Plant Tissue Cult. & Biotech. **32**(2): 157-166, 2022 (December) **ISSN 1817-3721, E-ISSN 1818-8745**
DOI: https://doi.org/10.3329/ptcb.v32i2.63550

PTC&B

In vitro Propagation of an Ornamental Bamboo (*Bambusa tuldoides* Munro)

Partho Sharothi, Raihan Iqbal Raju* and Mohd. Talim Hossain

Department of Botany, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

Keywords: Rapid propagation, ornamental bamboo, *in vitro* culture.

Abstract

This study was undertaken to standardize an efficient protocol for *in vitro* propagation of an ornamental bamboo *Bambusa tuldoides* Munro using nodal segments as explants. For direct shoot induction, liquid MS medium containing 2.0 mg/l BAP and 1.0 mg/l TDZ gave a maximum response (84%) with maximum number of shoots (4.80 ± 0.49) per explant. These shoots were proliferated efficiently on agitated liquid MS medium with 3.0 mg/l BAP and 1.5 mg/1 TDZ, which resulted in the formation of 15.40 ± 1.21 shoots per culture with 6.96 ± 0.65 cm shoot length. Shoots gradually increased in number and length during the first four subculture cycles in the same media combination but declined in 5th sub-culture cycle. After the 4th sub-culture cycle, the number of shoots per culture was 20.40 ± 1.44 and shoot length was 7.92 ± 0.78 cm. The addition of 10% coconut water with the above mentioned medium resulted in satisfactory shoot growth and development with 24.20 ± 1.16 shoots per culture. Maximum (84%) rooting with the highest number of roots per culture (7.20 ± 0.37) was obtained from half-strength MS medium fortified with 3.0 mg/l IBA. Well rooted plantlets were successfully acclimatized to the soil where the survival rate was 92%.

Introduction

The genus *Bambusa*, belonging to the family Poaceae, consists of approximately 157 species throughout the world (Sharma et al. 2014), in which *Bambusa tuldoides* Munro is the most widely cultivated ornamental species. Bright green culms with swollen internodes of this bamboo resembling the fat belly of the Buddha, hence this bamboo is commonly called "Buddha's belly bamboo". This bamboo species is also known as 'punting pole bamboo', 'verdant bamboo' in Indonesia; 'Bambu blenduk' in Malaysia; 'bulohbalai' in Vietnam (But and Chia 1995), and 'Ghoti bash' in Bangladesh. It is native to Asia, including China (Guangdong, Guangxi), Malaysia, Laos, Myanmar and Vietnam, and has been introduced to Central and South America, the Caribbean, tropical Asia and the Pacific region (Clayton et al. 2018).

*Author for correspondence: <raihan1792@gmail.com>.

B. tuldoides is frequently cultivated as an ornamental plant and is much treasured in bonsai and horticulture. To produce the swollen internodes, the plants must be potted under dried and unfertilized conditions. However, the culms are also used as punting poles and scaffolding, while the splits are used in weaving handicrafts (But and Chia 1995). Young shoots can be eaten as a vegetable (Fern 2014). In Chinese medicine, shavings of the culm cortex of *B. tuldoides* are used for febrile diseases, epistaxis, and infantile epilepsy (But and Chia 1995). This bamboo species is widely used in the production of cellulose and agglomerated panels (Morais et al. 2015). Now a day there is huge demand for this bamboo species for decorating houses, hotels and commercial buildings.

Current methods of bamboo propagation are mainly based on cutting, air layering or seed (Raju and Roy 2016). But, vegetative propagation methods have some limitations for large-scale propagation such as, planting materials being bulky to transport, insufficient in number (Mudoi et al. 2013), and not always available due to seasonal specificity (Singh et al. 2012). Although, propagation through seeds is possible, but not practical because the seed set is very poor due to sporadic flowering and low viability (Brar 2014). Because of the difficulties with these traditional propagation methods, large scale vegetative propagation of this ornamental bamboo species is quite impossible. In this regard *in vitro* propagation of this bamboo species could be an excellent alternative for rapid propagation. So, the present research work was carried out to establish an efficient and reproducible micropropagation protocol through direct shoot organogenesis for an ornamental bamboo species, *Bambusa tuldoides* Munro.

