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Macro - propagation of two commercial Bamboos *Bambusa balcooa* and *Dendrocalamus brandisii*

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MACRO-PROPAGATION OF TWO COMMERCIAL BAMBOOS
BAMBUSA BALCOOA AND *DENDROCALAMUS BRANDISII*

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Abstract of the project proposal

Project Code	KFRI 391/03
Title	Macro-propagation of two commercial bamboos: *Bambusa balcooa* and *Dendrocalamus brandisii*
Objective	Development of technologies for large-scale production of planting stock of *Bambusa balcooa* and *Dendrocalamus brandisii*
Principal Investigator	Dr. K. K. Seethalakshmi
Associate	V. P. Raveendran
Duration	Two years (2004-2006)
Funded by	Plan Funds, KFRI

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ABSTRACT

Technologies for large-scale production of planting stock are not available for many commercial bamboo species. This project was undertaken to standardise propagation techniques for production of planting stock of two priority species of bamboos, *Bambusa balcooa* and *Dendrocalamus brandisii*. Experiments conducted with culm cuttings of *B. balcooa* showed 100 per cent rooting and the response depended on concentration of growth regulator treatment and position of cuttings. Attempts to use branch cuttings showed varying results. About 30 per cent rooting was obtained in *B. balcooa* when cuttings were collected and planted in March. Experiments carried out inside the field propagation unit at Kottappara, which contained trenches covered with polythene sheet (poly tunnel) for maintaining high humidity did not give any promising results.

For *D. brandisii* culm cuttings were used to standardise the protocol of vegetative propagation using five different concentrations of two growth regulating substances - NAA and IBA; three seasons - summer, rainy and winter and three different positions – base, middle and top were taken for the study. In general, the cuttings collected from the basal portions of the culm during the summer season and treated with IBA gave maximum rooting response. Cluster analysis revealed that the cuttings collected duringsummer season from basal portion of the culms treated with 100ppm of IBA as the superior treatment. Branch cuttings did not give any positive result in this species.

INTRODUCTION

Raw material scarcity is identified as a major factor inhibiting the development of bamboo sector in India. Currently major share of the bamboo resources are located within the forest areas and both extraction and transportation are governed by rules and regulations of Forest Departments. This results in the inability to assure sustainable supply of raw material to the potential entrepreneurs. In addition to the resources in forest areas, promotion of bamboo cultivation in non-forest areas is a viable alternative to reduce the shortage of raw material availability.

During last decade National Mission on Bamboo Applications (NMBA) has identified the requirement of additional six million ha of bamboo plantations. Of these, three million ha is to be developed in the degraded forest land under JFM through the Ministry of Forests and Environment and the State Forest Departments. Two million ha are planned under Integrated Watershed Development Programme of the Department of Land Resources, and various other programmes of Ministry of Agriculture such as Watershed management for rain fed areas, Soil and Water Conservation, Wasteland Development and Jhum Control Programme. The remaining one million ha is planned to be developed under Poverty Alleviation Programme of Ministry of Rural Development. Based on the suitability for cultivation and properties, 16 species (*Bambusa balcooa, B. bambos, B. nutans, B. pallida, B. polymorpha, B. tulda, Dendrocalamus asper, D. brandisii, D. giganteus, D. hamiltonii, D. stocksii, D. strictus, Melocanna bambusoides, Ochlandra travancorica, Phyllostachys pubescence* and *Thyrsostachys oliveri*) have been identified as priority species. During 2006, National Bamboo Mission (NBM) was established under Ministry of Agriculture and Cooperation. Enhancement of bamboo resources through expansion of area under bamboo plantation in both forest and non-forest areas along with productivity improvement of existing bamboo areas comes under the top priority of NBM also. The scheme which is implemented through State Bamboo Missions provides the opportunity for financial assistance for raising planting stock, establishment and maintenance of plantations.

Technologies for large-scale production of planting stock are not available except for a few species such as *B. bambos, D. strictus* and *M. bambusoides* which produce seeds in abundance. Different macro-propagation methods like offset planting, rooting of culm cuttings, layering and marcotting can cater only to produce limited number of plants (maximum 40 plants from one bamboo culm). In micro-propagation, when explants are from mature bamboo culms, establishment of aseptic culture and root induction in multiple shoots still remains a challenge for many priority species. Hence there is an urgent need for intensive research to standardize macro-and micro-propagation methods for the selected priority species of bamboos.

Currently, root induction in culm cuttings is the best method among the known macro-propagation methods in the absence of seeds. Rooting zone in bamboos is only in the nodal region. Initially profuse sprouting occurs from the nodes. Natural thinning of excess sprouts and root formation follows this. Finally a few dominant sprouts remain and roots originate from the basal part of these sprouts leading to rhizome formation subsequently.

This project was undertaken to standardise macro-propagation techniques for large-scale production of planting stock for two priority species of bamboos, *Bambusa balcooa* Roxb. (*Dendrocalamus balcooa* (Roxb.) Voight) and *Dendrocalamus brandisii* (Munro) Kurz. (*Bambusa brandisii* Munro).

B. balcooa is a tall clumping bamboo forming distinct tufts, groups or clumps. The culms are 20–24 m tall, 8–15 cm in diameter, greyish green to light whitish in colour, thick walled (2–2.5 cm), nodes prominent with white ring above node, internodes 30–45 cm long and leaf blade oblong lanceolate (Plate 1 a-d). The species is distinguished by three characters: (1) Young shoot blackish green with acute tip; (2) Culm coarse, stout, dull grayish-green with pointed recurved branchlets towards the base; (3) Culm-sheath without auricles. It is indigenous to the North East, distributed in Bihar, Jharkand, Uttaranchal and West Bengal in India and Bangladesh. It is cultivated in villages of different states in India. *B. balcooa* is mainly used in structural and construction purposes, also for thatching, walling, roofing, handicrafts and novelty items. It is a good bamboo for scaffolding and ladders and also used in pulp, paper, rayon and agarbati sticks. Young shoots are edible. It is found suitable for new generation industrial products like flooring boards, gasification and activated charcoal.

