GENETIC ENHANCEMENT OF BAMBOO AND RATTAN

Edited by

J. T. Williams, I.V. Ramanuja Rao and A.N. Rao

Report of an Expert Consultation held at Los Banos, Philippines, 8-11 May 1995 and convened by the

INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN (INBAR)

in cooperation with the

INTERNATIONAL PLAN GENETIC RESOURCES INSTITUTE (IPGRI) *and the* **FAO-UNDP FOREST TREE IMPROVEMENT PROJECT (FORTIP)**

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PREFACE

Bamboos and rattans are multipurpose plants that have been adopted by communities the world over in areas of their occurrence, and rural living patterned around their numerous products and applications. Besides the household level, bamboos an rattans play a key role in the handicrafts sector and provide literally millions of lobs.

The industrial revolution caught up with these traditional plants this century with pulp and paper being the first such aplacations of bamboo. More recently, several other industrial products have followed, such as laminated bamboo, parquet flooring plybamboo, etc. Several of the traditional uses, such as bamboo shoots as food, chopsticks, toothpicks, have also been mechanised. An important advance was the conversion of the age-old woven bamboo mat into board through application of glue and hot-pressing. The latter has found an eager market.

Clearly, the time has come to address specific applications of bamboo and rattan, and to select and breed towards that end. This will also permit more efficient use of the resource, and will reduce the industry-community conflicts that are increasingly becoming apparent and contribute towards the conservation of the resource. In the long run, perhaps, much of the raw material required by industrial/semi-industrial applications could be met largely from plantations of improved bam oos and rattans, while the traditional use of the resource from the natural forest by communities could continue.

We trust the first important step towards this end has been taken through the organisation of the Consultation and the publication of this roceedings. This Consultation is also another im ortant milestone in the excellent working links that have been established between INBAR, and IPGRI and ORTIP

INBAR, IPGRI and FORTIP wish to thank Dr E.A. Rosario, Director of the Ecosystems Research and Develo ment Bureau for kind1 providing meeting space. We also thank the participants for their active involvement and contributing to what was certainly, a most successful meeting.

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Director, INBAR

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CONTENTS

INTRODUCTION

1. Two INBAR Consultations, organized as part of the work of the Production Working Group (the first on identification of priority species and the second on constraints to production), had emphasized the need for genetic enhancement of both bamboo and rattan. As a result, an Expert Consultation was organized by INBAR and co-sponsored by FORTIP (FAO/UNDP Regional Project RAS/91/004) and IPGRI (a centre of CGIAR). The Consultation was held in Los Banos, Philippines, 8-11 May 1995.

2. The agenda and list of participants are shown in Appendices 1 and 2. Participants were those involved with past INBAR-FORTIP activities and joint INBAR-IPGRI activities; the former focused on man-made-forest improvement and the latter on work on the genetic diversity and conservation of bamboos and rattans guided by an INBAR Working Group.

3. In addition, local arrangements were made by FORTIP in association with the Ecosystems Research and Development Bureau (ERDB) of the Philippines which kindly provided meeting space. Opportunity was also taken for exposure of participants from other countries, to the Philippines bamboo and rattan research, especially on diversity and production.

4. The Consultation was opened by Dr. K. Vivekanandan, Chief Technical Advisor and Project Coordinator of FORTIP, and participants were welcomed by Dr. E.A Rosario, Director, ERDB, Prof. A.N. Rao, Consultant, IPGRI, and Dr. Cherla B. Sastry of IDRC, INBAR Director.

5. Prof. J.T. Williams, Science Advisor to INBAR, provided a background to the meeting (Appendix 3). He stressed that the mosaic of supply/demand systems across Asia with overall demand exceeding supply was being addressed by the research community by a multiple approach to increasing productivity.

6. Although from a scientific point of view we know virtually nothing about the genetic variation of priority species of bamboo and rattans, there is an overriding need to enhance the materials currently used as planting materials. This is even more urgent as a major strategy for increasing production through plantations is implemented more widely. Identification of superior genotypes is necessary, despite forest practitioners lagging in this work. Research has been largely focused on management practices rather than on any concentrated effort on measurable traits that have a moderate to strong degree of heritability.

7. There has been a very limited selection of desirable phenotypes, or "plus" types which are propagated vegetatively and since rattans are raised from seed and most useful bamboos are considered outcrossing and seed is widely used, when available, there has been virtually no testing of progenies for identification of elite genetic materials. Due to the increasing over-exploitation of bamboo and rattan resources it is timely to consider what strategy should be adopted.

REPORT

APPROPRIATE APPROACHES TO GENETIC ENHANCEMENT OF BAMBOO AND RATTAN

8. Dr. M.J. Lawrence (Appendix 4) pointed out that evaluation trials with numerous plantation species have shown that substantial progress can be made by using unimproved wild-type germplasm and such trials are applicable to bamboo and rattan species. It can be assumed that wild and semi-natural stands consist of a large number of different genotypes and for those species with a wide geographical distribution, different populations will contain different arrays of genotypes. Results from evaluation trials with oil palm and rubber indicate that elite genotypes are quite rare and they occur in unpredictable parts of the distribution range of the species. Collection of material from a population should be random since there is no point in collecting from plants/clumps which appear to be superior since the heritability of quantitative characters is rarely above 50%. Thus, most of the phenotypic variations seen in the natural populations is environmental, rather than genetic. There is no reason to believe that bamboo and rattan are different.

9. Identification of superior genotypes through evaluation trials which are rigorously managed, well-designed and of sufficient scale can only be done when the initial survey, and identification of target areas for sampling, as well as the correct sampling procedures, are implemented. Also the maintenance of seedlings from each mother plant as separate entries is necessary; entries will have to be through a well-managed nursery stage prior to the trial and if vegetative propagation is used, in the case .of bamboos, entries will need to be

as physiologically similar as possible and a generation of vegetative reproduction needs to be interposed between the mother clumps of the germplasm nursery and the evaluation trial.

10. Methods now standardised for vegetative propagation of bamboos and tissue culture - designed to help availability of planting materials - can both be advantageous in developing evaluation trials of priority bamboo species.

11. Propagation of rattan is by seed. Families sampled from populations are starting materials for evaluation trials. Any problems in sampling e.g. access to limited natural populations could be overcome but would interpose other procedures but with less observation on original population differences.

12. Results from evaluation trials of both bamboo and rattan will provide starting points for systematic improvement programmes through crossing and selection. Controlled crossing, although, operationally difficult in rattans, is feasible; it will be farmore difficult in bamboos because of life histories and flowering behaviour.

13. The evaluation trials should be to identify genotypes of commercial/economic value; but they will also provide opportunities to systematically gather other information on basic biology of the species, knowledge of which is often based on opinions and needs to be confirmed.

PATTERNS OF VARIATION IN BAMBOO SPECIES

14. Prof. A.N. Rao stressed that understanding the patterns of variation in bamboo is helpful to improve both the quality of materials used in enhancement for sustainable use, and for genetic conservation. He pointed out that the identification of priority species at the end of 1993 was an effective reference point for work that has followed (Appendix 5).

15. Although intraspecific variation in the priority species, at least from a taxonomic point of view, appears limited, this does not obviate the occurrence of genetic variations. Hence the identification of genetic resources is following a pragmatic approach.

16. There are particular flowering cycles and patterns in bamboos which affect availability of seed for collecting. In addition various degrees of seed sterility may occur. Viability of seed in relation to storability needs investigation. At present there is limited work on the embryology of bamboos; this would help the understanding of sterility. Apomictic tendencies cannot be ruled out in some cases.

17. Germplasm will need to be categorized using selection criteria for improvement and materials are needed to characterize samples for conservation. Molecular methods, coupled with use of tissue culture to clean materials, offer possibilities made more attractive by the lack of many obvious highly heritable, easily seen characters, other than taxonomic characters which are species-specific and not useful in identifying intraspecific variations.

IN *VITRO* FLOWERING IN BAMBOO

18. Ms. Alfinetta B. Zamora took the questions of flowering cycles and sterility of bamboos further and summarized information on *in vitro* flowering (Appendix 6). This has been observed in micropropagation work and has been reported since 1988. Several reports have shown flowers produced from callus, embryoids or from multiple shoots from seeds. Species where this occurs include *Bambusa bambos, Dendrocalamus brandisii, D. hamiltonii* and D. *strictus.* Cytokinins are probably involved with induction. However, no viable seed has been produced reproducibly, probably because the *in vitro* environment is too damp for pollen maturation.

19. With refinement, it is almost certain that the phenomenon can be manipulated for a number of purposes such as crossing elite genotypes, wide crossing (hybridization), and research on haploids.

In vitro flowering could augment propagation programmes based on limited availability of seeds. Some refinements to induce *in vitro* flowering are needed to target it to identifiable problems in particular priority species.

PHENOTYPIC VARIATIONS

20. Dr. K. Gurumurthi reported on attempts to upgrade available planting material of Bambusa *bambos* by identifying vigorous phenotypes and grading seed obtained from them (Appendix 7). This was to address the often observed problem of less than high quality seeds being available for propagation and poor vigour being observed in a proportion of seedlings. Propagation through tissue culture produced better growing material in terms of culm length, diameter and weight.

HYBRIDIZATION IN BAMBOO SPECIES

21. Prof. Fu Maoyi reported on crossing between bamboo species in China (Appendix 8). In this report some basic studies have been carried out on pollen of Bambusa, Dendrocalamus, Phyllostachys as well as on *Pleioblastus* and *Pseudosasa.* Almost all species looked at have a degree of abortive pollen (ca 5-45%) and pollen germination can be low (ca. 3.5-30%). Pollen cannot be stored for more than one week even at low temperature.

22. A number of interspecific and intergeneric crosses were successful within *Bambusa, Dendrocalamus, Phyllostachys* and Sinocalamus, illustrating some genetic affinities hitherto unknown. Very little is known about the phylogeny of bamboos. Some progenies of successful crosses show heterosis and several lines of crosses are being tested through vegetative multiplication and comparing fibre length and tissue components of parents and progeny

DESIRABLE CHARACTERISTICS OF BAMBOOS AND SELECTION CRITERIA

23. Dr. R.L. Banik (Appendix 9) classified the desirable characteristics of bamboos in relation to utilisation: for structural and construction purposes; for thatching, basketry and weaving; for paper, pulp and rayon; and for edible shoots. A number of the characteristics are species-properties, hence the use of particular species for the particular utilisation. However, others are measurable quantitative characteristics which can be used as selection criteria in trials.

24. With reference to seedlings, phenotypic selections has been reported in two species so that resulting plants can be more productive in a shorter time. This relates to the grassy, grassy erect and grassy dwarf type seedlings of *Bambusa bambos* and B. glaucescens. Additionally for B. *polymorpha* and B. tulda, vigorous seedlings selected on the basis of measurement, are multiplied vegetatively through macroproliferation. This provides better planting material but simply shifts a population mean during the cultivation period and does not result in long-term genetic gains although production over a time period may be better.

25. Dr. Banik stressed the need for wider testing of exotic species and exotic material to supplement that of the same local species in most Asian bamboo growing countries. The priority species of INBAR merit wider attention in the drive to productivity and the move away from traditional multipurpose use for the sake of it. There appears to be some slowness in adopting this strategy; for instance, wood-eating insects destroy a significant part of post-harvest yield of bamboo in Asia but Guadua angustifolia of South and Central America, is possibly much more durable although insects in the Americas may be less devastating. Apart from this the priority species should be looked at for true genetic enhancement targeted to utilisation needs (which include traditional uses).

GENETIC IMPROVEMENT OF RATTANS

26. Mr. D. Alloysius and Dr. Marie Claude Bon outlined the work on rattan improvement, production and conservation at the Luasong Forestry Centre (LFC) in Sabah, Malaysia (Appendix 10). The Sabah Foundation, a quasi-governmental organization, manages 1 million ha of forest land and LFC is charged with enriching 40,000 ha of forest logged 20-30 years ago with rattan. This is in cooperation with Innoprise Corporation Sdn. Bhd. An agreement with CIRAD-Foret led to initiation, from 1989, of a programme of genetic improvement of rattan.

27. To date, the Innoprise and CIRAD-Foret cooperation has resulted in seed collection of the most important commercial species, establishment of seed stands, phenological studies, and trials and assessment of variation. Research is in progress on 166 seed lots mostly from Western Malaysia of Calamus manan, 102 mostly from Sabah of C. subinermis, 130 from Sabah, Sarawak and wild populations of C. *cuesius* and 31 from SAFODA of C. *trachycoleus* (most of which originated in Kalimantan). C. *merrillii* is also used in trials, and also C. *ornatus.*

28. Seeds from each mother plant are kept separately as sibs and 20-30 mothers and 5-10 sibs are used. Estimates of heritability are underway. The Consultation noted that this methodology is essentially what is required for bamboos (see paras. 9 and 12 above). Dr. Shim, although unable to be present, had provided participants with a paper relating to selection criteria in rattans (Appendix 11) and Dr. Renuka, also unable to be present, had provided information on reproductive biology (Appendix 12).

PATTERNS OF VARIATION IN RATTAN SPECIES

29. Dr. Bon outlined initial results of isozyme analysis which appear to separate species, and with wider screening of material, may

identify some geographical variation. Prof. Rao stressed that more than half of all the rattan species are present in Malaysia, Sumatra and Kalimantan but those occurring east of the Wallace line are neither well-collected nor well-identified. The INBAR priority species were based on potential for economic use and production.

30. Much basic information on even important rattan species is lacking and much of what is known is scattered in diverse publications (Appendix 13). For genetic enhancement as well as genetic conservation, much more needs to be known about intraspecific variation, particularly in relation to quantitative characters of use in selection. Additional data on ecology, cytology, pollination, fertilization and fruit development need to be gathered since evaluation trials will need to be followed by crossing. Sexuality of flowering is yet to be well-understood. This influences the rate and quality of fruit production and will contribute to the success of seed orchards.

31. Dr. Bon stressed that an element of the Innoprise research funded by the European Union was aimed at genetic conservation. This included cooperation between the Royal Botanic Gardens, Kew, UK; Sabah and West Malaysia but was wide ranging to include silviculture (provenance and silvicultural trials, pests and diseases) as well as understanding species and population levels of diversity.

32. The research in Sabah is also refining tissue culture propagation from embryo proliferation and inducement of axillary budding from seedling or wildling shoot tips. So far, for single stemmed rattans, micropropagation from callus from a range of explants, is the only feasible way and multi-stemmed species are more amenable to the techniques.

33. Participants noted that research towards genetic improvement will require more populations with larger sample size than hitherto have been made readily available as research materials.

BAMBOO AND RATTAN RESEARCH IN THE PHILIPPINES

34. MS. Cristina A. Roxas and Dr. ED. Virtucio outlined the results obtained from a UNDP/FAO technical assistance project which had enabled survey of indigenous and introduced species of bamboos, the recent introduction of material from Chile, China, Japan and Australia. Six species collections were established and 6 pilot plantation sites developed based on traditional use and known performances of a limited number of priority species - Bambusa *blumeana, B. vulgaris, Bambusa* sp. 1, *Bambusa* sp. *2, Gigantochloa levis, G. utter, Dendrocalamus asper* and *Schizostachyum lumampao.*

35. Ms. Aida B. Lapis outlined the IDRC-supported research on rattan in the Philippines. Rattans are harvested from 6.3 million ha; 2.8 million linear metres of canes come from dipterocarp forests and 1.7 million linear metres from residual forests (productivity being 1800 linear metres/ha of dipterocarp forests and 1488 linear metres/ha of residual forests). Rattans make up 90% of all raw timber forest products. However, raw cane is exported only to the value of about US $2000 per annum whereas importation is valued at US $0.9 million. Exports of processed cane (1993) resulted in US $83 million out of total furniture export worth US $165 million.

36. There are 91 taxa of rattans in the Philippines and Paliwan seems to be a centre of diverxity and hence for conservation. Of the 91 taxa *Calamus caesius, C. merrillii* and C. *ornatus* are INBAR priorities and there are a further 9 species of national high economic value: *C. dimorphacanthus, C. filispadix, C. javensis, C. microsphaerion, C. manillensis, C. ramulosus, C. scipionum, Daemonorops mollis* and *D. pedicellaris.* Existing commercial plantations are largely using C. *ornatus* and *C. merrillii* but at a national level 5 species are targeted for further development: *C. juvensis, C. merrillii, C. microsphaerion, C. mindorensis* and C. *ornatus.*

37. The Philippines has a policy to include both bamboo and rattan in commercial plantations and provides a range of tax incentives for producers (both tax and duty exemptions). Three other

approaches are taken: (1) nucleus estate smallholder approach through a government corporation, (2) development by the private sector to benefit local communities, and (3) a community-based approach.

DISCUSSIONS

38. Participants separated into two Working Groups to discuss recommendations on further research for genetic enhancement of bamboo and rattan, respectively. These Groups reported to the whole meeting which agreed to the recommendations listed in the following paragraphs.

RECOMMENDATIONS

I. Trials

39. Since all economic characters are quantitative, and therefore determined by a number of genes whose expression in the phenotype are modified by environmental conditions, virtually no genetic enhancement for such characters can be done without adequately designed statistical experiments. Scoring of plants in natural stands would not lead to the overall aim since ca 70% of the variation will be environmental and only the balance being heritable. The key to trials will be to recognize families and hence superior genotypes through evaluation trials. It was agreed that this methodology should be taken as the basic methodology to develop elite materials which will then be used as materials in a first round of breeding. In this respect it was stressed that:

i. A biological species approach must be taken rather than reliance on taxonomic variants.

ii. For both priority bamboo and rattan species the aim must be to advance the long process of domestication.

iii. There will be some differences between bamboos and rattans. Vegetative propagation will be essential at certain stages for the former; for the latter a nursery period is also necessary for up to 4 years.

iv. Even for the priority species, it will not be possible to focus on more than a few at the national or sub-regional level.

v. Suitably trained personnel are needed and commitment for a 10 year programme are needed, although a number of fundable modules exist within this period.

vi. Ability to form seed in most rattans and bamboos allows selfing and selfed lines are valuable. Research in this area is needed to run in parallel with the early trials.

vii. Providing a planned approach is taken to population sampling, the extraction of families and their testing, sampling does not need to await further research on markers to distinguish between species and variants.

viii Wide hybridization as a proposed method to search for new adaptations in major priority rattans or as a method to produce superior genotypes in bamboos would not form part of the mainstream attempts to gene tically enhance the two commodities but will be useful for other purposes (see below).

ix. Criteria for choosing institutes/personnel to conduct evaluation trials are:

- Ability to choose and sample populations in appropriate regions /areas. This requires travel, sampling based on genetic principles and not on plus types, with the same person doing the sampling to avoid problems at the start.

- Ability to set aside a sufficient nursery area and for bamboos to develop local contingency plans for tissue culture as a back-up.

- Adequate land and maintenance support for the trial.

- Commitment to continue the work for a minimum 10 year period whether outside funding is available or not.

- Commitment to use products of the research to guarantee wide and appropriate distribution.

II. Bamboos

40. The following are specific recommendations relating to bamboos:

i. For bamboos, the multi-purpose approach to utilisation in the past should not continue but elite materials for specific purposes should be developed. This does not obviate multi-purpose use at the local level by communities who may wish to continue growing traditional materials. Clearly, target elite materials will find their best use in plantations.

ii. Selection *criteria.* There should be 4 categories of targeted use as listed below:

1. Structural uses, construction, furniture frames and ply bamboo

Species with the relevant properties are well known but the following should rate highest priority: *Bambusa bambos, B. balcooa, B. blumeana, B. vulgaris, Dendrocalamus giganteus, D. strictus* and *Phyllostachys pubescens.*

Harvestable culms from clumps or plants in the case of *Phyllostachys* should be considered, extracted, and their height

and diameter at the 8th internode be measured along with a count of the number of nodes. Wall thickness should be recorded at the top and bottom ends as well as the middle of each culm. (No means should be made in the field e.g. wall thickness; but all raw data kept for subsequent use).

2. Thatching, walling and handicrafts

Highest priority should be accorded to Bambusa blumeana, B. textilis, Cephalostachyum pergracile, Gigantochloa apus, G. levis, Ochlandra stridula and Phyllostachys pubescens.

Harvestable culms/clump or plant should be considered, extracted, and their height and diameter at 8th internode be measured along with a count of the number of nodes.

3. Pulp, paper and rayon

Highest priority should be accorded to Bambusa textilis, Dendrocalamus strictus, and Phyllostachys pubescens.

Harvestable culms per clump/plant should be counted and further analyzed in the laboratory for content of silica, lignin and fibre quality.

4. Edible shoots

Highest priority should be Dendrocalamus asper but others could include Bambusa blumeana, D. Zatiflorus and Phyllostachys pubescens.

Harvestable weight of shoots should be recorded with suitable sampling and weight of the edible portion should be determined.

Additionally there should be due attention paid to environmental stabilization. In this case the selection criteria are broad guidelines which have to be modified for each species.

a) The first step would be to conduct a broad survey of the definition and distribution of agro-ecological and silvicultural zones, and the degraded zones to develop a plan to identify a range of variants suitable for such zones in semi-arid, tropical moist, subtropical moist and upland areas and develop conservation and propagation strategies. It was stressed that degradation due to slash and burn, shifting cultivation, overcutting, and overgrazing is largely a soil problem.

b) The most likely species within which suitable variants for propagation could be identified for particular purposes include:

Degraded soils: Highest priority: *Bambusa blumeana*, Melocannu bucciferu and Oxytenanthera microciliata. Others: B. bulcooa, B. bumbos, Dendrocalamus strictus, D. latiflorus and Schiwstachyum lumampuo.

Soil/moisture conservation for degraded mountain slopes: Melocannu bucciferu, Arundinariu spp. and Fugaria spp.

c) Other priority species with wide geographical occurrence which should be tested for degraded areas: B. bambos, B. blumeana, B. vulgaris, Dendrocalamus strictus and Melocanna bacci fera.

iii. Superior genotypes should be identified in properly designed evaluation trials for a limited number of priority species as a first phase of genetic enhancement. It is essential to recognize that these genotypes will be selected for specific end uses listed above.

iv. Identification of superior genotypes will be followed by the establishment of systematic breeding programmes to produce cultivars. It is recognised that crossing will be easier in sporadic flowering bamboos rather than gregarious flowering ones and most of the highest priority species are gregarious.

v. In the light of iv above there are occasional references to odd sporadic flowerings and intensive field studies are needed to identify these in predominately gregarious flowering species.

vi. Evaluation trials may be national, bilateral or regional. However, in view of the need to strictly enforce scientific standards it might well be more feasible for these to be, in the first instance, the responsibility of within country institutions. Trials for degraded lands and stressed environments might be subregional in scope. These may well include provenance trials as well as evaluation trials since in many cases their end use is mostly environmental stabilization and sustainable growth rather than intensive cultivation.

vii. Strategic research should be continued on micropropagation since this will be required with a range of superior genotypes and it must be fully applicable.

viii. In vitro flowering for propagation and seed production should be researched. There is a great need to look for this in gregarious flowering bamboos rather than sporadic flowering ones In vitro flowering also has implications on conservation strategies.

ix. Recognizing the urgent need to improve the basic knowledge on the genetic systems of bamboo species and the long duration of conventional field testing, innovative biotechnologies should be incorporated into genetic resources research aimed at a rapid screening of germplasm. This will require technical inputs from institutions experienced in the relevant technologies and components of technology transfer and human resources development in bamboo growing countries.

III. Rattans

41. The following are specific recommendations relating to genetic enhancement of rattans:

i. For rattans, qualities required are simple: diameter and length of cane and number of stems per plant. These are mostly quantitative and become the selection criteria. They include considerations of species habit (clustering or solitary) and production relates to growth rate.

ii. Harvesting and processing affect market value. They are difficult to control in material taken from the wild but are not a problem if materials come from plantations.

iii. The basic evaluation trial as prepared above is the most appropriate and is being followed in Sabah. Some basic modifications may be required in sampling since collection of seed has to be opportunistic in obtaining families from populations. This is overcome by treating 'sub'-samples as cohorts and subsequent development of a base population for the evaluation trial.

iv. It was stressed that vegetative propagation/tissue culture is not appropriate for mass propagation due to cost, but is very useful for germplasm exchange.

V. Countries will have to give due attention to the development of seed orchards to service needs of plantations. There is a need to conduct more research on the reproductive process, especially flowering and what induces floral initiation at a particular time. With reference to seed orchards, once superior genotypes are identified,3 there will be a need to develop clonal seed orchards.

vi. Priority species were discussed but these fall within those of INBAR. Highest priority remain *Calamus* manan, C. subinermis,

C. ornatus and C. merrillii for large canes and C. caesius for small diameter. (It is recognised that there are other species for specific areas e.g. Daemenorops jenkinsiuna for India/Bengal and C. scipionum for parts of the Philippines.)

42. Genetic conservation requires a careful approach to in situ conservation remembering that targets relate in the main to the species identity and enough variation for selection for economic traits. Probably these will be country specific, but need not be over-ambitious in terms of number of sites, although better knowledge of ecology would greatly help planning.

