Selection—A valuable method for bamboo improvement

Bamboos are a most useful group of plants. The majority of them occur in South-East Asia. Bamboos have innumerable uses from time immemorial. Nearly half of the bamboo produce is now used in pulp and paper industries. The use of bamboos as industrial raw material is leading to their over-exploitation and a steady decline of their natural stands. To meet the ever-increasing demand, it is necessary to enhance bamboo production. This can be achieved by two methods: (i) increasing the area under bamboo cultivation and (ii) production and use of improved varieties yielding more bio-mass in unit time. The peculiar flowering behaviour in bamboos make genetic improvement by hybridizations very difficult. The conventional method of improvement is by selection, which can be extremely effective in improving the genotype composition of populations. Selection procedures can be generally inexpensive and easily accomplished. Information available indicates that selection can play a very useful role in genetic improvement of bamboos and in substantially increasing their production. Though selection as a method of improvement is suggested by many workers[1], so far it is not widely put in practice in the large scale propagation of bamboos.

Peculiar flowering in bamboos

Most of the economically important bamboo species grow vegetatively for a species-specific supra-annual interval of a few to many years before flowering and seeding. This makes their propagation (by seeds) and breeding (by conventional hybridizations) very difficult. At the end of the vegetative growth phase, like other grasses, bamboos produce a large number of wind-pollinated flowers, set seeds and die[2]. This flowering and seeding at long intervals (7–120 years)[3] render the overlapping of flowering in more than one species, in the same locality very difficult to obtain, making attempts at hybridizations impossible. Induction of flowering *in vitro*[4], once properly standardized to give flowering comparable to that in nature is expected to help in overcoming this problem.

Factors favouring genetic variability

Reproductive biology is not well understood in most of the species. Two categories are apparent so far: (i) species which exhibit dichogamy and protogyny[5,6] and (ii) species in which the androecium and gynoecium mature at the same time. In species under the first category, only cross-pollination is possible. In the second category selfing is difficult, because of the differential position of the anthers and the stigma, when they are mature. Pollination takes place by wind. These characteristics favour open cross-pollination. The resultant seedling populations show genetic variability depending on the heterozygosity present in their parents. Albino seedlings are reported in many species of bamboos indicating their heterozygous nature[7–9].

Characters for selection

In most cases, culms are the produce of economic importance, hence increased biomass production is the character of foremost importance. Faster growth, higher rates of culm production, culm diameter, thickness of the culm wall, diameter of the lumen, length of internode, etc. are the characters which contribute to increased biomass production. In species which are used as raw material in pulp and paper industries, fibre length can be an additional character for selection. Resistance to diseases and pests can be of considerable value in preventing large-scale losses at times of epidemics and pest infestations. Bamboos are known to be susceptible to fungal pathogens belonging to the genera *Alternaria, Ascochyta, Colletotrichum, Curvularia, Dactylaria, Dasturella, Drechslera, Exserohilum, Fusarium, Ganoderma, Geotrichum, Helminthosporium, Rhizoctonia* and *Taphrina*. These pathogens cause damping-off and seedling rot, foliage disease, rhizome bud rot, rhizome decay, basal culm decay, culm rot, culm sheath rot, stem infection, foliage infection, witch's broom disease and little leaf disease[10,11]. The insect-pests which attack bamboos belong to the orders Coleoptera, Lepidoptera and Hemiptera. They can be classified into defoliators, shoot and culm borers and sap suckers[12]. Selection can also be made for suitability for use as ornamentals, fencing and fodder.

Phenotypic markers useful in selection

McClure[13] reported great diversity in vigour, habit of growth and ultimate stature, in seedling populations of *Bambusa longispiculata* and *Dendrocalamus membranaceus*. Kondas *et al.*[14] classified the seedlings of *Bambusa arundinacea* into four types based on their habit: grassy, grassy-erect, erect and very erect. Among these the erect and very erect types were more vigorous and fast growing. Bahadur *et al.*[15] observed that seedlings having left-handed or right-handed folding of the first leaf occurred in nearly the same proportion. The left-handed seedlings grew faster. They also suggested the use of this character in selection. The value of natural genetic variation to plant improvement is well documented. Extensive screening of *Bambusa arundinacea* and *Dendrocalamus strictus* seedlings, belonging to many cohorts, raised from seeds of gregarious flowering, collected from various locations (from India and abroad), at different ages, has shown high degree of variability in growth characteristics. Observations on mature clumps of different species have also shown the existence of variability. These indicated the usefulness of selection as a method for bamboo improvement. In species which exhibit both gregarious and sporadic flowering, this method will be more useful in seedlings from gregarious flowering than those from sporadic flowering. In the latter only few clumps are involved and chances of large scale cross pollination does not exist.

