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Low-cost planting stock production of bamboo (*Dendrocalamus strictus* Roxb.) using culm cuttings

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Abstract—A study was conducted to see the effects of various positions of cutting (basal, middle and apical) and growth regulators/chemicals on rooting and sprouting of culm cuttings of bamboo (*Dendrocalamus strictus* Roxb.). The growth regulators/chemicals used were also evaluated for their cost effectiveness. The findings indicated that coumarin and calcium chloride gave the best response in initiating the rooting in culm cuttings compared to other auxins tested. The most optimal cutting position was found to be the basal position of culm for the best interaction with the chemicals. These two chemicals were the most cost-effective and are recommended for low cost mass production of planting stock of bamboo for large-scale plantation programmes.

Key words: *Dendrocalamus strictus*; growth regulator; propagation; bamboo; plantation.

INTRODUCTION

Dendrocalamus strictus is one of the most important bamboos in India [1]. It is found to grow well in reclamation areas of ravine lands [2]. In India, it is extensively used as raw material in paper mills and also for a variety of other uses, including constructional purposes. This species is widely distributed in India in semi-dry and dry zones along plains and hilly tracts usually up to an altitude of 1000 m; it is also common throughout the plains and foot hills [3].

The flowering cycle of *D. strictus* ranges 20–60 years and after gregarious flowering, all flowered clumps subsequently die. Further, the low viability of seeds poses critical problems for propagation. However, vegetative propagation using different parts of the plant *viz.*, rhizome, culms and branches, etc., offers a great opportunity to overcome this problem. Culm cutting is the most practical and

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feasible method and provides better survival rates, as seen in other bamboo species [4–9].

The role of auxins in initiating adventitious rooting in bamboo has been reported by many researchers [8–12], but some other researchers have reported other chemicals, *viz.*, boric acid or coumarin, and recorded better results [7, 13–15]. In fact, these chemicals are cheaper than any typical auxin. Therefore, screening of cost-effective rooting substances is useful for large-scale bamboo plantation programmes using culm cuttings.

The present study was conducted to study the effectiveness of various growth regulators (chemicals) on rooting of bamboo culm cuttings, optimal positioning of cuttings and cost-effectiveness of rooting substance for large scale bamboo plantation programmes.

MATERIALS AND METHODS

The present study was conducted in the Plant Physiology Branch of the Forest Research Institute, Dehra Dun, India (30°20′40″N latitude, 77°52′12″E longitude and 640 m altitude) during the year of 2000. The following standard methods were adopted for the study.

Preparation of nursery beds

The nursery beds (10 × 1 m) were prepared by proper soil working, one week prior to planting the cuttings. Soil and sand were mixed in 3 : 1 ratio to loosen the planting area. Thiram (75% DS) at the rate of 100 g per bed was mixed with soil to prevent termite attack.

Preparation of culm cuttings and treatment with fungicide

Culms of *D. strictus* (1–3 years old) were extracted from healthy and approximately 10-year-old clumps growing in Forest Research Institute (FRI) campus. The top thin portion of the culm bearing leaves was discarded and the branches were removed without damaging the axillary buds. The complete culm was divided into three equal parts (i.e. apical, middle and basal) according to their positions. Binodal cuttings with healthy axillary buds were made from these culm segments with about 5 cm culm on each side, beyond the nodes. Cuttings were then treated with fungicide by dipping the cuttings in 0.1% bavistin solution for 30 min. An opening was then made in the middle of the culm cutting into the internodal cavity.

Treatment with growth regulator/chemical

The binodal cuttings were treated with different growth regulators/ chemicals, all of which were procured from Sigma (St. Louis, MO, USA). Two concentrations (10 and 100 mg/l) of indole butyric acid (IBA), naphthalene acetic acid (NAA), boric acid (BA), coumarin and calcium chloride were used for treating the cuttings and water was used as control. About 100 ml of the solution was poured into the culm cavity and closed by wrapping and tying it with a polythene strip.