Materials and Methods

The explants used in this research were nodal segments of *B. tuldoides* Munro containing pre-existing axillary bud. This bamboo species was identified by the authorities of Bangladesh National Herbarium, Mirpur, Dhaka (Accession no. DACB 66291). At first the nodal segments with single axillary buds were washed under running tap water for 15-20 min and sterilized first in distilled water with 2-3 drops of a liquid detergent (Tween-20) for 15 min, followed by 4-5 times washing with distilled water. Further sterilization of the explants has been done under laminar airflow cabinet with Bavistin (0.5%) for 4-6 min, followed by 70% alcohol for 30 sec, and then mercuric chloride (0.2%) for 4 min to ensure contamination free culture. After each treatment repeated (3-4 times) washing of explants with sterile distilled water was followed. Finally, the cut ends of nodal explant exposed to sterilants were removed with the help of a scalpel and forceps under laminar air flow before inoculation.

Surface sterilized nodal explants (2-3 cm) were inoculated individually on liquid MS medium supplemented with different concentrations of BAP (0.5-3.0 mg/l) alone or in combinations with TDZ (1.0-1.5 mg/l) for direct shoot induction. Induced axillary shoots were excised aseptically and cultured on agitated liquid MS medium supplemented with

different concentrations of BAP (1.0-4.0 mg/l) alone or in combinations with Kn (0.5-1.0 mg/l), TDZ (1.0-1.5 mg/l) and NAA (0.5 mg/l) for multiplication of shoot. In this investigation, effect of successive sub-culture cycles and different concentrations of coconut water (5%-15%) on shoot multiplication also experimented. *In vitro* raised shoots obtained from the multiplication media with 4-8 cm in length, were excised aseptically from the culture vessels and implanted on freshly prepared half-strength of liquid and gelled MS medium separately containing different concentrations and combinations of IBA (1.0-4.0 mg/l) and NAA (1.0-1.5 mg/l) for rooting. For root induction, the newly transferred cultures were kept in dim light for 3 days and then they were kept in the light.

The plantlets with sufficient root system were taken out from the culture vessels and the roots were washed under running tap water. The plantlets were then transferred to small polybags containing the soil mixture of garden soil, sand and compost with (1:1:1) ratio. They were then covered with transparent polythene bags and the inner side of the polythene bags was sprayed with water to maintain high humidity. The polythene bags were gradually perforated to expose the plantlets to the outer normal environment. After 3-weeks of transplantation, when the regenerated plants were fully established in the soil condition, they were then transferred to larger pots for further growth and development.

Results and Discussion

For the sprouting of axillary buds, nodal explants were inoculated on liquid MS medium with twelve different combinations of growth regulators. Sprouting of nodal explants were induced in all of the combinations, but the combined effect of 2.0 mg/l BAP and 1.0 mg/l TDZ was found to be most effective (84%) with a maximum of 4.80 ± 0.49 shoots per explant and 4.22 ± 0.20 cm shoot length after 14-21 days of inoculation (Table 1). Similar findings were also observed by Raju and Roy (2016) in the case of *B. bambos*. However, Das and Pal (2005) and Brar et al. (2014) reported that, 1.5 mg/l BAP and 1.5 mg/l Kn supplemented medium was best for direct shoot induction in *B. balcooa*. In this experiment, it has also been found that, the single effect of BAP was not as good as a combined effect of BAP and TDZ (Table 1). But, Cheah and Chaille (2011) and Wei et al. (2015) in *B. ventricosa*, reported 80-90% axillary bud sprouting on MS medium supplemented with only BAP.

