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Vegetative Propagation Techniques for Bamboo Species: A Review

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ABSTRACT

Bamboo has been used in many ways for food, building materials, artifacts and raw materials for production of pulp and paper products. As the destruction of natural bamboo resources increased the gap between the demand and supply of bamboo, there was a need to find suitable methods for large scale propagation of bamboo. Many researchers have worked towards achieving this goal, and the same are reviewed here. Vegetative propagation/ macro propagation is simple, easy, cost-effective, and involves the use of locally available materials. It is highly useful for sustained production of field plantable bamboo saplings in large numbers rapidly, perpetually and plentifully for any desired number of years depending upon the targets and the facilities available. It has also paved the way to many new avenues in the field of bamboo research. It is highly flexible as the mass propagation of bamboos can be undertaken from offsets, layering, culm cuttings or branch cuttings, and also extended to micropropagation through tissue culture techniques.

HIGHLIGHTS

- Vegetative means can be employed for producing clonal planting material of bamboos, to meet demands for its multifarious uses, in the absence of seeds.

Keywords: Macropropagation, bamboos, culms, offset cuttings, rhizome

Bamboo belonging to the family of grasses, Gramineae (Poaceae), is a woody perennial with unique qualities. It is a non-timber natural resource, which is renewable and self-regenerating; once established, bamboos are fast growing and self-sustaining. It is a multipurpose plant with numerous applications including construction material, furniture, fence, handicraft, pulp and paper, edible shoots and animal fodder (Kebede 2017). Their excellent splitting ability, tensile and compressive strength, and amenability of being harvested within 4-5 years after planting, makes bamboos very versatile. Endowed with a large number of bamboo species, India is one of the world's largest reserves of bamboos. There are 75 genera and 1250 species of bamboo throughout the world (Soderstrom and Ellis 1987) and India is second after China in bio-resource of bamboo. There are about 125 indigenous species and 11 exotic species in India. 8.96 million hectares of the 63.3 million hectares of forest land in India is covered by bamboo. This vast genetic resource of bamboo provides scope for selection of economically and industrially important species for propagation and improvement.

Being monocarpic in nature, the seeds of bamboos are always in short supply and difficult to store. Vegetative propagation methods are used for planting stock production in the absence of seeds. In macropropagation, conventional methods of offset planting, rhizome planting, rooting of cuttings

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and layering are used (Seethalakshmi 2015). These methods suit farmers due to their low cost and ease of management. Being monocarpic, flowering and seed setting in bamboos are accomplished at very long intervals. The length of flowering cycle varies from 10 to 60 years depending upon the species. Usually, the flowering is either gregarious or sporadic after long flowering cycle. Also, the possibility of raising bamboo plantation from seeds is limited and difficult, as most of the bamboos die after flowering. However, bamboos can be propagated through conventional vegetative methods, though seeds are not available most of the time (Seethalakshmi *et al.* 2008).

PROPAGATION OF BAMBOOS

Because of its multipurpose utility, the demand for bamboo is increasing gradually. Bamboo resources are being depleted fast in the region due to increasing demand and consequent overcutting. The demand is being met by shortening the felling cycles in the shifting cultivation system largely prevalent in the bamboo rich areas. As a result, our native resources are greatly threatened and needs immediate attention for their conservation. Propagation of bamboos can be carried out by reproductive method or vegetative method. Reproductive method involves the use of seeds for producing new bamboo plants, while the vegetative method makes use of rhizomes, culms and branches, which are vegetative parts (Ray and Ali 2017).

Seed Propagation

This method is very rarely used because of the rare and irregular flowering of most bamboos observed locally which produce infertile seeds or seldom develop seeds. This is the best method of propagation for bamboos when seeds are available, as the clump age would be known at the initial stage of its life cycle. Seeds formed after gregarious flowering can be collected, cleaned and stored for 6 months to more than a year employing special storage techniques like controlled moisture, low temperature etc. Apart from gregarious flowering, bamboos are also seen to flower sporadically in one or two clumps here and there. Such flowering is useful to obtain seeds for nursery trials. The seeds of *Dendrocalamus hamiltonii* and *Bambusa bambos* resemble wheat, and *Schizostachyum fuchsianum* seeds are bigger than peanut, whereas the seeds of *Melocanna baccifera* are large as a small apple. Since the viability of bamboo seeds is lost gradually, it is advisable to sow them immediately. Seeds are sown in mother beds with overhead shade, either broad casting or in lines. A thin layer of soil is used to cover the seeds and regularly watered. Seeds begin germination in 3-7 days, which will continue upto 15-25 days. Seed size varies from species to species. At three leaf stage, the seedlings can be transplanted to poly-pots. Initially, the transplanted seedlings are kept in partial shade for a month and then transferred to open beds. They need to be watered regularly, except during rains. Seedlings must be locally shifted after 3 months to avoid root penetration, and can be used for plantation when 6 months to 1 year old. Availability of seed after long time intervals, poor seed viability, and lack of suitable storage facilities, occurrence of highly heterogeneous seedling populations, and often poor overall seed set and their consumption by wild animals are the major limitations of using seeds for bamboo propagation. Therefore, propagation through seeds cannot be relied on for mass multiplication on a sustainable basis. Hence, there is strong need to explore the possibility of vegetative propagation for mass multiplication of bamboo. (Ahlawat *et al.* 2002; Banik 1987; Ray and Ali 2017).

