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Seasonal variation on rooting response of branch cuttings of *Dendrocalamus giganteus* Wallich ex Munro

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Abstract: The present investigation was carried out to develop an easy and cheap protocol for mass propagation of this important bamboo species. Branch cuttings collected from mature clumps were treated with different concentrations of auxins such as IAA, IBA and NAA (100, 200 and 500 ppm) in spring, summer, autumn and winter for three consecutive years (March 2008 to February 2011). From the analysis, it was revealed that the variation in treatments among different seasons in relation to rooting percentage was non-significant ($P \geqslant 0.05$). Maximum (63.33%) rooting was also recorded in untreated cuttings in rainy season while minimum (21.83%) rooting were recorded in the cuttings treated with NAA 200 ppm in autumn. As regards to rooting hormones, maximum (40.42%) rooting was discernible in untreated cuttings i.e. control followed by the cuttings (37.71%) treated with IBA 500 ppm, while minimum (28.12%) rooting has been achieved in the cuttings treated with NAA 500 ppm. The treated cuttings showed the rooting behavior in the order: Control> IBA 500 ppm > IBA 200 ppm > IBA 100 ppm > IAA 100 ppm > IAA 500 ppm > IAA 200 ppm > NAA 100 ppm> NAA 200 ppm > NAA 500 ppm. From the present study it was revealed that the maximum rooting can be achieved in the cuttings treated with control (simple tap water). So, this commercially important bamboo species can be propagated without application of rooting hormones which is cost effective and farmer friendly.

Key words: Vegetative propagation, rooted stem cuttings, *Dendrocalmus giganteus*

INTRODUCTION

Bamboo is a woody grass belonging to the sub-family *Bambusoideae* of the family *Poacae* (Gramineae). Bamboo has a very long history with humankind. It has been used widely for household products and extended to industrial applications due to advances in processing technology and increased market demand. The increasing demand and over exploration of *Dendrocalamus* species of bamboo for multifarious uses calls for its large scale propagation. Propagation of *D. giganteus* through seeds is difficult due to long gestation cycles (40-50 years). Vegetative propagation has the potential to utilize maximum genetic gains in shortest possible time, but its success depends upon a proper environment, genetic components and the physiological status

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of cuttings etc (Cunningham, 1986). Commercially, offset and rhizome planting has been practiced in most of the bamboo species (Banik, 1994; Hasan, 1997), but they are inconvenient to handle (Nath and Das, 1995), expensive and suffer from serious drawbacks for large scale plantation.

Many innovative techniques for rapid mass multiplication have been developed during the past few years. Tissue culture technique has been developed for a large number of species of bamboo for large scale production (Chaturvedi and Sharma, 1985; and Banik, 1987), but these techniques are yet to be commercialized fully. Further, tissue culture method needs highly skilled manpower in sophisticated laboratories which are generally not available in most of the developing countries. Kumar *et al.* (1988, 1992), Kumar (1991), Kumar and Pal (1994) have developed a method called macroproliferation, by which seedlings can be vegetatively multiplied by separation and planting stock and can be produced continuously. Although this is very easy and economically viable method, but this method also needs the separable propagules, which can be obtained from seedlings, however, seeds are not always available due to long gestation period of most bamboo species. This initial dependence on seed availability needs to be over come from production of bamboo planting stock by macropropagation method mostly by rooting of cuttings. Propagation of bamboo through branch cuttings could be a useful approach because of their availability and ease in handling. Hence, innovative methods for propagating *D. giganteus* are essentially required to fulfill heavy demands of planting material.

A protocol for mass propagation technology of *Dendrocalamus giganteus* has thoroughly been studied and presented in this paper. Towards realizing the objectives of seasonal variation on rooting response of branch cuttings of this economically bamboo species, the following experiment were carried out during March 2008 to February 2011.

MATERIALS AND METHODS

Experimental site

The experiment on propagation was conducted in Randomized Block Design (RBD) in the nursery of Plant Physiology Discipline, Botany Division, Forest Research Institute, Dehradun Uttrakhand (30^0 20' 40" N Latitude, 77^0 52' 12" E Longitude and 640.08 Altitude) during March 2008- February 2011.

Meteorological data

Meteorological data on maximum and minimum temperature, relative humidity, rainfall, evaporation etc. on mean monthly basis for the studied period (March 2008-February 2011) at FRI, Dehradun was collected from Ecology and Environment Division Forest Research Institute, Dehradun. The details are presented in Fig 1.

