed scientifically. Research is, therefore, necessary on bamboo management and in the future, this will be given high priority. Bamboo management research plots will be established in all the ecological zones of Nepal such as the terai, mid-hills and high mountains.

Even though people use bamboos for making different household implements and in house construction, they do not know much about other uses like making furniture and other types of woven products. There are very few furniture industries which use bamboo as raw material, though much scope exists for earning money from bamboo furniture, household implements, baskets and new shoots as vegetable, as bamboos are abundant all over Nepal. Bamboos can also be used for paper-making. Thus, the utilization of bamboos is an area of research to which priority will be given in the future. For this, contacts will be made with the Departments of Rural and Cottage Industries, and Paper Industries of Nepal. As the socio-economic impact of bamboos was not determined in the past, future surveys will take this aspect into account.

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Some Aspects of Bamboo and its Utilization in Sri Lanka

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Abstract

Bamboo has a long history of traditional use in Sri Lanka but is considerably less utilized in comparison to that in other Asian countries. This may be due to the paucity of native species of utility value, the majority of the island's ten species being shrubby montane types. However, the high endemicity among the native species (80%) and their distribution are of great interest to regional plant geography. In Sri Lanka, bamboo is largely used in the handicraft industry and in the housing and construction sector. Bamboo is also often cultivated along river banks for soil stabilization, is used for making floats for transport of logs and as support for bean vines. Two species, *Ochlandra stridula* and *Bambusa vulgaris*, are used almost exclusively for these purposes. Attention is drawn in this paper to the urgent need to intensify the use of the bamboo resources in Sri Lanka through systematic management and the promotion of its use as a substitute for small timber. Several exotic species with high utility value suitable for Sri Lankan conditions are also recommended for future introduction.

Introduction

Although bamboo has a long history of traditional use in Sri Lanka, it is considerably less utilized in this country when compared with most other Asian countries. Lack of information on the local bamboo resources and their utilization potential has been a drawback in its promotion. To address this problem, the International Development Research Centre (IDRC) has since 1984 supported a research project through the Forest Department of Sri Lanka. The project aims at determining the distribution and availability of individual species, developing mass-scale propagation techniques for the economically important species and establishment of trial plots.

Vivekanandan (1980, 1987) presented some preliminary information on the bamboo resources of the country and the Forest Department's experience with bamboo reforestation. As a result of the IDRC project, much more is known now about the taxonomy, distribution and utilization of bamboo in the country. Some of this information is presented here, together with suggestions for promoting the cultivation and utilization of commercially important species.

Native Bamboos

Sri Lanka possesses an extremely poor bamboo flora which consists only of ten species according to a recent revision of the group (Soderstrom & Ellis, 1988). A remarkable feature, however, is the high degree of endemism (80%) with one genus (*Davidsea*) and eight species being reported as unique to the country (Table 1).

Of the ten species, *Bambusa bambos* and *Dendrocalamus cinctus* are confined to the dry zone of the country. Of these, the latter is very restricted in distribution and is known only from one or two isolated forested inselbergs such as Ritigala located in the North-central region of the country. A third species, *Ochlandra stridula*, is found extensively in the wet lowlands of the South-western region. The remaining seven species are found in the high altitudinal montane areas of the central hill country (Fig. 1). The natural habitat of most of the bamboo species is the forest understorey. The exceptions are species confined to special habitats such as *Dendrocalamus cinctus* and *Arundinaria scandens* which have been reported from windswept mountain tops and *A. densifolia*

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Table 1. Native and introduced bamboos occurring in Sri Lanka

Species	Local name (English name)	Utility value
Native		
* <i>Arundinaria densifolia</i>	Bata	
* <i>A. debilis</i>	Bata	
* <i>A. scandens</i>	Bata	
* <i>A. fluribunda</i>	Bata	
* <i>A. walkeriana</i>	Bata	
* <i>Pseudoxytenanthera monadelpha</i>	Bata	Yes
* <i>Davidsea attenuata</i>	Bata	Yes
* <i>Ochiandra stridula</i>	Bata	Yes
* <i>Dendrocalamus cinctus</i>		
<i>Bambusa bambos</i>	Katu Una (Spiny bamboo)	Yes
<u>Introduced</u>		
<i>Bambusa vulgaris</i>	Kola Una (Green bamboo) Kaha Una/Rana Una (Yellow bamboo)	Yes
<i>Bambusa multiplex</i>	Cheena Bata (Chinese bamboo)	Yes
<i>Dendrocalamus giganteus</i>	Yodha Una (Giant bamboo)	Yes
<i>Dendrocalamus membranaceus</i>	Una	Yes
<i>Dendrocalamus asper</i>	Una	Yes
<i>Dendrocalamus strictus</i>	(Male bamboo)	Yes
<i>Thyrsostachys siamensis</i>	Siam bambu (Thai/Male bamboo)	Yes
*, endemic species; o, endemic genus		

from low temperature swamps within the montane grasslands.

The study of the taxonomy and distribution of the Bambuseae in Sri Lanka is of much interest in the light of recent speculations on the importance of the wet zone flora of the country in regional plant geography of South and South-east Asia (Ashton & Gunatilleke, 1987). In this context, the features of interest are the high endemism; the recognition of a new endemic genus (*Davidsea*); a new species of *Dendrocalamus* from Ritigala, a location thought to have retained some primeval dry zone forest (Gunatilleke & Ashton, 1987) and the recognition of a temperate genus *Arundinaria*.

Introduced Bamboos

According to available records 20 species are supposed to have been introduced into Sri Lanka of which seven are cultivated (Table 1). Among them,

the yellow variety of *Bambusa vulgaris* is most widely cultivated particularly in the rural areas of the wet low and mid-country and in the vicinity of waterways in the dry zone. *Dendrocalamus giganteus* is cultivated on a small scale in the wet highlands whereas *D. asper* and *D. membranaceus* are found in the intermediate highlands.

Dendrocalamus strictus which was introduced by the Forest Department to the dry zone (Vivekanandan, 1980) as a source of fibre for the paper industry, is now restricted in distribution to a few pilot plantations in the dry zone. Two species of bamboo cultivated for their ornamental value are *Bambusa multiplex* and the recently introduced *Thyrsostachys siamensis*, the former being found in most parts of the country, while the latter is currently restricted to urban areas.

The remaining 13 species are not cultivated but are found in the three Botanic Gardens of the country. The best collection of bamboos are in the

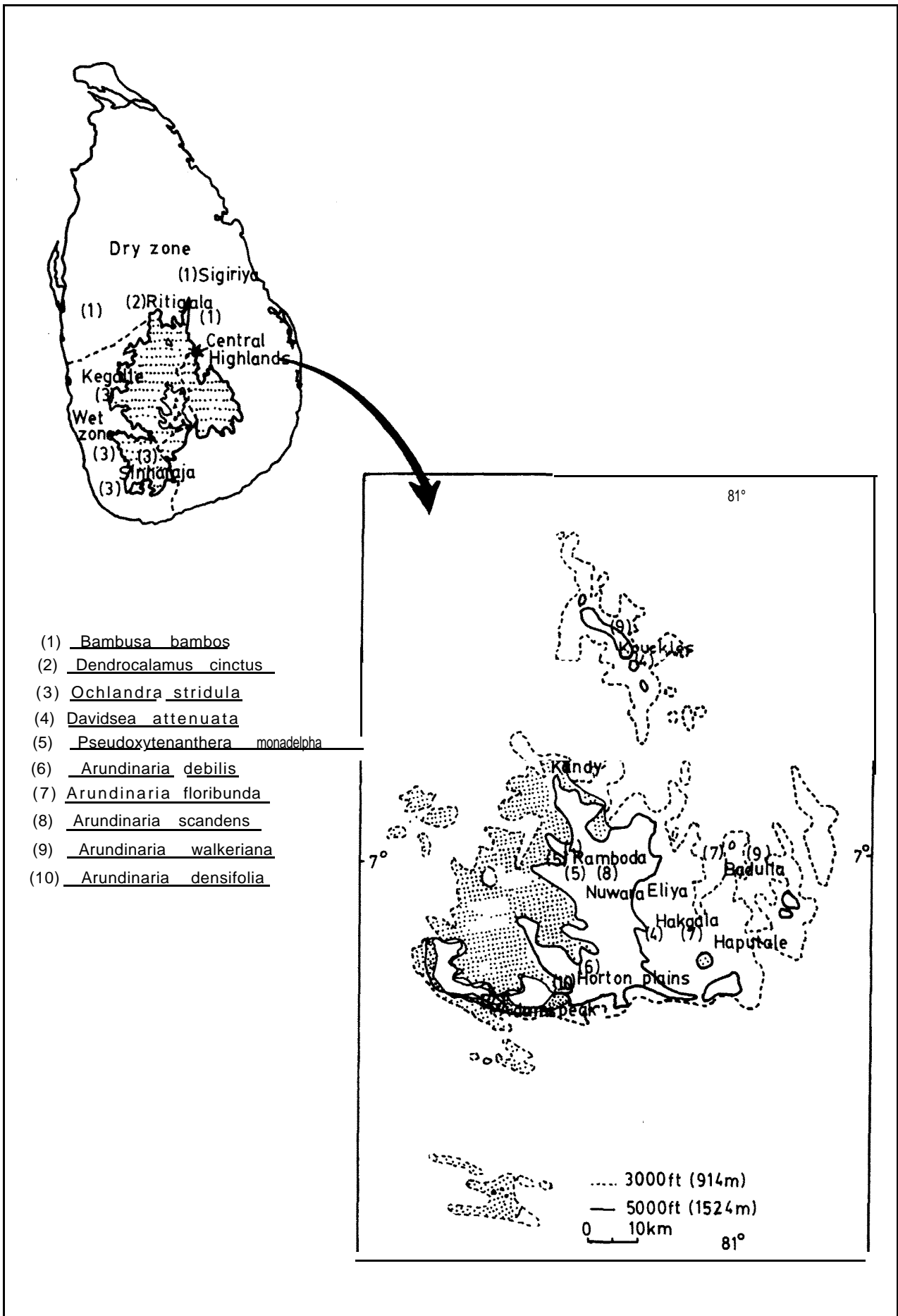


Fig. I. Distribution of native bamboo species in Sri Lanka.

Peradeniya Botanic Garden. The species are: *Arundinaria hindsii*, *Bambusa polymorpha*, *B. tulda*, *B. ventricosa*, *Dendrocalamus hamiltunii*, *D. longispathus*, *Gigantochloa utter*, *Melocana bac-cifera* and a few unidentified species.

Utilization of Bamboo

The relatively low utilization of bamboo in Sri Lanka is mainly due to the paucity of native bamboos of utility value as the majority are shrubby montane species with limited use (Table 1).

Bamboo use is largely in the handicraft industry and in the housing and construction sector. Of lesser importance is its use for the making of floats for transport of logs and in the construction of rafts, fish-pens and fish-traps in inland and estuarine waters. A few species have limited use as support for bean vine in the upcountry vegetable farms. Bamboo is also traditionally grown on the banks of rivers and streams for soil stabilization. For almost all purposes, the native (endemic) *Ochlandra stridula* and the introduced *Bambusa vulgaris* are exclusively used in the bamboo industry (Table 2).

Handicrafts

The manufacture of bamboo handicrafts has been a traditional cottage industry in the country and is largely based on a single species *Ochlandra stridula*. According to the Master Plan for Handicraft Development in Sri Lanka (Anonymous 1987), the manufactured products are mainly articles woven from bamboo strips such as baskets, strainers, winnowing fans, blinds and tats of household importance. Bamboo flutes are also made from the same species and are of cultural importance in folk music.

The traditional handicraft industry was in the past governed by certain social and cultural norms. Individual groups or castes of people had their own particular skills and thereby became associated with a particular type of handicraft. However, this tradition is fast disappearing.

The present day industry uses *Bambusa vulgaris* for more modern products such as baskets, vases, pencil and pen holders, kitchen containers, wall plaques, table mats and lamp shades, all of which have a decorative-cum-utility value. *Dendrocalamus giganteus* is also sparingly used in combination with other raw material such as rattan, wood and cloth.

Processing for both species is simple. *Ochlandra stridula* is simply cleaned and split into long strips. *Bambusa vulgaris* is cut into small pieces and boiled or steamed with water and preservative chemicals. The material is dried over a

fire, sand-papered and lacquered. The products made from *O. stridula* are strictly of utility nature and are used in rural areas whereas more sophisticated products are made of *B. vulgaris* to cater to the urban sector and the tourist market. The montane bamboo *Davidsea attenuata* is also worthy of mention and is used for the weaving of crude baskets for packing and transport of flowers and vegetables.

Housing and Construction

The use of bamboo in housing and construction is limited. In areas where *Ochlandra stridula* grows freely, whole culms have been traditionally used as wattle; strips for tats, blinds and inner partitions; and leaves for thatching, particularly among the low income groups. In other rural areas, *B. vulgaris* is widely used as wattle for crude temporary constructions such as out-houses, barns, shelters during harvest time, watch huts, fencing and props. It is often used for small bridges and as water pipes. The major demand for bamboo in housing is as scaffolding supports and props in the building sector within urban and new development areas.

Availability of Raw Material

The availability of *Ochlandra stridula* for the handicraft industry is fast decreasing. The raw material has to be transported from far distances at an increasingly high cost. The current methods of harvesting are also wasteful. Only the young pliable culms are used while the mature culms are discarded, even though these can be used for other purposes. Although on an island-wide basis *O. stridula* is becoming scarce, it can still be found abundantly in a few localized areas. In the plantation areas for instance, it is often considered as a weed and its eradication is promoted. Consequently in these areas, there is often a misconception that this resource is plentiful.

Bambusa vulgaris appears to be still plentiful. Earlier, this bamboo material was transported to the city in large quantities down the rivers during the rainy season. It is now largely transported by road and its supply and marketing is, therefore, more regulated and non-dependent on the rainy season. Transport by road, however, increases the cost of the material. A small quantity of bamboo material still arrives in the city in the form of floats for timber transportation down the rivers. For both *O. stridula* and *B. vulgaris*, a small but significant number of people are engaged either full-time or part-time in harvesting, transporting and marketing.

In recent times there is an increasing trend towards the substitution of bamboo with newer

Table 2. Major uses of bamboos in Sri Lanka

Type of use	Species									
	<i>Ochlandra stridula</i>	<i>Davidsea attenuata</i>	<i>Pseudoxytenanthera monadelphica</i>	<i>Bambusa vulgaris</i>	<i>Dendrocalaimus membranaceus</i>	<i>Dendrocalaimus giganteus</i>	<i>Dendrocalaimus asper</i>	<i>Bambusa multiplex</i>	<i>Dendrocalaimus stamensis</i>	
<u>Housing and construction</u>										
Scaffolding				x						
Wattle	x			x						
House frames				x						
Ladders				x						
Pipes				x						
Thatching			x							
Bridges				x						
Fencing				x						
Props				x						
<u>Handicrafts</u>										
Baskets	x									
Tats, wall hangings, strainers, winnowing fans, flutes										
Vases, pen holders, ornaments										
Bean vine sticks										
Soil stabilizers										
<u>Rafts and floats</u>										
Fishing gear										
<u>Ornamental</u>										

materials such as plastic bags and kitchen items, cement and brick walling and clay tiles for roofing. Bean vine sticks in the upcountry are now largely being substituted by stems of the grass species *Al-undo donax*. In the rural sector bamboo continues to be used only if other sources of hardwood are not readily available. However, new uses of bamboo are also developing such as the use of yellow bamboo in the manufacture of low-cost coffins due to shortage of hardwoods.

Recommendations

It is clear that the under-utilization of bamboo in Sri Lanka is largely due to paucity of suitable local species. However, there is much potential for intensifying the use of bamboo by promoting the cultivation of economically valuable exotic species that have already been established and by the introduction of potential newer species into the country. A number of recommendations are made in this paper towards promoting the cultivation and utilization of bamboo.

1. Initiate a quantitative island-wide assessment of raw material availability, and supply and demand trends.
2. Establish guidelines for sustained management of existing wild resources, in particular for the native *Ochlandra stridula*.
3. Promote the cultivation of useful species close to major use locations (this is comparatively easy as mass-propagation techniques for the extensively used *Ochlandra stridula* and *Bambusa vulgaris* have been perfected under the auspices of the IDRC project) along river and stream reservations, drainage lines, channel bunds, paddy field bunds and in other water-logged areas.
4. Promote cultivation of bamboo in mixed species plantations and among monocultures of pines, eucalypts and acacias to improve their diversity.
5. Promote the substitution of hardwood timbers with bamboo for semi-permanent or temporary construction purposes.
6. Provide access to raw material on state lands, plantations and community projects to the rural people.
7. Initiate a programme of research to improve the durability, strength, service life and other useful characteristics of bamboo for construction purposes. (Some programmes have already been initiated by the National Building Research Organization, the Department of Small Industries and National Housing Development Authority.)

8. Initiate programmes to popularize bamboo for large scale non-traditional or non-familiar uses such as structural components in housing, raw material for the paper industry and for production of edible bamboo shoots,
9. Restrict import of raw materials such as Tabashir (an extract of *Bambusa bambos* which is used in indigenous medicine) by promoting programmes for its cultivation in the country. (The Ministry of Indigenous Medicine has already initiated a programme for propagation of *Bambusa bambos* with seeds obtained from India.)
10. Initiate an active programme for introduction of newer species of utility value to supplement the present supply of bamboo raw material. A few species worthy of investigation are: *Bambusa polymorpha*, *B. tulda*, *B. nutans*, *Dendrocalamus strictus*, *D. hamiltonii*, *D. brandisii*, *Gigantochloa atter* and *G. laevis*.

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Status of Bamboo Research and Development in Thailand

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Abstract

The distribution of bamboos in Thailand is described in this paper. The development of research work on bamboos with regard to management of national bamboo forests, bamboo propagation and growth studies is outlined. Three living collections of bamboos have been established. The areas of current and future research on the economic bamboo species are also discussed.

Introduction

Thailand is one of the richest areas for bamboo species in Asia with 12 genera and 41 species (Smitinand & Ramyarangsi, 1980; Ramyarangsi, 1985). Due to the different climatic conditions from wet tropical to dry tropical in the south of the country to dry tropical (monsoon) in the north, the bamboo species that grow in the wet tropical area are different from those in the monsoon areas. Some species are, however, common to many parts of the country such as *Bambusa blumeana*, *B. nana*, *B. vulgaris*, *Dendrocalamus asper*, *D. membranaceus*, *D. strictus*, *Thyrsostuchys oliveri* and *T. siamensis*.

Bamboo grows naturally in the mixed deciduous and tropical evergreen forests or semi-evergreen hill forest, especially in the central highland where the rainfall is between 1000 and 2000 mm. However, the natural distribution of bamboo in these forests has been greatly altered by human intervention.

Bamboo is an important raw material for both rural and industrial use in Thailand. It is estimated that the annual production for the internal market is around 600 million culms worth more than US\$ 7 million. Thailand exports bamboos and bamboo products such as bamboo board, fish rods and edible bamboo shoots to various countries, worth about US\$500 000 annually since 1973. It has now been realized that the bamboo forests of Thailand are not fully and efficiently utilized to their full potential. Research on the bamboos will indeed contribute greatly to the economy of the rural people and to the country as a whole.

Research and Development of Bamboo

In the past, cultivation of bamboo was practised mostly by the rural people. Little technical work was done on bamboo due to plain ignorance and the prevailing attitude of taking bamboo for granted. In 1964, research work was started by the Royal Forestry Department (RFD) and Food and Agriculture Organization (FAO) specialists for improving the growth and yield of natural bamboos through silvicultural treatments for pulp and paper production. The first bamboo experimental station, the Hin-Lap Research Station, was established in order to study methods of propagation, cultivation and plantation. Subsequently bamboo research in Thailand has been continuously conducted and can be divided into four phases (Anonymous 1981-84, 1985, 1986).

Phase I (1964-1967)

The research projects during this three year period were conducted in the Hin-Lap Research Station in the Kanchanaburi region where large and compact bamboo forests occur naturally. Japanese bamboo experts as FAO specialists were associated with these projects. The main activities are detailed below.

Survey on management of natural bamboos for pulp and paper-making

Initially, there was only one mill in Kanchanaburi making paper from bamboos. Many bamboo species in Thailand are suitable for pulp-making such as *Bambusa atundinacea*, *B. tulda*, *Dendrocalamus longispachus*, *D. membranaceus*,

D. strictus and *Schizostachyum zollingeri* but occur in limited quantities (Ueda, 1966). In comparison, *Thyrsostachys siamensis* thrives almost everywhere in the central and northern parts of Thailand. It even occurs in dry and poor soil and was the main species used for paper and pulp. The management for increasing the growth and yield of bamboos was based on the cutting cycle. In the natural forests, *T. siamensis* culms generally die when they become over-aged (more than six to seven years old). The over-aged culms need to be cut and utilized before they die. A well-managed and skillfully cut bamboo forest usually has few dead culms. A three-year cutting cycle is suitable for improving productivity.

Studies on bamboo propagation

Asexual propagation: Experiments were conducted with rhizome and culm cuttings of *T. siamensis*, *B. arundinacea* and *D. longispathus*. The results showed that the one-year-old rhizome or culm has the most vigorous sprouting activity. In comparison, the two-year-old culms had diminished sprouting activity. The culms lose their sprouting ability when these are five to six years old.

Sexual propagation: The propagation of bamboos using seeds was also tried. Seed samples of *T. siamensis* were obtained from villagers who use bamboo seeds for feeding hogs. None of the seeds germinated. An attempt was made to carry out a germination test of *B. arundinacea* seeds in different media but with unsatisfactory results. The failure to obtain seed germination could have been due to lack of experience in seed storage methods resulting in poor or no viability.

Planting trials: Seedlings obtained from the natural forest were planted in order to study the growth of new shoots. The survival rate of the planted seedlings was high with very satisfactory shooting though watering was necessary during the dry season.

Thinning trials: In a thinning trial, it was found that the cutting of all culms older than three years was the best method.

Phase II (1967-1982)

Bamboo research work was at its peak during the end of 1969. There was close co-operation between Thai and Japanese scientists, with a training course on Silviculture and Management of Bamboos being arranged in the beginning of 1969. The main research work carried out during this phase was as follows:

Effect of light intensity on growth of seedlings

The results of this study revealed that 100 percent light interception retarded increase in leaf number

whereas 20 percent light interception limited the development of roots and rhizomes.

Shooting capacity

The shoot production in *B. arundinacea*, *B. tulda*, *B. vulgaris* and *T. siamensis* were studied.

Shoot growth

Shoot growth of *T. siamensis* during the night was two to three times greater than that during the day.

Intercropping of bamboos and legumes

No significant result was found in comparison with monoculture of bamboos.

Phase III (1983-1986)

The work during this phase was greatly aided by grants from the International Development Research Centre (IDRC) of Canada. The work accomplished is summarized below:

Living bamboo collections

The collections have been set up in three regions of the country: North, at Mae-Sa Botanical Garden in Chiangmai; Central, at Hin-Lap Research Station in Kanchanaburi; and South, at Songkla Forest Research Station in Songkla.

The living collections at Kanchanaburi and Songkla are on flat land whereas that at Chiangmai is in a hilly area. The area of each living collection is 3.2 ha (20 rai) and has been planted with 20 bamboo species, one rai for each species with different spacings depending upon the nature of each bamboo species.

Edible bamboo plantations

Edible bamboo plantations were established in four different locations: Chiangmai, Kanchanaburi, Songkla and Khonkaen (in the North-east) with an area of 50 rai or 8 ha in each location. The purpose of the experiment was to intensify and promote the use of local species for the production of edible shoots. *Bambusa arundinacea*, *D. strictus* and *D. asper* were planted on the farm at Chiangmai whereas *B. arundinacea*, *B. blumeana*, *B. burmanica* and *D. asper* were planted at Kanchanaburi. More species have been introduced to the farm in Songkla, i.e., *Arundinaria suberecta*, *B. arundinacea*, *B. blumeana*, *B. burmanica*, *D. asper*, *D. brandisii*, *Gigantochloa albociliata* and *T. siamensis*. The farm at Khonkaen was planted with four bamboo species: *B. burmanica*, *D. asper*, *D. strictus* and *T. siamensis*.

During this period, other research work conducted by the RFD was as follows:

1. Identification of some Thai bamboos.
2. Seed collection, germination, seed sowing medium and seed storage.

3. Survey and studies on natural bamboo forests.
4. Exploration of bamboo forest using remote sensing.

Phase IV (1986-1989)

Research projects under the responsibility of the RFD have been continuously conducted.

increase in the area and number of species in the living bamboo collections in the North and North-east regions

The total planted area in both regions was 60 rai (9.6 ha). The living bamboo collections were located at the Dong Lam Seed Orchard, Khonkhaen province and at Thung Salang Luang, Phisanulok province.

Plantation

Trial plantations were also established at the locations mentioned above. The total area of each location was 48 rai (7.7 ha). The four species planted at each site were *Bambusa blumeana*, *B. nana*, *Dendrocalamus asper* and *Thyrsostachys oliveri*.

Propagation methods

Seed and vegetative propagation by conventional and tissue culture methods have also been investigated. Economically important bamboo species, namely, *B. blumeana*, *B. nana*, *B. vulgaris*, *Cephalostachyum pergracile*, *D. asper*, *D. brandisii*, *D. giganteus*, *D. membranaceus*, *T. oliveri* and *T. siamensis* were selected for study.

Conclusion

The RFD is well aware of the importance of bamboos both in the present day national economy and in the future. Thus, the following research projects have been planned.

Arboretum Trial

This will be done in addition to the living bamboo collections which have already been supported by the IDRC. The aim of this trial is to collect all bamboo species within the country as well as exotic bamboos for planting at specific areas for further studies.

Research on Economic Bamboo Species

At least five species in each region will be taken up for study and research will be conducted in the following areas.

Ecology: Natural regeneration, flowering and seed setting.

Seed: Storage, seed pretreatment, seed sowing medium, germination, seedling growth and development, light and water requirements in relation to bamboo seedlings.

Vegetative propagation: Rooting media, rooting hormones, light intensity, watering, vegetative propagation via tissue culture.

Planting and tending: Spacing, weeding, watering and fertilizing.

Production and utilization: Harvesting methods, harvesting time, cost-benefit ratio analysis.

Studies on natural bamboo forests: Management on sustained yield basis, harvesting methods and timing, enrichment planting and natural regeneration.

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Bamboo Research in the Philippines

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Abstract

This paper presents a summary of important findings current research efforts and future research thrusts with reference to production and utilization aspects of bamboo in the Philippines.

Introduction

Bamboo is used in nearly every aspect of daily life. Its importance is better felt and understood in areas where it abounds or where timber and other traditional construction materials are not readily available or are extremely expensive. It supports many major industries such as housing and construction, handicraft and furniture, fishing, banana, food production and paper (Anonymous 1979). Bamboo has also been used for musical instruments, for ornamental purposes and as a landscape material. As a reforestation species, it helps control erosion and stabilize river banks. It also helps preserve the ecological balance of an area. Bamboo has become a popular material for these and other purposes because of its availability, workability and low cost. Unlike timber which requires a growing period of 20 years or more, bamboos can be harvested for use at the age of three years.

According to an inventory of bamboos by Sharma (1985), the Philippines has 55 species. Large tracts of bamboos occur in the northern provinces on marginal lands, courses of streams and rivers, village homelots and hillsides. Several climbing species of bamboos such as *Dinochloa* sp. form dense thickets in the forest in the southern regions. Bamboos occur over an area of 7924 ha which is 0.03 percent of the land area (Anonymous 1984 a,b). According to an estimate, there are 428 182 harvestable culms of bamboo, but this does not include the considerable number of bamboo on privately owned lands (Anonymous 1986).

Bamboo Production

Bamboo Distribution and Natural Habitat

According to Uchimura (1978), extensive bamboo forests are more or less confined to within

15-25° on either side of the equator. The Philippine Archipelago is located from 5 to 20° north of the equator and has climatic conditions favourable to the growth of bamboos.

Depending upon the species, bamboos grow on areas from sea level to as high as 2800-3200 m. They thrive best on well-drained sandy loam to clayey loam derived from river alluvium or from underlying rocks having a pH of about 5.0-6.5.

Regeneration, Cultural Management and Plantation Establishment

Generally, bamboos can be regenerated by asexual propagation using rhizome and culm cuttings. Layering and grafting can also be done. However, sexual propagation by seeds as studied by Caleda (1964), Lapis (1978) and Uchimura (1978) is also feasible although not quite practical due to the great length of flowering cycles.

Rhizome cuttings (Uchimura, 1978) are widely used in non-clump forming bamboos. The clump-forming type of bamboos are regenerated using cuttings. In the Philippines, quite a few investigations have been done in this area. Villamil (1915), Mabayag (1937), Cabanday (1957), Solarta (1959), Agleam (1960), Suzuki and Ordinario (1975), Uchimura (1978) and Palijon (1983) conducted studies on propagation by cuttings and layering of different bamboo species. The effects of growth regulators on the rooting and sprout development of bamboo cuttings were studied by Suzuki and Ordinario (1975), Bumarlong (1977), Uchimura (1978) and Palijon (1983). A project on bamboo propagation techniques was also undertaken jointly by the UPLB College of Forestry and the Tropical Agriculture Research Center of Japan, with the aim of obtaining information on various aspects of bamboo production and utilization.

Despite the presence of several privately

-owned bamboo plantations in the Philippines, not much research has been conducted in so far as plantation establishment is concerned.

However, quite a few studies have been carried out on the cultural management of bamboos in plantations. According to Chinte (1965), bamboo plantations can be established in logged-over areas having well-distributed rainfall throughout the year. Cleaning after planting is very essential for survival and development of a bamboo plantation. The annual yield of air-dry bamboo per ha of a three to four-year-old plantation was found to be 6000-6900 kg for *Bambusa vulgaris* and 660- 1070 kg for *Gigantochloa aspera*. Removal of spines and cutting of the culms close to the ground increased the number of shoots each year and reduced the percentage of shoot mortality (Ordinario, 1978). Decongestion of the clumps by removing high stumps from previous harvesting and cutting of deformed and over-mature culms resulted in higher culm production (Robillos, 1984).

Bamboo Utilization

Anatomical Properties

The first study on comparative vascular anatomy of five bamboo species, *Bambusa blumeana*, *B. vulgaris*, *Dendrocalamus merrillianus*, *Gigantochloa laevis*, and *Schizostachyum lumampao* was by Velasquez and Santos (1931). Grosser and Zamuco (1971) and Zamuco and Tongacan (1973) opined that bamboos could be identified and segregated based on the shape, size and arrangement of the vascular bundles. Quite a few investigations were done on bamboo fibre morphology. Milan (1957) reported that the average length of internode fibres in the three age classes of *B. vulgaris* was 2.33 mm compared to 1.20 mm in the node and 0.45 mm in the septa. In the study conducted by Tamolang *et al.* (1957), the fibre length of 13 species ranged from 1.36 to 3.78 mm. Zamuco (1972) reported that the length and percentage composition of fibres varied in the horizontal and vertical directions within the internodes as well as from the base, middle to top portions of the culm. Using these findings, bamboo could be apportioned to obtain maximum utilization. Espiloy (1983) showed that fibre length in *B. blumeana* increased from internode 2 of the butt portion to internode 18, after which it decreased. With increasing distance from the butt, there was a slight decrease in mean fibre diameter and mean cell wall thickness.

Chemical Properties

Monsalud and Nicolas (1958) found that bam-

boos contain more ash, silica and pentosans than woods. Semana *et al.* (1967) found that the Philippine bamboos had higher ash and silica content than those of Asian bamboos, but lower lignin content than the Indian species. The silica content increases in a linear fashion from internode 2 of the butt portion (1.6%) to internode 30 (9.9%) in *B. blumeana* (Espiloy, 1983). Shoots of three age levels (7, 10 and 15 days after emergence) of different bamboo species were chemically analyzed by Gonzales and Apostol (1978) for nutrient components. Results showed that the age level had no relation to the nutrient contents of the shoots which were largely similar,

Physical and Mechanical Properties

According to Espinosa (1930), a piece of *B. blumeana* about 30 cm in circumference when loaded at the centre on a span of 1.5 m can support 500 kg and when used as a post or column about 1.2 m high can support 4000 kg. The variability of specific gravity among clumps, among culms and along the culm length of *B. blumeana* was studied by Espiloy (1983). Variations among culms within clumps and internode were found to be significant. Specific gravity increased from internode 2 to 14 and then remained more or less constant up to internode 30.

The mechanical properties of six species, namely, *B. blumeana*, *B. vulgaris*, *D. merrillianus*, *G. aspera*, *G. laevis* and *S. lumampao* have been studied so far at the FPRDI as reported by Siopongco and Munandar (1987). Results of these studies (Espiloy & Sasondoncillo, 1976, 1978; Espiloy *et al.*, 1979; Espiloy & Robillos, 1985) showed a general increase in strength properties towards the top portion of the culm. This trend could be attributed to the corresponding increase in specific gravity and fibrovascular bundle frequency (Espiloy *et al.*, 1986).

Durability, Seasoning and Preservation

Bamboos are very susceptible to attack by decay fungi such as the soft rot, brown rot and white rot (Liese, 1970) and powder post beetles, particularly *Dinoderus minutus* Fabr. (Casin & Mosteiro, 1970). Observations have indicated that the starch in bamboo contributes to its susceptibility to attack by beetles (Liese, 1970). Under ordinary conditions, the natural service life of bamboo when used in contact with soil is one to three years and four to seven years when used indoors (Casin & Mosteiro, 1970). Materials exposed to fumes in kitchens in rural homes have a service life extending from 10 to 15 years. Under marine-water conditions, bamboo has been reported to have a life

expectancy of only six months. A study by de-Guzman (1978) tentatively classified the resistance of some bamboo species to fungal attack based on percentage weight loss of the specimens after a four month exposure. In a study conducted by Villalflor (1988) regarding construction and evaluation of bamboo houses for demonstration purposes, the sidings made from *B. vulgaris* deteriorated in six months whereas those made from *B. blumeana* and *G. levis* are still in good condition.

In the processing of bamboo for any use, drying is necessary. Bamboo culms, according to Casin and Mosteiro (1970), can be thoroughly dried in a dry, well-ventilated shed in about two to four months, while kiln drying of bamboo takes about nine days. Prior to machining, processing and finishing, the bamboo should be dried to turn out products that are durable, stable and of high quality (Anonymous 1984).

Factors that improve the durability of bamboos include non-chemical (curing, smoking, white-washing and soaking) and chemical methods (non-pressure by fumigation, brushing and spraying, butt treatment, green-tank method, Boucherie method and the pressure method) (Casin & Mosteiro, 1970). As reported by Garcia and Tesoro (1979), dipping of *B. vulgaris* in various solutions of water-soluble preservatives (CCA, FCAP-type A and Tanalith-C) each at a single test concentration of six percent and soaking in fresh running water for varying durations (1 day and 1,2,3,4 and 8 weeks) were equally effective and provided significant protection against powder-post beetles. Preservative treatment of green bamboo culms with zinc chloride, CCA, copper sulphate, boric acid and borax applied by the Boucherie process and its various modifications as well as soaking and spraying had been investigated by Laxamana (1966). As reported by Pangga (1937), coal tar, crude table salt and Paris green were used as preservatives for treating *B. blumeana* posts against subterranean termites.

Spray treatment of split or whole sections of bamboo with five percent DDT or BHC in kerosene was also effective against powder-post beetle infestation. This prophylactic treatment to newly-felled bamboo provides temporary protection and is particularly useful in the forest while the bamboo is awaiting transportation.

Bamboo as a Concrete Reinforcement

Purugganan *et al.* (1959) found that bamboo reinforcement in concrete beams considerably increased the load-carrying capacity of members over that of members without reinforcement. Concrete members reinforced with well-dried bamboo

splints treated with a thin coat of asphalt emulsion withstood loads better than members with untreated splints.

Bamboo Parquet

FPRDI has developed a bamboo parquet block which was granted Utility Model Patent No. 386 by the Philippine Patent Office. *D. merrillianus*, *B. blumeana* and *G. aspera* have been found suitable for the manufacture of parquet flooring material (Jaranilla & Laroya, 1966).

Laminated Bamboo

Laminated bamboo sheets, panels, boards, flitch and other forms of construction material for structural and decorative parts of houses, boats and furniture have been developed by FPRDI and were granted Utility Model Patent No. 43 by the Philippine Patent Office.

Bamboo Strips for Aircraft

A study was conducted by de-Leon (1956) using bamboo-woven mat glued to wood or laminated to another bamboo mat for use as stress-skin covering for light aircraft. Its fatigue strength under bending stress was found to be much higher than that of wood, and the bond strength of bamboo to bamboo was comparable to that between bamboo and wood.

Pulp and Paper

In the early 1960s, quality unbleached kraft paper was manufactured by the Bataan Pulp and Paper Mills Inc. with bamboo as the principal raw material. This marked the first time that paper was manufactured out of bamboo in the Philippines. However, the mill stopped using bamboo because of inadequate supply and the silica problem. However, in the following years, FPRDI researchers (Nicolas & Navarro, 1964; Escolano *et al.*, 1964, 1972; Gonzales & Escolano, 1965; Monsalud *et al.*, 1965; Semana 1965; Semana *et al.*, 1967; Bawagan, 1968) Escolano & Semana 1970 have shown the suitability of some Philippine bamboos such as *Bambusa at-undinacea*, *B. blumeana*, *B. multiplex*, *B. tulda*, *B. vulgaris*, *B. vulgaris var. striata*, *Dendrocalamus merrillianus*, *Gigantochloa aspera*, *G. laevis*, *Phyllosrachys nigra*, *Schizostachyum diffusum* and *S. lima* for pulp and paper manufacture.

Bamboo-craft and Furniture

Ella *et al.* (1982) have produced exquisite novelty products. The bamboo strips were dyed, woven and glued to fashion out barrettes of intricate designs such as rings and brooches of various pat-

terns, for example, bumble bee, butterfly, fish and flower. Tongacan et al. (1987) reported that novelty products like ash trays, jewellery boxes, etc. can be made from bamboo stumps and rhizomes. Studies on some basic characteristics and working properties of bamboo for furniture (Eala et al., 1987) and development of techniques for flattening of bamboo for furniture components (Laxamana & Tavita, 1987) were conducted at FPRDI. In conjunction with the government thrust to accelerate countryside development, FPRDI conducted non-formal short-course training on bamboo handicraft wherein the basic fundamentals in weaving bamboo crafts, namely, bamboo placemats, lampshades, fans and baskets, were taught.

There is an intensive information dissemination campaign and technical assistance rendered by FPRDI to bamboo furniture manufacturers in the areas of production technology, design, quality and marketing aspects (Garcia, 1986; Robillos, 1986).

Current Research on Bamboo

Bamboo is classified as a top priority research commodity by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) which sets the national research priorities in the Philippines. To date, there are a total of 25 on-going research studies, 19 of which deal with bamboo production and six with bamboo utilization (Table 1). The different researches are being carried out by the Ecosystems Research and Development Bureau (ERDB), the Forest Products Research and Development Institute, the College of Forestry and Institute of Plant Breeding of the University of the Philippines at Los Banos (UPLB). The researches on bamboo at UPLB-College of Forestry have been taken over by ERDB.

Research Thrusts and Recommendations

Bamboos are the fastest-growing and highest-yielding renewable natural resource and if managed on the sustained-yield basis, can be an inexhaustible source of goods and services. Unfortunately, the extent of harvesting is more than what the bamboo forest resource can produce. As a result, reproduction cannot keep up with exploita-

tion. A bamboo forest can be restored and made productive if exploitation is controlled and combined with natural and artificial regeneration.

An assessment of past researches on bamboo reveals that there are still gaps in the production and utilization aspects that need further investigation. There is also insufficient information on the actual extent and distribution of the different species of bamboos in the Philippines. Thorough and satisfactory taxonomic and phenology studies of the Philippine bamboos are needed. Propagation techniques have been developed for a few species only. No attempt has, thus far, been made on the genetic improvement of the various species with respect to rate of growth and resistance to pests and diseases. Factors affecting growth and development such as spacing, site preparation and fertilization are suggested for further study using other bamboo species.

Generation of information on utilization has been confined to very few species. The lesser-used or untapped species need to be studied intensively to develop them as possible substitutes for the commonly-used species. Product development and improved utilization should be pursued. Better uses of the tremendous waste incurred in the harvesting and processing of bamboos should be considered for energy generation and biofertilizer production. The lesser-used species need to be examined for their structural, chemical, physical and mechanical properties. Studies on economics and on available preservatives should be made with emphasis on suitability and environmental safety. Studies on the use of bamboo in housing and construction including jointing methods, design criteria and construction systems should be vigorously pursued.

Furthermore, through a systematic dissemination and promotion campaign, the results of research and development activities should reach the end-users. This could be done through various means such as the print and broadcast media, technical manpower development, technical assistance, industry linkages and cooperative projects with media-related organizations, and educational, research and development institutions. The ultimate aim of this mode of technology transfer is at reaching the widest audience and the largest number of end-users and consequently, having them adopt the technologies developed.