VEGETATIVE PROPAGATION

Vegetative propagation of bamboo involves using part of the parent plant to produce a new plant. There are several ways of accomplishing vegetative propagation including culm cutting, branch node cutting, whole culm burial, rhizomes or offsets, layering, macro proliferation and tissue culture. The following is a brief account on the different methods of vegetative propagation for bamboos.

Rhizome (offset) based propagation

Vegetative propagation by rhizome or offset is an age-old method. Though this is a traditional and most commonly used method of bamboo propagation, it is practical for cultivating few clumps only, particularly in small and accessible regions. Offsets or rhizomes are conventionally used for propagating sympodial bamboos. An offset is the basal portion of a single culm to which the rhizome axis and roots are attached. The propagating

material in this method is whole rhizomes or portions, each with single culm having three to five basal nodes (called offsets). Preferably 1- to 2-year-old culms from the peripheral portion of a clump are selected for offset planting, and cut at 1.0 - 1.5 m height. The culms are cut in a slanting manner with two to three nodes left at the base, or right above the node without damaging the basal portion of the branches. The rhizome attaching the culm is dug and cut 30 to 45 cm from the ground. The rhizome and roots attached must not be damaged when collecting the offsets, and the buds must also remain intact. The underground parts of the offset should be wrapped with moist substratum like banana stem, coir or gunny bag to avoid drying, in case of delayed planting due to transportation. These offsets can be planted in pits in the field, or alternatively potted in medium-sized gunny bags. The culm top should be covered with polythene bag and cavity filled with water to prevent drying in field. Alternatively, covering the cut end using soil - cow dung mix is also practiced (Seethalakshmi 2015; Ray and Ali 2017).

Offsets can be planted during the pre-monsoon showers or just before the beginning of the rainy season. They are collected during summer season, just two or three months before planting. The buds are liable to be damaged if collected later, as new sprouts are produced during this season. When required, watering has to be done during the dry period. During prolonged dry weather, daily watering is required in new plantations. In general, the success of offset planting in thin-walled bamboos is relatively poor and differs significantly between species. Bamboos with large culm diameter require larger rhizomes for planting. The use of rhizome for propagating bamboo has been limited mostly to non-clump forming species. However, mother plant collections of suitable species can be established initially using this method. The bulky offsets, and labour-intensive extraction and transportation are the major limitations of this method. They are also prone to desiccation, are season dependent and have a low survival rate, due to limited availability and a low regeneration capacity. Also, the number of offsets available per clump is limited to one or two, and hence, the method is not feasible for raising large-scale plantations (Islam *et al.* 2011; Razvi *et al.* 2011; Mudoi *et al.* 2013; Singh *et al.* 2013). *B. balcooa* is commonly propagated by culm cuttings, but root induction and development are limited to only 40-60% success (Gillis *et al.* 2007). Pattanaik *et al.* (2004) reported 66% of root and rhizome induction by two-noded cuttings.

Layering

For layering, a whole culm or a branch bearing part of the culm is brought in contact with a rooting medium when it is still attached to the mother plant. The branch is bent down to the ground so that the nodes are pegged into the soil. Roots develop from the nodal regions, which are then separated and planted in polybags for hardening (Seethalakshmi and Kumar 1998). Different types of layering include:

(a) Ground or Simple layering: Less than two year old culms are selected and the top parts are cut off to stimulate bud growth, and the side branches are trimmed. The culm is bent down into a shallow trench, pegged down and covered with soil or rooting medium. Rooting and sprouting occurs in the nodes, and after rhizome formation the nodes are separated by cutting at the internodal regions.