43. Ex situ conservation should be based on needs for economic production into the future, particularly from plantations.

44. All aspects of genetic conservation will require careful linkages and joint action between local forest institutes and private companies. The Philippines was discussed as a possible locality to use if ever an extractive reserve concept was to be applied to rattan and criteria for management developed.

45. Enhancing production requires continued experimentation on site-genotype interactions, on initiation of floral meristems in palms and on growth rates.

IV. Addendum on design of evaluation trials for bamboo

46. The purpose of an evaluation trial is to identify individuals of desirable genotypes. Since all of the characters of interest in bamboo, irrespective of end-use, are quantitative and controlled by many genes, this objective can be realised only when it is possible to separate the effects of the environment, in which clones have been raised, from genetic differences between them. In turn, this can only be done when the material has been randomised over the area occupied by the trial. Several designs are available; the choice will depend on the area occupied by the trial and the likelihood of soil

heterogeneity. In most circumstances, however, a completely randomised design is the most efficient and if desirable, can be replicated over two or more blocks.

47. It is assumed that, with good forward planning, it will be possible to collect cuttings from each of a number of plants of bamboo in each of a number of natural or semi-natural stands of the species in question in a short time. Ideally, these stands should be chosen so as to cover the distribution of the species. Within any one stand, it is important to sample plants that are sufficiently far apart to minimise the possibility that they are one and the same genotype, either because they are of the same clone or because they originated from the same maternal parent when the stand last flowered. That said, plants should be chosen, so far as is possible, at random; that is, no attempt should be made to choose plants for sampling that appear to be superior. It is doubtful whether it is worth collecting cuttings from more than 20 plants in each stand.

48. The ability to be able to clonally propagate the individuals of bamboo species is not only convenient in collecting material, but also very considerably enhances the recognition of superior genotypes. Cuttings collected from natural stands would be used, therefore, to establish mother clumps in a nursery. If 20 cuttings were taken from each of 10 natural stands, the nursery will contain 200 mother clumps, which must be randomised over the area of the nursery in a single block. When these clumps reach an appropriate size, 5 cuttings can be taken from each in order to provide the material for the evaluation trial. The insertion of a nursery phase between the collecting of material and the initiation of the evaluation trial also goes some way to ensure that material is of equivalent physiological status.

49. An evaluation trial containing 5 clonal replicates from each of 20 maternal clumps from each of 10 locations will contain 10 x 20 x 5 = 1,000 entries in all. As in the nursery, this material must be randomised over the area of the trial and the cuttings planted at a distance apart to allow access to them for measurement

during the duration of the trial. On the other hand, the density of the trial should be as close as possible to the likely density of commercial stands.

Notes

50. The term clump has been used in the foregoing, although strictly this applies only to sympodial bamboos. In the case of monopodial species where a genotype as a maternal clone can extend great distances, best-guesses need to be made regarding:

i. the extent of the population to be sampled, and

ii. the extent of spread of any mother plant.

This emphasizes the importance of survey and good planning.

51. Any vegetative propagation will require use of the most appropriate technique (a manual is available from INBAR). Excess cuttings will be needed to ensure adequate numbers; there are particular seasons when this should be done and this needs to be built into the planning. In some cases it might be wise to back-up the vegetative propagation with material of the original mothers sampled that are also held in tissue culture (derived from somatic material when cuttings represent the original sample). Any disaster in the nursery could be overcome by developing tissue culture plantlets.

APPENDIX 1

AGENDA

8 May 1995 — Registration

Welcome address:

Dr. E.A. Rosario DENR-ERDB
Dr. C.B. Sastry IDRC-INBAR
Dr. K. Vivekanandan FORTIP

Session 1 — Chair - Dr. C.B. Sastry

1. Prof. J.T. Williams - Background, justification and objectives of the Consultation
2. Dr. M.J. Lawrence - Methodologies relevant to genetic enhancement of bamboo and rattan
3. Prof. A.N. Rao - Patterns of variation in priority bamboo species

Discussion

Session 2 — Chair - Dr. M.J. Lawrence

4. Ms Alfinetta B. Zamora - In vitro flowering in bamboo
5. Prof. Fu Maoyi - Bamboo hybridization work in China
6. Dr. K. Gurumurthi - Production of priority bamboo clones
7. Dr. R. Finkeldey - FORTIP's SPIN programme on bamboo and rattan

Discussion

9 May 1995

Session 3 Chair - Prof. Fu Maoyi

8. Dr. R.L. Banik - Selection criteria and population enhancement of priority bamboos

9. Mr. D. Alloysius - Collection and trials of rattan in Sabah

10. Prof. A.N. Rao - Patterns of variation in priority rattan species

11. Dr. Marie Claude Bon - Research on rattan conservation and enhancement in Sabah

Session 4 Chair - Prof. A.N. Rao

12. Ms. Cristina Roxas and Dr. ED. Vertucio - Bamboo research in the Philippines

13. Ms. Aida B. Lapis - Rattan research in the Philippines

Discussion

10 May 1995 Visit to Mud Spring Bambusetum
Working Group meetings

Session 4 Chair - Prof. J.T. Williams

Reports of Working Groups
Discussion and adoption of recommendations

11 May 1995 Visit to plantations

APPENDIX 2

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APPENDIX 3

THE BACKGROUND TO GENETIC ENHANCEMENT OF BAMBOO AND RATTAN

J.T. Williams

INTRODUCTION

Without doubt the demand for bamboo for industries is exceeding supply in many producing countries. This is true whether products are culms for a multitude of purposes - including new generation building materials or for paper or for shoots. Added to the demand for industrial purposes is the local use of material which is huge in many countries, and has hardly been quantified. In fact, the latter demand is about 80% of the total exploitation.

However, patterns of supply and demand are known only in general: for instance, when there is a deficit of supply a country imports from any suitable source. In some countries, such as Japan and Malaysia, demand has reduced as traditional uses decline.

Supplies of rattans are less ubiquitous in Asia than supplies of bamboo and the bulk of demand is in Indonesia, Malaysia, Philippines and China. Whereas Indonesia and Malaysia produce most of the requirement, China imports as much as it produces. Demand locally and elsewhere has resulted in large-scale extraction in Myanmar, Papua New Guinea and Vietnam and also in parts of India. Depletion of resources is also related to widespread deforestation; that and extraction results in current over-exploitation and unsustainable management in many areas. Response to such constraints is usually simply to move extraction to new areas and also to substitute less desirable species.

Coupled with this mosaic of supply/demand patterns across Asia is the fact that over 90% of both commodities are harvested from the wild or from stands in degraded forest areas. For the past 10 years research has focused on improving management of such areas so that exploitation can be more sustainable, but there is still a long way to go. Although the concepts are clear and a number of technologies are available, there is need for their wider application across a wide range of management - from minimal to intensive, depending on areas and species.

RECOGNITION OF GERMPLASM NEEDS

The alternative to the management of natural areas and stands is to increase plantation production. Current constraints to both managed stands and plantations were discussed at an INBAR Consultation in 1994 (Anon. 1994). The over-riding constraint for bamboo appear to be a deficit in planting material and the commercialization of the systems making the materials available in an appropriate manner at appropriate times. For rattans, the propagules are mostly seeds, and are largely obtained from forests. Few countries maintain specific seed stands. Nonetheless, the Consultation noted the increasing demand for rattan seed.

The important goal of increasing productivity is being met by a multiple approach from the research community, whether by better silvicultural practices or better supplies of planting materials. For instance, since such a high percentage of production comes from natural stands, use of fertilisers is important.

Significantly, the 1994 Consultation noted that the multiple approaches would be more successful if a wider array of germplasm, both native and exotic, were to be used. Far too little attention has been paid to this. Attention to germplasm relates to a range of needed interventions - whether the reduction of genetic heterogeneity in seed-derived rattan plantations or enrichment - planting in natural stands of bamboo and rattan. Equally important is the need for planning in this area before any *in situ* community

genetic conservation can become appropriate - or viable in the long-term; similarly planning for ex situ conservation must go hand in hand with use of germplasm to increase productivity.

GENETIC ENHANCEMENT

When INBAR was planned it was clearly stated that selection of superior strains (and improved cultivation methods) to enhance economic production of both commodities is a major imperative (Anon. 1991).

I was delighted that an informal group of scientists associated with the INBAR Production Working Group which met after the Research Advisory Group met in China in 1994 noted that a discussion on genetic enhancement is one of the most urgent tasks. The original recommendation to INBAR and the decision last year resulted in the convening of this Consultation.

First of all we have to recognize that we know virtually nothing of the genetic variation in the species of bamboo and rattan. Even if we take the species agreed to be of priority for INBAR action (Williams and Rao, 1993), these are far more than current research interests can cope with, unless there are some rapid appraisal methods which could be designed and produce meaningful results in a cost-effective way. I have no doubt our discussions will be looking at ways to assess genetic variation.

Related to such needs is the recognition of superior genotypes and what we know from field trials, but the record is poor in these areas.

For bamboos, an exercise by INBAR to gather data on known superior genotypes resulted in little valuable data and an attempt to develop a regional trial for two species of bamboo in 4 countries has, after more than a year, not even got off the ground properly. There are clearly constraints here which, I suspect, relate to the programmes of forest research institutes and we .might have to discuss placing research on genetic variations into a broader research community since we cannot afford the delays we have been experiencing.

Specifically, we know very little about quantitative variation, and this is, I believe, because in the past material has been cultivated or used at a very local level and whatever material *is* available has been used as planting stocks. A discussion on selection criteria for diverse uses will be extremely valuable.

The emphasis in the past has been on "plus" types rather than on known and measurable superior genotypes. However, certainly for many bamboo species, a degree of local selection must have occurred especially in those propagated vegetatively but much of the gain will have been lost when populations seeded and a new cycle started from the progeny. If anything the genetic base has probably been negatively affected by selective harvesting over long periods.

RESEARCH RELEVANT TO GENETIC VARIATION

Many topics require further investigation. The following are a few relevant to future genetic enhancement:

1. In bamboos much clarification is needed on mating systems. We assume most are outcrossing, but some are known to self.

2. In bamboos we need many more chromosome counts and clarification of levels of ploidy. We do need to know the relative proportions of triploids and higher polyploids.

3. The flowering system in bamboos is odd to say the least with differences in the biological clock between species, differences in times to flowering and sterility in some. How difficult would it be to make plants flower when needed? We shall be discussing interesting data on in *vitro* flowering and deciding what its applications might be.

4. Tissue culture is a very useful tool but it has been geared to propagation so far. However, careful use of vegetative propagation and tissue culture will be assets in developing genetic enhancement.

5. Since rattans are dioecious they are outcrossing, but inbreeding can be achieved by mating among families in populations. Natural population structure is broken down in plantations when the normal propagules are seeds.

6. Tissue culture/vegetative propagation are less developed for rattans; again tissue culture was developed as a potential method for mass-propagation. Refinements are needed to support any strategically planned genetic enhancement.

7. Much more attention needs to be given to genepools rather than narrow species definitions in rattans. This point was stressed in the INBAR prioritization exercise.

8. Much will be gained from research being widened away from traditional silvicultural thinking to looking at a range of trees and perennial crops used for centuries in plantations (see Lawrence in Appendix 4).

WHAT DO WE HAVE TO ACHIEVE?

When the INBAR Biodiversity, Genetic Resources and Conservation Working Group met late in 1994 in Singapore, Dr. R. Finkeldey of FORTIP prepared genetic management plans linking genetic diversity measurement, conservation and utilisation. Much as such an overall strategy would be ideal, it is apparent that the current research capacity is unlikely to cope with it when the commodities we are dealing with compete with other agricultural and forestry needs. As a result, there is a need to identify and develop building blocks for the overall work needed and to plan the research strategy for each.

Four points are relevant:

1. Time span of the *research.* Like tree species, woody bamboos and rattans have long generation times. Funding is usually geared to projects of 3-5 years. We must be cognizant of phasing research to fit the constraints of time and funds and seek ways to reduce the overall time span.

2. *Research planning.* This has to be strategic and targeted to research outputs relevant to enhanced productivity rather than research being designed largely to produce useful scientific data.

3. *Supporting research.* Some actions do not require a great deal of research and we should identify these. Examples would be chromosome counts and agreement on selection criteria.

4. *Supporting operations.* A number of actions need to be considered which will support the overall goal of increased productivity but which are operational rather than research. Examples might include seed orchards, seed grading, permanent study plots, practicable guidelines for polycultures in areas of high genetic vulnerability; and there are many more.

CONCLUSIONS

Since the overall goal of INBAR is to encompass poverty alleviation of local peoples, it behoves us to move quickly to "tap the genepools" of priority bamboos and rattans in a manner not envisioned a few years ago. Even though many resources are over-exploited, the resources are there to be used more scientifically so that on the one hand sustainable income generation of local peoples can be generated and on the other pressure can be taken off many of the resources. I believe this can only happen by moving much more rapidly to plantations - with elite materials which have to be developed rapidly.

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APPENDIX 4

APPROACHES TO GENETIC ENHANCEMENT OF BAMBOO AND RATTAN

M. J. Lawrence

INTRODUCTION

While few plant breeders, given the choice, would volunteer to undertake the improvement of either bamboo or rattan, neither are as difficult to handle or assess as, say, coconut, whose annual seed output is meagre and which cannot (at present) be vegetatively propagated or temperate species of forage grasses, whose performance can only be measured by the weight gains of grazing animals. Bamboo has the great advantage of vegetative reproduction, which greatly aids the recognition of superior material in evaluation trials and its subsequent propagation for commercial plantations; and rattan has the advantage, once it has come into flower, of producing useful quantities of seed, which can be used to raise material in progeny trials.

Bamboo and rattan are similar in that neither, particularly the latter, have been subject to much systematic improvement in the past, so that almost any sensibly designed trial of their germplasm can be confidently expected to reveal superior material.

The collection and evaluation of germplasm is usually viewed as part of a long-term strategy for plant improvement that is designed to broaden the genetic base of a crop with respect to genes controlling quantitative characters and to provide sources of major genes for pest and disease resistance, and other desirable traits, not present in commercial cultivars. This view is based on the belief that the performance of wild, unimproved germplasm is unlikely

to match that of commercial material, so that the introgression of useful genes from the former into the latter will require several cycles of systematic breeding by, for example, the recurrent backcross method.

While this may be true of the major agricultural crops like maize, wheat and rice (but note current developments at IRRI on developing a new plant type from relatively unimproved land-races), two recent cases suggest that for other crops, wild germplasm can be of immediate interest to the breeder. Thus, an evaluation trial of oil palm germplasm collected in Nigeria in the 1970s revealed palms that yielded twice the amount of oil per annum as the best commercial material, some of which also had a low trunk growth increment and produced oil with a high iodine value. Again, trials of rubber germplasm, collected from the Amazon basin, are identifying a few trees that yield twice as much latex per annum as the best commercial clones, despite the fact that the latter are the products of ninety years of systematic improvement by breeders, during which the yield of latex has been increased five-fold.

There is no reason to believe that these successes are confined to oil palm and rubber. Indeed, a very recent evaluation trial of 400 accessions of sugarcane in Sri Lanka identified one (from a small-holder's backyard) that gave almost twice the yield of sugar per ha as the current commercial clone. It is necessary to emphasize, however, that in all of these cases the outstanding genotypes were identified in well-designed and managed evaluation trials of material that, for oil palm and rubber, had been systematically collected from their respective centres of primary diversity. It may be more difficult to justify the costs of thorough evaluation trials with bamboo and rattan, than those of these relatively high-value commodity crops, and the logistical problems of establishing the former may be more severe than with the latter. Evaluation trials, however, are probably less costly than long-termsbreeding programmes.

EVALUATION TRIALS

Bamboo

Although many species of bamboo are utilised in Asia, a number of high priority ones have been determined by INBAR. The next question to be considered is whether it is practicable to attempt to evaluate, say, six to ten different species in a single randomised trial. Answers to this question depend on the extent to which these species differ; it might not be sensible, for example, to include species whose growth habit and height differ markedly, unless the space between entries in the trial is so great that competition, between their aerial parts at least, can be discounted. If this were done, however, it is doubtful whether the results of the trial would have much relevance to commercial stands in which plant density would be much higher.

It would seem therefore, on balance, better to lay out separate trials for each high priority species at commercial densities. It the blocks containing each species were adjacent, some comparability of results could be achieved. Field staff would also find it easier to handle and maintain blocks containing a single species.

Bamboos appear to be cross-pollinating species which are morphologically very variable. It can be assumed, therefore, that natural stands consist of a large number of different genotypes and that for those species with a wide geographical distribution, different populations will contain different arrays of genotypes. An evaluation trial, therefore, should contain, so far as this is possible, accessions from the full width of the range of this distribution. When collecting material from a population it is, of course, important to sample clumps that are sufficiently far apart to minimise the possibility that they are of the same genotype. Provided that this is done, it is doubtful whether it is worth representing each accession in an evaluation trial by more than, say, ten genotypes. There is a trade-off between number of accessions and the number of genotypes representing each accession in any trial of a realistic size; if the latter is increased, the former must be decreased.

The results from oil palm and rubber evaluation trials indicate that elite genotypes are quite rare and that they occur only in certain, but unpredictable, parts of the distributional range of these species. It is important, therefore, that the trial should contain as many accessions as is practicable. The collection of material within a population should be random; there is no point in attempting to collect cuttings from clumps that appear to be superior because, since the heritability of quantitative characters even in well-designed experiments is rarely above 50%, most of the phenotypic variation observed in natural populations is environmental in origin, rather than genetic.

Clonal replication allows a more accurate estimation of the merit of genotypes than in its absence. The number of clonal replicates by which each genotype is represented in the trial depends on its design. If a completely randomised design is used, each genotype could be represented by, say, five clonal replicates. A single block of an experiment containing, say, 50 accessions, each of which is represented by 10 genotypes, would contain 50 x 10 x 5 = 2500 entries; this would not generally be regarded as a very large experiment. Provided that the area occupied by the trial was not markedly heterogeneous with respect to soil fertility, a single block would suffice. Many workers, however, prefer to lay out their material in plots on the grounds that this makes visual observation of entries easier than with completely randomised designs. If this were to be done, the minimum requirement for each block would be to represent each genotype in the experiment by, say, a pair of duplicate plots each containing five clonal replicates. This would double the number of entries in each block and also the area occupied by the trial. It would also reduce the statistical efficiency of the experiment since the basic data items would be plot means, rather than single plants, as in the completely randomised design. Thus, 80% of the degrees of freedom of the analysis of variance of the results would have to be discarded, whereas all can be used in that of the completely randomised design. The latter, therefore, are not only more efficient, but allow smaller experiments than the former.

Confounded designs are sometimes used with trials containing a large number of accessions that are planted out on heterogeneous areas. It is important to be aware that these designs are often used with the specific purpose of obtaining unbiased estimates of accession means and may not also allow the accurate estimation of the performance of genotypes within these accessions. With bamboo, it is single genotypes that are important, because once an elite genotype has been identified, it can be clonally propagated to provide material for commercial planting. Some care should be exercised, therefore, in choosing an experimental design for evaluation trials with bamboo.

A considerable amount of preliminary work will have to be undertaken if an evaluation trial is to be established. It is assumed that vegetative material sampled from wild or other populations will arrive on site over a period of time and will have, therefore, to be planted in a germplasm nursery as it arrives in a systematic and non-random way. The physiological age of this original germplasm (age from previous seeding) will not be known. It is important, however, to ensure that the clonal material of different genotypes planted in the trial is otherwise as physiologically similar as possible and to minimise carry-over effects from the original material clump. This could be achieved by establishing a clonal nursery in which each genotype is represented by a single cutting taken from the maternal clump at the same time as that of every other genotype in a randomised design. When these plants have grown to an appropriate size, five cuttings could then be taken from each for the evaluation trial. That is, a generation of vegetative reproduction should be interposed between the maternal clumps of the germplasm nursery and the evaluation trial.

Rattan

With the obvious exception that propagation of rattan is usually by seed, rather than by vegetative propagules, much of the foregoing discussion on bamboo is also relevant to the evaluation of rattan germplasm. INBAR's priority species are candidates for evaluation;

but there are too many to handle at any one location. While recognising that it is not possible to maintain the viability of seed for more than a few months, it should be possible, with careful planning, to organise the collecting of seed from a number of natural stands of rattan which can be used to raise material directly in an evaluation trial. It is important that the seed collected from each individual is kept separate from that of every other. If this is done, each population in an evaluation trial can be represented by a number of natural progenies, each of which is known to have the same maternal parent, so that the members of a progeny will be related as half-sibs. In these circumstances, it is possible to obtain an approximate estimate of the heritability of a quantitative character which allows the expected response to selection applied to the individuals of the population to be calculated.

There appears to be less information about the extent of geographical variation of species of rattan than there is for bamboo. It would be sensible, however, to attempt to collect seed from as wide a range of the distribution of each species as possible. On the other hand, most of the genetical variation (typically about 90%) of cross-pollinating species occurs within their constituent populations, rather than between t-hem. Where it is possible to collect seed from, say, twenty populations, a trial containing ten families of size 10 from each population would give a completely randomised experiment containing 2000 entries.

If it turned out to be difficult to collect seed from more than a small number of populations, this could be compensated for by raising a larger number of natural progenies from each. For example, if only ten populations could be visited, each could be represented by 20 families in the trial, giving the same overall size. If it is not possible to organise coordinated collecting of seed from natural stands, it would, as with bamboo, be necessary to establish a germplasm nursery from which seed used to raise the individuals of an evaluation trial could be obtained. While this would considerably increase the duration of an evaluation programme, it opens up the possibility of using full-sib families in the trial, which could be produced by making controlled cross-pollinations between

individuals paired-off at random in the germplasm nursery, assuming the difficulty of gaining access to the inflorescences of 5-7 year old individuals could be overcome. If this is not practicable, it would be necessary to use open-pollinated progenies from the individuals of the germplasm nursery, some of which, unlike those from natural populations, will result from an inter-population matings, so that differences between populations could be difficult to evaluate. It is clear, therefore, that it is better to obtain seed for an evaluation trial directly from natural populations of the species in question, which allows this comparison to be made.

Support for the individuals of a trial could be provided by rubber whose canopy is less dense than that of other species and, being clonally propagated, is (or should be) genetically uniform.

BREEDING PROGRAMMES

Bamboo

The extraordinary and apparently unpredictable flowering behaviour of the majority of species of bamboo, one of which - B. vulgaris - is, in any case, apparently sterile (but how does this specie persist in natural habitats, assuming that it does?), makes it impossible, on present knowledge, to design systematic breeding programmes with most of them. Furthermore, even if it were possible to solve this problem, response to selection for superior performance may be small, because many species appear to be tetraploid or hexaploid, so that the inheritance of genes controlling characters of interest could be polysomic, rather than disomic. Unless it is known, therefore, that a species of commercial interest flowers regularly or can be induced to do so, there is no point in considering improvement programmes of the conventional type. This may appear to be a rather dismal conclusion.

It is, perhaps, worth pointing out that all of the early progress with the improvement of temperate forage species, such as Lolium perenne, was made by identifying superior genotypes obtained from

long established, semi-natural grazing pastures in the 1920s and that some of the varieties founded on these ecotypic selections are still on the market. A thorough evaluation of bamboo germplasm can be confidently expected to produce similar results. For species which flower regularly, however, it would be possible to initiate a systematic improvement programme involving controlled crosses between plants of superior genotype of the conventional type used with outbreeding species.

Although flowering of the majority of bamboo species is unpredictable, it might be possible to collect sexual progeny from flowering stands either directly, as open-pollinated seed, or indirectly, as seedlings which later arise around the flowering clumps. In either case, the seed or seedlings taken from each clump should be kept separate from that of those of every other clump. Clumps should be chosen at random, as should the seed or seedlings collected from them. This material could then be used to establish an evaluation trial similar to that of rattan, except that each genotype could be represented by five clonal replicates. A trial of this kind would be similar to those used to evaluate sugarcane. Though this possibility is rather opportunistic, it appears to be the only way of directly exploiting the products of sexual reproduction and, hence, of genetic segregation, with most species of bamboo.

Rattan

While evaluation trials of rattan species can be expected to reveal superior genotypes that should meet commercial requirements for twenty years or more, sooner or later, it will be necessary to initiate systematic improvement programmes with these species. The chief problems with rattan appears to be the practical ones of gaining access to their inflorescences and of accurately identifying the individuals to which they belong. The second of these problems could be overcome by ensuring that the spacing used between individuals in a trial was sufficiently great to minimise the chance of their becoming entangled with their neighbours.

The first of these problems is, of course, a common one with tree species. Foresters use a variety of techniques including the use of scaffolds or hydraulic lifts, and grafting flowering shoots, taken from trees of interest, onto dwarfing rootstocks in a nursery. Assuming one or other of these techniques can be used with rattan, it would then be possible to cross individuals that have been identified as superior in the evaluation trial with one another to produce material for the next generation of selection in a trial whose design was similar to that of the evaluation trial. A trial of progeny produced by controlled pair-wise crossing would be capable of yielding estimates of the heritability of quantitative characters of interest and, hence, an estimate of the likely response to selection, as is the case with any other cross-pollinating species.