Table 1. List of on-going research on Philippine bamboo (as of 1988)

Title	Implementing agency
<u>Bamboo uroduc tion</u>	
1. Establishment of bambusetum and palmetum at ERDB Central Experiment Station	ERDB
2. Clump development, yield and economic rotation of selected commercial bamboo species in newly-established plantation as affected by cultural operations	ERDB
3. Rhizome and clump development and production of planting stocks from rhizome and branches of selected bamboo species	ERDB
4. Bamboo expansion programme	ERDB
5. Evaluation of different technology transfer schemes in disseminating bamboo production technologies in regions 5 & 6	DENR
6. Optimum cutting intensity and cutting interval of bamboo	DENR
7. Verification of propagation techniques and plantation establishment of bamboo in Talakag, Cosina, Bukidnon	DENR
8. Tissue culture of bamboo	UPLB-IPB
9. UNDP-FAO bamboo research and development programme	
a. Specimen collection, classification and identification of the different bamboo species in the Philippines	
b. Determination of chlorophyll distribution of selected bamboo species in immature culms and its components	
c. Studies on the role of culm sheath in culm development of selected bamboo species	
d. Microflora associated with rhizosphere of bamboo species	
e. Isolation and identification of different diseases of bamboo in the Philippines	
f. Screening of different culture media for callus initiation and differentiation of bamboos	
g. Site characterization for bamboo plantation establishment	
h. NPK requirements of some bamboo species Phase I. Nursery experiment under Los Banos condition	
i. Influence of hormone concentrations and sources on the survival and growth of culm cutting of some bamboo species in different soil media	
j. Bamboo growth and development as affected by types of planting stocks and methods of planting	
k. Bamboo utilization and documentation	ERDB
<u>Bamboo utilization</u>	
1. Relative susceptibility of bamboos and palms to powder-post beetles and termites	FPRDI
2. Physico-mechanical, chemical and anatomical structure relationship of Philippine bamboos and palms	FPRDI
3. Finishing techniques for local species of bamboo	FPRDI
4. Preservative treatment of bamboos for banana props	FPRDI
5. Service tests on treated poles and composite railway ties, bamboos for fishpens, and thinnings and branches for vegetable props	FPRDI
6. Design and development of improved roof trusses from bamboo, coconut wood and wood	FPRDI

ERDB (formerly FORI), Ecosystems Research and Development Bureau; FPRDI, Forest Products Research and Development Institute; DENR, Department of Environment and Natural Resources; UPLB-IPB, University of the Philippines at Los Banos-Institute of Plant Breeding,

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Bamboo Resource in the East African Region

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Abstract

The high rate of increase in human population in the East African countries and accompanied migrations have resulted in increasingly greater pressure being exerted than ever before on natural resources. Among the local renewable resources, bamboo is an important though undeveloped plant material with a high potential for increased productivity. It is also amenable to general management and integration into farming systems as a multipurpose resource species. In comparison with the continent of Asia, Africa has a small bamboo cover. The continent has only 1.5 million hectares which is predominantly distributed in the eastern part. The total world cover is 14 million hectares of which 80 percent occurs in tropical and subtropical Asia. Of the estimated total of 1250 bamboo species in 75 genera, only 43 species in 14 genera are found in Africa. Forty of these are distributed predominantly in Madagascar; the other three being East African mainland species. The information available on the utilization of these species and the attempts made on their-management are reviewed. Research aimed at developing mission-oriented as well as integrated management strategies are proposed and the potential for expansion of local and exotic bamboo germplasm is discussed.

Introduction

Bamboos occur in the natural vegetation of the tropical, subtropical and temperate regions, but are found in great abundance in tropical Asia. While bamboo taxonomy is still incomplete, it has been recorded that 75 genera and 1250 species occur in the world (Sharma, 1980, 1987). Only 14 genera and 43 species occur in Africa, all of which are mainly distributed in the East African region. The East African bamboo cover (and therefore African cover) totals about 1.5 million hectares compared to the world cover of 14 million ha (Sharma, 1980; Jiping, 1987; Kigomo, 1988). Eighty percent of the world bamboo resource is distributed mainly in the South Asian tropical region. Africa and South America are thus poorly endowed with bamboo resources while there is total absence of the resource in the Union of Soviet Socialist Republics (USSR), North America, Central and South Australia and the regions near the poles.

Although diversified skills in the use of bamboo are not as developed as in Asia, bamboo is among the most important grasses to the rural people of the East African region. The goods and services from

bamboo cater to the needs of both village and large scale national farming development. These also contribute and assist in providing employment, basic human needs such as food, construction material for shelter and other consumer goods. Apart from providing and diversifying employment opportunities and allowing better income distribution through its wide uses, bamboo plays a crucial role in protecting environmental degradation especially in combating soil erosion in the steep East African highlands, in landscaping, as windbreaks and hedges and in reforestation programmes.

There is already pressure on the existing cover of East African bamboo and a need, therefore, to protect and manage properly the remaining scattered bamboo resource. With the ever-increasing human population in this region, the principal problem is of maintaining and managing natural resources both for present and future needs. To be able to achieve this, generation of information on the proper management of this resource is a prerequisite. Also expansion of the bamboo resource through cultivation of local and exotic materials will be essential for meeting the needs of the future.

Distribution of Indigenous Bamboos of Eastern Africa

There has been no proper inventory of bamboo resources in Africa. While 43 species have been documented as being native to eastern Africa, several species under the genera *Arundinaria*, *Oreobambos* and *Oxytenanthera* have been described as occurring more widely (Fig. 1). The rest of the 40 species under 11 genera occur principally in Madagascar. Important genera include *Cephalostachyum*, *Decaryochloa*, *Hickella*, *Hitchcockella*, *Nastus*, *Perrier bambus*, *Pseudocoix* and *Schizostachyum* (Anonymous 1985).

Distribution of patches of bamboo in eastern Africa occurs from the temperate highland forest zone of Ethiopia and upper reaches of the Nile river in the north, to the Basutoland highlands, Natal and Madagascar in the south. In contrast with the formation of bamboos in Asia, the East African species form vast pure stands of single species or are in association with other trees as an understorey. The distribution and characteristics of the better documented bamboo species and genera are outlined below.

Arundinaria alpina K. Schum

This is distributed between 2290 and 3360 m

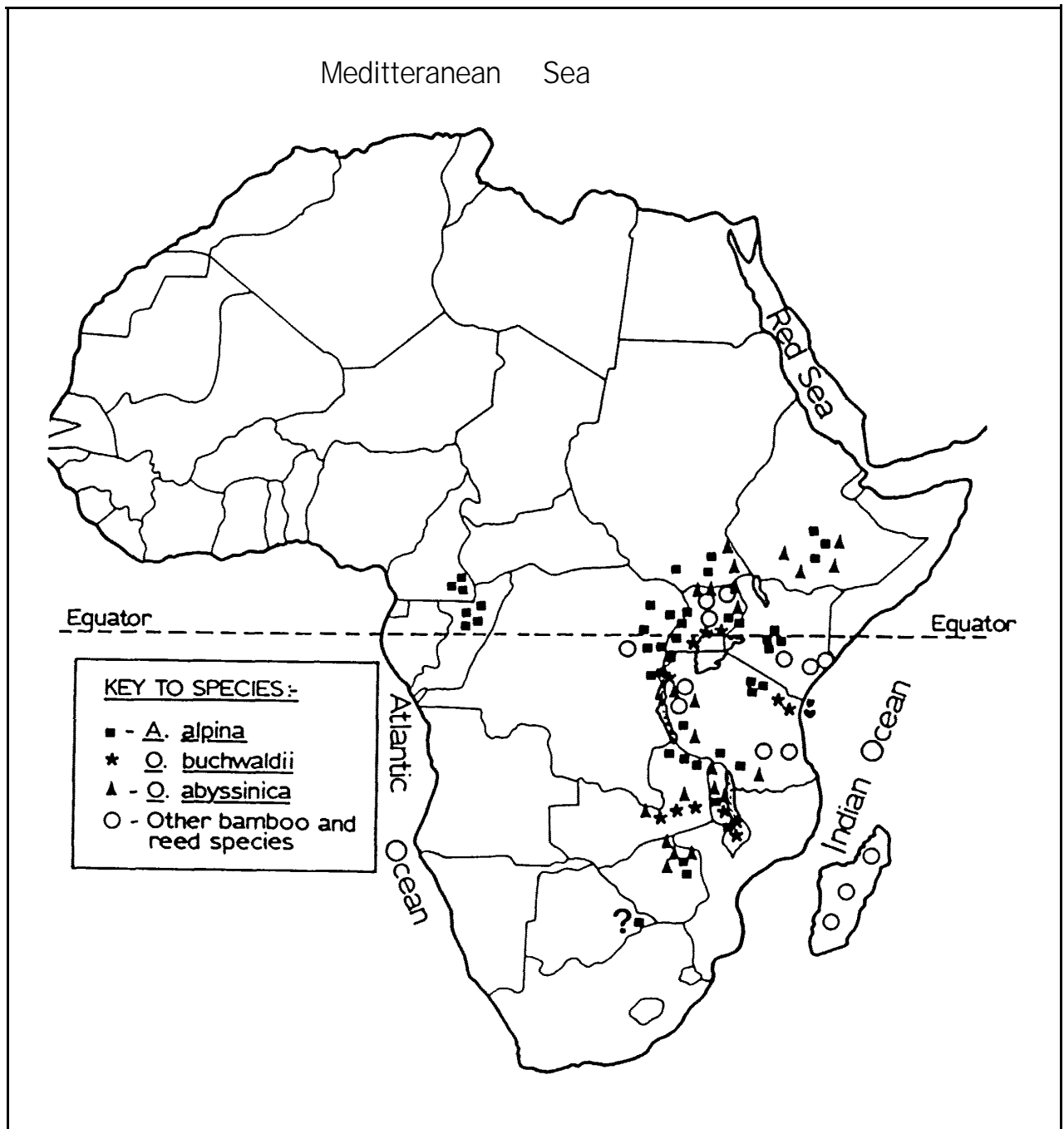


Fig. 1. Distribution of bamboo species in East Africa (in mainland Africa, 0- includes distribution of reed species.)

above sea level. It occurs gregariously (not in clumps) within mountain forests in tropical Africa (Wimbush, 1945; Dale & Greenway, 1961). This species is found growing in the highlands of Ethiopia, Southern Sudan, Congo, Zaire, Rwanda, Uganda, Kenya, Tanzania and Zambia. A species of *Arundinaria* was collected as far south as Cape Province, Natal but this was not confirmed as *A. alpina* (Phillips, 1926). Sterile specimens resembling *A. alpina* have been collected in Malawi (Clayton, 1970). The occurrence of *A. alpina* in Malawi has, however, been confirmed by Chapman and White (1970) who noted its growth in scattered clumps in broad-leaved montane forest formations. Clayton (1970) has also recorded the occurrence of *A. alpina* in Cameroun suggesting this to be its most westerly natural occurrence.

In Ethiopia, *A. alpina* occurs in the highlands (Mooney, 1963). In Kenya, this is the only indigenous bamboo species and occurs in irregular patches in the central highlands, particularly in Timboroa plateau (31,000 ha), Aberdare range (65,000 ha) and in Mount Kenya, Elgon, and Mau range (51,000 ha). The total cover area of *A. alpina* in Kenya is about 150,000 hectares. In Uganda, this species grows in Ruwenzori, western Elgon, and Mounts Virunga and Mgahinga (Eggerling, 1947; Clayton, 1970). In Tanzania, it grows in Mbulu, Arusha and Mbeya districts on the highlands of Iringa, Lukwangule and Ulugurus, and Mount Meru (Brenan & Greenway, 1949; Clayton, 1970). It is interesting that this bamboo species does not occur on Africa's highest mountain, Kilimanjaro (Wimbush, 1945) and yet is abundant on Mount Meru, only 48 km away.

***Oxytenanthera abyssinica* (A. Rich) Munro**

This is a medium-sized bamboo (8-16 m in height), widely distributed in eastern Africa. The young culms are usually semi-solid whereas the older culms are almost completely solid. It occurs in open areas in forests and often by rivers at altitudes between 1100 and 2100 m. The species has not been recorded in Kenya (Dale & Greenway, 1961; Kigomo & Kamiri, 1985) but occurs in other East African countries from Ethiopia in the north (Mooney, 1963) to Malawi, Zambia and Zimbabwe in the south (Williamson, 1974).

In Burundi, the species occurs around Bunjumbura and Lake Mossor regions at about 1600 m and 1400 m, respectively. In Ethiopia, its occurrence is on the hillside and savanna woodlands. It is the most hardy of the three commonly occurring East African bamboo species. In Tanzania, the species is found on poor soils and in dry forest formations. *O. abyssinica* has a wider distribution in Lindi,

Kigoma and Usaramo regions. Occurrence in Uganda is mainly in western Nile, Acholi, Karamoja and Mount Elgon regions.

In Malawi, Zambia and Zimbabwe, *O. abyssinica* is common at the medium altitude in semi-deciduous dry forest formation. In Malawi, however, the species extends into more forested areas especially on hillsides more exposed to the sun. *O. borzii* Matter, a smaller and less extensive species, grows in Ethiopia (Mooney, 1963).

***Oreobambos buchwaldii* K. Schum**

With the exception of Kenya, *Oreobambos buchwaldii* is indigenous to East Africa and occurs mainly between 300 and 1930 m. The green hollow culm of the species which may reach 18 m in height is weak and poorly erect (Clayton, 1970). In Burundi, the species occurs in a patch along river Kitima in Bubanza region. In Malawi and Zambia, it occurs widely between 400 and 1950 m. It is more common in open areas along rivers in the forest patches of the shire highlands in Malawi.

In Tanzania, *Oreobambos* occurs between 450 and 1000 m in solitary clumps, and in more open parts of the evergreen forests of the East Usambaras and Tukuyu highlands. Some clumps are reported to occur scattered in Ifakara vegetation at 300 m. The growth of the species in Uganda is less vigorous and the maximum height attained is about 12 m. Clumps are reported to occur in forest swamps around Mengo, Masaka, Bunyoro and scantily in Busonga forest districts.

Other Important Species

In addition to the three species described above, there are 40 less vigorous bamboo species distributed predominantly in Madagascar. Other tall grass (Gramineae) species of some economic importance in eastern Africa include the 'mauritanian reed' which is mainly represented by *Phragmites mauritianus* Kunth. Culms of this species grow to 9 m in height. This species is widely distributed within the dry and warm regions of East Africa especially on lakes and river shores. *Phragmites* produces erect culms with short internodes. Another common tall grass is the 'common reed', *Phragmites communis* Trin. (Edward & Bogdan, 1951; Bogdan, 1958). This species also grows along rivers in the drier areas of Kenya, Tanzania and Uganda (Clayton, 1970).

Utilization and Importance of Bamboo

Local Domestic Uses

Fencing

The uses of indigenous bamboo have been main-

ly confined to local needs. As a result, nowhere has specialization reached the Oriental scale. The main uses of bamboo are for fencing of homesteads and farms. *The large size of culms of O. buchwaldii* and also of *A. alpina* allow their use in fencing for protection against pigs and other animals.

Construction

Split and whole culms are widely used in the construction of residential houses, huts and farm granaries. Large bamboo culms are most suitable but in drier climatic regions, reed grasses, mainly the 'common' and 'mauritanus' reeds are used in building walls of huts, roofing, fish traps and fences.

Handicraft

Split culms of bamboo and reed are used in the production of handicraft articles such as mats and various utility baskets. In East Africa, tea picking baskets are predominantly made of split bamboo.

Water harvesting

In some drier regions, split bamboos have been used in the harvesting of rain water from house-roofs. In Tanzania, *A. alpina* has been used extensively as water pipes (Lipangile, 1984). About 100,000 people scattered in 28 villages were being supplied with water through a network of 150 km of bamboo pipelines by 1985. More people are expected to be covered by the project.

Pulp and paper

In contrast with the Asian bamboo resource, the African bamboo has not been exploited in the manufacture of pulp and paper. The average cellulose content of air-dry bamboo of *A. alpina* is 47.5 percent (Wimbush, 1945). Pulp manufactured from it gives a high class paper.

Food and foliage

Young shoots and grains of *O. abyssinica* are eaten as food in Tanzania and by the Acholi of Uganda particularly during famine times. The grain is cooked in the same way as rice and is said to taste much like it. While mature foliage of reed species are unpalatable, regrowth following cutting is of fairly good nutritive value to livestock. Leaves and small branchlets of *A. alpina* are edible and are also of nutritive value (Ayre-Smith, 1963).

Brewing

In Ubena, Songea and Usangara areas of Iringa province of Tanzania, *O. abyssinica* is cultivated by the Wakinga, Wahehe, Wapegwa and Walpera for the production of bamboo wine. Tips of young shoots are cut off and the stem portion bruised

every morning and evening for about a week. The exudate is collected and allowed to stand for two days to ferment. The fermented liquid can be kept for up to two weeks.

Medicinal

Roots of reed species are reported to be used as medicine for treating various maladies (Brenan & Greenway, 1949).

Utilization problems

Utilization of local bamboo, especially *A. alpina*, is limited by borer beetles, particularly *Dinoderus minutus* (Peake, 1948). Although use of chemicals for treatment of bamboo against insect attacks has been recommended, it is noted that soaking split bamboo in plain water for two or more months is the best method; a treatment discovered from the fact that bamboo used for rafts is immune to insect attack. The greatest handicap to the diversified utilization of the local bamboo resource however, is the lack of traditional skills.

Water and soil conservation role

Bamboo cover in the East African region occurs on the rugged highlands, escarpments and mountains. These are also the main water catchment areas and are prone to soil erosion if not properly covered. Bamboo cover on these lands is, therefore, of paramount importance in conservation.

The role of A. alpina in the conservation of watershed areas has been investigated against exotic softwoods by Pereira (1952). A bamboo crop of more than three years will intercept more moisture and consume less water than a cypress crop of about the same age. This suggests that natural bamboo cover remains superior in the conservation of catchment areas.

Current Management of Bamboo in East Africa

Indigenous Bamboo

Exploitation of indigenous stands of bamboo is not controlled by a management order. Selection cutting of the best culms is the common form of harvesting. A short-term investigation on *A. alpina* with the objective of finding factors influencing production of new culms was undertaken by Wimbush (1945). He noted that an undisturbed bamboo crop of this species has about 10,000 to 17,000 culms per hectare and can produce about 100 tonnes air-dry weight of culms.

Production of new culms is influenced by the amount of rainfall occurring during the previous one or two years. Abnormal drought may result in

Table 1. Bamboo species introduced in arboreta and botanic gardens in East Africa

Bamboo species	Trial site	Source of germplasm	Remarks
<i>Arundinaria alpina</i>	Muguga	Indigenous	2000 m asl, medium size
<i>A. falcata</i>	Entebbe	India	Small
<i>A. fortunei</i>	Entebbe		Small
<i>Bambusa vulgaris</i>	Muguga, Entebbe Amani and Zomba	Ornamental Asian bamboo	Big-yellow/ green stems
<i>B. multiplex</i>	Amani and Zomba	India and China	Small
<i>B. nana</i>	Entebbe	Burma	Very small
<i>B. nutans</i> Well.ex	Amani	India	Small to medium
<i>B. bambos</i>	Amani	Thailand	Big
<i>Chimonobambusa hookeriana</i>	Amani	India	Small
<i>Dendrocalamus giganteus</i>	Entebbe, Amani (but died after flowering), Zanzibar.	Burma	'Giant bamboo'. Much smaller in Entebbe
<i>D. strictus</i>	Amani and Entebbe	India and Burma	Medium to large. Drought tolerant
<i>Gigantochloa aspera</i>	Amani	Java	Big
<i>G. utter</i>	Amani	Tropical Asia	Big
<i>Melocalamus compactiflorus</i>	Entebbe	Burma	Medium
<i>Oxytenanthera abyssinica</i>	Muguga	Zimbabwe	Medium
<i>Phyllosrachys aurea</i>	Entebbe, Amani	China and Japan	Medium, 'yellow stemmed bamboo'
<i>P. henonis</i>	Entebbe	China	Small
<i>P. kumasaka</i>	Entebbe	China	Very small
<i>P. nigra</i>	Zanzibar	China and Pemba	Medium Japan
<i>P. bambusoides</i> Sieb	Amani	China	Small to medium
<i>P. sulphurea</i>	Entebbe	China	Small
<i>Phragmites mauritianus</i>	Amani	Indigenous	Small to medium
<i>Shibatea kumasasa</i>	Amani	Japan	'Dwarf bamboo'
<i>Thysanolaena maxima</i>	Amani	Tropical and subtropical Asia	'Tiger grass', Small
<i>T. agrostis</i>	Entebbe	Subtropical Asia	Small

Amani Arboretum - in North Tanzania; Entebbe Botanic Gardens - in South Uganda; Muguga Arboretum - in Central Kenya; Zomba Arboretum - in Malawi. (Source - personal observations; Dale, 1954; Williams, 1974; Williamson, 1974).

only sparse production. Clear-cutting depressed the rate of recovery of bamboo after cutting. It took eight or nine years to obtain full-sized culms after clear-cutting. When 10 percent of old culms are left standing evenly distributed, full-sized new culms may appear in the seventh or eighth growing season following cutting. If 50 percent of the number of culms are left standing, evenly distributed, the recovery period may be as short as three or four years. The cutting cycle is governed by rainfall, cutting intensity and, therefore, recovery period.

For *A. alpina*, it is seen that the cutting cycle is 14 years and may be as long as 21 years on poor sites where recovery to the normal full size is delayed. Fires also lengthen the recovery period of regenerating shoots of *A. alpina* (Phillips, 1961). Regenerating shoots are small, more per hectare and are also more variable. This will mean a longer cutting cycle for a crop that has gone through a fire.

There does not seem to be any management work undertaken on the other two common East African species, *O. buchwaldii* and *O. abyssinica*.

Eggerling and Dale (1951) reported that flowering in *O. abyssinica* occurs in large areas about once every seven years. After flowering the clumps die and new shoots appear after a year. Observations by Williamson (1974) in Malawi, however, indicated that flowering took place sporadically or in a gregarious manner after which the plants died. The lack of proper information on the biological and regeneration dynamics of local bamboo species in natural conditions limits proper management of the resource on a sustained yield basis.

Introduction of Exotic Bamboos

As a result of lack of serious interest in bamboo in the past, East African foresters and farmers have been slow in promoting indigenous bamboo and wherever necessary, in introducing exotic ones.

Table 1 summarizes information on Asiatic (Oriental) bamboo species that have been introduced in the East African arboreta and botanic gardens (Williams, 1949; Dale, 1954; Williamson, 1974). Few sources of germplasm introduced in 1930s and 1940s have been used in the expansion and establishment of various other trials in arboreta. Sources of seed and propagation materials and methods of establishment have not been properly documented.

Only two species, *O. abyssinica* (Zimbabwe source) and *B. vulgaris* (Indian source via Entebbe botanic gardens) have been introduced in Kenya. More species have been introduced in Uganda and Tanzania and these are doing well although many of them attain a smaller size when compared with their growth in native sites.

Overview and Recommendations

With the ever-increasing human population in the East African countries, the bamboo resource will inevitably continue to be under pressure. Bamboo is a valuable raw material with many excellent properties. But goods and services from the bamboo resource will not be sustainable unless several technical problems are addressed to and appropriate technologies developed to pave way for resource availability to all, both now and in the future.

Among the several needs is the development of an information base to enable efficient silvicultural interventions and utilization. This can be achieved through a strong research and development programme on bamboo. Such a programme should urgently address:

- 1 Problems of management of indigenous bamboo species and stands for developing suitable

- and sustainable cutting programmes;
- 2 Introduction of suitable and more versatile exotic bamboo species in different ecological zones, also with a view of diversifying materials;
- 3 Research on identifying suitable propagation materials and appropriate establishment techniques for different materials and sites;
- 4 Research on suitable silvicultural interventions and sustainable cutting techniques of cultivated species at different sites of introduction;
- 5 Appropriate transfer of technology through training in utilization skills for diversification of production obtainable from bamboo; and
- 6 Need for short-term socio-economic and ecological studies aimed at monitoring, evaluating and re-directing the needs and checks on intensive cultivation of the selected bamboo species in different farming systems.

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BAMBOO RESOURCES

Genetic Wealth of Bamboos in India and their Conservation Strategies

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Abstract

There is an urgent need for collecting the available variability in bamboo along major environmental gradients. Conservation of bamboo is possible by both in situ and ex situ methods. Ex situ conservation of bamboo can be done through seed banks, clone banks, bamboo gardens or in vitro culture techniques. Research on genetic diversity needs to be carried out on distribution, provenances, genecology, reproductive biology and breeding systems. Basic studies on the sampling method for ex situ conservation, determination of location and size of conservation plots in terms of both area and population size are needed to obtain viable self-sustaining gene pools. A long-term strategy to develop bamboo gardens should be adopted for conservation purposes in which stands must represent different ecotypes and gene combinations without regard to commercial applications. National bamboo reserves in different countries should be established. The existing indigenous collections available in the arbor-uta are few and need to be strengthened through exploration and introductions. Regional bamboo gardens should be established and exchange of germplasm encouraged. In vitro gene banks should be established for bamboo conservation and for facilitating exchange of materials. The available genetic diversity should be properly documented and conserved.

Introduction

Cultivation and utilization of bamboo are linked with mankind ever since the beginning of civilization. Because of its use as a long fibre raw material in the pulp and paper industry, bamboo has achieved the status of a versatile industrial material. In addition to its increasing demand in the paper, pulp, food and cottage industries, its high calorific value of 4600 to 5400 k. cal/kg makes it a good source of energy.

Bamboos are distributed both in the hills and plains in the tropical as well as sub-tropical regions of South and South-east Asia. Over 75 genera and 1250 species of bamboos are reported to occur in the world (Sharma, 1987). About 130 species belonging to 24 genera of bamboos have been reported from India (Sharma, 1987). Out of these, 20 are indigenous and four are of exotic origin.

Diversity in India

India is the second richest country in bamboo

genetic resources after China. These countries together hold more than half the total bamboo wealth distributed all over the world.

In India, the tropical moist-deciduous forests of the north and the south and the deciduous and semi-evergreen regions of North-east India are regions of bamboo diversity. Over 58 species of bamboo belonging to 10 genera are distributed in the North-eastern States alone.

Bamboo generally forms an understorey in the natural forests. These are distributed in the States of Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, hills of Uttar Pradesh and West Bengal. These also occur in the Andaman and Nicobar islands, Orissa, the Western and Eastern Ghats. Very few species occur in the North-western Himalayas.

Need for Collection

With increased population pressure, natural

stands of bamboo are being indiscriminately cut for fuel, wood and furniture, and for obtaining cultivable lands. The common practice of jhum cultivation in the North-eastern States has resulted in genetic erosion of several bamboo species. Over-exploitation of some species has also endangered some valuable germplasm collections. Efforts have been initiated by the National Bureau of Plant Genetic Resources, New Delhi and its stations in Trichur, Shillong and Ranchi, as well as the ICAR research complex for hill region (Arunachal Pradesh Centre) under the Indian Council for Agricultural Research (ICAR) to collect and build up genetic diversity of bamboo for evaluation and maintenance. Germplasm collections are being established for genetic evaluation at the New Delhi, Trichur and Ranchi centres.

Bamboo plants vary greatly in height, morphological characters, flowering and reproductive behaviour. The plants vary from very small to tall giant types. Though bamboos are in general less susceptible to diseases and pests, the germplasm will be evaluated for some pests and diseases which commonly attack bamboo plantations. The germplasm will also be evaluated for a minimum set of descriptors and information will be documented for utilization of promising types in the bamboo improvement programme of the country.

Conservation of Bamboo Germplasm

One of the most serious factors contributing to the destruction of bamboo wealth is shifting cultivation. This has resulted in the elimination of some of the valuable germplasm from natural habitats. Secondly, over-exploitation of some species for fuelwood and in the cottage industry has endangered others. Since natural variation is the basic genetic material required for selection and improvement, conservation of available genetic diversity needs to be accorded the highest priority.

Strategies for Conservation

In Situ Conservation

Conservation of wild bamboo species in natural ecosystems needs to be done. This method helps in the preserving of interspecific and intraspecific genetic variability. The conservation of provenances in natural habitats is the best gene conservation method provided full protection is given. The major limitation of in situ conservation is that natural stands of bamboo are scattered in pockets over large areas and it is difficult to declare several bamboo reserves. However, in places

where large areas of natural bamboo reserves occur together, National Bamboo Reserves can be declared.

Ex Situ Conservation

Seed banks

Ex situ conservation through seeds is the easiest and cheapest method. However, bamboo seeds remain viable for short periods. While the initial viability is good, the seeds rapidly lose germination vigour. The life span of bamboo seeds varies from species to species and is reported to be 30 to 35 days for *Bambusa tulda*, 55 days for *Dendrocalamus longispathus* and 65 days for *B. arundinacea* var. *spinosa*. Seed viability of *B. tulda* stored in a desiccator over silica gel can be increased to 18 months (Banik, 1987). By storage of seeds under suitable temperature and moisture, the longevity of *Dendrocalamus strictus* seeds could be extended up to 34 months (Gupta & Sood, 1978).

Bamboos are known for their irregular flowering. Whereas some species are annuals, most are perennial or flower once in a life-time. The availability of seeds and their supply is thus uncertain and irregular. Moreover, regeneration of bamboo plants from seeds will not produce true to type plants.

Clone banks

Bamboo plantations can be raised by rooted cuttings and suckers through vegetative methods. The advantages of using clonal germplasm raised from cuttings or clumps for conservation are substantial. Such clonal banks of bamboo germplasm will be useful in genetic conservation.

Bamboo gardens

Bamboo gardens can be established in different regions for conservation. The replicated germplasm lines of bamboo of known origin from different provenances can be used for basic and applied research work and will also provide material for germplasm exchange.

In vitro conservation

Considering the limitations of seed and vegetative methods of ex situ conservation, tissue culture methods are quite promising. In vitro culture work has been started in some Asian countries such as India, Malaysia, Japan, Thailand and others (Mehta *et al.*, 1982; Vasil, 1982). The excellent work on bamboo micropropagation by Mehta *et al.* (1982) in Delhi University using seeds of *Bambusa arundinacea* resulted in callus which differentiated into many embryoids. These regenerate into plantlets in vitro. This work has laid the foundation for bam-

boo micropropagation and in vitro conservation. Similarly, using vegetative material, studies have been made on callus formation in *Schizostachyum* and *Thyrsostachys* (Dekkers et al., 1987).

There are several advantages in the micropropagation of bamboo through tissue culture. It is very useful in germplasm collection, conservation and their regional exchange. It is also a quick method of propagation and enables high multiplication rates. Besides, large numbers of accessions can be conserved in a small space. Both in situ and ex situ conservation strategies should form an integral part of a programme for maintenance of bamboo genetic resources.

Systematic work on bamboo research under the ICAR was initiated under the All India Coordinated Research Project on under-utilized and under-exploited plants during 1982 at the research centre at Arunachal Pradesh. The main objective of the programme was to work on quick-growing annual, biennial and perennial bamboos suitable for cottage and paper industries. The work on collection and establishment of native species from the North-eastern region started in 1984. Genetic resources from the southern region are being collected and maintained at the National Bureau of Plant Genetic Resources station at Trichur (Kerala). Work on micropropagation of bamboo species through tissue culture at the Department of Botany, University of Delhi under a project from the Department of Biotechnology has resulted in the successful production of bamboo plants. These tissue culture-raised plants have been planted at the Issapur Farm of NBPGR, New Delhi for field testing under a collaborative programme. About 40 plants of *Bambusa arundinacea* and *Dendrocalamus strictus* were transplanted in the field during November, 1987. Most of the plants have established very well. Plants vary in height, leaf size, culm diameter and tillering. One-year-old plants show variation in height from 90 to 310 cm; culm diameter from 6 to 29 mm; leaf length from 6.1 to 17.3 cm and leaf width 1.2 to 2.5 cm.

Plants transplanted during winter remained dormant and rapid vegetative growth was observed from March onwards. More plants have been transplanted this year. Data will be recorded on different morpho-agronomic characters.

Research Needs

There is a need for developing commercial cultivars suitable for different agro-climatic conditions for industrial usage and edible purposes. Evaluation studies, particularly on breeding for improved types, timber engineering, pulp and paper technology, need to be done. Silvicultural and tissue culture techniques for quick multiplication require more attention.

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Arundinaria alpina in Kenya

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Abstract

The occurrence, habit, growth, flowering and conservation of *Arundinaria alpina* in Kenya are described.

Occurrence

Arundinaria alpina (K. Schum : African alpine bamboo) is the only indigenous bamboo in Kenya. It grows in the Mau range, Arbedare mountains, Mt. Kenya, Mt. Elgon and in the Timboroa (Kaptagat) plateau. Smaller stands are found in the Taita and Shimba hills. It usually occurs in the montane bamboo forest type vegetation. In its natural environment it grows together with several tree species including *Hagenia abyssinica*, *Juniperus procera*, *Ocotea usambarensis*, *Podocarpus gracilior* and *P. milanjanus*. The wildlife associated with bamboo forests include elephants, buffalo, bush-bucks and Sykes monkeys which use it as a food source.

Description

The genus *Arundinaria* comprises bamboos that are shrubby (tree-like) with woody culms, leptomorphic rhizomes and leaf blades disarticulated from the leaf sheath. They have paniculate or racemose inflorescences with one or more flowered spikelets. All flowers are hermaphrodite, reduced cylindrically and more or less compressed. The genus has about 150 species growing in the warm-temperate and sub-tropical regions of the world.

Arundinaria alpina is a gregarious bamboo with stout woody rhizomes. The culms are usually 2-20 m in height and 5-13 cm in diameter. They are erect, evenly spaced, green becoming yellow or brown and downy when young. The culms are thick-walled with several branches at each of the upper nodes. The culm sheaths are covered with reddish-brown bristly hairs or are glabrescent, tipped with a linear acute blade and fimbriate lateral auricles. The leaf blades are narrow, linear lanceolate, 5-20 cm long and 6-15 cm wide, glabrous with conspicuous transverse veins and narrowed apically to a fine bristle up to 2 cm long.

Panicles are terminal on branches and branchlets are 5-15 cm long. Spikelets are 1.5-4 cm long and 3-4 mm wide with 5-10 florets having 4-8 mm long glumes.

It flourishes best on deep volcanic soil rich in humus while it is usually poorly developed or absent on rocky soils. *Arundinaria alpina* varies greatly in size and its culms can be relatively short and slender at high altitudes.

Growth

The mature bamboos produce shoots every year throughout the rainy season. The shoots attain full height in 2-4 months but they are softer and less woody than older culms. The culms stay in the clump for 7-14 years and eventually die (slowly). If the older culms are not removed from the clump they restrict the development of the rhizome system and subsequent emergence of new shoots. Production of new culms is influenced by two major factors: ample soil moisture and good rainfall.

Flowering

Regeneration of bamboos in nature largely relies on yearly emergence of new shoots and to a very small extent on reproduction by way of seed. In Kenya, past observations put the flowering cycle of *A. alpina* in the Arbedare ranges at 40 years; flowering occurring in patches of 0.5-5 ha and extending over several hundred hectares of forest at a time. In the same forest area, flowering of bamboos has been observed continuously from 1986 to this year (1988), again in patches over fairly large areas.

In the Kaptagat forest area, flowering has been observed from 1987 till now (1988). Usually seeds can be obtained if there is a dry period after the 'long rains' and just before the 'short rains'. In the

Mt. Elgon area, flowering is said to occur every 15 years, usually in limited patches. Till 1970, no instance of gregarious flowering was recorded.

Utilization

Arundinaria alpina is used in Kenya for fencing (mostly untreated) and construction of nursery beds, houses (in very remote areas), basket weaving, covering coffee, etc. In old times bamboos were used for carrying arrows and storage of food materials (in hollow cut culms). At present, it is used for making curios, ornamental baskets, tooth picks, lampshades, pen-holders, etc.

This bamboo has been tested (elsewhere, not in Kenya) and shown to produce high quality pulp. It does not peel very well and hence its use in plywood is limited. In other places, bamboos are used for a whole range of purposes including scaffolding, paper-making, as vegetable (shoots), reinforcement of concrete, wooden products, fodder, floor tiling, roof-lattices, pillars, rafters, ceilings, bamboo plywood, etc. The list of possible uses of bamboo is very long as it is a very versatile material.

Conservation of Bamboo Forests in Kenya

From the early 1950s, bamboos in Kenya were being cleared to provide land for establishment of exotic softwood tree plantations (mainly *Cupressus lusitanica*, *Pinus patula* and *P. radiata*). This went on up to the early 1980s when it was stopped completely. The major reason behind the move was that a lot of areas were being left bare as bamboo was considered to be a "minor forest product". The plant was threatened as no re-planting of bamboo was usually done.

Further in the mid-1980s, the forest department closed most of the natural forest areas and as some of these have bamboos, it has been a great step towards their conservation. Right now foresters in the field are being encouraged to plant bamboos (in areas they occur) as part of their annual afforestation and reforestation exercise.

There is a proposal to establish more nature reserves in areas where bamboos occur, as a means of in situ conservation. Ex situ conservation of bamboo is being undertaken by growing them in existing arboreta and by the establishment of separate "bamboo arboreta" in several ecological zones all over the country.

Bamboo (*Dendrocalamus strictus*) Resources of the Outer Himalayas and Siwaliks of Western Uttar Pradesh: A Conservation Plea for Habitat Restoration

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Abstract

Bamboo (Dendrocalamus strictus) has been an important component of the habitat of large wild herbivores including the Asiatic elephant (Elephas maximus) in the forest divisions of Lansdowne and Kalagarh in the Outer Himalayas and Siwaliks of western Uttar Pradesh. These two divisions form the crucial and the only possible corridor between the Corbett and Rajaji National Parks and also represent the northern-most limit of the distribution of Dendrocalamus strictus. An analysis of the annual out-turn of bamboo exploited in the two divisions over 60 years shows a drastic decline of resources. This was confirmed by the results of a rapid field survey. Excessive exploitation in the past, coupled with mass flowering and death, followed by a serious failure of regeneration have all but decimated the resource. Immediate conservation action is needed not only for the restoration of the habitat of bamboo in the fragile ecosystems of the Outer Himalayas and Siwaliks but also for identifying in situ conservation reserves. A possible restoration measure is to carry out extensive planting of bamboo, with the active participation of the local people who have a stake in the development and utilization of the resource.

Introduction

The fragile mountainous ecosystems of the Outer Himalayas and Siwaliks in western Uttar Pradesh harbour bamboo (*Dendrocalamus strictus*) as one of the components of the habitat of large wild herbivores. Its widespread occurrence coupled with its extensive utility have resulted in exploitation from time immemorial. Therefore, there is urgent need to document instances of serious threats to bamboo populations and suggest conservation measures. In this paper, the status of bamboo resources of Lansdowne and Kalagarh forest divisions of the Outer Himalayas and Siwaliks is described. These two divisions are the vital habitat link for the Asiatic elephant (*Elephas maximus*) in the Corbett and Rajaji National Parks (Johnsingh *et al.*, 1988), apart from the fact that this area is the northern-most limit of the range of *D. strictus* in India.

Study Area

The forest divisions of Lansdowne (30° 8' and 29° 37' N lat; 78° 9' and 78° 43' E long) and Kalagarh (29° 26' and 29° 48' N lat; 78° 33' and 79° 26' E long) nestle in the outer Himalayan tract as well as on the northern flanks of the Siwaliks in the districts of Pauri Garhwal and Bijnor covering an area of 1760 km² (Srivastava, 1974; Mathur, 1979). The forests of Kalagarh are contiguous with that of Ramnagar division and the Corbett National Park. The altitude varies from 300 to 1300 m. The upper parts consist of shallow rocky slopes of shale with limestone and sandstone. The Siwalik region also includes the upper Siwalik conglomerates, middle Siwalik sandrock and the lower Siwalik sandstone. The mean annual rainfall of the tract varies from 1300 mm (Kalagarh) to 2200 mm (Lansdowne). The rainy months are from June to October. The monthly mean minimum and maxi-

mum temperatures are 0 C (in January) and 47 C (in April).

Occurrence of Bamboo

The occurrence of bamboo varies from a con-sociation (in bamboo brakes) to scattered clumps in the moist deciduous to dry and moist Siwalik vegetation types. The areas of occurrence in each of the two divisions of Lansdowne and Kalagarh, are given in Table 1. It is obvious that bamboo occupies a significant part of the forest area.

Exploitation of Bamboo Stocks

The bamboo forests are managed on a four-year cutting cycle. The extraction commences by the third week of October and ends by February (Srivastava, 1974) and is confined to removing culms with a length 3-4 m. It is also prescribed that for every new culm present in a clump, six old culms should be retained and the remaining be extracted. In addition, operations such as removing the malformed, bent culms from the congested clumps are also prescribed.

Out-turn of Bamboo in the Lansdowne Division

The results of such exploitation from the late 1910s to 1980s are given for the Lansdowne division in Table 2. It is evident that there has been

a sudden and drastic decline of the resource during the period 1962-73. While the average annual out-turn until 1962-63 worked out to be 7.37 million bamboos, by 1972-73 the out turn was a mere 0.89 million, registering an eight-fold decrease.

Out-turn of Bamboo in the Kalagarh Division

Table 3 gives data on the average annual out-turn of bamboo in the Kalagarh division. The extreme reduction of the resource is evident from the twenty-fold decrease registered in a span of merely six decades. From an average annual out-turn of about two million bamboos the extraction was a mere 0.1 million in 1978-79.

Present Status of Bamboo Resources

Against an estimated availability of 2 1 200 tonnes of bamboo from Lansdowne and Kalagarh divisions in 1950 (Srivastava, 1974; Mathur, 1964), the present day production is a mere 1000 tonnes. This is due to an almost total disappearance of the stocks. In order to assess the status of the stocks, a rapid 'road transect' of about 50 km in length was travelled in April 1988 from the north-western park of Lansdowne division to south-east of Kalagarh division. After every 300 meters, the locality was scanned on either side of the road to a distance of 30 meters, for the presence of significant patches of bamboo. It was an extraordinary coincidence

Table 1. Area under bamboo (*Dendrocolamus strictus*) in the constituent ranges of Lansdowne (modified from Srivastava, 1974) and Kalagarh (modified from Mathur, 1979) divisions

Division	Range	Area (ha)	Area under bamboo (ha)	Percent area under bamboo
Lansdowne	Chandi	14341	6442	45
	Gohri	18019	12517	69
	Kothri	17000	14244	84
	Kotdwara and Lansdowne	10550	9212	87
	Laldhang	19253	12161	63
	Average for the division			69.6
Kalagarh	Adnala	15242	11422	75
	Dhara	19267	17588	91
	Mandal	14484	9267	64
	Palain	11543	9029	78
	Sonanadi	24160	20661	85
	S.P. Dun	14890	10452	70
	Average for the division			77.2

Table 2. Out-turn of bamboo (*Dendrocalamus strictus*) in the forest division of Lansdowne

Period	Average annual number of bamboos extracted (x 10 ⁶)	Tons
1919-21	4.9	9840
1922-38	7.5	15160
1939-40	7.9	15800
1940-41	9.4	18720
1941-42	9.4	19120
1942-43	7.9	15720
1943-44	8.5	17080
1944-45	6.4	12880
1945-46	6.4	12800
1946-47	7.4	14760
1947-48	6.0	12000
1948-49	8.1	16080
1949-50	5.9	11800
1950-51	8.7	17520
1951-52	6.6	13200
1952-53	6.8	13760
1953-54	7.8	15680
1954-55	6.8	13760
1955-56	9.6	19200
1956-57	7.9	15960
1957-58	8.1	16280
1958-59	6.9	13960
1959-60	6.6	13280
1960-61	7.3	14680
1961-62	5.0	10040
1962-63	7.1	14240
1962-73	0.8	1780
1973-81	0.9	1800

that out of the 155 stations of sampling, not a single significant bamboo patch was observed. There were, however, occasional clumps which were highly congested and degraded. In order to verify these results, four 'foot transects' each covering a length of at least two km were laid in the once rich bamboo areas of Kunaun, Bedasni, Chandi and Hazara blocks. In addition, 14 plots each at least 256 m² were also laid in areas presently known to show traces of bamboo.