(b) Air layering or Marcotting: This involves application of root-promoting medium around nodes of the culm which may be wrapped with coconut fibre and/or water hyacinth roots. Marcotting is performed by bending the culm to a slanting position, supported by a prop. After pruning off the branches, the nodes are covered with suitable rooting medium and held in position by tying. Rainy season is best for marcotting, since the medium should always be kept moist (Ray and Ali 2017).

(c) Stump layering: This method is not common. The culm is cut leaving 2-3 basal nodes and the stump is covered using rooting medium. Use of IBA is found to enhance sprouting and rooting. The use of this method is limited by low success rate. Only 10% survival has been reported in *B. vulgaris* and *D. giganteus* through stump layering (Banik 1984; Serajuddoula 1985).

(d) Seedling layering: Polybags with seedlings are placed in horizontal positions allowing the nodes to touch the ground. The nodes are covered with rooting media with the branches standing above. Rooted nodes are then separated and transplanted

to poly bags. This process can be used repeatedly to produce more planting stock from limited number of seedlings (Seethalakshmi 2015).

Cutting-based propagation

Vegetative propagation using 'cuttings' is advantageous over rhizomes/offsets (Ntirugulirwa *et al.* 2012) as cuttings are easily available for large-scale propagation. This could be achieved by either 'culm cuttings' or 'branch cuttings'.

(a) Culm cuttings: The culm segments with 2-3 nodes are removed from mother plant and treated with root inducing chemicals. The method has been successfully tested for most of the economically important bamboos. Plants raised from cuttings develop faster to culms as compared to seedlings. Though it is applicable for both thick- and thin-walled bamboos, the success rate for thin-walled bamboos is quite low. This method enables the large-scale multiplication of superior varieties with rooting in 90 days. Culm/branch cuttings are more suitable for propagation because of easy handling and abundant availability, and they can be collected from the stock material without affecting the rhizome system. Culm cuttings are 40–80% more successful than the offset method.

(b) Branch cuttings: It is a simple and easy method of propagation, but the success of rooting is not as high as in culm cuttings. The primary branches are easily separated from the hollow main stem of an upright shoot and reduced to 2-3-node cuttings which are buried in growth medium. Though abundant availability and ease of handling are advantages of this method, it is restricted to thick-walled bamboo species with stout branches only, like *Bambusa* spp. or *Dendrocalamus* spp. This method is time-consuming, as branch cuttings require 6–12 months for rooting and 12–30 months for rhizome development. Also, species which bear small branches at the top of the culm e.g., *Thyrsostachys oliveri* and *T. siamensis* cannot be propagated in this way (Ray and Ali 2017).

Macro-Proliferation

In order to increase number of plantlets from rooted cutting and to reduce cost of production, macro-proliferation of 6 months old rooted cuttings with 2-3 tillers and miniature rhizomes may be done. To avoid the chances of shoot wilting and root drying, it is performed under shade, especially during morning or evening. The polythene cover and the potting mixture are removed without damaging roots and rhizome. Then, 1-2 tillers with roots and rhizome are separated using secature, and around 2 to 3 plants can be made from one six month old rooted cutting. Macro-proliferated plants must be kept in shade/ shade house for 2-3 weeks or till new root and leaf development takes place, after which, plants can be kept in open nursery. After 3 months, to boost growth of the plants, NPK solution or slow release of nutrients can be provided at regular one-month intervals. To get further plants, the process is repeated after six months, and about 5-6 folds multiplication can be achieved in one year from 6 months old single rooted cuttings using this method. This cycle can be repeated every year for planting stock production to raise large scale plantations. Depending on the species, each plant can be multiplied three to seven times using this method. Though seed dependency is a major drawback, a large number of planting stock can be produced from limited seeds, and the planting stock can be maintained in the nursery, without going for repeated nursery establishment every year (Ray and Ali 2017; Seethalakshmi 2015; Viswanath *et al.* 2013).

KEY FACTORS INFLUENCING BAMBOO MACRO-PROPAGATION SUCCESS

Age of the culm or branch cutting

1 to 5-year-old culms are better for many species. Though culm cutting material of different ages were used successfully in various bamboo species, juvenile culms with highly active buds are more suitable than older ones for efficient propagation.

Period of collection / Season

Bamboo macro-propagation is generally restricted to summer for several bamboo species. Better adventitious rooting in summer than winter, increased percentage of culm setting with more sprouts/node and roots/node during April compared to January, better rooting of culm cuttings in spring, followed by summer, but less during winter have been documented for various bamboo species. The interaction between species and season is critical, and summer is the most suitable season for majority of the bamboo species (Ray and Ali 2017).