From the genetical point of view, rattans are much easier species to handle than those of bamboo. Furthermore, since the improvement of rattans have received even less attention than that of bamboos, it should be correspondingly easier to find superior genotypes than with the latter.

SPECIES HYBRIDIZATION

Both Banik (1995) and Shim (1995) mention species hybridization in their respective reviews of bamboo and rattan. No natural hybrids of rattan are known and Shim recognises the difficulty of using species hybrids in a crop propagated by seed until reliable methods of vegetative propagation become available. Banik, however, reports two cases of natural hybridization between species that occurred in the bambusetum of the Bangladesh Forest Research Institute and that a systematic programme of species hybridization is being carried out in the Huonan Botanical Gardens in China. While it is obviously sensible to exploit the products of natural hybridization of bamboo, if these appear to be of potential commercial value, it is doubtful whether much time and effort should be devoted to systematic attempts to produce species hybrids at this early stage of an improvement programme, unless it is clear beyond all doubt that no single species possesses all of the attributes required for a

particular commercial use. The thorough evaluation of the germplasm of important species of bamboo is more likely to reveal intra-specific genotypes that meet such requirements, than opportunistic attempts to accomplish this with species hybrids.

OTHER TOPICS

Whereas the chief purpose of evaluation trials is to identify genotypes of commercial value, they also provide a valuable opportunity for the systematic gathering of basic information on the biology of the species in question, much of which appears to be little more than anecdotal. This opportunity should be seized, therefore, and the information obtained disseminated, so that the planning of future trials can be put on a sounder footing than is possible at present.

Bamboo

It is obvious that there is an urgent need to understand what factors control flowering in bamboo for two reasons. First, until flowering can be controlled and, therefore, time of flowering predicted, no systematic improvement can be carried out that involves conventional selection among successive generations of sexual progeny. Second, the age of clones of superior genotypes identified in evaluation trials will generally be unknown; it would be unfortunate, to say the least, if such material, having been multiplied and distributed to commercial plantations flowered and, thereafter, died shortly after its release. Though the investigation of flowering is primarily a task for physiologists, there appears to be some evidence that natural stands of some species may segregate for flowering time which, if this can be confirmed, would be particularly valuable material for this investigation. Fundamental physiological work of this kind could, perhaps, be contracted out to adequately equipped research groups with the appropriate expertise.

Rattan

The chief problem with rattan is the opposite to that of bamboo in that no reliable means of propagating superior genotypes of the former by vegetative means have yet been discovered. While the multiplication rate via seed appears to be sufficient to provide enough material for commercial uses, it would clearly be desirable to be able to accomplish this by clonal means. Experience with oil palm suggests that this might be possible by tissue culture, though the early problems with irregular fruiting of clonal oil palm ought to be borne in mind. Relevant research could be contracted out to an appropriate laboratory.

CONCLUSIONS

The objective of all improvement programmes is to exploit the genetical variation of the crop in question with respect to characters of commercial interest. The success of such programmes depends on the efficiency with which superior genotypes can be identified in the breeders populations. Experience with other crops indicates quite clearly that considerable progress can be achieved by conducting relatively simple trials of unimproved germplasm provided that these trials are carried out on a sufficient scale and are well-designed and well-managed. There is no reason to suppose that comparable success could not be achieved with bamboo and rattan evaluation trials.

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APPENDIX 5

PATTERNS OF VARIATION IN BAMBOO

A .N. Rao and V. Ramanatha Rao

INTRODUCTION

Bamboos are a somewhat homogeneous group of plants. Except for shape and size of the clumps, and the colour variation in stems of certain bamboos and leaf sizes, a common man will not be able to easily distinguish one type of bamboo from the other. Even a student of bamboo taxonomy has to spend a considerable amount of time before distinguishing the various genera and species of bamboos. Understanding the patterns of variations in bamboo is difficult but the knowledge is necessary to select better plants and improve their quality both for their conservation and sustainable use of plant materials over a long period of time. The limited information so far available on patterns of variations in bamboo is discussed in the present paper from different points of view. The coordinated activities undertaken by INBAR-IPGRI-FORTIP are briefly summarized.

SELECTED NUMBER OF.SPECIES FOR FURTHER RESEARCH

Bamboos have been used by people over several centuries. Taxonomically, there are about 75 genera and 1250 species of bamboo

1. The opinions expressed are those of the authors and are not necessarily those of IPGRI.

of which about 10 genera and 65 species are economically important in South and S.E. Asia. But about 30 species are more commonly used than others. In order to focus better attention for research expansion, about 19 economically important species belonging to 9 genera were selected by bamboo experts on a priority basis. The criteria adopted for selection of species included: utilization, cultivation, products and processing, available germplasm and genetic resources and agroecological variations (Table 1). It was noted that the list was by no means an exhaustive or a complete one and many other species that are important either locally or regionally were recommended to be further investigated at the national level (Williams and Rao, 1994). Earlier it was noted that in view of over-exploitation and genetic erosion of bamboo species, it was necessary to collect germplasm in several localities in each region for conservation purposes. Greater attention is also needed in the classification and identification of bamboos. Surveys should be conducted to determine the distribution of various species and to identify all the local uses. Ethnobotanical knowledge on bamboo should be properly gathered, selected and published.

Further, the priority list (Table 1) consists of 9 genera. Of these Guadua *is* present in Central and S. America. Although Ochlandra is not as woody, it is economically important since the various species produce large quantity of biomass, largely used in the west coast of India, for paper-making and in handicraft industries. *Phyllostachys* is a cold climate, monopodial bamboo commonly cultivated in China, Japan and Korea. Species of this genus are well-studied when compared to other woody bamboos of tropical and subtropical countries. After excluding the above mentioned three genera only Bambusa *(6),* Cephalostachyum (l), *Dendrocalamus (4), Gigantochloa (3), Melocanna* (1) and *Thrysostachys* (1) remain on the priority list with the number of species indicated in the brackets. When compared with the total number of woody species under each genus, the number of species included in priority list would represent only a small percentage of the total (Table 2).

Table 1. Taxa of bamboos meriting highest priority research (from INBAR Technical Report 1)

Taxa	Value			Domest-ication	Climate & Ecology		Genetic Resources				
	C	Ri	E		Ci	Sl	Ge	S	Iv	E	Survey
Bambusa bambos	++	++	++	D	h,d,s	r,m,p	H	L	M	M	H
B.blumeana	++	++	++	D	h,d,s	r,m,p	H	L	H	H	H
B. *polymer-pha*	+	+	-	D	h,d	r,m	H	H	M	H	H
B. textilis	+	++	+	D	st	r,m	M	L	H	H	L
B. tulda	+	++	+	D	h,d	r,m	H	M	H	H	H
B. vulgaris		-	++	D	h,d,s	r,m,p	L	L	L	L	L
Cephalo-stachyum pergracile	+	++	+	W	h,d	m	M	L	M	H	M
Dendro-calamus asper	++	+	++	D	h,d	r	H	H	M	H	H
D.gigan teus	+		++	D	h	r	H	H	M	H	H
D. lati-florus	++	+	+	D	h	r	M	L	M	H	L
D. strictus	++	+	++	D	d,s	m,p	M	L	L	H	M
Giganto-chloa apus	+	++	++	D	h	r	H	H	M	H	H
G. levis	+	++	++	D	h	r	H	L	H	H	H

G. pseudo-arundinaria	++	+	+	D	h,d	r	M	L	H	H	L
Guadua angus tifolia	++	++	++	W	h	r,m	H	H	H	H	H
Melocanna baccifera	+	++	+	Wh		r	H	M	H	H	M
Ochlandra	+	+	+	W	h	r	H	H	M	H	H
*Phyllo-stachys pubescens**	++	++	++	D	t	r,m	M	M	L	L	L
Thyrso-stachys siamensis	++	++	++	D	d.(h)	m,(r)	M	M	L	H	L

* Including *P. bambusoides* and *P. edulis*

Value

C = Commercialization potential: High (++), Medium (+), Little (-)
Ri = Rural industries: High (++), Medium (+)
E = Environmental hehabilitation: High (++), Medium (+), and Little (-)

Domestication

Wild = W, Domesticated = D

Climafe and ecology

Ci = climate: humid tropics (h), dry tropics (d), subtropical (st), semi-arid(s), temperate (t)
Sl = Soils: rich (r), medium (m), poor (p)

Genetic resources

Ge = Genetic erosion: High (H), Medium (M)
S = need for research on seed storage: High (H), Medium (M), Low (L)

Iv = need for research on in *vitro* storage: High (M), Medium (M), Low (L)

E = need for wider exchange: High (H), Medium (M), Low (L).

Survey = need for further field survey: High (H), Medium (M), Low (L).

Table 2. Percentage of woody bamboos included in the priority list

Genera included	No. of species in South East Asia	No. of species in priority list
1. Bambusa	37	6 (16%)
2. Cephalostachyum	11	1 (9%)
3. Dendrocalamus	29	4 (13%)
4. Gigantochloa	24	3 (12%)
5. Melocanna	7	1 (14%)
6. Thyrsos tachys	2	1 (50%)

Although national experts were consulted when the priorities were established, later correspondence requested lists of species from various national committees in order to record those meriting local attention. The species are as follows (those marked with * are in the first INBAR list of 19 or the second list of 18).

1. **Bangladesh** - **Bambusa balcooa, *B. tulda, *B. vulguris, *Melocanna baccifera* and *Neohouzeaua dullooa*

2. **Bhutan** - *Arundinaria racemosa, Borinda grossa, *Dendrocalamus hamiltonii, Neomicrocalamus andropogonifolius* and *Pseudostachyum polymorphum*

3. **India** - **Bambusa bambos, *B. nutans, *B. vulgaris, *Dendrocalamus hamiltonii* and **D. strictus*

4. **Korea** - **Phyllostachys bambusoideus, I7 nigra* var *lenonis, *P. pubescens, Pseudosasa japonica, Sasa borealis, S. borealis* var *chiisanensis, S. borealis* var *gracilis, S. coreana* and *S. kurilensis*

5. **Pakistan** - **Bambusa tulda, *B. vulgaris, *Dendrocalamus hamiltonii, D. longispathus* and **D. strictus*

6. **Sri Lanka** - **Bambusa bambos, *B. vulgaris, Dendrocalamus giganteus, *D. membranaceus* and **D. strictus*

7. **Vietnam** - *Arundinaria* sp, *Bambusa procera, B. stenostachya, B. variabilis*, Dendrocalamus asper*, D. membranaceus, D. sericeus, Neohouzeaua dullooa, Phyllostachys pubescens* and *Sinocalamus giganteus.*

INTER AND INTRASPECIFIC VARIATIONS

The progress of plant taxonomic research in the tropical countries is slow for several reasons including lack of institutional support and shortage of well-trained, objective and oriented manpower (Parnell, 1993). Taxonomic problems, the value of certain groups of plants, biodiversity-prospecting and potential economic benefits are often discussed (Shyamsunder and Lanier, 1995). Bamboos are no exception. From the economic point of view about ten woody bamboo genera with about 65 species in south and southeast Asia need particular attention since the natural populations of these economically important species are decreasing with increased rate, of deforestation (Tewari, 1992; Dransfield and Widjaja, 1995). Taxonomically, the majority of the species are well identified, though no comparison is made of different populations or of same species in various countries or collected from different geographical locations present in diverse ecological habitats. Such an evaluation is essential to determine intraspecific variations. The relativ

adaptability of the species or their varieties to a given set of edaphic and environmental conditions needs to be well determined if they were to be conserved or used in reforestation programmes and plantation establishments. Certain details regarding soil type, soil fertility, soil drainage, rainfall, number of rainy days per year and the terrain that promotes good growth of priority bamboo species were summarized (Rao, 1994). Many of the details of each of the above have to be further elaborated to match the species with the available edaphic and other related conditions or to conduct provenance trials. Evolutionary tendencies in bamboos are hardly studied. Broad survey of populations in different geographic areas are not conducted. Primary, secondary and tertiary genepools are not established, even though bamboo plantations are established on an ad hoc basis. To begin with and in each region, attention has to be focussed on a limited number of species and to select them on the basis of their usefulness. As mentioned earlier using certain criteria, 19 bamboos species were selected on priority species (Table 1).

Interspecific variations among the priority species and their taxonomic characters are well known for a few species (Tewari, 1992; Gilliland, 1968; Holltum, 1958). Besides botanical descriptions, a number of other valuable details like origin, distribution, commercial value, growth and development, ecology, propagation methods, silviculturej diseases and pests, harvesting yield, genetic resources and breeding propagules for plantations and other details have recently been published for some species (Tewari, 1992; Dransfield and Widjaja, 1995).

VARIATION IN GROWTH HABIT AND CHARACTERISTICS

Among the priority species, most of them are sympodial except for Phyllostachys and *Melocanna* species. The taller and bigger bamboos belong to the genera Bambusa, *Dendrocalamus, Gigan tochloa, Melocunna* and Phyllostachys, while *Thyrsostachys* and *Ochlandra* species produce thinner culms but nevertheless are important

because of their commonality, fast growth and production of biomass in vast quantities.

Tall (27-30 meters) and dwarf culm (7 meters) varieties (ratio 4:l) have been identified in Bambusa bambos. Dwarf forms are more common at high altitudes up to 1000m. In Bangladesh, three varieties of Bambusa tulda are recognized: (a) normal, (b) large with thicker culms, and (c) medium with large cavity and thin wall. Bambusa *vulgaris* is well known for its impressive culm colours: (a) plants with green culms - B. *vulgaris* var. *vulgaris,* (b) yellow culms with broad or narrow green stripes - B. *vulgaris* var. *stricta* or var. *vittata,* and (c) short form -Buddha's belly, 3 meters tall, extends upto 1200 meters, tolerant to cold climate and low temperature of *3°C. Dendrocalamus asper* has one cultivar with black culms. *Dendrocalamus latiforus* has one variety, *Zugenurius, 5-10* meters tall, 4-12cm diameter, used as an ornamental, with culms yellow green with dark green stripes. *Gigantochloa pseudourundinuceu* has three varieties: (a) robust form with wall thickness of 2cm, green and yellow; (b) less robust form or medium variety with lcm wall thickness, and (c) small form that provides edible shoots; wet and dry forms of this species are distinct.

NEED FOR DESCRIPTORS

Since bamboos are very homogenous in general appearance one has to rely mostly on morphological, vegetative characters. Both vegetative and floral characters are used in the preparation of taxonomic keys. Whether at generic or species level, the useful characters with diagnostic value are few, not exceeding about 6-8 in each case. The following floral characters are used: ovary is either narrow or fleshy, style is rigid, hollow or otherwise, paleas are bifid or not, spikelets big (75mm) or small with or without perfect flowers. Among the vegetative characters - culms with or without thorny branches and at different levels, internodes hairy or not hairy, climbing or erect forms, culm sheaths thick or thin, persistent or

otherwise. In view of such limitations, there is need to highlight about 6-8 spot field characters by using which one can identify various bamboo species fairly comfortably and accurately in the field. It is necessary to remember that people who grow, cut and trade bamboos are non-scientists. Of late the group of non-taxonomists like ecologists, geneticists and plant tissue culture scientists are conducting some valuable research to increase bamboo production, cultivation and conservation. They also need to have some easy guidelines to identify bamboos in the field before embarking on various research projects. For this reason, publications of descriptors and well-illustrated manuals are very necessary. Harvesting and trade operations do not wait for authentic species identifications or adequate conservation or quarantine measures. The bamboos are cut and sold to meet the market requirements and to meet the various uses of rural people who live next to the natural bamboo resources. Scientific knowledge on improvement for increased production and conservation is different from harvesting and utilizing bamboos from forests or plantations. They are completely different operations with different objectives. The utmost need of the hour is to create an awareness among the public about the importance of saving the biodiversity and genetic diversity of the most useful bamboos for sustained use by posterity.

GENETIC RESOURCES AND GERMPLASM COLLECTIONS

Availability of genetic resources and germplasm collections for certain bamboo species have been determined (Dransfield and Widjaja, 1995). The names of places where such genetic resources are present with different species are as follows:

1. Lampung, Sumatra - *Bambusa atra, B. blumeana, B. vulgaris, Dendrocalamus asper, D. giganteus, D. latiflorus, Gigantochloa apus, G. atter, G. nigrociliata, G. pseudoarundinacea, G. robusta* and *Schizostachyum zollingeri.*

2. Bangladesh - Bambusa balcooa, B. tulda - big and small forms and *Dendrocalamus giganteus.*

3. Arunachal Pradesh, India - *Bambusa balcooa, B. polymorpha, B. tulda, Dendrocalamus giganteus, D. membranaceus* and *D. strictus.*

4. ERDB, Philippines - *Dendrocalamus latiflorus* and *Schizostachyum brachycladum* and *S. lumampao.*

5. Sabah Agriculture Dept. - *Schizostachyum latifolium.*

6. Forest Research Centre, Bogor - *Gigan tochloa manggong* and G. *pseudoarundinacea.*

7. Several botanic gardens at Nanjing, Bogor, Penang, Singapore, Peradeniya, Bali and others - *Bambusa vulgaris, Cephalostachyum pergracile, Dendrocalamus asper, D. latiflorus, Gigantochloa hasskarliana* and others.

Some special efforts should be made to collect the names of all the bamboo species present in various botanic gardens of South and South East Asia. If the origin of the materials are well recorded for various species i.e. the original place of collection, date of collection, name of collector, etc. such data would very much help to trace the genetic resources and the natural home of several species. Such data will be very helpful in improving the quality of bamboos. It is also very likely that many of the species originally collected in India were sent to various places through the botanic gardens, Calcutta, which was the main administrative centre for forest research activities of S. E. Asia during the colonial period.

SUPERIOR GENOTYPES OF BAMBOOS

In October 1994, questionnaires were sent to coordinators of INBAR national programmes to obtain information on superior genotypes of priority bamboo species. The information obtained from Bangladesh, India and Indonesia was helpful to prepare the list of

superior bamboo types (Table 3). It is to be noted that the details of these superior types are yet to be characterized. No superior types are so far recognized in Bambusa blumeana, B. textilis , Dendrocalamus latiforus and Gigantochloa levis.

Table 3. Superior genotypes of bamboos

1. Information from national programmes:

- **Bangladesh, India, Indonesia responded**

2. Known superior types - yet to be characterized

Species	Number of types
1. *Bambusa bambos*	**3**
2. *B. polymorpha*	**3**
3. *B. vulgaris*	**6**
4. *Cephalos tachyum pergracile*	**2**
5. *Dendrocalamus asper*	**1**
6. *D. giganteus*	**2**
7. *D. strictus*	**3**
8. *Gigan tochloa apus*	**1**
9. *G. pseudoarundinacea*	**1**
10. *Melo canna baccifera*	**3**
11. *Ochlandra beddomei*	**1**
0. ebractea ta	**1**
0. scriptoria	**4**
0. travancorica	**4**
0. wightii	**1**
12. *Phyllos tuchys pubescens*	**1**
13. *Thyrsostachys siamensis*	**1**

3. No superior types recognized

1. *Bambusa blumeana*
2. *B. textilis*
3. *D. latiflorus*
4. *G. levis*

VARIATIONS IN FLOWERING HABIT AND OPPORTUNITIES FOR HYBRIDIZATION

Majority of bamboos are known to flower rarely or very rarely but simultaneously over a long period of time irrespective of geographic localities where they are present. The causal factors for this special flowering habit, many times synchronously, are not known except for general explanations like mobilization of adequate nutrients, possible hormonal controls, biological rhythm, etc. However, three major patterns of flowering are recognized in some of the well known species, (a) gregarious type, (b) sporadic type, and, (c) continuous type. Among the priority species, the following variations are noticed. In *Bambusa bambos*, gregarious flowering is recorded over an interval of 16-32 and 45 years. Sporadic flowering is recorded in Thailand and plants in certain localities flower every year or once in two years (Anantachote, 1987,199O; Sharma, 1994). In B. *blumeana* the gregarious cycle is between 20-30 years, *B. polymorpha* 50-60 years, B. *tulda*, gregarious 25-40 years, sporadic 2-3 years; in B. *vulgaris*, flowering is rare or not common; *Cephalostachym pergracile* flowers every year; flowering cycle is very poorly recorded for *Dendrocalamus asper*; D. *giganteus* 30-40 years; D. *latiflorus* data not well recorded but occasionally flowering has been recorded in China, Philippines and Indonesia; D. *strictus* flowering cycle is between 27-75 years; *Gigan tochloa apus* has 50-60 years flowering cycle and so also G. *pseudarundinacea*, but for G. *levis* the data is not well recorded; *Melocanna baccifera* flowers gregariously once in 30-45 years and sporadic flowering is common every I-2 years; *Thyrsostachys siamensis* flowers commonly and frequently. In order to obtain regular seed supply it is better to collect the sporadic flowering types from different locations or countries and grow them in easily accessible locations. In such cases, details of flowering behavior may be well recorded and suitable materials can be collected for hybridization work. Good and continuous seed supply will help to promote bamboo production and selection of superior plant materials. Details of hybridization

work done in China are published (Zhang and Chen, 1987) but many of the scientific details are yet to be clearly explained.

SEED STRUCTURE AND VIABILITY

There are limited studies on bamboo seed development and structure. General statements are made saying that bamboo fruits (caryopses) are similar to most of other members of Gramineae. Only species of Dinochloa, Melocanna, Melocalamus and Sphaerobambos produce fleshy fruits. Bamboos that produce fleshy fruits are present both in the old and new world and the number of seeds produced per plant is inversely proportional to their size. Whether the fleshy fruits resemble the dry caryopses and how similar are the structural details between the dry and fleshy fruits have been studied by Harigopal(l982).

Bamboo seeds (= fruits, caryopsis) whether dry or fleshy have a short viability period (usually about 4 weeks) in most cases. Under refrigeration, the viability can be extended for a few months. Some data has been published on seed germination and longevity of Melocanna baccifera, Bambusa bambos, B. tulda, Dendrocalamus Zongispathus, D. strictus and Phyllostachys sp. (Banik, 1987, 1994; Varmah and Bahadur, 1980). Seed sterility is not uncommon and a high degree of fungal infection deteriorates seed viability (Anantachote, 1987). Among the villagers and other users, it is a common practice to soak the seeds in water briefly before germinating them. Only those that sink are selected for further germination and the seeds that float are generally considered as sterile and discarded. What causes seed sterility also need to be well studied starting from pollination and the sequential development of caryopsis. Very good model studies on grass seed development are there including those of rice, wheat and maize. Wherever possible, at least in case of those bamboo species which flower sporadically, experiments may be conducted to obtain fertile

seeds with good viability. The period of seed viability should be determined for most of the species with the objective of extending seed life to prolong conservation. Some research work has been recently started to determine the seed viability in some of the priority species of bamboos.

CYTOLOGICAL VARIATIONS

An important and reliable cytological method followed to distinguish varieties is to understand the chromosome numbers and their morphology. Of late there are very few researchers who are conducting this type of basic research. More attention is paid to protein and DNA analysis and their variation to determine intraspecific variation of different taxa. Much work needs to be initiated in bamboos and different problems involved are discussed elsewhere (Reiner, 1994). The chromosome numbers for a number of priority bamboo species have been determined in the past (Varma and Bahadur, 1980; Zhang, 1987).

The haploid number of x=12 and some variations in numbers are also reported but causal factors of variations have not been analyzed. The details of chromosome numbers are as follows: *Bambusa bambos 2x=70, 72; B. blumeana 2x=78; B. polymorpha 2x=72* (Haploid=H); *B. tulda 2x=72; Cephalostachyum pergracile 2x=72; Dendrocalamus latiforus 2x=72, 74, 68* (H); *D. giganteus 2x=72* (H); *D. strictus 2x=72* (H); *Gigantochloa arundinacea 2x=72* (H); *Melocanna baccifera* 2x=72 (H). The chromosome numbers for *Dendrocalamus apus, Gigantochloa levis* and *Thyrsostachys siamensis* are not yet determined. It is important to emphasize the importance of basic knowledge of cytology and embryology to understand genetic variation, seed development and to plan for hybridization work. Since bamboos are grasses, apomictic tendencies cannot be ruled out. Seed sterility is common among bamboos. Flower development after long unpredictable time intervals is another limitation or handicap to study the reproductive biology of bamboos and properly

plan for hybridization work. The only hope for solving the various problems is to concentrate on those species or their clones that flower regularly. Identifying suitable locations for such species and studying their phenology are important.