D. brandisii has large sized culms (19-33 m tall; 13-20 cm diameter and internode length of 30-40 cm) sympodial, edible bamboo species mostly found in South and North Eastern India and Myanmar and introduced to South East Asia. Natural population in India is limited to tropical forests up to an elevation of 1300m in Manipur and Andaman. It is widely cultivated in Karnataka and Kerala and the species is found to occur on calcareous rocks also (Seethalakshmi and Kumar, 1998). *D. brandisii* is considered as a superior bamboo for construction, baskets, handicrafts and furniture. Young shoots are edible and are of good quality (Rao *et al.*, 1998). It is suitable for cultivation in homesteads due to the growth form such as straight culms with branching mainly towards top of the culm and thick-walled. Although propagation through seeds is efficient and cost effective, *D. brandisii* is a gregariously flowering bamboo with a long flowering cycle of 40-45 years. In the absence of seeds, vegetative propagation using culm cuttings has been reported for a number of bamboo species like *Bambusa balcooa, B. bambos, B. tulda, Dendrocalamus hamiltonii; D. strictus,* etc. (Banik, 1980; Seethalakshmi *et al.*, 1983; Surendran *et al.*, 1983; Sharma, 1986). The rooting response depends on various factors such as season of collecting the cuttings, effect of growth regulating substances, position of the cuttings, etc. (Banik, 1980; Surendran *et al.*, 1983). Hence, standardisation of a species-wise protocol, for vegetative propagation by rooting of culm cuttings for large-scale planting stock production of these two species taking into consideration all these factors is envisaged in this study. During the study period, flowering was also observed in one of the species, *D. brandisii* in Madikeri, Karnataka and observations were taken (Plate 2, c and d).

Plate 1. I.Clumps of *B. balcooa* 2. Basal part of the clump 3. A double noded portion suitable for rooting 4. Immature culm with culm sheaths

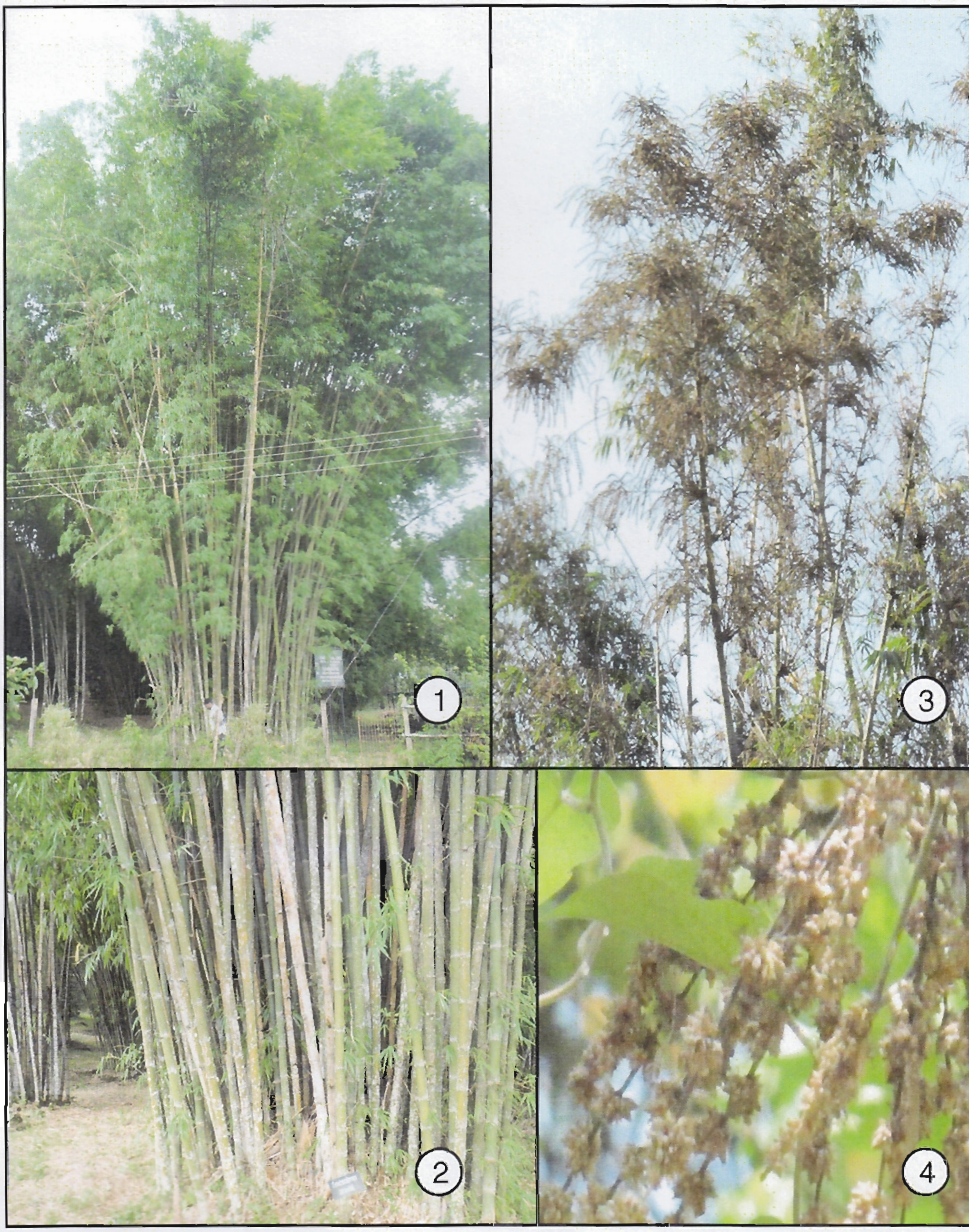


Plate 2. 1. A clump of *D. brandisii* 2. Basal part of the clump without much branches 3. Flowered clump in Madikeri, Karnataka during 2010. 4. Close up of the inflorescence

MATERIALS AND METHODS

Propagation using culm cuttings

Selection of mother clumps: Mother plants of *Bambusa balcooa* for extraction of culm and branch cuttings were selected from the healthy clumps growing in the campus of Kerala Forest Research Institute, Peechi. These clumps originated from vegetatively propagated planting stock which was planted in 1982, the mother materials of which are obtained from one single clump occurring in the campus of Forest Range Office, Peechi. Parent material for *Dendrocalamus brandisii* was from the campus of Kerala Forest Research Institute Field Research Centre (KFRI-FRC), Velupadam. The clumps were raised from the seeds received from Thailand during 1988 and 18 years old when culm cuttings were taken for the study.

