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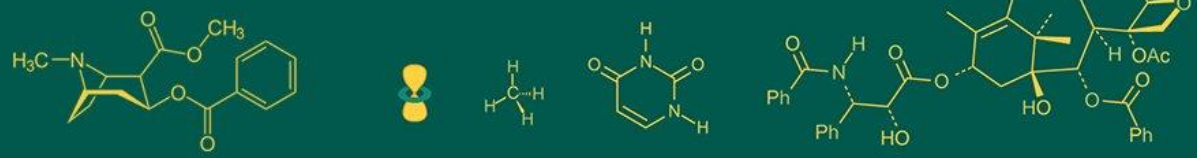

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Nursery techniques: An overview on vegetative propagation studies of Indian bamboos

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Abstract
Bamboo plants are an essential element in Indian socioeconomics and ecological development. Traditionally food, construction materials, antiques, and raw materials for pulp and paper manufacture have all benefited from the use of bamboo. Bamboo is a highly renewable plant. However most bamboo species has long flowering cycle. Moreover many species do not produce viable seed. The selected genotype can be spread effectively through vegetative propagation. because the mass replication of clonal planting material made it feasible to employ better genetic material for the construction of seed orchards, nutrition experiments, increasing hybrids with more accurate genetic makeup for testing, and the establishment of big industrial plantations . Hence cloning by rooting of cuttings has advanced significantly. The difficulty of traditional vegetative propagation techniques and the lack of readily available planting material for bamboo are perennial issues. In lieu of breeding, vegetative propagation is a quick means to spread. During vegetative propagation, the young plant receives the entire genetic potential of the parent plant, including non-additive variance. Vegetative population aids in maximizing genetic improvements in the quickest amount of time. Numerous variables affect vegetative propagation's ability to succeed, including the cuttings' physiological condition, genetic makeup, and habitat.

Keywords: Vegetative propagation, mother plant, culm segments, clonal, physiological

Introduction
A woody perennial with special morphological features, the grass family Poaceae (Gramineae) includes bamboo. It is a naturally occurring non-timber resource that is renewable and self-regenerating; once established, bamboos grow quickly and may support themselves. It is a versatile plant that may be used for a variety of things, comprising furnishings, fencing, handicrafts, paper and pulp products, edible shoots, and animal feed. (Kebede 2017) [16].

The demand for bamboo is gradually rising. Bamboo supplies are rapidly running out in the area as a result of overharvesting and rising demand. In the shifting cultivation approach that is primarily used in the bamboo-rich regions, the need is being satisfied by shortening the felling cycles. As a result, our natural resources are seriously endangered and require rapid conservation efforts. Both vegetative and reproductive methods can be used to propagate bamboos. While the vegetative approach uses rhizomes, culms, and branches, which are vegetative elements, the reproductive method uses seeds to create new bamboo plants. (Ray and Ali 2017) [21].

Formerly known as the "golden grass," bamboo is now known as the "wood of the wise man." Monocotyledonous perennial grasses include bamboo. Next to China, India is the country that produces the most bamboo. Because of its fast-growing nature, easy establishment, greater adoptability and readily available market, it is cultivated everywhere in India except Kashmir. Almost every state in India, from the tropical to the temperate, and from the alluvial plains to the high mountains, has some type of bamboo. (Kaushal *et al*., 2011) [15].

Bamboos are versatile, quickly growing, short-rotating plant species with significant. Bamboo is among the most widely utilized plant products. The Poaceae family contains 1250 species spread across more than 75 genera, known by the common name "bamboo" around the world (Soderstrum and Ellis, 1988) [30].