While the findings of the 'foot transects' once again confirmed the observations on the 50 km 'road transect', the results of 14 plots indicated

densities ranging from a minimum of zero to 500 clumps/ha (Table 4). There seems to be a difference in density between the different cover types, the highest being in open canopy condition and the lowest in case of Lantana-dominated cover. The observed densities are some of the highest estimates comparable to those observed elsewhere (Prasad, 1985). These estimates are a pointer to the fact that given optimum conditions of habitat, bamboo can locally dominate and be of importance to wild herbivores even at this stage of apparent resource decimation. It is of course next to impossible to expect regeneration in areas totally lacking in bamboo, but restorative measures such as extensive planting in proper habitats would go a long way in re-establishing the bamboo crop. That bamboo can have a good potential for growth can be inferred by examining the growth (new culm/old culm) ratios for 21 clumps in Ranipur area (Siwaliks). The mean ratio was 0.18 with a minimum of 0.08 and a maximum of 1.0. Since bamboo exhibits a unique growth phenomenon of exponential increase, this rate of growth would enable the culm population to double within 3 to 4 years

Table 3. Out-turn of bamboo (*Dendrocalamus strictus*) in the forest division of Kalagarh

Period	Average annual number of bamboos extracted (x 10 ⁶)	Tons
1918-19 to 1920-21	2.3	4600
1921-22 to 1926-27	2.3	4600
1927-28 to 1935-36	1.1	2200
1936-37 to 1939-40	1.6	3200
1940-41 to 1945-46	2.3	4600
1946-47 to 1950-51	2.6	5200
1951-52 to 1953-54	2.1	4200
1954-55 to 1963-64	2.0	4000
1965-66	2.1	4200
1966-67	2.2	4400
1970-71	1.7	3400
1971-72	1.9	3800
1972-73	2.8	5600
1973-74	2.2	4400
1974-75	1.5	3000
1975-76	1.8	3600
1976-77	2.0	4000
1977-78	0.6	1200
1978-79	0.1	200

Table 4. Bamboo (*Dendrocalamus strictus*) population densities in Siwalik (Ranipur) and outer Himalayan (Kunaun) ranges in relation to plant cover

Locality	Sampling area (m ²)	Density (clumps/ha)		Total
		Immature <3m height	Mature >3m height	
Ranipur (open canopy condition)	540	445	55	500
	540	185	130	315
Teak plantation	576			260
<i>Bombax ceiba</i> plantation	1024			117
<i>Lantana</i> dominated area	256			234
	256			156
Sal open canopy	256			117
	256			78
<i>Lantana</i> dominated area	256			39
	256			0
	256			0
Kunaun open canopy	320			125
	400			150
Chandi open canopy	256			312

provided this growth rate continues and there are minimal biotic interferences in the form of grazing, fire, lopping and large scale extraction.

Again, careful management practices such as a complete ban on extracting the flowered and dead clumps for a period of three years and imposing rotational grazing or fencing should be adopted. A thorough examination for regeneration in the flowered areas revealed that while no seedling occurred in open areas, there were three instances of flowered and dead clumps harbouring seedlings. There were of course a large number (26) of flowered and dead clumps with no seedlings at all. It appears that due to heavy grazing prevalent in these localities, dead clumps offer a 'refugium' for regeneration. Therefore, there exists a strong case for retaining flowered and dead clumps in the remaining bamboo areas. Since, the flowered and dead clumps constitute no more than 10 percent of the clump population, retention of these clumps would perhaps not affect the availability of bamboo for local inhabitants.

Even before launching an extensive planting, there should be an immediate effort to collect germplasm (in the case of bamboo by way of vegetative propagation) from all known areas of its occurrence. This is imperative as we are likely to lose various flowering cohorts of *D. strictus* per-

manently. The three most crucial reasons for such an effort are:

1. These flowering cohorts represent a spectrum of genetic diversity of the northern-most population of *D. strictus* adapted to low and high temperatures at higher altitudes.
2. Together, a collection of various cohorts in a given locality can withstand the onslaught of biotic and climatic disturbances better than a single cohort could.
3. True northern-most populations have the relatively rare characteristic of long internodes and hollow culms (Deogun, 1937).

Conclusion and Suggestions

The northern-most population of *Dendrocalamus strictus* has shrunk both in its extent of occurrence as well as in the total density. Although there has been no industrial pressure on the resources unlike in rest of the country (Prasad, 1984), the decimation here is attributable to the combined pressures of local over-exploitation and severe grazing. The proposed conservation measures include:

1. Establishment of bamboo plantations utilizing various cohorts found locally.
2. Setting up of in situ bamboo conservation areas wherever feasible. These areas are,

tentatively, Ranipur (Rajaji National Park); Luni in Laldhang range; parts of Gwalagarh, Sattikhala, Saneh in the ranges of Kotdwara and Kothri (Lansdowne division); parts of Sonanadi, Dhara, Mandal, Adnala and Palain ranges of Kalagarh division. In these localities, ideally, extraction should not be carried out considering the very thin base of the bamboo genetic resource. In case a complete ban on extraction is not feasible, a drastic reduction in the intensity of felling and lengthening of the felling cycle should be enforced.

3. Immediate collection of germplasm and vegetative propagation of various cohorts of this tract.
4. Involvement of local people not only in raising plantations but also in active management.

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Reed Bamboos (*Ochlandra* in Kerala: Distribution and Management*

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Abstract

Among the 136 species comprising the 21 genera of bamboos recorded from India, 24 species consisting of eight genera are known to occur in peninsular India. Of these, nine species of *Uchlandra* which are reeds are used in the pulp and paper industry and for mat and basket-making in the traditional industrial sector in Kerala. Five species of *Uchlandra*, *O. beddomei*, *O. ebracteata*, *O. setigera*, *O. sivaairiana* and *O. talhortii* are reported to be endangered and restricted in distribution. In this paper, the distribution of *Ochlandra* spp. in Kerala is discussed and management strategies to be adopted are suggested.

Introduction

Bamboo plays an important role in the lives of people, particularly in the rural areas. It has been put to use for various purposes both in the traditional as well as in the modern sectors. Prior to its use as a raw material for the paper industry, the entire deciduous forest tracts of India were rich in bamboo stocks. The opening up of the forest for timber extraction and for raising of teak plantations favoured the growth of bamboo species. The early working plans of the forest department, in fact, prescribed the eradication of bamboo, identifying it more as a weed of the teak plantations (Kadambi, 1949). However, the use of bamboo as an industrial raw material has entirely changed this picture.

The first bamboo-based paper mill in India was established in 1919 (Prasad & Gadgil, 1981). Since then, bamboo stocks all over the country have been rapidly depleted and the paper industry which earlier used to depend on bamboo for 100 percent of its requirement has reduced its demand to 50 percent, having switched over to the use of other softwoods. While the industries can afford to do so, the traditional users cannot and hence they have to go through considerable hardship (Gadgil & Prasad, 1978).

Although bamboo has been the subject of a number of investigations, the emphasis has been on the utilization aspects (Varmah & Bahadur, 1980).

A few silvicultural investigations have also been carried out (Deogun, 1937; Kadambi, 1949; Bhargava, 1956; Seth & Mathuada, 1956). In comparison, ecological studies on bamboo are rare. A study by Prasad and Gadgil (1981) indicated that of the three major growth forms of bamboo species in India, 45 percent constitute the tree forms which are found to be most abundant in deciduous forests while 36 percent of the species are of shrub forms, found in restricted habitats such as stream banks or in the ecotones of evergreen forests. The remaining 19 percent are climbers and occur in closed canopy evergreen forests. Heterogeneity in the densities of bamboo population is attributed to the diverse influences of biotic factors on the establishment and growth of bamboo stands.

Distribution

Bamboo forms a significant component of the natural vegetation in India, particularly in the dry and moist deciduous forests and in montane, subtropical, temperate and alpine forests. It occurs as an important associate in southern hill-top forests, tropical evergreen forests, west coast tropical evergreen forests, wet bamboo brakes, west coast semi-evergreen forests, moist teak-bearing forests, dry bamboo brakes and reed brakes.

Ochlandra travancorica is the most important associate of the tropical evergreen forests and at-

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tains maximum growth in the very wet type of evergreen forests. In the evergreen types, the most important associations of *Ochlandra* include *Hopea parviflora*, *Cullenia exarillata*, *Canarium strictum*, *Dipterocarpus indicus*, etc. In the semi-evergreen type, the associations include both evergreen and deciduous species in the top canopy such as *Terminalia* spp., *Xylia* sp., *Sterculia* sp., etc. *Ochlandra* being shade-tolerant, grows well even under the closed canopy of evergreen forests. In the tropical wet evergreen forests, the reed-*Calophyllum* association, a localised edaphic climax type is observed. Here the reeds are found occurring in considerable stretches in marshy areas. The canopy of trees chiefly belong to *Calophyllum elatum*, *Hopea glabra*, *Bischofia javanica* and *Eugenia* spp. The reed-*Poeciloneuron* association is again found to be an edaphic climax prevailing under conditions of heavy rainfall where the soil tends to be marshy. Near the summit of the hills and along the higher slopes of various mountain ranges at an elevation of 1000 m and above, extensive areas are covered with reeds as seen at Bonacaud and Kakki areas of Kerala forests.

Gamble (1896) described a total of 74 species of bamboo from India. Subsequently, considerable work has been done on the taxonomy and distribution of bamboos, adding new records and a few taxa to the Indian bamboos (Chatterji & Raizada, 1963; Raizada & Chatterji, 1963; Bahadur & Naithani, 1976; Bahadur, 1979; Bahadur & Jain, 1980; Varmah & Bahadur, 1980). Among the 136 species comprising the 21 genera of bamboos so far recorded from India, 24 species consisting of eight genera are known to occur in peninsular India. Of these, nine species of *Ochlandra* constitute the reeds used in the pulp and paper industry and for mat and basket-making.

From the Kerala forests, six species and one variety of *Ochlandra* have been reported so far (Table 1 ; Fig.1). The most common ones, *O.*

travancorica (Bedd.) Benth. ex Gamble and *O. scriptoria* (Dennst.) C.E.C. Fisher, are widespread, extending throughout the Western Ghats. The small-sized reed occurring along most of the river and stream banks is *O. scriptoria*. Species such as *O. beddomei*, Gamble, *O. ebracteata* Raizada & Chatterji and *O. setigera* Gamble are restricted to a few localities only. However, during recent surveys, *O. setigera* was located at Nilambur and *O. sivagiriana* Camus has been located at Sholayar.

Since the reeds occur in patches in the forests, no reliable information is available on the extent of reed resources. It was estimated that there are 185 km² of reed areas in the Kerala forests (Chandrasekharan, 1973). However, significant changes have taken place since then accelerated by various factors like fire, over-exploitation and other reasons. The survey of the Forest Department (1975/76) in the Thenmala Forest Division showed that at Thenmala, Achankoil and Arienkavu, there are 56 km² of reed area under different forest types, of which 45 km² occur as scattered patches and 11 km² area are densely populated.

In general, the forest divisions of Malayattoor, Ranni, Konni, Trivandrum, Thenmala and Punalur are comparatively rich in reed resource. A large portion of the ridges forming the northern, eastern and southern sides of the Kulathupuzha valley of Trivandrum division are covered entirely by reeds. In the semi-evergreen forests of the Malayattoor division, especially around the proposed Pooyamkutty hydroelectric project, reeds occur in large patches. Large scale reed extraction is carried out from the Pooyamkutty area and from Pambumkayam belt of Mankulam special division for industrial purposes.

Management

The management of bamboos and bamboo reeds has been attempted in Kerala for a long time.

Table 1. Distribution of *Ochlandra* in Kerala

Species	Forest division
<i>Ochlandra beddomei</i>	Konni, Wynad, Nemmara, Palghat and Quilon
<i>O. ebracteata</i>	Trivandrum
<i>O. setigera</i>	Nilambur
<i>O. scriptoria</i>	Kozhikode, Chalakkudy, Palghat, Konni, Malayattur, Ranni, Trivandrum and Thenmala, at low elevations on stream-sides
<i>O. travancorica</i>	Plain and hills of Kerala and throughout the Western Ghat
<i>O. travancorica</i> var. <i>hirsuta</i>	Thenmala, Ranni, Konni and Trivandrum
<i>O. wightii</i>	Achankoil and Thenmala

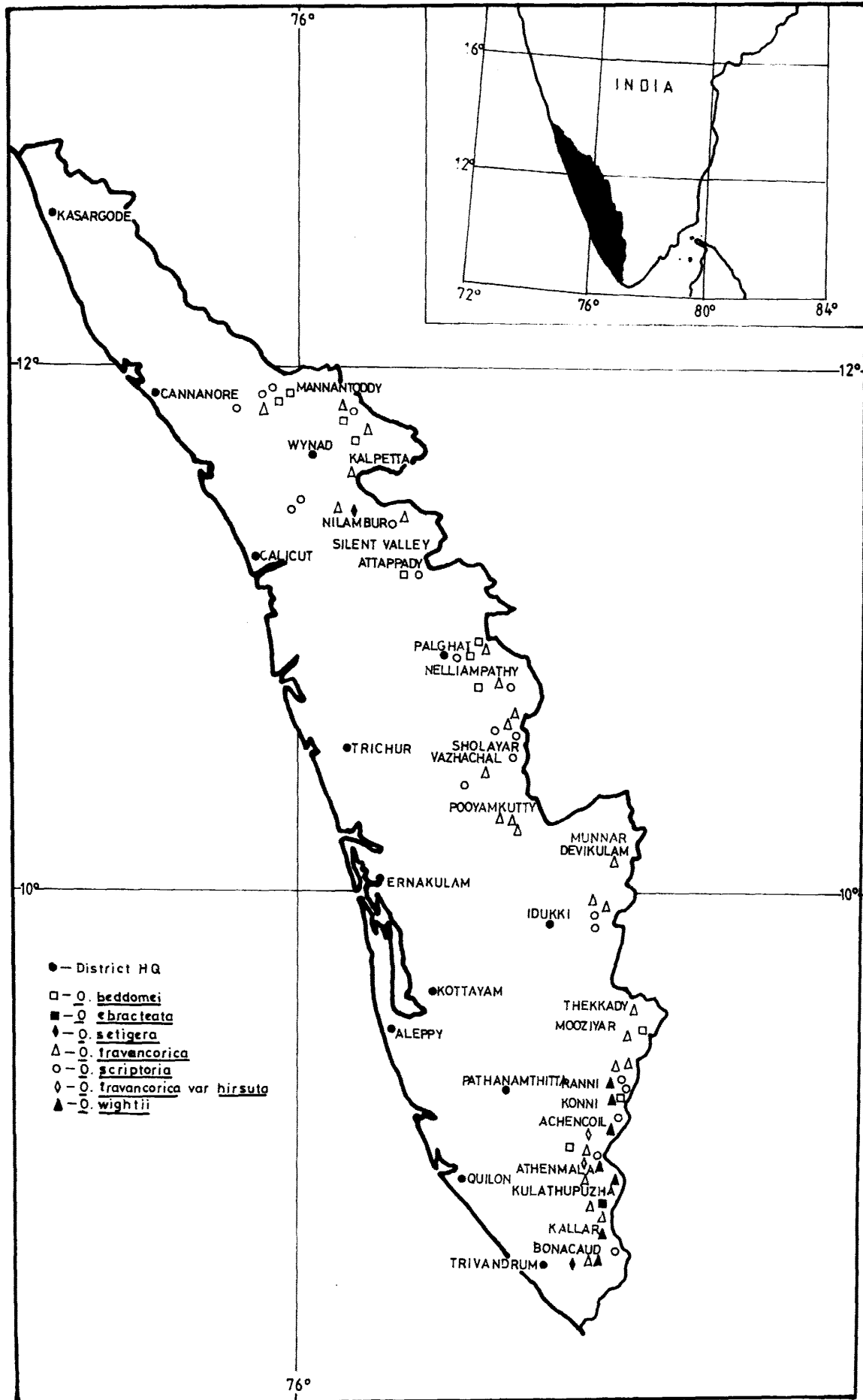


Fig. 1 Distribution of *Ochlandra* spp. in Kerala.

Regular working circles with more or less similar prescriptions have been constituted in every working plan. The management, in general, involves a selective felling system with a felling cycle of four years. The following felling rules are prescribed.

1. Culms less than two years old should not be cut and removed.
2. All the new culms and 25 percent of the old culms should be retained.
3. No clump should be clear-felled except after flowering and when seeding has been completed.
4. Culms should be cut as low as possible leaving one internode above ground.
5. Cutting should begin from the side opposite to where new sprouts are emerging.

Traditional users opt for the selective felling system, as immature culms are unsuitable for basket-weaving. However, with the emergence of the pulp and paper industries as the major consumer of reeds, the system has suffered badly and payment based on weight favours a system of clear-felling. In spite of incorporating the felling rules in the agreement executed with the agencies, these are not scrupulously followed. The same area is exploited year after year by various agencies.

Conclusion

In the absence of any systematic management based on long term planning, the bamboo/reed resource in the State has been severely depleted owing to the following reasons.

1. Decline in the extent of natural forests as a result of agricultural extension, river valley projects, expansion of man-made forests.
2. Biotic factors such as fire and grazing.
3. The unscientific working of bamboo areas.
4. Lack of effort to take up compensatory planting.

A high level expert committee constituted by the Government of Kerala during 1986 emphasized the need to conserve the bamboo/reed natural resources and its scientific management (Nair, 1986). Considering the multifarious uses of these, the committee suggested two strategies: conservation of reed resources and extending it to new areas to ensure a steady supply of the raw material to different consumers. Very little work has been done on reed ecology, microclimate and edaphic conditions favouring regeneration and associations. In order to effectively manage the existing resources, the following points need to be given emphasis.

1. Streamlining reed extraction to ensure that exploitation is limited to the increment.
2. Protection of reed areas from fire and other

biotic factors.

3. Periodic assessment of growing stocks.
4. A separate felling series to be allocated to meet the demands of the traditional and modern sectors.

The reed resources of the State are being depleted at a rapid rate. Construction of river valley projects invariably leads to the loss of prime reed areas. However, it will be worthwhile to attempt planting of reeds in the catchment areas of the river valley projects which would also help in preventing soil erosion.

It is imperative that the production of bamboo and reeds in Kerala is increased by intensive cultivation by resorting to plantation forestry. Suitable high-yielding species should be selected or introduced to Kerala to enhance the annual yield.

Acknowledgements

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Bamboo Resource in the Homesteads of Kerala*

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Abstract

Homesteads in Kerala are a source of bamboo resources. The species most commonly found is *Bambusa arundinacea*. Other species like *B. vulgaris* and *Dendrocalamus strictus* are sparsely found in homesteads. A sample survey with a stratified three-stage sampling procedure has been conducted to gather information on the extent of area occupied by bamboo, stocking, density and availability in the homesteads as well as on the quantity of bamboo used for construction and other purposes by the household sector in Kerala. The results of the survey indicate that bamboo occupies an area of 581 ha with 39 million culms in the homesteads. The harvest during the year 1987-88 was 9.1 percent of the growing stock. It also reveals that the quantity of bamboo used during 1987-88 was around 3.2 million culms mainly for house construction and as a support for the banana crop.

Introduction

Bamboo as a forest produce has many uses. In Kerala, it occurs in the forests and is also raised in homesteads. In the homesteads it is either found mixed with a large number of other species of trees or purely in patches. Bamboo harvested from the homesteads is mainly used by the household sector for house construction and in making farm implements, mats, fences, baskets and other handicrafts and as supporting poles for agricultural crops.

A sample survey has been conducted to quantify the stocking, density and availability of bamboos in the homesteads and the quantity of bamboo used for construction and other purposes by the household sector in Kerala during the year 1987-88. In this paper the results of the survey are discussed. This information will be of considerable importance in formulating any plantation forestry or homestead cultivation programme with bamboo.

Methods

A stratified three-stage sampling procedure was adopted for selection of the sample. The revenue villages in Kerala were classified based on population density¹ and the percentage² of dry-land area under agricultural use to total area under agricultural use in each village; thereby 15 strata were formed. Revenue villages in each stratum were treated as first-stage units for sampling. Out of the total number of villages in Kerala, 2.5 percent were distributed in different strata approximately in proportion to the dry-land area under agricultural use in each stratum. In all, 30 villages were selected and distributed in the different strata, thus ensuring that at least one village was included from each stratum. The villages in each stratum were chosen at random. Census villages or *desoms* were taken as the second-stage units of sampling since several *desoms* form a revenue village. One *desom* each

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¹ The various classes are 500,500-1000 and 1000 persons per sq. km. The village-wise population density was computed from the data given in the report, Census of India 1981, Series-10, Kerala, Paper 3.

² The different classes are 0-50, 50-70, 70-80, 80-90 and 90-100.

³ The dry-land area under agricultural use was calculated from the data available in the files of the State Land Use Board.

⁴ A two-way stratification was adopted since the stocking of bamboo depends on the extent of dry-land area under agricultural use and the intensity of bamboo-use partly depends on population density.

Table 1. Average number of bamboo clumps per hectare and number of culms per clump in different strata

Stratum (S _{ij})	Average no. of clumps/ha	Average no. of culms/clump
S ₁₁	27.0	11.5
S ₁₂	7.0	7.1
S ₁₃	2.9	8.0
S ₂₁	35.6	10.2
S ₂₂	4.1	12.1
S ₂₃	2.1	15.4
S ₃₁	0.1	5.9
S ₃₂	3.4	7.6
S ₃₃	3.3	12.4
S ₄₁	1.3	7.9
S ₄₂	1.3	5.7
S ₄₃	0.1	11.6
S ₅₁	0.6	8.5
S ₅₂	0.9	9.8
S ₅₃	0.2	4.3

S_{ij} indicates the (ij)th stratum where i stands for the different classes of percentage of dry-land area under agricultural use to total area under agricultural use and j stands for different classes of population density

was randomly selected from the chosen revenue villages. The homesteads where bamboo grows and the households where bamboo was utilized for constructing houses⁵ or for other purposes during the year 1987-88 formed the third-stage units of sampling for estimating the growing stock, and the removal of bamboo from homesteads and the quantity of bamboo used by the household sector, respectively. Twenty five homesteads were randomly selected from each of the chosen desoms for assessing the stocking and removal of bamboo. Out of the 20 households selected from each desom, 10 were randomly selected from the list of households where bamboo was utilized for house construction and the remaining were chosen at random from the list of households where bamboo was used only for purposes other than house construction.

Results and Discussion

The results presented in this paper are based on the data pertaining to 27 villages out of the 30

⁵ Houses include building or sheds used for residential and non-residential purposes.

⁶ The conversion rate used was one tonne of oven-dried bamboo culms is equivalent to 50 numbers of green culms with culm-diameter above 10 cm or 100 numbers with diameter between 5 and 10 cms or 200 numbers with diameter below 5 cms. These conversion rates are provisional estimates.

Table 2. Area (in ha) occupied by bamboos under various culm-diameter classes in different strata

Stratum (S _{ij})	Culm diameter* classes			Total
	5 cm	5-10cm	10 cm	
S ₁₁	6.3	17.4	4.8	28.5
S ₁₂	7.0	13.5	N	20.4
S ₁₃	8.9	4.1	N	13.0
S ₂₁	18.3	82.9	N	101.2
S ₂₂	25.5	66.5	N	92.0
S ₂₃	11.1	54.8	1.7	67.6
S ₃₁	0.0	1.2	N	1.2
S ₃₂	16.1	22.0	N	38.1
S ₃₃	9.0	54.2	N	63.2
S ₄₁	12.1	26.9	N	39.1
S ₄₂	6.8	26.0	2.0	34.8
S ₄₃	0.3	3.2	N	3.5
S ₅₁	12.3	33.9	0.8	47.0
S ₅₂	3.5	25.4	2.1	30.9
S ₅₃	0.1	0.3	N	0.3
Total	137.3 (23.6) ⁺	432.2 (74.4)	11.4 (2.0)	580.9 (100.0)

*, diameter at breast height; N, not in the sample: 'percentage of total'

selected. The most common species of bamboo found in the homesteads of Kerala is *Bambusa arundinacea*. It is widely distributed and frequently cultivated in the homesteads. Species like *B. vulgaris* and *Dendrocalamus strictus* are also sporadically found in homesteads,

The average number of clumps per ha of dry-land and area under agricultural use and the culm density as determined in various strata of Kerala range from 0.1 to 35.6 clumps and 4.3 to 15.4 culms per clump, respectively (Table 1). The total area occupied by bamboo in the homesteads of Kerala is estimated to be about 581 ha (Table 2). Results of the assessment of bamboo stock in the homesteads of Kerala reveal that the total standing crop is around 39 million culms (Table 3). This, in terms of oven-dried tonnage, amounts to around 0.33 million tonnes⁶. The harvest during 1987-88 is estimated to be around 3.6 million green culms which accounted for 9.1 percent of the present growing stock.

Table 3. Growing stock of bamboo (number of culms in thousands) coming under various culm-diameter classes in different strata

Stratum (Sij)	Culm diameter classes			Total
	5 c m	5-10cm	10cm	
S ₁₁	409	1570	74	2053
S ₂	808	869	N	1677
S ₁₃	1091	193	N	1284
S ₂₁	2268	6069	N	8337
S ₂₂	2026	3854	N	5880
S ₂₃	798	2799	64	3661
S ₃₁	12	45	N	57
S ₃₂	1939	989	N	2928
S ₃₃	1003	3286	N	4289
S ₄₁	920	1099	N	2019
S ₄₂	528	1460	110	2098
S ₄₃	44	114	N	158
S ₅₁	1153	1561	49	2763
S ₅₂	282	1250	126	1658
S ₅₃	7	8	N	15
Total:	13288 (34.2)*	25166 (64.1)	423 (100.0)	38877

N, not in the sample; *, percentage of total

The use of bamboo for construction and other purposes by the household sector in Kerala during the year 1987-88 is estimated to be 31 million metres which is equivalent to 3.2 million culms⁷. As indicated in Table 4, bamboo is mainly used for the construction of houses and as supports for the banana crop.

Conclusion

The homesteads of Kerala are abundant in bamboo resources and account for 39 million bamboo

Table 4. Pattern of bamboo-use* by the household sector in Kerala

Use	Percentage of total quantity used
House construction	28.16
Supports for crops	26.02
Fencing	9.21
Cattle stays	7.38
Ladder	4.13
Plucker	2.77
Farm implements	0.29
Others ⁷	22.04
Total	100.00

*, bamboo-thorn is not included; + includes household articles and utensils, mats, basketries, fishing gear, long pole of boatman, etc.

culms. During 1987-88, the harvest from homesteads and the quantity of bamboo used by the household sector were 3.6 and 3.2 million culms, respectively. A major share of the total quantity of bamboo was used for constructing houses or as supporting poles for various agricultural crops.

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⁷ The balance of 0.4 million culms (difference between annual harvest and use) may be utilized by others.

Utilization of Remote Sensing Data in Identifying Bamboo Brakes*

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Abstract

The possibility of utilizing remote sensing data to identify bamboo brakes was investigated. The study showed that large scale aerial photographs can be used to determine bamboo resources with reasonable accuracy (>85%).

Introduction

The spatial distribution of forests along with their composition, ecological characteristics and economic properties is the most crucial information needed for the successful planning and execution of forestry-related programmes in the country. Such information is most conveniently represented in the form of maps which earlier had to be generated through costly ground survey methods. The efforts required, in terms of time and money for the vegetation map preparation can be considerably reduced if we rely on remote sensing data, coming in the form of aerial photographs and satellite information (Lillesand & Kieffer, 1979; Swain & Davis, 1978).

Information extraction from remotely-sensed data requires the aid of several techniques (Townshend & Justice, 1981). This paper attempts to study the feasibility of using large scale aerial photographs and satellite information in determining bamboo brakes in the natural forests of the Western Ghats. As a case study, about 30 sq. km. of Attappady Reserve was selected and various land cover types were mapped.

Study Area

The Attappady Reserve lies between 11° 05' to 11° 08' N lat and 76° 30' to 76° 33' E long in Palghat district of Kerala State. The area is rugged, hilly and well-drained, with an elevation of 250 m to 1500 m above m.s.l. The average annual rainfall in the area is about 2000 mm and the average monthly temperature ranges between 15 to 30 C.

Method

To meet the aim and objectives of the survey, standard remote sensing techniques were adopted. Black and white aerial photographs in the scale of 1:15 000 (approx.) with 60 to 80 percent forward overlap, 10 to 40 percent lateral overlap and 23 x 23 cm format size were used for the study. The photostratification scheme was adopted for the purpose of interpretation. Various photoelements such as tone, texture etc. were used as the basis, and the structural classification scheme was slightly arbitrary in nature: for example plant height was into three classes as height class 1, 2 and 3 of < 15 m, 15 to 25 m and > 25 m respectively; crown density into five classes as density class A, B, C, D and E with percentage density of 5-20, 21-40, 41-60, 61-80 and > 80 (Fig-1).

Plantations were classified into two major groups as young (< 5 m height) and old (> 5 m height). The moist deciduous forest was further classified into two major groups as forests with bamboo (2% as MB; 50% as BM) and those without bamboo (MD). The land cover type map (1:25 000) thus prepared was further field checked and necessary corrections made. The extent of land in various categories was calculated using the dot grid method with 0.2 mm dot grid (Table 1).

An attempt was also made to delineate moist deciduous forest with bamboo from Landsat MSS CCTs of March 1987, using suitable classification algorithms. Subsequently, training sets were fed to a computer system (VIPs Numelec 2000 Pericolour) and the percentage distribution of pixels in the training sets to different cover types were evaluated.

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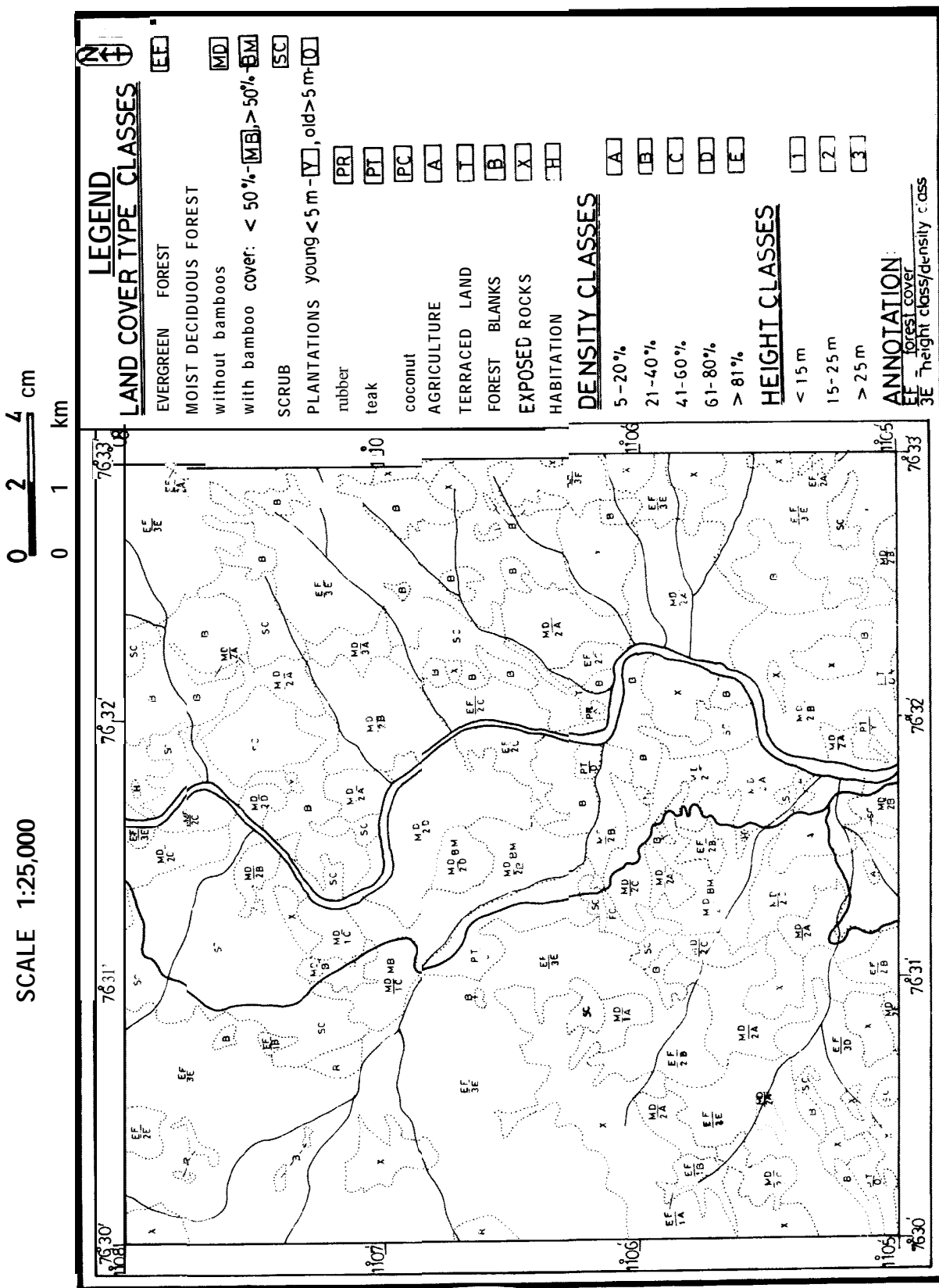


Fig. 1 Land cover map of Attappady region (Kerala) (prepared from 1:15 000 black and white aerial photographs).

Table 1. Distribution of cover classes from aerial photomaps .

Class	Area Percentage (km ²)	
Moist deciduous forest without bamboo	6.39	21.12
Moist deciduous forest with bamboo (> 50%)	1.52	5.02
Moist deciduous forest with bamboo (< 50%)	1.15	3.80
Evergreen forests	11.10	36.69
Scrub	3.32	10.98
Blanks	2.52	8.33
Plantations	0.88	2.91
Rocks	3.05	10.08
Agriculture	0.21	0.69
Habitations	0.03	0.01
Terraced land	0.08	0.26
Total	30.25	99.99

Table 2. Distribution of pixels of training sets in bamboo-clad areas

Class	No. of Percentage pixels	
Moist deciduous forests with bamboo	56	68.3
Wet evergreen forests	12	14.6
Dry deciduous/open forests	7	8.5
Moist deciduous forests without bamboo	3	3.7
Teak plantation	1	1.2
Crop land	1	1.2
Reject	2	2.4

Results

The percentage distribution of different cover classes (Table 1) in the area reveals that the moist deciduous forest occupies about 30 percent of the total study area. 21.12 percent of the area is under moist deciduous forests without bamboo and 8.82 percent with bamboo cover. 5.02 percent of the land have bamboo with 50 percent crown density and 3.82 percent has 2 percent crown density coverage. Other land types distribution data are recorded in Table 1.

Since the radiance value, as recorded on Landsat MSS CCTs, is dependent on the amount of green biomass present in the area (Tucker *et al.*, 1983), in digital analysis the accuracy of classifica-

tion mainly relies on the training set selection of the respective class. In the present study, the training sets fed to the computer had a coverage of 82 pixels and the distribution of these pixels with respect to D.N. values shows that 68.3 percent are classified correctly as moist deciduous forest with bamboo. 14.6 percent of pixels are in the wet evergreen class, 3.7 percent in moist deciduous forests without bamboo, 8.5 percent in dry deciduous forests, and 1.2 each in teak plantation and plant class. The reject threshold was 2.4 percent (Table 2).

Conclusions

A number of land use and land cover classification systems have been proposed from time to time. They cannot, however, yield maps of high accuracy in all regions of the country as discrimination among cover type is highly dependent on the fidelity of the spectral measurements that are recorded by the sensor (Singh, 1987,1988). Hence in the present study greater stress is given to the use of large scale aerial photographs, rather than satellite information. The study reveals that the potentiality of large scale aerial photographs in identifying bamboo-clad areas is immense and the aerial photographs of more than 1: 15 000 scale can conveniently be used as a tool for determining bamboo brakes. The lighter tone of bamboo mixed areas in the aerial photographs when compared to the moist deciduous forests without bamboos, and the smooth a texture than the semi-evergreen cover type are some of the identifying photoelements in the study. In 1: 15 000 and 1: 10 000 scaled aerial photographs, the texture is more coarse than that of teak and rubber plantations (Tomar & Masilkar, 1972). The moist deciduous forests without bamboo show medium texture and darker tone than those with bamboo mixing. Similarly, the moist deciduous forests with bamboo show darker tone than those of the rubber plantations in large scale aerial photographs. A casual observation of ground stereograms of the area revealed that bamboo patches are more or less stellate in appearance, and stand out prominently in the case of moist deciduous forests.

The use of photographs and imageries taken in the correct season are vital since most of the works are based on visual interpretation techniques. The tonal and textural variations during the flowering season of bamboo is yet another tool for proper identification in aerial photographs. This study also takes into consideration the use of large scale aerial photographs for determining the bamboo resources in inaccessible areas with a reasonable (more than 85%) accuracy limit.

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Population Aspect of the Phenological Behaviour of Bamboo Germplasm

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Abstract

Bamboo germplasm studies were taken up under an All India Coordinated Project at Sang district due to the prevalence of more than 15 species in this small pocket alone. Thirty-one distinct types have been established at the Arunachal Pradesh Centre bambooorium in singles or duplicates. Comparative population studies for Bambusa tulda Dendrocalamus hamiltonii and B. pallida at West Siang and North Lakhimpul showed little interspecific and more intraspecific variation for seven clump management and five culm morphological traits in the base population sampled at W. Siang. Inter se associations among these traits show possibility of improvement through selection for individual traits vis-a-vis single plus bamboos or polymorphs. Internode volume was found to be a better selection criterion than length or girth alone. A phenological quotient is proposed as an index for decision-making in cutting management. The vigour of one-year-old nodal plants was more than of seedlings. Chemical mutagenesis has been initiated in B. pallida for plant improvement studies.

Introduction

Although reports on the status of research, inventory, production and utilization aspects of Indian bamboos are recorded in literature (Tomar, 1974; Varmah & Bahadur, 1980; Gaur, 1985; Varmah & Pant, 1981; Sharma, 1987; Thomas *et al.*, 1987), these are inadequate. Studies were taken up on bamboo germplasm under an All India Coordinated Project at the A.P Centre located at Basar, from 1984 (Anonymous 1988). The primary objective was to identify fast-growing species for higher biomass production of good quality. A review of available diversity indicates the occurrence of about 125 species of bamboos all over India.

Nearly 60 species occur in the North-eastern region alone (Varmah & Bahadur, 1980; Gaur, 1985; Shukla, 1986). Survey and collection expeditions for bamboos in West Siang district of Arunachal Pradesh have revealed the occurrence of more than 15 species/types, in one district alone. At present 31 distinct bamboo types in singles or duplicates, from five States of North-eastern India have been established at the A.P. Centre bambooorium (Table 1). The materials have attained one to three years of age. Preliminary data have been recorded on 12 species which are three years old

and the plants classified into three categories: tall and shy prolific, medium tall and medium prolific, and short and highly prolific (Kochhar & Rai, 1988).

A preliminary appraisal of the available diversity and distribution of bamboo types showed that there is ambiguity in the taxonomic classification. Kochhar (1986a,b) cited the example of *Dendrocalamus humiltonii* which was called differently in seven different dialects of the North-eastern Hill Region (NEH). All of these are not the earlier recorded synonyms for the species. Reports are available in literature where the criteria for classification have varied from flowering to culm sheath characteristics, anatomical characteristics, cytology and electrophoretic pattern (Alam, 1982; Gaur, 1985; Liese, 1985; Varmah & Bahadur, 1980). However, none of these classifications gives a foolproof key to bamboo identification under field conditions because of changes in clump morphology with the microclimatic changes in different niches, particularly at the vegetative stage.

Cultivation Practices

Prasad and Kochhar (1986a,b) outlined an experimental approach for bamboo preservation and

Table 1. List of bamboo germplasm in the Arunachal Pradesh Centre bamboorium (September 1988)

Genus	Species	Local name	No. of clumps	Place of collection
<i>Arundinaria</i>	<i>callosa</i>	Tao (A.G.)		West Siang
	<i>griffithiana</i>	Boji (A.G.)		-do-
	<i>hir suta</i>	Sejnaka (Kh.)	2	Khasi Hills
<i>Bambusa</i>	<i>balcoa</i>	Boluka (Ass)	2	Assam
	<i>khasiana</i>	Tabum (A.G.)		West Siang
	<i>multiplex</i>	Hedge		Accession
	<i>nana</i>	---	2	Accession+
	<i>nutans</i>	Mokal (Ass)	2	Assam
	<i>pallida</i>	Bijuli (Ass)	3	West Siang
		ESO (A.G.)		
	<i>teres</i>	---	2	Khasi Hills
	<i>tulda</i>	Jati (Ass)	3	West Siang
		Ejo (A.G.)		
<i>Cephalostachyum</i>	<i>fuschianum</i>	Taok (A.G.)		West Siang
	<i>pergracile</i>	Madang (A.M.)		
<i>Dendrocalamus</i>	<i>giganteus</i>	Aphi Bo(Naga)	2	Nagaland
	<i>hamiltonii</i>	Kako (Ass)		
		Eni (A.G.)	2	West Siang
	<i>hookerii</i>	Sejlong (Kh)	2	Khasi Hills
	<i>membranaceous</i>	Katva (Hindi)	1	Accession
	<i>sikkimensis</i>	Egi(A.G.)	2	West Siang
<i>Phyllostachys</i>	<i>manii</i>	Tabo (A.G.)	2	-do-
	<i>reticulata</i>			Accession
<i>Pseudostachyum</i>	<i>polymorphum</i>	Tador (A.G.)	2	West Siang
Botanically unidentified	types:			
	Boom		2	Tripura
	Bushy Dwarf			Shillong
	Hard jati			Nagaland
	Khupri			-do-
	Murli		2	Assam
	Paura		2	Tripura
	Tachur		1	West Siang
	Tajir		2	-do-
	Tapin		1	-do-
	Bee		2	L. Subansiri

A.G., Adi Gallong; Accession+, collected from VVK, Chessa (Arunachal Pradesh); A.M., Adi Minyong; Ass, Assamese; Kh, Khasia

cultivation in the NEH region. They observed a higher variation in clump characteristics over other culm morphological traits in four species of plus bamboos. The authors further discussed the need for a minimum sample size of 20 clumps for getting unbiased statistical parameters. The possible occurrence of polymorphic forms was propounded. Inventory classification of bamboos based on maturity class, soundness and weight of culms, clump size, age, length, diameter, etc. was proposed by Tomar (1974) for bamboo forest management. Von Carlowitz (1985) proposed a multiple tree database in relation to taxonomy, location,

biophysical data, phenology and morphology. Preparation of a data book-cum-descriptor class catalogue is under way in which source, planting and phenological data; morphological characteristics of rhizome, culm, branches, leaf sheath, leaf and flower; histological characteristics; pulp and wood quality parameters and cutting management data are indexed for long-term comparative analysis of the species.