Bambusa balcooa: Mature (2-3-year old) bamboo culms were extracted by cutting from the base; the whole culm was then divided into three equal parts; basal, middle and top and two-nodded culm cuttings were made out of each portions. Treatments with two growth regulators (GRS), Indole Butyric Acid, Merck (IBA) and Naphthyl Acetic Acid, SRL (NAA) were given for cuttings prepared from each part separately. Controls were also maintained. Three blocks of six cuttings each were used for treatment. Treatment with GRS was given by cavity method (KFRI 1990). A hole is made in the centre of the internode to provide an opening to the cavity and about 100 ml of the growth regulating substance is poured into the cavity. The hole is sealed with a polythene strip, (KFRI, 1993). The details of growth regulator treatments and positions used are given in Table 1. Observations on percentage of rooting were recorded four months after treatment and planting.

Dendrocalamus brandisii: Mature culms (2-3 year old) were extracted from the clumps of *D. brandisii* grown in KFRI-FRC Campus, Veluppadam. The collected culms were divided into bottom, middle and top portions and two-noded cuttings were prepared from each portions separately. Cuttings were treated with five concentrations (100, 200, 300, 400 and 500 mg/l) of two GRS viz. IBA and NAA by cavity method of treatment (KFRI, 1993). The different treatment combinations are given in Table 2.

Table 1. Position of cutting and GRS treatments in *B. balcooa* culm cuttings

Position - Base	Treatment	Position - Middle	Treatment	Position - Top	Treatment
B T1	Control	M T1	Control	T T1	Control
B T2	IBA-100	M T2	IBA-100	T T2	IBA-100
B T3	IBA-250	M T3	IBA-250	T T3	IBA-250
B T4	IBA-500	M T4	IBA-500	T T4	IBA-500
B T5	IBA-750	M T5	IBA-750	T T5	IBA-750
B T6	NAA -100	M T6	NAA -100	T T6	NAA -100
B T7	NAA -250	M T7	NAA -250	T T7	NAA -250
B T8	NAA -500	M T8	NAA -500	T T8	NAA –500
B T9	NAA -750	M T9	NAA -750	T T9	NAA –750

Table 2. Number* allotted for treatment for season, position, GRS and concentration in culm cuttings of *D. brandisii*

Position Treatment/ treatment numbers	Season								
	Feb-May (Summer)			Jun-Sept (Rainy)			Oct-Jan (Winter)		
	Base	Middle	Top	Base	Middle	Top	Base	Middle	Top
Control	1	12	23	34	45	56	67	78	89
NAA100	2	13	24	35	46	57	68	79	90
NAA200	3	14	25	36	47	58	69	80	91
NAA300	4	15	26	37	48	59	70	81	92
NAA400	5	16	27	38	49	60	71	82	93
NAA500	6	17	28	39	50	61	72	83	94
IBA 100	7	18	29	40	51	62	73	84	95
IBA 200	8	19	30	41	52	63	74	85	96
IBA 300	9	20	31	42	53	64	75	86	97
IBA 400	10	21	32	43	54	65	76	87	98
IBA 500	11	22	33	44	55	66	77	88	99

* These numbers are used in statistical analysis

Ten nodes constituted one treatment and it was replicated thrice. The treated cuttings were planted horizontally in trenches on standard nursery beds with sufficient depth so as to cover by at least 2.5 cm deep soil.

The experiment was repeated during summer (February to May), rainy season (June to September) and winter (October to January) of the year 2002-2003 to study the effect of season on sprouting/rooting. The weather parameters like temperature and precipitation at the experimental nursery at KFRI-FRC are given in Table 3.

Table 3. The weather parameters in the nursery site at KFRI- from FRC - June, 2002 to May, 2003

Month	Temperature (°C)			Relative humidity (%)		Precipitation	
	Max	Min	Mean	Morning	Evening	Rainfall (mm)	Rainy days
June	31.8	31	31.4	93	78	533.5	22
July	29.8	21.4	25.6	94	74	354.2	21
August	31.4	21	26.2	94	78	506.6	19
September	33.3	21.6	27.3	92	62	124.0	8
October	33.4	22.5	27.8	91	74	387.7	19
November	33.2	22.3	27.8	83	60	22.1	3
December	33.4	16.8	25.1	72	45	0	0
January	35.3	19.5	27.4	66	34	0	0
February	36.8	21.6	29.2	83	43	162.1	5
March	36.0	20.4	28.2	86	37	94.8	4
April	37.8	23.4	30.6	86	58	23.8	3
May	35.6	23.5	29.5	88	56	40.3	3

The sprouted cuttings were uprooted after six months and observations were made on number of sprouts per node, height and collar girth of the sprouts, rooting percentage, number of roots and length of the longest root.

Statistical analysis (*D. brandisii*): Bartlett's test of sphericity was conducted on the matrix of correlation coefficients between the various parameters of the sprouted *D. brandisii* cuttings. Factor analysis was carried out using SPSS

(Norusis, 1988). Principal component analysis was used as the method of factor extraction in the initial step and all the seedling parameters with eigen values >1 were admitted. Theses factors were subjected to oblique rotation with Kaiser Normalisation (Kaiser, 1958) using Direct OBLIMIN option. Factor scores for each of the admitted parameters were computed and subjected to Analysis of Variance to examine how the sprouting and rooting parameters represented by the corresponding factors varied with the season, position of the cutting and concentrations of GRS. In order to group the different treatments a cluster analysis was carried out taking different treatment combination as entities and different sprouting and rooting parameters as characters. Clustering was done using average linkage method and squared Euclidian distance as distance measure (Hair *et al.*, 2005).

Propagation using branch cuttings

Bambusa balcooa

Experiments on root induction in branch cuttings were carried out at two locations, one at KFRI campus, Peechi and another at Field Clonal Multiplication Unit (FCMU) at Kottappara. At Peechi campus, experiments were carried out inside the mist propagation unit and in conventional nursery while at FCMU poly tunnels were used for the experimentation.