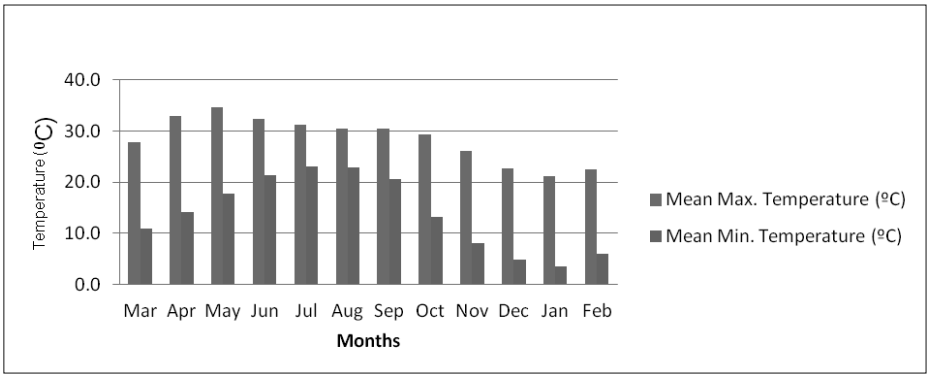

Figure 1: Mean average Maximum and Minimum temperature (March 2008-February 2011) at FRI Dehradun

Selection of superior culms

Superior culms of *D. giganteus* were selected on the basis of phenotypical characters viz. height, diameter, heavy crown, disease resistant, and straight boles from cohorts of *D. giganteus* growing at Forest Research Institute campus. The mature culms (above three years) were chosen and their branches were culled off for various experiments.

Planting Material

The experimental material consisted of branch cuttings extracted in March, June, September and December. The fresh cuttings were collected and put in plastic buckets filled with water to avoid desiccation and brought to Plant Physiology laboratory.

Preparation of cuttings

Binodal (two nodal) branch cuttings (10-15 cm) were prepared with the help of sharp secateurs. Care was taken not to cause injury to nodal buds.

Design: The summary of the experiments followed was designed as:

(a)	Number of species	:	One
(b)	Auxin treatments	:	Three (IAA, IBA and NAA)
(c)	Concentrations	:	Three (100, 200 and 500 ppm)
(d)	Replications	:	Three (R_1, R_2 and R_3)
(e)	Ramets	:	20 per replicate
(f)	Designs	:	Randomized Block Design (RBD)
(g)	Planting	:	Four seasons i.e. Rainy (June-August), Autumn (September-November), Winter (December-February) and Spring(March-May)
(h)	Planting of cuttings	:	After every three months
(i)	Planting conditions	:	Nursery beds and Earthen pots
(j)	Planting medium	:	Soil, Sand and FYM (2:1:1 ratio)

Effect of Plant growth regulators and season on rooting response

The experiment was confined to four seasons March-May (spring), June-August (rainy), September-November (autumn) and December-February (winter). Nodal branch cuttings were collected and prepared afresh during these seasons for three consecutive years (March 2008-February 2011). The data presented is the mean values of three years.

The different concentrations of these auxins with three replicates were prepared afresh by dissolving desired amount of auxins in running tap water.

Planting of cuttings

The cuttings in all the three experiments were divided into two groups. One group planted horizontally in nursery beds and the other group vertically in earthen pots. The cuttings were watered regularly to keep them moist.

Observations and collection of Data

The rooted branch cuttings were carefully uprooted from the rooting medium (Nursery bed and earthen pots) after three months (90 days) and observations were made on rooting percentage, number of roots, root length, number of sprouts and sprout length.

Rooting percentage

Profuse rooting occurs within 4 weeks of planting in nursery beds, however, observations were taken after completion of three months. A cutting is regarded to be rooted when it had at least one visible root. The rooting percentage was calculated as;

$$Rooting = \frac{\text{Number of cuttings rooted}}{\text{Total number of cuttings planted}} \times 100$$

Sprouting percentage

A cutting is said to be sprouted when it had at least one shoot greater than 1 cm. sprouting percentage was counted under each treatment and calculated as;

$$Sprouting = \frac{\text{Number of cuttings sprouted}}{\text{Total number of cuttings planted}} \times 100$$

Root number & length /Sprout number & length

The number of roots and shoots produced on individual cutting was counted. Length of roots and sprouts produced on each cutting was measured with a centimeter scale and expressed in centimeter (cm).