BAMBOO TISSUE CULTURE AND MASS PROPAGATION OF PRIORITY SPECIES

In vitro culture studies on bamboos are conducted using a wide range of plant materials of about 20 genera, 63 species and 4 cultivars (Zamora, 1994). Full or part organogenesis has been obtained in most of the species. Nodal segments, leaf materials and seeds were used as explants and plantlets were obtained in the following priority species - *Bambusa bambos, B. polymorpha, B. tulda, B. vulgaris, Cephalostachyum pergracile, Dendrocalamus giganteus, latiflorus, D. strictus, Gigantochloaapus, Phyllostachys pubescens* and *Thyrsostachys siamensis*. Mass propagation protocols have been established in the last few years for B. bambos, D, giganteus, Dstrictus and *Phyllostachys edulis*. Large number of plants grown by tissue culture methods have been transferred to the field. Further research may help to select superior clones of each species to establish good genetic varieties. *In vitro* flowering and seed production has raised considerable hope. If some of the limitations are overcome, this method can also be successfully used for genetic improvement of bamboos. By using tissue culture technique methods, large quantities of selected plant propagules can be raised for genetic analysis and clean materials will be helpful for isozyme and DNA analysis. Intraspecific relationship can be easily built up by using such materials obtained from the desired clones.

NEED FOR MULTI-DISCIPLINARY STUDIES

Earlier, taxonomic studies involved the collecting the specimens, and identifying and assigning them correct taxonomic positions. Only experts or professional taxonomists examined large numbers

of herbarium specimens representing wide geographical collections to verify, check or confirm species identifications. When some of the specialists like Soderstrom, Bor and others visited various herbaria they checked the local collections and confirmed the correct names for certain species. The species descriptions were based on characters of type specimens and localities. But no comparative studies have so far been made to identify the ecotypes or genotypes. Specimens of same species collected from different geographical locations or countries, and ecological habitats involving edaphic, environmental and altitudinal variations have not been compared to assess the range of variations. Such an exercise is an important one since identification of ecotypes within a species is essential for using the selected plant material for greater production, reforestation, biomass production, soil conservation and to improve the quality of natural watersheds. Increasing greenery and growing of bamboos on wastelands is a very profitable operation and there is great demand for such work in various countries. Evolutionary tendencies of the chosen bamboo species need to be well established. While it is possible to trace the origin and geographic distribution of some species, others remain as "camp followers" following the path of the immigrant people who took the bamboos along with them to the new places of settlement in Asia. For this reason there is an urgent need for a broad survey of natural or cultivated bamboos in different geographic areas to identify variations within the species, or their varieties or clones and to identify the superior plants. In the first instance, attention should be paid to the list of priority species. When broad intra-specific variations are determined such variations should be identified to determine primary, secondary and tertiary variants. Well established methods already used for crop plants can be followed to recognize the useful variants in bamboos (Rao and Riley, 1994).

INBAR, the International Network for Bamboo and Rattan, was established in 1993 and many activities have been conducted since then to meet the various research needs of bamboo and rattan. IPGRI is collaborating and supporting the program areas that deal with biodiversity, genetic resources and conservation. The collection,

conservation (ex situ and in situ) and handling of genetic materials of bamboo and rattan are much different from the established methods used in crop germplasm. Many gaps in our present day knowledge need to be filled up with good scientific data to formulate and carry out good research projects. Trained manpower shortage is acute in bamboo growing tropical countries to carry out the various research projects. Many meetings jointly and recently organized by INBAR, IPGRI and FORTIP have helped to focus and promote the necessary research in different countries of South and South East Asia. The various publications brought out by these three organizations record the progress made from time to time. It is hoped that more rewarding results will be achieved in the near future to conserve both bamboo and rattan genetic materials, improve the quality of plant materials and use them on a sustainable basis.

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APPENDIX 6

IN VITRO FLOWERING AND ITS IMPLICATIONS FOR BAMBOO DEVELOPMENT

I.V. Ramanuja Rao and Alfinetta B. Zamora

INTRODUCTION

The development of bamboo hybrids which may be better than those already available in nature is limited by *in situ* flowering of possible parental culms. Flowering 'in bamboo occurs after a lengthy vegetative growth period ranging from 3 to 120 years (Mandal and Subramaniam, 1992). Watanabe (1984) collected data on the life cycle of several bamboos worldwide, confirming their rather lengthy vegetative interval. Fertility in bamboos varies and seeds may be more easily recovered from some species than others. Mandal and Subramaniam (1992) noted that "in general, all bamboos would fall between two physiological stages of constant sterility (Bambusa *vulgaris)* and constant fertility *(Bambusa atra).*Also, two types of flowering are noted in bamboo, i.e. sporadic and gregarious. When they flower gregariously, all culms die.

The nature of flowering in bamboos, the long gestation period for a breeding project, possible locations of flowering clumps of good provenances of bamboo, communication-related problems between local people with knowledge of flowering clumps and scientists are among hindrances to bamboo improvement through hybridization. Futhermore, there may be an attitude problem arising from the question, "Is there a need to develop new bamboos? Are the existing species inadequate to meet the perceived needs of the bamboo industry?"

STATUS OF RESEARCH ON IN VITRO FLOWERING

The focus of this paper is on *in* vitro flowering, an advance in tissue culture with direct implication for bamboo improvement. Flowering has been observed to occur spontaneously in micropropagation work and more importantly from induced cultures.

Prutpongse and Gavinlertvatana (1992) noted spontaneous flowering in Bambusa nana, B. *bambos, B.* sp. Dan Khan, *B. glaucescens, B. brandisii, B. multiplex, Dendrocalamus membranaceus* and *Cephatostachyum pergracile.* They were unable to associate flowering to any particular factor during their micropropagation research. Banik (pers. comm.) also did not associate *in* vitro flowering with any particular culture medium, but thought that flowering was associated with genotypes, with some seed lines more amenable to flowering. In our laboratories where experiments were not directed to *in vitro* flowering but to micropropagation *per* se, spontaneous flowering was noted when cultures were not subcultured at the optimum stage of growth. Under these "stress environments", flowering was observed to occur from nodes and tips of shoots or plantlets, and also directly from the callus.

The earliest report on *in vitro* flowering was in 1988 by Rao and Rao in *B. bambos* and *D. strictus.* Flowers were obtained in 8-10 weeks on B5 + 2, 4-D + BAP + coconut water from compact calli with embryoids cultured on B5 + 2,4-D + BAP and later transferred to B5 + GA3 + ABA + ethephon. The flowers arose directly from the embryoids.

In 1990, an Indian group of researchers published a paper on *in vitro* flowering that caught the interest of media worldwide. Nadgauda et *al.* (1990) induced *in vitro* flowering from *B. bambos* and *D. brandisii* in culture medium with 2.2 pM BA and coconut water. Using multiple shoots derived from aseptically germinated seeds of *D. hamiltonii,* Chambers et *al,* (1992) reported that in vitro flowering was obtained in 13-15 weeks on MS + 4.4 uM BA and also on the medium of Nadguda et al., (1990). They were able to increase efficiency of *in vitro* flowering to 47% with a preculture of multiple shoots on MS + 22.2 uM BA for 8 weeks prior to subculture to a plain MS medium.

Shamsi and Rao (unpub.) recently increased substantially the percentage of cultures with *in vitro* flowering in B. bambos and further observed that the inflorescences could be induced to develop further inflorescences in culture. Pure inflorescence cultures were obtained and to date (May 1995) are in the 16th subculture cycle. An interesting observation of Shamsi and Rao was that the inflorescence could be shifted to vegetative growth and vice versa. These results indicate that flowering can be controlled.

In these studies, seeds were used as the primary explant for embryogenic callus (Rao and Rao, 1988) or multiple shoots (Nadgauda et al., 1990; Mascarenhas et al., 1990; Chambers et al., 1992). Recently Rao et al. (unpub.) observed spontaneous flowering from nodal explants taken from juvenile plants of Bambusa balcooa. Although a freak occurrence, there is the possibility that the response can be repeated. The mother plant remained vegetative.

Rao noted that the number of florets produced and the extent of inflorescence branching *in vitro* was directly related to the vigour of the plantlet. Plantlets with greater numbers of leaves had more florets. It was also noted that floret sizes were normal, although the plants/shoots were small and there were viable pollen grains. Rao and his co-workers and Chambers et al. (1992) were unable to obtain seeds from the species they worked with while Nadgauda et al., (1990) reported *in vitro* seeding. Rao observed a low pollen count, and a high percentage of non-viable pollen in the species worked with while Chambers et al. observed that the stigma was extruded earlier than the anthers, implying an outcrossing habit for D. *hamiltonii.* As different growing conditions, aside from bamboo species, were used in their experimentation, it is recommended that further studies be concentrated on factors influencing germination of pollen on the stigma *in vitro.*

The studies on induced *in vifro* flowering were successful with four species, namely *B. bambos, D. strictus, D. humiltonii* and *D. brundisii.* Two of these species, namely B. bambos and *D. strictus,* are among the 19 INBAR highest priority species and the others are lower INBAR priority.

IMPLICATIONS OF IN VITRO FLOWERING

The results on in *vitro* flowering have far reaching implications for bamboo improvement programmes and micropropagation systems. For bamboo improvement, the research on *in vitro* flowering could lead to a greater understanding of the flowering process in different species and genera, induced flowering *in situ* and *in vitro,* hybridization, haploid culture and doubled haploid generation.

A. Bamboo improvement programmes

1. Basic knowledge of flowering

The results on *in vitro* flowering to date have shown the following:

a. The growth pattern of bamboo from the juvenile stage to the mature stage can be manipulated to induce flowering *in vitro.*

b. Seed-based tissue cultures are not exempt from the possibility of occasional precocious flowering which is also known in nature. However, significantly higher percentages of flowering can be reproducibly obtained in culture .

c. Flower induction is not understood. Although Chambers et al., (1992) suggested that cytokinins may be associated with *in vitro* flowering, their effect on floral induction is still unclear.

The prospect of understanding the basis of flowering could lead to manipulation of growing conditions to induce (or to hinder) flowering. In bamboos, gregarious flowering leads to death of the whole clump, which is disastrous to the local people dependent on bamboos for livelihood. However, for containerized plants of bamboos, flower induction would be useful. In the Philippines, mango is an example where chemical induction has replaced traditional methods of flower induction. The active ingredient in

the flowering inducers, potassium nitrate, shifts the shoot meristems to floral meristems.

2. Induced flowering and seeding in *vitro* and *in situ*

Flowering is important for production of seeds for seed-based propagation systems, whether the propagation is in the greenhouse or in the laboratory. Seeds are ideal for planting, particularly when vast areas are to be replanted and where access to areas for replanting is a problem.

However, the research will have to focus on pollen morphology, viability and storage from induced systems, particularly those arising from *in vitro* flowering, as well as fertilisation. Rao and Rao (1988) noted that induced plants could be potted out, with actual expansion of the inflorescence and florets accompanied by anther dehiscence taking place ex *vitro.*

3. Interspecific and intergeneric hybridization

Should sufficient technical knowledge be developed for floral induction of various species of bamboos, proliferating cultures of shoots could be established and induced to flower simultaneously for a controlled hybridisation program. What would be needed would be protocols for micropropagation of shoots, particularly from selected parents and protocols for flower induction in the selected species.

4. Haploids and doubled haploids

In *vitro* flowers can provide anthers and pollen for haploid and doubled haploid work, resulting in pure lines useful in breeding. Tsay et al. (1990) demonstrated that embryoids could be obtained from the embryogenic calli arising from anthers of *Sinocalamus latiflora* and that plantlets could be derived from the embryoids.

Plantlets were haploid and further research was recommended for diploidization.

B. Micropropagation programs

Induced flowering can be useful for generating seeds as initial material for micropropagation programmes but spontaneous flowering is detrimental. For a micropropagation programme, flowering is detrimental because it implies a maturation of the plantlets in the culture system. We have noted that spontaneous *in* vitro flowering was associated with a decline in regenerating cultures. In vitro flowered plants died in culture or upon potting out (Rao and Rao, 1988; Prutpongse and Gavinlertvatana, 1992; Zamora, 1994) for Bambusa bambos, B. brandisii, *B. glaucescens, B.* nana, *B.* sp. Dan Khan, Cephalostachyum *pergracile, Dendrocalamus membranaceus* and D. *strictus.* Only flowered plants of *B. multiplex* were reported to survive potting out (Prutpongse and Gavinlertvatana, 1992).

SUMMARY AND RECOMMENDATIONS

In vitro flowering has been successfully induced from embryoids or shoots/plants derived from embryoids and from multiple shoots in four bamboo species, namely *Bambusa bambos, B. brundisii, Dendrocalanus humiltonii* and D. strictus. Embryos and multiple shoots were derived from seed-based micropropagation systems. Greater support should be given not only to research on *in vitro* flowering but also the development of micropropagation systems, particularly for systems initiated from non-seed explants, for the INBAR priority species.

More importantly, further research on *in vitro* flowering can lead to a deeper understanding of flowering *in* situ and its control.

The need for improved bamboos should be closely evaluated. The natural diversity is yet to be fully exploited.

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APPENDIX 7

SELECTION CRITERIA AND METHODOLOGY FOR PRODUCTION OF BAMBOO CLONES

K. Gurumurthi, Madhavi Rani and Rishi Kumar Verma

INTRODUCTION

Extensive studies on micropropagation of various species of bamboo have been carried out (Rao et. al., 1992; Usha Rao et. *al.,* 1992 and Tewari, 1992, 1994). Many of these studies have originated from tissue culture laboratories which concentrated on developing protocols using suitable explants like axillary buds. Thus, abundant information is available on "how to multiply", bamboos and practically no information is available on "what to multiply". This is due to inadequate knowledge on the genetics and improvement of bamboos. Realizing this constraint, INBAR has attempted since 1994 to direct research towards mass-multiplication of quality planting stock (Anonymous, 1994). At the same time, the need for genetic improvement of bamboo is urgent due to impoverishment of natural stock resulting in loss of genetic material (Rao, 1992).

Genetic improvement programmes in perennial species require establishment of seed production areas, clonal seed orchards, seeding orchards and clone banks, as commonly practised for eucalyptus, casuarina, teak and acacias. Yet, the same strategy cannot be followed for bamboo. Most flower gregariously and set seed after long intervals and die thereafter (Venkatesh, 1988). The unique flowering nature of bamboo is the major limiting factor in improvement programmes. Simple procedures such as selection are also not carried out in bamboo due to its peculiar architecture. Thus, there are no fixed selection criteria. The parameters that can be considered are number of culms, internodal length, culm height, fibre length etc. Even these parameters are influenced by soil, water availability, temperature and humidity. However, vigour and

growth habit of seedlings are effective criteria for selection (Venkatesh, 1988).

SEED QUALITY AND SEEDLING VIGOUR

Gregarious flowering bamboos produce abundant seed and the viability of the seeds can be very high with excellent germination. In India, often the area where bamboo has flowered is covered with a carpet of seedlings in the ensuing rainy season. The high germinability and the out-crossing maintains genetic variation, segregation and recombination. Venkatesh (1992) suggested that the large seedling variance observed in open-pollinated progeny can be used for selection of Bambusa *bambos* and B. glaucescens. Kondas et. al. (1973) observed seedling segregation as grassy, erect, grassy erect and highly erect with the last one highly vigorous and fast growing that can be used for selection. Banik (1980) also reported high segregation with erect ones showing faster growth along with elongated internodes which could be used as an indicator for rapid culm production.

In our laboratory the flowering behaviour was assessed empirically when flowering began in B. *bambos* in Wynad, Kerala. Variations in clump side, culm size, height etc. were noticed. Vigorous clumps produced abundant flowers and seeds. There was a distinct correlation between the culm size and the seed weight (Madhavi Rani, 1994).

GROWTH CORRELATIONS AND GENETIC DIVERGENCE

Natural stands as well as plantations-derived from seedlings show considerable variations in growth. Various field measurable parameters include clump circumference, annual culm production, culm diameter, rate of growth of culms and dry matter production of culms. Venkatesh (1992) suggested the possibility of identifying plus clumps for eight different species of bamboo in Arunachal Pradesh. They collected plus bamboo rhizomes from diverse localities to establish a clone bank. Data on survival, average height, average girth and number of culms were recorded. Some selections were promising. Singh (1993) analyzing the genetic divergence in

B. tulda collections from North-East India concluded that internodal length and girth of the culm contribute the most towards total genetic diversity. Also, number of culms per clump, length of internode and girth of the clump contributed as much as 75%. Selection strategy needs to be concentrated on such characters.

SELECTION AND MULTIPLICATION OF QUALITY PLANTING STOCK

Production of good quality seed on the mother plant of bamboo, in which senescence sets in with the onset of flowering, is conditioned by the vigour of the mother plant. There are no references available to support this contention in bamboo, though many references are available for agricultural crops (Rajendran, 1982; Vanangamudi, 1982). Effective photosynthesis and translocation into the seeds is an important factor.

Secondly, even if good quality seeds are produced, they have to be harvested and stored appropriately to maintain their vigour. Further, under optimum storage conditions, high quality seeds will maintain viability and also vigour for a longer period of time. A series of investigations were focused on collection of seeds from selected vigorous clumps, culling poorly filled seeds, grading seed lots based on size and storing under different conditions.

Seed size is an important factor that decides propagule quality as it indicates the quality of reserve food supply available for seedling emergence. The importance of seed size in obtaining good seedlings and yield was examined as early as 1893 by Hays. Since the ultimate aim was to achieve good planting stock, the impact of seed size in multiple shoot production *in vitro* was also studied. Seeds of B. bambos were obtained from selections made in the Tholepatty range of Wynad Forest Division in Kerala.

In order to study the effect of seed size on viability and vigour of seeds during storage and their further response under *in vitro* conditions, the seeds of B. bambos were graded manually as:

Gl	-	Ungraded seeds	-	as collected normally
G2	-	Large seeds	-	well-filled seeds of 4-5 mm length
G3	-	Small seeds	-	less than 3 mm

Graded seeds were stored at 0°C and tested for viability, vigour and response under *in vitro* conditions by recording the following observations at bi-monthly intervals - germination percentage, root and shoot length, and response under *in vitro* condition (percent seedlings producing multiple shoots).

Table 1 and 2 presents data on the interactive effect of seed size on germination and seedling size. Large seeds performed better. The *in vitro* response (Table 3) showed no significant difference in multiple shoot production between large and small-sized seeds under culture conditions.

Table 1 Effect of seed size on germination percentage of the seeds after different seed storage intervals

Period after collection (months)	Seed grades		
	Ungraded (Gl)	Large (G2)	Small **(G3)**
0(S0)	92 (73.57)	91 (72.54)	93 (74.66)
2(s1)	89 (70.63)	93 (74.66)	90 (71.57)
4(s2)	91 (72.54)	90 (71.57)	80 (63.43)
6(S3)	87 (72.54)	91 (71.57)	78 (63.43)
8(S4)	80 (63.43)	88 (69.73)	72 (58.05)
10(S5)	75 **(60.00)**	**89 (69.03)**	**64 (53.13)**
12(S6)	71 (57.42)	86 (68.03)	59 (50.18)
Mean	**83.57 (66.64)**	89.71 **(71.38)**	**76.57 (61.87)**
SE	G 0.2600**	S 0.3971**	GS 0.6878**
CD	0.5254**	0.8025**	1.3900**

(The values in parentheses ir dicate arc sine values)
** Significant at 1% level.

Table 2. Effect of seed size on shoot length and root length cm) of seedlings after different seed storage intervals

Period after cbllection (months)	Gl		G2		G3	
	shoot length	root length	shoot length	root length	shoot length	root length
s0	6.3	6.0	6.4	6.2	6.3	6.1
s1	6.0	5.9	6.3	6.2	6.0	5.6
s2	5.9	5.5	6.0	6.0	5.3	4.7
s3	5.7	5.4	6.1	6.0	4.6	4.2
s4	5.4	4.9	5.9	5.6	4.5	4.0
s5	5.0	4.6	5.9	5.5	3.8	3.2
s6	5.1	4.4	5.8	5.5	3.1	2.9
Mean	5.63	5.24	6.06	5.86	4.8	4.36

	Shoot length			Root length		
	G	S	GS	G	S	GS
SE	0.0243*	0.0371*	0.0642'	0.0621"	0.0948,	0.1643*
C D	0.0491+	0.0750'	0.1298*	0.1255'	0.1917*	0.3320*

* Significant at 5% level

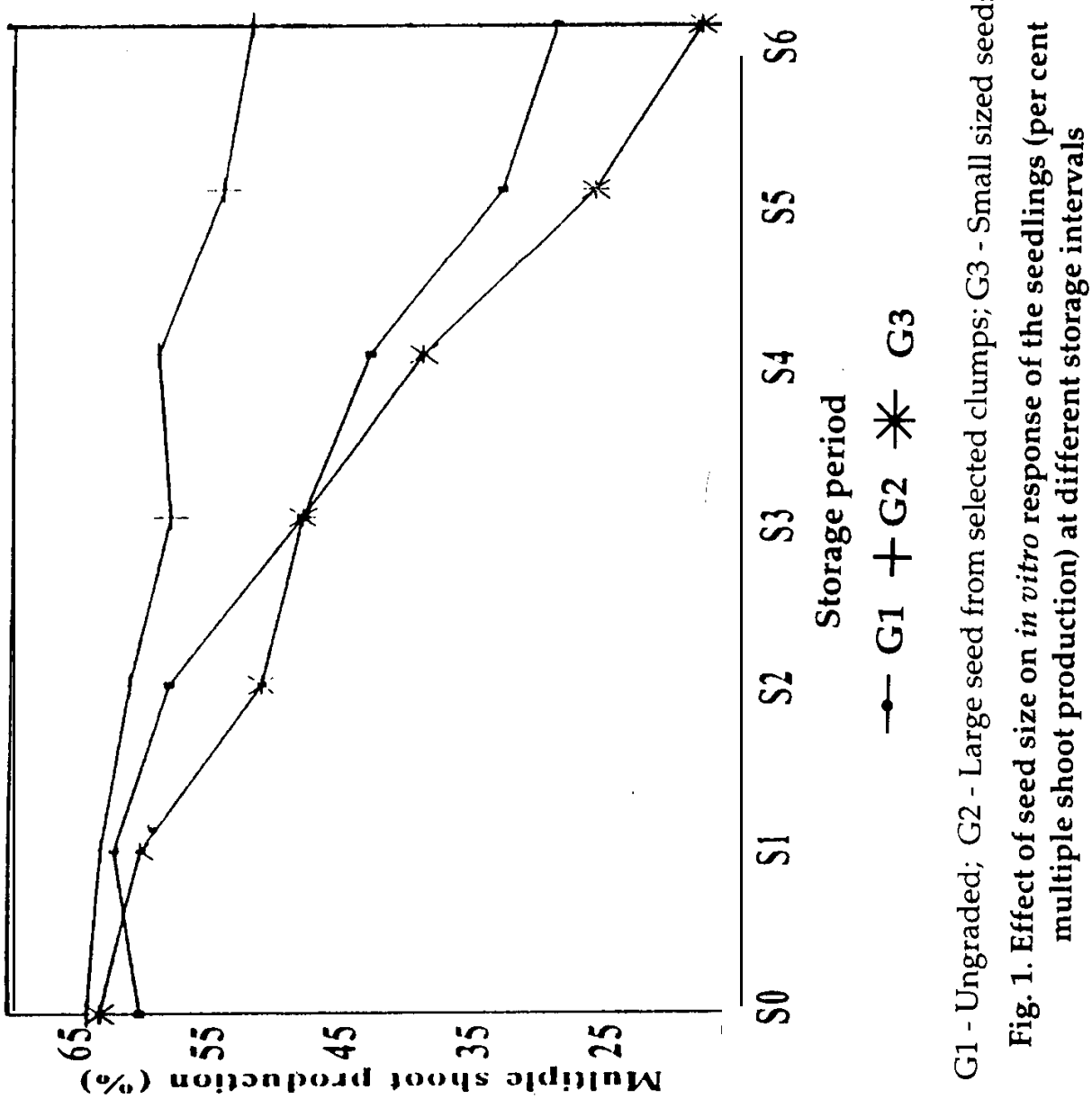
Table 3. Effect of seed size on in vitro response of the seedlings (multiple shoot production) at different storage intervals

Period after collection (months)	Gl	G2	G3
s0	60 (50.77)	64 (53.13)	63 (52.54)
s1	62 (51.94)	63 (52.56)	60 (50.77)
s2	58 (49.6)	61 (51.35)	51 (45.57)
s3	48 (43.85)	58 (49.60)	49 (43.95)
s4	43 (41.06)	59 (50.18)	39 (39.65)
s5	33 (35.06)	54 (47.29)	26 (30.66)
S6	29 (32.59)	52 (46.15)	18 (25.1)
Mean	47.57 (43.55)	58.71 (50.04)	43.57 (40.63)
	G	S	GS
SE	0.2882*	0.4403	0.7626
C D	0.5825*	0.8898*	1.5412*

(The values in the parenthesis indicate arc sine values)

* Significant at 5% level

However, plantlets developed through tissue culture when transferred to the shade-house and hardened following the usual procedures (Preetha et *al.,* 1992) and propagated through rhizome separation, (Adarsh Kumar et *al.,* 1988) showed that large seeds were significantly superior to the small and ungraded seeds for multiple root producing ability (Fig. 1).