Planting of the culm cuttings

Treated cuttings were planted horizontally following the randomised block design (RBD) (3 replications with 10 cuttings per replication) in the nursery beds ensuring that the opening faced upwards, and were covered with an about 2-cm-thick layer of soil. The nursery beds were irrigated regularly. The cuttings were protected from insect pests and disease by using chemical sprays as and when required. Manual weeding was carried out on 15-day intervals.

Observations

The following parameters were recorded: sprouting percentage was recorded twice, once after 15 days and again after 30 days of planting, and rooting percentage was recorded six months after planting.

Data analysis

After recording observations on various parameters, data were analysed statistically using statistical package for social sciences (SPSS-7.0). The calculated value of F obtained for different sources of variation was compared with the tabulated value at 5% and respective degree of freedom of source and error.

RESULTS

Sprouting

The data collected on the percentage of sprouting are presented in Tables 1–3. The results are as follows.

Effect of growth regulator/chemical treatments. The data reveal that growth regulator/chemical treatments affected sprouting significantly. Maximum sprouting (40.3%) was observed in cuttings treated with 10 mg/l solution of NAA, followed by 100 mg/l coumarin (36.9%), 10 mg/l BA (33.7%), 10 mg/l calcium chloride (30.3%), 100 mg/l calcium chloride (30.3%), 100 mg/l BA (26.9%), 100 mg/l IBA (26.8%) and the lowest percentage of sprouting (6.7%) was recorded in cuttings, treated with water (control).

Effect of position of cutting. The effect of position of cutting was also observed to significantly affect sprouting of the cuttings. The maximum sprouting (38.5%) was observed in cuttings taken from the basal position followed by those taken from middle position (24.8%) and the least from cuttings taken from the apical position of the culm (19.3%).

Table 1.
Sprouting percentage in culm cuttings influenced by growth regulators/chemical treatments and position of cuttings in *Dendrocalamus strictus*

Time of observation	Position	Treatment (mg/l)										Control	Mean position
		IBA		NAA		Coumarin		BA		$CaCl_2$			
		10	100	10	100	10	100	10	100	10	100		
After 15 days	Apical	0.0 (4.05)	0.0 (4.05)	20.4 (21.24)	20.4 (21.24)	20.4 (21.24)	20.4 (21.24)	60.2 (55.60)	40.3 (38.42)	20.4 (21.24)	20.4 (21.24)	0.0 (4.05)	20.3
	Middle	40.3 (38.42)	0.0 (4.05)	40.3 (38.42)	20.4 (21.24)	20.4 (21.24)	0.0 (4.05)	20.4 (21.24)	20.4 (21.24)	20.4 (21.24)	20.4 (21.24)	0.0 (4.05)	18.5
	Basal	20.4 (21.24)	20.4 (21.24)	60.2 (55.60)	20.4 (21.24)	40.3 (38.42)	40.3 (38.42)	20.4 (21.24)	20.4 (21.24)	20.4 (21.24)	0.0 (4.05)	0.0 (4.05)	23.9
	Mean	20.2	6.8	40.3	20.4	27.0	20.2	33.7	27.0	20.4	13.6	0.0	
After 30 days	Apical	20.4 (21.24)	40.3 (38.42)	40.3 (38.42)	0.0 (4.05)	0.0 (4.05)	20.4 (21.24)	20.4 (21.24)	0.0 (4.05)	40.3 (38.42)	20.4 (21.24)	0.0 (4.05)	18.4
	Middle	20.4 (21.24)	60.2 (55.60)	40.3 (38.42)	20.4 (21.24)	20.4 (21.24)	40.3 (38.42)	40.3 (38.42)	40.3 (38.42)	40.3 (38.42)	20.4 (21.24)	0.0 (4.05)	31.2
	Basal	40.3 (38.42)	40.3 (38.42)	40.3 (38.42)	60.2 (55.60)	40.3 (38.42)	100.0 (89.96)	40.3 (38.42)	40.3 (38.42)	40.3 (38.42)	100.0 (89.96)	40.3 (38.42)	53.0
	Mean	27.0	46.9	40.3	26.8	20.2	53.6	33.7	26.8	40.3	46.9	13.4	

* Values in parentheses are $\sin^{-1}$ transformed.

