

STUDIES ON THE STRUCTURE AND GROWTH OF BAMBOO BUDS IN THE LIGHT OF THEIR PROBABLE USE IN TISSUE CULTURE

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The long interval of flowering and seeding has made propagation of bamboos very difficult. Offset plantings are not suitable for large scale plantations. Attempts with branch cutting, layering, etc. for propagation showed low percentage of success. Tissue culture has yet to be tried.

The present study showed that rhizome buds are monoprimordial, represented by the cone of rudimentary sheaths only. The food stored in the rhizome and rhizomatous swelling is utilized by their lateral and terminal buds. The root primordia are borne outside rhizome-buds. The culm and branch-buds are multiprimordial. Each structure is similar to the rhizome consisting of root, rhizome and shoot primordia.

The number of primordial structures and their relationship with the breaking of buds, dormancy and continuous growth in various species of bamboos have been investigated, analysed and discussed.

In tissue culture the entire primordial structure might have to be used as a propagule unlike the use of only callus tissue as in the case of dicots.

INTRODUCTION

The important limiting factor in the cultivation of bamboos is the difficulty of obtaining artificial regeneration. Bamboo soils are not easily available due to long interval of flowering and seeding. Till the present time the regeneration of bamboos is carried out by vegetative propagation which involves many problems. For the purpose offsets are used which are bulky, heavy and difficult to handle and transport. A limited supply of the planting material is available per clump and therefore, large scale plantation is not practicable. Studies at the Forest Research Institute (FRI), Chittagong, and other parts of the globe have shown that, successful branch cuttings could be used for the propagation purposes. This would overcome the difficulty of the limited supply of planting material and the volume in transportation. In early stages of this research, Pathak (1899), Lin (1964) and Chinte (1965) failed to draw a distinction between dicots and monocots. Pathak (1899), Debral (1950), Lin (1964), Chinte (1965) tried culm sections in the same way as are used in sugarcane. Their studies were made on a limited material for a short period and just by observing, the sprouting, they drew the conclusion that bamboos could be propagated easily from culm segments. Similarly Cabanday (1957) tried ground-and air-layering of culm and culm-buds and reported good percentage of success in a few species. However, such propagules soon die out after planting in the field. A clone is not suitable for planting in the field unless

rhizomes are formed and new shoots start emerging. Abeels (1961) tried branch cuttings and came to the conclusion that the planting medium was of little significance as long as the swollen basal portion of branch was present. McClure and Durand (1951) pointed out that for striking of roots, the basal buds are slow to sprout and during this time many of the planted materials die resulting in low percentage of success. Hasan (1977) showed that a branch cutting takes 6 to 30 months to develop into a good planting material. Roots may develop in 6 to 12 months but the time for development of rhizome takes 12 to 36 months. The planted materials start dying before the development of root and also in the intervening period between root and rhizome development. He also observed that use of humidity tents prolonged the life of cuttings but did not improve the rooting. White (1974) pointed out that root promoting substances, at the usual concentrations, have no effect on bamboo rooting. The advantage of branch cutting over offset is its ease in transportation, though it is not simple to raise. The percentage of success, however, was low. The difficulty of obtaining satisfactory results with all known methods of vegetative propagation with or without root promoting substances together with the long period of waiting (30 to 36 months) cannot be said to be either easy or economic.

However, tissue culture has remained untried. In dicots and conifers excised embryos and fragments of seedlings appear to develop callus and plantlets in culture media

readily ; but callus material taken from older parts need more complex treatment. Inductions of bud and root on cotyledonary tissue and primary needles of pine has been reported by Sommer and Brown (1974). In these trials cotyledonary tissues and primary needles of pine treated in culture media became vigorous enough in 12 to 14 weeks to be transplanted to soil for continued autotrophic development. Callus tissue cultures have been successfully established from nodal segments of seedlings of *Eucalyptus grandis* by Cresswell and Fossard (1974). However, the whole operation of getting plantlets from tissue culture taken from older parts need several stages and many chemicals. Fossard (1974) reports that in some species of *Eucalyptus* addition of 2,4-D or a combination of indole acetic acid and kinelin induced formation of roots from undifferentiated callus. Durzan and Papushanski (1975) observed that in *Ulmas americana* cell suspension cultures transferred on agar and other similar media during one-month period produced shoot, but maintenance of high auxin concentrations produced root but no shoot.