G1 - Ungraded; G2 - Large seed from selected clumps; G3 - Small sized seeds

Fig. 1. Effect of seed size on *in vitro* response of the seedlings (per cent multiple shoot production) at different storage intervals

The larger seeds expressed higher vigour at all periods of study compared to small-sized seeds. In bamboo, flowering and senescence are initiated concurrently. Therefore, seeds that are

effective sinks are expected to be of better quality. However, they may or may not be of high genetic quality though the capacity to create a sink is a genetic attribute. Further, rapid translocation of the photosynthates and nutrients to the dominant sinks would starve the roots and concomitantly the seats of the photosynthetic activity, reducing the accumulation of dry matter in the late-formed seeds. Such altered physiological conditions of the plant can also cause overall reduction in vigour and viability in smaller seeds during storage. According to Perry (1976), the causes for vigour differences are genotype-environment interactions.

In the present study, the high germinability was due to initial care taken to collect from the field. The seeds were collected from phenotypically selected superior clumps (good clumps with long culms) and were then cleaned and stored immediately after collection.

FIELD EVALUATION OF PROPAGULES

The propagules produced through tissue culture were planted in the field and their growth monitored. Physiological parameters such as chlorophyll fluorescence and protein content were also included in the assessment. For this study, the propagules were planted in the field in rows. All the propagules obtained from a single seed were classified as a clone.

The results showed the superiority of these propagules over seedling-raised plants (Tables 4 & 5). Culm formation occurred early in the propagules compared to seedling-raised plants which may be due to the precocious induction of rhizome in the cultures. The increase in culm height, average diameter of culms and internodal length was also found to be higher in the tissue culture propagules.

Though the superiority of the plantlets was established, their genetic superiority per se was not proved. Nevertheless, analysis of the genotypic and phenotypic coefficients of variation for different characters provide adequate evidence of existence of genotypic

variation for all characters and there existed considerable variability in the population established in the clone bank and further selection can be practised. This has to be further supported by collecting growth data of these plants for up to 3 or 4 years and subjecting them to statistical analysis, so that superior ones can be chosen for multiplication through vegetative means.

Table 4. Comparative mean monthly increment data

Clone number	No. of culms per clump	Culm height (m)	Culm diameter (cm)	No. of branches per culm	No. of nodes/ culm	Internode length (cm)
1	0.60	0.31	0.22	1.35	1.88	2.06
2	0.60	0.30	0.24	1.25	1.85	1.94
3	0.63	0.30	0.22	1.18	1.80	2.23
4	0.53	0.30	0.21	1.20	1.72	1.99
5	0.68	0.29	0.21	1.10	1.50	2.10
6	0.80	0.26	0.17	1.03	1.50	1.97
7	1.08	0.03	0.24	1.00	1.50	2.23
8	0.75	0.31	0.21	1.13	1.45	2.06
9	1.13	0.29	0.24	1.03	1.40	2.19
Seedling-raised plants	0.32	0.14	0.11	0.56	0.67	0.733

Table 5. Growth data of tissue culture raised plants 10 months after planting

Clone lnumber	No. of culms per clump	Culm height (cm)	Culm diameter (cm)	No. of branches per culm	No. of nodes/ culm	Internode length (cm
1	6.00	3.07	2.22	18.75	13.50	20.58
2	6.00	2.95	2.37	18.50	12.50	19.38
3	6.25	3.03	2.24	18.00	11.75	22.30
4	5.25	2.95	2.11	17.25	12.00	19.90
5	6.75	2.90	2.11	15.00	11 .00	21.00
6	8.00	2.58	1.69	15.00	10.25	19.67
7	10.75	3.00	2.36	15.00	10.00	22.35
8	7.50	3.07	2.11	14.50	11.25	20.65
9	11.25	2.85	2.39	14.00	10.25	21.88
Mean	7.52	2.93	2.18	16.22	11.39	20.86
c.v.(%)	14.797	6.849	9.559	12.138	11.677	9.918

Reproduction in bamboo is mostly dependant on vegetative sources from the peripheral parts of the underground rhizome (Krishnaswamy, 1957). Thus in bamboo, the **vigour of** culm growth would be directly related to the good growth of the peripheral rhizomes. The new culms are mostly produced in the rainy season

which is often preceded by production of culm buds. The culm buds produced during winter often emerge out of the soil during the rains, and develop into full-fledged culms within a growing season. The buds formed during summer or warmer months often fail to develop into vigorous culms. Buds formed in older rhizomes seldom develop into full culms. Almost always the buds that are formed on the younger rhizomes develop into full- fledged culms (Krishnaswamy, 1956). It is also pertinent to mention that the culm production is conditioned by the availability of moisture/good rainfall. With good rainfall from season to season, the pattern of culm production from the peripheral rhizome is normal. However, in the years when rainfall is poor, the culms emerge from two or three year old rhizomes and not from the recent or one year old rhizomes. The culms produced from older rhizomes under such circumstances are of poor quality. In other words, the normal culm production relationship in a bamboo clump is conditioned by the availability of moisture. At the same time, the clump can develop culms from older rhizomes as a survival strategy.

This growth response explains the growth variability of culms which one observes in different culms. It also explains the inadequate relationship between clump growth and the culm growth. Often the problem is compounded by planting of two or more seedlings in a clump.

Analysis of the data for Phyllostachys *heteroclada* (Tienren *et al.,* 1985) is shown in Figs. 2-4 and shows linear relationships between culm diameter and yield attributes like culm weight, branch-leaf weight and total'weight.

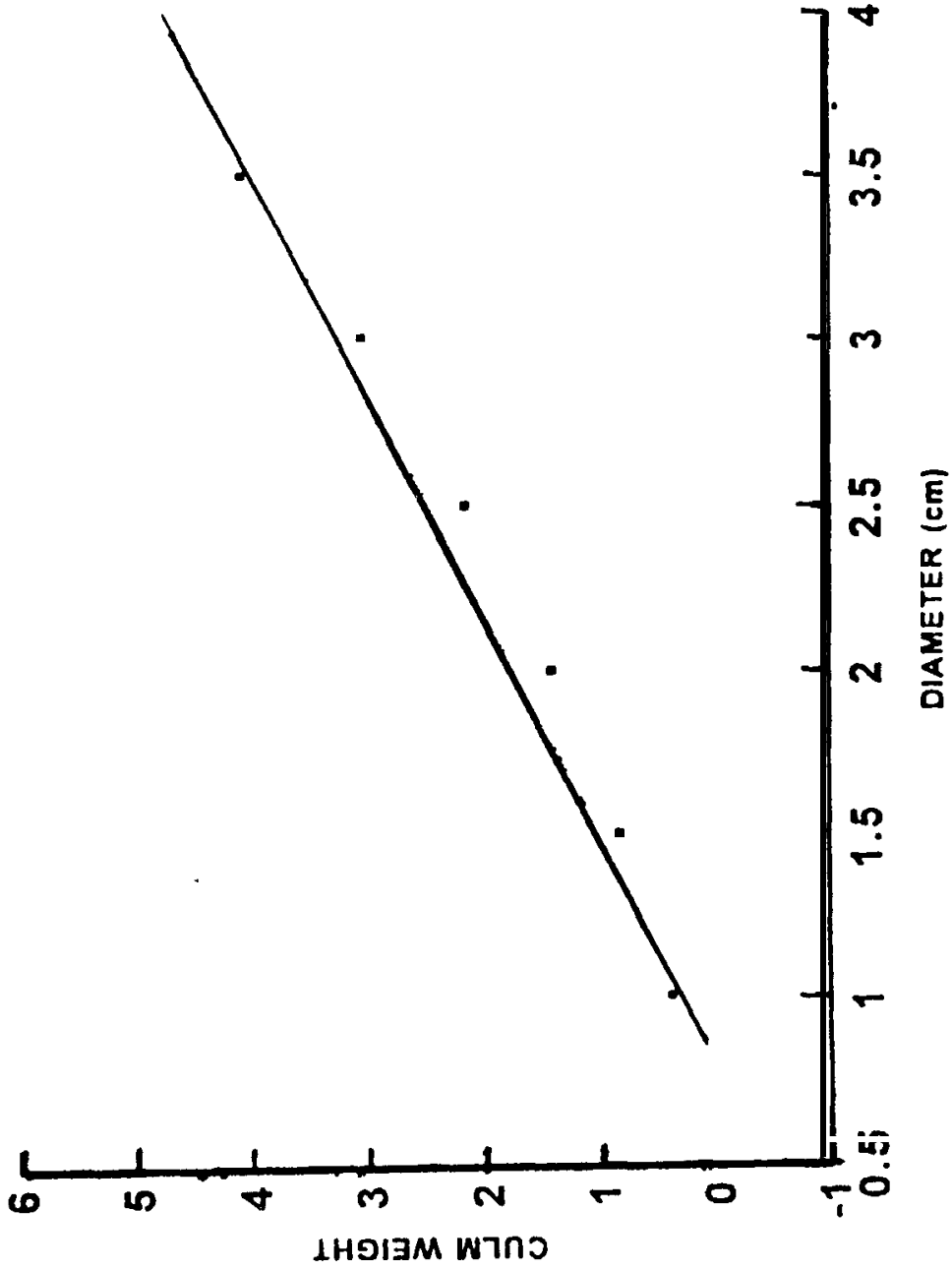


Fig. 2. Relation between culm diameter and culm weight

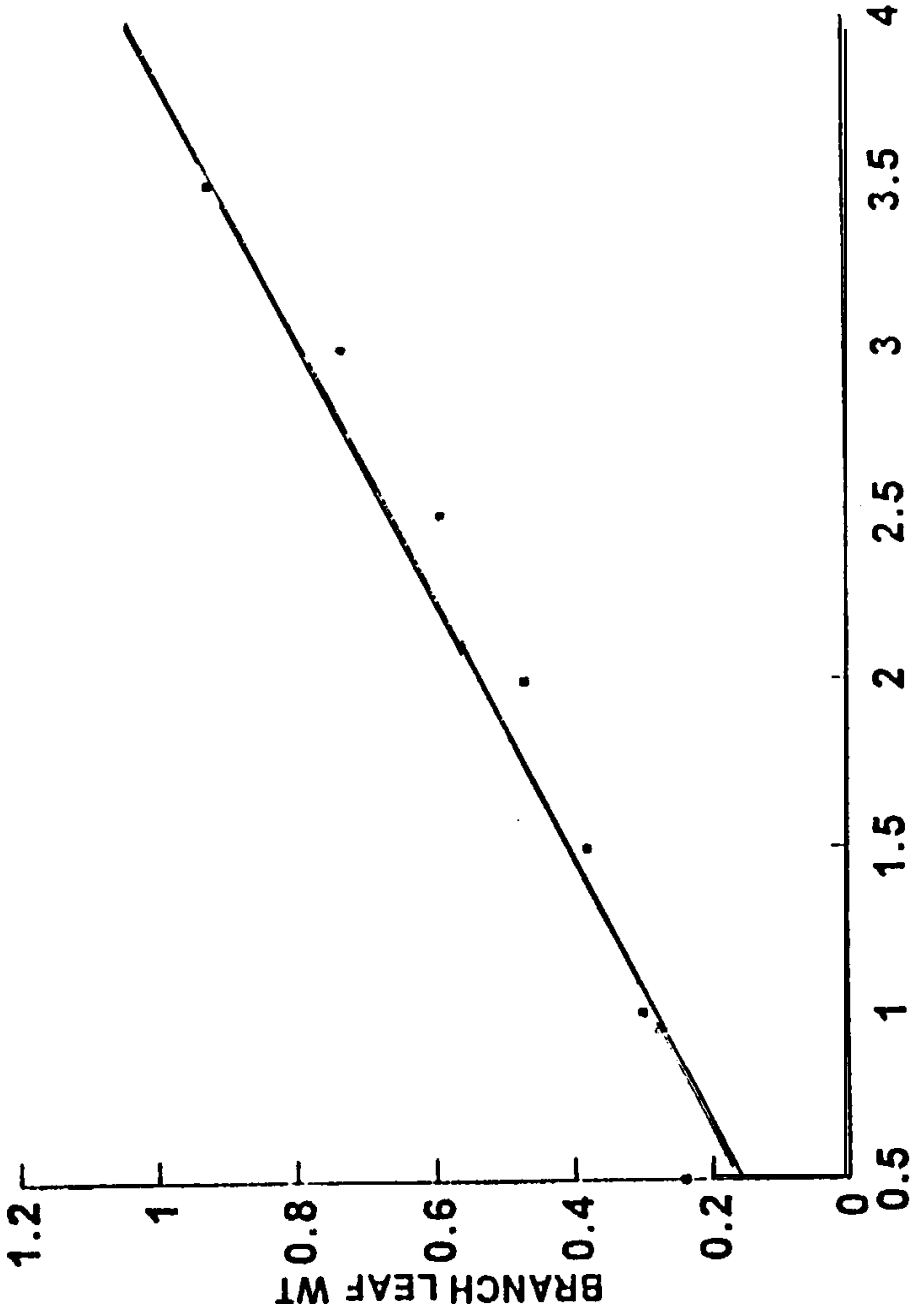


Fig. 3. Relation between culm diameter and branch-leaf weight

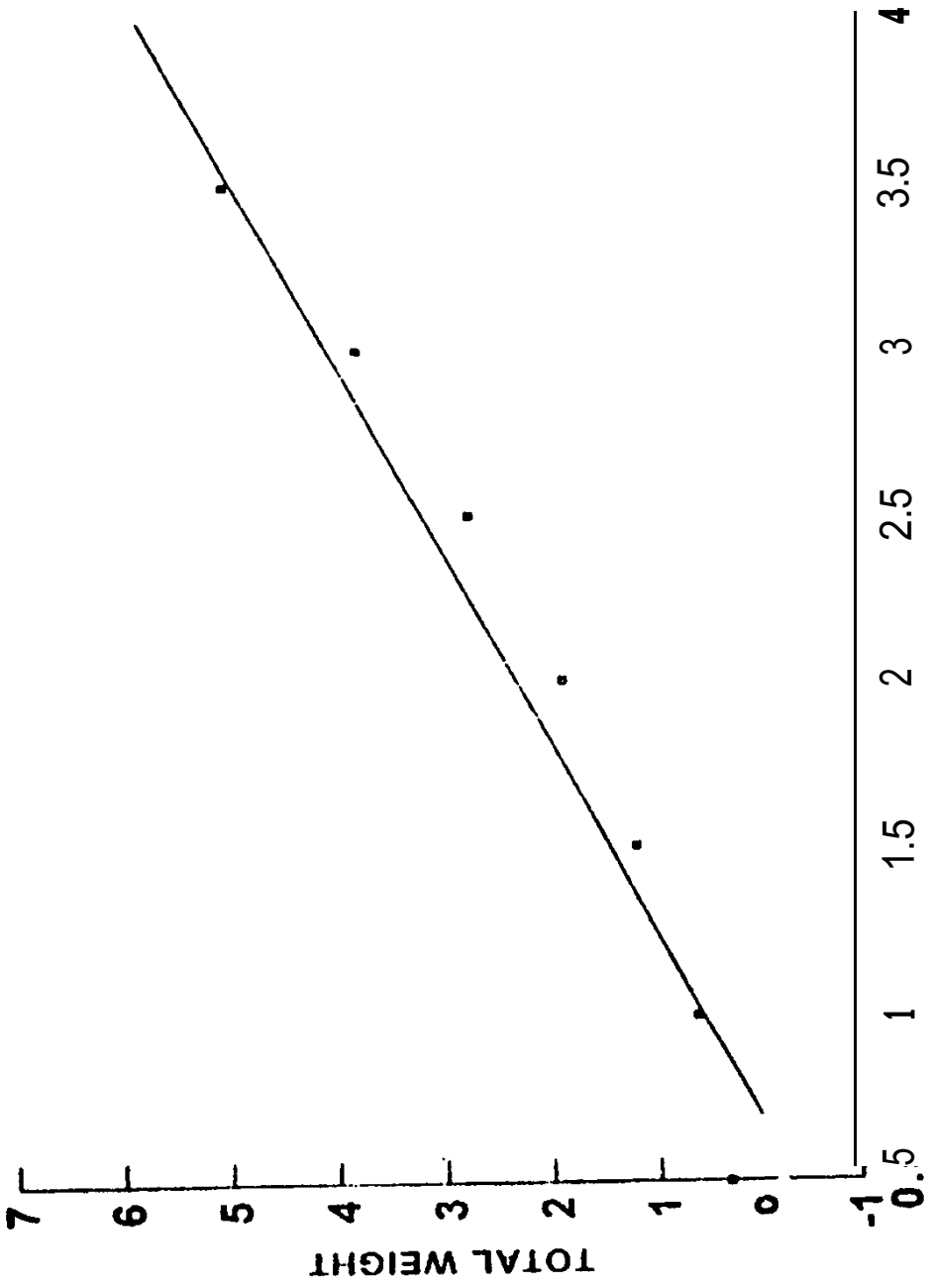


Fig. 4. Relation betweenculm diameter and total weight

Kochhar ef *al.* (1990) investigating the clump characteristics (clump height, clump circumference, culm number, culm girth and culm thickness) in populations of *Bambusa tulda, Dendrocalamus hamiltonii* and *Bambusa paltida,* concluded that culm morphology is least affected by environment in comparison to clump morphology. Thus, culm diameter alone or with height can be used as a selection criterion.

One could also look at coefficients of variations of the culm population during the last 2 or 3 years prior to flowering in clumps anticipated to flower.

In species that do not flower, a study of the relationship between culm diameter, culm height and the culm weight coupled with population analysis can be carried out. This must be followed up with analysis for genetic divergence (Singh, 1993) so that genetically divergent individuals are identified.

Thus, identification of patterns of variation, collection of suitable material followed by mass multiplication would help in strategically enhancing the genetic quality of bamboos.

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APPENDIX 8

A REVIEW ON CROSSING BETWEEN BAMBOO SPECIES IN CHINA

Fu Maoyi

INTRODUCTION

Generally, bamboo planting materials are obtained for asexual propagation and the method is easy to operate. But in this method there is lower genetic variation and sometimes anomalities of bamboos are lower. It is, possible to develop fine hybrids or new varieties according to man's need through selective naturai hybridisation, selection and cultivation of superior clones, sexual crossing, mutation breeding, etc. During the past 30 years, some research workers in China have researched in this area and have obtained significant results. This paper reviews the basic work done on bamboo and discusses the possibilities of strengthening the work further.

BASIC STUDIES

1. Bamboo Flowering: Bamboos are mostly monocarpic perennials usually with one terminal flowering and fruiting. Once it flowers gregariously, all the culms in a clump die. Regeneration is by seeds or by sub-rhizomes of stumps. There are three hypotheses about bamboo flowering.

i. **External causes.** Bamboo flowering is caused by some environmental conditions such as unusual climate, imbalance of nutrient supplement, lack of proper management, diseases and pests, mechanical destruction and

C/N ratio change, etc. This hypothesis offers opportunities to control the growth of bamboo stands by working against the natural physiological growth regime.

ii. Cyclicity. Bamboo flowering is controlled by the inner rhythm of plants or a biological clock, and environmental conditions will have minimum influences. It is an old hypothesis with some validity, which is based on bamboo flowering in clumps distributed in various places over very long distances if they originate from the same parental clump (Table 1). This hypothesis tries to explain the occurrence of a timed flowering cycle even though they are growing under different environmental conditions.

iii. Synthetic view. It is the combination of the above mentioned two hypotheses and considers that once the plants are mature, bamboo will flower but the onset of flowering will be influenced by environmental conditions, to some extent responding by accelerated or delayed flowering. This hypothesis seems to be better than the other two mentioned above, and is accepted more widely.

Wu Guanming (1988), Wang Guihong and others studied hormonal changes in bamboo. It is found that that in various flowering bamboos, there is an accumulation of IAA and gibberel lin Some growth hormones show reduced activity while that of B-inhibitor increases. This indicates that the hormone balance needed for bamboo flowering is regulated by its flowering gene, while the activation of flowering gene is controlled by the time-reckoning mechanism of biological clock.

2. Pollen: Pollen study has helped to understand fruit set in various bamboo species. Zhang Guangchu, and Zhang Wenyan et *al.* have studied pollen of 17 species belonging to 5 genera i.e., *Bambusa*, Dendroc alamus, Phyllost achys, Pleiobl astus and Pseudos asa. It is found that almost all bamboo pollens have high sterility rates. Besides,

Table 1. Periodic interval of flowering of some Phyllos tachys species

Species	Location	Flowering Year	Flowering Cycle	Information Source
P. bambusoides	China	999		
	China	1114	115	
	Japan (from China)	1716-1735	120	a
	Japan	1844-1847	120	
	Japan, USA.	1966-1969	120	
P. henonis		813		
		931	59	
		1247	63	
	Japan (from China)	1666	60	
		1786	60	a
		1848	62	
		1908	60	
P. aurea	Europe & England (from China)	1876		
		1904-1905	28-29	
		1919-1921	14-17	a
		1934-1938	13-19	
P. pubescens	Japan (from China)	1912		
		1979	67	b
l? dulcis	USA (from China)	1910-1911		
		1953-1958	43	c

a. Janzen., D.H. (1976)

b. Watanabe andHamada (1981)

c. Adamson, W.C. (1978)

P. pubescens (26.5-64.1%), D. *latiflorus* (5.4-40.4%), and B. *multiplex cv. Silverstripe* (25.4-43.4%), the germination percentage of pollen of all studied bamboos is low and around being 30%, the lowest being 3.4%. After soaking in water, placing in sunlight or dry environment for for half an hour, bamboo pollen lose their germination ability. Storage at 4°C extends viability for 7 days.

In studying the morphological properties of pollen, its size can be measured under the microscope while surface structure properties can be determined using the electron microscope. The germination percentage is usually tested by the hanging drop method after incubation in 2-10% sugar solution with 5-10 ppm boron acid or sodium borate for half an hour.

3. Chromosome: Chromosomes are carriers of genetic matter. Their study will help to understand relationships between bamboo species and to explain many genetic phenomena. Zhang Guangchu, Huang Shaopu, Fang Wei ef al. have studied chromosomes of 150 bamboo species, varieties and forms, belonging to 29 genera. Root tips were used for counting chromosomes.

Results have shown that generally, the basic number of bamboo is x=12 but sometimes x=9 *(D. latiflorus* or x=8 *(B. pervariabilis, B. textilis).* Species which have similar basic even numbers have high affinity, are easy to cross and their progeny develop well. The chromosome numbers of various bamboo species are usually 48,64 and 72 (rarely 36 and 54), and the maximum 96 while 68 belongs to a bamboo hybrid. The pattern of 72 - 64 - 48 shows the course of bamboo evolution was influenced by climate changes in the tropics, subtropics and warm temperature conditions, respectively.

CROSS-BREEDING

Crossing: Cross-breeding is an important method to obtain new hybrids for producing high quality products, higher yield and economic benefits. Cross-breeding technique includes selection of parents, hand pollination, hybrid production, and progeny selection.

Table 2. Cross-breeding between different species of bamboo

Female Parent	Dendro-calamus *latifZorus*	*Sinocalamus mitior*	*Bambuk texfilis*	*Bambusa peruaria-*bilis	*Bambusa sinospinosa*	*Bambusa chungii*	*Phyllo-stach ys edulis*
Male parent D. latiflorus		+	*	*	x		x
S. minor							
B. textilis	x			x			x
B. pervariabilis	x		x				x
8. sinospinosa	x		x				
B. chungii							
p. edulis			x	x	x	x	
D. latiflorus + *B. texfilis*				*			
D. la tiforus + *I? edulis*				x			
D. latiforus + *B. pervariabilis*			x				
p.. edulis *is.. minor*					x		

Note: * means excellent crossbreeding combination

a. Selection of parent - Parent plants should have qualities desired in the breeding programme; there should be high affinity between parents and the flowering stages should coincide.

b. Preparation for pollination - Select some strong culms from flowering clumps and transplant them into big pots. When transplanting, the culms should be planted slantingly or topped so that it is easy to pollinate. After planting, apply P,K fertilizer for accelerating flower bud development. The following details are important.

1. Select flowers for pollination through thinning and by keeping flower buds at the middle part of the branch. This can reduce nutrient consumption and raise fruiting percentages.

2. Select a suitable period and time for pollination. The stage of full bloom or early bloom is in the early morning. Thus 5-7 a.m. is ideal for pollination. Lower temperature and higher humidity will give a higher percentage of fruit set.

3. Pollinate soon after collecting pollen. Before flowers close shading should be provided to avoid grain drop. Later they should be exposed to sun for raising the fruiting percentages.

4. Spray 0.1% D.D.V. 2 or 3 times for pest control.

5) Cover with seed bags. After 7-10 days of pollination, observe and mark developing seeds 2-3 days before maturing and cover with seed bags to prevent seed fall and loss.

C. Hybrid propagation

(i) Sowing of seeds: Seed should be sown in a nutrient bag. After 5-10 days, the seeds germinate. When the seedling is l0-15 cm high, it should be transplanted into a flower pot, and when it reaches 1 meter height, the seedling can be planted in the field.

(ii) Asexual propagation: The hybrid seedlings can be multiplied through tillering, cutting and/or tissue culture method for obtaining more propagules.