Table 2.
Mean sprouting percentages obtained in this study

Parameter	Mean
Treatment	
IBA 10	23.6
IBA 100	26.8
NAA 10	40.3
NAA 100	23.6
Coumarin 10	23.6
Coumarin 100	36.9
BA 10	33.7
BA 100	26.9
$CaCl_2$ 10	30.4
$CaCl_2$ 100	30.3
Control	6.7
Position	
Apical	19.3
Middle	24.8
Basal	38.5
Time	
15 days	20.9
30 days	34.2

Critical differences at 0.05: Treatment 13.2, time 5.6, position 6.9, treatment × position not significant. time × position 9.7, treatment × time 18.6, treatment × time × position 32.3.

Table 3.
Sprouting percentage influenced by growth regulators/chemical treatments and position of cuttings in culms of *D. strictus*

Position	Treatment (mg/l)										Control
	IBA		NAA		Coumarin		BA		$CaCl_2$		
	10	100	10	100	10	100	10	100	10	100	
Apical	10.2	20.2	30.35	10.2	10.2	20.4	40.3	20.2	30.4	20.4	0
Middle	30.4	30.1	40.3	20.4	20.4	20.4	30.4	30.4	30.4	20.4	0
Basal	30.4	30.4	50.3	40.3	40.3	70.4	30.4	30.4	30.4	50.0	20.2

Time of sprouting. It was observed that sprouting was 34.2% at 30 days after planting and 21.0% at 15 days after planting.

Interaction effects of various treatments. The interaction of growth regulator/chemical treatment and cutting position was not significant (Table 3). However, the maximum sprouting (70.2%) was recorded in 100 mg/l coumarin-treated cuttings taken from the basal position of the culm, followed by those treated with 10 mg/l NAA and 100 mg/l calcium chloride (50.3%) and from basal position, whereas no sprouting was observed in control cuttings taken from both apical and middle positions of culm.

The interaction between time of observation and position of cutting was significant on sprouting. Maximum sprouting (53.0%) was recorded in cuttings taken from basal position after 30 days of planting, while the minimum (18.4%) sprouting in cuttings taken from apical position after 30 days of planting (Table 1).

The interaction of chemical treatment and time taken for sprouting was also significant. The maximum (53.6%) sprouting was recorded in 100 mg/l coumarin-treated cuttings after 30 days of planting, followed by 46.9% in 100 mg/l IBA and 100 mg/l calcium chloride treatments after 15 days of planting. No sprouting was observed in control treated cuttings.

The interaction of chemical treatment, time taken and position of cuttings was also found to be significant. Max (100%) sprouting was recorded in 100 mg/l coumarin- and calcium-chloride-treated cuttings taken from basal position of culm after 30 days of planting and minimum (0%) in control cuttings taken from both apical and middle position of the culm at both times of observation. In general, sprouting was most in all treatments with basal position after 30 days of planting, followed by middle position after 30 days of planting, while it was least in cuttings taken from apical position and 15 or 30 days after planting (Tables 1 and 2).

Rooting percentage

Results on the rooting behaviour of culm cuttings are presented in Table 4. Significant differences were observed of the effects of chemical treatments, position of cutting and their interactions on rooting of cuttings.

Table 4.
Rooting percentage influenced by growth regulators/chemical treatments and position of cuttings in culms of *D. strictus*