Potential use of bamboo

Because of its exceptional mechanical, chemical, and physical properties, it is well-known as well as the wide variety of applications in around 10,000 goods. Various names for it include "Poor man's timber," "Green Gold," and "21st century steel." (Azeem *et al*. 2020; Archila *et al*., 2018; Ahmad and Kamke 2003, 2005) [5, 3, 2, 18]. Additionally a superior and healthful food source, bamboo (Choudhury *et al*., 2012; Silva *et al*., 2020) [8, 28]**.** Traditional artisans employ a significant amount of bamboo items, but so do major enterprises like those that produce paper, fibreboards, charcoal, scaffolding for houses, and other things, (Awoyera and Ede 2017; Bajpai 2018; Nguyen *et al*., 2018; Tanpichai *et al*., 2019) [4, 6, 17, 32]. Previously the paper industry makes paper uses around 35% of the bamboo that is produced. (Tripathi *et al*., 2018) [32]. In a changing energy requirement of India, bamboo is thought to be potential raw material for producing ethanol, biochar, biogas and energy pellets. Bamboo cultivation is a most effective mechanism for combating global warming and climate change challenges.

Bamboo distribution: India

India is home to one of the largest bamboo "reserves "in the world. Worldwide, there are 1250 species and 75 genera of bamboo (Soderstrom and Ellis 1987) [31] and in terms of bamboo bioresources, India comes in second to China. In India, there are 11 foreign species and roughly 125 indigenous species. Bamboo covers large 23.80% of India's 63.3 million hectares of forest area.

The overall area of India that bears bamboo is thought to be 15 million hectares, per the Forest Survey of India's report on the nation's bamboo resources (FSI, 2021) [10]. The biggest bamboo-bearing area is found in Madhya Pradesh (1.84 million hectares), Odisha (1.12 million ha), Arunachal Pradesh (1.57 million ha), and Maharashtra (1.37 million ha) are next in size. It is possible to choose economically and industrially significant species for multiplication and improvement using this abundant genetic resource for bamboo.

The 160 species of bamboo that may be found in India, which include both valued and required species from numerous genera, are categorized as *Bambusa bambos* (L.) Voss, *B. balcooa* Roxb., *B. nutans* Wall. Ex Munro, *B. cacharensis* R.B. Majumdar, *B. tulda* Roxb., *B. polymorpha* Munro, (Synonym of B. multilplex), *B. multiplex* (Lour.) Raeush. Ex. Schult., *B. vulgaris* Schrad., *Bambusa pallida* Munro, *Bambusa polymorpha* Munro, *Dendrocalamus giganteus* Munro, *D.asper* (Schult.) Backer, *D. hamiltonii* Nees & Arn. Ex Munro, *Pseudoxytenanthera stocksii* (Munro) T.Q. Nguyen, *D. brandisii* (Munro) Kurz, D. *strictus* (Roxb.) Nees, *Pseudoxytenanthera ritcheyi* (Munro) H.B. Naithani, *Ochlandra scriptoria* (Dennst.) C.E.C. Fisch, *O. travancorica* (Bedd.) Gamble, *O. ebracteate* Raizada & Chatterji, *Thyrsostachys oliveri* Gamble, *Schizostachyum dullooa* (Gamble) R.B. Majumdar, *Drepanostachyum falcatum* (Nees) keng f., *Melocanna baccifera* (Roxb.) Kurz, *Thamnocalamus spathiflorus* (Trin.) Munro, *Gigantochloa rostrata* K.M. Wong, G. *atroviolacea* Widjaja (Sharma and Nirmala 2015; Kaur *et al*., 2016; Singh and Kumari 2018) [27, 14, 29]

Need of vegetative propagation

Macro/vegetative propagation is straightforward, inexpensive, and uses resources that are readily available in the area. Planting stock is created via vegetative propagation methods in the absence of seeds. The traditional techniques of layering, offset planting, rhizome planting, and cutting germination are used in macro-propagation. (Seethalakshmi 2015) [24]. These techniques are suitable for farmers because they are inexpensive and simple to use. Bamboos blossom and set seeds at unusually lengthy intervals because they are monocarpic. Depending on the species, the flowering cycle can last anywhere between 10 and 60 years. After a lengthy flowering cycle, flowering is typically either gregarious or scattered. Additionally, it is difficult and limited to grow bamboo plantations from seeds because the majority of bamboos perish after flowering. Never the less, bamboos can be multiplied by traditional vegetative methods, even when seeds are frequently unavailable. (Seethalakshmi *et al*., 2008) [25]. It is highly beneficial for the continued production of field plantable bamboo saplings in large numbers swiftly, forever, and abundantly for any required number of years, depending on the goals and the facilities available. It has also opened up a lot of new doors for bamboo study.