Different concentrations and combinations of plant growth regulators in the medium influenced the rapid multiplication of the induced axillary shoot. Among the different types of cytokinins tested, BAP found to be the best cytokinin for the shoot multiplication of *B. tuldoides* Munro. The maximum rate of shoot multiplication (72%) was observed when only BAP was used at the concentration of 3.0 mg/l (Table 2). Similarly, Sharma and Sarma (2011) in *B. balcooa* and Arya et al. (2006) in *Dendrocalamus giganteus* also reported a maximum rate of shoot multiplication in MS medium incorporation with only BAP. Comparatively, the conjoint addition of BAP and Kn in the medium did not

increase the rate of shoot multiplication (Table 2). But on the contrary, Waikhom and Louis (2014) in *B. tulda* and *Melocanna baccifera* reported that, the combined effect of BAP and Kn increased the shoot multiplication rate.

Table 1. Effect of different concentrations of BAP alone or in combination with TDZ in liquid MS medium on direct shoot induction from the nodal explants of *B. tuldoides* Munro.

Concentrations of growth regulators (mg/l)		% of responding explant	No. of shoots produced per explant (Mean ± SE*)	Shoot length (cm) (Mean ± SE*)
BAP	TDZ			
0.5	-	25.00	1.20a ± 0.20	1.64a ± 0.08
1.0	-	40.00	1.40a ± 0.24	2.08ab ± 0.11
1.5	-	53.33	2.40abc ± 0.51	2.28abc ± 0.08
2.0	-	68.00	3.40c ± 0.60	3.02cd ± 0.31
2.5	-	70.00	3.60cd ± 0.40	3.24d ± 0.38
3.0	-	46.67	2.80bc ± 0.58	2.90bcd ± 0.45
1.0	1.0	55.00	2.00ab ± 0.32	2.36abc ± 0.14
1.0	1.5	65.00	2.80bc ± 0.49	2.96cd ± 0.33
1.5	1.0	73.33	3.60cd ± 0.24	3.56de ± 0.26
1.5	1.5	63.33	2.80bc ± 0.37	2.84bcd ± 0.40
2.0	1.0	84.00	4.80d ± 0.49	4.22e ± 0.20
2.0	1.5	72.00	3.60cd ± 0.51	3.52de ± 0.18

At least 25 cultures were maintained for each experiment; values are means (± SE* = Standard error of mean) obtained from five independent treatments; the same letters within a column indicate treatments are not significantly different by DMRT at an alpha level of 0.05.

In the current study, the combined effect of BAP with TDZ has been found to be more satisfactory, particularly in the agitated MS liquid medium supplemented with 3.0 mg/l BAP and 1.5 mg/l TDZ for shoot proliferation than other combinations (Table 2). In this combination the rate of shoot proliferation was maximum (86.67%), and the number and length of shoots per culture were 15.40 ± 1.21 and 6.96 ± 0.65 cm, respectively. Confirming results were reported by Kapruwan et al. (2014) on *D. strictus*. They found the maximum number of shoots in the combination of 4.0 mg/l BAP with 0.25 mg/l TDZ. Similar observations were also made in *B. bambos* by Raju and Roy (2016). The combined effect of BAP with TDZ and NAA in shoot multiplication was also tested in which a moderate multiplication rate (64%) of axillary shoots of *B. tuldoides* was observed (Table 2). On the contrary, Wei et al. (2015) in *B. ventricosa* reported the best multiplication rate in the combination of BAP, TDZ, and NAA.

Table 2. Effect of different concentrations and combinations of BAP, Kn, TDZ and NAA in agitated liquid MS medium on shoot multiplication of *B. tuldoides* Munro.