Tissue culture has never been tried with bamboos. It is apparent that the branches in bamboos have the advantage of having root and rhizome primordia (Hasan 1977). The development of rhizome ultimately results in the development of new shoots. In bamboo the meristematic zone is localized to the bud. These structures are likely to give better result than those of either dicots or conifers. It is, therefore, necessary to

study the structure of the buds bamboo thoroughly before taking up its tissue culture.

MATERIALS AND METHODS

Studies were made on bamboo clumps growing in the FRI Abooretum,, Chittagong. These clumps were raised during 1972 to 1976. Clums of each year were marked. Culm-buds were taken from culms of different ages. A scalpel was pushed around the margin of the bud to make a continuous cut. The scalpel was then pushed behind the bud from the upper end to cut the bud from behind. When this cut reached the cut made earlier at the base of the bud, the entire bud came out easily. Rhizome were exposed by digging the soil and the buds were removed from the rhizome in a similar way. The buds were taken from 19 species and two varieties of bamboo. The removed buds were dissected in the laboratory and drawings were made.

OBSERVATIONS

Rhizome buds : On a bamboo plant, buds are borne on the nodes of rhizomes, culms and branches. The rhizome-buds are slightly different from the culm-and branch-buds. All rhizomes have two rows of 4 to 10 lateral buds on alternating nodes and a terminal one (Fig. 1). The lowest bud is the largest. The size of the buds reduces in the ascending order. In longitudinal section the rhizome appears as a thick-walled bony shell (Fig. 1) enclosing long fibres and food materials. The lateral buds are set in depressions of the shell

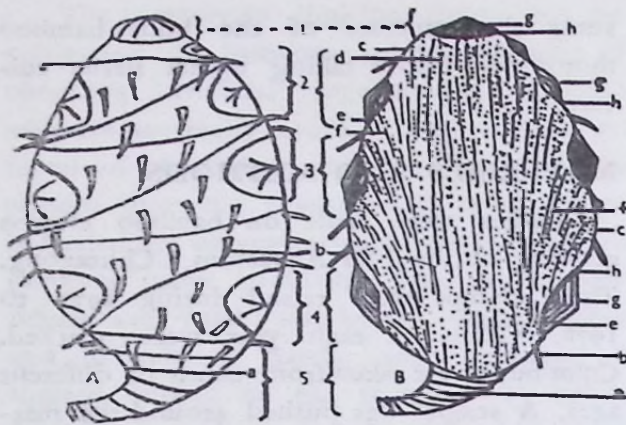


Figure 1. Drawing of a rhizome with all sheaths removed (A) and Longitudinal section through a rhizome showing position and inner structure of buds (B) detailing terminal or culm-bud (1), lateral or rhizome-bud (2-4), rhizome stalk (5), rhizome node (a), root stubs (b), rhizome wall (c), food material inside the rhizome (d), hole in rhizome wall through which the vascular system passes to the bud (e), vascular supply system in the rhizome (f), cone of sheaths of bud (g), and meristematic disc (h)

with a small hole at the bottom through which the vascular system is connected to the bud. All buds on the rhizome are circular to oval in shape, flat to bulging and yellow with an intramarginal apex. The inner structure of all the buds on a rhizome is identical but different in behaviour. The terminal bud produces the culm while the lateral buds produce only rhizomes. The basal nodes of each branch are swollen with internodes which are much broader than long and bear four to six buds on alternate nodes. This part is morphologically similar to the rhizome and so has been referred to as rhizomatous swelling of branch bases. The inner structures of the buds on the rhi-

zome and the rhizomatous swelling are similar and the roots are borne outside the buds. In longitudinal section the buds appear as rudimentary sheaths folded in a cone-like fashion and arranged one above the other. In this way each bud on the rhizome and rhizomatous swelling of basal nodes of branches is monoprimordial.

Culm-and branch-buds : These are borne in depressions nodes and vary greatly in size and shape from species to species and even from culm to culm. These consist of two to four dormant prophylls of varying sizes and shapes with a marginal to intramarginal apex.

