Environment

Commercial plantation and management

Propagation methods

Propagation of *Sinarundinaria falcata** Chao & Renvoize (Hill bamboo) for Sustainable Development in Garhwal Himalayas

*EDITOR NOTE: According the new World Checklist of Bamboos and Rattans, published by Kew and ICBR, 2017, <page 386> the correct name is
Drepanostachyum falcatum (Nees) Keng f.

For other nomenclature clarification, consult the World Checklist of Bamboos and Rattans, Kew & ICBR, 2017 CABI

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Abstract

Sinarundinaria falcata Chao & Renvoize (Ringal) is economically an important hill bamboo species which finds myriad of uses in Garhwal Himalayas of Uttarakhand (India) however, Basketry is the mainstay of livelihood for many villagers and artisans who are solely dependent on this life supporting resource. Due to illegal and unscientific harvesting along with degradation of habitat, the species is shrinking very fast in nature. The villagers are facing acute scarcity of material and hence their economics shattered.

The long gestation cycles of this species has compelled us to investigate alternative methods for multiplication as well as conservation. We took initiative and developed many farmer friendly, easy techniques of multiplication and *In situ* conservation which have not been yet reported for this species.

The traditional multiplication trials included rhizome planting, part clump division, ground layering, culm cuttings and macroproliferation. Among various technologies, culm cuttings followed by macroproliferation are the most feasible method for large scale plantings. In order to maximize propagule production, culm cuttings were propagated in three different seasons with various auxins. The interactive effect of season and auxin significantly (0.01%) yielded maximum rooting (57%) with IAA 500 ppm in summer at par with control in Rainy season. There was no rooting in winter. The effect of season and hormone was more pronounced in allied parameters. Further separation of the propagules through macroproliferation yielded substantial planting material.

For *In situ* conservation, an innovative technique was devised through pinning down of intact peripheral young culms in the field itself. This way even after removal of mature culms by the villagers from forests, new clumps are produced providing villagers with Ringal material sustainably. The technologies suggested would not only conserve the species but would also generate sufficient material for sustainable development of local rurals in Garhwal Himalayas enhancing their economic status.

Key words

Sinarundinaria falcata , Multiplication, *In situ* conservation, Innovative technology, Sustainable development

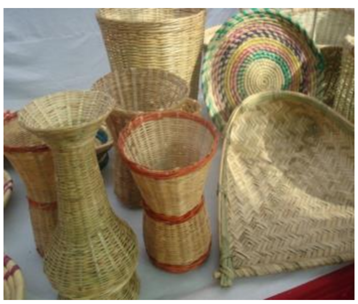
Introduction

Uttarakhand state of India is represented with four hill bamboo species viz. *Sinarundinaria jaunsarensis* (Gamble), *Sinarundinaria falcata* (Nees), *Thamnocalamus spathiflorus* (Trin.) Munro and *Thamnocalamus falconeri* (Hook f. ex Munro) collectively called Ringal. The genus Sinarundinaria is well distributed in Northeastern and East India (Kashmir, Himachal Pradesh, Uttar Pradesh, Sikkim, Meghalaya, Mizoram), Nepal, Bhutan and Myanmar. Among four hill bamboos, *Sinarundinaria falcata* Chao & Renvoize (Gol Ringal) is the most preferred species due to its wide occurrence in Garhwal Himalayas of Uttarakhand, India. It occurs at 1500-2100 amsl on slopes and ridges, generally on moist shady places as moderately dense undergrowth in evergreen forests of oak, chir pine, deodar, and rhododendron species. Ringal finds myriad of uses in day to day life of villagers in the form of roofing material for temporary hutments, live hedges for protection and ornamental purposes, agricultural implements, baskets, hookah pipes, stakes for cash crops, vegetables, medicines (Kapoor 1991), fuel, fodder in lean period, handicrafts, walking sticks, fishing rods and mats, however, Basketry is the mainstay of livelihood which contributes significantly to their income. Apart from other uses, the species has ecological significance in fragile hills, checking soil erosion and land slides, providing natural habitat to wild animals and pheasant species.

Due to many factors including illegal and unscientific harvesting, degradation of habitat, frequent forest fires, gregarious flowering resulting into death of entire parent stock coupled with insufficient replanting, the species is declining very fast in nature. The old artisans having skills of weaving baskets are affected most due to scarcity of this vocation. The women suffer drudgery of travelling long distances to carry a head load of Ringal for their daily needs and hence affected most. To meet the crisis of this species, large scale planting is required but these replanting efforts are restricted to limited supply of planting stock as the seeds are not readily available due to long flowering cycle spanning from 28-30 years (Troup 1921;

Campbell 1988) with short viability of 6-8 months. For sustainable production of planting material, it is essentially imperative to search for alternative methods. The species is obstinate to root due to thin culms and presently there is no report of its propagation through vegetative means although micropropagation of *Thamnocalamus spathiflorus* is reported (Bag et al. 2000). The work presented in the present paper is the Gist of many technologies devised for this species to cope up the problem of scarcity of planting material. The techniques developed are innovative, cost effective, easy and can generate substantial planting material for innumerable years providing sustainable source of income to the villagers.