Statistical analysis

Data collected were compiled and subjected to one way Anova, to find out the significance of difference ($P \leqslant 0.05$) of the treatments in different seasons, cutting position on culms and cutting diameter. For rooting trial a completely randomized factorial design (RBD) was used with three replicates (20 cuttings per replicate). The percentage values were transformed to arcsine before carrying out the analysis. However, other analysis was performed on untransformed data.

All the data pertaining to rooting and subsequent growth was subjected to analysis of variance using Genstat statistical package (Genwin 3.2 version). In the analysis of variance for studied parameters, the mean values of each replication were estimated. For comparison of different interaction of treatment means, the critical difference (CD) were calculated based on student's t test at p=0.05 level. Critical Difference (CD) value was calculated by Schiff's method and is based on F-Statistics (Scheffé, 1959), CD is the minimum variance permissible between the means of treatments for grouping them as statistically non significant.

RESULTS

Interactive effects of Seasons (S) and Treatments (T) (S xT):

Mean number of roots

The interactive effect of season and treatment revealed a significant effect in all seasons (5% level) except cuttings planted in December (winter season) on the mean number of roots (Table-2). In spring season, maximum 5.16 number of roots were noticed in the cuttings treated with IBA 5 mg/l followed by the untreated cuttings with 4.65 roots. Minimum 4.15 roots were observed in the cuttings treated with IAA 5 mg/l. In rainy season, maximum 5.56 number of roots were recorded in the cuttings treated with IBA 5 mg/l however, minimum 4.18 roots were recorded in the cuttings treated with IAA 2 mg/l . While in autumn season, maximum 4.88 roots were recorded in the cuttings treated with IBA 5 mg/l followed by the cuttings treated with IBA 1 mg/l with average 4.58 roots and minimum 4.31 roots were recorded in the cuttings treated with IAA 100 ppm and NAA 500 ppm. As regards to winter season, no rooting was recorded. Overall, the maximum number of roots per cutting 5.56 was recorded in June-August with IBA 500 ppm treated cuttings.

Mean root length

The treatment effect is significant at ($P \leqslant 0.05$) in all four seasons with regard to mean root length except December planted cuttings (Table-2). In spring season maximum (29.14 cm) root length was noticed in the cuttings treated with IBA 500 ppm followed by the NAA 500 ppm (26.32 cm). Minimum (23.37 cm) root length was observed in the cuttings treated with IAA 500 ppm. In rainy season, maximum (26.81 cm) root length was recorded in the cuttings treated with IAA 500 ppm. however, minimum (23.43 cm) root length was recorded in the cuttings treated with NAA 500 ppm. While in autumn

season, maximum (27.67 cm) root length was recorded in the cuttings treated with IBA 500 ppm closely followed by the cuttings treated with IBA 200 ppm with average (27.34 cm) root length while, minimum (24.95 cm) root length was recorded in the cuttings treated with IAA 200 ppm. In winter season no rooting was recorded. Overall, the maximum root length (29.14 cm) was recorded in March-May with IBA 500 ppm.

Table 1: Different treatments given to *D. giganteus* cuttings in different seasons.

Treatment and Concentration	Season			
	March-May	June-August	Sep-November	Dec-February
Control	1	11	21	31
IAA 100 ppm	2	12	22	32
IAA 200 ppm	3	13	23	33
IAA 500 ppm	4	14	24	34
IBA 100 ppm	5	15	25	35
IBA 200 ppm	6	16	26	36
IBA 500 ppm	7	17	27	37
NAA 100 ppm	8	18	28	38
NAA 200 ppm	9	19	29	39
NAA 500 ppm	10	20	30	40

Rooting percentage

It was noticed from the analysis that the variation in treatments among different seasons in relation to rooting percentage was non-significant ($P \leqslant 0.05$). In spring season, maximum 55.83% rooting were noticed in untreated cuttings followed by the IBA 500 ppm treated cuttings with 50.83% rooting. Minimum 35.83% rooting was observed in the cuttings treated with NAA 500 ppm. In rainy season maximum 63.33% rooting was also recorded in untreated cuttings followed by the cuttings treated with IBA 500 ppm showing 56% rooting. However, minimum (40.0%) rooting was recorded in the cuttings treated with NAA 200 ppm and NAA 500 ppm. In autumn season, maximum (52.2%) rooting was recorded in the cuttings treated with IBA 200 ppm while, minimum (21.83%) rooting were recorded in the cuttings treated with NAA 200 ppm. However, in winter season no rooting was recorded. Overall, the maximum rooting (63.33%) was recorded in June-August in untreated control cuttings (Table-2).