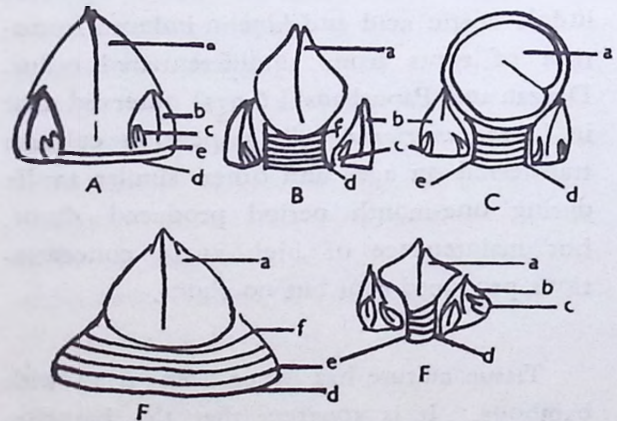


Figure 2. Dissected culm-buds of bamboos showing arrangement of primordial structures within, detailing central primordial structure (a), lateral primordial structure in axil of first two prophylls (b), primordial structure of second order (c), node of first prophyll (d), node of second prophyll (e), node of stalk of rhizomatous swelling without any primordial structure in the axil of the prophyll (f)

The inner structure of culm-buds in all species is more or less the same. On removal of the first prophyll, a bud-like primordium is found in its axil. Similarly, on removal of the second prophyll the same kind of primordial structure with prophylls and other components can be seen (Fig. 2). This is followed by a few prophylls without any primordial structure in their axil. In some species such as *Bambusa arundinacea* and *Dendrocalamus strictus* the primordia in the axil of the first and the second prophylls are absent (Fig. 2). In most of the other species primordial structures of the second, third and subsequent orders may be seen (Fig. 2) in the axil of the prophyll of the respective primordial structures. The arrangement of the primordial structures is cymose. The lateral primordial structures are found with the central ones. Each lateral primordial structure in turn, has a second order of two subsequent primordial structures just below them. The second order also has two similar primordial structures and so on. Subsequent orders of primordial structures have diminished in sizes in relation to the central one and consequently end up in microscopic primordia which develop later.

In each primordial structure in the culm-bud the development of component parts into branch-sheath occurs after the bulbous swelling of the basal nodes of the branch and the stalk are completed. This somewhat

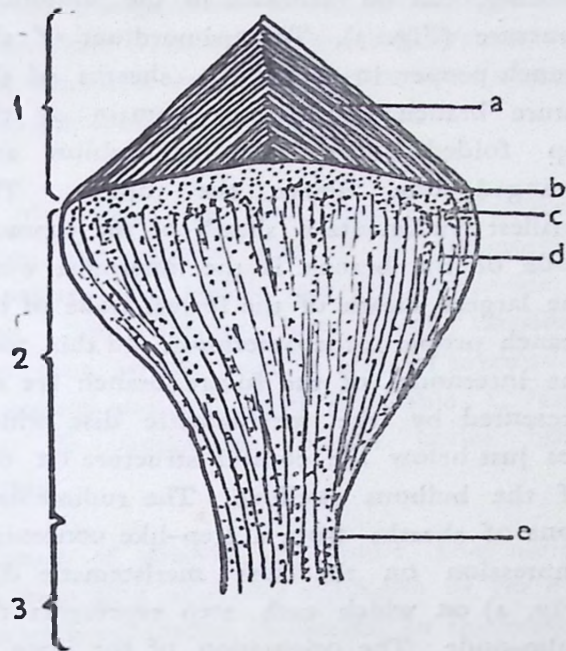


Figure 3. Schematic drawing of a longitudinal section through the central primordial structure showing partly differentiated primordium of branch (1), partly differentiated primordium of rhizomatous swelling (2) and well developed primordium of the stalk of rhizomatous swelling (3); detailing rudimentary branch sheaths folded in cone-like fashion (a), meristematic disc (b), tightly packed food in the rhizomatous swelling (c), the food gets thinner lower down, vascular supply system to the bud (d), and remains of the nodes of the stalk of the rhizomatous swelling (e)

differentiated primordial structure takes the form of a bud with all component parts such as prophylls, marginal cilia, etc. This primordial structure is very similar to that of the underground rhizome. Three different zones of the branch—the branch proper, the swollen basal nodes or the rhizomatous swelling and the stalk of the rhizomatous