Nursery techniques for Vegetative propagation for various bamboo species

The many techniques for bamboo vegetative propagation are briefly described below:

Cutting-based propagation

'Culm cuttings' or 'branch cuttings' could be used to accomplish this.

Branch cutting

Branch cuttings are the most efficient method since they don't harm the bamboo clump, speed up clump formation, are simple to do, don't take a lot of time, and are available in huge quantities (Sari *et al*., 2016) [23].

Dendrocalamus asper

Cuttings are made from the branch bases, including the bases of the two branch parts. For two hours, all cuttings were immersed in a Rootone-F solution. Topsoil and compost are combined to create a planting medium that is prepared in polybags that measure Size: 20 by 25 cm. Each cutting was inserted vertically into a poly bag containing medium after being soaked in a solution containing the hormone Rootone-F, with one half buried in the earth and the other part raised above it. To retain air humidity, all cuttings are organized in a polybag and covered with plastic. In conditions of field capacity, bamboo cuttings were watered daily to maintain soil media moisture. (S.A. Paembonan *et al*., 2020). Through branch cutting, *Dendrocalamus asper* can be multiplied easily and simply in nurseries.

Bambusa vulgaris

The axillary buds were left unharmed and the cuttings were defoliated. On both sides of cuttings, roughly similar amounts of the internodes were left. Depending on where they were taken from the branch, cuttings were divided into thick (basal end) and thin (top end) varieties. Six types of cuttings were prepared: One noded cutting basal end, (4 cm in diameter and 6.5 cm in length). One-noded cutting top end, (2.5 cm in diameter and 5.5 cm long), Two-noded cutting basal end, (4 cm in diameter and 40 "cm in length), Two-noded cutting top end, 38 cm in length and 3 cm in

diameter, Three-noded cutting basal end, (4.5 cm in diameter and 60 cm long) and three noded cutting top end, (58 cm in length and 3 cm in diameter). The prepared cuttings were placed vertically in the sand (Yadav *et al*., 2022).

Culm cutting

The mother plant's culm segments with two to three nodes are cut off, and chemicals that promote root growth are applied. For the majority of the economically significant bamboos, the technique has been tested with success. Compared to seedlings, plants grown from cuttings reach the culm stage more quickly. Despite being relevant to both bamboos with thick and thin walls, bamboos with thin walls have a far lower success rate. With 90-day rooting, this technique makes it possible to multiply better cultivars on a huge scale. Due to their simplicity of usage and wide availability, Cuttings from culms or branches work well for propagation. because they may be removed from the source material without harming the rhizome system. Culm cuts are 40 to 80 percent more effective than the offset technique.

Bambusa bambos and Dendroclamus stocksii

Priority species are *Bambusa bambos* and *D. stocksii*. Selected CPCs should have their clusters of 1-2year old culms picked using a sharp knife. Then, culms were collected from the bottom to the top and formed into double and triple node cuttings. Cuttings were carefully made to avoid splitting at the cuttings' end. When moving the cut-up materials from the bambusetum to the nursery, moisture loss was prevented by wrapping them in damp gunny bags. Cuttings were prophylactically treated with 0.25% Bavistin for 10-15 minutes after side branches were cut off using secateurs. After washing with water, cuttings were treated for 30 minutes with a 2500ppm IBA solution (consisting of 2500mg IBA dissolved in 10ml ethanol and "built up to" 1 litre by adding distilled water). After that, in sand beds, the IBA-treated cuttings were arranged horizontally with roughly half of their diameter submerged in sand, covered with a 2 cm layer of sand, and frequently watered. Regularly soaking the bed with Bavistin (0.5%) and Chlorpyriphos (0.5%) is advised to prevent damage to cuttings. Depending on the ambient temperature. The cuttings finished rooting in 45 days after sprouting in 10 to 15 days. The cuttings with strong roots were taken out of the sand bed and placed in poly bags measuring 1000–1500 cc that contained FYM–sand–soil (40–50:10) that had been treated with SSP is 2.5 kg/m^3, and neem cake is 10 kg/m^3. With this method, rooting success rates can reach more over 90% (Ginwal 2021) [11].