D. Observation, early test, selection of hybrid progeny In order to decide if the progeny from cross-pollination is a real hybrid, some selection has to be done towards meeting the breeding objective. Early progeny tests and selections are necessary Usually, l-2 years after planting, growth and anatomical studies are done; 3 or 4 years later, the biological properties are examined when the growth is stable. Physical properties of culms should be tested after 6-7 years. Chromosome studies are also necessary for obtaining cytological evidence.

SUCCESSFUL EXAMPLES OF HYBRIDS IN CHINA

Twenty one combinations among 7 species of 4 genera have been tested by Zhang Ghangchu et al and 4 hybrids have been obtained (Table 2), out of which a series of clones have been cultivated and 4 best ones selected, i.e. No. *1.* of *B. pervuriabilis X (D. latiflorus. + B. textilis), No. 25,34,36* of *B. pervariabilis X D.* latiflorus. A. comparison among hybrids and parents are listed in Tables 3,4, 5 where A25, A34, A36 are equal to No. 25,34,36 respectively, B1 is equal to No. 1 and El, E3 are the parents, *B. pervariabilis* and *D.* latiflorus, respectively

From the data presented in the three tables and other details studied, it is found that bamboo hybrids show the following desirable.properties.

1. Fast growth and fineculm form

The height growth of all hybrids is 3-4 times greater than that of the parents. In particular, Bl has upper branching and thicker culm wall, which are useful for construction (Table 3).

Table 3. A comparison on height growth betweehybrids and parents

No.	Culm height (m)	Diameter (cm)	Number of current culms	Branching node	Culm form	Culm wall
A25	**12.3**	**6.8**	**5**	**1**	straighter	-
A34	**9.4**	**5.8**	**6**	**1**	straighter	
A36	**7.2**	**4.9**	**18**	**3**	straight	thinner
Bl	**10.1**	**5.2**	**8**	**5-7**	straighter	thicker
El	**2.3**	**1.9**	1	1	straight	big knot
E3	**3.6**	**4.1**	**3**	**3-4**	slanting	

2. High content of long fibre

Fibre length in the hybrids increased over that of the parents and cell types were better than that of the parents. Among them, A25 has the longest fibre and the thinnest parenchyma cells, which is the best raw material for paper-making (Tables 4,5).

Table 4. Tissue percentage

No.	Fibre length	Vessel & Protoxylem	Sieve Tube & Parenchyma
A25	50.8	6.5	42.5
El	47.1	5.9	47.0
B1	44.2	5.9	49.9
A34	44.3	4.2	51.3
A36	42.6	4.8	52.5
E3	35.6	0.9	57.5

Table 5. Fibre length, width and their ratio

No.	Length (u)	Width (u)	Length:Width
A25	2212	17	139.66
A36	2194	13	139.35
A34	1814	16	119.50
Bl	1739	14	124.36
El	1493	16	95.92
E3	1613	17	108.87

3. **Longer life of culm utilization**

Culms of hybrids and parents were exposed in the open and their disintegration (cracking level) was El > A25 > Bl, i.e. culms of B1 had only a little crack and could be used much longer.

4. **Higher cold resistance**

When the temperature was -5" C, leaves and culms of E3 were partly damaged while that of A25 and A36 showed lower and Bl had almost no damage.

SUGGESTIONS

As bamboo processing industries increase in number in the world, people are paying attention not only to the management of bamboo stands but also to the need for better varieties to meet their requirements. The area of bamboo genetic breeding is still the weakest one among all bamboo studies. Therefore, more studies and improvements are needed.

1. To establish a data base on bamboo genetic improvement, recording all investigations and review all past and present studies.

2. To exchange information, researchers and genetic resources and to organize technical training with support from INBAR, IPGRI, FORTIP and other agencies in this area.

4. Through cooperative programmes/projects, and surveys in bamboo growing countries, the collection and conservation areas for genetic resources need to be established so as to increase the production of seeds.

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APPENDIX 9

SELECTION CRITERIA AND POPULATION ENHANCEMENT OF PRIORITY BAMBOOS

Ratan La1 Banik

INTRODUCTION

Human beings have long played an important role in the introduction and distribution of bamboos in newer areas. In Asia, where bamboos are closely interwoven with the day-to-day life of the people, the widespread distribution of some species doubtless parallels past human migration. Holttum (1958) in his discussion on Malayan bamboos, speaks of village (or cultivated) and native (or forest) bamboos. Species of Gigantochloa found in Java and some planted in Malaysia probably were transplanted by man in the past from Myanmar where the genus is said to be native (Soderstrom and Calderon, 1979). Bamboos may also have been carried along several ancient maritime spice routes between China, Indonesia, Sri Lanka and India. Man has certainly spread propagules of Bambusa vulgaris throughout the tropics; its distribution is general that one cannot establish with certainty where it originated (McClure, 1966; Soderstrom and Calderon, 1979).

Bamboos, in habit, vary from strictly erect, erect with pendulous tips or climbing, through broadly arched to clambering. The differences among the bamboo species are well-documented and their uses are also known to the growers and users. For construction purpose, the big, rigid bamboos of the genera Bambusa, *Dendrocalamus, Gigantochloa* and *Oxytenanthera* are more important than those with weak and slender stems of *Schizostachyum,*

Dinochloa, Cephalostachyum, Ochlandra and others. Arundinaria species are weak-stemmed and almost look like reed with limited biomass. Some of these may be economically unprofitable to cultivate in bamboo farms but may be useful in soil binding or to cover waste-lands. Melocannabacciferahas both economic and ecologic importance. The species is a major raw material for housing and in pulp and paper industries of Bangladesh. It has a vigorous underground rhizome net system which binds the soil and thus controls and reduce the soil erosion (Banik, 1989). The size of the rhizome net of a culm may vary from 100 m^2 to 1000 m^2.

Selection and introduction of a species always depends on its use and utility. About 90 years ago, *Dendrocalamus asper* was brought from China and introduced to the farmers in Prachinburi province of Thailand. Since then this bamboo species has been cultivated commercially for the production of edible shoots and farmers of this province have economically benefitted by bamboo shoot farms.

Most staple crop plants have long histories of selection and tend now to have a restricted genetic base. On the other hand, forest crops, especially bamboo, have only recently or never been domesticated, selected or bred. Out of the 1250 species of bamboos, not more than 5% are fully exploited and about 10% are semi-domesticated. As a result, about 90% of the species are in a wild to semi-wild state and, therefore, possess enormous potential for development. Each species is categorised into geographic sources (provenances) and individuals. Thus, there is scope for identification of bamboos species /provenances and plus clump selection for improvement of productivity.

SELECTION CRITERIA AND SPECIES SELECTION FOR SPECIFIC END USES

The characters to be considered during selection of bamboo species for specific end uses include those botanical characters typifying species and also qualitative characters. Since botanical characters

are species-specific, those for practical selection will mostly be the qualitative ones.

i) For structural and construction use

Criteria:

- Erect, straight and stout culm.
- Tall and big culm (diameter 8-25 cm).
- Thick culm wall (more than 1.0 cm) with solid internode.
- Comparatively short internodes with siliceous cover.
- Durability to powderpost beetles and fungal attack.
- Ease of preservative treatment. The large diameter metaxylem vessels (above 95.0 um) in bamboo are the main channel for penetration of solution in the vertical direction, and the size of vessels is most important, since it affects vertical permeability.
- High density of culm wood.
- Low moisture content and shrinkage value.
- Higher number of vascular bundles per sq. mm.

Some species fitting the criteria:

Bambusa bambos, B. balcooa, B. blumeana, B. tulda, B. vulgaris, Dendrocalamusasper, D. giganteus, D. membranaceus, D. strictus, Gigantochloaapus, G. levis, Guadua angustifolia, Phyllostachys pubescens, Schizostachyum brachycladum, S. zollingeri.

ii) For thatching, walling roofing. handicrafts and novelty items

Criteria :

Erect to clambering.

Small to medium size culm diameter (3-10 cm), smooth, less branching (and not throughout).

Thin culm wall (usually less than 1.0 cm)

Comparatively long internodes (usually 0.3 to more than 1.0 m) with shiny skins.

Durability to powderpost beetles and fungal attack.

Highest value of modulus of elasticity (more than 150000 kg/cm^2).

Good splitting ability for fine strips and veneer.

Some species fitting the criteria :

Bambusa bambos, B. blumeana, B. tulda, B. polymorpha, B. *vulgaris, Cephalostachyum pergracile, Dendrocalamus asper, D. longispathus, Gigantochloa verticillata, G. utter, Guadua angustifolia, Melocanna baccifera, Neohouzeaua dullooa, Ochlandra stridula, Phyllostachys pubescens, Schizostachyum brachycladum, S. lima, S. lumampao, S. zollingeri, Thyrsostachys siamensis.*

iii) For pulp,paper, and rayon

Criteria:

Should have vigorous growth and maximum biomass production.

Easy to chip.

Less in silica, lignin and extractive contents and higher in cellulose.

Long fiber (usually more than 2.0 mm), higher ratio of length to width and high ratio of fiber tissue.

Some species fitting the criteria:

Bambusa bambos, B. tulda, B. vulgaris, Dendrocalamus hamiltonii, D. longispathus, D. strictus, Gigantochloa aspera, Melocanna baccifera, Ochlandra travancotica.

iv) For edible shoots

Criteria:

Shoots should be edible, fast growing.

More open nature of clump for easy harvesting.

Less branching and non-thorny clump is preferred.

Wider range of culm emergence period.

No or low natural mortality of shoots at juvenile stage of emergence.

Resistance to pests and diseases.

Higher number of shoots produced per clump.

Low amount of covering sheaths in relation to total biomass of shoot, less hairs and bristles on the sheaths, easy to remove sheaths.

Succulent and palatable, no smell, not astringent, not bitter.

Higher nutrition value.

Easy to boil and cook.

Good storage and canning capability.

Some special fitting the criteria:

Bambusa blumeana, B. polymorpha, Dendrocalamus asper, D. latiflorus Gigantochloa aspera, G. levis, Melocanna baccifera, Phyllostachys edulis, P. pubescens, Schizostachyum brachycladum, Thyrsostachys siamensis.

STEPS IN SELECTION METHODOLOGY

Selection of desired species/provenance/genotypes involves exploration, evaluation and trials. Collection of propagules from exotic sources sometimes become difficult. Since seeds are not regularly available, other types of propagules, such as offsets, branch cuttings and culm cuttings have to be collected. Quarantine procedures for transportation of such materials from one country to another are always lengthy and it usually takes more than 5-10 days. During this period, in most cases, propagules become dry and ultimately die. To avoid such delays, INBAR, IPGRI and FORTIP (FAO) officials could negotiate with both donor and recipient countries for smooth and quick transportation of propagules.

I. species introduction and Provenance trials: The difference among most of the traditionally cultivated bamboo species are well documented and their uses are also known to the growers and users. However, for the introduction of a species one must identify the species of desired end-use. Species and their varieties should be selected as per need and habitat suitability.

Most species with their large natural ranges are likely to be genetically variable. No one seed lot or vegetative propagule can be considered as representative of the species. Genetic variability within species may be present in the following catagories:

Geographic (or provenance) variants

Individual or superior plants within stands.

The priority species agreed by INBAR are to be found in Williams and Rao (1994). This publication also lists the major traditional uses of the species. Countries are urged to initiate suitable species trials based on these priorities.

Introducing some species from other parts of the world, as done previously with *Phyllostachys* sp. of temperate China and Japan to South Asia, would be worthwhile. *Guadua angustifolia* native to north-eastern South America is naturally durable and has promise in Asia except in Nepal and Bhutan as it cannot tolerate cold.

After identification of species for specific end-uses, one must test their performance through multi-location field trials. A randomized complete block design with 3 to 5 replicates may be used for laying out field experiments. Each plot may contain 25 or 49 propagules. Each species or provenance is represented only once in each block and the block is replicated 3 to 5 times depending on the availability of propagules. Spacing is 5 m between the propagules. Pit size may be 45 cm x 45 cm x 45 cm. Fertilizer (NPK 2:1:1) may be applied mixed with cowdung 15 days before planting. In the beginning small plots may be set up. Survival and growth data (number of culms emerged, culm length and diameter, culm girth) have to be collected annually in the months of December to January from each of the clumps, By analyzing the data obtained after the second or third, year of trial, it is normally possible to select the best species for further provenance trials. Longer field trials-may be needed to test for disease resistance.

2. Individual 'clump' selectoon (plus clump): In selecting superior phenotypes, the following desirable characters may be considered.

1) The 'clump 'should be healthy and not infected by a disease.

2) Branching should be mostly at the top or not at the bottom.

3) Clump should be somewhat open (not congested) to facilitating easy harvesting.

4) Culm emergence should be spread over a wide growing period.

5) High number of culms per clump.

6) No or little mortality at juvenile stage of culm emergence.

7) Succulent and palatable shoot.

8) Comparatively capable of growing in waterlogged or flooded areas.

9) Comparatively capable of growing in drier areas.

10) Easy to propagate vegetatively.

11) No or only partial death after flowering.

12) Simultaneous sexual (seeding) and vegetative growth.

13) Higher capacity of viable seed production.

A clump may not have all the above characters. Depending on the end-use, other characters may also be considered in selection.

3. Juvenile (seedling) selection: Since bamboos are reported to be highly cross-pollinated species (Banik, 1986), it gives enormous opportunity for selection of superior seedlings having desired combination of characteristics after each gregarious/sporadic flowering (Venkatesh, 1984). Natural seedling populations of bamboos with genotypic diversity may afford an opportunity for

selecting, as clones, individual plants which may be superior (McClure, 1966). Kondas et al. (1973) and Banik (1980) reported seedling segregation of characters into grassy, grassy erect and very erect types in *B.* bambos and *B.* glaucescens. The erect and very erect types have shown fast growth rates and more vigour with rapid culm production. The grassy dwarf type may be selected for ornamental purposes. Therefore, in bamboos, early recognition of progenies or individuals with a high genetic yield potential would be of great advantage. The following procedures were taken for selecting clones of *Bambusa* tulda and *B. polymorpha* in Bangladesh. The same procedure may be followed in other countries for seedling selection in other species.

1. Collect seeds from a population of flowering clumps of a desired specie (for seedling selection, avoid seed collection when only one or two clumps flower).

2. Raise a minimum of 20,000 seedlings using the same potting mixture containing similar containers under partial shade for 3-4 months and then under direct sunlight.

3. Provide all the seedlings similar nursery treatments.

4. At three months start taking growth data on randomly selected 200 average seedlings out of the total. The observations are to be taken on overall health, length, diameter at the collar zone of the shoots and number of leaves. Measure the leaf area of three leaves taken from base, mid-regions and tip of the crown; and other interesting visible characters, if any. Mark these 200 seedlings as Al, A2, .A3 . . . A200. They represent an average of the total population. Determine the average value of all the observations with standard error of measurement.

5. Repeat the data recording every quarter up to one year on the same 200 seedlings.

6. When the whole population is nine months old, observe carefully all the individuals in the population for their overall healthy appearance. Identify healthy seedlings having many tall shoots.

7. For these identified seedlings from the population, record similar data as with the 200 randomly selected seedlings.

8. The identified healthy seedlings are placed separately in the nursery by the side of the total seedling population.

9. Obtain data on growth again from the identified vigorously growing seedlings and also from the randomly selected seedlings.

10. Assess the growth data and select seedlings from the identified seedlings which scored highest values in comparison to the randomly selected 200 average seedlings.

11. Suppose 10 vigorous healthy seedlings are selected. Mark then serially as H1 H2..... Hl0.

12. Multiply each of the healthy seedling through macro-proliferation techniques.

13. Try to obtain at least five multiplied individuals from each of these 10 selected seedlings. As each of these 5 individuals are the clones of the same seedling, they should be marked H1/1, H1/2, H1/3 and so on. This indicates that all the 5 individuals are the clones of healthy seedling number one (H1)

14. Multiply similarly any 10 seedlings from the randomly selected 200 average seedlings and mark them accordingly.

15. At 24 months, 5 plants of each healthy (H) and average (A) growing seedlings are planted in a randomized design in the field, side by side.

16. Assess the growth of each of the individuals up to 5 years.

17. Select those "H" clones which show better growth over "A" clones after 5 years.

(4) Clonal trial and maintenance (Clone Bank): After selecting the suitable species, outstanding provenances, and phenotypically superior individuals, they are to be multiplied asexually. The propagules thus developed from one individual source are the members of one clone. Accordingly, a number of clones may be obtain from one species/provenance and by centralizing them, a clone bank can be developed. The clones are to be evaluated in multi-locational field trials.

(5) Pilot plantationa:A pilot plantation in a few hundred hectares may be established as an intermediate step before the commencement of a large scale commercial plantation programme. In general, such plantations may demonstrate the viability of the selected clone(s) to potential investors and farmers. These plantations will also act as production gardens or clonal multiplication areas.Within 5 years of establishment, these gardens can start supplying quality planting stock for commercial plantation programmes. Risks from a narrow genetic base of clonal plantations can be minimized by including several genetically unrelated clones in the commercial plantation programmes.

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JOINT RATTAN RESEARCH BETWEEN INNOPRISE CORPORATION SDN BHD (ICSB) AND CIRAD-for& IN SABAH,MALAYSIA

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and
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INTRODUCTION

In 1989, a Memorandum of Understanding (MOU) for collaboration in research was signed between Innoprise Corporation Sdn Bhd (ICSB), the holding company of Sabah Foundation, and CIRAD-for& (formerly CTFT), the Forestry Department of the French Centre for International Cooperation in Development-Oriented Agricultural Research for tropical and subtropical zones. ICSB is currently involved in the management, utilization and development of a forest concession of 972,804 ha in the State of Sabah, Malaysia, and in the development of commercial forest and agriculture plantations. CIRAD-foret is a French State-owned industrial and commercial body which has been involved in tropical forestry and wood technology development projects and consultancy for over thirty years.

Under the principal MOU, two Supplementary Memoranda were sequentially signed for two separate projects, namely Plant Improvement and Seed Production (PISP) Project in 1989 and Plant Biotechnology Laboratory Project (PBL) in 1991.

THE PLANT IMPROVEMENT AND SEED PRODUCTION PROJECT

The PISP project was started in June 1989 with the following short-term objectives:

- To develop a plant-improvement strategy for rattans, high-value timber species and industrial timber species.
- To establish a seed/planting material production programme for rattans, high-value timber species and industrial timber species to meet the seed and other planting material requirements of ICSB.
- To develop the technical capability in plant improvement and seed/other planting material production of ICSB.

Since then, the rattan research was joined with the commercial rattan plantation project, and is currently being implemented in Luasong Forestry Centre (LFC), located about 100 km from Tawau.

There are two major aspects of rattan research under PISP both mainly focused on upgrading the quality of rattan plantation in LFC. These are described below.

1. Conservation and Genetic Improvement

In rattan generally, there is still little or no research on genetic improvement. In any breeding programme, a broad base population is essential in order to be able to capture as much genetic gain as possible for future generations. When the PISP project was first formulated, there was no collection of rattan either *in situ* or ex *sifu* which could be used as a base population in the planned genetic improvement programme. Hence, the main task of PISP was to initiate broad genetic collections of rattan particularly for the main

commercial species like *Calamus manan, C. subinermis, C. caesius, C. trachycoleus* and *C. merrillii*.

1.1 Seed collecting

Seed collecting has been conducted to gather materials from th wild and also from established plantations around Malaysia. During each seed collection operation, mature fruits were collected and separated according to mother plants. These collections were purely progeny collections (also known as Individual Seedlots of particular species). Normally about 200 fruits were collected from each mother plant, and if possible samples were taken from about 25 to 30 mother plants per location (in fact it is very difficult to find 25 to 30 plants with fruit in a given area, especially from wild populations!). The collected progenies were raised and detailed records regarding the collecting time, location, individual plant measurement and any relevant information are being maintained in LFC. The list of collected material so far is presented in Table 1. There were some occasions where plenty of fruits came to LFC's Commercial Nursery from ICSB's fruit suppliers. These fruits were actually for the commercial planting operation, but if they came from known provenances, samples were taken randomly and maintained as a bulk seedlot for the PISP project.

Table 1. List of collected material for PISP project

SPECIES	TYPE OF SAMPLES		ORIGIN
	INDIVIDUAL	BULK	
C. manan	**166**	**6**	West Malaysia Kalimantan (see Fig. 1)
C. subinermis	**182**	**13**	Sabah (see Fig. 1)
C. caesius	**146**	**13**	Sabah , Sarawak
C. trachycoleus	**31**	**NIL**	Kalimantan
C. opti mus	**2**	**NIL**	Sarawak
C. ornatus	**23**	**NIL**	Sabah

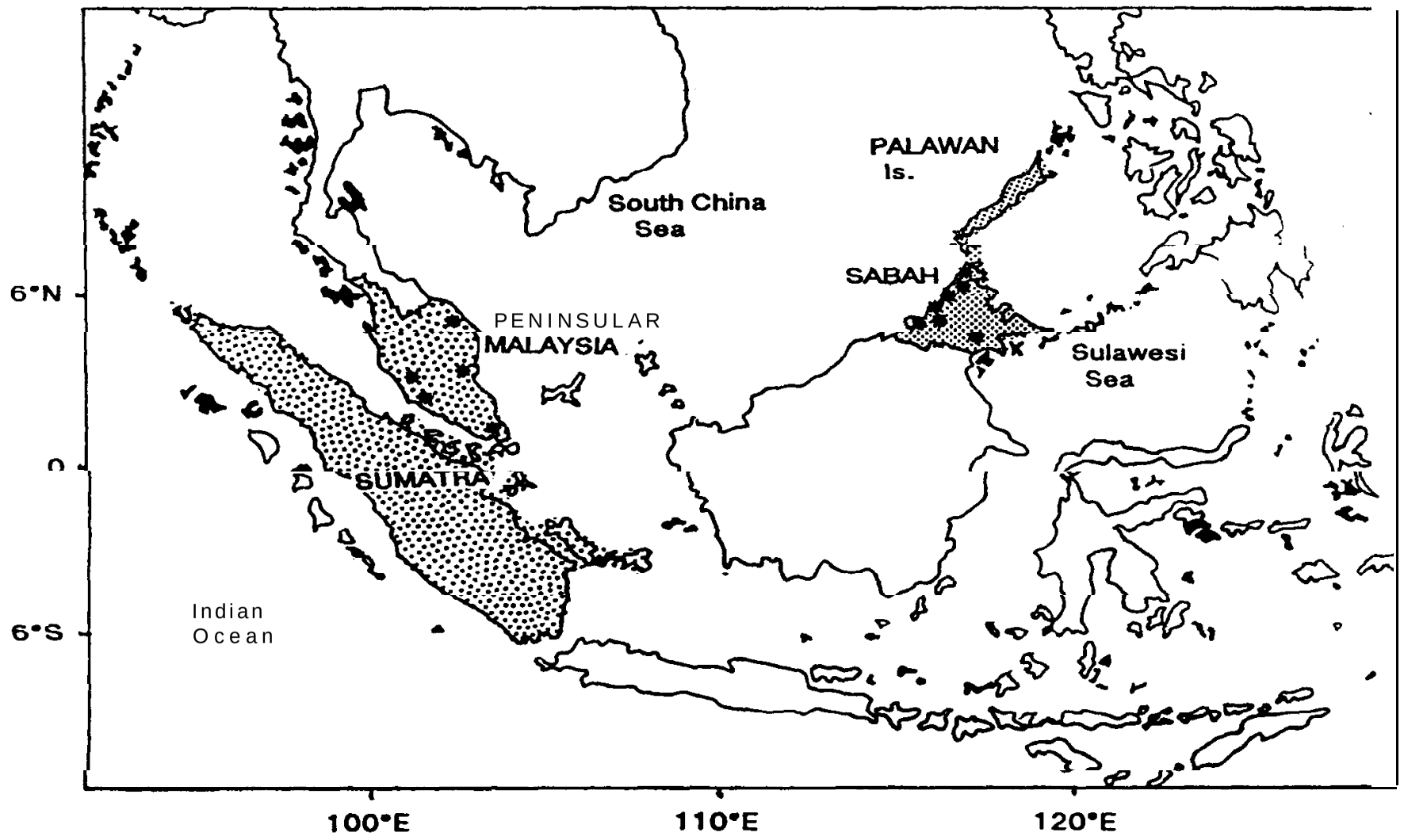

Figure 1. The range of *Calamus manan* and *Calamus subinermis* and the location of sampled populations *

1.2 Field Planting and Assessment

Rattan fruits cannot maintain their viability if stored for long periods, thus any collected fruit has to be sowed immediately. This problem restricts the possibility of having even-aged plants for high number of progenies, which is crucial for any field evaluation trials such as progeny or provenance trials. Other related problems which equally contribute to difficulty of having even-age plants are lack of manpower to conduct seed collecting simultaneously in all areas and also differences in fruiting seasons for a particular species. Due to this, comprehensive evaluation trials involving all the collected materials cannot be done at one time.