Mist Propagation Unit, KFRI Campus, Peechi: In March 2004, branch cuttings from the basal one-third portion of the culm of *B. balcooa* were prepared. A linear concentration ranging from 1000 to 5000 ppm of two GRS, NAA and IBA were used for root induction. The treated cuttings were planted in trays in mist chamber. Observations were made on percentage of rooting after four months.

Conventional nursery, KFRI Campus, Peechi: Branch cuttings of *Bambusa balcooa* were prepared from the parent clumps at Peechi campus and the treatments given are shown in Table 4. The treated cuttings were planted horizontally in nursery beds and observations were recorded in July, 2004.

Table 4. Treatments given to branch cuttings for root induction

Sl. No.	Treatment	Sl. No.	Treatment
1	Control	7	NAA -1000
2	IBA-1000	8	NAA -2000
3	IBA-2000	9	NAA -3000
4	IBA-3000	10	NAA-4000
5	IBA-4000	11	NAA-5000
6	IBA-5000		

For each treatment three replicates of 8 cuttings each were used.

Field Clonal Multiplication Unit, Kottappara: FCMUs were established at Kottappara during the clonal propagation of *Eucalyptus* spp. (Sharma *et al.*, 2001). This included two trenches of 11 m x 1.35 m x 0.6 m size provided with a row of 15 nozzles in the middle of each trench for providing mist. Each trench had a protective tunnel type polythene cover and two such trenches of a mist chamber were provided with a hut type semicircular frame covered with polythene sheet. To reduce intensity of heat and light, an overhead covering of 50 percent shade net was provided (Sharma *et al.*, 2001). Effect of mist, nature of cuttings and rooting medium on root induction of cuttings of *B. balcooa* was observed using the poly tunnel facility at FCMU. Branch cuttings were extracted from Peechi campus and treatments were given as mentioned in Table 4. Three blocks of 20 cuttings each were kept for one treatment and the treated cuttings were planted in root trainers. Observations were recorded on rooting and sprouting response three months after planting. Experiments were carried out twice a year in March and August 2004.

Dendrocalamus brandisii

D. brandisii had prominent branches only towards the top-one third of the culm. Branches were collected by lopping and two-nodded branch cuttings were made. All the treatments mentioned in Table 2 and 4 were given for branch cuttings of this species and experiments were carried out in two locations at Peechi and Kottappara.

Table 5. Treatments given to study the effect of type of cutting, rooting medium and GRS treatment on rooting of branch cuttings of *B. balcooa*

Rooting medium	Type of cutting	Treatment with GRS (ppm)	Rooting medium	Type of cutting	Treatment
Vermiculite	Double node	NAA 500	Vermiculite + charcoal	Double node	NAA 500
		Control			Control
	Single node	NAA 500		Single node	NAA 500
		Control			Control
Sand	Double node	NAA 500	Sand + charcoal	Double node	NAA 500
		Control			Control
	Single node	NAA 500		Single node	NAA 500
		Control			Control

Observations were noted on sprouting and rooting behaviour of the cuttings in all the locations.

RESULTS

Sprouting and rooting response of culm cuttings

Bambusa balcooa

In general rooting response was better in cuttings treated with GRS than in control. Cuttings from basal and middle portions rooted even without GRS treatment. Better percentage of rooting was observed in cuttings from basal and middle portion of the culm than the top (Table 6).

Table 6. Rooting response of culm cuttings in *B. balcooa*

Position	Treatment GRS	Percent age of rooting	Position of cutting	Treatment GRS	Percent age of rooting	Position of cutting	Treatment GRS	Percent age of rooting
Base	Control	50.0	Middle	Control	33.33	Top	Control	0
	IBA-100	100		IBA-100	100		IBA-100	33.33
	IBA-250	100		IBA-250	100		IBA-250	66.67
	IBA-500	100		IBA-500	83.33		IBA-500	100
	IBA-750	83.3		IBA-750	72.22		IBA-750	66.67
	NAA -100	66.67		NAA -100	100		NAA -100	72.2
	NAA -250	100		NAA -250	100		NAA -250	16.67
	NAA -500	16.67		NAA-500	16.67		NAA-500	0
	NAA -750	16.67		NAA-750	16.67		NAA-750	0

The results indicate that it is an easy to root species. More experiments were carried out to standardise technology for rooting of branch cuttings.

Dendrocalamus brandisii

A maximum of 57 per cent rooting was obtained, the average being 30 to 40 percent. In general, cuttings collected during summer season responded better than those in winter and rainy seasons. Of the three positions, cuttings from basal part were better and treatment with growth regulators enhanced rooting response (Tables 6 a, b, c). Of the two growth regulators used, IBA was found better. The cuttings collected during the summer season from basal portion of the culms treated with IBA 100 ppm produced maximum number of roots (309) and length (78.03 cm)

Table 6a. Sprouting and rooting responses of *D. brandisii* during Summer

Trt. No.	Treatment (GRS)	Ht of sp. (cm)	Girth of sp. (cm)	Rooting (%)	No. of sprout	Root leng. (cm)
	Position of cutting - Base					
1	Control	338.3	3.9	33.3	94.0	64.0
2	NAA100	710.0	9.5	40.0	240.7	62.7
3	NAA200	353.3	4.5	33.3	79.3	69.7
4	NAA300	340.0	5.6	33.3	105.7	71.2
5	NAA400	266.7	3.0	33.3	69.3	39.7
6	NAA500	465.0	6.7	46.7	144.0	64.3
7	IBA 100	555.0	7.5	36.7	338.3	80.3
8	IBA 200	915.0	13.4	46.7	376.7	104.0
9	IBA 300	381.7	6.0	40.0	157.3	60.0
10	IBA 400	476.7	8.2	20.0	210.0	56.7
11	IBA 500	621.7	10.6	23.3	428.0	46.5
	Position of cutting - Middle					
12	Control	271.7	2.7	33.3	132.3	66.0
13	NAA100	320.0	5.5	23.3	104.0	41.0
14	NAA200	270.0	3.1	43.3	86.0	63.3
15	NAA300	326.7	4.8	23.3	155.7	64.7
16	NAA400	141.3	5.3	26.7	98.3	56.3
17	NAA500	290.0	4.0	13.3	96.7	27.0
18	IBA 100	463.3	6.2	23.3	149.7	60.7
19	IBA 200	221.0	3.2	26.7	78.0	77.0
20	IBA 300	243.3	4.5	10.0	155.0	32.3
21	IBA 400	286.7	4.7	26.7	85.0	61.7
22	IBA 500	206.7	2.5	10.0	103.0	31.7
	Position of cutting - Top					
23	Control	0.0	0.0	0.0	0.0	0.0
24	NAA100	63.3	1.7	6.7	80.0	37.3
25	NAA200	31.7	0.7	3.3	6.7	6.0