In situ population studies of three species of bamboos in mid-hill and valley conditions have been undertaken to determine the population structure of cultivated bamboos both between and

Table 2. Comparative means \pm S.E., range and coefficient of variation for various clump characteristics in cultivated bamboos of West Siang and plus bamboos of North Lakhimpur

Trait	Species	Location					
		West Siang			North Lakhimpur		
		X \pm S.E.	Range	C.V.	X \pm S.E.	Range	C.V.
Clump height (m)	Bt	15.39 \pm 0.40	9.9-21.0	20.4	19.14	17.0-24.0	10.3
	Dh	13.51 \pm 0.37	9.1-17.0	14.8	21.00	20.0-23.0	
	Bp	14.13 \pm 0.39	7.5-18.5	21.3	17.93	17.0-20.0	3.7
	Pooled	14.42 \pm 0.23	7.5-21.0	20.3			
Clump circumference (m)	Bt	9.98 \pm 0.43	4-17	36.6	25.13	18.0-45.0	27.4
	Dh	8.70 \pm 0.45	4-12	35.3	15.75	8.0-24.0	
	BP	9.54 \pm 0.44	3-16	40.5	20.93	13.0-30	22.2
	Pooled	9.47 \pm 0.26	3-17	38.2			
Number of culms/clump	Bt	51.80 \pm 0.95	18-81	35.1	81.32	193-721	61.7
	Dh	51.33 \pm 1.39	16-92	63.5	45.75	71-177	
	BP	46.00 \pm 0.78	24-85	33.7	21.13	132-640	45.4
	Pooled	49.56 \pm 0.59	16-92	39.3			
Number of fresh sprouts (WS) /No. of dry culms (NS) per clump	Bt	8.00 \pm 0.42	4-15	43.5	6.59	0-23	91.2
	Dh	9.80 \pm 0.60	3-19	48.2	0.79	0-2	
	Bp	9.25 \pm 0.44	3-16	46.3	5.73	0-20	113.0
	Pooled	8.95 \pm 0.28	3-19	48.2			
Number of young culms per clump	Bt	13.70 \pm 0.56	2-27	45.4	49.68	21-109	50.2
	Dh	14.13 \pm 0.73	4-29	57.3	14.00	7-30	
	Bp	12.80 \pm 0.59	5-30	53.8	53.07	19-120	55.5
	Pooled	13.49 \pm 0.36	2-30	52.1			
Number of old culms/clump	Bt	15.40 \pm 0.56	6-26	40.1	228.59	100-400	34.7
	Dh	13.47 \pm 0.66	5-28	47.8	84.50	58-105	
	BP	11.85 \pm 0.50	6-28	41.5	91.07	50-450	56.4
	Pooled	13.58 \pm 0.36	5-28	44.3			
Number of cut culms/clump	Bt	15.10 \pm 0.65	5-41	56.0	93.72	5-300	88.8
	Dh	13.93 \pm 0.73	3-30	59.6	46.50	6-90	
	BP	12.10 \pm 0.46	3-20	35.2	71.26	1-200	67.7
	Pooled	13.48 \pm 0.36	3-41	54.1			

Bt, *Bambusa tulda*; Dh, *Dendrocalamus hamiltonii*; Bp, *Bambusa pallida*

within various species for detecting polymorphic forms for improvement through selection. Table 2 gives data on clump characteristics in cultivated bamboos of W. Siang (Basar) as well as of plus bamboos of N. Lakhimpur (near Chessa) for *Bambusa tulda*, *B. pallida* and *Dendrocalamus hamiltonii*. A perusal of the table shows that the mean clump expression of all the three species growing in W. Siang are similar for seven traits. The slightly lower value for clump height (m) of *D. hamiltonii* in W. Siang (13.51 \pm 0.37) in comparison with the corresponding values for *B. tulda* (15.39 \pm 0.40) and *B. pallida* (14.13 \pm 0.39) is due to the semi-drooping habit of *D. hamiltonii*. The corresponding mean expression for clump height at N. Lakhimpur is higher for all species than in W. Siang, probably due to the more favourable agro-climatic condi-

tions for these species in the valley than in the mid-hills. *D. hamiltonii* gave the highest mean culm height (21.0 m) followed by *B. tulda* (19.1 m) and *B. pallida* (17.9 m) at North Lakhimpur. The range for clump height shows much variation within the three individual species but an overlapping range is observed in pooled analysis.

A moderate level of coefficient of variation (C.V.) suggests the possibility of improvement through selection. The C.V. for *B. tulda* and *B. pallida* for plus bamboos of N. Lakhimpur is low which confirms their non-random sampling. The C.V. for *D. hamiltonii* was not computed and means for individual traits are found to be slightly affected upwards or negatively due to small population size (less than 20 clumps per species). Sampling size is, therefore, important in population improvement

Table 3. Comparative means, range and coefficient of variation for various culm characteristics in cultivated bamboos of West Siang and plus bamboos of North Lakhimpur

Trait (cm)	Species	West Siang			North Lakhimpur		
		X ± S.E.	Range	C.V.	X	Range	C.V
Culm girth	Bt	24.24 ± 0.50	12.2-31.2	20.6	27.69	25.5-30.0	5.00
	Dh	29.32 ± 0.60	21.0-40.0	18.4	52.90	49.0-55.0	-
	Bp	24.49 ± 0.50	17.2-34.0	20.2	27.61	24.3-29.0	4.99
	Pooled	25.71 ± 0.32	12.2-40.0	21.6	-	-	-
Culm thickness	Bt	2.67 ± 0.15	2.0-3.5	16.6	1.84	1.5-2.5	15.1
	Dh	2.86 ± 0.22	2.0-4.0	26.4	2.00	2.0-2.0	-
	Bp	2.12 ± 0.17	1.2-3.4	26.3	1.80	1.5-2.0	13.6
	Pooled	2.52 ± 0.11	1.2-4.0	26.3	-	-	-
Hollow of culm	Bt	1.80 ± 0.20	1.3-4.2	42.6	-	-	-
	Dh	3.67 ± 0.32	1.3-8.0	42.7	-	-	-
	Bp	2.14 ± 0.18	1.1-4.0	30.3	-	-	-
	Pooled	2.44 ± 0.15	1.1-8.0	52.5	-	-	-
Culm diameter	Bt	7.72 ± 0.28	3.9-9.9	20.6	8.81	8.1-9.5	-
	Dh	9.28 ± 0.34	6.7-11.8	18.7	16.83	15.6-17.5	-
	Bp	7.79 ± 0.28	5.5-10.8	20.2	8.79	7.7-9.2	-
	Pooled	8.17 ± 0.18	3.9-11.8	21.6	-	-	-
Internode length	Bt	33.71 ± 0.45	30-42	12.2	41.27	37-47	5.5
	Dh	31.48 ± 0.69	27-37	9.2	30.00	28-32	-
	Bp	33.89 ± 0.49	28-45	14.5	34.47	29-43	11.1
	Pooled	32.62 ± 0.33	28-45	18.3	-	-	-

studies. A similar trend is observed for within and between (pooled) species mean expression for clump circumference. At W. Siang, the range is wide and hence the C.V. is higher. The circumference of the plus bamboos clumps at N. Lakhimpur was much higher than that at Basar. This can be partially attributed to age of clumps, fertility of soil and favourable climatic conditions at the former location. Nonetheless, further studies are needed to ascertain such confounding at the population level which may be due to genome/environment interaction or the occurrence of polymorphic forms (varieties) of potential use. Data on number of culms per clump show that the average size of the clump in *B. tulda* and *D. hamiltonii* was 5.180 ± 0.95 and 5.133 ± 1.39 culms, respectively, whereas clumps of *B. pallida* were marginally smaller (46.00 ± 0.78). The range of culms per clump for the three types showed the occurrence of even smaller clumps in the first two species in comparison with *B. pallida*. Since the co-efficient of variation for all the species varies from moderate to high, the population can as such be treated in equilibrium. A few confoundings in such sample data may be the number of seedlings planted in individual pits and age/health of seedling; alternately, size and vigour of rhizome if planted through vegetative means or edapho-

climatic factors can be considered. A perusal of the culm management characters shows a wide range and coefficient of variability for number of fresh sprouts, and young, old and cut culms in W. Siang, but the means and standard errors were again similar for all the three species. These characters can, therefore, be dependent on the cutting management of the base population. It is seen from the pooled analysis that nearly nine new culms are growing in a fully grown clump of *B. tulda*, *D. hamiltonii* or *B. pallida* whereas the proportionate occurrence of young, old or cut culms is about 1.5 times this figure in W. Siang. Seth and Mathauda (1956) and Sharma (1987) have stressed the proportionate retention of young and old culms for maintaining high economic returns and quality of the produce under different cutting practices. In the present case, corresponding values for plus bamboos at N. Lakhimpur show that the size of the *Bambusa* clumps is much higher as compared with *D. hamiltonii* (145.75 culms/clump). Culm management characters also show a similar trend. The number of dry culms/clump were recorded at N. Lakhimpur instead of fresh sprouting as at W. Siang. This is due to the phenological stages of the bamboos under study at the two sites. The results, nonetheless, indicate the differential adaptability and vigour of these species in mid-hills (W. Siang)

Table 4. Interrelationships among various culm morphological characters in three species of bamboos at Basar

Character	Type	Internode length	Culm thickness	Diameter of hollow
Culm girth	Bt	0.09	-0.06	0.04
	Dh	0.57*	0.18	0.46
	BP	0.32	0.30	-0.46*
Internode length	Bt		0.13	0.27
	Dh		0.10	0.26
	BP		0.47*	-0.15
Culm thickness	Bt			0.16
	Dh			0.21
	BP			-0.06

For critical value of r see table 5.

and valley land (N. Lakhimpur) conditions. The choice of species for commercial cultivation may, therefore, vary from place to place within a small geographical region.

The comparative mean expression and variability for culm morphological characters in the three species at the two locations is presented in Table 3. A perusal of the table shows higher culm girth of 52.90 cm for *D. hamiltonii* at N. Lakhimpur as compared with 29.32 ± 0.60 cm at W.Siang. On the other hand, internode length was slightly lower at N. Lakhimpur. Internode volume may, therefore, be a more stable character in *D. hamiltonii* than its length or girth.

Corresponding figures for *B. tulda* and *B. pallida* for culm girth and internode length at the two locations are marginally higher for plus bamboos at N. Lakhimpur than the bamboos at W. Siang (Table 2). It can, therefore, be concluded that the culm morphological characters are less affected by the environment in comparison to clump morphology and management traits. Interrelationships for various morphological and cutting management traits are also computed for W. Siang data and presented in Tables 4 and 5. *Inter se* associations among internode length, culm thickness, diameter of hollow and culm girth show non-significant and low r -values. This indicates that there is a possibility for improvement through a selection of individual traits. Moderate r -value for correlation between internode length and culm girth (0.57) and between diameter of hollow and culm girth (0.46) in *D. hamiltonii* indicates that internode volume is a better selection criterion than individual component traits. Table 5 shows that clump size is positively correlated ($r=0.88^{**}$) with the number of culms for *D. hamiltonii* whereas these values were low to moderate in the case of *Bambusa* spp. Interrelationships of culm girth, internode length, thick-

ness and diameter of hollow with clump size and number of culms show a significant positive correlation between clump circumference and internode length (0.70^{**}), and diameter of hollow (0.69^{**}) and a moderate value (0.48^*) in the case of culm girth in *B. tulda*. Culm thickness was negatively but insignificantly associated ($r=0.16$) with clump size. Thus, it is important to maintain an optimum size of the clump to get thicker culms whereas direct selection can be practised for other characters in *B. tulda*. In *D. hamiltonii* the correlation between clump size and diameter of hollow was negative (-0.22). In *B. pallida* the correlation matrix was similar for girth and hollow and varied for internode length and culm thickness as compared with *B. tulda*. The interrelationships of culm morphological characters with clump size or number of culms may be determined further in relation with completely mature clumps and samples at the growing stage to determine selection criteria. Further, the association pattern of cutting management component traits with number of culms is highly correlated in all the species except for a low value of r in *B. pallida* for number of cut culms and total culms/clump (0.25). This clearly shows consistency in cutting management of cultivated bamboos irrespective of species under cultivation in W, Siang. The corresponding matrix is, however, not similar when clump circumference is used for computations hence further sampling is required.

Cultivation Propagules

Bamboo propagation is by and large from seed, offsets, cuttings and layers (Varmah & Pant, 1981). Prasad and Kochhar (1986) reviewed these propagation practices. Selection criteria regarding the vigour of the propagule and its relation with adult plant performance have been reported in

Table 5. Character association for clump size and number of culms/clump with various culm characteristics and cutting management parameter

Character Species/Type	Clump			Number of culms		
	Bt	circumference Dh	BP	Bt	Dh	BP
<u>Culm morphological characters</u>						
Girth	0.48*	0.18	0.45*	-0.42	0.64*	0.34
Internode length	0.70**	0.07	0.08	-0.04	0.01	0.14
Culm thickness	-0.16	0.19	0.23	0.19	0.89**	0.45**
Diameter of hollow	0.69**	-0.22	0.77**	0.35	0.12	-0.20
Number of culms/clump	0.33	0.88**	0.45*	0.33	0.88**	0.45*
<u>Cutting management parameter</u>						
Cut	-0.06	0.62*	-0.27	0.79**	0.91**	0.25
Old	0.66**	0.59*	0.55*	0.61**	0.94**	0.76**
Young	0.55*	0.20	0.47*	0.86**	0.74**	0.89**
Juvenile	0.32	0.32	0.53	0.60**	0.89**	0.71**
YN	20	15	20	20	15	20
<u>Critical value</u>						
of r- at 5% level	0.44	0.51	0.44	0.44	0.51	0.44
- at 1% level	0.56	0.64	0.56	0.56	0.64	0.56

literature for selection in favour of erect types (Kondas *et al.*, 1973 a,b), right-handedness (Bahadur *et al.*, 1978) and one-year-old seedlings in preference to two-year-old ones (Varmah & Bahadur, 1981). Raising of seedlings from chemical treatment of culm cuttings is successful in certain species (Waheed Khan, 1972, Surendran *et al.*, 1983). Sharma (1986) reported 77 percent success in growth of nodal plants of *D. hamiltonii*. Studies are being carried out at the A.P Centre using two-noded culm cuttings of *B. tulda*. Table 6 shows a comparison between the morphological characters of one-year-old seedlings raised from seed (*B. pallida*) and through chemical treatment (*B. tulda*) for six characters. The number of culms is around four in both cases but greater consistency is seen for seedlings raised from seed (C.V.= 8.7). The mean maximum culm height was greater for nodal plants whereas the mean average culm height was comparable for seedlings (96.48 ± 0.63 cm) and nodal plants (98.00 ± 1.58 cm) in the first year of growth. Internode length in the two cases was also comparable (Table 6). The number of roots was found to be highly variable (C.V. = 57.8 and 95.1) but mean values were similar in seedlings (24.13 ± 0.41) and nodal plants (22.70 ± 1.29). Root length on the other hand varied considerably between the

two seedling types. The mean root length in nodal seedlings was higher (27.53 ± 0.62 cm) than in seedlings (15.51 ± 0.63 cm) but the coefficient of variation was comparable. This can be attributed to the application of growth-inducing chemicals to nodal plants. The vigour of one year-old seedlings may also be improved if boric acid at 100-200 ppm or other growth regulators are applied at the six to nine months stage.

Improvement Studies

A glance at the collections at the A.P Centre shows a wide variation in morphological traits of the vegetative propagules (rhizomes) collected during different expeditions, namely, culm diameter (0.5-16.5 mm), culm thickness (0.5-3.3 cm), hollowness (0.3-12.5 cm), internode length (6.0-52.0 cm) and other characters. These traits are directly related to the utility aspect of the species. It is proposed to work out an index for determining the phenological stage of individual clumps/population to facilitate decision-making in cutting management or during replanting. A phenological quotient (P) can be derived from simple or weighted analyses of (i) key to growth stage of individual clump and culms within a

Table 6. Morphological characters of one year old seedlings raised from seed and through chemical treatment of two nodal cuttings at Basar

Character	Seedling type	X ± S.E.	Range	C.V.
Number of culms/seedling	Seed	4.17 ± 0.16	2-7	8.68
	Nodal	4.00 ± 0.33	1-7	35.36
Culm height maximum (cm)	Seed	130.46 ± 0.90	84-261	30.34
	Nodal	143.00 ± 1.82	58-220	30.12
Culm height average (cm)	Seed	96.48 ± 0.63	60.5- 147.3	19.76
	Nodal	98.00 ± 1.58	54-149	30.50
Internode length (cm)	Seed	16.13 ± 0.27	8.5-29.0	22.72
	Nodal	13.60 ± 0.59	8.3-24.7	33.33
No. of roots	Seed	24.13 ± 0.41	11-45	57.82
	Nodal	22.70 ± 1.29	2-42	95.08
Root length (cm)	Seed	15.5 ± 0.26	8.8-26.8	32.30
	Nodal	27.53 ± 0.62	6.0-42.0	37.94

clump, (ii) proportionate number of culms in different growth stages, (iii) weighted mean for individual culm-class and (iv) expected maturity span left to be completed after a particular cutting operation.

Further, in order to attain the ultimate objective of fast-growth and early maturity for obtaining vigorous and better quality types, a chemical mutagenesis programme has been designed and undertaken on *B. pallida*. Initial observations show segregation in M-1 for seedling height, leaf size, etc. The studies are continuing.

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Role of Bamboos in Secondary Succession after Slash and Burn Agriculture at Lower Elevations in North-east India

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Abstract

Slash and burn is the prevalent agricultural practice in North-east India. The secondary succession after this man-made disturbance is rapid. The plant communities are continually developing, changing and disappearing, giving way to another community. Bamboos are one community which prevails on these lands for a longer period of time due to their longevity and fast growth. The species seen in North-east India are Dendrocalamus hamiltonii, Neohouzeua dulloo and Bambusa khasiana. Their varied densities, growth patterns and adaptability towards a changing environment help in community stabilization. The greater affinity of bamboos towards cations, particularly potassium, helps to conserve these elements. The present study investigates the role played by bamboos in succession, especially in the conservation of nutrients, which is an important factor in the management of successional forests in North-east India.

Introduction

It is generally accepted that most types of vegetation are subject to temporal changes both in species composition and in the relative importance of constituent life forms. These changes are of two kinds: successional and cyclic. The successional change is characterized by progressive alteration in the structure and species composition of vegetation (Clements, 1916; Watt, 1947). Bamboos are one community that colonizes disturbed lands in the tropics (Drew, 1974; Soderstrom & Vidal, 1975). Troup (1921) and Haig *et al.* (1958) also stated that as a result of shifting agriculture, huge expanses of grass and bamboo forests have been established in Asia. In North-east India, bamboos constitute the major vegetation after slash and burn agriculture (Ramakrishnan *et al.*, 1981; Toky & Ramakrishnan, 1983a). Due to their adaptability (Rao & Ramakrishnan, 1987; 1988a, b) and nutrient conservational role (Toky & Ramakrishnan, 1982; Rao & Ramakrishnan, 1988c), they play a special role in succession. The present study deals with the role of bamboos in succession.

Methods

The study was done at different places in North-East India during 1983-85 and a summary of observations is presented here. The vegetation association was analysed in the 1.5, 10, 15, 20, 25 and 60-year-old fallows using thirty 10 x 10 m quadrats for shrubs and trees and thirty 1 x 1 m quadrats for herbaceous vegetation. Biomass estimations were done by the destructive method for herbs and bamboos and a linear regression (diameter at breast height and plant weight) was determined for trees and shrubs (Rao, 1986). The chemical composition was analysed using techniques suggested by Allen *et al.* (1974).

Results and Discussion

The farming settlements in the humid tropics follow traditional bush-fallow agriculture also called as slash and burn agriculture or shifting cultivation. This process, locally called 'jhum', involves slashing of forest vegetation, burning it and cropping for a short period followed by a

Table 2. Biomass (kg/ha) in different jhum fallows

Component	Fallow age (yr)		
	5	10	15
Herbs	413	65	35
Bamboos	796	2825	4925
Shrubs & trees	757	2200	4715

placed by more competitive K-strategists (bamboos and perennial weeds) and the succession involves the C-S-R-strategies of Grime (1979).

Standing biomass contribution by the ruderal (R-) strategists (herbs) reduces drastically with increase in fallow age while competitive (C-) strategists (bamboos) and stress-tolerant (S-) strategists (trees and shrubs) contributed more (Table 2). Bamboos, with their plasticity in architecture (Rao & Ramakrishnan, 1988a), create shade and reduce nutrient availability, thereby affecting the reproductive efforts of ruderals. While the biomass contribution of bamboos increases up to 25 years of fallow regrowth (Rao & Ramakrishnan, 1988a), in a 60-year-old fallow, shrubs and trees contribute more (Singh & Ramakrishnan, 1982).

A sharp increase in the above ground biomass occurs during secondary succession. According to Lugo (1973) the maximum biomass value for tropical forests is approached in about 30 years at a level of 250 t/ha. The rate of accumulation of biomass is faster in the early stages of succession but may decline in the subsequent years. The rate also depends upon the type of initial vegetation established and on other environmental conditions (Uhl & Jordan, 1984; Toky & Ramakrishnan, 1983a; Mishra & Ramakrishnan, 1983a). It is noted that the slower growth rate of shrubs and trees, in comparison to herbs during the early stages of succession is due to the heavy loss of photosynthate for supporting structures at the expense of leaf area. The competitive bamboos have rapid rates of dry matter production, continuous stem ex-

tension and leaf production during the growing period and rapid phenotypic adjustments in leaf area and shoot morphology in response to shade (Rao & Ramakrishnan, 1988a, b).

While losses of nitrogen, phosphorus, calcium and magnesium were found to diminish with fallow age (Fig. 2), losses of potassium increased up to 20 years of fallow re-growth (Toky & Ramakrishnan, 1983b). Nitrogen, phosphorus and potassium are the most essential elements in tropical soils. After burning, nitrogen is volatilized (Allen, 1964; Knight, 1966; Debell & Ralston, 1970) and phosphorus is fixed into unavailable forms or volatilized (Lloyd, 1971; Gebhardt & Coleman, 1974; Tinker, 1977; Parfitt & Lee, 1979; Mishra & Ramakrishnan, 1983b; Swamy, 1986). Loss of potassium through run off and percolation is higher than calcium and magnesium because of its easily soluble nature (Allen, 1964; Lloyd, 1971). While the reduction of losses in nitrogen, phosphorus, calcium and magnesium is due to their accumulation in standing biomass, the continued potassium losses can be attributed to the high turnover of this element through bamboo leaf litter.

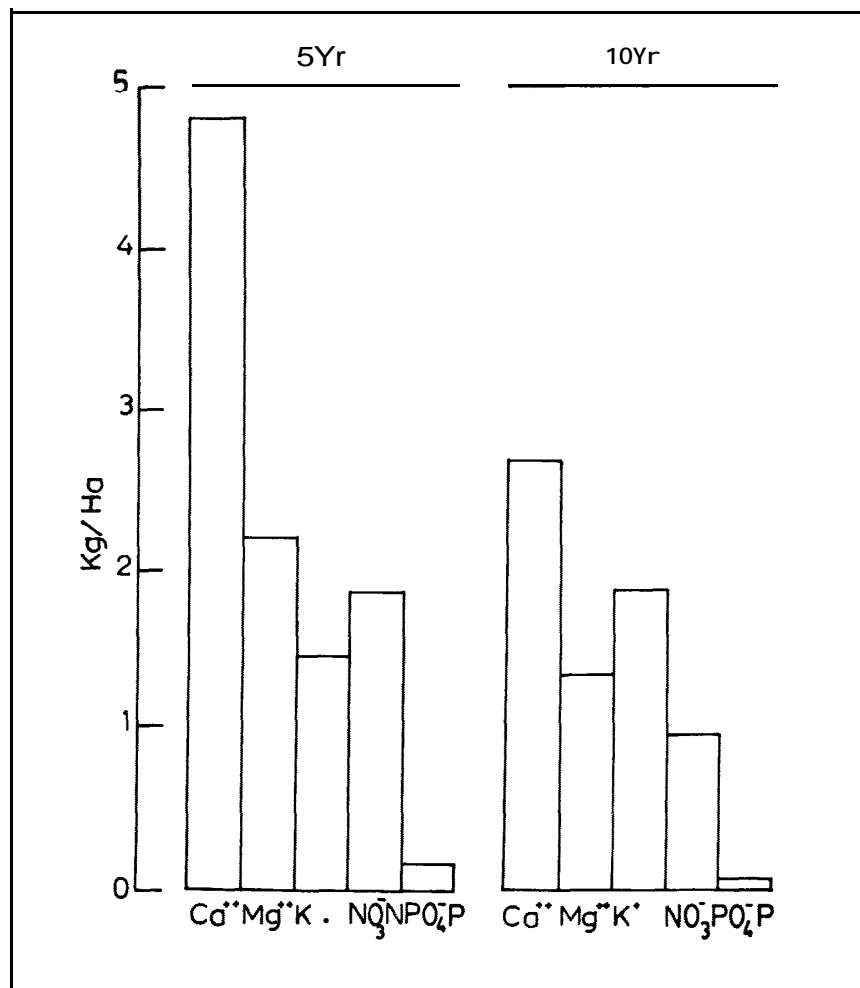


Fig.2. Loss of nutrients through wafer from jhum fallows.

Table 3. Density of elements (kg/ha) in the vegetation in jhum fallows

Fallow age (yr)	Element	Herbs	Bamboos	Shrubs & trees	Total
5	Nitrogen	4.3	48.5	20.6	75.4
	Phosphorus	8.9	15.5	6.7	31.4
	Potassium	9.6	175.4	96.4	281.3
	Calcium	3.7	18.7	90.8	112.9
	Magnesium	4.8	12.7	60.4	77.8
10	Nitrogen	1.0	155.6	106.8	263.3
	Phosphorus	1.3	41.3	23.2	65.9
	Potassium	0.9	487.0	307.8	795.7
	Calcium	0.6	51.9	296.8	349.3
	Magnesium	0.8	41.3	137.7	179.9
15	Nitrogen	0.7	217.2	133.2	351.1
	Phosphorus	1.0	63.1	39.3	103.5
	Potassium	0.9	772.5	369.4	1246.3
	Calcium	0.4	85.4	306.1	391.9
	Magnesium	0.4	65.7	137.3	203.4

Table 4. Inventory of nitrogen and phosphorus in total vegetation and in the bamboo component (parentheses) in different jhum fallows

Inventory	Fallow age (yr)		
	5	10	15
<u>Nitrogen</u>			
Above ground biomass (kg/ha)	75.4 (48.5)	263.3 (155.6)	351.1 (271.2)
Release through litter (kg/ha)	36.7 (17.1)	77.2 (47.2)	88.9 (74.9)
% annual turnover	48.6 (35.2)	29.3 (30.5)	25.3 (34.5)
Annual nutrient accumulation (kg/ha)	12.0 (6.3)	20.7 (15.8)	17.4 (6.8)
Enrichment ratio	(7.7) (7.7)	12.8 (9.9)	20.2 (31.8)
<u>Phosphorus</u>			
Above ground biomass (kg/ha)	31.1 (15.6)	65.6 (41.3)	103.5 (63.1)
Release through litter (kg/ha)	16.6 (3.3)	13.0 (5.9)	24.9 (11.2)
% annual turnover	53.2 (21.0)	19.7 (14.2)	24.0 (17.7)
Annual nutrient accumulation (kg/ha)	(0.3) (0.3)	5.2 (4.6)	6.8 (3.3)
Enrichment ratio	45.3 (62.3)	12.7 (8.9)	15.2 (19.1)

Table 5. Inventory of potassium, calcium and magnesium in total vegetation and in the bamboo component (parentheses) in different jhum fallows

Inventory	Fallow age (yrs)		
	5	10	15
<u>Potassium</u>			
Above ground biomass (kg/ha)	281.3 (175.4)	795.7 (487.0)	1246.3 (772.5)
Release through litter (kg/ha)	45.4 (20.4)	69.3 (58.8)	102.9 (82.7)
% annual turnover	16.1 (11.7)	8.7 (12.1)	8.3 (10.7)
Annual nutrient accumulation (kg/ha)	53.6 (31.0)	118.2 (54.7)	113.7 (52.3)
Enrichment ratio	5.3 (5.7)	6.7 (8.9)	9.3 (14.8)
<u>Calcium</u>			
Above ground biomass (kg/ha)	112.9 (18.4)	349.3 (51.9)	391.9 (85.4)
Release through litter (kg/ha)	39.2 (2.5)	49.9 (8.1)	55.3 (13.4)
% annual turnover	34.7 (13.7)	14.3 (15.7)	14.1 (15.7)
Annual nutrient accumulation (kg/ha)	3.8 (0.3)	17.8 (5.7)	30.8 (5.7)
Enrichment ratio	30.2 (57.6)	19.7 (9.1)	12.7 (15.1)
<u>Magnesium</u>			
Above ground biomass (kg/ha)	77.8 (12.7)	179.9 (41.3)	203.4 (65.7)
Release through litter (kg/ha)	21.4 (2.7)	21.6 (7.7)	26.8 (12.6)
% annual turnover	27.5 (21.0)	12.0 (18.6)	13.2 (19.2)
Annual nutrient accumulation (kg/ha)	1.6 (0.2)	2.8 (0.5)	2.8 (0.7)
Enrichment ratio	50.4 (63.4)	63.8 (87.9)	72.2 (91.3)

The density of elements in the standing biomass is given in Table 3. Competitive bamboos store more nitrogen, phosphorus and potassium than stress-tolerant shrubs and trees while the reverse is true for calcium and magnesium. While the amount of nitrogen and phosphorus held in the above ground biomass and that released through litter improved in older fallows, the annual turnover percentage of nitrogen declined with fallow age while that for phosphorus declined in the 10-year old fallow and improved in a 15-year-old one (Table 4). Whereas the enrichment ratio for

nitrogen improved, that for phosphorus remained more or less constant. Potassium, calcium and magnesium held in above ground biomass and released through litter improved with fallow age (Table 5). Annual nutrient accumulation improved with fallow age and the enrichment ratio for the three elements showed improvement. Among the three bamboo species, *N. dulloa* was a more efficient conserver of nitrogen, phosphorus and potassium, as is evident from tissue concentration (Rao, 1986). Bamboos thus play an important nutrient conservational role in these ecological conditions.

The observations from the present study show that the bamboos follow a strategy of faster uptake and storage of essential elements and a quicker turnover to supplement the soil flux, thus efficiently dominating the stress tolerant shrubs and tree species for a long duration. Bamboos promote stability in the ecosystem through regulation of its functions like other competitive early successional species.

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Flowering Characteristics of some Bamboos in Thailand

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Abstract

Flowering of bamboos occurs every year- in Thailand. The earliest flowering period, from flower initiation to seeding starts in October and ends in February. In general, bamboos start flowering by late November or early December which continues till March/April. Three patterns of flowering were observed: clump flowering, culm flowering and continuous flowering. With the exception of the continuous flowering pattern, all bamboos die after the flowering period. The morphological characteristics of the inflorescence and seed of bamboos are distinctively different. However, it was noticed that large-sized bamboos produced smaller-seeds than small-sized bamboos. Those that flowered gregariously and have the clump-flowering pattern produced more viable seeds than bamboos that flowered sporadically.

Introduction

Flowering of bamboos after extended intervals has long been recognized. With the exception of one or two species, bamboo clumps die after flowering. There is no scientific method available to predict the flowering cycle of bamboos unless the year of seed production is known. Since bamboo has become commercially important among other tree species, an investigation on the most suitable propagating material, the seed, is important. Its distinct flowering characteristics were also studied.

Flowering Period of Bamboo

In Thailand, sporadic flowering of bamboo occurs every year in different geographic locations. The period from flower initiation to seeding takes approximately five months. The earliest flowering starts in October and ends in February. In some locations, bamboo comes to flower in November or December and sets seed in March or April, correspondingly. It has been noticed that most bamboos in the northern and north-eastern parts of Thailand flower earlier than those in the central and southern parts. It has also been observed that most bamboos in the southern part seldom flower whereas those in other parts of the country, flower every year.

Flowering Patterns

Unlike other plants, flowering can be considered as one of the most distinct characteristics of bamboo. Bamboos have considerably long flowering or seeding cycles and it is impossible to predict exactly when flowering is likely to occur. In some areas where forest fire causes severe damage, flowering can be initiated by the underground rhizome (Figs. 1 A-D, 2 A-C).

In general bamboo flowers both gregariously and sporadically. They basically exhibit three patterns of flowering.

Clump Flowering

When bamboos reach the flowering stage, flower buds are initiated instead of vegetative buds. Every culm in the clump flowers (Fig. 3A,B). Bamboos which belong to this flowering pattern are *B. arundinacea*, *B. nutans*, *Cephalostachyum pergracile*, *C. virgatum*, *Dendrocalamus asper*, *D. brandisii*, *D. strictus*, *Gigautochloa albociliata* and *G. hasskarliana*.

Culm Flowering

In sympodial bamboos, there are some species which take more than a year to complete flowering. During the flowering period, it is observed that some culms continued to grow vegetatively while the others flower and die. Thus, culms that do not



Fig. 1A-D. Flowering from severely damaged clump of (A,B) *Bambusa nutans* and (C,D) *Gigantochloa hasskarliana*,

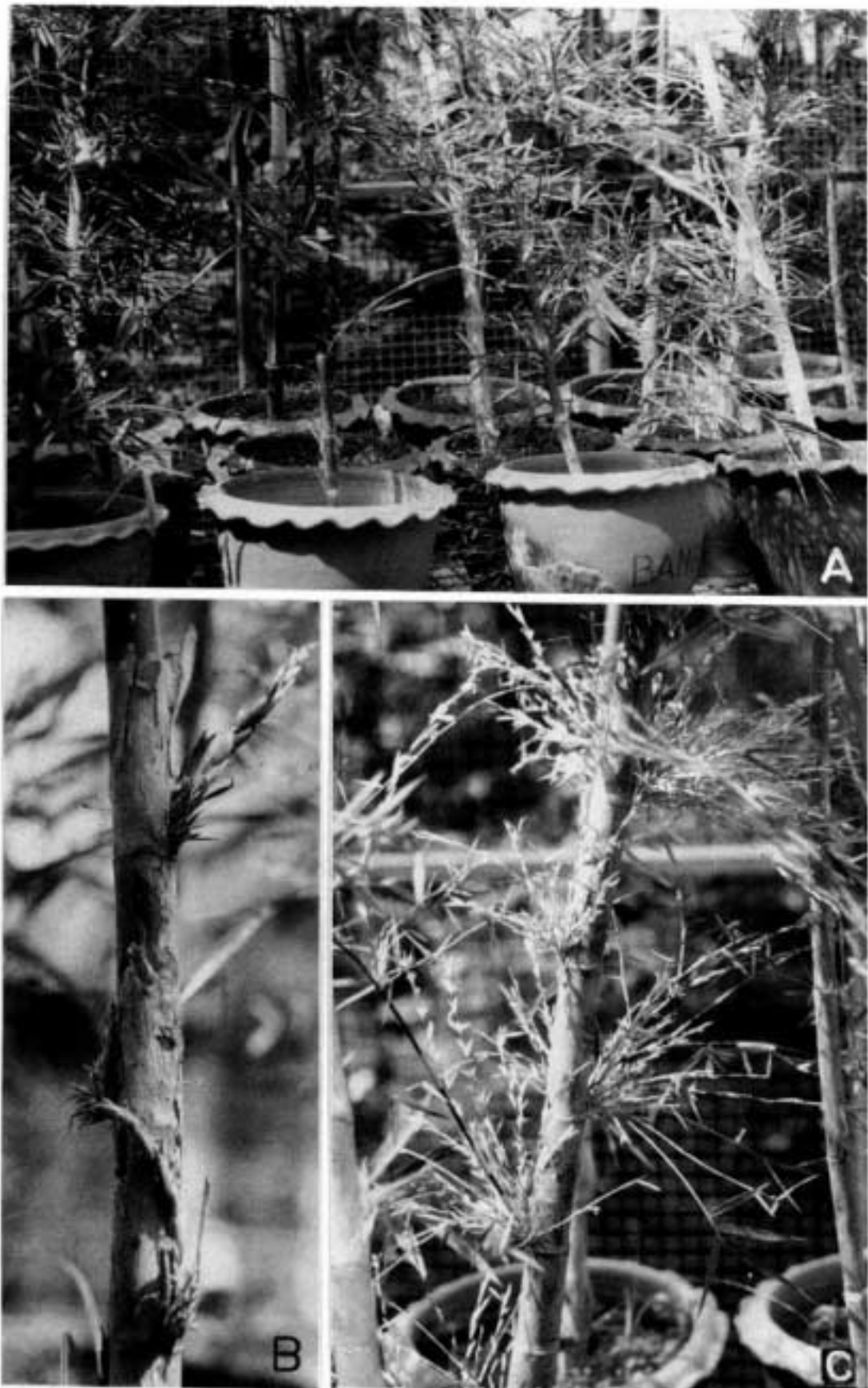


Fig. 2A-C. Flowering of transplanted culms of *Thyrsostachys siamensis*.

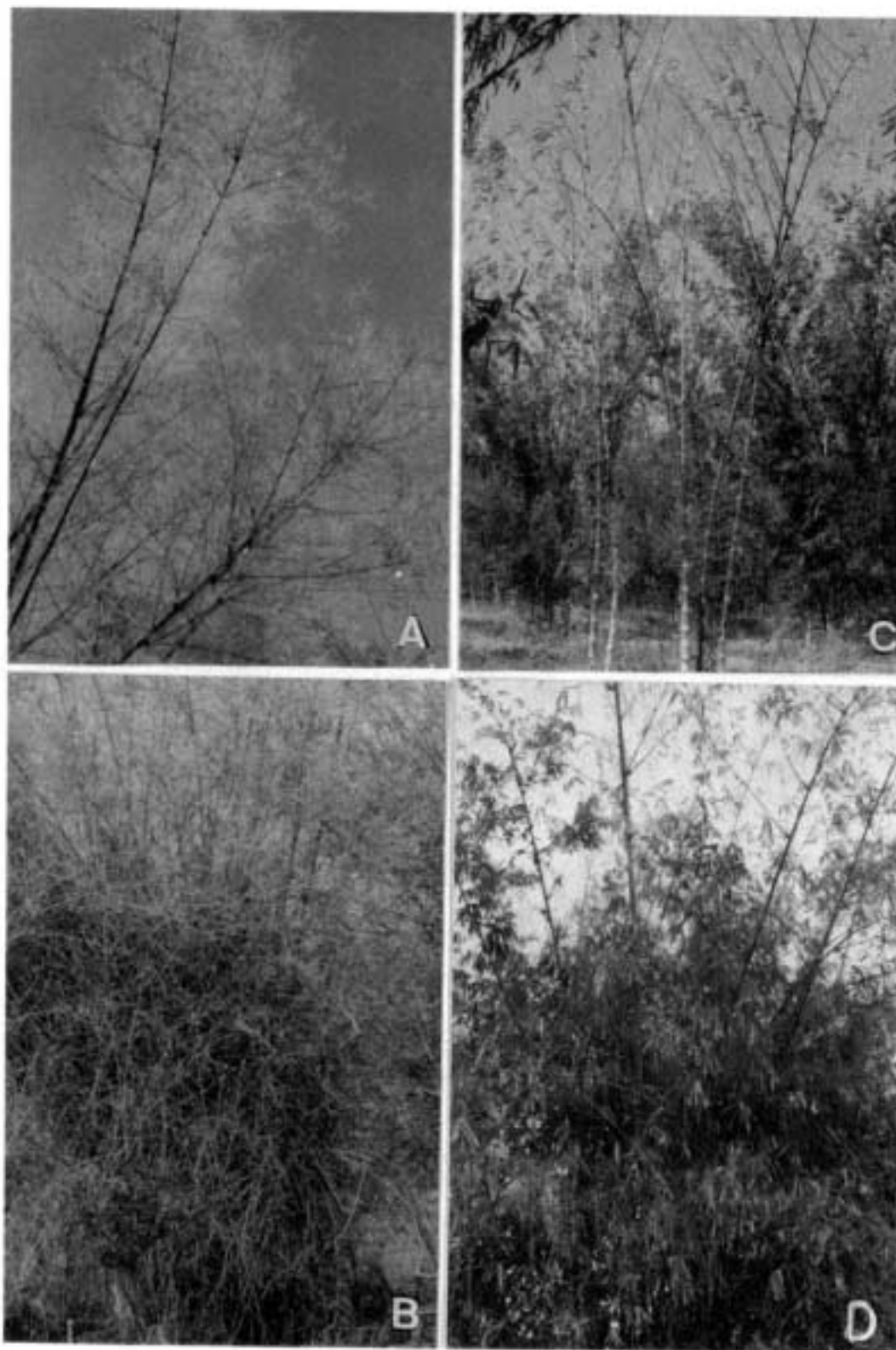


Fig. 3A-D. Clump flowering pattern of (A,B) *Bambusa arundinacea* and (C,D) *Dendrocalamus endrocalamus asper*.



Fig. 4 A-D. Continuous flowering of *Schizostachyum brachycladum*.