Position	Treatment (mg/l)										Control	Mean
	IBA		NAA		Coumarin		BA		$CaCl_2$			
	10	100	10	100	10	100	10	100	10	100		
Apical	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Middle	20.0 (17.99)	20.0 (17.99)	20.0 (17.99)	20.0 (17.99)	0.0 (0.00)	40.0 (35.99)	40.0 (35.99)	40.0 (35.99)	0.0 (0.00)	20.0 (17.99)	0.0 (0.00)	20.0 (17.99)
Basal	80.0 (71.97)	20.0 (17.99)	60.0 (53.98)	40.0 (35.99)	20.0 (17.99)	100.0 (89.96)	40.0 (35.99)	40.0 (35.99)	80.0 (71.97)	20.0 (17.99)	40.0 (35.99)	49.1 (44.16)
Mean	33.3 (29.99)	13.3 (12.00)	26.7 (23.99)	20.0 (17.99)	6.7 (6.00)	46.7 (41.98)	26.7 (23.99)	26.7 (23.99)	26.7 (23.99)	13.3 (12.00)	13.3 (12.00)	

* Values in parentheses are $\sin^{-1}$ transformed.
CD values at 0.05: position 9.9, treatment 18.8, position × treatment 42.1.

Effect of growth regulator/chemical treatment. Maximum rooting (46.7%) was recorded in 100 mg/l coumarin-treated cuttings, followed by 26.7% in 10 mg/l NAA, 10 and 100 mg/l BA and 10 mg/l calcium chloride treatments. Minimum rooting (6.7%) was observed in 10 mg/l coumarin, and 13.3% rooting was seen in control, 100 mg/l IBA and calcium chloride treatments.

Effect of position of culm cutting. Maximum rooting (49.1%) was recorded in cuttings taken from the basal position of the culm, followed by 20.0% in cuttings from the middle position, while cuttings taken from the apical position of culm failed to root.

Interaction of growth regulator/chemical treatment and position of cutting. The interaction effect between growth regulator/chemical treatment and position was significant. Overall, the maximum rooting (100%) was recorded in 100 mg/l coumarin-treated cuttings taken from the basal position of the culm, followed by 80% in 10 mg/l calcium chloride and IBA and 60% in 10 mg/l NAA-treated cuttings taken from the same position. In the case of cuttings taken from the middle position, no rooting was observed in controls and those treated with 10 mg/l coumarin and 10 mg/l calcium chloride. None of the cuttings rooted, irrespective of growth regulator/chemical treatment in case the cuttings were taken from the apical (top) portion.

DISCUSSION

The results of the study show that treatment with coumarin, BA, calcium chloride, IBA and NAA promoted rooting as well as sprouting in culm cuttings of *D. strictus*. Treatment with 100 mg/l coumarin produced maximum percentage of rooting and maximum percentage of sprouting. Other researchers [2, 7, 8, 12, 16–19] have also reported that treatment with auxins, BA and coumarin promoted rooting and sprouting in culm cuttings of several species of bamboo. Coumarin has been reported to give better results for rooting of cuttings of other plant species as well [13–15]. However, in the present study, treatment with calcium chloride also was observed to have stimulatory effect on rooting and sprouting in culm cuttings of *D. strictus*. No literature is available so far on the effect of calcium chloride on rooting specially in bamboos. The stimulatory effect of calcium chloride may be due to the fact that calcium pools in many plants are generally very poor [20], the external application of these elements may improve rooting and sprouting by improving the availability of this element in plant tissues.

Further, studies on interaction with position of cutting on culm and growth regulator/chemical treatment revealed that best combinations of treatments were basal position and 100 mg/l coumarin. It is now generally believed that coumarin promotes rooting of culm cuttings by synergising the effect of endogenous or

Table 5.
Comparative costs of different growth regulators per 100 g

Growth regulator	Price (US$)
Indole butyric acid (IBA)	532.00
Napthalene acetic acid (NAA)	50.40
Boric acid (BA)	21.60
Coumarin	14.50
Calcium chloride ($CaCl_2$)	7.72

Source: Biochemicals and Reagents for Life Science Research (2002–2003), Sigma-Aldrich (St. Louis, MO, USA).

externally applied auxins [7]. The results indicate that chemicals like coumarin and calcium chloride may be used for successful vegetative propagation of *D. strictus*. These chemicals are also cheaper than any typical auxin (Table 5). Therefore, these two chemicals may be recommended for low cost production of planting stock for large-scale plantation programmes.

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