D. strictus,* and *D. somdevai

Root initiation was used to culm cuttings. According to the proper experiment design, varied auxin concentrations were applied to the cuttings. The cutting displayed about 70% sprouting after 20 days of treatment with constant humidity. However, it was found that these cuttings had very poor root initiation. As a result, there were only a few plants with an average rooting percentage of 10.05% (clones' percentages ranged from 1.16% to 25.71%)." could be obtained from this experiment.

In all of the chosen clumps, a second series of experiments utilizing in the months of June and July, the hormone (IBA+NAA) concentration of 4000 ppm was set up. With an average rooting percentage of 25.51% (with a range across clones of 1.96% and 50.53%), The best time to induce roots in cuttings in this site was discovered to be during this season. (Ginwal 2021) [11].

B. balcooa, B. tulda, B. nutans, and D. hamiltonii

The period from March to April. Culms were chosen during the second growing season. Strong central branches in culms were taken into consideration for propagation. A hole was created for the hormonal treatment and two culm node cuts were prepared. Segments are taken from the lower to middle portion of the culm, while the upper portion is disregarded. Cut ends waxed or wrapped in straw, gunny sacks, coconut husks, etc. At the inter node's center, a 7mm-diameter hole is formed. The segment cavity was filled with IBA, 200 ppm solution, and the holes were sealed with cello tape. Sand, soil, and cow manure used to prepare nursery beds in a 3:1:1 ratio. Cuttings from culms are arranged horizontally, with a 6 cm dip from the top layer and a space of 30 cm between each culm. Then fine sand was applied to the culms. The crib is maintained in a wet environment with some shade.

Rhizome (offset) based propagation

Rhizome or offset vegetative propagation is a tried-and-true technique. Although this is the oldest and most popular way of growing bamboo, it is only useful for growing a small number of clumps, especially in easily accessible areas. Sympodial bamboos are often propagated using offsets or rhizomes. For offset planting, culms from a clump's periphery that are preferably 1 to 2 years old are chosen and cut at a height of 1 to 1.5 meters. The culms are split at an angle, leaving two to three nodes at the base or immediately above the node to prevent damaging the basal sections of the branches. Cut the rhizome that connects the culm to the ground between 30 and 45 cm down. When gathering the offsets, care must be taken to avoid damaging the rhizome, the connected roots, or the buds. with the event that planting is delayed due to transportation, the subterranean portions of to prevent drying, the offset should be wrapped in a moist material like banana stem, coir, or gunny bags. These offsets can either be potted in medium-sized gunny bags or planted in field pits. To prevent drying in the field The cavity should be filled with water, and the culm top should be wrapped in a plastic bag. As an alternative, covering the cut end with a mixture of earth and cow manure is also done. (Seethalakshmi 2015; Ray and Ali 2017) [24, 21].

The offsets were planted in substantial polythene bags, treated with organic fertilizer, and watered per the suggested schedule. After the offsets begin to grow new shoots, rhizome splitting was used to increase their numbers even further. Although the process is sluggish, the speed for the mass multiplication gradually increases. Rhizomes began to sprout after about 20 days. (Ginwal 2021) [11].

Layering Methods

Layering is the best approach to guarantee that a culm or branch comes in contact with soil or another rooting medium so that roots can form. There are four different forms of layering, including plain or ground layers. Air layering, marcotting, seedling layering, and stump layering (Ahlawat *et al.*, 2002; Pandalai *et al.*, 2002) [1, 19]. To encourage rooted and sprouting at each node, the whole bamboo layering approach has been used. Serajuddoula

(1987) [26] described how *Melocanna baccifera* and *bambusa vulgaris* reproduce through stacking. On *B. vulgaris* and *M. baccifera*, ground-layering and air-layering trails were done. In the air-layering experiment, all of the *B. vulgaris* treated branches produced fruitful propagules.Twelve culms of this species ground-layering resulted in 23 roots and rhizome propagules.In both stacking trials, the beginning of roots and rhizome development only emerged in the branches of the mid-culm zone. None of the layering methos elicited a response from *M. baccifera*, *Guadua anguistifolia* is successfully propagated by using layering. (Verma *et al*., 2013) [34].