Size (number of nodes)

The number of nodes per culm cutting influences rooting and survival in bamboo species, with one- to three-nodal cuttings showing higher responses in comparison with whole culm cuttings. Even though six- node cuttings have been reported, one-node cuttings are the most promising for propagation and highly recommended, because they are economical and easy to handle.

Culm characteristics

The middle parts of the culm have sufficient vigour for both root and shoot generation and provide the best material. Whereas, cuttings from the top and basal region result in lesser sprouting. Also, the orientation of cutting in the bedding material is critical to get optimum response during propagation. Horizontal setting was found more effective in terms of survival percentage compared to vertical setting, which could be due to the increase of surface area resulting in high nutrient/ water uptake from the medium (Stapleton 1985).

Auxin

When rooting is difficult, plant growth regulators, especially auxins, are widely used for bamboos. The effect of these growth regulators depends on the season and species also. The endogenous level of hormones varies with season and the seasonal dependency of growth regulators is reported for many bamboo species. While some species do not need growth regulator treatment, others require the application of growth regulators. IBA was the most effective for several bamboo species following cutting-based propagation. The effect of growth regulators also depends on setting orientation of cutting materials, with horizontal setting resulting in higher rooting (Ray and Ali 2017).

Rooting medium

The type of substrate / rooting medium used in the propagation beds for establishment of the macro-propagules, is also important, as it supports the plant pieces by fixing them in a particular position. Different types of rooting media *viz*., fine sand, soil, sand and loamy material, mixtures of coarse sand and gravel, coarse sand mixed with fine gravel, different ratios of soil, sand and farmyard manure, and coarse sand, soil, and sand plus soil and vermiculite have all been reported to improve rooting during bamboo macro-propagation. Sand is more advantageous as it is inexpensive, with good drainage and aeration, and maintains a relatively uniform temperature (Ray and Ali 2017).

Genotype

The adult population and plantation of bamboo shows considerable variation, along with variation in the provenance. Based on phenotypical characters like number of culms per clump, height, thickness and girth of culms, length of internodes, fiber length, disease and pest resistance etc., superior clones of bamboo clumps can be selected. The selected superior clumps of bamboo must belong to different cohorts and must be at the beginning of the intermost cycle to ensure long production life of the plantation. Superior clones of bamboos thus selected may be clonally propagated for large scale plantation.

Incubation conditions

Environmental factors such as temperature, humidity, water balance, light intensity, wind speed, and pests and diseases, are also limiting factors for the macro propagation of bamboos (Banik 1995; Senyanzobe *et al.* 2013).

GROWTH AND BIOMASS PRODUCTION

Bamboo culms are ready for harvest from the clump at the end of 4 years depending on the type of planting material, species and management. From the fifth year, the culms may be harvested every year. Also, since lignification is not complete, one year old immature culms are not recommended for harvest, and at least two years maturity is advisable. Maturity marking of culms is necessary to identify their age. 50% of matured culms in the clump may be retained to support the emergence of fresh young shoots, and felling or culm extraction is recommended between November to May. Also, the extraction of culms may be avoided during monsoon, which is the growing phase of emerging culms. (Viswanath *et al.* 2013).

CONCLUSION

Bamboo, one of the most important non-timber

forest products in the world caters to the economic needs of about 2.5 billion people. The international trade in bamboo amounts to over 2.5 billion US dollars per year and its demand is increasing with each passing year. High commercial demand has led to a decline of bamboos from its natural stands. Efforts are being made to combat the rapidly dwindling natural resource of bamboo by restoring, propagating, conserving and large-scale replanting. Efforts of replanting are slow and expensive using offsets or culm cuttings. Though seed propagation is cheaper and easier with the seedlings being raised in nurseries and transplanted to the forest, this offers only a limited answer to the problem since most of the larger, economic bamboos flower only once in 30-60 years. Therefore, there is a need to find suitable methods for large scale propagation of bamboo. Since seed supplies are often variable and limited, bamboo is currently propagated mainly using vegetative methods. The present literature study reveals that culm cutting is the best regeneration option to meet the global need for bamboo planting stock. It is also the simplest and most cost-effective method developed over the last few decades. Also, the vegetative propagation techniques can be replicated at micro levels through plant tissue culture, which presents many advantages over the macro-propagation methods.

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