Mean sprouting percentage

The statistical analysis revealed that the effect of treatment is highly significant ($P \leqslant 0.001$) in all seasons with mean sprout percent except December to February planted cuttings (Table-2) which could not respond to rooting. In spring season maximum 95.5% sprouting was noticed in the cuttings treated with IBA 500 ppm followed by the NAA 500 ppm treated cuttings with 89.3% sprouts. Minimum 60.5% sprouting was observed in the untreated cuttings. In rainy season maximum 100% sprouting was recorded in the cuttings treated with IBA 500 ppm however, minimum 72.1% sprouts

are noticed in the cuttings treated with IAA 500 ppm. In autumn season maximum 90.2% sprouts were recorded in the cuttings treated with IBA 500 ppm while, minimum 70.4% sprouts were recorded in the cuttings treated with IAA 100 ppm. No sprouting was recorded during winter season (December-February) planted cuttings in any of the treatments. Overall, the maximum sprouting percentage 100% was recorded in June-August planted (rainy season) cuttings with IBA 500 ppm.

Table 2: Interactive effect of SXT on rooting and allied parameters.

Season	Characters						
	Treatment	Mean No. of roots	Mean root Length (cm)	Mean rooting %	Mean No. of Sprouts	Mean sprout Length (cm)	Mean sprouting (%)
March-May	Control	4.65	25.04	55.83	5.67	28.02	60.50
	IAA100ppm	4.50	24.62	45.83	2.83	27.29	74.40
	IAA200ppm	4.25	25.23	45.00	2.66	27.72	82.30
	IAA500ppm	4.15	23.37	40.00	2.84	25.54	73.50
	IBA100ppm	4.25	23.81	45.00	4.00	25.01	64.00
	IBA200ppm	4.18	23.94	43.67	2.50	26.82	70.50
	IBA500ppm	5.16	29.14	50.83	5.00	33.28	95.50
	NAA100ppm	4.23	23.54	43.67	2.33	27.91	82.00
	NAA200ppn	4.43	23.90	44.17	2.33	26.73	81.50
	NAA500ppm	4.28	26.32	35.83	1.16	25.90	75.30
	Mean	4.408	24.891	44.983	3.132	27.422	75.95
July-Aug	Control	4.50	26.13	63.33	6.33	28.01	91.33
	IAA100ppm	4.56	25.50	45.00	4.00	23.90	83.40
	IAA200ppm	4.18	25.06	44.50	2.50	26.54	75.00
	IAA500ppm	4.23	26.81	53.67	4.16	24.91	72.10
	IBA100ppm	4.41	25.10	45.00	1.83	26.58	83.40
	IBA200ppm	4.48	26.54	43.67	2.16	26.31	94.50
	IBA500ppm	5.56	25.85	55.00	5.50	34.97	100.00
	NAA100ppm	4.45	25.31	32.17	2.66	25.81	73.00
	NAA200ppn	4.48	24.75	40.00	1.50	25.76	62.50
	NAA500ppm	4.26	23.43	40.00	2.00	24.04	74.60
	Mean	4.511	25.448	46.234	3.264	26.683	80.983
Sep-Nov	Control	4.45	23.52	44.50	4.00	24.19	75.50
	IAA100ppm	4.40	23.92	35.83	1.66	24.30	70.40
	IAA200ppm	4.41	24.95	35.83	1.00	25.73	83.50
	IAA500ppm	4.31	24.73	31.33	1.66	25.57	75.20
	IBA100ppm	4.58	23.94	31.33	1.16	25.18	82.00
	IBA200ppm	4.51	27.34	54.50	4.33	30.51	87.40
	IBA500ppm	4.88	27.67	45.00	3.20	30.78	90.20
	NAA100ppm	4.31	23.77	32.17	1.83	25.42	85.40
	NAA200ppn	4.35	24.81	31.83	1.33	24.23	75.50
	NAA500ppm	4.37	23.52	36.67	1.83	25.26	84.00
	Mean	4.457	24.817	37.899	2.2	26.117	80.91
Dec-Feb	Control	0	0	0	0	0	0
	IAA100ppm	0	0	0	0	0	0
	IAA200ppm	0	0	0	0	0	0
	IAA500ppm	0	0	0	0	0	0
	IBA100ppm	0	0	0	0	0	0
	IBA200ppm	0	0	0	0	0	0
	IBA500ppm	0	0	0	0	0	0
	NAA100ppm	0	0	0	0	0	0
	NAA200ppn	0	0	0	0	0	0
	NAA500ppm	0	0	0	0	0	0
	Mean	0	0	0	0	0	0
Significance		*	*	NS	***	***	***
CD		0.381	2.631	-	1.103	4.734	2.34