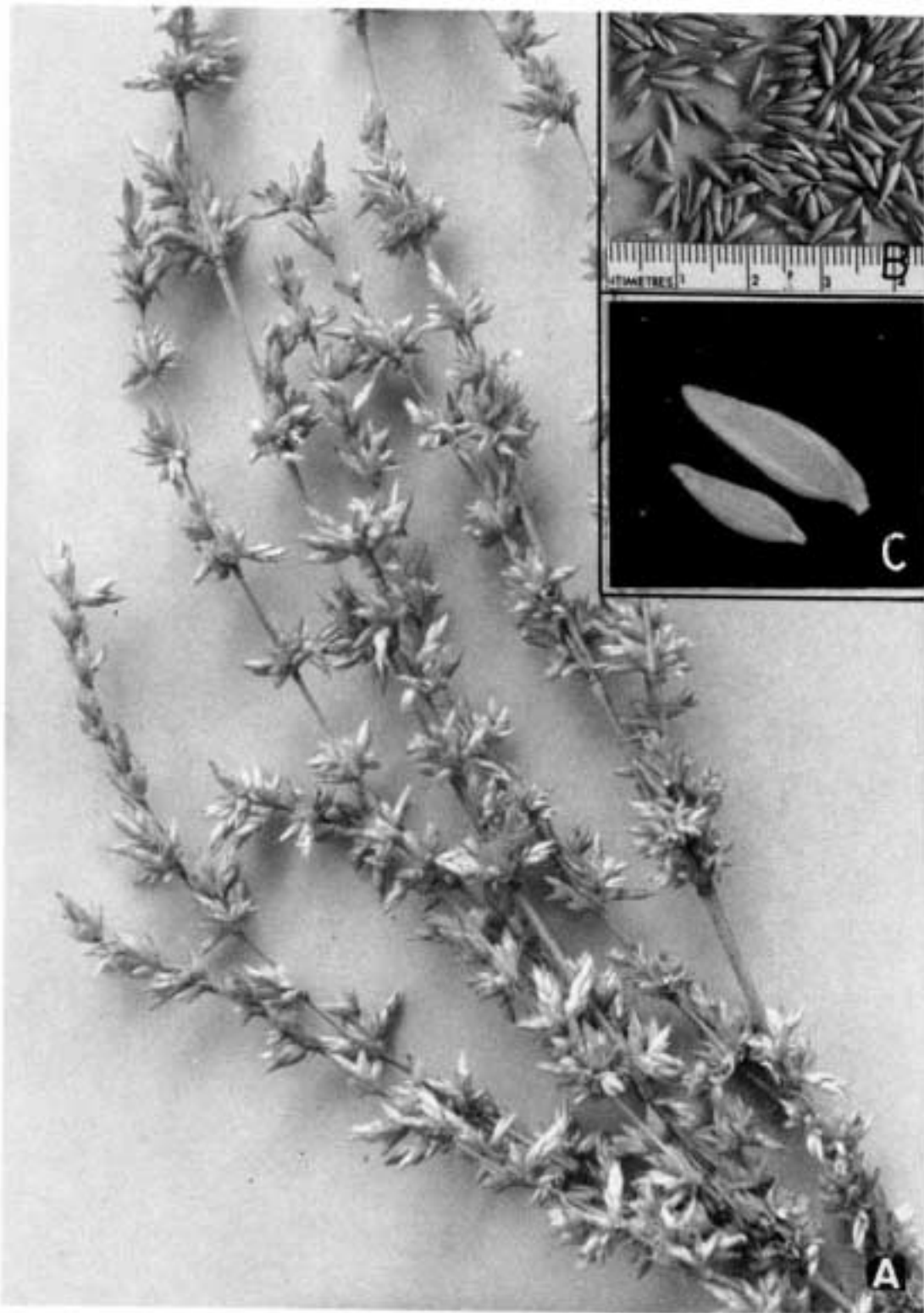


Fig. 5 A-C. Morphological characteristics of inflorescence and seed of *Bambusa arundinacea*.

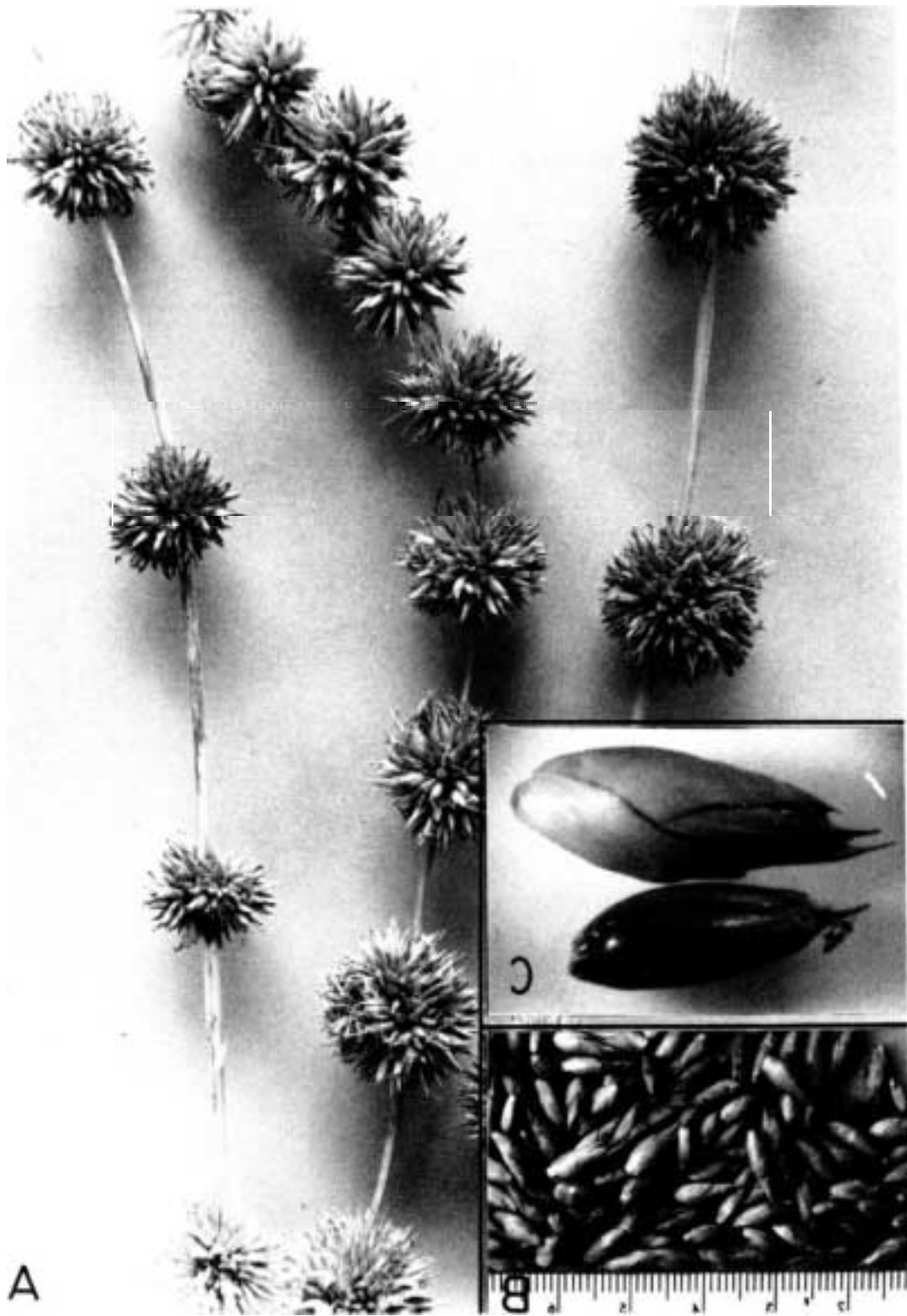


Fig. 6 A-C. Morphological characteristics of inflorescence and seed of *Dendrocalamus strictus*.



Fig. 7 A-C. Morphological characteristics of inflorescence and seed of Cephalostachyum pergracile.

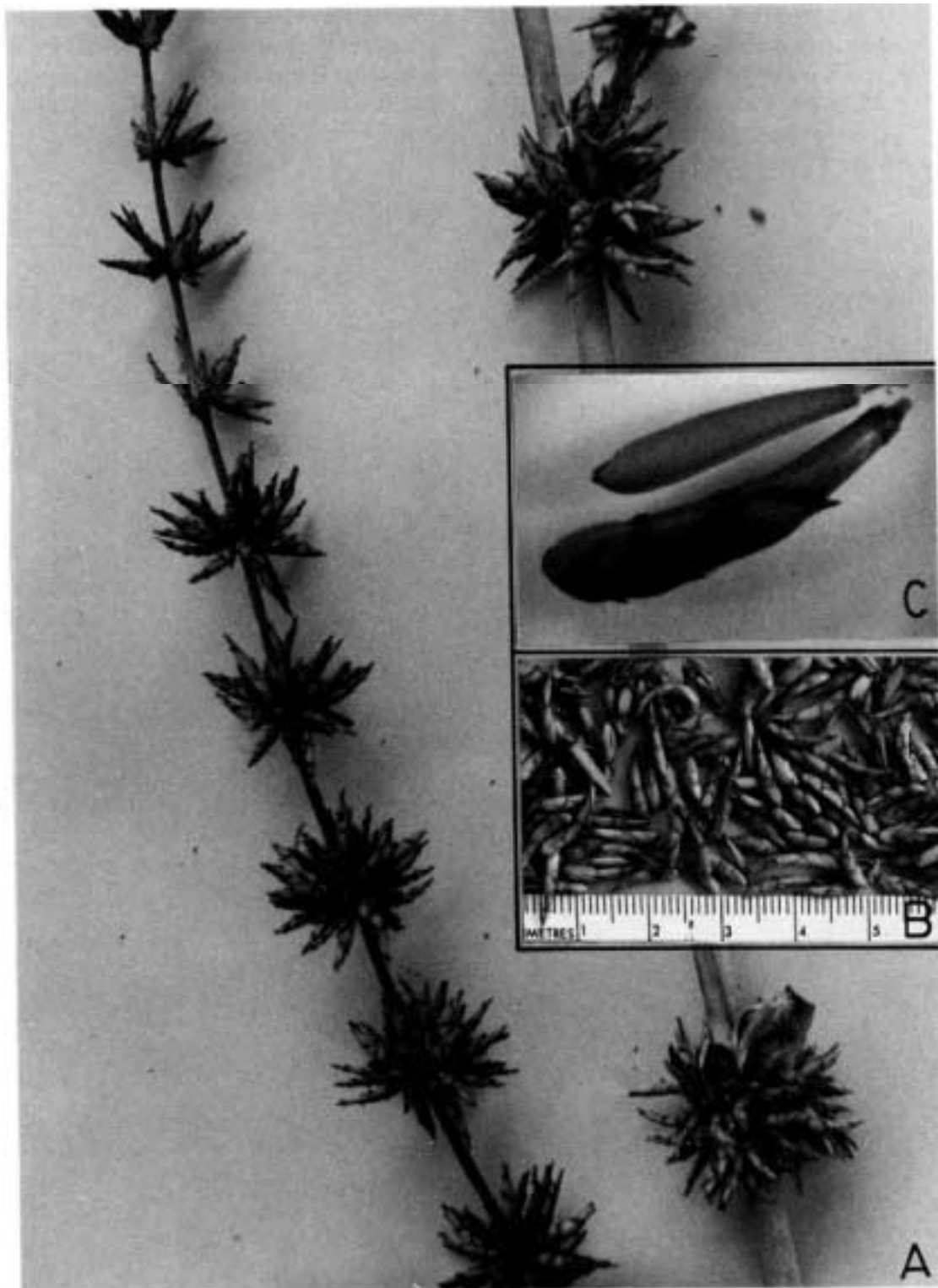


Fig. 8 A-C. Morphological characteristics of inflorescence and seed of Gigantochloa hasskarliana,

flower in the first year did so in the following year or two years later (Fig.C,D). However, the whole clump will die after every culm has flowered. This pattern of flowering is observed in *Dendrocalamus asper* and *Thyrsostachys siamensis*.

Continuous Flowering

In general, bamboos die after flowering. However, it was observed that *Schizostachyum brachycladum* continuously flowered. In addition to vegetative growth, flowering was seen to occur in some parts of the culms within the clump (Fig. 4A-D). Species which exhibit this flowering pattern seem to grow continuously and do not die after flowering.

Seed Production

Collection of bamboo seeds in Thailand is carried out every year from *Bambusa arundinacea*, *Dendrocalamus strictus*, *Gigantochloa albociliata* and *G. hasskarliana*. The morphological characteristics of the inflorescence and seed of these species are shown in Figures 5 to 8. Among the species, flowering and seed characteristics are distinctively different and can be used for identification. It has been observed that large-sized bamboos produced smaller seeds when compared to small-sized ones.

PROCEEDINGS OF
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MANAGEMENT OF
BAMBOO FORESTS

Scope for Change in the Management of Natural Bamboo Stands

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Abstract

A proposal is made for modification in the management practice of bamboo forests. Clear-felling of congested clumps should be carried out. Sporadically-flowered clumps should be worked on a priority basis irrespective of whether the particular coupe is due for working or not. The flowered areas should be treated so as to retain the number of seedlings necessary for restocking the area and their growth ensured by opening up the canopy, soil working and weeding. Adequate protection should be provided against biotic factors to allow adequate regeneration. Besides, other bamboo species also need to be propagated through the establishment of plantations.

Introduction

Bamboo is a very important forest produce. It plays a vital role in the socio-economics of the rural population. In India, bamboos have a wide range of distribution forming an understorey in several forest types. The tropical moist deciduous forests of northern and southern India and the deciduous and semi-evergreen forests of north-eastern India are the natural habitats of bamboos. The total forest area covered by bamboos in the country is about 9.6 million hectares (Sharma, 1985). This is about 12.8 percent of the total forest area of the country. In Madhya Pradesh (M.P.), the bamboos cover more than 1.8 million hectares of area (Dutta & Tomar, 1984). The major species are *Bambusa arundinacea*, *Cephalostachyum pergracile*, *Dendrocalamus strictus* and *Oxytenanthera nigrociliata*. Of these, only *D. strictus* is exploited on a commercial basis as the other species are found only in small patches. *B. arundinacea* occurs in 14 districts of the State. *Oxytenanthera nigrociliata* occurs only in Bastar and Raipur districts. *Cephalostachyum pergracile* occurs only in Bastar district.

In Madhya Pradesh, bamboo forests are managed on scientific and systematic lines for the supply of raw material to the paper mills and to meet the requirements of the rural population.

This paper outlines a proposal for modification in the management practises of bamboo forests of Madhya Pradesh. These modifications can also be made applicable to the bamboo forests in other

States in India and countries having bamboo forests, provided the local conditions are favourable.

Present Status Of Management of Bamboo Forests

Till 1970, the bamboo forests were being worked through a contractor system, but at present, these are being worked departmentally. The felling cycle has been fixed at four years throughout the State. The bamboo forests have been categorised as under:

Type I

Good quality bamboos with high density (Hoshangabad, Betul and Chhindwara districts)

Type II

Bamboo forests of inferior quality and of low density (Bastar, Chhindwara, Seoni and North Raipur districts)

Type III

Good quality bamboos on slopes (Bastar and Kanker districts)

Type IV

Bamboos with high density but in scattered patches (Bastar district).

For the purpose of bamboo working in the coupe, the area is differentiated into the above types purely based on the density and height of bamboos. Thereafter, the marking of bamboos to be retained

in each clump is done with black paint at breast height. The number of culms for retention in a clump is written on a prominent reserved culm of the clump. Records of both the culms to be felled and those to be retained are maintained. The marking of the culms is based on the following rules

1. One and two-year-old culms will not be cut under any circumstances.
2. Rhizomes will not be dug out and exposed.
3. The height at which the culm will be cut shall not be less than 15 cm or more than 45 cm and in no case will the culm be cut below the first prominent node.
4. All cut debris will be kept at least one meter away from the clump.
5. Felling of bamboos will not be done in the period between 1 July and 15 October.
6. Clumps showing sporadic flowering will invariably be cut provided they have shed the seed.
7. In the event of gregarious flowering, all flowered clumps irrespective of their location in the coupe under working or elsewhere will be clear-felled after they have shed their seed. Disposal of such bamboos to be is expeditiously arranged so that they do not deteriorate and also cause a fire hazard.
8. Felling of bamboos should be completed by the end of March.
9. Bamboo forests should be strictly protected from fires and in no case should forest fires occur during the year of working and in the subsequent year.
10. Grazing will not be allowed during the rains in the worked up bamboo forests in the first year.
11. A clump shall be distinguished as an independent one, where its periphery is easily differentiated from adjacent clumps irrespective of its distance from others.
12. The minimum number of culms to be retained in a clump of various quality classes is as under:

Quality I	20 culms
Quality II	15 culms
Quality III	10 culms
13. The retained culms should be well-spaced and preferably at the periphery. These are retained in order of preference as shown below:
 - a) one-year-old culms,
 - b) two-year-old culms,
 - c) young green bamboos,
 - d) older live bamboos, and
 - e) others as per availability.
14. The commercial fellings are done only in the Type-I (well-stocked and well-grown bamboos)

areas. In the other type areas, only cultural operations consisting of felling of dead, dying, over-mature, burnt, broken and damaged bamboos are done. Congested clumps are clear-felled by forming triangular segments and the clump is clear-felled over three felling seasons.

15. The Type-IV areas are supplemented by establishing plantations of bamboos.

The above mentioned bamboo management rules came into force in the year 1974 (Anonymous 1974).

The result of the Departmental working in the bamboo forests of the State has been a continuous increase in the yield. The yield data for some years have been shown in Table 1.

Although, the present working of bamboo forests is quite satisfactory, practical and scientific, the present yield of bamboos is not sufficient for fulfilling the requirements of the paper mills and other users. The results of a study on the requirements of bamboos in the State for various purposes on the basis of the 1971 census of human population are as under (Lal & Joshi, 1977):

House-making, repairs, etc.	172 200 tonnes
Pan growers	6 000 tonnes
Cottage industry	125 900 tonnes
Small industries	164 412 nos.
Big industries	230 000 nos.

Efforts, therefore, need to be made for increasing the yield of bamboos in the State. On the basis of the recent research findings there is scope for amendments in the present management practices.

Proposed Amendments to Rules for Management of Bamboo Forests

Clear-felling of Congested Clumps

Congested clumps pose a problem not only for the felling of the culms but also of fire as they contain dead and dry culms. In the present management rules, the whole clump has to be clear-felled in three fellings. First the clump has to be divided into three parts and then one part is to be worked in one season. This results in unnecessary retention of the dead and dried culms in a clump for quite a long period. A study conducted in Shahdol district (Prasad, 1987) has shown that clear-felling of the congested clumps and allowing the new shoots to come up is more beneficial than the prevalent practice of working the congested clumps. This is because the congested clumps do not allow new shoots to come up easily; even if any shoot comes up it becomes malformed. On the other hand, if the clump is clear-felled in one stroke, good quality

Table 1. The yield figures of bamboo for different years (in tonnes)

Year	Commercial bamboo exploitation	Industrial bamboo exploitation	Total exploited bamboo
1973-74	25961.5	87206.0	113168.6
1974-75	24553.9	346668.2	371222.2
1975-76	4242 1.5	283970.1	32639 1.7
1976-77	83421.7	308758.2	392 179.9
1977-78	82183.0	276852.7	359035.7
1978-79	106391.0	294230.0	40062 1.0
1979-80	101089.3	260660.0	36 1749.3
1980-8 1	84782.0	183179.0	26796 1.0
1981-82	97286.0	191838.0	289 124.0
1982-83	99141.0	180923.0	280064.0
1983-84	77 157.0	16022 1.0	237378.0
1984-85	138512.0	19777 1.0	336283.0
1985-86	138000.0	2 11000.0	349000.0

culms can be obtained in greater numbers after four years.

Working of Sporadically-flowered Clumps

Although gregarious flowering in bamboo takes place at an interval of 25-40 years or more, sporadic flowering can be observed at any time in between two successive gregarious flowerings. Sometimes the number of clumps affected by sporadic flowering is quite high. But sporadic flowering occurs only in patches. In the present management rules, provision for felling of the (sporadically) flowered clumps is there only for those falling within the coupe. This provision needs to be amended and if the number of such clumps in a locality is reasonably high, they should be worked out. This will not only reduce wastage but also the fire hazard.

Treatment of Flowered Areas

So far, different management practices have been applied for the restocking of the gregariously-flowered areas of bamboo. In addition to the complete closure of the area from biotic interference, in some places, working of soil in strips has also been resorted to. A study was carried out in the flowered areas of Jabalpur district by Hakeem (1985). This revealed that if (i) the canopy of the upper storey is lightly opened in the areas after the working of bamboo, (ii) the new seedlings that come up are retained at a rough spacing of 4 x 4 m, and (iii) soil working and

weeding around the adopted bamboo seedlings are done in the first and second year, then the area can be restocked in a comparatively shorter period. As against the plantation cost of Rs 4000/ha, the expenditure in this case is only Rs 650/ha. This method is cheaper and also enables quicker restocking of the flowered area.

Protection Against Biotic Factors

Biotic factors play a negative role as far as the regeneration of bamboo is concerned. In the present management rules, provision for control of grazing in the felled coupes of bamboo is only for the first rainy season. This is insufficient. A study carried out on the effects of closure of flowered areas of bamboo against grazing (Prasad, 1985) has shown that in a period of three years, as against 3944 established bamboo seedlings in the unprotected areas, 8293 seedlings were found established in protected areas. It is, therefore, proposed that the flowered areas should be closed from grazing for five years. This will certainly allow the continued growth of new seedlings and shorten the time required for restocking of the area.

Propagation of Various Species

In Madhya Pradesh only *D. strictus* has been given attention as it occurs naturally in large areas. Plantations of *Bambusa arundinacea*, *B. vulgaris* and *D. strictus* have been raised at Jabalpur. Their growth data (Table 2) show that each of them can be planted in that locality. It is, therefore, proposed

Table 2. Growth data for different species of bamboo at Jabalpur

Species	Two years age		Four years age	
	Survival %	Height (m)	Survival %	Height (m)
<i>Dendrocalamus strictus</i>	95	2.42	95	4.42
<i>Bambusa vulgaris</i>	100	3.09	97	4.18
<i>Bambusa arundinacea</i>	97	2.62	96	4.86

that other species of bamboos should also be propagated through plantations.

The above proposals though mainly intended for the bamboo forests of Madhya Pradesh can be applied to other States also. It is hoped that the application of the above amendments/prescriptions will add to the quantity (yield) and quality of bamboos.

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Management of Bamboo Forests*

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Abstract

Bamboos are poor-man's timber. They are used for cottage industries and a large number of tribals depend on them. They are also used for manufacture of paper. Natural bamboo forests have been worked in India on cutting cycles of two to four years. The frequency of cutting cycles is based on working convenience. Periodic flowering coupled with misuse and lack of protection has reduced the extent of bamboo forests. Some foresters believe that bamboo rhizomes extend outwards and young bamboo culms depend on the support of the old culms. Studies have shown that the development of new culms is not peripheral. Culms older than two years do not affect the production of new culms. The productivity of bamboo forests depends on the production and size of new culms. Clump age is controlled by the genetics of the seed but culm age depends on the provenance and climatic conditions. Removal of dry culms increases the production of new culms. Vegetative reproduction methods have been worked out for several bamboo species but the success depends on the age of the culm and the season of cutting. Tissue culture work has succeeded only with juvenile seedlings.

Introduction

Bamboo forests occupy large tracts of land in India. Bamboos have also been planted in a sufficiently large scale in many States of the country. Among the many bamboo species found in India, the ones of commercial importance are *Bambusa arundinacea*, *B. tulda*, *B. vulgaris*, *Dendrocalamus strictus*, *Melocanna baccifera*, *Ochlandra travancorica*, *Oxytenanthera stocksii* and *Thyrsostachys oliveri*.

The flowering cycles of these bamboos vary from 7 to 60 years except for *Bambusa vulgaris* which has not gregariously flowered in India for the past 90 years. Bamboo forests were managed primarily for local use till about the year 1940 when it started being extensively used as a raw material for paper production. Much larger forest areas started being worked to meet the increasing demand of bamboos for the paper industry.

Flowering and Growth

Bamboo differs significantly from other vegetation in its flowering behaviour. Generally,

most bamboo species flower gregariously at fixed intervals and all culms including those of the current year die after flowering. The majority of the bamboos fall between the two states of constant flowering and constant sterility. An example of the former is *Bambusa atra* and that of the latter, *B. vulgaris*. Some bamboos die within two years of flowering like, *B. arundinacea*, while others do not die but their growth slows down during the flowering period as in *Phyllostachys* and *Arundinaria*. Most bamboo species have a more or less defined flowering cycle of 3, 7, 11, 15, 30, 48, 60 or 120 years. This flowering is like an alarm clock set to go off at a particular time in the entire population of a given species raised from the same seed source. No matter where they are situated all these bamboos would start flowering at the same time. Seeds of *Thyrsostachys oliveri* that flowered in Burma in 1891 were sown at Calcutta and Dehradun, 1500 km away from each other. The clumps raised from these seeds flowered simultaneously at Calcutta and Dehradun in 1940. These flowered again in 1987-88. This indicates a flowering cycle of about 48 years. *Dendrocalamus strictus* is known to flower both sporadically and gregariously at long

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intervals of 20-65 years. The period between two gregarious flowerings over the same area for a species is called its physiological cycle. This cycle is more or less constant for a particular provenance of a given species. In case of sporadic flowering, only the culms that flower die and not the entire clump. This is the case with *Bambusa vulgaris* where only sporadic flowering has been noticed. In the case of gregarious flowering, the whole clump dies including the rhizome after the ripe seeds have fallen.

Clump and Culms

Most bamboo species of commercial importance form clumps in India. The new seedling produces rhizomes which develop into culms. New rhizomes are produced from the previous year's rhizomes and the number of new rhizomes formed may vary from one to many. Some seedlings fail to produce clumps. This may be due to a selfing depression. Unlike a tree, bamboo does not acquire more girth as it grows; the new sprouts emerge with full diameter. It reaches full height in 60 to 120 days. In India, new culms generally appear during the rainy season. An unusual rain during the winter months may induce the emergence of new culms. Though the culms do not grow in diameter after sprouting, they continue to change in density and strength properties. Two kinds of buds are observed on the rhizomes, the scaly pointed buds and the flat buds. The former develop into rhizomes and the latter into culms. The scaly buds are formed during the summer months while the flat culm buds develop during the winter months. The culm buds emerge out of the soil with the early rains and grow rapidly. It is mostly the youngest rhizomes which produce the culms; they give rise to either scaly pointed buds or flat buds at a time and seldom do both of these develop simultaneously. In rare instances where climatic conditions are very favourable, three-year-old rhizomes may produce culms. The culms are very tender during the growing period. They are sometimes cut and made into vegetable or pickles. At this stage there is no terminal bud in the culm. Height growth is caused by the successive elongation of the internodes. The basal internode is the first to grow and the top-most one the last. However, several internodes from the bottom upwards grow simultaneously and 40-50 percent of the daily increment in height is contributed by only four to six internodes. The internodes are enclosed in sheaths. It is usually after completion of 65-75 percent of their height that the internodes become visible above the edges of the sheaths. Early ex-

posure of internodes from the sheaths results in stunted growth of the culm. The base of an internode is the most active part so far as growth is concerned. The age of an individual culm is not related to clump age. Culms are tender during the first year. They grow tough during the second year and are mature in the third year, when they acquire full density and strength. After this age they start changing colour. Depending on the climatic conditions and the species, culms dry up in 4 to 12 years. They die earlier in dry localities and have a longer life in moist areas.

Rhizomes

Rhizomes generally grow at an upward inclined angle. The angle of the incline depends on the species and the conditions of the soil. During this period of growth any exposure to sunlight stops rhizome development. Consequently, the bamboo clumps that are covered with earth or humus produce more culms whereas in areas where soil erosion takes place, the production of new culms is reduced. Rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear from anywhere in the clump provided overhead light is available for the emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery.

Coppicing

The green culms produce coppice shoots after cutting. These are thinner than the culms and are sometimes referred to as switches. These are covered with culm sheaths and are sometimes difficult to distinguish from the actual culms. Coppice shoots are also produced by injury to young culms and green culms of all ages may produce coppice shoots. If dry culms are not removed from a clump, the coppice shoots produced in such a clump may cause congestion.

Congestion

Congestion in bamboos is one of the most serious problems in clump management. Damage by man is probably one of the main causes of congestion in bamboos. Also heavy and irregular cutting make the bamboos non-workable while non-working of clumps causes further congestion.

Working Plan Prescription

In several working plans for the management of bamboo plantations, it is laid down that the first

working should start from 10-12 years after planting. This is very undesirable and most clumps are found congested in the very first year of working. In most bamboo forests, the cutting cycle ranges from three to four years. It is also prescribed that a coupe which is not worked in the year when it is prescribed will only be worked when it is due in the next cycle. This results in the presence of many dry culms as well as a large number of coppice shoots which develop from the dying culms. Many working plans also prescribe retention of a minimum number of old culms varying from 6 to 10 for providing support to the new culms. Development of new culms, however, takes place near the previous year's culms. Consequently, culms older than three years do not provide any support to the new culms.

Desired Prescription for Management

The following rules should be applied for obtaining high productivity with the desired quality of culms.

1. All bamboo culms above three years should be harvested.
 2. Harvesting should preferably be done each year. In natural forests where harvesting every year is not possible, it should be done in alternate years. In the intervening years where work is done after a gap, all the coppice shoots should be removed and intensive cultural operations carried out.
 3. Where congestion has already set in, the congested culms must be removed even if it leaves only the current year's culms.
 4. Where the young culms are twisted from the top they should be cut so that the new culms grow freely.
 5. No felling operations should be carried out between April and October.
 6. Bamboo areas should be strictly protected from grazing.
7. Mounding or heaping earth around the bamboo culms should be carried out each year before the rainy season.
 8. Trees providing light shade to bamboos should not be removed as bamboos grow better under the shade of trees such as neem, siris, amla and other light-crowned species.
 9. In no case should bamboo clumps be clear-felled. The clear-felled clumps generally degenerate into a bushy form.

Aerial Seeding

Aerial seeding for the regeneration of bamboos was carried out over vast areas in Maharashtra. This turned out to be a total failure. Although germination of the seeds was fairly high in certain protected pockets, these bamboos did not form clumps as the rhizomes got exposed to the sun and died.

Genotypes

When attempting a plantation of bamboos, it is essential that the proper genotype is used. Planting can be done either by seed or through rooted culm cuttings. Bamboos are also often planted through rhizome offsets. This method, however, has limited use because of the limited availability of the planting material. Rooted culm cuttings can be successful with most bamboo species. The age of the culm and the period when these cuttings are put out for rooting are important considerations. Two-year-old culms and the spring season have been found to give best results.

Tissue Culture

Several groups in India have worked on the tissue culture of bamboos. The success in producing plantlets has been only from juvenile seedlings. Efforts to produce plantlets from mature culms have not been successful so far.

Horse-shoe Harvesting Trials in Natural *Gigantochloa hasskarliana* Stands

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Abstract

Harvesting trials were conducted in the natural *Gigantochloa hasskarliana* stand at Thong-pha-phum, Kanchanaburi, using the completely randomized design with six treatments which varied in the intensity of harvesting in each clump. The production of bamboos was measured and analysed by analysis of variance. The results indicated that clear-cutting killed the bamboo plants, but selection cutting of those culms older than three years increased their production.

Introduction

Bamboo in Thailand is not only a "rural plant" but also an "industrial plant". As a rural plant, it plays a direct role in the normal daily life of the rural people. They make extensive use of bamboo as a building material and for manufacture of farm implements and household utensils. Bamboo shoots are an important food of the rural people, particularly in the rainy seasons, and are freely collected from the natural forests. As an industrial plant, bamboo is a raw material of the pulp and paper industries and furniture manufacturers.

It is estimated that about 600 million culms of bamboo are cut each year in Thailand. Some 7000 tonnes of bamboo poles and stalks valued at USD 730 000 were exported in 1980. The harvesting of bamboo is not supervised by any authority, nor any tending is ever practised. The tremendous amount of both bamboo culms and shoots taken out from the natural stands without any silvicultural practice, has resulted in depletion of the bamboo resource, resulting in a shortage in several areas of the country.

With these considerations in mind, horse-shoe harvesting trials were conducted in a natural stand of *Gigantochloa hasskarliana* (Kurz) Back. ex. K. Heyne at Thong-pha-phum, Kanchanaburi, to determine the most effective means of increasing production.

Site Description

Thong-pha-phum, Kanchanaburi, is located at

14° 40' N lat and 99° 50' E long. It is about 225 m above the sea level. The topography of the study area is plain with a gentle slope (15%). The high annual rainfall of more than 2500 mm is evenly distributed during late April to October. The annual mean temperature is 28 C with a maximum of 35 C and a minimum of 12 C. The soil is about 70 cm deep with a clayey loam texture and high organic matter content.

Method

The method of harvesting bamboo clumps in the shape of a horse-shoe as shown in Figure 1 was used in the experiments which were to determine the optimum intensity and age of the bamboo culms to be harvested in a clump. The experiments were carried out in a natural bamboo stand of *G. hasskarliana*. A completely randomized design with five replications was used in the trial. The treatments included the following levels of cutting in each clump:

- T₁ = 50% cutting of culms older than two years,
- T₂ = 100% cutting of culms older than two years,
- T₃ = 50% cutting of culms older than three years,
- T₄ = 100% cutting of culms older than three years,
- T₅ = 100% cutting of all culms at any age or clear-cutting,
- Con = control or no cutting.

Thirty clumps of *G. hasskarliana* were selected for uniformity, and a treatment was ran-

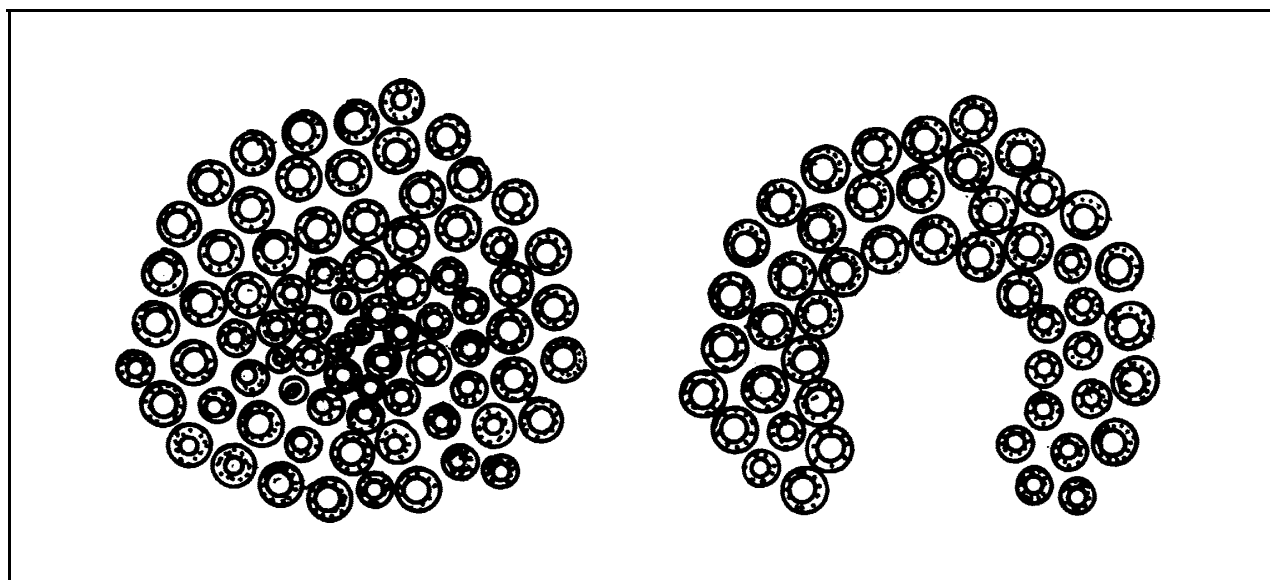


Fig. 1. A cross-section of a bamboo clump. At left is a clump before harvesting; at right is the same one after horse-shoe harvesting.

domly applied to each clump. The number and diameter at breast height of the new culms produced each year were measured. The data were analysed by the analysis of variance.

Results and Discussion

From the six treatments including the control, it was found that clear-cutting (T5) completely destroyed the *G. hasskarliana* clumps. One year after they were clear-cut, the plants could not give rise to any new shoot that could develop into a new culm. Small branches were found at the cut ends of the culms in each clump and the plants remained in this “grass-like” condition. Two years later the branches bore flowers and fruits and finally died. Similar results were reported in *Thyrsostachys siamensis* by Suwannapinunt *et al.* (1978; 1982).

Among the first four treatments and the control (T1, T2, T3, T4, and Con), the harvesting methods had no effect on the size of the new culms produced annually. This was because the *G. hasskarliana* stands used were mature. The average dbh of the culms was 10.0 cm.

The harvesting methods clearly affected the production of new culms as shown in Figure 2. When all culms older than three years and which are physiologically inactive (Ueda, 1960; 1968) were harvested in T4, the plants produced more culms in the following years. On the other hand, when more young culms, which are physiologically active (Ueda, 1960; 1968) were harvested in T2, the bamboo plants produced comparatively fewer culms in the following years. In the case of T3 where some inactive old culms were taken off and

some left, the production decreased in the following years. In the control where no harvesting was carried out, the annual production of culms remained constant.

Figure 3 depicts the average total production in three years. Statistical analysis shows a highly significant difference in the production. From further analyses by the LSD, the following is found:

	Con	T2	T1	T3	T4
Average total number of new culms produced	17	21.2	23.0	23.2	27.2

(under-line means non-significant differences)

It is quite clear that harvesting of *G. hasskarliana* should be done by cutting culms older than three years while leaving the younger ones since these are physiologically more active, have vigorous rhizomes and can produce more culms (Ueda 1960; 1968). In management, therefore, the selection system with a three or four year rotation should be recommended and those culms more than three years old should be harvested from each clump. Since *G. hasskarliana* has a sympodial type rhizome and older culms are inside the clumps, the horse-shoe harvesting technique is recom-

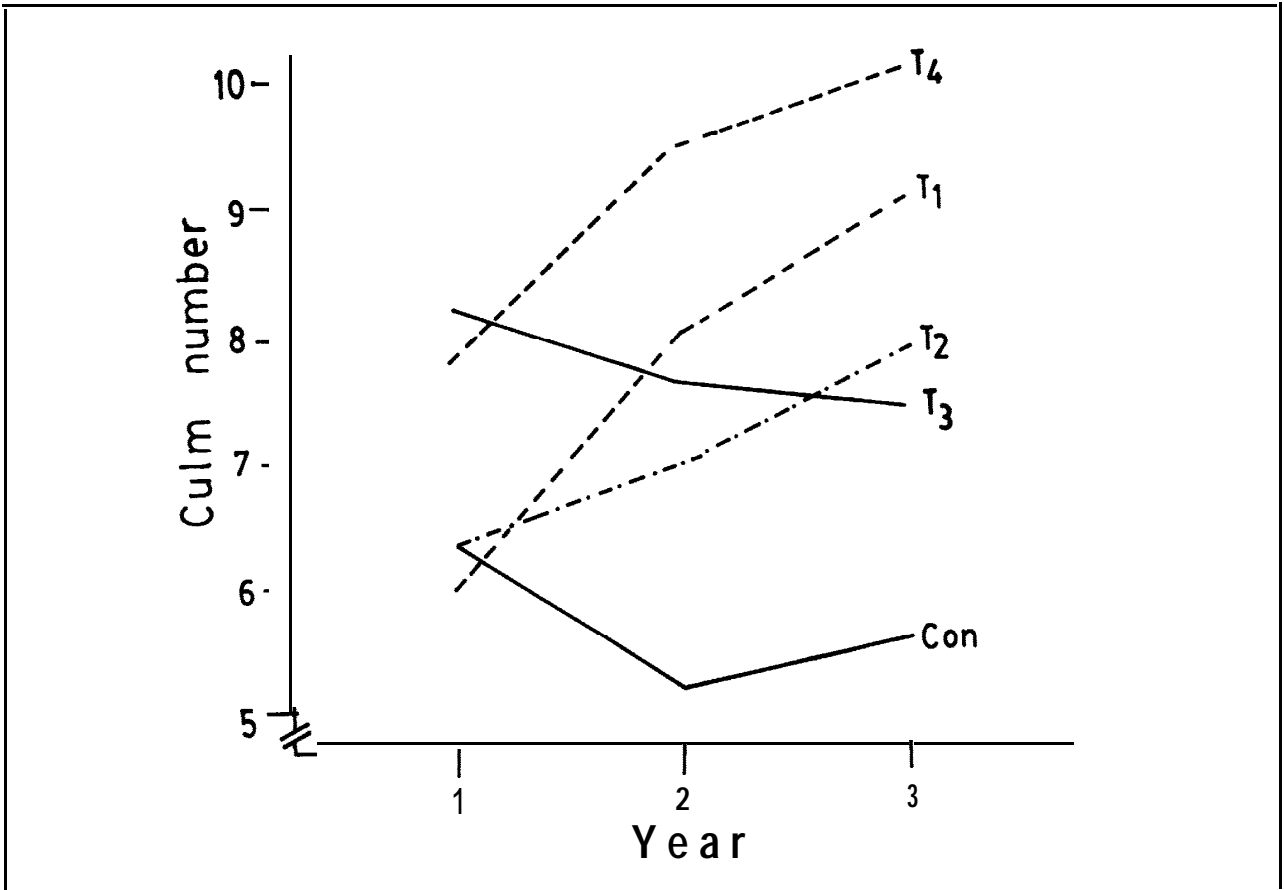


Fig. 2. Average number of new culms produced each year after treatment of *Gigantochloa hasskarliana* clumps in a natural stand at Thong-pha-pum, Kanchanaburi.