swelling, can be identified in the primordial structure (Fig. 3). The primordium of the branch proper in which the sheaths of the future branch are formed remain at the top folded in a cone-like fashion and arranged one above the other. The smallest rudimentary sheath of the topmost node of the branch is the innermost while the largest sheath of the lowest node of the branch proper is the outermost. In this zone the internodes of the future branch are represented by the meristematic disc which lies just below the conical structure on top of the bulbous swelling. The rudimentary cone of sheaths from a step-like concentric impression on the soft meristematic disc (Fig. 4) on which each step represents the culm-node. The orientation of the cone of the rudimentary sheaths depends on the location of the apex of the bud. In species where the apex is marginal the orientation is vertical and in cases where the bud has an intramarginal apex the cone is oriented horizontally (Fig. 2). The second zone of the branch, the rhizomatous swelling, is also preformed and is represented by the bulbous swelling at the bases of the rudimentary sheaths. On this part the nodes with their sheaths are well defined but no buds or root primordia outside the bud are formed. The third zone, the stalk of the rhizomatous swelling, is also well defined where the nodes and the accompanying sheaths are well formed. The sheaths on the stalk of the rhizomatous swelling and the rhizomatous swellings itself are larger than the rudimentary sheaths of the branch and

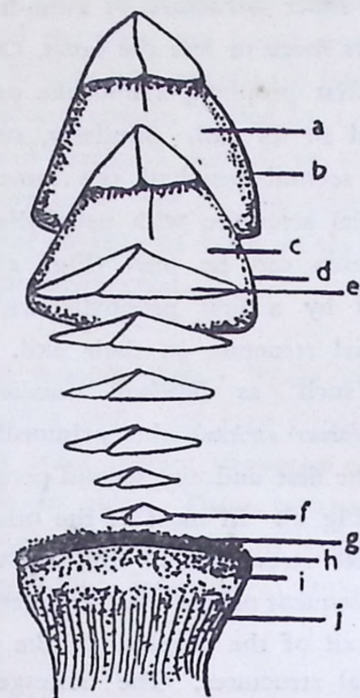


Figure 4. Schematic drawing of the adaxial side of a dissected culm-bud showing prophyll of first node (c), junction of prophyll with culm-internode (b), prophyll of second node (c), junction of prophyll with culm-internode (d), outermost rudimentary branch-sheath folded in a cone-like fashion (e), innermost rudimentary branch-sheath (f), step-like impression left by rudimentary branch-sheaths on the soft tissue of the meristem which form the rudiments of nodes and internodes (g), meristematic disc (h), tightly packed food in the rhizomatous swelling (i), and vascular supply system to the primordial structure (j). Branch sheaths e-f fit into each other and are located within the keels of the first two prophylls

cover the entire primordial structure; thus indicating a dual function of protecting the microscopic primordium of the future bud in

their axil and also serving as scales of the primordial structure, as a whole.

A schematic diagram of the longitudinal section through the central primordial structure has been drawn (Fig. 3). The primordial structure of the second, third and subsequent orders were not dissected for study because these were small and difficult to handle. The arrangement of the parts of the primordial structures can better be understood from a schematic diagram of the adaxial side of dissected bud (Fig. 4).

Number and size of primordial structures in culmbuds : From the point of view of the number of primordial structures in a culm-bud, bamboos can be classified into four groups (Table 1). Odd number of primordial structures is usual in each species. From Table 1 it is evident that some species occur in more

than one group. Three, five and seven primordial structures were recorded in different varieties of *D. longispathus*. In *N. dullooa* three and seven and in *O. nigrocilata* three and five primordial structures were observed. In other species such distributions were not found.

Two types of buds can be identified when the relative size of the primordial structures in a bud is taken into consideration. The species have been classified according to the relative size of primordial structures and are listed in Table 2. Here also *D. longispathus* occurs under both types.