Gregarious growth of *S. falcata* in nature   Harvesting Ringal from forests



Handicrafts from Ringal   Baskets from Ringal   Mats from Ringal

Material and Methods

Experimental site : The present work was conducted in experimental area of Plant Physiology Discipline at the campus of Forest Research Institute, Dehradun, India which is situated at Latitude 30˚20′10.31" N, Longitude 77˚59′ 55.32" E and Altitude of 650 amsl.

The various multiplication and *In situ* conservation techniques developed in *Sinarundinaria falcata* are highlighted below:

Multiplication :-

Traditional methods employed were Part clump planting, offset planting, Rhizome cultivation and Ground layering. To generate substantial planting material, multiplication through culm cuttings was followed by macroproliferation. The various techniques are cited below:

Part clump planting

Part clump planting is one of the important conventional methods for propagating bamboos. Unlike offset planting, the material here constitutes clump (4-6 culms with the rhizome) for propagation (Figure 1a). The clump extracted from nature are not separated further, instead planted else as whole in the field at Magra (1834amsl). The rhizome has buds through which profuse sprouting takes place developing new culms. (Figure 1b). Nearly 50 clumps were extracted from the forest area of Hathipau (Mussorrie) and planted in the field at Magra (Mussorrie) resulting to 98% success when planted in the months of May-June.

Figure 1a

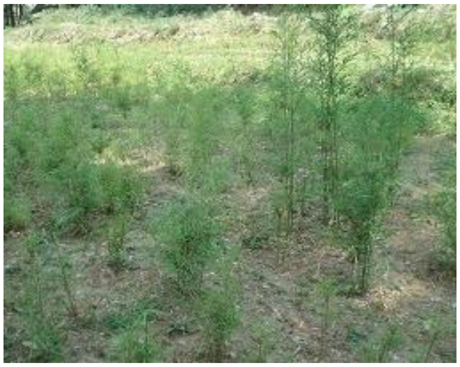


Figure 1b

Offset planting :-

Offset planting has long been practiced for propagation of bamboos but still not has been probed for hill bamboos. An offset represents one rhizome with few buds and culms. Offsets of *S. falcata* were extracted from forests of Chopta and Mandal areas (Chamoli district). They were separated in such a way that each offset constituted single culm with a small rhizome piece and few roots (Figure 2a). They were planted in the field at Magra (1854 amsl) in nursery beds/ tinned cans before onset of Monsoon. Thirty (30) such offsets were planted in three replicates. After a span of 50 days, the buds in the rhizome sprouted and formed new culms (Figure 2b). About 93% survival was detected for this species if planted before Monsoon. This method is tedious, time consuming and not appropriate for large scale plantations. Moreover, it is restricted to limited number of rhizomes which are difficult to extract.

Figure 2a

Figure 2b

Through Rhizome

Rhizomes were collected from wild in Hathipau (Mussorrie). The culm portions were removed. These were made into small portions containing few buds with the help of sharp secateurs (Figure 3a). The rhizome pieces were grown initially in plastic trays with Soil: Sand: Compost (2:1:1). A total of 60 rhizome pieces were planted in trays. They were watered as and when required. Care was taken to avoid over watering. New sprouts emerged from buds after 20-25 days followed by profuse rooting and rhizogenesis which were then separated (Figure 3b) and planted individually in the field before onset of monsoon. Nearly 70% success was achieved when planted in the field.


Figure 3a Figure 3b

Ground Layering

The lower portions of the culms of Ringal (3-4 nodes) already growing in beds were covered with heaps of garden soil containing rich Humus before Rainy season. Precaution was taken to replenishing the soil if required. A total of 20 clumps with nearly 67 culms were covered. Nearly 50% of the culms generated roots at the lower portions in 6 weeks period (Figure 4a) which were separated after Monsoon (Figure 4b) and planted individually in the polybags (Figure 4c). This is in fact, a nondestructive method of propagation as the underground portions of mother clump unlike in other methods were not disturbed generating new shoots.