26	NAA300	112.0	3.1	16.7	44.7	36.7
27	NAA400	35.7	0.7	3.3	10.0	8.3
28	NAA500	33.3	0.8	6.7	9.3	9.7
29	IBA 100	97.0	2.1	16.7	19.0	26.3
30	IBA 200	0.0	0.0	0.0	0.0	0.0
31	IBA 300	0.0	0.0	0.0	0.0	0.0
32	IBA 400	0.0	0.0	0.0	0.0	0.0
33	IBA 500	0.0	0.0	0.0	0.0	0.0

Table 6b. Sprouting and rooting respones of *D. brandisii* in Rainy season

Position of cutting - Base						
Trt. No.	Treatment (GRS)	Ht of sp. (cm)	Girth of sp. (cm)	Rooting (%)	No. of sprout	Root leng. (cm)
34	Control	0.0	0.0	0.0	0.0	0.0
35	NAA100	240.7	3.1	30.0	57.7	64.0
36	NAA200	207.0	2.4	16.7	25.0	35.0
37	NAA300	245.7	3.0	30.0	45.0	66.7
38	NAA400	54.3	2.0	26.7	40.0	57.7
39	NAA500	110.7	3.1	16.7	31.3	50.3
40	IBA 100	148.7	2.2	23.3	69.3	60.0
41	IBA 200	125.3	2.3	30.0	59.0	52.7
42	IBA 300	173.0	2.3	26.7	63.0	40.7
43	IBA 400	45.7	1.4	20.0	23.0	31.3
44	IBA 500	0.0	0.0	0.0	0.0	0.0
Position of cutting - Middle						
45	Control	76.7	1.6	20.0	20.7	39.7
46	NAA100	126.7	2.4	16.7	49.7	55.7
47	NAA200	134.0	2.5	26.7	28.3	42.0
48	NAA300	173.0	2.2	26.7	36.0	48.3
49	NAA400	102.0	1.5	40.0	33.0	37.3
50	NAA500	176.3	2.0	26.7	42.3	33.7

51	IBA 100	206.7	2.1	40.0	65.7	50.3
52	IBA 200	218.0	3.1	43.3	76.7	50.0
53	IBA 300	300.0	2.4	56.7	63.7	44.3
54	IBA 400	125.7	2.5	17.4	13.0	25.3
55	IBA 500	198.3	3.0	26.7	38.0	60.3
Position of cutting - top						
56	Control	88.0	3.1	16.7	29.7	36.3
57	NAA100	0.0	0.0	0.0	0.0	0.0
58	NAA200	53.3	2.2	46.7	26.0	33.0
59	NAA300	167.7	2.0	13.3	32.0	41.3
60	NAA400	101.3	2.2	20.0	23.3	39.3
61	NAA500	177.0	2.4	30.0	33.3	32.7
62	IBA 100	148.7	1.7	20.0	37.3	47.3
63	IBA 200	63.7	1.7	6.7	17.3	16.7
64	IBA 300	62.0	1.6	6.7	35.7	17.0
65	IBA 400	0.0	0.0	0.0	0.0	0.0
66	IBA 500	68.0	0.8	6.7	35.0	29.0

Table 6c. Sprouting and rooting responses of *D. brandisii* in Winter season

Position of cutting - Base						
67	Control	0.0	0.0	0.0	0.0	0.0
68	NAA100	287.3	4.2	20.0	19.3	37.3
69	NAA200	166.3	2.6	13.3	53.0	28.3
70	NAA300	285.0	2.8	30.0	68.0	38.0
71	NAA400	120.3	2.2	10.0	41.0	36.7
72	NAA500	88.0	2.1	10.0	6.0	8.2
73	IBA 100	25.7	1.4	13.3	26.7	22.5
74	IBA 200	305.7	5.3	30.0	45.0	5.1
75	IBA 300	172.0	2.1	6.7	63.7	22.3
76	IBA 400	0.0	0.0	0.0	0.0	0.0
77	IBA 500	0.0	0.0	0.0	0.0	0.0

Position of cutting - Middle; Season - Winter						
78	Control	145.7	1.8	13.3	41.7	31.0
79	NAA100	272.7	3.1	26.7	45.0	48.0
80	NAA200	0.0	0.0	0.0	0.0	0.0
81	NAA300	416.7	3.3	30.0	142.0	50.0
82	NAA400	59.3	2.6	16.7	37.3	69.3
83	NAA500	135.0	3.1	26.7	47.7	49.7
84	IBA 100	114.7	3.7	16.7	45.0	35.3
85	IBA 200	0.0	0.0	0.0	0.0	0.0
86	IBA 300	257.0	4.9	23.3	82.7	35.0
87	IBA 400	225.3	4.8	16.7	124.0	55.7
88	IBA 500	300.7	4.8	10.0	281.0	61.0
Position of cutting – Top						
89	Control	98.0	1.3	20.0	17.7	23.3
90	NAA100	0.0	0.0	0.0	0.0	0.0
91	NAA200	167.0	5.4	10.0	224.3	34.3
92	NAA300	247.7	3.0	10.0	135.7	46.7
93	NAA400	73.3	2.0	6.7	60.3	17.0
94	NAA500	115.0	2.4	10.0	55.3	46.0
95	IBA 100	237.7	4.5	16.7	227.3	50.7
96	IBA 200	0.0	0.0	0.0	0.0	0.0
97	IBA 300	0.0	0.0	0.0	0.0	0.0
98	IBA 400	59.3	1.3	16.7	36.7	13.7
99	IBA 500	198.3	3.6	10.0	52.0	32.7

The data were subjected to statistical analysis and the interpretations are given below.