Nature of growth of buds : The nature of branching after the activation of the bud varies from species to species. In this respect bamboo species can be classified into four

Table 1. Number of primordial structures within the bud in bamboos

No. of primordial structures	Species
1	<i>Bambusa arundinacea</i> , <i>Dendrocalamus strictus</i>
3	<i>Bambusa langispiculata</i> , <i>B. vulgaris</i> , <i>Cephalostachyum pergracile</i> , <i>Dendrocalamus Longispathus</i> var <i>Dholai</i> , <i>Neobauzeana dullooa</i> , <i>Oxytenanthera nigrocilata</i>
5	<i>Bambusa burmanica</i> , <i>B. oliveriana</i> , <i>B. nutans</i> , <i>Dendrocalamus longispathus</i> var <i>Koila</i> , <i>Oxytenanthera nigrocilata</i>
7	<i>Bambusa multiplex</i> , <i>B. polymorpha</i> , <i>Dendrocalamus calostachyus</i> , <i>D. giganteus</i> , <i>D. longispathus</i> , <i>Melocanna bambusoides</i> , <i>Neobauzeana dullooa</i> , <i>Thyrsostachys oliveri</i>

Table 2. Relative size of primordial structures within culm-buds in bamboos

Relative size of primordial structures	Species
Sub-equal	<i>Dendrocalamus longispathus</i> var <i>Koila</i> , <i>D. longispathus</i> var <i>Dholai</i> , <i>Melocanna bambusoides</i> , <i>Neobambusa dullooa</i>
Central one more than twice the size of the lateral ones	<i>Bambusa burmanica</i> , <i>B. langisipulata</i> , <i>B. multiplex</i> , <i>B. nutans</i> , <i>B. oliveriana</i> , <i>B. polymorpha</i> , <i>B. tulda</i> , <i>B. vulgaris</i> , <i>Cephalostachyum pergracile</i> , <i>Dendrocalamus calostachyus</i> , <i>D. giganteus</i> , <i>D. longispathus</i> , <i>Oxytenanthera nigrocilata</i> , <i>O. albocilata</i> , <i>Thyrsostachys oliveri</i>

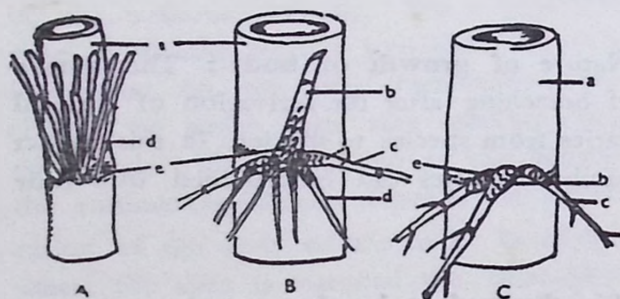


Figure 5. Branch complements showing pleio-clade (A), trioclade (B) and trioclade without small branches (C) detailing internode (a), largest central branch (b), medium lateral branch (c), small branches (d) and basal rhizomatous swollen nodes of the branch (e)

groups (Table 3). In species like *M. bambusodes* and *N. dullooa* a dense tuft of similar subequal branches appears at all nodes. The central and other branches are indistinguishable by size (Fig. 5). Bamboo species falling under this type have been included in group 1, Table 3. In most of the other species the central branch appears at first and lateral branches are very unequal and

remain dominant. Subsequent branches have progressively diminished in dimensions (Fig. 5). These have been referred to as small branches in Table 3. In trioclade branch complements the replacement or augmentation of damaged or deciduous branches is through these small branches.

The number of branches in a branch complement on culms of a given age is fixed. Table 3 gives the count on one- to two-year old culms. It appears from table 3 that some species have pleio-clade branch complements on all nodes while in some others namely, *D. giganteus* and *O. nigrocilata* the nodes below the mid-culm region have pleio-clade and those above have trioclade branch complements. In case a culm is damaged or broken at top, all nodes including those at the base, produce trioclade branch complements. In *B. arundinacea* the development of branches is variable. On some nodes only the

central branch develops while on others both the central and the lateral branches develop but no small branches normally appear (Fig. 5). In other species like *C. pergracile* and *D. strictus* no small branches develop on some nodes while other nodes may have varying number of small branches. In most of the other species branch complements consist of one central, two lateral and varying number of small branches.

Order of breaking of buds : The starting point of breaking of culm-buds, in species where it is acropetal, is either from the mid-culm region or from one of the lower nodes. Similarly, in species with basipetal breaking of buds, as in *B. oliveriana* and *D. calostachyus*, it is continuous upto the base, while in *B. polymorpha*, *B. vulgaris*, *D. longispathus*, *M. bambuosoides*, *N. dullooa* and the two species of *Oxytenanthera* it stops somewhere in the middle and either remains so for a long time or may proceed, breaking a few buds annually, to the base. In *B. polymorpha* the case is somewhat different. In one of the varieties the culm-buds below the mid-culm region are either poorly developed or remain underdeveloped and therefore no breaking of buds normally occurs. In the variety of this species the breaking of buds is acropetal and starts at the base.