NS=Non Significant, *=Significant at $P \leq 0.05$, ***= Significant at $P \leq 0.001$

Number of sprouts

It was evident from the analysis that all the treatments had significant influence ($P \leqslant 0.001$) on mean sprout length per cutting in relation to season (Table-2). In spring season maximum 33.28 cm sprout length was noticed in the cuttings treated with IBA 500 ppm followed by the untreated cuttings (control) showing 28.02 cm sprout length. Minimum 25.01 cm sprout length was observed in the cuttings treated with IBA 100 ppm. In rainy season maximum 34.97 cm sprout length was recorded in the cuttings treated with IBA 500 ppm followed by the untreated cuttings with 28.01 cm sprout length. However, minimum 23.9 cm sprout length was recorded in the cuttings treated with IAA 100 ppm. While in autumn season maximum 30.78 cm sprout length was recorded in the cuttings treated with IBA 500 ppm closely followed by the cuttings treated with IBA 200 ppm with average 30.51 cm sprout length and minimum 22.3 cm sprout length was recorded in the cuttings treated with IAA 100 ppm. In winter season, no sprouting was recorded. Overall, the maximum sprout length 34.97 cm was recorded in June-August with IBA 500 ppm treated cuttings.

Effect of Treatment

Number of roots

The statistical analysis of results showed highly significant values ($P \leqslant 0.001$) in all the treatments with regards to the mean number of roots (Table-3). Maximum numbers (4.40) of roots were noticed in the cuttings treated with IBA 500 ppm followed by the untreated cuttings (3.90), while minimum (3.67) roots were observed in the cuttings treated with IAA 500 ppm.

Table 3: Effect of phytohormones on rooting and allied parameters in branch cuttings of *D. giganteus*

Treatments	Characters					
	Mean No. of roots	Mean root Length (cm)	Rooting %	Mean No. Sprouts	Mean sprout Length (cm)	Mean sprout percentage
Control	3.90	11.67	40.42	3.37	20.06	64.72
IAA100ppm	3.87	18.51	33.67	1.33	18.37	60.42
IAA200ppm	3.71	18.31	30.83	1.50	20.00	67.05
IAA500ppm	3.67	18.23	32.29	1.33	19.01	61.57
IBA100ppm	3.83	18.21	33.88	1.25	19.19	67.22
IBA200ppm	3.79	19.45	33.96	1.30	20.91	67.60
IBA500ppm	4.40	20.66	37.71	2.66	24.76	81.42
NAA100ppm	3.75	18.15	30.00	1.25	19.78	68.43
NAA200ppn	3.81	18.36	29.79	1.33	19.18	61.62
NAA500ppm	3.86	18.32	28.12	1.00	11.60	63.85
Significance	***	*	***	***	***	***
CD	0.190	1.316	4.225	0.551	1.367	4.954

*=Significant at $P \leqslant 0.05$, ***=Significant at at $P \leqslant 0.001$

Root length

A significant variation at 5% level was observed on mean root length per cutting in all treatments (Table-3). Maximum (20.66 cm) root length has been noticed in the cuttings treated with IBA 500 ppm closely followed by the cuttings (19.45 cm) treated with IBA 200 ppm. However, minimum (18.15 cm) root length of was recorded in the cuttings treated with NAA 100 ppm.

Rooting percentage

The variation in rooting percentage among different treatments was highly significant at $P \leqslant 0.001$ (Table-3). The maximum (40.42%) rooting was discernible in untreated cuttings i.e. control followed closely by the cuttings (37.71%) treated with IBA 500 ppm, while minimum (28.12%) rooting has been achieved in the cuttings treated with NAA 500 ppm.