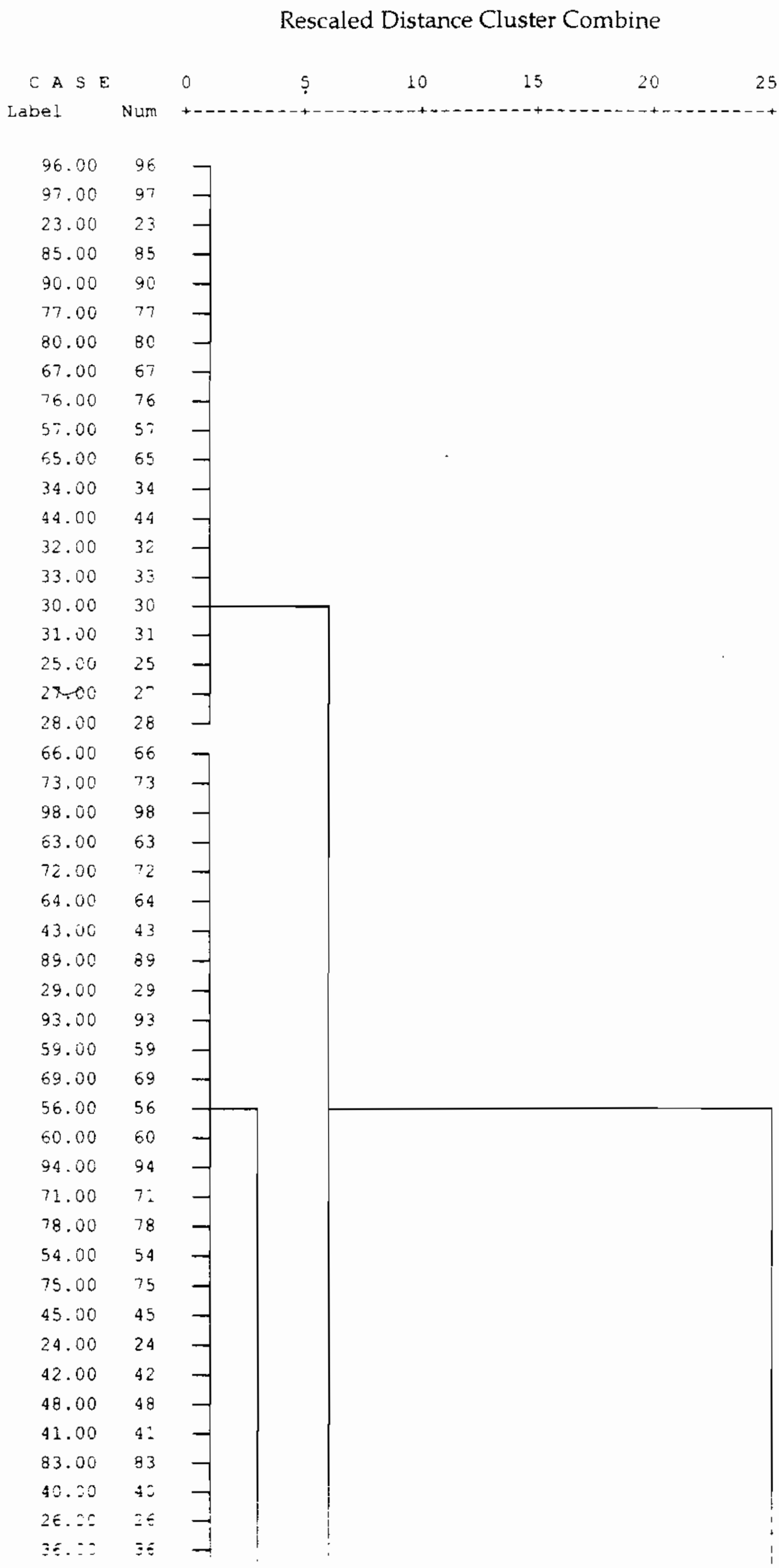
Factor analysis

Principal component analysis identified a single factor, which accounts for 73.33 per cent of the total variance in all the parameters. More than 85 per cent of the variance is observed in spout height and girth of sprout, more than 70 per cent in number of roots and maximum root length, and 49 per cent rooting percentage is explained by the retained factor (Table 7). The elements of structure matrix for the extracted factors and the communalities after extraction are given in Table 8. Coefficient of all the variables for computing the factor score is given in Table 9. Analysis of Variance of factor scores is given in Table 10. Results of ANOVA showed that the three-factor interaction is significant (P=0.01) indicating that each treatment given to different positions of the culm has separate effect in different seasons. Hence, all the treatment combinations (3 seasons, 3 positions and 11 treatments) were subjected to cluster analysis to identify the most superior treatment.

The cluster analysis carried at 25 % variance level gave two homogenous clusters *viz.* first cluster containing the treatment combinations 96 to 92 and the second containing treatments 2, 7, 8 and 11 (cuttings collected in summer season from the basal portion of the culm treated with NAA 100 ppm and IBA 100, 200 and 500 and ppm respectively) with a relatively higher values for sprouting and rooting parameters observed (Figure 1). Of the second cluster, the treatment combinations 2, 7 and 11 are more homogenous and treatment 8 is significantly different at 20 % level.

The data pertaining to sprouting and rooting parameters of *D. brandisii* as affected by season, position and various concentration of growth regulating substances are given in Table 6. Maximum 57 per cent rooting response was obtained, the average being 30 to 40 percent. In general, cuttings collected during summer season were better than those of winter and rainy seasons. Of the three positions, cuttings from basal part were better and treatment with growth regulators enhanced rooting response. Of the two growth regulators, IBA was found better. The second cluster containing the treatment combinations 2, 7, 8 and 11 gave maximum values in sprouting and rooting parameters. The treatment 8 *i.e.*, the cuttings collected during the summer season from basal portion of treated with IBA 200 ppm produced largest sprout height (915.0 cm), collar girth (13.4 cm), 46.7 % rooting with 376.7 roots and maximum root length (104.0 cm).