Need for more makers

It is possible to use modern methods of molecular biology in identifying more markers associated with higher biomass production. Huang and Murashige[16] noticed distinct glutamate-oxaloacetate-transaminase isozymes among four bamboo species. Polyacrylamide gel electrophoresis of isozymes and leaf proteins will be useful in identifying and indexing superior genotypes[17]. Recently Frier and

Kochert[18] used the RFLP (restriction fragment length polymorphism) technique for studying bamboo systematics, evolution and germplasm screening.

When to select

Since desirable characters for maximum biomass production are expressed in the adult state, selection at that state is desirable. The huge size of the clumps at the adult stage will need a vast area for raising large numbers of clumps required for selection. This will result in variations due to soil and environmental factors which do not have any genotypic basis. The time required and the cost involved can also be prohibitive. Vegetatively propagated bamboo clumps flower at the same time as their parents[19–20]. Hence it is very essential to know the age of the parent clump while collecting the vegetative propagules. It takes around 5–10 years for the new plantation to come in yield, depending on the species and the method of propagation employed. Planting stocks produced from seedlings and seedling multiplication take longer times than offsets and clump divisions. In case of bamboos having longer intermast periods of 45, 60 and 120 years, a loss of 5–10 years can be acceptable, though with some reduction in the total yield. In these species selection can be done at a later stage, at the age of 5–10 years, when the clumps reach maturity. In bamboos having shorter intermast periods of 7, 15 or 30 years, a loss of even 5 years of the life of a plantation can result in considerable reduction in total yield and make such plantations financially unviable. In these species selection at the seedling stage would be desirable. Hence it is necessary that more phenotypic and molecular markers at seedling stage for faster growth and higher biomass production be identified in all economically important species of bamboos.

At present only natural selection can be done in bamboos. Due to the large size of the clumps, wind pollination and longer intermast periods, coupled with lack of knowledge about their genetics, raising a population combining desired characters/character combinations is not possible. However, the long intermast period can be used advantageously because the selected individuals can be multiplied using a variety of vegetative propagation methods. The plantations raised using selected individuals remain in yield for many years, up to the time they undergo another flowering and seeding (sexual reproduction) necessitating a fresh round of selection.

Propagation methods

Bamboos are propagated by seeds or by a variety of vegetative methods, based both on conventional and modern tissue culture techniques.

The most easy method of bamboo propagation is by means of seeds. Due to their smaller size, they can be easily transported to far-off places. Propagation of economically important bamboo species by seeds is not possible annually because of their very long inter-mast periods. The longevity of the seeds varies from species to species. Under natural conditions it is for 2–3 months. By controlling the moisture contents of the seeds and the storage conditions, it can be enhanced[21].

Conventional vegetative propagation methods are by seedling multiplication, offset and clump division, rhizome cuttings, layering, culm cuttings, pre-rooted and pre-rhizomed branch cuttings as well as branch cuttings and nodal bud chips[22].

Seedling multiplication

Seedlings produce new culms at the age of 30–40 days and develop rhizomes. They attain a 4–5 culm stage around 9 months. At this stage they can be separated into 3 units, each having rhizome, roots and shoots[23]. The seedlings can be multiplied three times for a few years to produce a large number of propagules. This method is useful in selection in almost all species. Seedlings can be raised immediately after seed production. At the age 9–12 months, selection can be done on the basis of phenotypic/molecular markers and be used for raising plantations and in further multiplication.

In recent years methods are standardized for large scale production of bamboo propagules by tissue culture methods[24–30]. Most of these methods are based on micropropagation and somatic embryogenesis using seedling rhizome, seedling nodes and seedling basal nodes as explants. Somatic embryogenesis from inflorescence, immature and mature embryos, seedling sheath and seedling root explants are also employed. Though shoot formation was achieved earlier from mature node, shoot and rhizome explants, rooting could be induced only in a small percentage of the cultures. In recent times there are few reports of successful tissue culture methods for large-scale propagation of bamboos using nodal explants derived from mature clumps of varying ages[31–33].

Tissue culture methods make available large number of plantlets which are identical to their parents from which the explants have been derived. Tissue culture raised plantlets are smaller in size and easy to transport compared to a majority of the conventional vegetative propagules[34].

Rejuvenation by sexual reproduction resets the internal calendar. If such a resetting of the internal calendar is achieved by somatic embryogenesis, it will have a useful application in bamboo propagation[35]. Once methods have been standardized for obtaining somatic embryogenesis from mature explants, this method can be used for large scale cloning of individual superior trees of different species of bamboo, without losing their vegetative growth phase.