The order of breaking of culm-buds in bamboos is given in Table 4. It is clear that most of the species are restricted to one group. *B. polymorpha*, however, occurs

in three groups and *B. vulgaris*, *C. pergracile*, *D. calostachyus*, *D. longispathus* and *D. strictus* occur in two groups.

D. giganteus and *O. nigrocilata* appear to belong to a completely different class where the breaking of buds is centripetal but the lower half of the culm behaves differently from the upper half, as far as, the size of the components of the branch complements is concerned. In these species the lower half of the culm produces pleioclade branch complements and follow a centripetal succession of breaking of buds while the top half produces markedly trioclade branch complement and proceeds basipetally.

DISCUSSION

The investigation reveals that the so-called primordia in bamboo rhizome-and culm-buds have partially preformed parts. Generally, all primordial structures take the form of a bud. There are six to ten lateral and a terminal bud on the rhizome (Fig. 1). All these buds are represented by the cone of rudimentary sheaths and appear mutually to share the food stored in the rhizome. Thus all rhizome-buds are monoprimordial. Similar is the case with the rhizomatous swelling of the basal nodes of branches. In the primordial structure of culm-buds, only the terminal cone of rudimentary sheaths is formed and other parts such as the root primordia on the internodes and the lateral cones, which develop into rhizome-like structures under suitable conditions, probably,

develop later with the branch-buds, in the axil of the rudimentary sheaths. On a fully developed branch, well formed buds and root primordia outside the bud are found on the rhizomatous swelling. The cone of sheaths representing the lateral buds of the rhizome as the primordium of the stalk of the future rhizome and the actual bud of the rhizome develops when the internodes on the rhizome stalk are about to complete their growth (Hasan 1978). Probably, similar is the case with the rhizomatous swelling of the basal nodes of branches. In the first phase the stored energy is used up by the terminal bud to develop into a culm in the rhizomes and again by the branch in the primordial structures. Later, energy from the same source is used for the development of lateral buds to form rhizomes. In the case of branch, energy is drawn only under exceptionally suitable conditions and secondary branches are formed only through a rhizome-like structure.

The culm-buds are multiprimordial. It is evident from Figure 3 that in individual primordial structures of culm-buds all the major components of a branch are represented in one form or the other. The rudiments of the stalk of the rhizomatous swelling are represented by the nodes without primordia, at the bottom of the bulbous swelling. The rhizomatous swelling of the branch bases is represented by the bulbous swelling above it, and the terminal branch-bud by the cone of rudimentary sheaths above. The stem of the branch is included in the disc of meriste-

matic tissue at the base of the cone of rudimentary sheaths. In the step-like concentric impressions on this disc, the nodes are represented by the steps themselves and the tissue between two steps represents the internode.

It is clear from earlier works that the shoot growth in grasses particularly the bamboos is intercalary instead of being terminal, (Tomar 1963, McClure 1967). Excepting the terminal bud of the rhizome and the rhizomatous swelling, there are no other terminal buds and the growth in length is caused by the successive elongation of the internodes. The growth of individual primordial structures starts from the centre of the cone-like structure and proceeds outwards. As a result, the smallest central rudimentary sheath comes out first and becomes the topmost node and the largest outermost rudimentary sheath becomes the lowest node just above the rhizomatous swelling of the branch. At first, the meristematic activity spreads over the entire node and as the elongation of the cells goes on to form the internodes, the nodes are separated and the meristematic tissue shrinks ultimately being restricted to the bud. No other part of the fully grown branch has such a property. The growth of the culm and distribution of the meristematic tissue are identical.