Cluster analysis carried out at 50 per cent variance level gave three homogenous clusters. As the rooting is the prime factor, which triggers the growth of the propagules and eventually their establishment in the field, the treatment combinations with highest number of roots and root length were preferred over sprouting parameters. Due to lower performance in sprouting and rooting (>30%) the first cluster was discarded from the study and the second cluster with relatively higher rooting parameters was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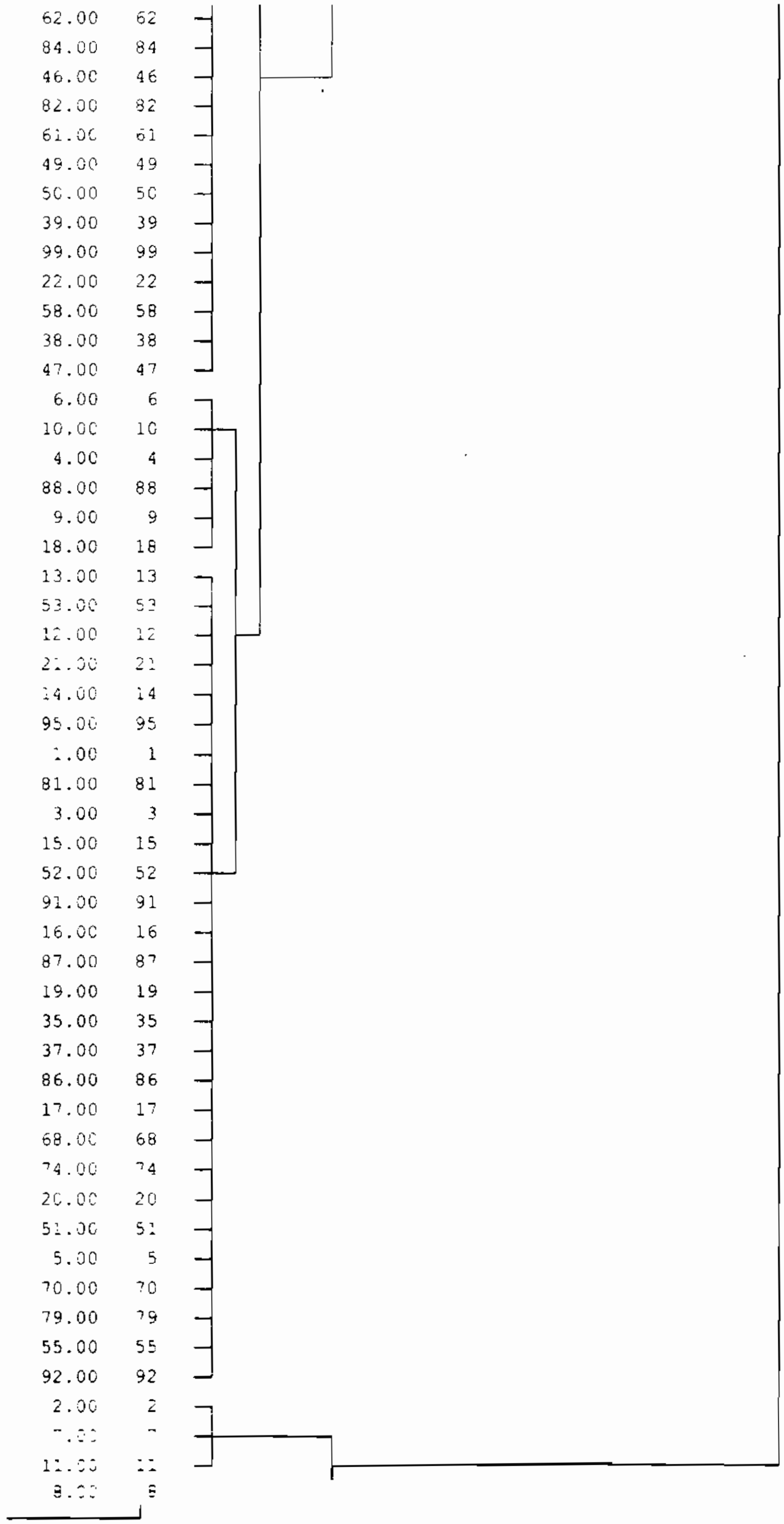

Fig 1. The Dendrogram at 25 per cent variance level for treatment combinations

again clustered in to homogenous groups. The dendrogram at 25 percent variance level obtained for different treatment combinations is depicted in Figure 1. The third cluster contained the treatment combination 86 *i.e.*, cuttings collected during rainy season from the middle portion of the culm treated with 300 ppm IBA. Treatment no.86 produced 5.67 sprouts; sprout height of 300 cm and collar girth 2.42 cm. The rooting percentage was 56.67 % and produced 64 roots on an average with a maximum length of 41.65 cm.

The cluster analysis carried out for the second cluster at 25 per cent level gave two homogenous clusters viz., first cluster containing the treatments 19 to 5 and the second containing treatments 6 to 9 (Fig. 1). The treatments in the second cluster (Sl no. 1-12) produced the largest rooting parameters (Table 7). The treatment combinations in the first cluster, which gave at least 30 per cent rooting, are also given in Table 7 (Sl no.13 to 23).

Table 7. Factor structure matrix and communalities of the variables

Variables	Factor loadings	Communalities after extraction	Variables	Factor loadings	Communalities after extraction
Sprout height	0.940	0.884	No of roots	0.849	0.721
Girth of sprouts	0.928	0.861	Root length max	0.845	0.714
Rooting %	0.697	0.486			

Table 8. Factor Score Coefficient Matrix

Variables	Factor 1	Variables	Factor 1
Sprout height	0.256	Root length max	0.232
Girth of sprouts	0.253	Rooting %	0.230
No of roots	0.190		

Table 9. Analysis of variance of Factor scores

Source	Degrees of freedom	Sum of squares	Mean square	F-Value
Season	2	30.83	15.42	70.44**
Replication	2	0.83	0.41	1.89ns
Error 1	4	0.88	0.22	
Position	2	48.51	24.21	106.98**
Treatment	10	15.15	1.52	6.70**
Position x treatment	20	30.67	1.53	6.78**
Season x position	4	64.89	16.22	71.69**
Season x treatment	20	14.49	0.72	3.20**
Season x position x treatment	40	36.45	0.91	4.03**
Error	120	27.15	0.23	

Observations on sprouting and rooting responses revealed that rooting occured during all the seasons and of the three seasons summer months were found the best. Of the three positions, cuttings taken from the basal portions of the culms performed better than the other two parts. Of the two GRS, IBA was found better. Use of growth regulating substances enhanced rooting response in all the seasons. The interaction between season, position, growth regulating substances and concentration was found significant and a cluster analysis to select best combination was carried out. On further analysis of two distinct clusters which gave ideal responses, the cuttings collected in summer season from basal portion of the culms treated with IBA 100ppm were found to give best result.