Plant growth regulators (mg/l)			% of culture showed shoot proliferation	No. of regenerated shoots per culture (Mean ± SE*)	Shoot length (cm) (Mean ± SE*)
BAP	Kn				
1.0	-		28.00	3.60a ± 0.40	3.02ab ± 0.35
2.0	-		60.00	6.80c ± 0.80	4.32bc ± 0.57
3.0	-		72.00	9.40d ± 0.93	5.06c ± 0.37
4.0	-		64.00	6.60bc ± 1.03	4.30bc ± 0.57
1.0	0.5		32.00	3.20a ± 0.49	3.00ab ± 0.48
1.0	1.0		52.00	4.20a ± 0.73	3.98bc ± 0.53
2.0	0.5		40.00	3.20a ± 0.58	3.90bc ± 0.39
2.0	1.0		56.00	4.60ab ± 0.87	4.06bc ± 0.31
3.0	0.5		36.00	3.80a ± 0.58	3.88c ± 0.12
3.0	1.0		44.00	3.40a ± 0.51	3.84bc ± 0.25
4.0	0.5		24.00	3.20a ± 0.49	3.14ab ± 0.34
4.0	1.0		16.00	3.00a ± 0.84	2.12ab ± 0.53
BAP	TDZ				
1.5	1.0		26.67	4.20abc ± 0.80	2.84a ± 0.27
1.5	1.5		36.67	4.60abc ± 0.81	3.04ab ± 0.31
2.0	1.0		43.33	4.40abc ± 0.51	3.38ab ± 0.34
2.0	1.5		53.33	5.80abc ± 1.36	4.38bcd ± 0.22
2.5	1.0		63.33	6.80bcd ± 0.80	4.88cde ± 0.42
2.5	1.5		70.00	8.80d ± 0.97	5.36de ± 0.57
3.0	1.0		76.67	12.40e ± 1.17	6.18ef ± 0.59
3.0	1.5		86.67	15.40f ± 1.21	6.96f ± 0.65
3.5	1.0		73.33	9.20d ± 0.97	5.70def ± 0.39
3.5	1.5		66.67	7.20cd ± 1.32	4.98cde ± 0.42
4.0	1.0		56.67	4.00ab ± 0.55	4.38bcd ± 0.36
4.0	1.5		40.00	3.20a ± 0.49	3.80abc ± 0.59
BAP	TDZ	NAA			
1.0	1.0	0.5	24.00	2.60a ± 0.68	3.06a ±0.10
1.0	1.5	0.5	36.00	3.20a ± 0.80	3.70a ± 0.45
2.0	1.0	0.5	36.00	3.60a ± 0.68	3.96a ± 0.27
2.0	1.5	0.5	52.00	6.20bc ± 1.11	4.44ab ± 0.76
3.0	1.0	0.5	64.00	8.40c ± 0.81	5.84b ± 0.74
3.0	1.5	0.5	56.00	6.60bc ± 0.93	4.60ab ± 0.46
4.0	1.0	0.5	44.00	4.60ab ± 0.75	4.24a ± 0.38
4.0	1.5	0.5	32.00	3.00a ± 0.55	3.62a ± 0.19

Culture period 30 days; 25 shoot units (3-4) were inoculated in each combination for multiplication; values are means (± SE* = Standard error of mean) obtained from five independent treatments; the same letters within a column indicate treatments are not significantly different by DMRT at an alpha level of 0.05.

After selecting the best multiplication medium, each cluster having more or less 4 shoots of *B. tuldoides* was sub-cultured into the responsive optimal medium for observing their effect on shoot multiplication. It has been found that the shoots gradually increased in number and length during the first four subculture cycles. The maximum number and length of regenerated shoots per culture were 20.40 ± 1.44 and 7.92 ± 0.78 cm respectively obtained after 4th sub-culture cycle (Table 3). However, the potential of sub-cultured shoots in terms of number and length per culture declined in 5th sub-culture cycle. Hossain et al. (2018) and Ramanayake and Yakandawala (1997) also showed similar findings on shoot multiplication for *D. giganteus*. However, Arya et al. (2008) and Mudoi et al. (2014) maintained the shoot multiplication rate up to 6th sub-culture cycle in the case of *D. asper* and *B. nutans*, respectively.

Table 3. Effect of successive subcultures on shoot multiplication of *Bambusa tuldoides* Munro in agitated liquid MS medium supplemented with 3.0 mg/l BAP and 1.5 mg/l TDZ.

Sub-culture cycle	Number of regenerated shoots per culture (Mean ± SE*)	Shoot length (cm) (Mean ± SE*)
Cycle-1	15.40a ± 1.21	6.96a ± 0.65
Cycle-2	16.60ab ± 1.17	7.06a ± 0.55
Cycle-3	18.20ab ± 1.50	7.22a ± 0.69
Cycle-4	20.40b ± 1.44	7.92a ± 0.78
Cycle-5	17.00ab ± 1.30	7.38a ± 0.76

Culture period 30 days; values are means (± SE* = Standard error of mean) obtained from five independent treatments; the same letters within a column indicate treatments are not significantly different by DMRT at an alpha level of 0.05.