The individual primordial structure specially the bulbous part is similar to rhizome. The cone of rudimentary sheaths which is the topmost one is similar to the terminal

bud of the rhizome. The stalk of the rhizomatous swelling, the lowest one, is similar to the stalk of the rhizome in bearing large sheaths that cover the entire structure but do not have any bud in their axil. The internodes on the bulbous swelling itself, like those of the rhizome are much broader than long and the nodes bear sheaths covering entire primordium. During the time of examination lateral bud did not develop on the nodes of the primordial structure. However, the root primordia outside the bud could be seen on them. These buds, like the lateral buds of the rhizome, are similar to the terminal bud in having only the cone of rudimentary sheaths and thus apparently are structures that may be referred to as monoprimordial. The food stored in the rhizome and the bulbous swelling of the primordial structure is apparently a common source of energy for all the cone-like structures on the rhizome and the rhizomatous swelling. The similarity between the underground rhizomes and the branch bases in their morphology, physiology and functional behaviour has been demonstrated by Hasan (1977). From the present study of the structure of the bud the similarity also becomes clear from the point of view of their development. Porterfield (1930) pointed out that the first appendages to appear behind the apex of growing point of grasses is the sheath. Next to develop is the primordium of the buds which are subtended by each sheath. It seems probable that the primordial structure in bamboo culm-buds are preformed upto the sheath stage and the primordia of the branch- and rhizome-buds

still remain in the unicellular or microscopic stage. Unless the subsequent primordia are formed the root primordia normally borne on the internodes remain as a part of the bud.

The bamboo culm-buds, like many other grasses, are multiprimordial. Sharman (1942, 1947) has divided the grasses of several genera into three groups on the number of primordia in the growing point. From this study, upto seven primordial structures have been found in bamboo culm-buds. In species like *D. longispathus* three, five and seven ; in *N. dulloa* three and seven and in *O. nigrocilata* three and five primordial structures have been recorded in different samples. This is probably due to the different stages of development at which the buds were collected for observation. It is clear that in these species the branch complements consist of 19 to 20 components in the first two and 6 to 11 components in the last mentioned species (Table 3). It may, therefore, be suggested that the buds found with fewer primordial structures were still in the developing stage. The buds swell as the number of primordial structures increase ; when the maximum is reached, the prophylls are forced apart. Consequently, the buds break and due to the exposure to light, the chlorophyll is formed and the branch complements start growing rapidly. In dormant buds, the rate of increase of primordial structures is slower and these break only when the maximum number of primordial structures are reached. This may also occur as a result of strong stimulants forced by decapita-

tion, etc. Porterfield (1933) suggested that this outward manifestation of breaking of buds, at different times on different nodes, is the result of internal physiological processes that operate through biochemical gradients. Discrete steps may probably manifest partially in the first year and completely in the subsequent years.

In addition to the number of primordial structures (Table 1) the species of bamboos also show differential relative sizes of primordial structures in the mother bud and the species have been grouped accordingly (Table 2). In some species and varieties such as *M. bambusoides*, *N. dullooa*, *D. longispathus* var *Koila* and *D. longispathus* var *Dholai* the primordial structures on all the nodes are more or less of equal size. The same species exhibit small branching type and no distinction can be made in the sizes of the branches (Table 3). *D. gigantens* and *O. nigrocilata* have been included in the class where the central primordial structure is more than twice the size of the lateral ones. Yet the nodes below the mid-culm region are found to develop subsequel branches while those above the mid-culm region have branches of different sizes. The order of breaking of the buds is, therefore, so important. However, there is a marked relationship between the size of the primordial structure in the bud and the size of the branches in the branch complements. The differences in size of the primordial structures appear to be connected with varietal differences and not much with species. The central

largest primordial structure develops into the central largest branch and the lateral companion primordial structures develop into relatively smaller lateral ones. The primordial structure of the second, third and subsequent orders produce still smaller branches.

The number of branches in a branch complement does not appear to be the same as the number of primordial structures in a bud (Table 1). The number of branches is always much more than the number of primordial structures. This is probably due to the fact that the arrangement of the primordial structures, both visible and microscopic, is cymose and therefore the appearance of smaller branches is continued for the augmentation and replacement of branches after they are dead or fall due to their deciduous habit.