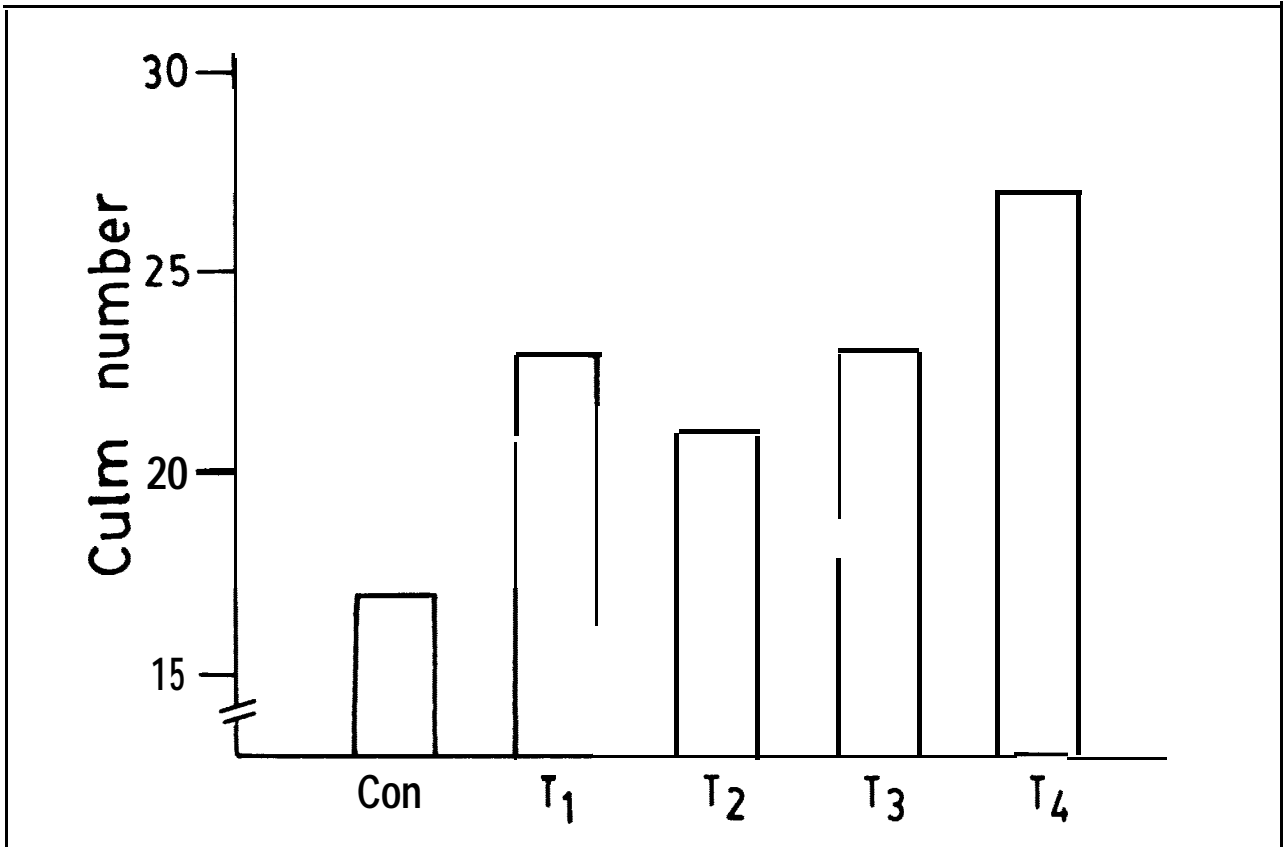


Fig. 3. Average total number of new culms produced in three years after treatment of *Gigantochloa hasskarliana* clumps in a natural stand at Thong-pha-pum, Kanchanaburi.

mended. The clump is worked into a horse-shoe to enable a man to get into the clump easily and work on all three sides.

Conclusion

By clear-cutting all culms in *Gigantochloa hasskarliana* clumps, the plants could not form new culms and eventually died. On the other hand, by selection cutting of culms older than three years in each clump, the plants produced more new culms which are of the same size as those cut; hence production can be both increased and sustained.

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Gregarious Flowering of *Dendrocalamus strictus* in Shahdol (Madhya Pradesh) - Some Management Considerations*

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Abstract

Dendrocalamus strictus has two kinds of flowering behaviour, (a) sporadic and irregular flowering and (b) periodical gregarious flowering. The period of gregarious flowering varies from 20 to 75 years depending upon the locality, management practices, biotic interferences, etc. Gregarious flowering in bamboos has a tremendous impact on the management of bamboo forests. Suggestions are made in this paper for effectively dealing with gregariously flowered areas and for ensuring adequate regeneration.

Introduction

The common bamboo (*Dendrocalamus strictus*) occurs in deciduous forests all over India except in North-west Bengal, Assam and moist regions of the west coast (Troup, 1921; Varmah & Bahadur, 1980). In Madhya Pradesh, it occurs as an understorey in the teak, sal and mixed deciduous forest types covering an area of about 1.8 million hectares (Dutta & Tomar, 1964; Anonymous 1976). The districts which are rich in bamboo forests include Balaghat, Bastar, Bilaspur, Mandla, Hoshangabad, Betul, Raipur, Shahdol, Sidhi, Panna, etc. In Shahdol it occurs in North Shahdol and Umaria forest divisions in an area of about 42 500 ha.

Dendrocalamus strictus has two kinds of flowering behaviour (a) sporadic and irregular flowering and (b) periodical gregarious flowering (Brandis, 1906; McClure, 1966). Important characteristics of sporadic flowering are: (i) scattered nature of flowering with only a few clumps involved in flowering, (ii) only a few culms flower in a clump, (iii) the culms may or may not die after flowering, (iv) the clump does not die, and (v) usually it takes place irregularly almost every alternate year.

Gregarious flowering in *D. strictus* is a recognized phenomenon. The characteristics of

gregarious flowering are: (i) flowering occurs almost over the entire area, (ii) it involves almost all or some proportion of the culms, (iii) flowering takes place in all the clumps, (iv) flowering is followed by the death of the clump, (v) it follows a cycle which occurs after a long interval, (vi) it progresses in a definite direction like an epidemic wave beginning at one definite edge of an area and (vii) it takes a few years, commonly between two to four years to complete flowering in the area. The period between two gregarious flowerings over the same area is believed to be somewhat constant and is called the physiological cycle. Different periods for the physiological cycle have been reported for different areas. Clements (1956) reported that *D. strictus* introduced in Cuba from the 1912 seeding in Garhwal (Uttar Pradesh) flowered in 1956, indicating a cycle of 44 years. A plantation raised in Taiwan in 1912 from seeds obtained from Bihar (India) flowered in 1969, showing a physiological cycle of 57 years. A plantation of *D. strictus* raised in the Forest Research Institute (FRI), Dehradun, during 1937 flowered during 1987 indicating a cycle of 50 years. Similarly, different workers have reported different physiological cycles ranging from 20 to 100 years for different areas (Deogun, 1936; Mathauda, 1952; Kurz, 1975; Varmah & Bahadur, 1980; Suri & Chauhan, 1984; Chaturvedi, 1986).

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Table 1. Record of gregarious flowering in Madhya Pradesh

Area/Forestdivision	Year of gregarious flowering,			Physiological cycle (yr)
	First	Second	Third	
Balaghat (North & South)	1916	1963		47
Bastar (South)	1948	1981		33
Betul	1940	1968		28
Bilaspur and	1895	1960		65
Bilaspur North Harda	1942	1976		34
Jabalpur	1930	1965	1985	27
Khandwa (North & South)	1910	1954		44
Mandla (South)	1900	1921	1946	23
Mandla (North)	1930	1967		37
Raipur	1924	1960		36
Seonl	1921	1939	1964	21
Seonl South	1922	1964		42
Shahdol (Umaria)	1909	1984		75

Observations on Flowering

In Shahdol area gregarious flowering took place during 1984 and continued up to 1987. There is no available record for previous gregarious flowering in this area. Enquiries from older persons indicated that such flowering took place almost 75 years ago. The available information on gregarious flowering in Madhya Pradesh is summarized in Table 1 (Dutta & Tomar, 1964; Anonymous 1976; Prasad, 1986).

It is clear from Table 1 that the period of gregarious flowering varies from 20 to 75 years depending upon the locality, management practices, biotic interferences, etc. Several reasons have been put forward to explain the process of gregarious flowering. Kawamura (1927) believed that gregarious flowering is related to the life cycle of the bamboo, Storage of large quantities of starch, sugar and other substances in the clumps aid flowering (Gamble, 1896 ; Dutta & Tomar, 1964).

Similarly, some workers have tried to relate gregarious flowering with injury, nutrition, climatic conditions, genetical constitution, soil factors, etc. (Nicholson, 1922; Patil & Panchal, 1980; Hussain, 1980).

Factors Affecting Gregarious Flowering

Observations taken in the Shahdol area indicate that the following factors affect the intensity of gregarious flowering:

(a) age of the crop

(b) site quality

(c) management practices

(d) biotic interferences.

Age of the Crop

It is often believed that the period of gregarious flowering depends upon the age of the clump. Only those clumps which have attained the age of physiological maturity flower and subsequently die. In natural forests of bamboo which are worked under a selection system, it would be wrong to presume that most of the clumps are of the same age. In good forests, there will be a continuous formation of clumps and clumps of all age classes would be present as sufficient seeds are available from sporadic flowering. If that is the case then only those clumps which have reached the age of physiological maturity should flower and die and gregarious flowering should affect only a small proportion of the clump population. Another explanation which can be given is that most crops are from seeds obtained during the previous gregarious flowering. In that case it is logical to conclude that most clumps are of the same age. More definite information would be available in the near future from plantations. The plantations which are 12 to 14 years of age and adjoin the natural forest have not shown signs of gregarious flowering.

Site Quality

Observations in Shahdol circle indicate that site quality has a considerable effect on bamboo flowering. In the same area, good sites tended to delay and decrease the extent of gregarious flowering,

Table 2. Period and extent of gregarious flowering in Shahdol circle

Forest division	Felling series	No. of plots	Quality of bamboo	Year of flowering	Percentage of flowered clumps
North Shahdol	1. Ghunghut	10	III	1984	81
	2. Machheha	5	I	Not flowered up to 1987	-
	3. Beohari	10	III	1984	90
Umaria	1. Salkania	10	I	1985	51
	2. Pator	10	II	1984	60

Observations taken in 45 plots randomly selected in five felling series are indicative of this (Table 2).

Management Practices

In areas where clumps are properly worked, the proportion of flowered clumps is comparatively less than in areas with unworked and congested clumps (Table 3).

Table 3. Flowering in congested and uncongested clumps in Ghunghuti felling series

Category	Clump (no.)	Clumps flowered	Percentage
Congested clumps	150	148	99
Uncongested clumps	180	114	63

Biotic Interferences

Biotic interferences such as grazing as also the incidence of fire increase the intensity of gregarious flowering. The bamboo forests located near villages have a greater flowering intensity, whereas those located in comparatively protected areas away from habitation flowered partially. The areas with heavy biotic interference coupled with poor site quality had almost 100 percent flowering. This may be due to the fact that areas subjected to heavy biotic pressure did not have younger clumps. Most of the existing crop consisted of malformed and degraded clumps.

Management Considerations

Gregarious flowering in bamboo has a tremendous impact on the management of bamboo forests. The points needing attention are:

- seed collection
- rescheduling of felling operations
- protection of natural regeneration

- creation of a rhizome bank and artificial regeneration.

Seed Collection

Bamboo is a commercially and socially important species. It is being planted on a large scale in different States. Usually there is a great demand for bamboo seeds from several sectors. It is, therefore, necessary to collect as much seed as possible after assessing the requirement. The seed would also need proper storage for longer viability.

Seed production potential in Shahdol area was assessed by the State Forest Research Institute, Jabalpur. Prasad (1986) reported that the average seed production in a gregariously flowered area varied from 0.9 to 1.5 tonnes/ha. Even taking a value of 0.6 tonne/ha, the average seed production was about 25 000 tonnes. Out of this, about one-third to one-fourth of the quantity of seed could have been collected. But only about 100 tonnes were collected during 1985 and 1986. Although a greater amount of seed was available, these could not be purchased due to paucity of funds.

Rescheduling Felling Operations

After gregarious flowering, the clumps die and need to be harvested as quickly as possible. Delay in harvesting may result in loss due to rotting and fire. The experience in Shahdol circle indicates that whereas the annual harvest from the bamboo forest was about 10 000 tonnes during normal years, about 100 000 tonnes were available for harvesting during 1985 due to gregarious flowering. This necessitated rescheduling of felling operations. The whole quantity was removed in two years: i.e., 60 000 tonnes in 1985-86 and 40 000 tonnes in 1986-87. The operation required (i) more budget allocation for harvesting, (ii) more labour force, (iii) additional organization, (iv) additional support for transport, (v) more number of depots, and (vi) arrangements for sale and additional supplies to paper mills, etc.

Depending upon the felling cycle one-third or one-fourth of the coupes are due for normal work-

Table 4. Regeneration count in protected and unprotected areas

Felling series	Average no. of seedlings			
	1986		1987	
	Protected	Unprotected	Protected	Unprotected
Ghungthuti	650	26	150	3.0
Beohari	450	31	126	4.5
Salkania	1550	46	700	4.0
Pator	1050	51	320	3.0

* Ten plots each measuring 10 x 10 m were maintained

ing as per working plan prescriptions. Since yields are increased several times due to harvesting of dried bamboo, a decision is necessary about the working in coupes due in that year. It is better to work only with the flowered clumps as otherwise the future yield can be considerably affected.

Regeneration of Bamboo Areas

Protection of regeneration of bamboo in flowered areas is perhaps the most important operation because it will decide whether bamboo forests will again appear in the area. Since abundant seed is available near the flowered clump, sufficient regeneration usually springs up in the area except where the soil is deficient or the soil surface is too hard. In most places seedling regeneration comes up in large numbers, several time more than that required for restocking the area.

The area also needs protection from grazing and fire. Due to grazing pressure and other socio-political problems it is not possible to close the entire area from grazing. In Shahdol, after persuading and discussing with the local people, it was decided to close half of the area in each felling series for grazing. Cattle proof trenches were dug and the closed areas were notified. Additional organization in the form of grazing watchers and fire watchers were deployed and effective protection was ensured.

Regeneration assessment was done in protected and unprotected areas in some felling series in 1986 and in 1987 during the month of May-June which indicated that sufficient regeneration existed in the protected area (Table 4).

It is clear that in the unprotected areas, regeneration is poor. The seedlings existed only in places where some physical and mechanical obstruction was provided by stones and boulders, bamboo stumps, lops and tops, etc. However, these seedlings are likely to be grazed and browsed in the subsequent years. On the other hand, in protected areas it is expected that enough seedlings exist to

regenerate the area. Protection of the area for at least six to seven years appears essential. When protection against grazing and fire is not provided, the seedlings are grazed/browsed and killed but the rhizome remains alive for some period. Experience in Mandla and Betul (both in Madhya Pradesh) indicates that even if protection is provided after five years of gregarious flowering, the regeneration could be revived to some extent.

Creation of Rhizome Bank and Artificial Regeneration of Areas with Deficient Natural Regeneration

New nurseries need to be established and existing nurseries expanded to create a large rhizome bank to cater to the plantation needs for a few years. This is necessary for undertaking plantation of bamboo in areas where natural regeneration is deficient as also to utilize the existing seeds properly.

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Management of Wild Bamboo Seedlings for Natural Regeneration and Reforestation

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Abstract

Several clumps of *Bambusa tulda* Roxb. and *Dendrocalamus longispatus* Kurz. flowered gregariously and then died in different forest areas of Chittagong and Sylhet. The growth of seedlings took place between May and August. The variation in seedling (1-2 months old) density (3 to 45/100 cm²) might occur due to variation in availability of seeds, physiographic and site conditions. At the early stage of regeneration, partial shade from the dead mother clump helped in survival and growth, whereas complete shade killed most of the bamboo seedlings. Cutting operations of dead mother bamboo, grazing and sometime incidence of forest fires were major disturbances in the regeneration process. At the two to four leaf stage, 700-1000 seedling per m² were removed from the thickly populated areas and quickly potted in the nursery. These survived well (*B. tulda*, 96% and *D. longispatus*, 86.6%) in the nursery and were later on planted in the field. Delay in cutting operations of dead bamboos for at least nine months helped the regenerating seedlings develop a healthy rhizome system. Weeding and protection from grazing are important steps to be taken for the successful natural regeneration of bamboo.

Introduction

Most of the bamboo species of Bangladesh flower gregariously and then die after producing a large number of seedlings on the forest floor. These generally flower between 7 and 45 years of age, although 10-30 year seeding cycles are common (Hasan, 1973; Banik, 1980). Therefore, in one decade, flowering of any one or more of the bamboo species is not uncommon in Bangladesh and as such the occurrence of natural regeneration is also not an event of a century as is the case with the species of the temperate zones. In this paper, the identification of the major factors responsible for successful natural regeneration of bamboo and the possibility of utilizing the wild seedlings for creating man-made bamboo forests have been examined.

Materials and Methods

Many clumps of mitinga bamboo (*Bambusa tulda* Roxb.) flowered and ultimately died during 1977 in Shishak area of Chittagong hill tracts, in

1978-79 in Sagoal block of Patharia Reserve of Sylhet forest, and also in 1983-84 at the Bambusetum of the Forest Research Institute (FRI), Chittagong. Large numbers of seedlings germinated from the seeds shed from the flowered bamboo clumps.

Similarly orah bamboo (*Dendrocalamus longispatus* Kurz.) flowered in Koila block of Chittagong forest and in the Bambusetum of the FRI during 1972-73 and 1977-79, respectively. These plants also produced numerous seedlings on the forest floor after flowering and then died. Both the species flowered in February and started producing seeds during May and June.

The population density of bamboo seedlings of these two species were determined after different periods under various habitat conditions: full of weeds, lesser amount of weeds, under complete shade (by neighbouring tree/bamboo crown), and partial shade (by dead flowered bamboo clump). In each species, counts were made in the Bambusetum in ten quadrats of 10 x 10 cm in these habitats. The effect of burning due to *jhuming* and clear-felling of the dead mother bamboo clumps on the

Table 1. Average density of natural bamboo seedlings (no.1100 cm²) under various site conditions

Age (months)	Full weed exposed		Less weed exposed		P. shade & less weed		C. shade & less weed		P. shade thinned		P. shade & unthinned	
	1	2	1	2	1	2	1	2	1	2	1	2
3	24.6	25.7	24.9	26.0	27.0	26.7	26.0	26.1	13.5	13.2	27.1	26.8
6	6.2	4.9	9.2	8.6	14.2	11.4	2.2	3.1	7.5	8.1	8.4	10.3
12	0.1	0.2	0.3	0.3	0.5	0.6	0.0	0.0	0.8	0.6	0.4	0.5

P, partial; C, complete; 1, Bambusa tulda Roxb; 2, Dendrocalamus longispatus Kurz.

regenerating bamboo seedlings was also observed in Koila block of Chittagong forests and Sagoolal block at Sylhet. Growth of the seedling height and diameter of culm and its production/clump/per year were measured at 3, 6 and 12 months of age in the above habitats. The wild seedlings of both species were thinned out at the two to four leaf stage (30-45 days of age) from the thickly populated areas to minimize inter-seedling competition. During the thinning operation, 700- 1000 seedlings per m² were removed leaving 1300- 1400 seedlings per m².

The thinned out seedlings were planted within 36 hours in polyethylene bags (15 x 10 cm) containing soil and cowdung in the ratio of 3: 1. During the first two days these potted seedlings were kept in the nursery shed for hardening and subsequently exposed to direct sunlight. Daily watering of the seedlings was done. When 12- 14 months old, the seedlings were planted in the field at 4 x 4 m spacing (625/ha) covering a forest area of 4.05 hectare during the months of June and July. Survival of the seedlings in the nursery bed as well as in the field (up to three years) were determined. Quarterly weeding operations were carried out up to two years of planting.

Results and Discussion

Germination of seeds started within a week of falling on the ground. A very large number of seedlings were produced below the dying mother

clump during May-August. Several seeds and germinating seedlings were carried away by rain water, often far from the mother plant. The density of seedlings after one to two months was about 45/100 cm² in depressions and valley areas and lower on the slopes (3/100 cm²). It was also observed that some factors like shade and weeds influenced the density and survival rate of the regenerating seedlings (Table 1). Many seedlings died because of suppression and competition by weeds. Common weeds were *Eupatorium odoratum* Linn, *Imperata cylindrica* Beauv, *Strebilus asper* Lour, *Desmodium trifolium* DC and *Mikania scandense* Willd. The number of seedlings present per unit area under the dead mother clump and also in areas with a lower weed density was higher than in areas under complete shade or full of weeds (Table 1). Almost all seedlings died within 7- 12 months under complete shade condition. The dead mother clumps provided partial shade to the regenerating seedlings and this condition seemed to favour the regeneration process. After 12 months it was observed that seedling density was better in thinned out than in the unthinned areas (Table 1). Competition between seedlings was high in the unthinned areas and as a result the rate of mortality was higher than that in the thinned areas.

Burning or clearfelling of the dead mother bamboo clumps within one to three months of seed germination was found to stop the regeneration process by killing almost all the bamboo seedlings.

Table 2. Average density of regenerating bamboo seedlings (no.1100 cm²) after felling of dead mother clump or burning of the areas. Observed after 4 and 10 months of regeneration

Species	1 to 3 months age		6 to 9 months age	
	Burning	Clump felled	Burning	Clump felled
<i>B. tulda</i>	0	0.09	0.71	0.63
<i>D. longispatus</i>	0	0.04	0.77	0.58

Table 3. Average growth of regenerating bamboo seedlings in different habitat conditions

Habitat condition	Age (months)	Species	Total culm/clump (no.)	Culm		Remarks
				Ht (cm)	DMC (cm)	
Full weeds (exposed)	3	Bt	2.0	20.1	0.08	wirey stem
		Dl	2.0	23.0	0.09	
	6	Bt	1.3	18.1	0.24	same
		Dl	1.4	20.3	0.28	
	12	Bt	2.2	16.0	0.28	same
		Dl	1.9	14.9	0.30	
Less weed (exposed)	3	Bt	3.0	25.6	0.24	normal stem
		Dl	2.7	26.2	0.26	
	6	Bt	2.6	32.6	0.26	same
		Dl	2.2	30.2	0.30	
	12	Bt	6.2	34.2	0.36	green strong stem
		Dl	6.3	32.4	0.38	
Less weed (complete shade)	3	Bt	3.8	25.8	0.12	very wirey stem
		Dl	3.9	24.0	0.11	
	6	Bt	0.0	20.7	0.10	same
		Dl	0.0	18.4	0.09	
	12	Bt	0.0	0.0	0.0	all died
		Dl	0.0	0.0	0.0	
Thinned (Partial shade & less weed)	3	Bt	4.2	25.3	0.31	green strong stem
		Dl	4.4	24.0	0.29	
	6	Bt	5.8	33.0	0.41	same
		Dl	5.9	35.2	0.42	
	12	Bt	6.2	60.3	0.58	same
		Dl	5.9	62.1	0.60	
Unthinned (Partial shade & less weed)	3	Bt	4.0	31.3	0.25	green
		Dl	4.2	35.7	0.27	
	6	Bt	6.3	38.0	0.30	same
		Dl	5.6	39.0	0.34	
	12	Bt	6.8	66.7	0.42	same
		Dl	6.2	68.2	0.49	

Bt, Bambusa rulda; Dl, Dendrocalamus longispathus; DMC, diameter at mid-culm position

The effect was not as hazardous if burning was done after six to nine months of age (Table 2). According to Troup (1921) and Mc Clure (1967), bamboo seedlings generally produce an underground rhizome after four to six months of age. Burning and felling operations after six to nine months of age only destroyed the aerial part of the bamboo seedlings and within a few months, shoots again appeared from the underground rhizome as

observed by Naito et al. (1968) on *Sasa palmata* in Japan. Ahmed (1954) and Seth (1954) also discouraged felling operation of dead culms in the early stage of the regeneration process. They were of the opinion that the dead clumps would considerably benefit the regenerating bamboo crop and lead to a well-developed stand with healthy clumps.

The condition of the bamboo seedlings was found to be better under partial shade and lower

Table 4. Survival percentages of the wild bamboo seedlings after potting in the nursery and planting in the field

Species	Nursery		Field			
	Total seedlings	Number survived (no.) (%)	Survival percentage & r	1st	2nd	3rd
<i>B. tulda</i>	5000	4805 96.1	88.3	73.4	70.3	
<i>D. longispathus</i>	5000	4330 86.6	82.4	70.2	68.4	

weed conditions than under full weeds and complete shade (Table 3), which indicates that the bamboo seedlings require some light at the early stage of development. In complete shade, almost all seedlings perished after 12 months. In both weed conditions, the seedlings survived but the general condition of the seedlings was comparatively better in areas with lesser weeds (Tables 1,3). It appears that the influence of light on seedling mortality and their health is comparatively more important than weed competition at least in the early stages of regeneration. Felling of the dead mother clump if delayed for at least for 9- 12 months will provide partial shade to the regenerating bamboo seedlings. Seedlings in the thinned area showed better diameter growth than those in the unthinned areas (Table 3). In both species, seedlings which were thinned out showed a good survival percentage both in the nursery and thereafter also in the field (Table 4). The ultimate establishment (survival) of the thinned-out bamboo seedlings in the field was round eight percent in *D. longispathus* and 70 percent in *B. tulda* after three years of plantation. Thinning can, therefore, be useful both for natural regeneration as well as for plantation purposes.

Conclusion

This study reveals that regenerating bamboo seedlings cannot grow under complete shade. Partial shade and occasional weeding are important for successful natural regeneration of bamboo seedlings after each gregarious flowering in the forest.

For providing partial shade to the regenerating seedlings, felling of the dead mother clump must be delayed for at least nine months. Light thinning of bamboo seedlings from densely populated regenerating areas did not adversely affect the regeneration process and on the other hand, decreased competition among the seedlings. In addition, 700- 1000 bamboo seedlings/m² were obtained for further plantation programmes.

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GROWTH AND YIELD
OF BAMBOOS

Effect of Container Size on Growth of *Bambusa arundinacea* Seedlings*

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Abstract

The growth of *Bambusa arundinacea* Willd. seedlings in polythene containers of two sizes, 13 x 18 and 18 x 40 cm, was studied. The results at the end of one year showed 581, 212, 177, 170, 111 and 60 percent increase in root biomass, total biomass, shoot biomass, root length and the number of roots, respectively, in the larger container. The number of shoots and the height of the plants were not influenced by container size. The shoot-root-rhizome biomass ratios in smaller and larger containers were 75:10:15 and 65:22:13, respectively.

Introduction

Bamboos are an important forest produce in Asia and the Pacific. Though a major portion of the requirements are met from the natural stands, the increasing demand can be met only through plantations. For large scale plantations, seedlings are more handy than other types of propagules (Kondas, 1982). The success in planting, however, greatly depends on the quality of the planting stock. The superiority of containerized seedlings over bare-rooted seedlings is well-known. Studies on the effect of container size on seedling growth of a number of species point to the positive effect of using larger containers (Funk *et al.*, 1980; Sturion, 1980; Ward *et al.*, 1981; Wood & Hanover, 1981; Arnott & Beddows, 1982; Pratap Singh *et al.*, 1985). In the present study the growth of *Bambusa arundinacea* Willd. seedlings in containers of two sizes has been examined.

Material and Methods

The study was conducted at Nilambur (1 1°17'N, 76°4'E) during 1987-88. Polythene bags of two sizes, 13 x 18 and 18 x 40 cm (flat width x length) were filled with sandy loam soil collected from the moist deciduous forest area in the vicinity. All stones and roots were removed from the soil before filling. The bags were provided with a few lateral holes at the bottom to drain off excess water.

The small and large bags contained 690 cm³ (8.3 cm dia/12.9 cm depth) and 3430 cm³ (11.5 cm dia/33.3 cm depth) of soil, respectively. About one cm of the bag at the top was left unfilled to facilitate watering. Four-day-old seedlings of uniform size were potted into polythene bags from a nursery bed and the plants maintained in nursery beds for one year. At the end of the treatment period, 25 plants were randomly selected from each treatment and various growth parameters recorded. The plants were oven-dried for biomass determination. The relationship of all growth parameters to rhizome development was studied through multiple linear regression analysis.

Results

The effect of container size on various growth parameters is summarized in Table 1. On the whole, the seedlings in the larger containers (T₂) grew better than those in the smaller ones (T₁). The increase in total biomass was 212 percent. Other parameters which showed a significant increase were root biomass (581%), rhizome biomass (177%), shoot biomass (170%), length of the longest root (111%) and number of roots (60%). However, the number of shoots (culms) and the height of the tallest shoot (culm) were not affected by container size. The better growth in T₂ could be attributed to the larger volume of soil, facilitating greater root development, moisture retention and

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Table 1. Comparison of various growth parameters at the end of one year ($\bar{x} \pm S.E.$)

Treatment	No. of shoots (culm)	Height of tallest shoot (culm; cm)	Shoot biomass (g)	No. of roots	Length of longest root (cm)	Root biomass (g)	Rhizome biomass (g)	Total biomass (g)
Small polythene container T ₁	6.08a ± 0.38	72.32a ± 2.14	6.7664a ± 0.7261	24.92a ± 1.56	29.08 a ± 1.78	0.8876a ± 0.0746	1.3356a ± 0.1704	8.9896a ± 0.9494
Large polythene container T ₂	7.92a ± 0.53	70.96a ± 2.64	18.2720b ± 1.2723	39.88b ± 2.25	61.24b ± 3.42	6.040b ± 0.7240	3.6964b ± 0.3046	28.000b ± 1.9886

x, mean values; S.E., standard error; values denoted by the same letter in a column are not significantly different; number of roots is significantly different at $P \leq 0.05$ and all other parameters at $P 10.01$

Table 2. Multiple linear regression of rhizome biomass (BRh) on other parameters

Parameter	Partial regression coefficient	
	T ₁	T ₂
Number of shoots (NS)	0.116821*	0.1 94644 ns
Height of tallest shoot (HT)	-0.002883'''	-0.02 1856 ns
Shoot biomass (BS)	0.190889**	0.164393**
Number of roots (NR)	-0.017513ns	-0.004694'''
Length of longest root (CR)	0.011566ns	-0.005673'''
Root biomass (BR)	0.236404'''	0.0824 12ns
F value of ANOVA	31.74	84.47
Coefficient of determination	91.36	73.79

*, **, significant at $P \leq 0.05$ and 0.01 , respectively; ns, non-significant

Table 3. Intercorrelation between all growth parameters in T₁(13 x 18 cm) and T₂ (18 x 40 cm)

	NS	HT	BS	NR	LR	BR	BRh
H T T ₁	.349						
T ₂	.015						
BS T ₁	.581	.650					
T ₂	.215	.718					
N R T ₁	.723	.476	.785				
T ₂	.733	.379	.644				
LR T ₁	.210	.113	.159	.183			
T ₂	.046	-.066	.066	-.110			
B R T ₁	.662	.492	.834	.807	.235		
T ₂	.225	.395	.554	.615	.181		
BRh T ₁	.700	.572	.922	.756	.296	.836	
T ₂	.547	.390	.732	.770	.040	.577	
BT T ₁	.622	.638	.996	.800	.192	.866	.950
T ₂	.300	.651	.937	.744	.113	.798	.819

uptake of nutrients. Further, the larger spacing between plants in T₂ (11.5 cm in T₂ as against 8.3 in T₁) could have enabled better availability of sunlight when arranged in the nursery bed. The shoot-root-rhizome biomass ratios in T₁ and T₂ were 75:10:15 and 65:22:13, respectively.

An examination of the partial regression coefficients (Table 2) points to the prominent relationship between shoot biomass and number of shoots on rhizome biomass in T₁ whereas in T₂, the shoot-rhizome biomass relationship alone was prominent.

In correlation analysis (Table 3), rhizome biomass was found to be positively correlated with shoot biomass (.92), root biomass (.84), number of roots (.70) and height of tallest shoot (.57) in T₁ and with number of roots (.77), shoot biomass (.73), root biomass (.58) and number of shoots (.55) in T₂.

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Leaf-litter and its Decomposition in Bamboo Timber Stands

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Abstract

The dynamics of leaf litter in timber stands of *Phyllostachys pubescens* was studied in four locations in South China. Ninety litter traps in 21 blocks and 400 litter decomposition bags in another 20 blocks were set up and continuously monitored over three years. Loss of weight as well as leaching of N, P, K, Ca and Mg from the litter were determined by periodic field collections and laboratory analysis. Results indicate that there are two annual peaks of litter fall though the dates for these varied with the geographic locations of the stands. Litterfall during the first peak was about 80 percent of the annual fall. Weight loss of litter was initially rapid but stabilized after 20 weeks. Nutrient release differed from element to element and took place after an initial accumulation stage.

Introduction

The recycled nutrients from decomposing forest litter are one of the main nutrient sources for maintaining the growth of forest trees (Staaf & Berg, 1981; Wareing, in press). It is important to study litter decomposition for understanding the growth of forest trees in regions where the soil is poor and cannot receive nutrients from applied fertilizer as well as in other areas where fertilizing measures have been adopted. This will provide a scientific basis for determining whether an area should be fertilized or not.

Although studies have been carried out on the decomposition of litter, most are concentrated on the coniferous or broad-leaved forests and not on bamboo forests (Berg & Staaf, 1981; Berg *et al.*, 1981; Will *et al.*, 1983). Information on bamboo forests is essential, considering the importance of these in South-east Asia. In China, the area under bamboo forests is more than 2.7 million ha. In areas where bamboo stands are intensively managed, applying fertilizer is one of the important measures to obtain high yields. This paper reports the results of a study conducted on nutrient cycling in stands of *Phyllostachys pubescens* to determine the most economical fertilizing method.

Material and Methods

Annual Variation in the Quantity of Leaf Litter

Installation of bamboo leaf trap

The experimental stands were located in Fuyang and Anji county of Zhejiang province in the northern subtropical region, and Fenxi county of Jiangxi province and Lianjiang county of Fujian province in the middle subtropical region. Five experimental plots were randomly selected in each of the above four sites and four leaf traps with an area of 0.5 m² were installed in each plot. In the last mentioned site, experimental plots were selected with five traps for each plot. The traps were designed such that once the litter is trapped, it would be retained in the containers and the litter within or outside the trap would not get intermixed either by the wind or small animals or undergo loss from decay due to collection of water within them.

Sampling and weighing

Leaf litter was collected every fortnight from the traps, dried in an electric oven at 85 C for 48h and weighed after cooling.

Decomposition of Leaf Litter

Preparation of leaf samples

The fallen bamboo leaves were collected from the experimental sites and dried in an electric oven at 85 C for 48 h. After cooling, a part of the sample was analysed for N, P, K, Ca and Mg and the rest retained for later use.

Incubation in bamboo stands

In the same five experimental plots at each of the

Table 1. Climatic conditions of the experimental sites

Site	Average temperature (C)			Maximum temp.(C)	Minimum temp.(C)	Precipitation (mm)
	Annual	July	Jan.			
Fuyang, Zhejiang	16.1	28.9	3.3	37.8	-8.4	1700.0
Anji, Zhejiang	14.5	28.3	2.6	39.2	-8.3	1875.7
Fenyi, Jiangxi	17.9	29.0	5.3	39.9	-8.3	1593.7
Lianjiang, Fujian	16.9	28.5	9.5	38.0	-3.8	1540.1

Table 2. Soil conditions of the experimental sites

Site	Texture	pH	Total N%	Total P ₂ O ₅ %	Exchangeable K (ppm)
Fuyang, Zhejiang	silt or clay loam	5.0	0.2068	0.05 17	87.38
Anji, Zhejiang	heavy loam, light clay	5.1	0.1742	0.0699	70.58
Fenyi, Jiangxi	heavy loam	4.9	0.1234	0.0534	67.00
Lianjiang, Fujian	silt loam or clay	5.0	0.1449	0.0300	79.50

sites mentioned above, an area of 1 m² was randomly selected, cleaned and levelled. Twenty sample net bags measuring 15 x 20 or 20 x 25 cm with 1 mm holes and containing 15 or 27.4 g of dried leaf samples, respectively, were laid out on the prepared ground. The bags were fixed in place by long iron needles.

Sampling and determination of nutrient content in decomposed litter

After incubation periods of 3,5,12,19,31,45,58, 71,84,97 and 110 weeks, a litter sample bag was randomly picked up from each plot. The samples were cleaned, dried and weighed. The five leaf samples of each site were pooled and the N, P, K, Ca and Mg content determined.

Description of Experimental Site

The experimental sites (Tables 1 and 2) are located in Miaoshanwu, Fuyang county (30°03'N, 119°57' E) and Hetangwu, Anji county (30°39' N, 119°41' E) of Zhejiang province in the northern subtropic band, Shangcun, Fenyi county of Jiangxi province (27°30' N, 114°30' E) and Xiache, Lianjiang county of Fujian province (26°23' N, 119°22' E) in the middle subtropic region. The soil is acidic (pH 4.9-5.1) and the texture varies from silt loam to light clay. The N content is slightly higher in the Zhejiang sites whereas the K content is rich and the P content extremely poor in all sites. The soil layer

in Anji is shallow (less than 30 cm on an average) with a high boulder content. The highest site, Xiache, Lianjiang county, is located on a slope at an altitude of 600 m. Besides, the bamboo culms in Fuyang, Fenyi and Lianjiang are generally tall whereas those in Anji are shorter and were attacked by *Pantana sinica* Moore and *Hipota dorsalis* in 1987.

Results and Discussion

Annual Variation in Bamboo Leaf Litter Quantity

Although leaf fall in *Phyllostachys pubescens* stands occurs throughout the year, the quantity changes with its growth characteristic and the season. Generally, there are two peak values in the quantity of litter each year (Fig. 1). The first (major) one occurs in spring (April, May) and the second (minor) one in late autumn (November). The quantity variation of leaf litter is small between years for the even-year stands, but the opposite response is obtained for both on-year and off-year stands (Fig. 2).

The annual litter quantity and the first peak value are usually lower in the on-year than in the off-year. In addition, the ratio between the first peak value and the annual one in an on-year is also lower (17-31%) than in the off-year (43-56%). The various management practices (e.g. harvesting of

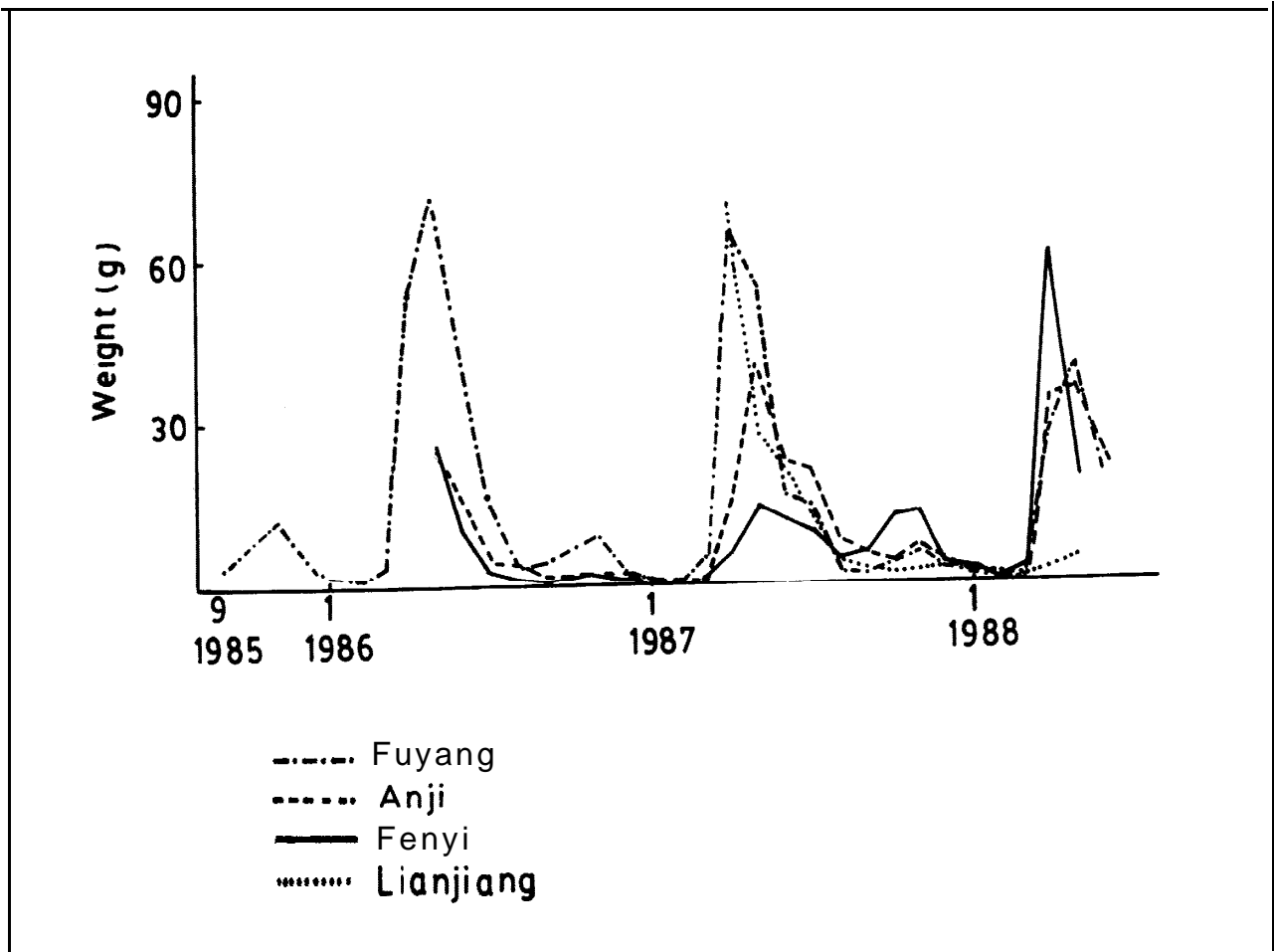


Fig. 1. Dynamics of bamboo leaf litter in different sites.