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C. K. JOHN
M. S. JOSHI
R. S NADGAUDA
A. F. MASCARENHAS

Division of Plant Tissue Culture
National Chemical Laboratory
Pune 411 008, India

Mineralogy of polymetallic sulphide mineralization in Archaean greenstones at TISK-USGAO, Goa, India

Goa is predominantly occupied by the Archaean supracrustals which are considered to be the northwestern extensions of the Shimoga–Dharwar schist belt. The lithounits constituting this belt in Goa, are included under the Goa Group[1] which comprises four formations. The oldest, Barcem Formation is dominated by metavolcanics at places pillowed with subordinate agglomerates, red tuffs and phyllites. The remaining three formations namely Sanvordem, Bicholim and Vagheri are predominantly composed of metagreywacke-argillites, calcareous-mananiferous- and ferruginous-sediments which are overlain by metagreywacke-metavolcanics. The Anmod Ghat Trondhjemitic Gneiss dated at 3400 ± 140 Ma forms the basement for the supracrustal assemblage of Goa Group[2]. The latter is emplaced by syntectonic Chandranath Granite dated at 2650 ± 100 Ma associated with first cycle of folding[3]. The Goa Group is traditionally correlated with Chitradurga Group of the Dharwar Supergroup[3].

The Tisk-Usgao area is predominantly occupied by metasediments (banded hematite quartzites) and interlayered metavolcanics. These are intruded by a mafic-ultramafic complex[4,5]. A large part of the area has a thick soil and vegetation cover. The metasediments are traversed by a NW–SE trending prominent shear zone which extends over a distance of

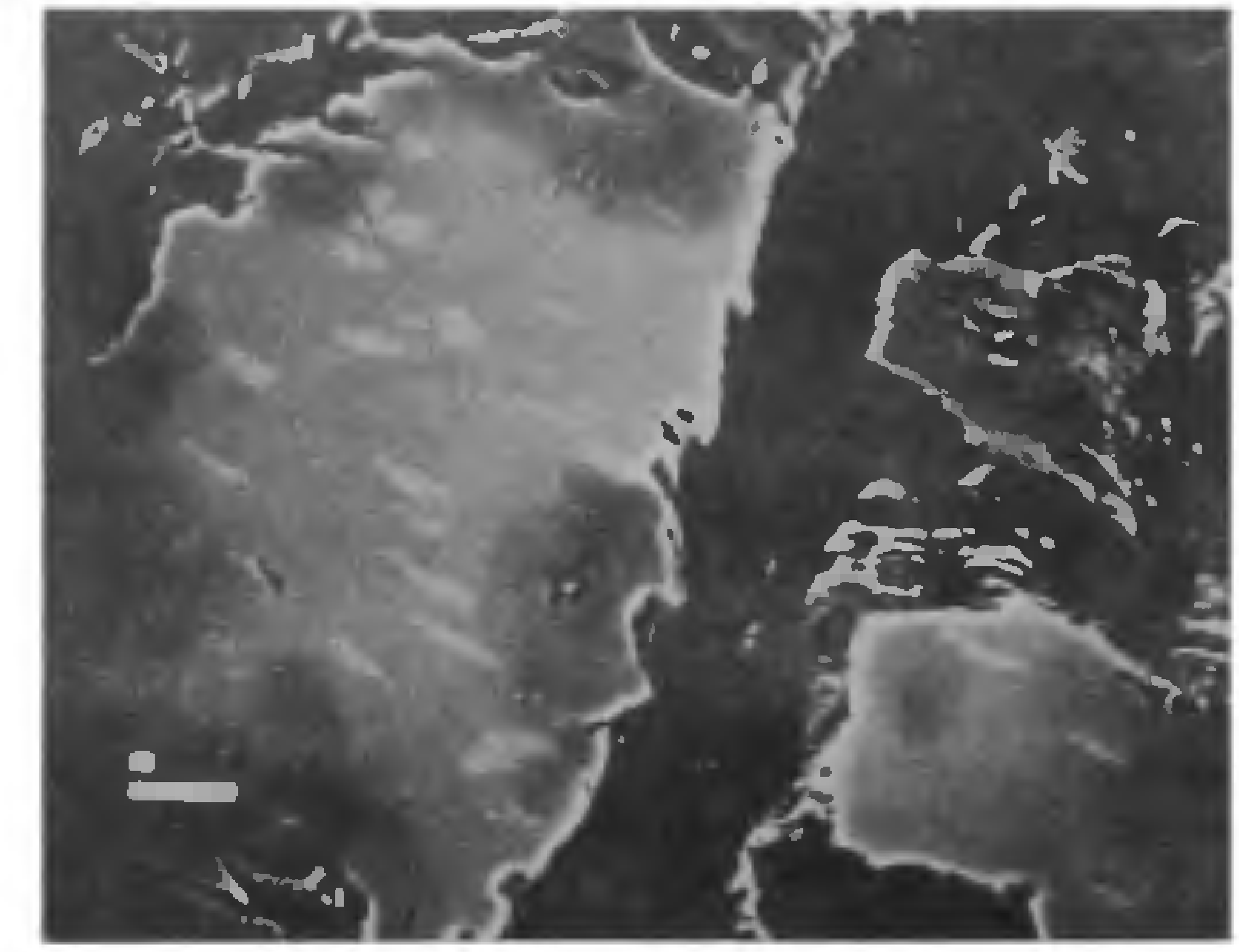

Figure 1. Bright exsolution lamellae of pentlandite in pyrrhotite medium grey intergrown with pyrite darker grey (Bar = 100 μm).