Sprouting and rooting response of branch cuttings

Bambusa balcooa

From the different experiments conducted in two locations for induction of rooting in branch cuttings, the cuttings treated and planted immediately in KFRI campus, Peechi gave better results. Earlier experiments with the same species had already shown that summer is the best season for rooting. A maximum of 29 percentage rooting was obtained and the effect of GRS was not evident (Table 10).

Table 10. Sprouting and rooting response of branch cuttings

Treatment	Per cent* rooting	Treatment	Per cent* rooting
Control	29.1	NAA - 1000	29.1
IBA-1000	25.0	NAA - 2000	25.0
IBA-2000	25.0	NAA - 3000	25.0
IBA-3000	8.33	NAA - 4000	16.6
IBA-4000	8.33	NAA - 5000	8.33
IBA-5000	4.1		

* Mean of three replicates of 8 nodes/treatments each

The success rate at FCMU, Kottappara was not at all encouraging. Although nearly 50 per cent of the cuttings showed sprouting in response to treatment with NAA, rooting response was very poor (Maximum 6.67). There was not much difference due to rooting medium or mixing with charcoal (Table. 11).

Table 11. Sprouting and rooting response of branch cuttings

Rooting medium	Type of cutting	Treatment	Mean* Sprouting %	Rooting*
Vermiculite	Double node	NAA 500	48.33	1.67
		Control	30	0
	Single node	NAA 500	1.67	0
		Control	0	0
Sand	Double node	NAA 500	46.67	6.67
		Control	41.67	0
	Single node	NAA 500	1.67	0
		Control	0	0
Vermiculite + charcoal	Double node	NAA 500	4.67	1.67
		Control	36.67	0
	Single node	NAA 500	0	0
		Control	0	0
Sand + charcoal	Double node	NAA 500	38.33	6.67
		Control	21.67	0
	Single node	NAA 500	6.67	0
		Control	0	0

* Mean of three replicates of 10 cutting each.

Dendrocalamus brandisii

Branch cuttings of *D. brandisii* was treated and planted with similar treatments with GRS and rooting medium as given to *B. balcooa* in both locations viz. Peechi and Kottappara. Although sprouting was observed, there was no positive response with regard to rooting.

DISCUSSION

Due to limitations of non availability of seeds for seedling production, conventional vegetative propagation methods such as offset planting, layering and rooting of culm cuttings have been tried in various species of bamboos to produce planting stock (Banik, 1980; Surendran *et al.*, 1983; McClure, 1966). Every node of segmented axis of a bamboo plant bears a bud or branch, which in turn has bud on its axis (Banik, 1980). Transforming as many buds as possible into planting material is the target of the propagation using culm cuttings. It is established that there is wide variation in the rooting efficacy of different species. During adventitious root induction, generally thick walled bamboo species suc h as *Bambusa balcooa, B. bambos* etc respond better than thin walled bamboo species like *Ochlandra travancorica* and *Melocanna baccifera* (Surendran *et al.*, 1983, Seethalakshmi *et al.*, 1990, Adarshkumar *et al* ., 1988, 1990). The influence of season, age of the culm and position of the node on rooting of bamboos is well established. The positive response of growth regulating substances such as NAA, IBA, and chemicals such as boric acid, coumarin. etc. on rooting has been reported in earlier work (Surendran *et al.*, 1983). Since rooting response is based on species and several other parameters, a species-specific protocol needs to be standardised after preliminary experiments considering all the parameters before going to large scale production of planting stock. The project envisaged to standardize a simple protocol for conventional vegetative propagation of two important priority species viz, *B. balcooa* and *D. brandisii*, which are selected by both NMBA and NBM for cultivation in India. Earlier reports showed the possibility of rooting of culm cuttings of *B. balcooa* but there was no report on vegetative propagation of *D. brandisii*

Experiments conducted with culm cuttings of *B. balcooa* showed 100 per cent rooting and vigour of rooted cuttings depended on concentration of growth regulator treatment. Since effect of season and position of cutting was studied during the previous projects (Seethalakshmi *et al.*, 1983; Seethalakshmi, 1991) detailed experiments were not conducted in the present study.

In *D. brandisii* rooting response is medium, reaching maximum of 57 percent. Basal part of the culm collected during summer months showed better rooting response and treatments with growth regulating substances although did not increase rooting percentage much, enhanced the root number and length of roots indicating that it will help better field establishment of rooted cuttings. Of the 99 treatment combinations tried, considering both rooting and sprouting responses, cuttings collected in summer season from basal portion of the culms treated with IBA 100ppm (treatment 86) was found superior. Considering mainly the rooting response, a cluster of 12 treatments (Table 1 - 1-12) was found to give maximum favourable response.

Although this is the first study on vegetative propagation of *D. brandisii*, the results agree with earlier observations in other species of bamboos with regard to influence of season, position of cutting and effect of growth regulating species (Adarshkumar *et al.*, 1988, 1990; Alhawat and Singh 2000) Due to the limitation in availability of parent material for collection of culm cuttings, the effect of age of culm on rooting response was not studied. It may be possible to increase the rooting percentage further by selecting the cuttings from culms of optimum maturity for rooting. This species can be treated as easy to root along with *B. balcooa* and *B. vulgaris* in which rooting is obtained without any growth regulators and rooting is possible throughout the year although the percentage obtained was low in rainy and winter season.

The experiments for rooting of branch cuttings gave positive results only for *B. balcooa*. The response was very poor when FCMU was used. This may be mainly due to the delay occurred in transporting involved from Peechi to Kottappara. The positive results obtained with branch cuttings indicate that it is possible to develop a protocol and use all the material from a culm for planting stock production.

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