Inclusion of 10% CW with 3.0 mg/l BAP and 1.5 mg/l TDZ proved to be the most effective for enhancing the shoot proliferation rate with an average of 24.20 ± 1.16 shoots per culture and 8.16 ± 0.41 cm in length (Fig. 1A and B). However, the increase in the concentration of coconut water above 10%, causes a decrease in the number and length of regenerated shoots per culture. Similarly, Saxena and Bhojwani (1993) in *D. longispathus* and Raju and Roy (2016) in *B. bambos* used 10% coconut water in the medium for shoot proliferation. However, Ramanayake and Yakandawala (1997) in *D. giganteus* and Das and Pal (2005) in *B. balcooa* reported that, 8% coconut water enhanced shoot proliferation.

A significant rooting was obtained within 3-4 weeks in micro-shoots of *B. tuldoides* when 3.0 mg/l IBA was used with 84% rooting efficiency and 7.20 ± 0.37 roots per culture with 9.34 ± 0.67 cm in length (Table 4). Similar results were obtained by Venkatachalam et al. (2015) in *B. arundinacea* and Ramanayake and Yakandawala (1997) in *D. giganteus*, whereas Hossain et al. (2018) and Devi et al. (2012) used 4.0 mg/l IBA. The conjoint

addition of IBA and NAA in the half-strength MS medium did not increase the rooting efficiency (Table 4). In contrary, half-strength MS medium augmented with IBA and NAA was found effective in rooting of *D. asper* (Singh et al. 2012), *B. bambos* (Raju and Roy 2016), etc.

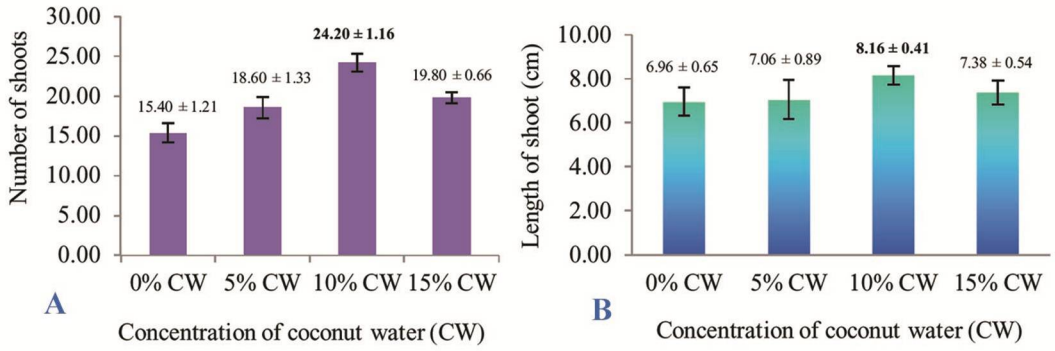

Fig. 1 (A-B). Effect of different concentrations of coconut water along with constant 3.0 mg/l BAP and 1.5 mg/l TDZ on (A) shoot number and (B) shoot length.

Table 4. Effect of different concentrations and combinations of IBA and NAA in solidified ½ MS medium on rooting of *in vitro* raised shoots of *B. tuldoides* Munro.

Concentrations of auxins (mg/l)		Percentage of rooting	Number of roots per unit shoot (Mean ± SE*)	Root length (cm) (Mean ± SE*)
IBA	NAA			
1.0	-	24.00	2.80ab ± 0.37	3.32ab ± 0.25
2.0	-	60.00	4.60bc ± 0.75	4.88b ± 0.76
3.0	-	84.00	7.20d ± 0.37	9.34d ± 0.67
4.0	-	76.00	6.00cd ± 0.45	6.86c ± 0.81
1.0	1.0	36.00	2.60a ± 0.40	3.22ab ± 0.26
1.0	1.5	28.00	3.20ab ± 0.58	3.14a ± 0.26
2.0	1.0	48.00	3.40ab ± 0.60	3.84ab ± 0.40
2.0	1.5	40.00	3.20ab ± 0.37	3.68ab ± 0.38
3.0	1.0	64.00	4.40abc ± 0.75	4.82ab ± 0.60
3.0	1.5	52.00	4.00ab ± 0.63	4.28ab ± 0.57
4.0	1.0	56.00	3.60ab ± 0.60	4.46ab ± 0.48
4.0	1.5	32.00	3.40ab ± 0.51	3.78ab ± 0.34