For the PISP project, all progenies collected at approximately the same time were planted in statistically well-designed plots. These research plots (known as Seed Stands or Trial Plots) will be used as base populations and breeding populations, after some manipulation, for the rattan genetic improvement programme in LFC. The plots also serve as genebanks for conservation of particular species. Yearly growth assessments were conducted in all the plots' and pre-detection of superior plants will be done as the beginning of the selection activity. The list of seed stands/trial plots currently available in LFC are presented in Annexes A-C.

1.3 Phenology and Reproductive Biology Studies

A good understanding of the biology of sexual reproduction of rattans is necessary for the success of the breeding programme. Phenology and ontogeny studies were started in 1991 in well-established plantations, such as in SAFODA's (Sabah Forestry Development Authority) Sg. Pin Plantation near Batu Puteh, Kinabatangan. Recently, a programme to study the floral biology of rattans and the possibility of controlled pollination was initiated in LFC.

1.4 Wild Rattan Collection

To complement the conservation activity, a Wild Rattan Collection was established in LFC. In the Collection area, different species were planted: up to now twenty species are available. The plot will also be used as a study field for rattan identification courses by ICSB or other interested parties.

2. Silviculture

Due to lack of manpower, this important activity has lagged somewhat in the PISP project. Nevertheless, some studies were conducted to study growth patterns and to determine fertilizer regimes in the nursery and in the field. Besides that, a rattan yield study was started in the established plantation in LFC. For the yield study, 30-plant plots were demarcated inside the LFC plantation area and yearly assessment are being conducted. There are 19 plots for C. caesius, 21 plots for C. trachycoleus and 13 plots for C. *subinermis.*

PLANT BIOTECHNOLOGY LABORATORY (PBL)

The main objectives of this research and development-oriented unit are to support tree and rattan improvement and planting programmes. Special attention has, therefore, to be devoted to the most rational ways to use biotechnologies to achieve this goal, being conscious of the respective limits of conventional methods of tree improvement and vegetative propagation on the one hand and on the other the costs of tissue culture for plant propagation.

Since late 1992, two main fields of activities have been developed within the unit to fulfil the above mentioned objectives, namely:

* Tissue culture; and
* Genetic marker investigations,

1. Tissue Culture

Rattan micropropagation, which can be carried out either from seeds or young seedlings, or from mature selected individuals, appears very helpful as regards the following:

- Germplasm or genepool conservation of the most important/endangered rattan species or populations, that can be subsequently used for breeding programmes using long-term preservation methods such as cryopreservation, or short term preservation methods like seed dehydration and storage at low temperature. Due to possibilities to maintain contamination-free vegetative organs alive and even growing in a very space-restricted environment, tissue culture is very useful to transfer vegetative plant material worldwide, with limited quarantine problems.

- Mass propagation of precious genotypes - for instance within-species genetically superior genotypes resulting from special crosses, or quantitatively limited from a highly desirable species or variety - either as a mixture ("Bulk propagation"), or as clones. Furthermore, tissue culture must be rightly considered as the only means to clone single stem species like the highly valuable C. manan.

- In the same way as for other species, tissue culture propagated rattans can be produced continuously all through the year, regardless of the in situ fruiting period. In addition, and especially for cloning programmes, it can be very beneficial to have access to some aspects of the genetics of rattans such as the evaluation of site-genotype interaction and the understanding of clonal behaviour.

Owing to the strategic importance of the rattans for ICSB, the species selected by the company to be micropropagated so far are large diameter canes, namely C. manan (Rotan manau), C. *subinermis* (Rotan batu), and C. *merrillii* (Rotan Palasan). Micropropagation through axillary budding will be preferred when the purpose in view is to clone proven superior genotypes. Micropropagation through adventitious budding or somatic embryogenesis can be considered in the case of very juvenile genotypes, unselected individually, and eventually extended for single stem palm species in which leaf, root or maternal inflorescence tissues have been successfully utilized to mass propagate asexually mature selected plants. So far this methodology appears as the sole means to propagate vegetatively single stem species like C. *manan,* taking into account that such species have only one shoot meristem that is terminal, and excision will result in the death of the mother plant.

Shoot proliferation method from juvenile materials

For the three species, a shoot proliferation method has been used by introducing *in vitro* germinated excised embryos [as proposed by Aziah and Manokaran (1985) and Umali-Garcia (1985)] onto Murashige and Skoog basal medium (1962) supplemented with BAP. Pilot systems for mass production through tissue culture of C. *manan* and C. *subinermis* plantlets have been successfully established involving the handling of several thousands of shoots and leading to the transfer of several hundreds of rooted shoots for acclimatization to outdoor conditions.

As the period for germination could be long, for C. *subinermis* particularly, and the availability of seeds sporadic, the shoot proliferation method has been applied to nursery seedlings or wildlings with a proper disinfection method.

Organogenic callus formation

It seems highly risky and not appropriate for the future of the selected plant material to restrict our tissue culture procedures to the shoot tip only.

With a view to cloning mature selected plants from the wild without damage, we started some experiments on organogenic callus induction involving vegetative parts of the plant other than the shoot apex or the apical portion including the unique meristem. These were leaf portions and root tips from nursery seedlings, and root portions collected from mature rattans in the field.

The results obtained so far indicated that C. *merrillii* explants display greater potential for shoot proliferation and callus induction than C. manan and C. *subinermis* submitted to the same experimental conditions.

2 . Genetic Marker Investigations

Access to genetic markers are beneficial for plant improvement and propagation of superior quality planting material, and permit investigations in the following fields:

- Taxonomy, with special concern for:

  identification of clones, species, hybrids, seed lots; authentication of controlled crosses; and study of species relationship in complex taxa.

- Population structure, including:

  geographical variations; provenance variations; and introgression.

- Reproductive characteristics, involving

  the study of mating systems and outcrossing behaviour in natural populations and in seed orchards.

Since January 1995, we have been working within the framework of a EEC funded project (STD3) focused on Conservation, Genetic Improvement and Silviculture of Rattans covering the whole of Malaysia. This project links The Royal Botanic Gardens, Kew (UK), Forest Research Institute Malaysia, and the Forest Research Center of Sandakan (Sabah). Within this project, and as a prerequisite for development of conservation and genetic improvement strategies, basic understanding of patterns of genetic diversity within and among populations and of geneflow should be provided by genetic markers.

In our context, genetic markers have been deliberately restricted to isozymes, this being the easiest way to obtain results at the lowest costs. The assessment of genetic diversity will be done on the commercially most important and endangered species, C. manan and- *C. subinermis* .

Genetic diversity of C. manan and C. subinermis

The survey on genetic diversity involved almost the whole collections of C. *manan* and C. *subinermis,* which were established in the framework of provenance and progeny trials under PISF! One plant per progeny was sampled. Locations of the sampled populations are mapped in Figure 1.

Leaf tissue was used for isozyme analysis in preference to seed because it is abundantly available from any individual, irrespective of sex and time. Young leaves from individual rattan plants aged 2 to 5 years located in the nursery or in plantations were used. A simple protocol for collecting and dispatching of rattan leaf samples for isozymes purposes has been established.

The results showed that both *Calamus* species exhibit a high level of genetic diversity, He=0.47. It is surprising that the diversity of the narrowly distributed C. *subinermis* is of the same order as the diversity of C. *manan* whose distribution is much larger. The diversity in the C. manan populations may, therefore, be reduced artificially by a two step sampling procedure - only part of the range

of C. manan has been surveyed in the present analysis, no material from Sumatra was available and - C. manan "populations" were mainly collected from plantations. C. manan seems to exhibit a deficit of heterozygotes while C. subinermis seems to be in Hardy-Weinberg equilibrium (Bon et al., 1995).

Genetic differentiation has been observed among populations of C. manan but populations from the West Coast of C. subinermis do not show genetic differentiation and this needs comparisons with populations from the East Coast (Bon et al., 1995).

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Annex. A

List of Calamus *manan* seed stands/trial plots under PISP in LFC

TRIAL NO.	DATE PLANTED	NO. OF PROGENY	TOTAL PLANTS	PLANTED AREA (ha)
CMBl	FEB 92	5	100	0.20
CMB2	FEB 92	4	104	0.20
cMB3	FEB 92	3	90	0.10
cMB4	JAN 93	20	1000	1.25
CMB5	JUN 94	20	400	0.50
CMB6	JUN94	6	180	0.22
CM87	JUN94	9	180	0.22
CMB8	JUN 94	30	300	0.38
CMB9	NOV 94	7	210	0.26
RESOURCE 1	JUN 94	6 (BULK	197	0.25
RESOURCE 2	JUN 94	14	256	0.32
RESOURCE 3	JUN 94	8	244	0.31
RESOURCE 4	JUN94	12	310	0.39
RESOURCE 5	JUN94	17	170	0.21
RESOURCE 6	NOV 94	6	300	0.38
TOTAL			4041	5.19

Annex. B

List of Calamus subinemis seed stands/trial plots under PISP in LFC

TRIAL NO.	DATE PLANTED	NO. OF PROGENY	TOTAL PLANTS	PLANTED AREA (ha)
CSBl	JUL 91	5	75	0.10
CSB2	JUL 91	3	165	0.20
CSB3	DEC 91	6	240	0.30
csB4	DEC 91	5	150	0.19
CSB5	FEB 93	14	700	0.90
CSB6	JUN94	6	180	0.22
CSB7	JUN94	30	450	0.56
CSB8A	NOV 94	72	432	0.54
CSB8B	NOV 94	72	432	0.54
CSCl	DEC 90	6	420	0.63
RESOURCE1	JUN 94	4 (BULK:	200	0.25
RESOURCE2	JUN94	9	170	0.21
RESOURCE4	DEC 94	74	394	0.49
TOTAL			4008	5.13

Annex. C

List of Calamus *caesius* seed stands/trial plots under PISP in LFC

TRIAL NO.	DATE PLANTED	NO. OF PROGENY	TOTAL LANTS	PLANTED AREA (ha)
CCBl	MAY 91	43	645	1.00
CCB2	MAY 91	35	525	0.80
CCB3	JUN91	25	625	0.90
CCB4	SEP 91	10	400	0.60
CCB5	DEC 91	40	600	0.90
CCB6	DEC 91	35	700	1.10
CCB7	DEC 91	33	660	1.00
c c c 1	MAY 92	9	270	0.30
RESOURCE 1	JUN91	60	300	0.45
RESOURCE 2	SEP 91	10	50	0.08
RESOURCE 3	DEC 91	40	200	0.30
TOTAL			4975	7.43

Annex. C Contd.

List of other rattan species seed stands/trial plots under PISP in LFC

SPECIES	TRIAL NO.	DATE PLANTED	NO. OF PROGENY	TOTAL PLANTS	TOTAL AREA(ha)
C. trachycoleus	CTBl	DEC 90	31	2480	3.72
C. merrillii		MAY 92	BULK	142	0.21
C. *pogonacanthus*	CPDl	DEC 90	1	92	0.14

SEED COLLECTION

SPECIES	TYPE OF COLLECTION		ORIGIN
	INDIVIDUAL	BULK	
C. manan	166	6	West Malaysia Kalimantan
C. subinermis	182	13	Sabah
C. caesius	129	13	Sabah, Sarawak
C. trachycoleus	31	Nil	Kalimantan
C. optimus	2	Nil	Sarawak
C. omatus	23	Nil	Sabah

APPENDIX 11

SELECTION CRITERIA AND METHODOLOGY FOR POPULATION ENHANCEMENT OF RATTANS

P.S. Shim

INTRODUCTION

Malaysia, Indonesia, China and the Philippines have all embarked on large scale plantations of various species of rattans.The. silvicultural techniques for the establishment of the different species used are fairly well known. However, improvement of rattan is a new line of research and very few countries are involved with it.

Progeny tests have to be carried out for population enhancement and selection criteria are described below.

SELECTION OF PRIORITY RATTANS

Rattans are distributed over a vast area from the tropical to the cool monsoonal areas of the Afro-Pacific region. Each country within this region will have their own priority species which are normally species producing high quality canes. Important species of the tropical South East Asian countries are:

Large diameter canes	Calamus manan
	Calamus merrillii
	Calamus subinermis
	Calamus zollingeri
	Culumus ornatus
Small diameter canes	Culumus caesius
	Calamus trachycoleus

Other countries will have their own priority species. Calamus tetradactylus, C. *simplicifolius* and *Daemonorops margaritae,* for instance, would be priority species in China where large areas have been planted with these species although they cannot compare in quality with priority species of the perhumid countries as listed above.

Selection should be based on adaptability of the species to site and its end use. The end use of most rattan species, depending on whether they are large or small diameter, are well known. Before any selection can be made towards improvement of quality of canes for whatever its end purpose, species and/or provenance trials have to be carried out initially. This is because different species, have different abilities to grow well in different sites.

Generally, species from cool monsoonal areas are not expected to grow well in perhumid areas and vice versa. Thus, a high quality species like C. *trachycoleus* has the ability to withstand severe floods better than other Calamus species. In soils derived from ultramatic rocks for example, C. manan, C. *cuesius* and C. trachycoleus grew without any apparent side effects but C. *merrillii* and the coconut palm turned yellow on the same site.

Once the species/provenance has been identified, selection for improvement will be from plantation plants.

SELECTION CRITERIA FOR IMPROVEMENT

In looking at selection criteria for improvement, more weight should be put on economic considerations. A number of criteria are listed below:

i. Sucker production

Sucker production depends on availability of sunlight, nutrients and water but, under optimum conditions, some plants produce more suckers than others.

With C. manan, a small percentage of the plants produce suckers. These are preferred over single-stemmed plants. However, the odd plant may produce multiple suckers that compete against each other with the end result that all suckers are stunted and of the same height with no dominant canes. These should not be selected for.

In the case of C. *merrillii* from Mindanao, a small percentage of the plants are single-stemmed while the majority produce multiple suckers which are of course preferred. In Luzon, the plants not only produce suckers at the base of the clump but also from the nodes of the canes higher up. When this occurs, the canes are flattened on one side, lowering the quality of the cane. Where possible, only plants that produce suckers at the base of the plants should be selected.

Lee and Chia (1995) found that sucker production rate increases with clump size and age, however, the rate of spread of a clump will ultimately depend on the length of the rhizomes/stolons produced. C. trachycoleus is invasive because of the long stolons produced. With C. *caesius* the rhizomes are short and the suckers have to compete against each other. In the process, many suckers either become dominant or die out. Plants with long rhizome should be selected for. It has been verbally reported in Sabah that certain provenances do produce fairly long rhizomes and they were initially thought to be C. *trachycoleus.*

ii. Growth rate

Growth rate or stem elongation is much affected by the amount of sunlight, nutrients and water received. However, preliminary results of Lee and Chia (1995) showed that on similar sites and at similar light intensities, there is a significant trend of increase in internode production rate with clump size and age but not with stem length. Since increase in internode production rate varies with age, stem elongation rate must therefore depend on both internode production rate and length of internodes.

iii. Internodal length

Lee, Jong and Swaine (unpub.) examined the phenology of four species and gave the frond production rate (number per year) as follows: C. *subinermis,* 31; C. manan, 22 and C. *trachycoleus, 22.* If frond production rate does not vary much for the species, then, growth rate depends largely on internodal length. This is thus an important criterion in the selection of canes for population enhancement not only as as indication of rate of growth but also in the manufacture of furniture where both large and small diameter canes with long internodes of over 30 cm in tropical countries are preferred to those with short internodes. In cool or warm monsoonal countries, canes normally have much shorter internodal lengths and the standard has to be lowered.

In small diameter canes like C. *caesius* and C. *trachycoleus* the lower few internodes are longer than normal. These cannot be used for selection purposes. By about the tenth internode and above, the normal length is much shorter and these should be used for measurements. In very long canes, there is also the tendency for distal internodes to be slightly shorter.

iv. Nodal diameter differences

The smaller the nodal difference, the better the quality of both large and small diameter canes. This difference is noticeable mainly between species but not noticeably different within the species. This criterion is thus important only in the selection of species for plantation and not in progeny tests. With C. *ornatus* for example, the nodes have to be whittled down before it can be used for furniture making and it cannot be peeled for its skin although it produces white, good quality cores in the Philippines.

v. Cane diameter

The preferred diameter sizes of small diameter canes is between 6 and 10 mm as most machines are manufactured to split canes of

this size range and for large diameter canes, 3 cm and above are considered premium canes. Unfortunately, diameter of canes depends firstly on species and secondly on the environment. Low light conditions, poor nutrient status and water stress produce canes of small diameter. Additionally, canes near the base have small diameter which increases in size with length. Thus, diameter should not be used as a criterion for selection within species.

v. Colour and blemish of skin

This is observable only after processing. Colour of the skin depends more on the species and method of treatment but blemish appears to be controlled by the environment. As an example, C. caesius in Sabah produces canes with much higher skin blemish when grown in wet seasonally flooded plains than in the mountains.

vi. Inflorescence production

When an inflorescence is produced, the following internode is flattened on the side of the inflorescence and the internodes tend to be very short. Canes that start producing inflorescences later in life and those that do not flower every year, if at all, are to be preferred. However, Lee, Jong and Swaine (unpub.) found that frequency of flowering is influenced by light availability.

POPULATION ENHANCEMENT OF RATTANS

Population improvement of rattans can be done either by silvicultural means or by breeding. Enhancement in this paper is taken to mean improvement of genetic qualities. However, enhancement by silvicultural means involves the right planting age of seedlings, healthy planting stock, the right time of planting, i.e. before the dry season sets in, proper maintenance i.e. optimum light, nutrient and water requirement, and suitable soil type.

Progeny tests and recurrent selection

From plantation plants, seeds of 50 selected plants or more (depending on the size of the plantation available for mass selection) are used for progeny tests. Any breeding system can be used but each family plot must consist of 5 seedlings for the purpose of selecting male and female plants at a later stage.

It is recommended that at least 20% of the males be left. Acount made on the number of male flowers from the two inflorescences on the stem of C. caesius and the number of male flowers from two inflorescences on the stem of **a** male plant gave a female:male flower ratio of 1:l0. Since there are 6 anthers per male flower, a male inflorescence in theory is sufficient to pollinate all the flowers of 60 female inflorescences. Most of the anthers will, however, be lost to insects. The plants can only be selected for male and female plants during flowering when the inflorescences have elongated.

The breeding population is open pollinated because rattan species (especially those from the perhumid zone) are rapid growers with annual length increments of 3 - 7 m and by the time. the cane flowers, the stem is 10 - 42 m in length and hence it is difficult to perform controlled pollination.

A lattice incomplete block design is proposed for the progeny tests.

a) Each block consists of 50 families and each family plot of 5 seedlings. Each block contains 250 plants.

B) Blocks are replicated 5 times.

c) 30% of the poorest families to be rogued.

d) The families in the first block/replicate are numbered in the running order 1,2,3,4...50, down the first row, up the second row, down the third row and so on.

e) One selected male is retained (the other 4 plants removed) for the first, sixth, eleventh, sixteenth, twenty-first and so on of

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This is observable only after processing. Colour of the skin depends more on the species and method of treatment but blemish appears to be controlled by the environment. As an example, C. caesius in Sabah produces canes with much higher skin blemish when grown in wet seasonally flooded plains than in the mountains.

vi. Inflorescence production

When an inflorescence is produced, the following internode is flattened on the side of the inflorescence and the internodes tend to be very short. Canes that start producing inflorescences later in life and those that do not flower every year, if at all, are to be preferred. However, Lee, Jong and Swaine (unpub.) found that frequency of flowering is influenced by light availability.

POPULATION ENHANCEMENT OF RATTANS

Population improvement of rattans can be done either by silvicultural means or by breeding. Enhancement in this paper is taken to mean improvement of genetic qualities. However, enhancement by silvicultural means involves the right planting age of seedlings, healthy planting stock, the right time of planting, i.e. before the dry season sets in, proper maintenance i.e. optimum light, nutrient and water requirement, and suitable soil type.

Progeny tests and recurrent selection

From plantation plants, seeds of 50 selected plants or more (depending on the size of the plantation available for mass selection) are used for progeny tests. Any breeding system can be used but each family plot must consist of 5 seedlings for the purpose of selecting male and female plants at a later stage.

It is recommended that at least 20% of the males be left. A count made on the number of male flowers from the two inflorescences on the stem of C. caesius and the number of male flowers from two inflorescences on the stem of a male plant gave a female:male flower ratio of 1:l0. Since there are 6 anthers per male flower, a male inflorescence in theory is sufficient to pollinate all the flowers of 60 female inflorescences. Most of the anthers will, however, be lost to insects. The plants can only be selected for male and female plants during flowering when the inflorescences have elongated.

The breeding population is open pollinated because rattan species (especially those from the perhumid zone) are rapid growers with annual length increments of 3 - 7 m and by the time. the cane flowers, the stem is 10 - 42 m in length and hence it is difficult to perform controlled pollination.

A lattice incomplete block design is proposed for the progeny tests.

a) Each block consists of 50 families and each family plot of 5 seedlings. Each block contains 250 plants.

b) Blocks are replicated 5 times.

c) 30% of the poorest families to be rogued.

d) The families in the first block/replicate are numbered in the running order 1,2,3,4...50, down the first row, up the second row, down the third row and so on.

e) One selected male is retained (the other 4 plants removed) for the first, sixth, eleventh, sixteenth, twenty-first and so on of

the remaining family plots i.e. one male in every 5 families or 10 males per plot. For the next block/replicate, which is randomized, one male from family plots 2,7,12,17,22 and so on is retained and for the third replicate, males from plots 3,8,13,18, etc. are retained. For the fourth replicate it is 4,9,14,19,24 and so on and for the fifth replicate, males of families 5,10,15,20,25 etc. are retained. For all remaining plots, all plants are removed leaving only one selected female. The end result is that from 5 replicates, each family has **1** male and 4 female plants retained.

The identity of most of the males and females may not be known until possibly year 6 or 7. From the progeny test, seeds are collected from the best 50 plants for the establishment of the next generation breeding population. Plants are selected for (a) growth rate and sucker formation and (b) internodal length.

Seeds from the best few plants are used for establishment of the seed orchard which will also be culled based on performance of the second generation progeny tests.

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APPENDIX 12

REPRODUCTIVE BIOLOGY OFRATTANS

C. Renuka

INTRODUCTION

Rattans are gaining importance as plantation crops in many Asian countries. When large scale plantations are grown, the use of genetically improved seeds is desirable. In order to produce genetically improved rattans, basic information on floral biology and breeding systems are essential. At present our knowledge on pollination mechanisms and fruit set is very limited.

Rattans are dioecious, the male and female plants being separate and the flowering is annual, although *Korthalsia* is a monoecious genus in Asia and the flowers are bisexual. Two types of flowering are seen among rattans: hapaxanthic and pleonanthic. In hapaxanthic flowering the topmost nodes of a rattan produce inflorescences more or less simultaneously and in so doing, the apex become exhausted and the stem dies after flowering and fruiting e.g. Korthalsia. In pleonanthic flowering the stem continues to grow after flowering e.g. Calamus and *Duemonorops.* Some of the *Duemonorops* species are hapaxanthic (Dransfield, 1979).

Beetle pollination has been reported in some of the rattan genera (Dransfield, 1979) although bees appear to be the most likely pollinators of many species of *Calamus.* Some species seem to be wind pollinated also.

In rattans even though fruits are produced in large quantities in natural forests, practically no natural regeneration from seeds is seen near the mother plant in many areas. Whether this is due to dispersal mechanisms or due to other ecological reasons is not known.

In India, reproductive biology of rattans has not been studied in detail mainly because of lack of rattan plantations and the inaccessibility of the natural populations in forests. Generally the cane growing areas in forests are infested with elephants which makes it risky to stay in the field overnight to study details of floral behaviour such as time of opening and anthesis.

The Kerala Forest Research Institute recently initiated some studies on the reproductive biology of rattans with financial assistance from IDRC, the results from which are given below.

In most of the Indian species, flowering starts between October and January and fruits mature between April and June (Renuka, 1992). In NE India, certain species start flowering in March-April and the fruits mature during November-December.

SPECIES INVESTIGATED

Three species, Calamus thwaitesii, C. *hookerianus,* and C. pseudotenuis were selected for the studies. For observing the time of floral opening and anthesis it was necessary to stay in the field during night hours.

To study the pollen viability and stigma receptivity, pollen was collected at the time of anthesis and kept in small glass tubes. Branches of female inflorescences, in which the flowers had started opening were selected and bagged. The flowers of 2 branches were pollinated with the collected pollen, bagged and labeled. After 2 h, the process was repeated in another 2 sets of selected branches. The pollination was continued for 8 hours. Then the time gap was increased and the pollination was continued to 24 h. Observations were continued on the development of fruits.

To study fruiting phenology, 12 plants of each species were selected at one locality. Inflorescences were selected and tagged. Plastic nets were spread below the inflorescences to collect the falling fruits. Monthly observations were taken on the number of fruits in each selected inflorescence and on the number of fallen fruits.