Sprouting percentage

The statistical analysis depicted variation in rooting percentage among the different treatments which ($P \leqslant 0.001$) was highly significant (Table-3). The maximum (81.42%) sprouting percentage was discernible in the cuttings treated with IBA 500 ppm while minimum (60.42%) sprouting has been achieved in the cuttings treated with IAA 100 ppm.

Number of sprouts

It was noticed from the analysis that the number of sprouts per cutting per treatment was also significant at ($P \leqslant 0.001$). Maximum (3.37) sprouts were noticed in the untreated cuttings (control) closely followed by the cuttings (2.66) treated with IBA 500 ppm, while minimum (1.00) sprouts were observed in the cuttings treated with NAA 500 ppm.

Sprout length

A highly significant variation was observed ($P \leqslant 0.001$) in mean sprout length. The maximum (24.76 cm) sprout length was recorded in the cuttings treated with IBA 500 ppm followed by IBA 200 ppm (20.91 cm) treated cuttings. The minimum (18.37 cm) sprout length was observed in the cuttings treated with NAA 200 ppm. It is interesting to note that rooting response of branch cuttings in *D. giganteus* was found better in untreated cuttings for all parameters rather than treated cuttings.

DISCUSSION

Several attempts were made earlier by Nautiyal *et al.,* 1991; Nautiyal and Rawat, 1994; Sorin *et al*., 2005 on rooting behavior of cuttings. It is well established fact that all auxins IAA, IBA and NAA generally stimulated adventitious root formation but in this case, it is interesting to note that maximum rooting was observed in untreated

control cuttings followed by IBA which is in confirmation of earlier results by Nautiyal *et al.* (2007) in *Bumbusa vulgaris* var. striata and in *Bumbusa vulgaris* cv wamin (Razvi *et al.,* 2011). This may the case of the other monocots who behave differently as compared to dicots in which the auxin application has been found much useful. In broad leaved species like *Jatropha curcas* Ghosh and Singh (2010) observed rooting without external application of auxins (IBA). Without auxin (IBA) treatment, it produces sufficient sprouting and rooting. However, the effectiveness of these auxins in our work followed a pattern of Control>IBA>IAA>NAA. Similar comparison of exogenous hormones was also reported in bamboos earlier indicating improvement in rooting by application of hormones e.g. IAA in *Bambusa balcooa, Dendrocalamus hamiltonii* and *B. vulgaris* (Nath *et al.*, 1986), NAA in *B. arundinacea* and *D. strictus* (Surendran *et al.,* 1983), *B. tulda* (Kumar, 1989; Nath *et al.,* 1986) and IBA in *B. arundinacea* and *Dendrocalamus strictus* (Surendran *et al.,* 1989).

The rooting of cuttings is influenced by many external and internal factors, which have been known for a long time and excellent reviews on this subject had appeared periodically (Allen and McComb, 1955; Leopold, 1960; Hyun, 1967). Of the external factors, season play an important role on adventitious rhizogensis. The seasonal changes and effect of their choice on rooting of stem cuttings have been reported by many workers (Hitchcock and Zimmerman, 1930; Mirov, 1994; Morishita. 1964; Nanda *et al.,* 1968; Arya and Haque, 1982; Uniyal *et al.*, 1993). The influence is probably due to changes in the temperature, light and humidity conditions, which prevail at the time of collection and planting of cuttings.

Effect of season or period of collection of cuttings on rooting frequency has been reported in various tree species. Khali and Sharma (2003) observed high rate of rooting from the branch cuttings of *Taxus baccata* collected during March-October, whereas in *Ficus religiosa*, March-July proved the best period for rooting. Winter (November-February) period proved ineffective in root induction from both the species. Palaniswamy *et al.* (1998) reported that maximum rooting percentage in stem cuttings of *Azadirachta indica* and *Pongamia pinnata* was observed in the stem cuttings collected in the month of February and March respectively. In our study, it was notice that the variation in treatments among different seasons in relation to rooting percentage is non-significant ($P \geqslant 0.05$). In spring season (March-May), maximum (55.83%) rooting was noticed in untreated cuttings followed by the IBA 500 ppm treated cuttings with (50.83%) rooting. Agnihotri and Ansari (2000) also reported that cuttings collected in February and April showed significantly maximum root induction and growth of adventitious roots in *B. bamboos* and *D. strictus,* respectively. In rainy season (June-August) maximum (63.33%) rooting was recorded in untreated cuttings followed by the cuttings treated with IBA 500 ppm with (56.0%) rooting. Capuana *et al.* (2000) reported that period of collection of cuttings has significant influence on rooting in *Cupressus sempervirens* clones. They observed that cuttings collected during April exhibited highest rooting percentage, whereas poor rooting response was observed from the cuttings collected during December from all the tested clones. Singh *et al.* (2002) reported that single nodal culm and culm branch cuttings of