Culture period 35 days; 25 shoot units (3-4) were inoculated in each combination for rooting; values are means (± SE* = Standard error of mean) obtained from five independent treatments; the same letters within a column indicate treatments are not significantly different by DMRT at an alpha level of 0.05.

In this study, the rooted plantlets were acclimatized successfully with 92% survival rate in a soil mixture containing garden soil, sand and compost mixture with 1:1:1 ratio. Using the same soil mixture, Arya and Arya (2009) and Anand et al. (2013) reported 80-90% survival rate in *B. bambos*, Devi et al. (2012) and Hossain et al. (2018) reported 90% survival rate in *D. giganteus*. However, Rathore et al. (2009) reported over 90% of survival rate in *B. bambos*, *B. nutans*, *D. strictus*, *D. stocksii* and *Guadua angustifolia* using the same soil mixture with the ratio of 1:2:2. After a month, the acclimatized plants were transferred to the larger pots containing garden soil and compost with 1:1 ratio for sufficient growth. Different stages of *in vitro* regeneration of *B. tuldoides* Munro have been depicted in Fig. 2.

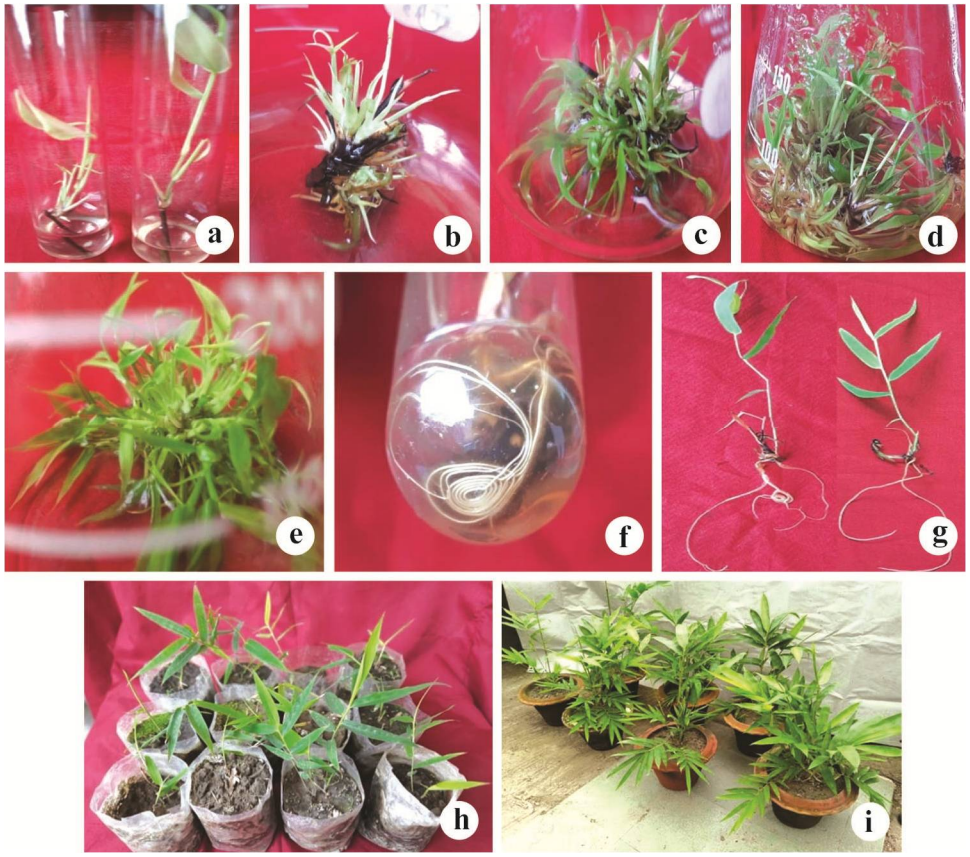

Fig. 2(a-i): *In vitro* regeneration of *B. tuldoides* Munro. (a) Direct shoot induction on MS liquid medium supplemented with 2.0 mg/l BAP + 1.0 mg/l TDZ. (b-d). Multiple shoot formation in agitated liquid MS medium supplemented with 3.0 mg/l BAP and 1.5 mg/l TDZ after *b.* 15 days of 1st subculture; *c.* 30 days of 1st subculture; *d.* 30 days of 4th subculture. (e) Incorporation of 10% CW with the above mentioned medium for rapid shoot multiplication. (f) *In vitro* root induction on half-strength of gelled MS medium supplemented with 3.0 mg/l IBA. (g) Complete plantlets. (h) Two-weeks old acclimatized plants established in the soil. (i) Hardened plant in the earthen pot after 2 months.

The present study describes an effective regeneration and multiplication protocol for *in vitro* clonal propagation of *Bambusa tuldoides* Munro using nodal segments. The morphological characters of *in vitro* derived plantlets were similar to that of *in vivo* plants. Thus, the use of pre-existing axillary buds for propagation reduces the possibility of any variation among the progeny. However, this propagation protocol could be exploited for commercial cultivation of ornamental bamboo species in our country.