The affinity in the succession of breaking of buds appears to be connected more with provenance or varieties than with species. Most of the species exhibit the acropetal or basipetal succession. But in the case of acropetal succession the starting point is not always the base but anywhere in the middle, and therefore, has to be grouped seperately (Group 2, Table 4). Takenouchi (1931) made similar observations in the case of Japanese bamboos. The dormant buds below the node, during the first breaking burst basipetally over successive years, bursting only a few annually. These species may be termed as 'staggeringly centrifugal' where only the lower half has the staggering break-

ing of buds and the upper half completes the breaking along the culm in quick succession. Similarly, in species with basipetal breaking of buds the bursting stops somewhere in the middle of the culm and may either remain as such or proceed downwards, breaking only a few annually. These may therefore, be subdivided into 'basipetal proper' and 'staggeringly basipetal'. *B. polymorpha* is, however, an exception in this respect. In one of the varieties of this species culm-buds at the lower nodes are either poorly developed or remain undeveloped and, therefore, the breaking does not proceed downward. *D. giganteus* and *O. nigroclata* are different from all the other species. Here the culm is divided into two halves. The lower half of the culm produces pleioclade branch complements and follows a centrifugal succession, while the upper half produces markedly trioclade branch complements and proceeds basipetally. The larger primordial structures are not present in buds on the lower nodes, due to some reasons not known yet. However, these structures are not activated at the lower nodes and the growth is limited to the smaller primordial structures only. Both the species are centripetal in this behaviour (Table 4). If considered from the point of view of a period of two to three years of the life span of a culm all the species grouped under 2, in fact, belong to group 4. Porterfield (1933) pointed out that the external form of homologous parts of a bamboo culm varies with their respective positions. These differences in outward form reflect the underlying physiological process that may

operate through biochemical gradients, as well as, by discrete steps. A distinction has, therefore, to be drawn between the physiological mid-culm and physical mid-culm region which may not really coincide. The node on which the first bud breaks is the physiological mid-culm and the point where the culm can be divided into two equal halves is the physical mid-culm. The physiological mid-culm is the region where the biochemical gradient starts or stops and proceeds downwards or upwards.

It has become clear from earlier discussion that the individual primordial structures are the miniature rhizomes. The rhizome-bud is represented only by the primordium of the rhizome stalk and the root primordia are borne along the internode outside the bud (Fig. 1). It is, therefore, only the culm- and branch-buds that can be used for vegetative propagation as these include root, rhizome and shoot primordia within the bud and also include a disc of meristematic tissue, the essential parts that form a bamboo clump. Like embryos, buds have a period of dormancy and consist of primordia of all the structures of the whole plant. Shoots emerging from buds can be taken equal in age of a seedling and can be conveniently used as material for vegetative propagation. This was demonstrated in Teak by Hussain *et al* (1976) where buds from selected clones of Teak were nipped of stock stumps and grown successfully in polythene bags in a green house, with artificial cooling and mist spraying. Older parts of this species did not develop

roots under any circumstances. This behaviour is similar to the results obtained with excised embryos and fragments of seedlings of Pines and *Eucalyptus* in culture media.

It appears that in bamboos the whole primordial structure may have to be used for tissue culture which is in contrast with dicots, where the callus tissue is used. Hasan (1977) in his trials on the vegetative propagation of bamboos, by branch cutting, has termed the branch as a miniature culm because of morphological, physiological and functional similarity between the two. In a culm the underground rhizome is the pivotal point and in the branch, though it is not apparent, the rhizomatous swelling of the basal nodes of the branch is the most important part. In a fully developed branch this swollen part produces roots and rhizome-like structure spontaneously under certain conditions. Although the direct use of branch cutting with the swollen basal nodes gave poor results there are possibilities that the use of primordial structures in tissue cultures might give better results as the root, rhizome and shoot primordia are not fully developed and the outer walls of the primordium are soft and thin-walled. The use of stimulants may help in their proper differentiation. However, in tissue culture trials, the entire primordial structure have to be used, as the root and rhizome primordia are located on the bulbous swelling in the middle of the structure. The terminal structure is also necessary for the development of the shoot. The differences in the size of primordial structures and their position on the

cymose arrangement will automatically form important variables in such trials.

CONCLUSIONS

Bamboo culm-buds are the only organs where the meristematic activity is found and these are the only organs that can be used for vegetative propagation. The primordial structures in a culm-bud are partly preformed and root, rhizome and shoot primordia are separated on different parts. Therefore, in case of bamboo, a monocot, it is necessary to use the entire primordial structure as a propagule, unlike the use of only callus tissue as in case of dicots.

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