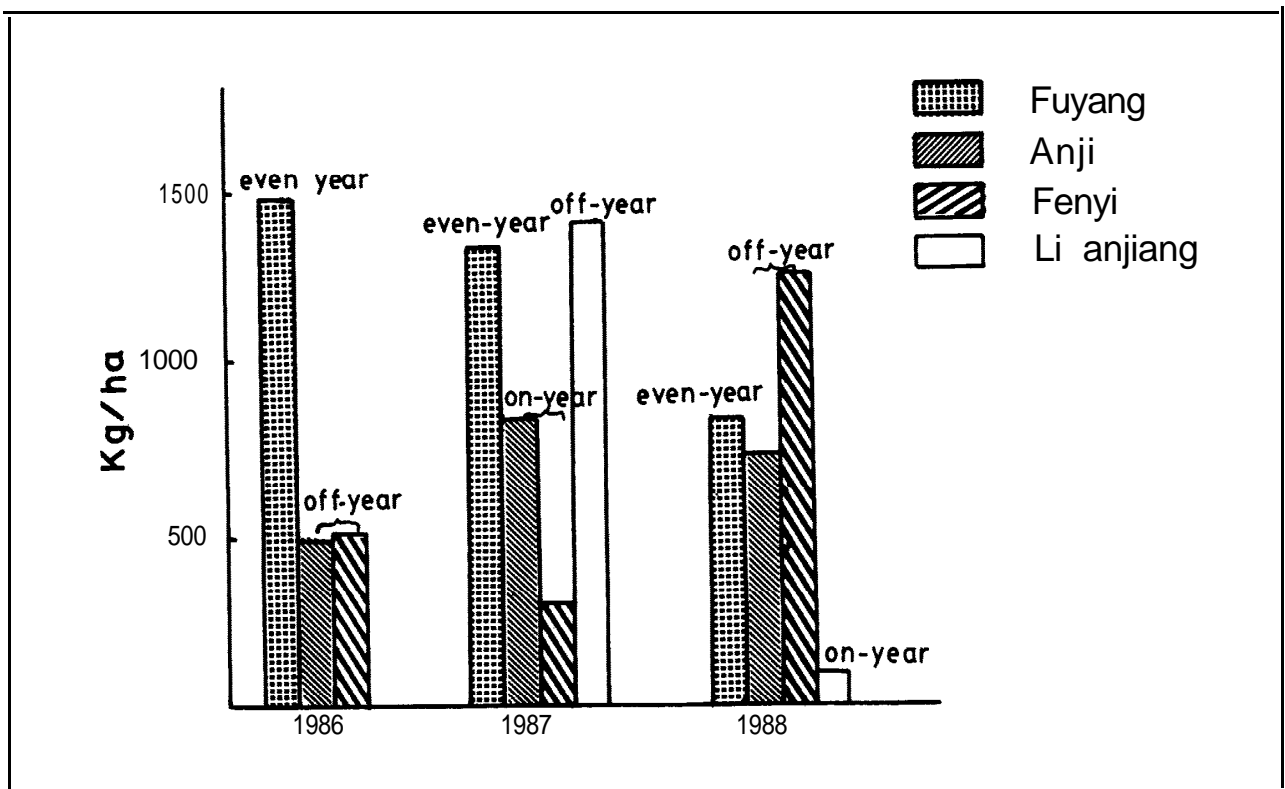


Fig. 2. Comparison of the peak values for bamboo leaf litter in various sites.

Table 3. Leaf litter quantity at various sites (kg/ha)

Year	Site			
	Fuyang	Anji	Fenyi	Lianjiang
1986 (May-Dec.)	3098.45 (even year)	1145.40 (off-year)	923.97 (off-year)	—
1987 (April-Dec.)	3594.00 (even year)	2656.58 (on-year)	1755.87 (on-year)	2925.97 (off-year)
1988 (Jan. -May)	1440.18 (even year)	1507.90 (off-year)	1384.00 (off-year)	197.57 (on-year)

Table 4. Decay and time parameters of leaf litter decomposition in bamboo forests at different sites

Site	Decay parameters		Time parameters (year)	
	Based on original dry weight (K)	Specific rate (K')	Half-life (0.693/K)	95% (3/K)
Fuyang	0.47	0.38	1.46	6.34
Anji	0.51	0.40	1.37	5.91
Fenyi	0.41	0.33	1.70	7.37
Lianjiang	0.71	0.51	0.98	4.25

Note: K and K' in the table are calculated from the formula $M_t/M_0 = e^{-Kt}$; $K' = 1 - e^{-Kt}$, where M_t is the dry weight of leaf litter incubated at a certain time; M_0 is the initial dry weight of leaf litter.

uncut bamboos) did not significantly affect litter quantity and its time of occurrence. However, damage by pests and diseases significantly increased the litter quantity in the Anji experimental site even in an on-year (see Figs. 1 and 2, and Table 3).

Decomposition of Bamboo Leaf Litter in *Phyllostachys pubescens* Stands

Effect of site conditions on the decomposition rate of bamboo leaf litter

The site conditions significantly affected the decomposition rate as can be seen from Figures 3 and 4, and Table 4. The leaf litter decomposition rate in various sites is in the order, Lianjiang, Anji, Fuyang, Fenyi (relative rate is 1: 0.8: 0.7: 0.6). Lianjiang is located in the South-east coast at a high altitude. The constant temperature and high humidity there may favour the development of certain kinds of microbes so that the resulting population can decompose the material faster than if the temperature fluctuates. Anji is located in the North-eastern part but receives a high amount of precipitation. In addition, top-cutting was carried out there and the soil contains a lot of boulders. The temperature and high moisture conditions could have favoured the high decomposition rate. In

Fuyang and Fenyi, however, the bamboo stands have dense canopies with no top-cutting. The temperature in the forest is lower: besides Fenyi is located inland where the annual temperature fluctuates widely. This probably inhibits the growth and activity of microorganisms.

Dynamics of nutrient elements during decomposition of bamboo leaf-litter

It is known that during decomposition of leaf litter, the nutrient elements go through three stages of leaching, accumulation and release. In the present study it was observed that the concentrations of N, P and K were initially low for a short period but increased gradually; that of Ca and Mg reduced rapidly in the initial ten-week period of incubation following which the loss was slower (Fig. 5).

The increment or reduction in the concentration of a certain element cannot completely determine the stage of decomposition of the element in the decomposing litter. For this, the ratio between the actual remaining value of the element in the residual litter and the initial value of the same element before decomposition needs to be calculated.

Both Figures 6 and 7 show that when the mineral constituents are followed over a three-year

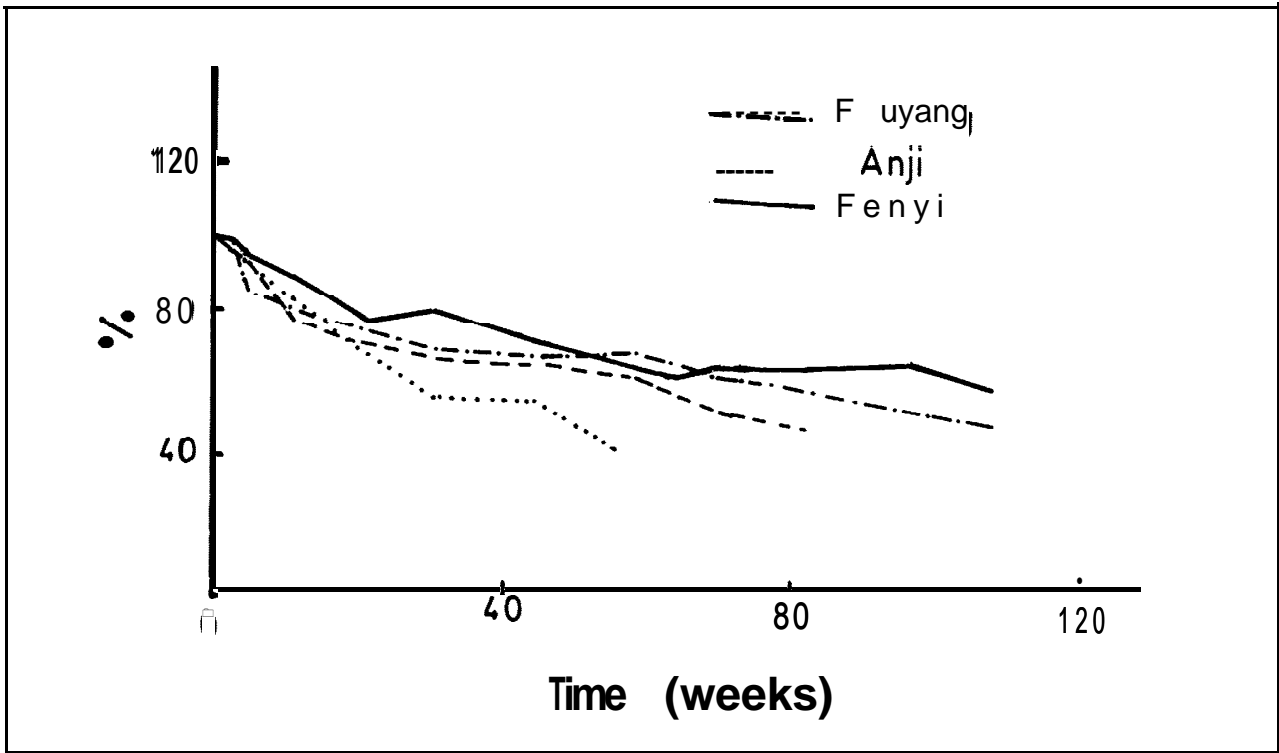


Fig. 3. Weight loss of leaf litter when decomposed in bamboo forests at various sites.

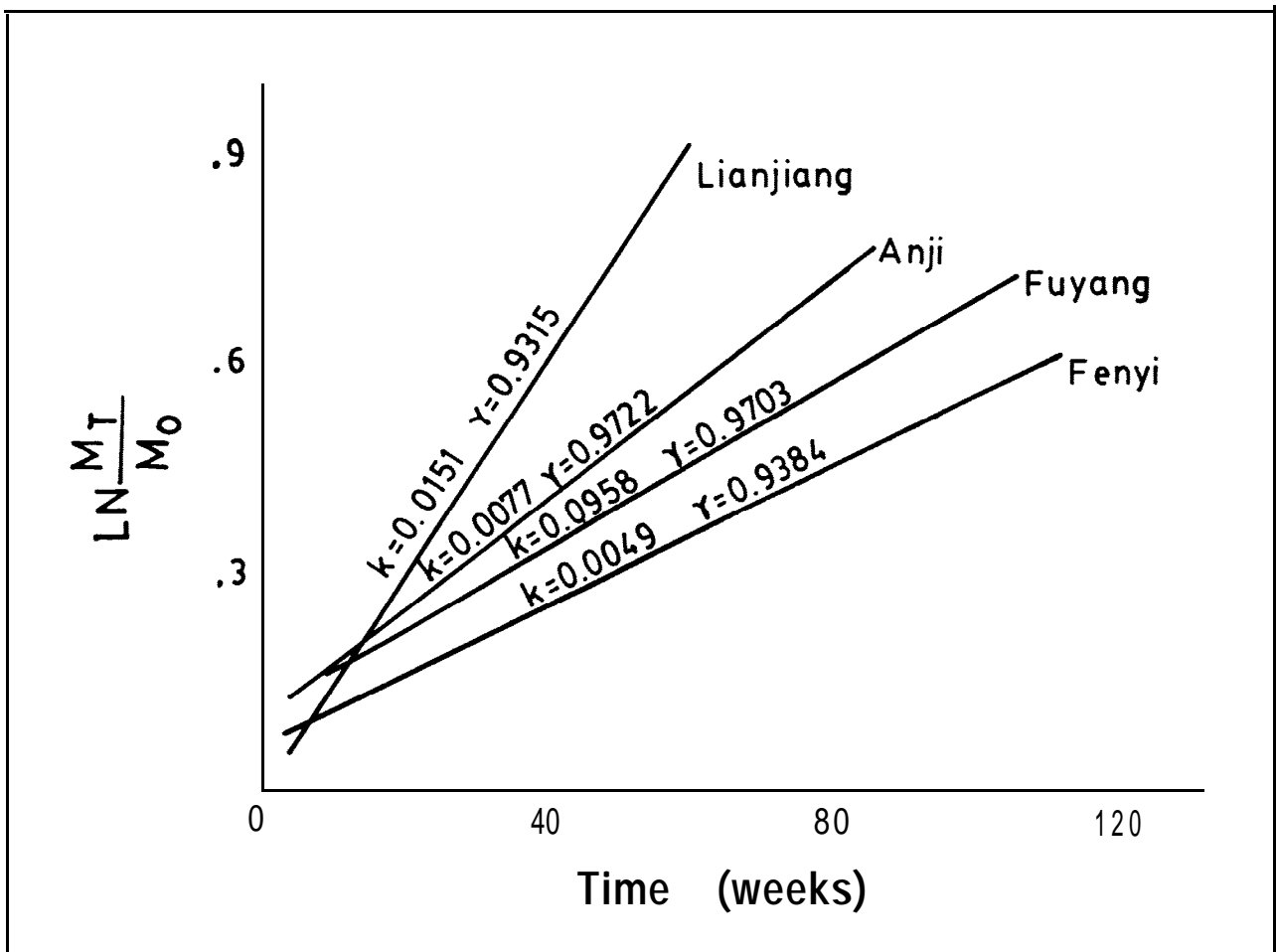


Fig. 4. First order kinetics of leaf litter decomposition of bamboo forests at various sites.

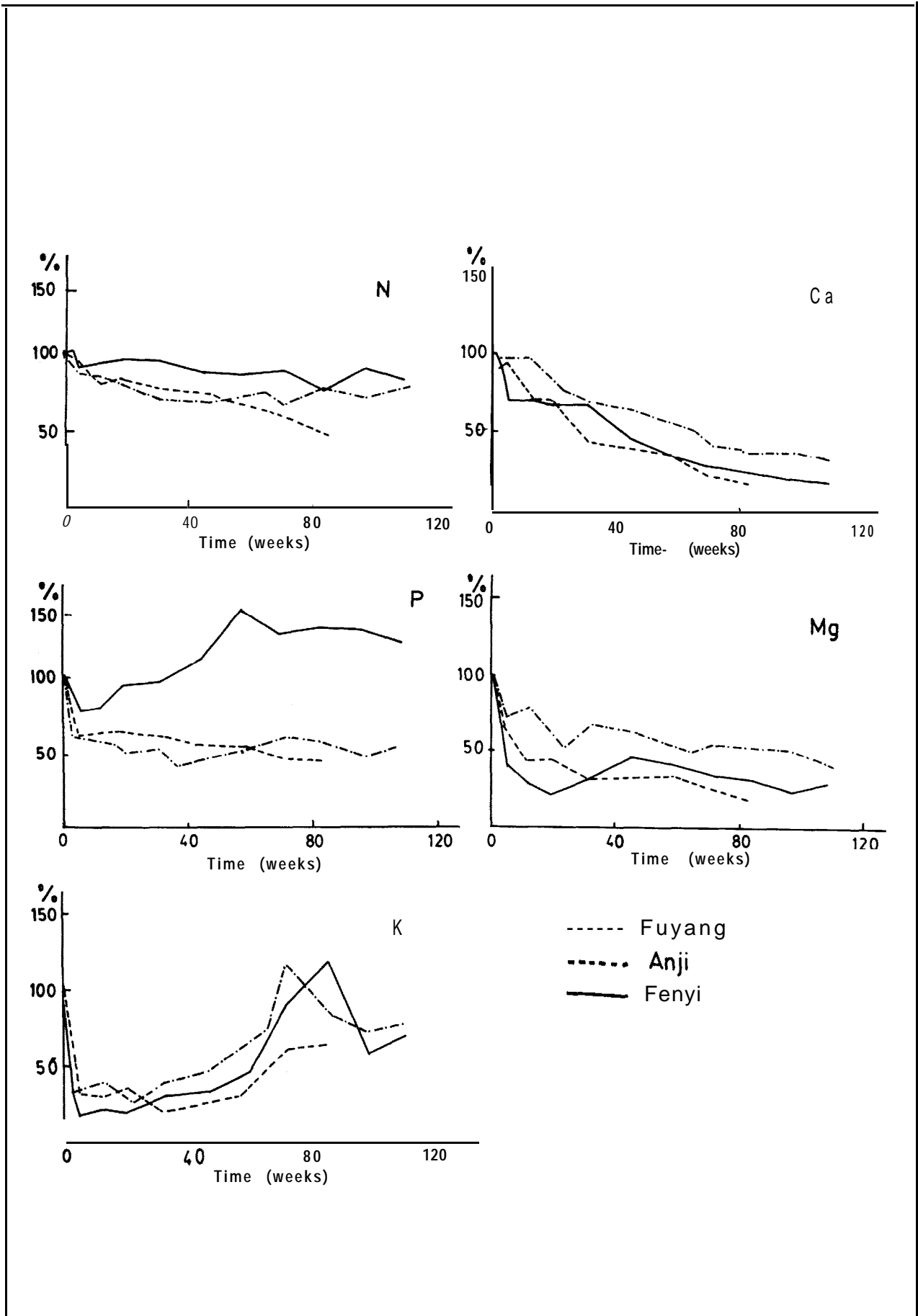


Fig. 5. Concentration variation of the main elements in the decomposed leaf litter residue of *P. pubescens*.

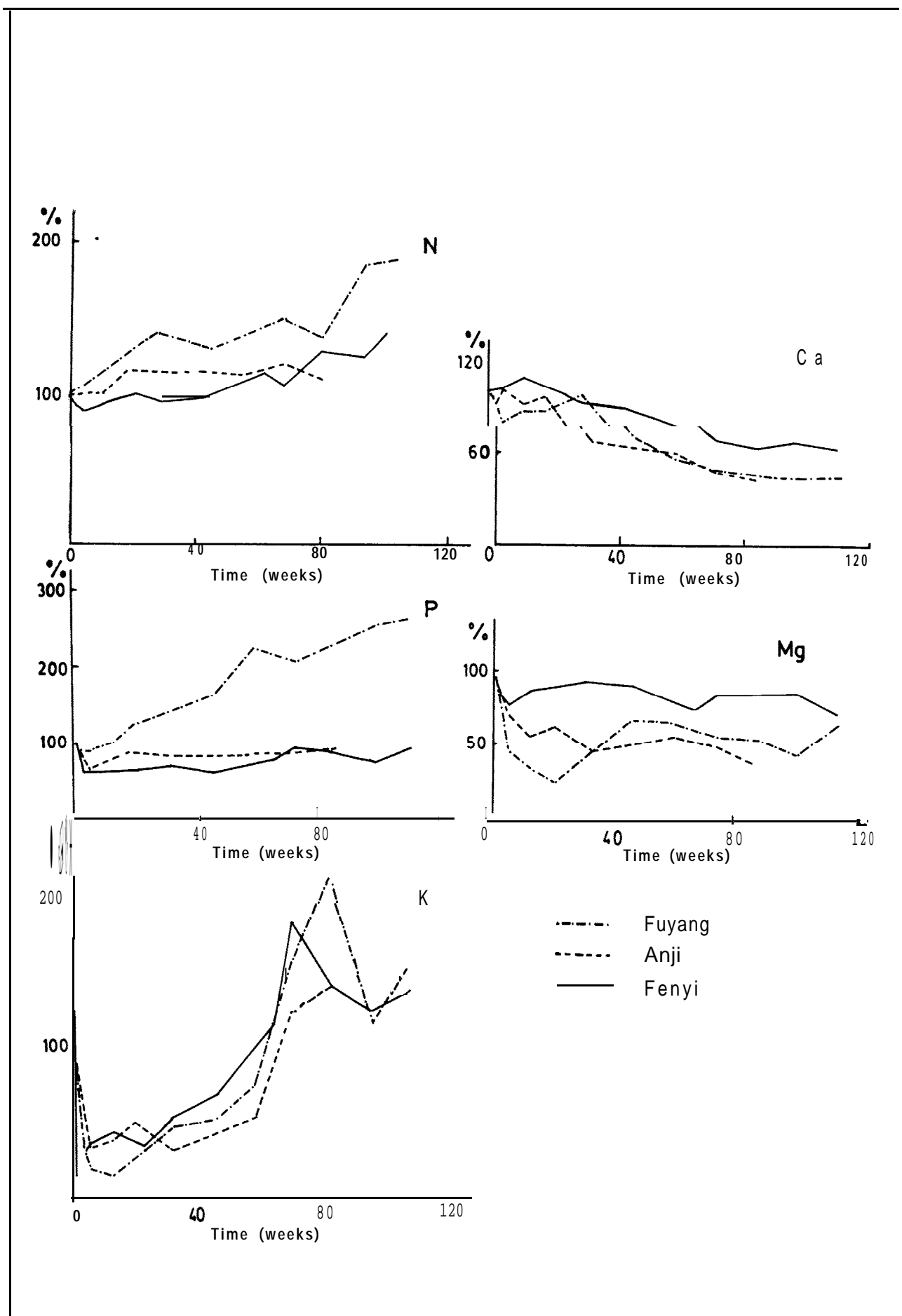


Fig. 6. Decomposed stage of main nutrient elements in the residual bamboo leaf litter.

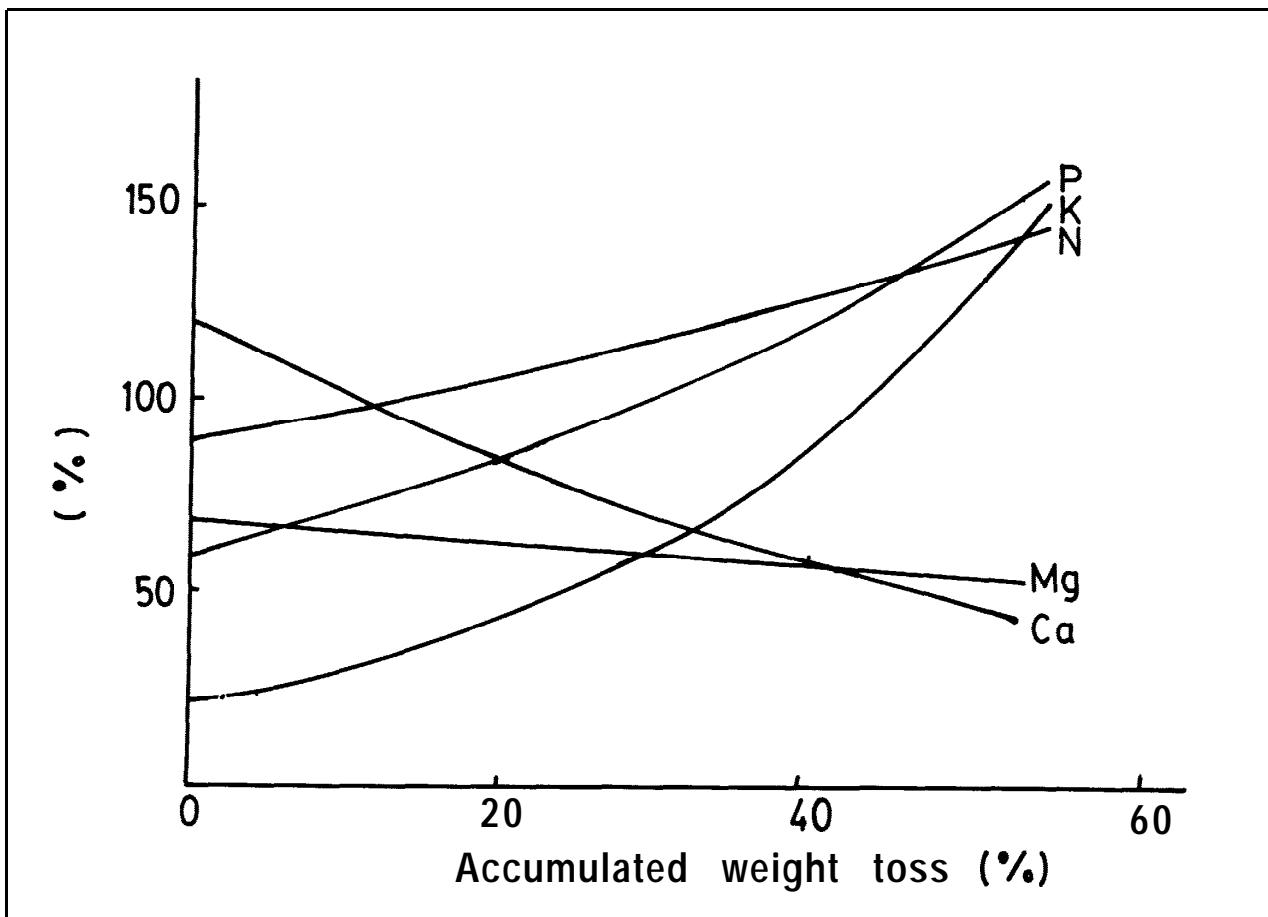


Fig.7. Dynamics of nutrients in bamboo leaf litter- decomposed over three years.

period in decaying bamboo leaves, N, P, and K show a rather high increase. The differences in the quantity of the same element in various sites is probably a reflection of the difference in leaching intensity of the whole decomposition process (Fig.6).

Conclusions

Bamboo leaf-litter occurs over the whole year, but has two annual peaks - in spring (April or May) and late autumn (November). The annual quantity of leaf-litter is greatly affected by both the biological properties of bamboo and the environmental conditions; an attack of pests or disease significantly increases the amount of litter. The decomposition of bamboo leaf-litter includes three stages of leaching, accumulation and release. N, P and K usually have a long accumulative stage, while Ca and Mg are released very early. Temperature and precipitation significantly affect the decomposition of bamboo leaf litter, for they influence the level of the microbial population.

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Performance of Bamboo under Varying Spacing and Fertility Levels

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Abstract

Investigations were carried out to determine the effect of varying spacing and fertility levels on the growth and nitrogen uptake of bamboo. A field experiment was conducted on the bamboo, *Dendrocalamus strictus* (Roxb.) Nees with three spacings 1 x 1, 2 x 2 and 3 x 3 m and two fertilizer levels: 100 + 50 + 50 kg and 200 + 100 + 100 kg NPK/ha per year on clayey loam soil. In the closer spacing treatment (1 x 1 m), 9.9 culms per clump were obtained as compared to 6.5 and 5.2 in the medium (2 x 2 m) and wider (3 x 3 m) spacing treatments, respectively, at 572 days after planting. The closer spacing resulted in a higher leaf area (LA) per clump, leaf area index (LAI), leaf area duration (LAD), rate of dry matter production (DM) and crop growth rate (CGR), which were instrumental in increasing total dry matter (TDM) production. TDM increased from 4 tonnes/ha in the control to 12.5 tonnes/ha with an application of 100 + 50 + 50 kg NPK/ha per year.

Introduction

The most common bamboo in India is *Dendrocalamus strictus* (Roxb.) Nees which is found in the deciduous forests. The productivity of this species is low. An experiment was conducted to investigate the effect of spacing and fertilizer levels on the growth of bamboo during 1977 at the Forest Research Station, Prabhunagar, near Dharwad, Karnataka.

Methods

The experiment was conducted on a clayey loam soil belonging to the oxisols order. The physico-chemical analysis of the soil is presented in Table 1. The experimental site lies between latitude 15°24' and 15°29' N, and longitude 74°49' and 74°53' E. The mean annual rainfall of the area is 948 mm with heavy rains in July. The highest mean monthly temperature was recorded during May (31.2°C) and the lowest mean monthly temperature during the month of December (12.2°C).

The experiment comprised three spacing treatments, 1 x 1, 2 x 2 and 3 x 3 m and two fertilizer levels, 100 kg N₂ + 50 kg P₂O₅ + 50 kg K₂O /ha per year and 200 kg N + 100 kg P₂O₅ + 100 kg K₂O/ha

per year and the unfertilized control. The experiment was laid out in a split-plot design with four replications in plots measuring 18 x 18 m. One-year-old seedlings of bamboo were planted on 1 July, 1977. Fertilizers (urea, single superphosphate and muriate of potash) were applied on 20 August, 1977 and on 5 July, 1978.

The diameter of the culms was measured at the base, 5 cm above the first visible node. Leaf area per clump was computed from the oven-dry weight of the leaves in the clump and leaf area was determined with the help of a planimeter. LAD was worked out as per the formula suggested by Power *et al.* (1967). CGR was worked out using Watson's formula (1952).

Results and Discussion

Effect of Spacing

An increase in the number of culms per clump and a corresponding enlargement in the height and diameter of the clumps were noted in the closer spacing treatment as compared to medium and wider spacing treatments at 207, 388 and 572 days after planting (Table 2). Kim *et al.* (1976) observed better establishment of *Phyllostachys nigra* and *P. edulis* as the plant density was increased from 500 to 2000 plants/ha.

Table 1. Physical and chemical analysis of the soil at the experimental site

Property	Depth (cm)		
	0-15	15-30	30-60
<u>Physical properties (%)</u>			
Coarse sand	14.09	15.01	14.57
Fine sand	22.88	22.55	23.26
Silt	30.83	32.73	33.05
Clay	32.10	30.96	30.90
<u>Chemical properties</u>			
Organic carbon (%)	0.63	0.64	0.60
Total nitrogen (%)	0.044	0.030	0.032
Available phosphorus (ppm)	4.93		
Available potassium (ppm)	118.0		
pH (1:2.5 soil: water suspension)	7.6	7.7	7.5
FC(millimhos/cm at 25 C)	0.0115	0.075	0.092
CFC (meg/100 g)	31.42		

Table 2. Number of culms per clump, average height and diameter of culms of bamboo as influenced by spacing and fertilizer levels

Treatment	Days after planting								
	207			388			572		
	No. of culms/clump (cm)	Height of culms (cm)	Dia-meter of culms (cm)	No. of culms/clump	Height of culms (cm)	Dia-meter of culms (cm)	No. of culms/clump	Height of culms (cm)	Diameter of culms (cm)
<u>Spacing (m)</u>									
1 x1	3.60	101.26	0.87	7.78	153.82	1.23	9.88	185.98	1.38
2 x2	1.73	91.00	0.72	4.88	112.25	0.93	6.40	123.75	1.04
3 x3	1.75	88.54	0.68	4.70	109.20	0.89	6.20	119.38	0.99
L.S.D.(0.05)	1.24	NS	0.15	0.41	21.34	0.15	2.34	32.57	0.20
<u>Fertilizer levels (kg/ha/year)</u>									
N P ₂ O ₅ K ₂ O									
0 0 0	1.95	75.96	0.67	4.76	102.84	0.84	5.87	110.07	0.92
100 50 50	2.56	106.72	0.84	5.61	136.78	1.11	6.92	161.42	1.25
200 100 100	2.56	98.12	0.77	6.91	135.65	1.10	9.69	157.62	1.24
L.S.D.(0.05)	NS	16.43	0.10	1.38	17.45	1.11	1.94	27.94	0.16
<i>NS, Not significant</i>									

Table 3. Leaf area (LA) (dm²/lump) and leaf area index (LAI) of bamboo as influenced by spacing and fertilizer levels

Treatment	Days after planting					
	207		388		572	
	LA	LAI	LA	LAI	LA	LAI
Spacing (m)						
1 x 1	28.9	0.29	370.3	3.70	477.4	4.77
2 x 2	14.5	0.04	228.2	0.57	241.1	0.85
3 x 2	11.3	0.01	170.6	0.19	287.4	0.32
L.S.D.(0.05)	11.9	0.12	NS	0.60	98.1	0.28
Fertilizer levels (kg/ha/year)						
N P ₂ O ₅ K ₂ O						
0 0 0	12.9	0.07	89.6	0.47	129.4	0.68
100 50 50	20.0	0.11	299.3	1.86	410.4	2.37
200 100 100	21.8	0.15	380.2	2.13	566.1	2.89
L.S.D (0.05)	NS	NS	120.3	0.58	127.3	0.71

NS, not significant

Table 4. Effect of spacing and fertilizer levels on the leaf area duration (LAK:days), rate of dry matter production (DM: g/clump/day) and crop growth rate (CGR:mg/dm²/day)

Treatment	Planting to 207 days			208 to 388 days			389 to 572 days		
	LAD	DM	CGR	LAD	DM	CGR	LAD	DM	CGR
Spacing (m)									
1 x 1	42	0.44	5.0	361	2.91	44.6	779	10.72	108.4
2 x 2	15	0.20	0.5	55	1.99	8.3	131	6.60	18.6
3 x 3	13	0.14	0.2	18	0.98	1.8	47	6.34	7.7
L.S.D. (0.05)	13	NS	3.2	46	1.02	5.5	66	NS	38.8
Fertilizer levels (kg/ha/year)									
N P ₂ O ₅ K ₂ O									
0 0 0	19	0.13	0.8	49	1.14	10.1	106	1.77	12.7
100 50 50	23	0.32	2.2	179	2.02	20.8	389	9.94	54.4
200 100 100	28	0.32	2.7	206	2.72	23.8	462	11.95	67.6
L.S.D. (0.05)	NS	0.19	NS	53	0.73	9.0	107	4.42	34.0

NS, not significant

Table 5. Effect of spacing and fertilizer levels on total dry matter (TDM) production and nitrogen uptake (kg/ha)

Treatment	Days after planting									
	207			388			572			
	TDM			TDM			TDM			
	(g/ clump)	(tonnes/ ha)	Nitrogen uptake (kg/ha)	(g/ clump)	(tonnes/ ha)	Nitrogen uptake (kg/ha)	(g/ clump)	(tonnes/ ha)	Nitrogen uptake (kg/ha)	
<u>Spacing (m)</u>										
1 x1	114	1.14	10.73	641	6.41	42.08	2613	26.13	38.51	
2 x 2	64	0.16	1.77	425	1.06	5.79	1638	4.09	7.39	
3 x 3	52	0.06	0.68	229	0.25	1.75	1395	1.55	3.78	
L.S.D. (0.05)	42	0.50	4.28	205	1.58	15.03	NS	8.12	14.23	
<u>Fertilizer levels (kg/ha/year)</u>										
N P ₂ O ₅ K ₂ O										
0 0 0	49	0.27	2.62	255	1.71	9.32	581	4.00	6.44	
100 50 50	89	0.51	4.51	456	2.70	18.87	288	12.51	16.15	
200 100 100	90	0.58	6.05	583	3.31	21.43	2781	15.26	27.09	
L.S.D. (0.05)	NS	NS	NS	123	0.53	5.80	851	6.17	10.91	

NS, not significant

Increased LA per clump and LAI were observed in the closer spacing treatment as compared to wider spacings (Table 3). Niciporovic (1960) opined that if the crop could achieve an optimum LAI within a very short period and then maintain it throughout the growing season, enormous yields could be achieved. Arnon (1975) observed that as long as LAI is less than one, some of the incident solar energy which is not intercepted by the leaves, reaches the soil. Under wider spacings, during much of the growing season, much of the solar energy was not made use of by the canopy, because of the very low LA and LAI. This was reflected in the significant positive correlation ($r = 0.6529$) between LAI and TDM. Closer spacings also resulted in higher LAD, rate of dry matter production and CGR (Table 4). As a result of the higher LA per clump, LAI, LAD and CGR, the TDM production in closer spacing increased over wider spacing (Table 5).

The nitrogen uptake was also higher under closer spacing (Table 5). Moursi (1974) observed that dense planting results in good ramification of roots within the soil, which mostly accounts for the increased capacity of roots per unit soil volume to absorb nutrients and water. A slight reduction in

the nitrogen uptake in all the spacings at 572 days as compared to that at 388 days was probably due to the periodic shedding of leaves by the bamboo.

Effect of Fertilizer Levels

Application of 200 kg N, 100 kg P₂O₅ and 100 kg K₂O/ha per year, increased the number of culms produced at 388 and 572 days after planting over the unfertilized control. The number of culms produced per clump at 572 days was 9.7, whereas it was only 5.9 in the unfertilized control. An improvement in the height and diameter of the culms in the fertilized plots was noticed. Ferrer (1949) recorded a higher number of new shoots of bamboo in fertilized clumps than in the control. Ueda (1960) observed that one year after the application of fertilizers, the number of culms produced by *Leleba* multiplex increased several times as compared to the culms produced in the non-fertilized plots. Suzuki and Narita (1975) reported that the number of sprouts from the fertilized plots was 1.7 to 1.9 times that of the control.

Fertilizer levels did not significantly influence the TDM production in the early stage of the crop (Table 5). This may be because there was no marked increase in the LA per clump, LAI, LAD

and CGR (planting to 207 days). At later stages (388 and 572 days), however, there was an improvement in TDM production after the application of fertilizer. The TDM production at 572 days after planting increased from 4.0 tonnes/ha in the unfertilized control to 12.5 tonnes/ha after fertilizer treatment (100 kg N, 50 kg P₂O₅ and 50 K₂O/ha per year). Increase in the dry matter production due to fertilizer application has been observed by many workers (Anonymous 1957 a,b; 1958). Hsieh (1970) also reported significant increases in the yield of bamboo (*Sinocalamus latiflorus*) in response to combined application of N, P and K.

The increased TDM production due to fertilizer application at later stages was due to the increased LA, LAI and LAD per clump. The improvement in leaf characteristics after fertilizer treatment may have resulted in greater and more efficient interception of solar radiation over the extended growing season and which ultimately might have resulted in increased biomass production. Watson (1952) emphasized the importance of the size and activity of the leaf surface as the two components governing crop growth rate. There was an increase in the uptake of nitrogen by the plants, to the extent of 150 and 320 percent with the application of medium and high levels of fertilizers, respectively.

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Effect of N, P and K on Growth of *Bambusa arundinacea* Seedlings in pots*

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Abstract

A 3^3 factorial experiment with N, P and K was conducted on the growth of *Bambusa arundinacea* seedlings in pots. N was applied at 20, 40 and 60 g, P at 9, 18 and 27 g and K at 25, 50 and 75 g per pot to *B. arundinacea* seedlings and the biomass estimated. The results indicate that N, P and K at all levels and combinations increased the biomass production significantly over the control except for $N_3 P_3 K_3$ which showed a retarding effect. Among levels 1, 2 and 3, a significant difference was observed only in the case of N and specifically in shoot and rhizome production. Interaction between N and P was significant in the production of leaf, shoot, root and rhizome while K interacted with N, P and NP in the production of shoots. N was found to be the most important element for enhancing biomass production, while P was effective in combination with N. K exerted only a minimum influence. $N_2 P_3 K_1$ was selected as the best treatment combination through ranking of the treatments.

Introduction

The most common species of bamboo in Kerala is *Bambusa arundinacea*. It grows well on acidic non-calcareous soils of varying texture formed mainly from granitic gneisses and basalt and prefers humid conditions. It tolerates water-logging to some extent (Khader Hussain, 1980). Although *B. arundinacea* thrives on a variety of soils, its growth is reduced on coarser soils of low nutrient status and moisture. It is generally found on soils rich in organic matter, nitrogen, iron, aluminium, manganese and potassium (Yadav et al., 1963). From a study of the chemical composition of plant ash, Varitseva (1977) came to the conclusion that bamboo falls in the group of Mn-Al-Fe-Si loving plants.

Being an extremely fast-growing species, bamboo can be expected to consume large quantities of nutrients. Studies carried out elsewhere have shown that the supply of nutrients considerably increases growth and biomass production (Anonymous 1961; Adamson et al., 1978; Khader Hussain 1980; Madhusoodhana Rao et al., 1980; Patil et al., 1980; Uchimura, 1980; Kinhal, 1985; Huang, 1987; Qiu & Maoyi, 1987; Shi et al., 1987).

The present study was undertaken to determine the influence of various levels of nitrogen, phosphorus and potassium on the growth and biomass production of seedlings of *B. arundinacea*.

Material and Methods

Subsoil from the campus was used for the experiment. This was done in order to determine the response on poor soils so that the results could be applied while planting in degraded sites. The subsoil is acidic sandy loam with medium gravel content, massive structure, rich in sesquioxides, and poor in organic carbon and nutrients. It was sieved through an 8 mm sieve, mixed thoroughly and filled into concrete pots of 35 cm height and 26 cm internal diameter. The pot could contain 21 kg of soil. Six-month-old seedlings of *B. arundinacea* raised in polybags were transplanted in the concrete pots on 5 February, 1988. Nitrogen, phosphorus and potassium were applied at three levels each in a 3^3 factorial design with three replicates. Fertilizer was applied one month after transplanting in the form of a band around the plant and covered with soil. N was applied at levels of 20, 40 and 60 g, P at 9, 18 and 27 g and K at 25, 50 and 75 g per pot.

* KFRI scientific paper no. 183

Table 1. Analysis of variance - biomass production

Source	Leaf	F values Shoot	Root	Rhizome
N	2.2540	6.9090**	1.3648	6.4604**
P	0.7270	2.5261	1.0227	1.4473
K	1.1168	1.3558	0.0592	2.1988
NP	7.3782**	12.9909**	4.9278**	5.8905**
NK	0.7075	4.2335**	0.0606	2.3245
PK	1.2954	4.9978**	0.1378	0.6386
NPK	0.7456	2.7951*	0.5463	0.7774

*, significant at 5%; **, significant at 1%

A control was maintained separately. Watering was done to maintain soil moisture.

The plants were harvested seven months after transplanting, washed clean, the leaf, shoot, root and rhizome separated and oven-dried at 80 C for 24 h. The data were analysed statistically using analysis of variance and Duncan's new multiple range test (Keppel, 1973). Ranking of treatments was done with respect to each character and the best treatment combination selected.

Results

Leaf

Significant increases in leaf biomass occurred at all levels of N, P and K over the control (Fig.1). The increase by N₁, P₁ and K₁ when compared with the control was 133, 131 and 136 percent, respectively. Although the second levels of N, P and K produced slightly higher yields than the first, the third level was not as effective. There was no sig-

nificant difference among the three levels of N, P or K while the interaction between N and P was significant.

Shoot

N, P and K produced significantly higher shoot biomass at all levels when compared with the control (Fig. 2). N₁ increased it by 256 percent over the control. The increase by P₁ was 235 percent and that by K₁, 229 percent. The use of the second level of all the three elements was slightly most effective in improving growth. There was a significant difference between the three levels of N on shoot biomass and all the three elements interacted significantly in shoot production.