References

Anand M, Brar J and **Sood A** (2013) *In vitro* propagation of an edible bamboo *Bambusa Bambos* and assessment of clonal Fidelity through molecular markers. J. of Medic. and Bioengine. **2**(4): 257-261.

Arya ID and **Arya S** (2009) Propagation of bamboos through tissue culture technology and field plantation. 8th World Bamboo Congress Proceedings. **6**: 132-144.

Arya S, Rana PK, Sharma R and **Arya ID** (2006) Tissue culture technology for multiplication of *Dendrocalamus giganteus* Munro. Indi. Forest. **132**(3): 345-357.

Arya S, Satsangi R and **Arya ID** (2008) Direct regeneration of shoots from immature inflorescences in *Dendrocalamus asper* (edible bamboo) leading to mass propagation. J. of Amer. Bamb. Soc. **21**: 14-20.

Brar J (2014) Micropropagation of some edible bamboo species and molecular characterization of the regenerated plants. Ph.D. Thesis, Department of Biotechnology, Thapar University, Punjab, India.

Brar J, Shafi A, Sood P, Anand M and **Sood A** (2014) *In vitro* propagation, biochemical studies and assessment of clonal fidelity through molecular markers in *Bambusa balcooa*. J. of Tropi. Fore. Scien. **26**(1): 115-124.

But PPH and **Chia LC** (1995) *Bambusa tuldoides* Munro. In: Plant Resources of South-East Asia (No. 7), Dransfield S and Widjaja EA (Eds.), Backhuys Publishers, Leiden, the Netherlands, pp. 72-74.

Cheah KT and **Chaille LC** (2011) Somatic embryogenesis from mature *Bambusa ventricosa*. College of Tropical Agriculture and Human Resources, Department of Tropical Plant and Soil Sciences. University of Hawai'i, Manoa. Biotechn. pp. 1-5.

Clayton WD, Govaerts R, Harman KT, Williamson H and **Vorontsova M** (2018) World Checklist of Poaceae. Facilitated by the Royal Botanic Gardens, Kew. Available from: http://wcsp.science.kew.org

Das M and **Pal A** (2005) *In vitro* regeneration of *Bambusa balcooa* Roxb: Factors affecting changes of morphogenetic competence in the axillary buds. Plant Cell Tiss. and Org. Cultu. **81**(1): 109-112.

Devi WS, Bengyella L and **Sharma GJ** (2012) *In vitro* seed germination and micropropagation of edible bamboo *Dendrocalamus giganteus* Munro using seeds. Biotechnol. **11**(2): 74-80.