Planting of Culm cutting in bed

Rooted plants in bed

Rooted plants

Planting of branch cutting in bed

Rhizome splitting

Shoot initiation from rhizomes

Role of Plant growth hormone in Vegetative propagation methods

In terms of the proportion of culm/shoot and rhizome formation during the preparation of cuttings in the nursery stage, nursery beds can offer better growing conditions for branch cuttings compared to polybags. However, compared to bare root (prepared in nursery beds) plantings, polybags cutting provided the highest proportion of survival after one year of field planting. Preparing polybags of cuttings for field planting is more practicable, and utilizing commercial IBA 2000 powder applied by contact method can make this even better. (Othman 2005) [18].

Suitability for Different bamboo Species in Plantations under Different Regions

Local species (Type of plantation)	Suitable planting localities for better growth	Common utilization
B. balcooa	All over Indian subcontinent except drier and cooler areas	ST, PP, AS, ES
B. bambos	Central and southern India's hills and valleys	PP, FN, ST
B. tulda	All of the Indian subcontinent's lower slopes and valleys, with the exception of drier areas, are in north and northeast India.	ST, PP, MT, AS
B. vulgaris, *B. vulgaris* var. striata, *B. vulgaris* cv. Wamin	All over the Indian subcontinent, excluding drier regions.	PP, AS, OR, ST
B. polymorpha	Manipur, West Bengal and Tripura.,	ES, NI, AS, or OR
B. cacharensis	Lower Assam, Manipur, West Bengal and Tripura Manipur, West Bengal, and Tripura	FI, MT, ST, NI, AS
B. nutans	North, northeast, and east of India; Nepal; and the Sub-Himalayan zone	MT, NI, ES, MT
M. baccifera	Northeastern Indian hills, sultry, humid hills of tarai,	MT, ES, PP, AS
D. strictus	Indian hills and valleys in the north, east, and center.	ST, PP, FI
D. hamiltonii	In the highlands of north and northeast India, culm growth is at its best.	ES, MT, PP
D. longispathus	Northeast India's lowlands and lower slopes	ES, PP, AS
M. baccifera	Northeastern Indian hills, the damp, warm tarai hills	MT, ES, PP, AS
Ochlandra sp.	South India's marshy terrain (Trivancore, Kerala),	MT, PP
S. dullooa	Northeast India's highlands have moist gullies.	KT, MT, AS
T. oliveri, T. siamensis	Lower Assam, West Bengal, Manipur, and Tripura	FI, FR, FN, OR
P. stocksii	Kerala, Goa, and the Maharashtra Konkan region	S, T, F, O, and NI

(**Source:** Banik 2016; Ginwal, 2021) [11],

Utilization: AS= Agarbatti sticks, ES= Edible shoot. FN= Fencing, Fl= Furniture industry, FR= Fishing rod, MT= Mats, Nl= Novelty items, ST= Structural and construction works, PP= Pulp and paper industries, OR= Ornamental purpose. KT= Kite making.

Conclusion

Utilizing local, efficient, and timely vegetative propagation methods, it is possible to establish a consistent and sufficient supply of quality planting stock. Since it enables the faithful replication of plants that either do not breed for seed or are sterile, vegetative propagation is crucial. The overview of vegetative propagation studies indicates that various methods, such as rhizome cuttings, culm cuttings, and tissue culture, have been explored to propagate Indian bamboo species. Each method comes with its advantages and limitations, requiring careful consideration of species-specific traits and environmental conditions. While some methods might yield quicker results, others ensure genetic fidelity and disease-free planting material. Nursery techniques play a pivotal role in successfully implementing these propagation methods. Proper management of bamboo nurseries involves selecting suitable substrates, maintaining optimal moisture levels, providing appropriate shading, and preventing pest and disease infestations. The success of these techniques greatly influences the survival and growth rates of propagated bamboo plants when transplanted into their final planting sites.

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