Root

N₁, P₁ and K₁ increased it by 153, 150 and 152 percent, respectively, over the control (Fig. 3). N₂, P₂ and K₂ brought about a further increase in root growth as compared to the first level whereas the

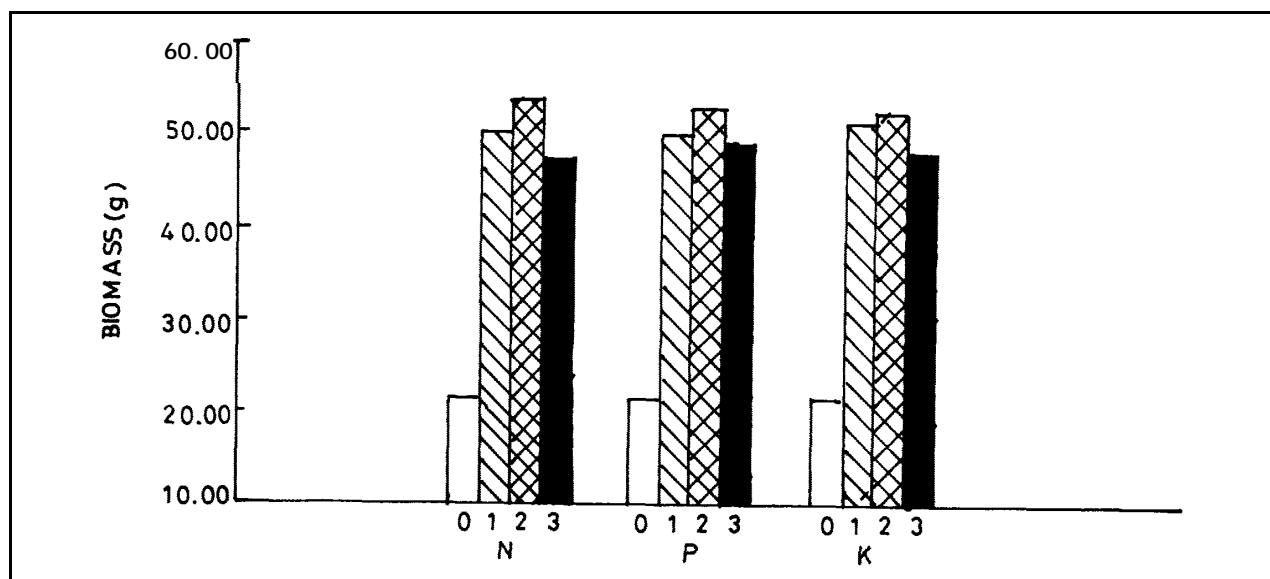


Fig. 1. Biomass production of leaf.

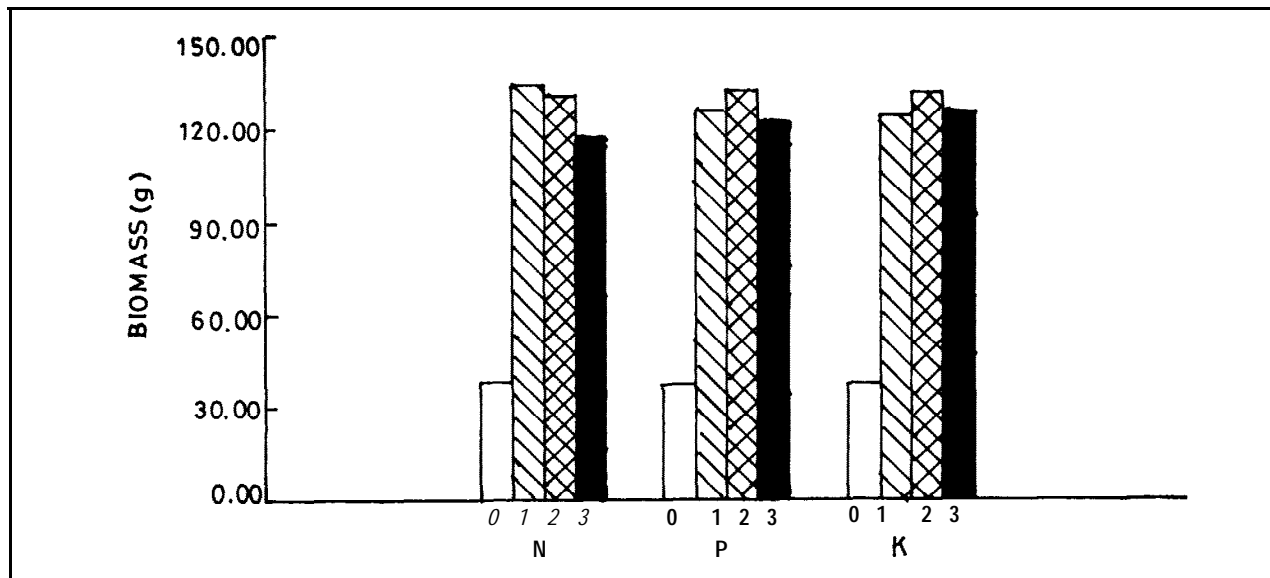


Fig. 2. Biomass production of shoot.

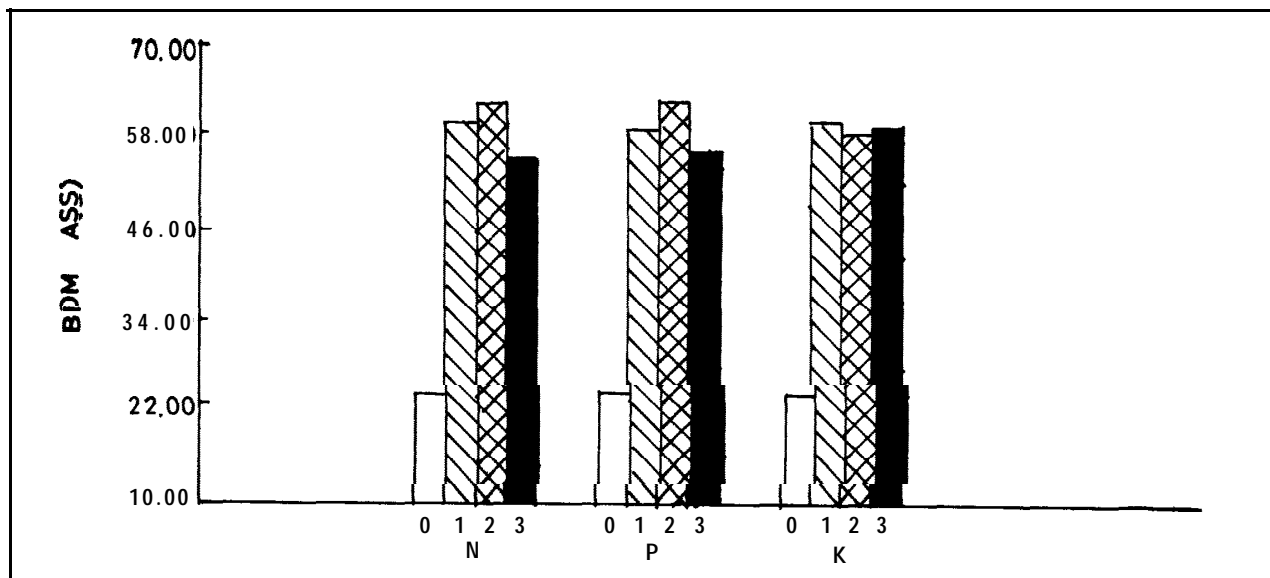


Fig. 3. Biomass production of root.

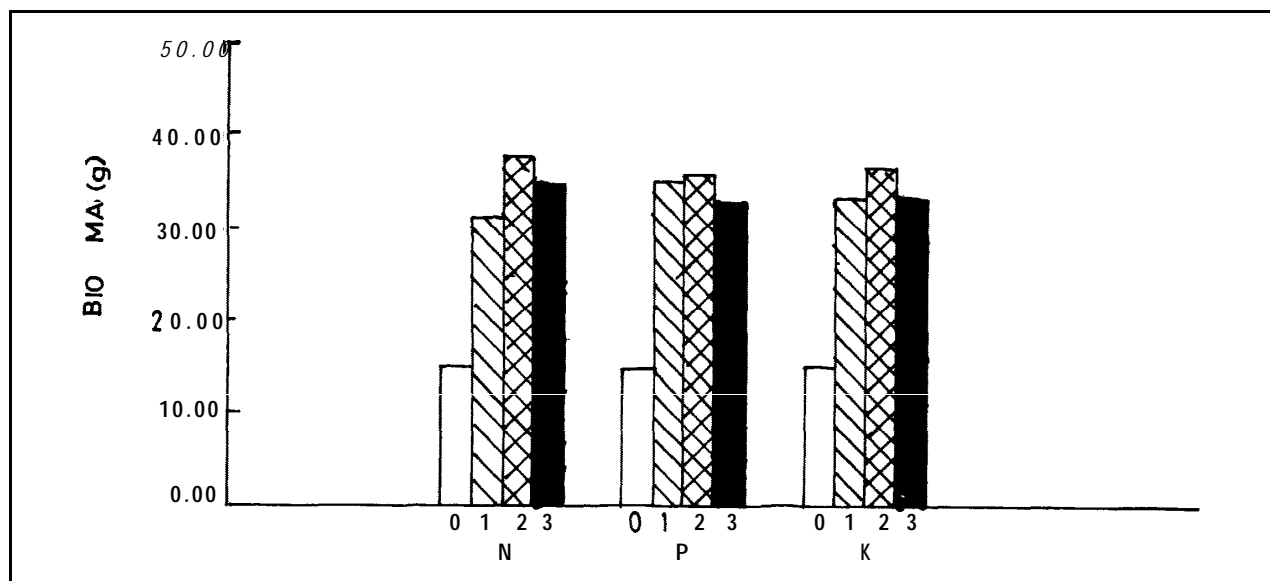


Fig. 4. Biomass production of rhizome.

third level either decreased it or did not cause any increase. The differences between the first, second and third levels were not significant whereas interaction between N and P was significant.

Rhizome

Rhizome growth increased significantly at all levels of N, P and K in comparison with the control (Fig. 4). The increase by N_1 , P_1 and K_1 over the control was 109, 135 and 123 percent, respectively. There was a notable increase in rhizome growth at the second level over the first for all the three elements. N levels differed significantly in their effect on rhizome production whereas there was no significant difference between the P and K levels. Interaction was significant only between N and P.

Discussion

N, P and K at all levels and combinations significantly enhanced growth and dry matter production of *B. arundinacea* seedlings over the control. Among the treatments, no significant differences were observed except with N, which showed a significant effect in shoot and rhizome production. Significant interaction occurred only between N and P in increasing the dry matter yield of leaf, shoot, root as well as rhizome, whereas in shoot production, N, P and K interactions were significant. N has previously been found to improve the growth of other species of bamboo (Adamson *et al.*, 1978; Patil *et al.*, 1980; Shi *et al.*, 1987; Qiu & Maoyi, 1987). P was also found to be useful, though its effect was significant mostly in combination with N. This interaction was consistent for all the growth parameters considered. K appeared to be less essential than N and P. It, however, exerted a greater influence on shoot production where it interacted significantly with N, P and N x P. Huang (1987) also observed the interaction between N, P and K on the growth of *Phyllostachys pubescens*.

The best treatment combination was found to be $N_2P_3K_1$ by the ranking of treatments. It increased the yield of leaves, shoot, root and rhizome by 22, 410, 235 and 183 percent, respectively, over the control. Considering the high content of Fe and Al in the soil used in the present study, it is possible that the availability of P was low resulting in a better response when P_3 was added. The highest level combination $N_3P_3K_3$ was detrimental to biomass production.

Conclusion

The results of this study indicate that N, P and K application can boost the growth and biomass

production of *B. arundinacea* seedlings. Among the three elements, N has been found to exert the greatest influence, followed by P and K. N x P interaction was significant in the production of leaf, shoot, root and rhizome biomass.

Acknowledgements

I express my sincere gratitude to Dr C.T.S. Nair, former Director and Dr K.S.S. Nair, present Director for giving sanction to this study, Dr T.G. Alexander for his guidance and encouragement, Dr R. Gnanaharan for suggestions, Ms I. Rugmini for advice and help in statistical analysis, Ms. D. Sumangalamma for wordprocessing the manuscript. Mr A.V. Velayudhan for assistance in the experimental part and IDRC, Canada for financial support.

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Effects of Fertilization on Growth and Yield of Bamboos

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Abstract

Fertilization experiments were conducted on *Thyrsostachys siamensis*, *Dendrocalamus asper*, *Bambusa* sp. and *D. strictus* in three-year-old plantations at Dong-lam in Khon Kaen. The randomized block design with four treatments was used in these experiments. The treatments were different fertilization rates of 15-15-15 NPK fertilizer at 0, 100, 200 and 300 kg/ha. The results showed that 100 kg/ha of fertilizer was sufficient for increasing the production of *Thyrsostachys siamensis*, *Dendrocalamus asper*, and *Bambusa* sp. However, for *Dendrocalamus strictus*, kg/ha 200 of fertilizer was found to be necessary.

Introduction

Traditionally, bamboo has been referred to as a minor forest produce. However, the status of bamboo has changed considerably and it is rapidly emerging as an important plant group in many forestry programmes. During the past few decades, several Asian countries have embarked on large-scale cultivation of economically important species. In Thailand, the species include *Thyrsostachys siamensis*, *Dendrocalamus asper*, *Bambusa* sp. and *D. strictus*. While conventional silvicultural treatments or tending operations are being carried out in these plantations, fertilization has never been attempted. Experiments were, therefore, carried out in the bamboo plantations to determine the optimum level of fertilizer needed for increasing production.

Materials and Method

The experiments were carried out on four bamboo species at Dong-lam plantation in Khon Kaen. The species included *Thyrsostachys siamensis*, *Dendrocalamus asper*, "Pai Warn" (*Bambusa* sp.) and *D. strictus*. These were planted in 1983 and were, therefore, three years old when the studies were first begun in 1986. Their planting spacings are 4 x 4, 8 x 8, 8 x 8 and 4 x 4 m, respectively. Forty plants of *T. siamensis* and *D. strictus*, and 28 plants of *D. asper* and *Bambusa* sp. were selected

for uniformity and divided into ten and seven groups or blocks, respectively, with four clumps in each block. The randomized block design with four treatments was used in these experiments. The treatments comprised the following fertilization rates with U-15-15 NPK fertilizer: 0, 100, 200, 300 kg/ha.

The crown size of each selected plant (clump) was measured and its crown cover area calculated. The fertilizer was applied according to the treatment and the crown cover area. The application was carried out successively once a year in 1986 and 1987 at the beginning of the growing season. The number and diameter at breast height (dbh) of new culms produced were measured and analysed by the analysis of variance.

Results and Discussion

The 15- 15- 15 NPK fertilizer showed a significant effect in increasing the yields of *Thyrsostachys siamensis*, *Dendrocalamus asper*, *Bambusa* sp. and *D. strictus* (Table 1). The effects are shown clearly in Figure 1 and their statistical analyses by the method of the least significant difference (LSD) are given in Table 2. A significant effect of the fertilizer on the size of new culms annually formed was obtained in *T. siamensis* (Table 1), but not in the case of *D. asper*, *Bambusa* sp. and *D. strictus* (Table 1). Further analyses by the LSD test revealed that the mean value of the control in *T. siamensis*

Table 1. Analysis of variance (F-values) of number and dbh of new culms

Species	No. of culms	Dbh
<i>Thyrsostachys siamensis</i>	6.22**	5.54**
<i>Dendrocalamus strictus</i>	12.85**	1.35 ^{ns}
<i>Bambusa</i> sp.	12.07**	0.97 ^{ns}
<i>Dendrocalamus asper</i>	3.12*	0.75 ^{ns}

*, significant; **, highly significant; ns, non-significant

Table 2. Comparison (by least significant difference LSD) of mean number of new culms produced by four bamboo species treated by H-15-15 fertilizer at different rates

Species	Fertilizer rates (kg/ha)			
	Control(O)	100	200	300
<i>Thyrsostachys siamensis</i>	10.0	14.5	14.9	14.8
<i>Dendrocalamus asper</i>	3.1	4.3	5.0	5.4
<i>Bambusa</i> sp.	18.0	23.7	25.7	27.3
<i>Dendrocalamus strictus</i>	5.2	6.7	7.4	7.9

mean values not underscored by a continuous line are significantly different at the 95% confidence level

differed significantly from the means of the treatments at 100,200 and 300 kg/ha, but the latter were not significantly different among themselves.

In *Thyrsostachys siamensis*, *Dendrocalamus asper* and *Bambusa* sp., 100 kg of 15-15-15 NPK fertilizer/ha was adequate for increasing their production. Though the higher rates of 200 or 300 kg/ha seemed to increase their yield, statistical analyses showed insignificant differences especially in the yields of *T. siamensis* and *Bambusa* sp. For *D. strictus* also, fertilization at 100 kg/ha increased its yield but this did not differ significantly from that of the control (Table 2). In comparison, the treatments 200 and 300 kg/ha differed greatly from the control, but not significantly from that of the treatment 100 kg/ha.

The size of the new culms produced annually by the bamboos seems to be affected by the strength of their underground rhizomes and food produced by their mother culms (Ueda, 1960, 1968; Suwanapinunt et al., 1982). When the bamboos grow to their maturation stage, their culm size becomes constant; no amount of fertilization will enhance

their size but will rather affect their yield (Ueda, 1960). The plants used in these experiments were three years old and all the species, excepting *Thyrsostachys siamensis*, were regenerated by offset planting. The former will reach maturation early and their sizes were, therefore, nearly similar to those of the mature plants. Fertilization of *Dendrocalamus asper*, *Bambusa* sp. and *D. strictus* did not, therefore, yield significant results. However, for *T. siamensis*, the plants were regenerated from the seedlings and fertilization caused a marked effect on the size of the new culms.

Conclusion

The use of 15-15-15 NPK fertilizer had a pronounced effect on the yield of *Thyrsostachys siamensis*, *Dendrocalamus asper*, *Bambusa* sp. and *D. strictus*. Fertilizer application at 100 kg/ha is sufficient to increase the yield of *T. siamensis*, *D. asper* and *Bambusa* sp. For *D. strictus*, use of 200 kg/ha of 15-15-15 NPK fertilizer was found to be appropriate.

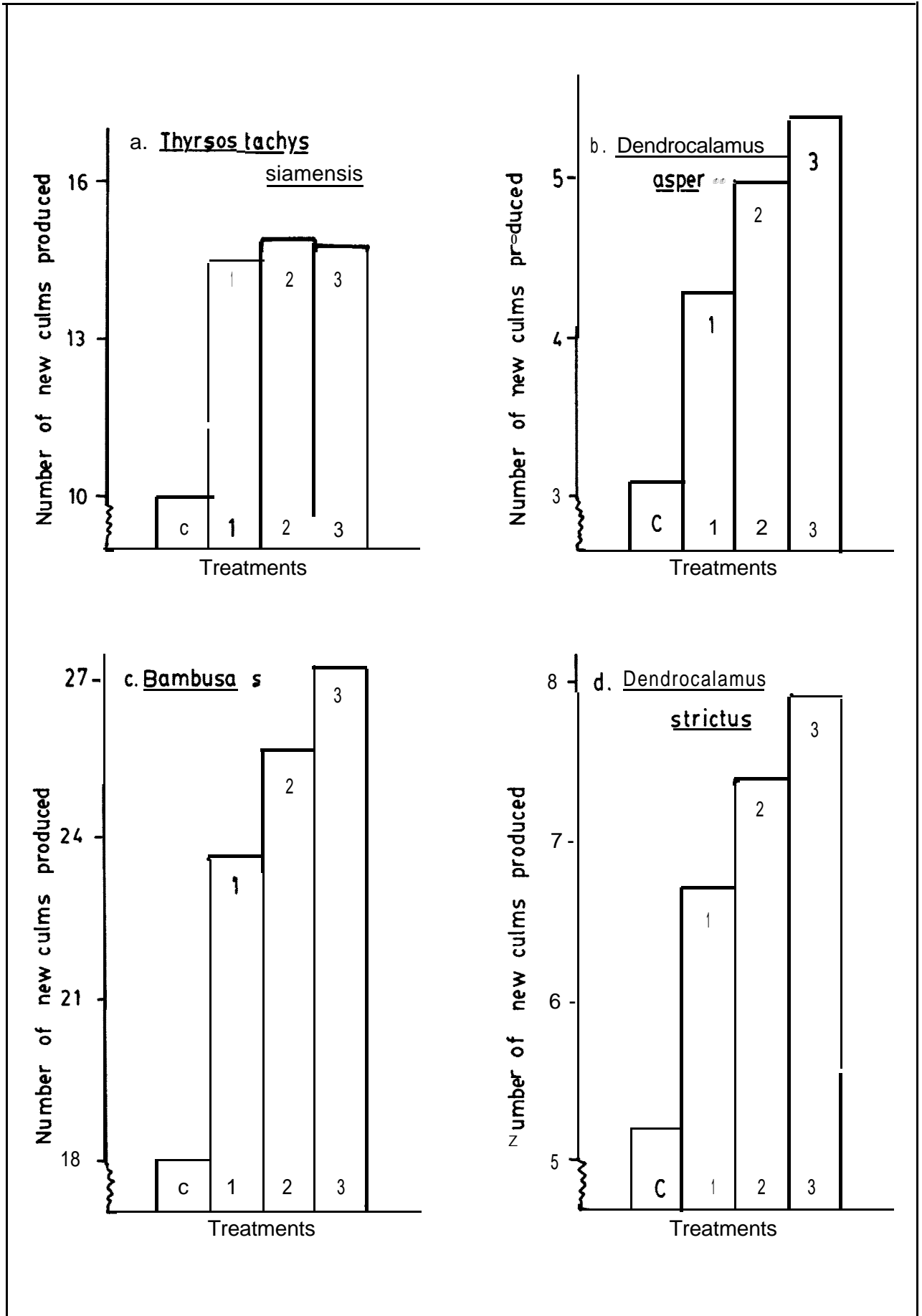


Fig. 1. Effects of 15-15-15 compound fertilizer on growth of four bamboo species; C, 1, 2, and 3 in the bar charts are control (0), 100, 200, and 300 kg/ha of fertilizer, respectively.

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Fertilization Studies in Bamboo Timber Stands

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Abstract

Fertilizer trials were carried out in stands of *Phyllostachys pubescens* in the South-east part of China. A total of 40 plots were laid out, each measuring 400 m². Three treatments at two levels were carried out: (1) fertilizer (two levels), (2) fertilizer application time (spring and autumn) and (3) fertilizer application method (in furrows or stumps). The fertilizers used were compounds of N, P, K and Si. Results showed that spring application in furrows at 375 kg/ha gave a yield of 7870 kg of culms. This gave the farmers a net income of RMB 830.00 or USD 225.00.

Introduction

The nutrients needed for the growth of trees mainly come from mineralization of soil, rain, decomposition of litter, soil animals and microorganisms, fertilization, and from nutrient mobilization among the organs or tissues of the trees. Among these, the only factor which can be controlled artificially is fertilization. In China, fertilization is carried out to increase the productivity of *Phyllostachys pubescens*.

Since the development of the fertilizer industry in China and with increasing demand of bamboo materials, the fertilized area of the forests under bamboo has expanded. A number of fertilization studies of bamboo stands have been carried out in the past 30 years, to arrive at economic levels for bamboo forests. It is with a similar purpose that the current investigation was undertaken.

Experimental Sites

Four experimental sites were established during the spring of 1985: (1) Miao Shan Wu, Fuyang county, Zhejiang province (30° 03' N, 119° 57' E), (2) Hetangwu, Anji county, Zhejiang province (30° 39' N, 119° 41' E), (3) Shangcuen, Fenyi county, Jiangxi province (27° 30' N, 114° 30' E), and (4) Xiache, Lianjiang county, Fujian province (26° 23' N, 119° 22' E).

All the sites are located in the main productive region of *P. pubescens*. The soils found here are silty loam, heavy loam, clay loam or light clay soil

which show strong acidity (pH 4.9- 5.1). The soils in Zhejiang are rich in nitrogen while the soils in Jiangxi or Fujian province have a lower concentration of nitrogen. Though all the soils in the region are rich in potassium, they are deficient in phosphorus. Besides, the soil layer is less than 30 cm deep on an average and contains large quantities of gravel, especially at the experimental site of Anji, Zhejiang province. The density of the standing bamboo is consequently low with around 2250-3000 culms/ha, and the brow-height girth is small (3 1.7 cm). Tables 1 and 2 give details on the climate and soil conditions at the experimental sites.

Design and Method of Experiment

Selection of the Experimental Plot

Unlike trees, *P. pubescens* has an underground rhizome which enlarges and grows laterally. Besides, as the bamboo groves are often distributed on hills and mountains with a complex topography, it is necessary to determine the optimum area of the experimental plots. So several bamboo stands with size of 40 x 40 or 32 x 32 m were randomly selected and divided into equal plots of 4 x 4 m. The total productivity - the yield of all standing culms, and the current year's productivity - the yield of new culms were determined in all the plots and the coefficient of variability (C.V.) calculated. The conjunctive plots were then put together step by step and the yield and C.V. recalculated each time. Figures 1 and 2 show the relationship between plot area and C.V. It is seen that the C.V. of yield of new

Table 1. Climatic conditions at the experimental sites

Site	Average temperature (C)			Highest temperature (C)	Lowest temperature (C)	Precipitation (mm)
	Annual	July	Jan.			
Anji, Zhejiang	14.5	28.3	2.6	39.2	-8.8	1875.7
Fuyang, Zhejiang	16.1	28.9	3.3	37.8	-8.4	1700.0
Fenyi, Jiangxi	17.9	29.0	5.3	39.9	-8.3	1539.7
Lianjiang, Fujian	16.9	28.5	9.5	38.0	-3.8	1540.1

Table 2. Soil conditions at the experimental sites

Site	Texture	pH (water extract)	Total N (%)	Total P ₂ O ₅ (%)	Exchangeable K(ppm)
Anji, Zhejiang	heavy loam light-clay	5.1	0.1742	0.0699	70.58
Fuyang, Zhejiang	silt loam clay loam	5.0	0.2068	0.0517	87.38
Fenyi, Jiangxi	heavy loam	4.9	0.1234	0.0534	67.02
Lianjiang, Fujian	silt loam silty clay	5.0	0.1449	0.0300	79.53

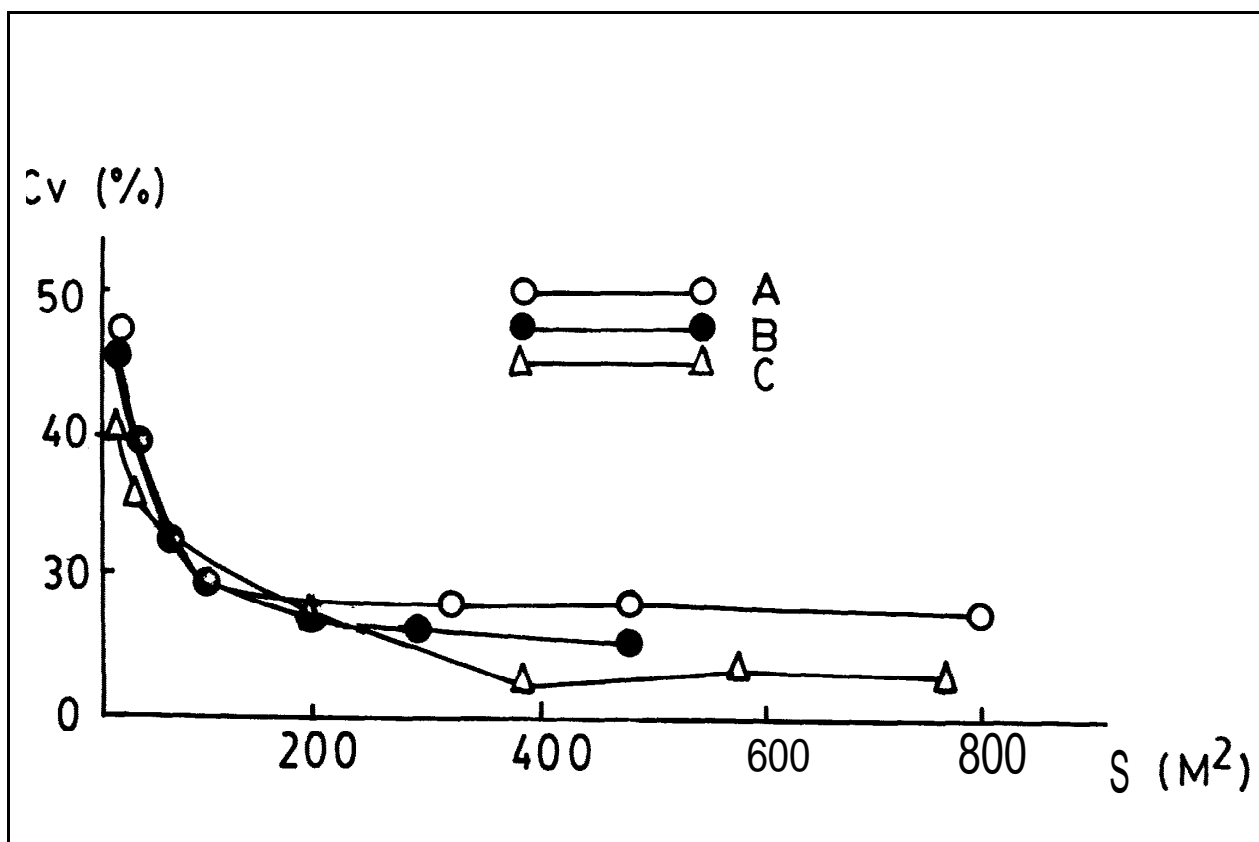


Fig. 1. C.V. of total standing culms in plots with different areas. A, B and C are sites at Anji, Fuyang and Fenyi, respectively.

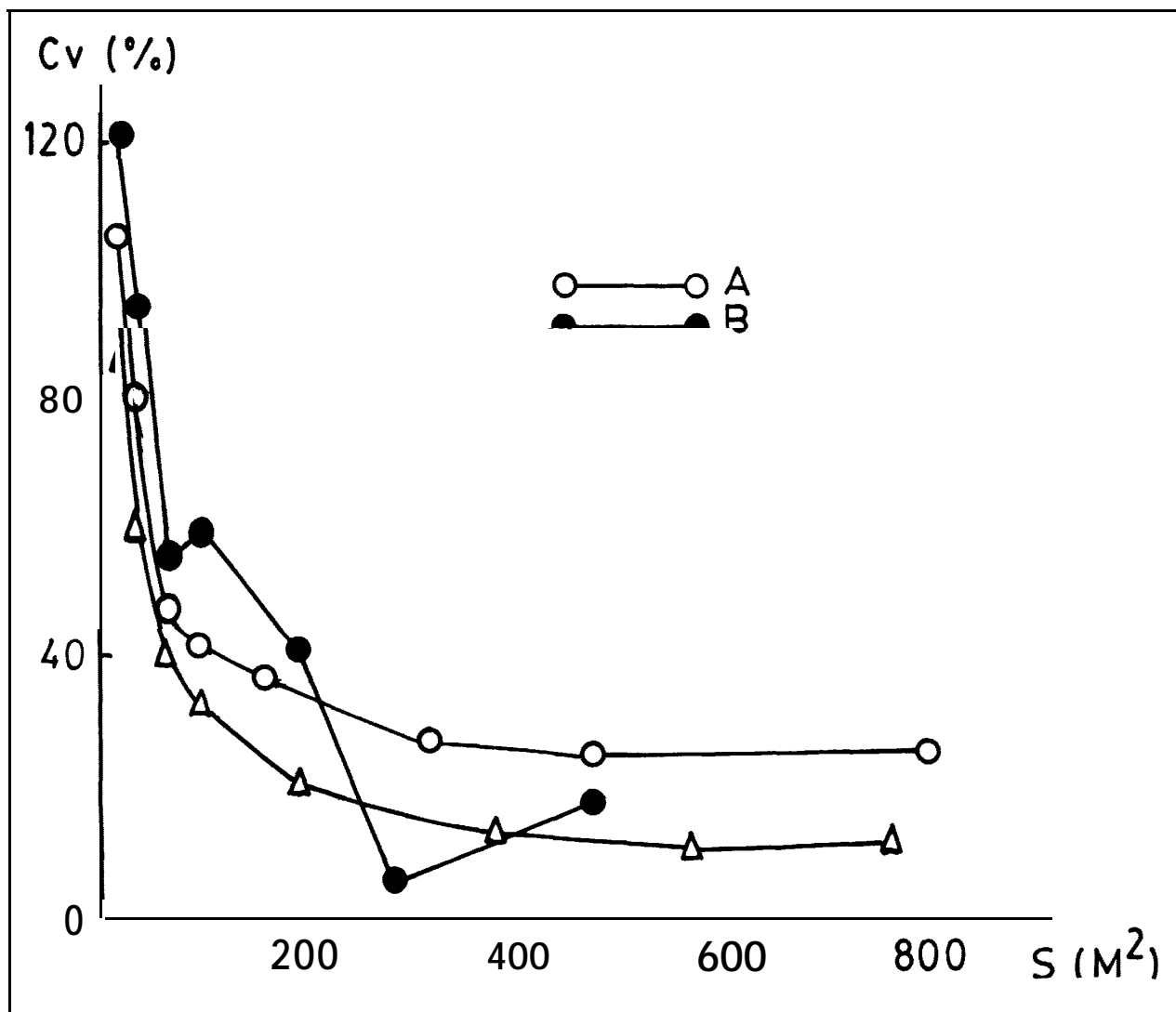


Fig. 2. C.V. of new culms in plots with different areas. A, B and C are sites at Auji, Flyang and Fenji, respectively.

culms or total standing culms reduces when the plot area is broadened. Based on the result obtained and taking into account the growth characteristics of the rhizome system, the optimum area of the experimental plots was determined as 400 m².

Establishment of Buffer Zone and Isolating Ditch

A buffer zone with a width of 10 m was made between the conjunctive plots and an isolation ditch 40 cm wide and 50 cm deep was dug in the middle of the zone. The treatment within the buffer zone was similar to that in the conjunctive plot.

Experimental Design and Data Processing

This was based on the methods of Steel and Torrie (1960) and Zhac and Yu (1984).

Experimental design

Fifteen plots, located at each experimental site,

were divided into three blocks each. Each block included a control plot (without fertilization) and four plots with the experimental combination of two fertilizing times (February- March, August-September), two fertilizing methods (fertilizing in furrow or in stump), and two levels of fertilization (N P K Si compound fertilizer at 375 or 750 kg/ha (see Table 3). All the treatments were randomly arranged in each block. The fertilization was carried out annually according to the design beginning from the autumn of 1985.

Data processing

Observations were made on shoot production and number and the yield of current culms, one year after the fertilization treatment. Using the product of the standing culm number (N), the average diameter of all culms at breast height (dbh) and the average height of all clear culms (Hc) in each plot before treatment as a covariate, the analysis of

Table 3. Fertilization treatments in *P. pubescens* timber stand

Treatment	Factor			Description of treatments
	1	2	3	
1	1	1	1	Spring and furrow application 375 kg/ha
2	1	2	2	Spring and dump application 750 kg/ha
3	2	1	2	Autumn and furrow application 750 kg/ha
4	2	2	1	Autumn and stump application 375 kg/ha
5	0	0	0	Control (unfertilized)

Table 4. Adjusted yield in different plots (kg)

Treatment	1	2	3	4	5	6	7	8	Mean	Percentage
A(1)	1348.2	1089.8	1313.4	1230.8	1038.5	906.3	1003.7	851.5	1097.8	129.5
A(2)	1541.4	1376.1	942.8	1155.9	1050.7	774.0	973.3	839.3	1081.7	127.6
A(3)	1030.7	1069.0	1028.1	871.5	1231.6	721.0	872.3	813.2	954.7	112.6
A(4)	1281.2	1068.1	943.7	1020.2	1216.0	750.5	910.6	754.9	993.2	117.2
A(5)	858.4	1035.9	721.8	940.2	801.0	761.0	778.4	883.6	847.5	100.0
T(R)	6059.9	5638.9	4949.8	5218.6	5337.8	3912.8	4538.3	4142.5	39198.6	

Table 5. Visible analysis of plot yield after fertilization

Factors Treatment	(1)	(2)	(3)	1	2	3	4	5	6	7	8	T(T)
(1)	1	1	1	1348.2	1089.8	1313.4	1230.8	1038.5	906.3	1003.7	851.5	8782.2
(2)	1	2	2	1541.4	1376.1	942.8	1155.9	1050.7	774.0	973.3	839.3	8653.5
(3)	2	1	2	1030.7	1069.0	1028.1	871.5	1231.6	721.0	872.3	813.2	7637.4
(4)	2	2	1	1281.2	1068.1	943.7	1020.2	1216.0	750.5	910.6	754.9	7945.2
K 1	17435.7	16419.6	16727.4	5201.5	4603.0	4228.0	4278.4	4536.8	3151.8	3759.9	3258.9	33018.3
K 2	15582.6	16598.7	16290.9									
M1	1089.7	1026.2	1045.5									
M2	973.9	1037.4	1018.2									
R	115.8	11.2	27.3									

Table 6. Table of variable analysis according to table 5.

Source	ss	D F	MS	F	Fa
Blocks	855389.9122	7	122198.5589	7.94**	FoO ₅ (1,21) = 4.32
Factor A	107311.862	1	107311.8628	6.97*	Fo.O ₁ (1, 21) = 8.02
Factor B	1002.4003	1	1002.4003	0.07	Fo.O ₅ (7, 21) = 2.49
Factor C	5954.1328	1	5954.1328	0.39	Fo.O ₁ (7, 21) = 3.64
Error	323334.3666	21	15396.8746		
Total	1292992.6747	31			

covariance for the current culm yields in all plots was carried out. If the F-test was significant, the adjusting regression coefficient would need to be calculated for adjusting yields of current culms to comparable levels. Visual and variance analysis of the adjusted yield data was also done.

Other measures

In order to enable direct utilization of the experimental results, all the experimental plots were managed based on silvicultural measures generally practised in *P. pubescens* stands which included soil-loosening, weeding, removing the dying-back shoots, cutting the the tops of bamboo and harvesting them in the appropriate season.

Results and Discussion

The F test of the regression variance analysis of current culm yields was significant ($F=205.97^{**}$) and hence the adjusting co-efficient b was calculated ($b = 0.1303$). The adjusted yields of all experimental plots are given in Table 4.

It was seen that the fertilizing time has a statistically significant effect on the new culm yield. Application of the N P K Si compound commercial fertilizer in early spring (about one month before bamboo shoots emerge out from the ground towards the end of February) was found to be better than applying in autumn (at the stage of differentiation of the bamboo shoot bud: Tables 5, 6; Fig.

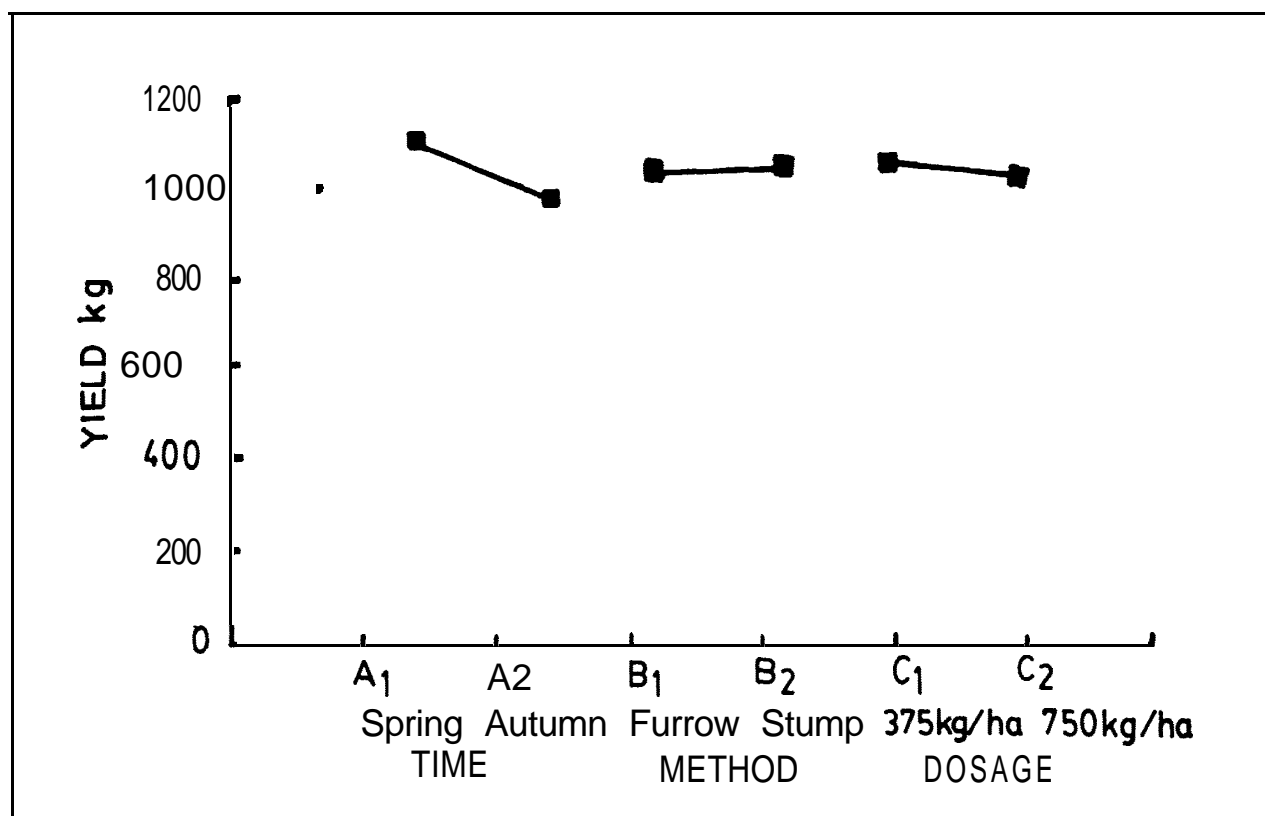


Fig. 3. Effect of factor level on yield (A:time; B: method; C: dosage).

Table 7. Table of variable analysis

Source	ss	DF	MS	F	Fa
Blocks	764280.56	7	109182.94	6.24**	F _{0.01(7,28)} = 3.36
Treatments	331617.07	4	82904.27	4.74**	F _{0.01(4,28)} = 4.07
Error	490173.38	28	17506.19		
Total	1586071.01	39			

Table 8. Qs values

P		2	3	4	5
Qs	(.05)	2.90	3.50	3.87	4.12
Qs	(.01)	3.91	4.49	4.84	5.09
LQs	(.05)	135.66	163.73	181.03	192.73
LQs	(.01)	182.91	210.04	226.4 1	238.11

Table 9. Results of Qs test

Treatment	X	X-847.5	x-954.7	x-993.2	X-1081.7
1	1097.8	250.2**	143.1	104.6	16.1
2	1081.7	234.2**	127.0	88.5	
3	993.2	145.6	38.5		
4	954.7	107.1			
5	847.5				

Table 10. Shoot formation in *P. pubescens* timber stand after fertilization

Treatment	Block									Mean	Percentage
	1	2	3	4	5	6	7	8			
1	107	100	112	48	42	62	84	55	76	140.7	
2	133	112	86	53	48	58	54	81	78	144.4	
3	116	130	136	53	46	62	62	89	87	161.1	
4	83	64	93	40	47	47	47	69	62	114.8	
5	64	95	77	27	25	55	43	48	54	100.0	