Fern K (2014) Useful tropical plants database: *Bambusa tuldoides* Munro. Available from: (https://tropical.theferns.info/viewtropical.php?id=Bambusa+tuldoides). Last update on: 20/07/2022.

Hossain MA, Khan BM, Uddin MA and **Rahman MM** (2018) *In vitro* propagation of the Giant Bamboo *Dendrocalamus giganteus* Munro. J. of Bam. and Ratt. **5**: 117-226.

Kapruwan S, Bakshi M and **Kaur M** (2014) Rapid *in vitro* propagation of the solid bamboo, *Dendrocalamus strictus* nees, through axillary shoot proliferation. Biotechnol. Interna. **7**(3): 58-68.

Morais WWC, Haselein CR, Susin F, Vivian MA and **Morais JBF** (2015) Physical and mechanical properties of panels aglomerated with *Bambusa tuldoides* and *Pinus taeda*. Ciência Floresta. **25**(4): 1015-1026.

Mudoi KD, Saikia SP and **Borthakur M** (2014) Effect of nodal positions, seasonal variations, shoot clump and growth regulators on micropropagation of commercially important bamboo, *Bambusa nutans* Wall. ex. Munro. Afri. J. of Biotechn. **13**(19): 1961-1972.

Mudoi KD, Saikia SP, Goswami A, Gogoi A, Bora D and **Borthakur M** (2013) Micropropagation of important bamboos: a review. Afri. J. of Biotech. **12**(20): 2770-2785.

Raju RI and **Roy SK** (2016) Mass propagation of *Bambusa bambos* (L.) Voss through *in vitro* culture. Jahangirn.Univer. J. of Biol. Scien. **5**(2): 15-26.

Ramanayake SMSD and **Yakandawala K** (1997) Micropropagation of the giant bamboo (*Dendrocalamus giganteus* Munro) from nodal explants of field grown culms. Plant Scien. **129**(2): 213-223.

Rathore TS, Kabade U, Jagadish MR, Somashekar PV and **Viswanath S** (2009) Micropropagation and evaluation of growth performance of the selected industrially important bamboo species in southern India. 8th World Bamboo Congress Proceedings. **6**: 41-55.

Saxena S and **Bhojwani SS** (1993) *In vitro* clonal multiplication of four year old plants of the Bamboo *Dendrocalamus longispathus* Kurtz. *In Vitro* Cellu. and Developme. Biol. - Plant. **29**: 135-142.

Sharma P and **Sarma KP** (2011) *In vitro* propagation of *Bambusa balcooa* for a better environment. In: International Conference on Advances in Biotechnology and Pharmaceutical Sciences, Bangkok, pp. 248-252.

Sharma PK, Nath SK and **Murthy N** (2014) Investigation on fibre characteristics of *Dendrocalmus strictus* and *Bambusa bambos.* Int. J. of Engine. Innova. and Rese. **3**(3): 254-258.

Singh SR, Dalal S, Singh R, Dhawan AK and **Kalia RK** (2012) Micropropagation of *Dendrocalamus asper* {Schult. & Schult. F.} Backer ex K. Heyne: an exotic edible bamboo. J. of Plant Biochem. and Biotechnol. **21**(2): 220-228.

Venkatachalam P, Kalaiarasi K and **Sreeramanan S** (2015) Influence of plant growth regulators (PGRs) and various additives on *in vitro* plant propagation of *Bambusa arundinacea* (Retz.) Wild: A recalcitrant bamboo species. J. of Gene. Engine. and Biotechnol. **13**(2): 193-200.

Waikhom SD and **Louis B** (2014) An effective protocol for micropropagation of edible bamboo species (*Bambusa tulda* and *Melocanna baccifera*) through nodal culture. The Scienti. World J. **Vol. 2014**: 1-8. (Article ID: 345794)

Wei Q, Cao J, Qian W, Xu M, Li Z and **Ding Y** (2015) Establishment of an efficient micropropagation and callus regeneration system from the axillary buds of *Bambusa ventricosa*. Plant Cell, Tiss. and Org. Cult. **122**(1): 1-8.

(Manuscript received on 28 September, 2022; revised on 06 October, 2022)