B. nutans collected in the month of April and May and treated with IBA were effectively good for large scale vegetative propagation. In autumn season (September-November), maximum (52.2%) rooting was recorded in the cuttings treated with IBA 200 ppm while, minimum (21.83%) rooting was recorded in the cuttings treated with NAA 200 ppm. In winter season, no sprouting has been recorded which is non confirmatory to the results by Agnihotri and Ansari (2000) in *D. strictus* who exhibited steep decline in rooting percentage and no root induction was observed from the cuttings collected during August to January. Kumar *et al.* (1997) reported that *B. tulda* produces adventitious roots almost the whole year, except in the month of December; whereas, *D. strictus* did so for six months i.e. from February to July only. Raveendran *et al.* (2010) observed in *D. brandisii* that the rooting occurs during all the seasons and of the three seasons summer months were found to be the best. However, Ghosh and Singh (2010) studied that among the three seasons tested, rainy season gave maximum (7.20 cm) root length in *Jatropha curcas* while it was lowest (5.19 cm) in winter. Rainy season yields highest (5.33) root numbers whereas, winter has lowest (6.36) root numbers. Rooting was highest (58.90%) in rainy season and lowest (22.50%) during winter season. Sprouting was also maximum (91.70%) in rainy season and minimum (51.30%) in autumn season.

Seasonal variation has distinct effect on the growth of plants. Light intensity, day light, temperature, humidity in air and sub soil moisture are known factors to influence growth. Stored energy like; carbohydrate, protein contents and minerals play key role in rhizogenesis process and their concentrations are variable during different seasons. There are conflicting reports about the best season (period) of collection and planting of cuttings for good rooting response.

The above studies clearly indicate in *D. giganteus* rooting period of bamboos during the present investigation coincides with the cessation of winter season and continues till the end of warm season. This possibility reveals that the rooting in bamboos are related to the resumption of active growth by rhizome which are the store houses of photosynthates and auxiliary substances. In turn, these substances become available to new culms and culm branches which also incidentally developed during March to September in most bamboos in India. Very little information is available with regards to rooting behavior of bamboos as related to various seasons. However, the rooting performance in deciduous tree has been correlated to emergence of new sprouts after winter leaf fall. The reason for such behavior of trees is ascribed to mobilization of stored food material in the shoots together with the synthesis of auxin and other rooting co-factors in the new sprouts (Avery *et al*., 1987).

It is also established that for adventitious root formation and growth, seasonal variations dominate over other factors such as IAA, IBA and NAA application in this bamboo species. This is conceivable as the competence of vegetative cells to respond to rooting stimuli is conferred during a specific period of year and determined by external factors, especially temperature and length of photoperiod (Dykeman, 1976; Kester, 1983). These studies have established that high temperature and long

photoperiod favours rooting in broad leaved deciduous trees. However, adventitious root formation in *D. giganteus* as noted in this experiment coincides with the high temperature, rainfall and long photoperiod. Thus, the emergence of warm climate could have conferred competence to cells to respond to exogenous application of simple tap water as compared to IAA, IBA and NAA and adventitious root in June and March. Thus, the result of seasons to rooting response in bamboos also established the fact that low temperature during winter completely inhibits the rooting and sprouting because of the low metabolic activities during this time. Similarly, low rooting in autumn season also indicates that from September onwards the temperature in Northern regions of India starts decline which has a direct bearing on all metabolic activities of plants. Accordingly, *D. giganteus* also respond to lower rooting and sprouting in the cuttings planted in the month of September.

CONCLUSION

Considering the forgoing scenario, as well as the rapidly increasing demand of economically important bamboo species, many innovating techniques for rapid mass multiplication have been developed during the past few years. Propagation of bamboo through branch cuttings could be a useful approach because of their availability, non destruction of clumps and ease in handling. From the present study it was interesting to note that maximum rooting response was observed in the cuttings treated with tap water only. Hence this important bamboo species can be easily propagated without the application of rooting hormones which is cost effective and easy one.

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