RESULTS

1. Floral opening and anthesis:

In C. *thwaitesii,* the male flower starts opening around 1 am and is fully open by 4 am. The female flowers also open by 4 am. Anthesis starts immediately and by 6 am all the pollen is shed from the flower.

In C. *pseudotenuis* and C. *hookerianus,* the opening of the flower does not take much time and the flowers are opened around 4 am. In C. *hookerianus* another set of flowers open at 4 am also. In these species, anthesis follows immediately after opening of the flower and all the pollen is shed within 2 h.

The pollen viability and stigma receptivity decreases after 12 h of anthesis.

2. Pollination mechanism:

All the three species are wind-pollinated. The pollen grains are shed from the anthers within two hours from anthesis. Even though some insects were seen visiting flowers, evidence is lacking that they are pollen carriers.

3. Fruiting phenology:

The observations were started in November and continued after the formation of young fruits until almost all fruits had fallen

C. pseudotenuis

There was a gradual reduction in the number of fruits from' November to March when the fruits mature. After March there is a sudden increase in the rate of fall.

C. hookerianus

Here most of the fruits had fallen at a very young stage. From January onwards there is a reduction in the rate of fall until the fruits mature in February. By April all fruits had fallen.

C. thwaitesii

The rate of fall of fruits is comparatively less in this species. By the end of April fruits had matured and by June almost all fruits had fallen.

To find the rate of reduction in the number of fruits with respect to initial number of fruits a linear regression was employed (Table 1). The rate of reduction in C. *pseudotenuis* was 0.1614 while that of *C. hookerianus* was 0.188, and in C. *thwaitesii it was 0.1097. The* adjusted r2 obtained were 0.96,0.88 and 0.79, respectively, showing that the actual values will coincide with predicted values.

Table 1.

Species	Model	r2
C. thwaitesii	**Y=1.0901 - 0.1097 x**	**0.79**
C. pseudo tenuis	**Y=1.0417679 - 0.161375 X (0.0483) (0.01341)**	**0.96**
C. hookerianus	**Y=O.85807 - 0.18841 X (0.09389) (0.03101)**	**0.88**

Y = proportion, X = month,
Values within brackets indicate SE.

4. Dispersal mechanisms

Birds, small animals and people act as agents for dispersal of seeds. The seeds of C. hookcrianus and C. *pseudotenuis* are eaten by people, birds, squirrels, monkeys etc. Children, after eating the pulp throw away the seeds in the vicinity of the mother plant itself. Birds and other animals are the real agents which help disperse seeds to distant areas.

The fruits of C. *thwaitesii* are somewhat sour and monkeys prefer this. They remove the scaly pericarp and eat the rest of the fruit. In places where monkeys are prevalent, not even a single mature fruit reaches the ground near the mother plant.

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PATTERNS OF VARIATION INRATTANS [1]

A. N. Rao and V. Ramanatha Rao

INTRODUCTION

Rattans are a unique group of climbing palms in tropical rain forests. Most species grow as clumps and only a few are single-stemmed. Some species are small in size with underground stems forming rosettes. *Calamus* (400 species) and *Daemonorops* (115) are the largest genera. Others like Korthalsia (26), *Plectocomia* (16) and *Eremospatha* (12) have fewer species. The other eight genera have less than 10 species each including three genera that are monotypic. *Eremospatha* (12), *Laccosperma* (7) and *Oncocalamus* (l-3) are confined to Africa and the rest are all present in South and South East Asia, including Southern China. *Calamus* is the common genus present in Asia and Africa. Nearly 300 rattan species are said to be present in Malaysia and Indonesia although the inventory work is not complete (Anonymous, 1991). The need for more intensive survey of rattan in the eastern provinces of Indonesia including Kalimantan was emphasized. The importance of taxonomic inventory work both for selection of more economically important species as well as their cultivation on a plantation scale has been recently emphasized (Wan Razali et al., 1992; Dransfield and Manokaran, 1993). Rattans are traded using only common or local names in certain countries. All the species in such countries e.g. Myanmar, need to be scientifically

1. The opinions expressed are those of the authors and are not necessarily those of IPGRI

identified. A bibliography on rattan was published in 1986 and a host of other publications have appeared in recent years largely due to research and conference support provided by IDRC, Canada. These along with few earlier publications give us some details on taxonomy, availability and uses (KongOng and Manokaran, 1986; Wong and Manokaran, 1985; Rao et al., 1989; Manokaran, 1990; Wan Razali, et al., 1992; Basu, 1992; Renuka, 1992,1995)

RESOURCE INVENTORY

Some valuable data and work programme for rattan resource survey have been published (Nandakumar and Menon, 1993). Remote sensing methods for survey may not be very feasible unless large areas of rattan with uniform growth are to be surveyed. Rattans are climbers and always depend on the supporting trees. Remote sensing methods may not be that precise as to distinguish the tree as well as the climbers that grow on them. Manpower development is necessary at different levels especially to conduct the survey at ground level. With good survey work completed by such trained persons many more rattan species can be identified that are suitable for cultivation to increase commercial production. Outlines for research expansion and research gaps on resource diversity have also been published. The strategic research programme for rattan improvement would include resource assessment and conservation, resource production and management, and resource utilization. National programmes on rattan research should consider these topics on a priority basis with necessary modifications wherever necessary (Anonymous, 1991). The greatest diversity of rattan is seen in lowland tropical rain forests. Most of the species are well spread out and present in isolated patches (Manokaran, 1990). Branching is not common in the genus Calamus whereas most Korthalsia species are branched. Population biology, density of species or individuals per given area, ratio between male and female plants in a population, natural regeneration of plants after harvest and many other details are yet to be studied as part of resource inventory studies. Some of the important details that need to be critically studied relate to ecology and natural history of rattans

(Dransfield, 1992). Annual growth rates have been recorded for four species of rattan ranging from 1 to 4 metres per year (Manokaran, 1985). Such details are necessary to estimate the increase of stem length and plan for harvesting schedules. Variation in rattan growth is possible depending on seed source, edaphic and biotic conditions prevailing, degree of maturity of fruits, establishment and growth phases of stems and others.

RATTAN PRIORITY SPECIES AND PLANTATIONS

Only about 20 of the 600 species are commercially used and about 6 species are cultivated on a plantation scale. Some species are used only with common or local names without any reference to botanical names. This fact would emphasize the urgent need to conduct taxonomic survey work in some of the countries. In order to concentrate and focus close attention about six well identified species of rattan and 3 species complexes were selected for further research on conservation, greater production and continuous utilization. The selection of these species to be focused on as widely as possible, was based on their commercial value, degree of domestication, climate and ecology as well as available or known genetic resources ((Table 1 from Williams and Rao, 1994). Rattan cultivation on a plantation scale was started in Kalimantan by Christian missionaries around 1850, followed by small scale growers. Since then government forest departments and private foundations have extended this activity both in Malaysia and Indonesia, using secondary forests and rubber plantations (Aminuddin, 1995). Only about 10% of market supply comes from these plantations and the rest are collected from natural stands in the forests (Anonymous, 1991; Williams and Rao, 1994). The taxonomic identity of many *Calamus* species is still uncertain and the relationship between the various species within the complex or section also has to be clearly defined. There are very few well qualified rattan taxonomists who are doing active research at present. Considerable progress has been made in the last l0-15 years even though only a few persons have been involved (Anon, 1992;

Table 1. INBAR priority taxa

Taxa	Value			Domestication	Climate & Ecology		Genetic Resources			
	Cs	C	Ri		Ci	H	Ge	Iv	E	Survey
Calamus manan	*L*	*++*	*+*	D	h	d	H	L	H	M
C. caesius	S	++	++	D	h	d/w	H	L	H	M
C. 'trachycoleus	S	++	++	D	h	seas.f	L	L	M	L
Calamus Sect. Podocephalus	*M-L*	++	+	SD	h,s	saline mangrove to montane	H	L	H	H
C. subinermis (and relatives)	*M-L*	++	+	SD	h,s	dry (coastal hills)	H	L	H	M
C. palustris (and relatives)	*M-L*	+	++	SD	s	varied (monsoonal)	H	L	H	H
C. tetradactylus	*S*	+	+ +	' D	cool	d,s	L	L	L	L
C. deerratus	*S-M*	+	++	W	h	w	H	L	H	H
C. hollrungii (and relatives)	*M - L*	+	+	W	h	d	H	L	H	H

Value

cs =	cane size: large (L), medium (M), and small (S)
c =	commercialization potential: high (++), medium (+), and not fully known (+)
Ri =	rural industries : high (++), medium (+)

Domestication

Wild	= W, semi-domesticated = SD, domesticated = D

Climate and ecology

Ci =	climate: humid tropics = h, subtropical = S
H =	habitat: dryland = d, wet = w, seasonally flooded = seas.f

Genetic resources

Ge =	genetic erosion: high (H), low (L)
Iv =	need for research on *in vitro:* low (L)
E =	need for exchange: high (H), medium (M) low (L)
Survey	= need for further field survey: high (H) medium (M), low (L)

Basu, 1992; Dransfield and Manokaran, 1993; Lakshmana, 1993; Renuka, 1992,1995,1995a; Wan Razali et al., 1992). It will take more time to analyze the relationships of all the priority rattan species and their relatives, totalling about 40 'species' in all (Williams and Rao, 1994). Potential species suitable for plantation establishment and details of forested and rubber plantation areas planted with rattan have been discussed (Aminuddin, 1995).

RATTAN ECOLOGY

Certain ecological factors that influence establishment and growth of rattan have been identified. Adequate light is necessary for good growth of Calamus egregius and the plants cannot stand full sunlight. Mature rattan plants in the equatorial climate are adjusted to full day length of l0-12h, but in certain cases, growth improves under partial shade conditions. Seedlings of C. *simplicifolius* prefer semishade conditions and cannot withstand full sunlight. Abundant sunlight promotes good growth of C. *truchycoleus.* Alluvial soils are said to be best suited for C. *caesius,* C. *scipionum* and C. *tumidus.* Rich moist soil promotes better growth in the case of C. *egregius, C. ornatus* and C. *tetradactylus.* C. *javensis* can adopt to a wide range of soils. Growth is much better on well-drained soils in the case of C. *ovoideus* and loamy soil in the case of C. *wuilong.* Slightly acidic soil is preferred by *Daemonorops margaritae* and C. *tetradactylus.* Very few Calamus species grow at 1000m or higher including C. *egregius, C. manan, C. merrillii, C. ornutus, C. simplicifolius, D. murguritue* and a few others. Many of them are lowland species with good growth near streams and water margins. Very few of them are coastal species. The majority tolerate high humidity and heavy rainfall characteristic of the equatorial tropics. *C. cuesius, C. simplicifolius, C. tumidus* and *Daemonorops subut* thrive well under floods or swamp and abundant soil moisture conditions. In contrast, C. *trachycoleus* cannot withstand stagnant water conditions for too long. Some general information on the ecology of rattans and soil types that promote good growth of certain *Calamus* species have been summarized (Rao, 1994). From these details it becomes evident that

most of the information on ecological requirements have been gathered on the spot from casual observations but not from any in depth studies. Very few studies have been conducted on the ecophysiology of rattan species and the relative growth performances of various species under optimal growth conditions (Aminuddin, 1989; Dransfield and Manokaran, 1993; Nur Supardi and Wan Razali,'1989; Rao et al., 1989; Wan Razali et al., 1992).

ECOLOGICAL VARIATIONS

The occurrence of rattans in different kinds of forests and ranges of altitude are recorded (Dransfield and Manokaran, 1993). Light requirements, soil types, relative rainfall, wet/dry conditions and other details regarding seedling survival rate and their abundance are mentioned just for a few species and this indicates that detailed information needs to be gathered for the majority of species, including those that are commercially most important e.g. C. manan, C. *ornatus,* C. palustris and others. The ecological details so far outlined are mostly based *on* general observations and some of the details recorded from nursery and silvicultural practices (Aminuddin, 1989). Experimental details are very much needed for the majority of species (Wan Razali et al., 1992).

GENETIC RESOURCES

Botanic gardens and arboreta in certain countries include rattan plants. Provenance trials and plantations have included certain superior varieties and base populations. Large scale nurseries have been established in Sabah, Peninsula Malaysia and Indonesia which include millions of seedlings raised from seeds collected from natural stands in the forests. A critical analysis of such seedlings could help to choose certain superior varieties and these may be further improved by experimental methods. Very few intraspecific varieties are recognized so far and plenty of scope for research is available in this field. A rattan genebank has been established at UPLB, Philippines, which includes C. *merrillii* and C. *mindorensis.*

The botanic gardens at Peradeniya, Sri Lanka has a good seed collection of C. ovoideus and good collections of local rattan species are available in botanical gardens in China (Dransfield and Manokaran, 1993).

CYTOLOGY AND RATIO OF SEXES IN A POPULATION

Basic chromosome numbers have been determined for some species of *Korthalsia* (2n = 32). There are no data for species of Calamus. This paucity of knowledge appears to be mainly due to inaccessibility of material for investigation. Good cytological data is necessary to plan for hybridization research. Similarly, investigations are necessary on pollination, pollinating agents and details of fruit development. Rattans are dioecious plants. About 254 plants of Calamus *caesius* were studied in detail between 1981-1985. In 1985 only about 41 plants flowered, 14 of which were female, 13 male and the sex of another 14 plants was not certain (Manokaran, 1989). The reason for such a small number of plants flowering at any one time needs to be determined and more studies are needed on the flowering behaviour of rattans.

VARIATION IN FLOWERING AND FRUITING PATTERN

Palm inflorescences show different gradations and evolutionary tendencies starting from separate male and female inflorescences as in *Borassus* and oil palm; male and female flowers present on the same inflorescence but at different, distinct portions as in coconut, arecanut and Nipa; or gradual reduction of bisexual flowers into unisexual condition as in Calamus (Corner, 1966). In the majority of Culumus species, the female flower is surrounded by many staminodes; male and female inflorescences are borne on separate plants. Calamus species have complicated inflorescences. More detailed studies of various species are needed to determine the gradation between the fully fertile and semi-sterile flowers

(Whitmore, 1973). Male and female flowers show distinct differences in size and shape, the latter being usually bigger than the former. The ratio between male and female plants in a Calamus population is yet to be well determined for the majority of Calamus species. This study is important since it has a direct bearing on pollen availability, pollen load, pollination and successful fruit production. Any imbalances created in the ratio of male and female plants in a given area may have an adverse effect on fruit production (Manokaran, 1985). The data on flowering and fruiting has been from different publications for 35 species of rattans as follows. Starting from seedling stage, plants of C. *tetradactylus* flowered in *2.5 - 3* years; *C. trachycoleus* in 4 years; C. *caesius, C. manan* and *D. marguritae* in 5 - 5.5 years. Details for other species are not known. Some flowers‘and fruits are found throughout the year in the case of *D. margaritae* in China, though mature fruits are more abundant during November to January. Two flowering periods within a year are recorded for certain species: C. *cuesius* (July-August, October-November in Malaysia) (Manokaran, 1989), *C. manan* (January-February, May-June in Malaysia), C. *viminalis* (February-April, July-October in Malaysia). Other species studied in Sri Lanka and India flower once a year, mostly from October to January and a few of them from April-June. The fruit development takes a longer period of 14-16 months in C. *caesius* and *C. manan,* and about 7-8 months in C. *longisetus.* All the other species flower once a year and fruit development follows (Table 2).

The observations recorded are incomplete in most cases. More details of flowering and fruiting are needed to improve our knowledge regarding the reproductive biology of various species, especially commercially important ones. Based on the data on hand, it may be generally assumed that rattans in wet moist tropical forests take a longer period for fruit maturity than ones that are present in relatively dry conditions of subtropical forests. A study on the development and physiology of fruits will be very interesting; and also simultaneously growing the same species or clones under two relatively different moist or humid and temperature conditions. The causal factors that induce flowering and help fruit maturation can be identified. The total number of fruits produced per plant or

Table 2. **Seasonality of flowering and fruiting in rattan species**
(Some species are entered more than once in this table: *See* footnote)

Index: ▬▬ *Flowering*
xxxx *Fruiting*

Species	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*Sept*	*October*	*November*	*December*
1. C. caesius	*xx*	*xxx*	*xxx*				▬▬ *(16 numths after)*	▬▬		▬▬ *xxx*	▬▬ *xxxx*	▬▬ *xxxx*
2. C. hookerianus	*xxx*	▬▬ *xxx*	▬▬ *(10-11 numths)* *xxx*	▬▬	▬▬							
3. C. longisetus						*xxx*	*xxxx*				▬▬	▬▬
4. C. nanan	▬▬	▬▬ *xxx*	*xxx*	*xxxx*	▬▬ *xx*	▬▬	*xxxx*	*xxxx*				
5. C. tetradactylus				*xxxx*	*xxxxx*	▬▬ *xxxx*	▬▬ *(10-12months)*					
6. C. trachycoleus			*xxxx*	▬▬ *(11-12 months)* *xxxx*	▬▬ *xxx*							
7. C. viminalis		▬▬	▬▬			▬▬	▬▬	▬▬	▬▬			

Table 2. Contd.

Index:

▬▬ Flowering
xxxxx Fruiting

Species	January	February	March	April	May	June	July	August	Sept.	October	November	December
8. *C. ovoideus*				▬▬					xxxx	xxxx		
9. *C. pachy-stemonus*											▬▬	
10. *C. radiatus*		▬▬	▬▬		xxxx							
11. *C. pseudotenuis*				▬▬	▬▬	▬▬		xxxx	xxxx	xxx	xxx	
12. *C. delicatulus*	▬▬	▬▬	xxx	xxx	xxx	▬▬						▬▬
13. *C. rotang*											▬▬	▬▬
14. *C. rivalis*									xxxx	xxxx	▬▬	
15. *C. brandisii*				xxx	xxxx	xxxx				▬▬	▬▬	▬▬

Table 2. Contd.

Index:

Flowering

xxxxx Fruiting

Species	January	February	March	Apı	May	June	July	August	Sept.	October	November	December
16. *C. dransfieldii*				xxx	xxxx							
17. *C. gamblei*					xxx	xxx						
18. *C. hookerianus*								xx	xxx	xxx	xxx	xxxx
19. *C. hegelianus*										xxxx	xxxx	
20.*C. karnatakensis*					xxx	xxxx						
21. *C. lacciferus*					xxx	xxxx						
22.*C. lakshmanae*					xxx	xxxx						
23. *C. metzianus*					xxx	xxx						

Table 2. Contd.

Index:

▬▬ Flowering
xxxxx Fruiting

Species	January	February	March	Apri	May	June	July	August	Sept	October	November	December
24. C. nagbettai	▬▬				xxx	xxxx						
25. C. prasinus					xxx	xxxx					▬▬	▬▬
26. C. pseudotenuis	▬▬	▬▬		xxx	xxx	xxx	▬			▬▬ xxx	▬▬ xxx	▬▬
27. C. Wang			xxxx	xxxx	xxxx					▬▬	▬▬	▬▬
28. C stoloniferus			**xxxx**	xxxx							▬▬	▬▬
29. C thwaitesii	▬▬	xxxx	xxxx	xxxx	xxx							
30. C. travancorus				xxxx	xxxx	xxxx	xxxx			▬▬	▬▬	▬▬
31. C. vattayila				xxxx	xxxx				▬▬	▬▬		
32. Daemonorops *margaritae*	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx	▬▬ xxxx

China = 5,32
India = 15-31
Malaysia = l-4,6
Sri Lanka = 8-14

clump is counted in some cases. This point is very significant since it provides basic information to estimate the quantity of fruits produced in a given population. Fruits are important and much needed to raise seedlings for replanting.

The colour and size of mature fruits, and the number of fruits per kilogram are known for certain species. The smaller the fruit size, e.g. C. *trachycoleus* (10 x 7mm) the greater will be the number of fruits per kilogram (3340); whereas large-sized fruits (26 x 20mm) of C. manan were only 700-790 per kilogram. The number of fruits per kilogram was as follows for different species: C. caesius (1669), C. manan (700-790), C. *ornatus* and C. *tetradactylus* (1000), C. *trachycoleus (3340)* and *D. margaritae(600).* Details are not recorded for other species. Number of fruits produced per inflorescence are variable from species to species and the recorded cases are very few (Yap, 1992). Fruit development and maturity progress in stages and it is likely that the early formed fruits drop off before the majority of fruits at the middle and terminal positions mature. For this reason, it is very likely that fruits collected at random may contain a high percentage of immature fruits since collectors gather them en mass from forests. The sarcotesta is usually removed before sowing and seed viability rate drops off if good storage condition is not maintained with proper moisture content (Mori, 1980). Only one or two species have been studied to determine the relationship between percentage germination, moisture content and period of viability. Seed viability studies of other species should be undertaken to extend the period and to develop suitable methods for conservation.

CONSERVATION AND COMMERCIALIZATION

The conservation status of some Malaysian rattan species is discussed in Dransfield, 1989; Kiew, 1989; Dransfield and Johnson, 1989; and Pearce, 1989. *Some* of the Malaysian species are cultivated in arboretum of FRIM; Arboretum, University of Malaya; Penang

Botanic Garden; Singapore Botanic Garden; and Royal Botanic Garden, Kew. These include 10 species of Calamus (including C. manan, C cuesius - priority species), seven species of Daemonorops and Korthalsia hispida. Conservation status of 61 species of Calamus, 22 of Daemonorops, 4 species of Plectocomiopsis and Myrialepis paradoxa has also been evaluated (Kiew, 1989). The conservation status and distribution pattern of 40 species of Calamus, 18 species of Daemonorops, 11 species of Korthalsia, 3 of Plectocomiopsis and 2 of Plectocomia are accounted for in Sabah (Dransfield and Johnson, 1989). The occurrence and conservation status of 46 Calamus species in Sarawak are summarized in Pearce, 1989. All three papers provide valuable information regarding the distribution of important rattan species, and are helpful in planning for both in situ and ex situ conservation. Almost 104 rattan species are recorded from Peninsula Malaysia and about 20 species are commercially important - (a) rattans used in furniture industries - C. manan, C. tumidus, C. cuesius;(b) furniture, second grade, Korthalsia sp., C. scipionum,Plectocomia sp., C. laevigatus and C. ornatus; (c) split rattan - C. insignis, C. filipendulus, various Calamus sp., C. diepenhorsti, C. densiforus, C. luridus, C. scabridus;(d) core - C. ornatus, Daemonorops sp. C. erinaceus, D. angustifolius, D. melanochaetes; and (e) basketry and mats - Korthalsia sp. Only two of the priority species namely C. manan and C. cuesius are included in the list and these two species are also cultivated. The rest of them are collected from natural stands and used. Some attention should be paid towards their conservation and propagation to sustain regular supply for various industries and to help the rural poor who are largely involved with the trade (Kiew, 1989a).

Very few countries have or have published up-to-date information on production, export and consumption of rattan. Indonesia is the biggest producer of rattan, mostly in central Sulawesi, central and East Kalimantan. Of the total 145 million tons of rattan produced in 1992,57 million tons were consumed locally and the rest exported (Nasendi, 1994). Details of species involved are not mentioned, although this would be necessary to plan for in situ and ex situ conservation. For resource development planning a

good inventory study of rattan resources is needed in the country. Rattan should be widely cultivated as a community forestry plant species to sustain market supply Good quality plants should be identified and their genetic qualities determined before introducing them to plantations.

Suitable methods should be established for in situ and ex situ conservation of rattan. The nearest examples of palms are coconut and oil palm. The methods already followed in those cases should be examined to outline the conservation programmes for rattan (Ng, 1985).

The methods followed for rattan harvesting vary from country to country with regard to: (a) frequency of harvesting; (b) period of harvesting; (c) number of mature canes cut per given clump; and (d) the number of stems left per clump after harvesting for further growth. All these data need to be systematically collected and some standard methods established to improve the methods of harvesting. Good dependable data on each species would help to estimate the future growth and yield after each harvest. Some clumps of rattan may give better yield and better quality canes than others and therein lies the indication to select superior clones or varieties of a given species. The commercial value of rattan is based on the stem size and the mechanical properties (Kiew, 1989a; Bhatt, 1992). About 98 species of rattan were classified according to the size of their stem diameter (without sheath). Nineteen of them were of big size (80-30mm), 25 of them medium (30-15mm) and 54 of them (15mm or less) were of small size. Most of the 40 species of the priority list are included in this analysis. The good commercial species belong to the first group of big-sized rattans and others are important locally since no rattan is wasted by the farmers and the rural people. They are very effectively used for cordage, in small rural handicraft industries and for packing. In order to improve the quality of life of rural people who depend on these rural industries, the species that produce big canes need to be urgently conserved and used more effectively Recently, several organizations have started active cooperation to promote genetic conservation and

improvement of bamboo and rattan genetic resources. They include INEAR, IPGRI and FORTIP besides others. NGO participation needs to be encouraged. The local scientists should take more interest in the proposed conservation and development programmes. Work on utilization and industrialization is progressing faster than conservation and production. Necessary correction factors have to be introduced to save the genetic materials that are necessary to improve the quality of materials used in industries. Application of both basic and modern methods of research are important in such programmes (Rao and Rao, 1995).

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