Figure 4a Figure 4b Figure 4c

The conventional methods discussed above are tedious and are limited to generation of few plantlets. To meet heavy demands of planting stock in this species, propagation through culm cuttings followed by macroproliferation is the most appropriate method as cited below in details:-

Propagation through Culm Cuttings

Young culms representing one year's growth were extracted from mature clumps of Ringal growing in hilly areas (Hathipau) or Khirsu Germplasm of Uttarakhand. Single or binodal cuttings were prepared with the help of sharp secateurs and tied in bundles (Figure 5a) to be dipped overnight in plastic buckets containing growth hormones (IBA , NAA, IAA) in concentrations of 500 ppm (Figure5b). The cuttings were pretreated with a fungicide Bavistin (0.1%) and planted horizontally in beds (drenched with Aldrin) or trays containing Soil: Sand: Compost in 2:1:1 ratio (Figure 5c) in Randomized block design with three replicates of 20 ramets each. Care was taken not to injure nodal buds keeping them in lateral position in beds/trays so that they are not suppressed. The cuttings were planted seasonally to find out the best season of propagation. Initially shade was provided with regular watering and weeding. The new sprouts (Figure 5d) were observed after 6-8 weeks followed by rooting and rhizogenesis (Figure 5e). The cuttings were removed after 10-12 weeks and observations on rooting and allied parameters recorded. The rooted plantlets were transplanted in polybags (Figure 5f) or earthen pots containing normal garden soil weighing nearly 2.5 and 5 kg respectively and kept under shady conditions for a couple of days for acclimatization, aftermath shifted to open conditions. The whole process is shown in Figures 5a to f.

Figure 5a

Figure 5b

Figure 5c

Figure 5d

Figure 5e

Figure 5f

Macroproliferation

The propagules generated through culm cuttings (Figure 6a) were uprooted and separated carefully (Figure 6b) after six months growth in such a way that each propagule contained three essential entities viz. a piece of rhizome, at least one culm and few roots. (Figure 6c). The separated propagules were planted in polybags (24x18 cm) containing a mixture of sieved soil, sand and farm yard manure (2:1:1) (Figure 6d). Initially they were kept under shade house and gradually shifted under direct sunlight when fully established. New growth appeared in 3-4 weeks. The separated propagules were allowed to grow for six months, separated as above and replanted in polybags of the same size having same mixture as described above. One-fourth of the propagules could be retained for further multiplication while 3/4th were planted in the field. The complete methodology is cited in Figure 6a to 6d.

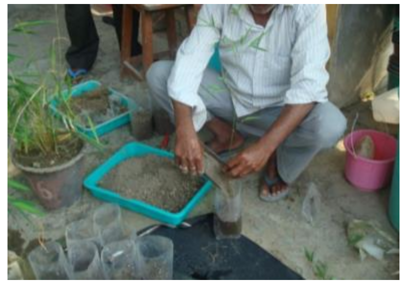



Figure 6a Figure 6b


Figure 6c Figure 6d

In situ Conservation :

For *In situ* conservation in the field, a unique method was applied. Young peripheral flexible culms representing six months to one year's growth were selected and bend down to touch the ground. They were then buried intact in trenches (6-9 inches deep) (Figure 7a) and pinned down with U shaped hooks to keep them in position. The trenches were well covered with humus rich soil and rotten leaves (Figure 7b). A total of 40 peripheral culms in different clumps were pinned down before monsoon. The trenches were kept moist initially by regular watering. New sprouts were visible from nodes after 4 weeks followed by rooting which was completed in 6 months. (Figure 7c). The proliferated shoots were either separated from mother clump and grown as individual plant in polybags containing Soil: Sand and Manure (2:1:1) or left *In situ* in the field. Nearly 60 % rooting was achieved through this method. The total number of culms after 8 months of planting in polybags comes out to 144 with 6 culms/propagule which was further enhanced via macroproliferation technique. This is the most suggestive method for conservation of Ringal *In situ*.

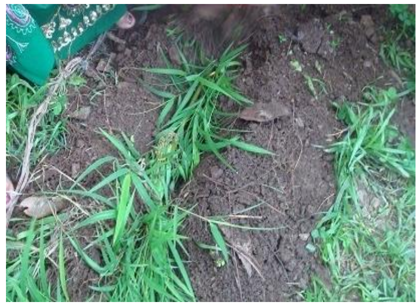


Figure 7a Figure 7b Figure 7c

Statistical Analysis

All the data pertaining to sprouting and rooting parameters was uploaded in Microsoft Excel. Analysis of Variance was carried out using Genstat Statistical Package (Genwin 3.2 version). For ANOVA, mean values of each replication was calculated. For comparison of means, Critical difference was calculated based on student's test at p< 0.05 level.

Results

Since limited propagules could be obtained through conventional methods using Rhizome planting, offset and part clump planting, their methodology with success rate has been discussed under Material and Methods, however, the results on seasonal behavior of rooting of culm cuttings followed by macroproliferation is cited below in details:

Rooting through culm cuttings:

Seasonal behavior of rooting via culm cuttings was studied for 3 seasons viz. Summer (March-June), Rainy (July-October) and Winter (Nov.- Feb.). The rooting behavior with respect to sprouting %, number of sprouts, sprout length (cm), rooting percentage (%), number of roots per cutting and root length (cm) were recorded during these periods under different treatments and seasons and analyzed for ANOVA.

Interactive effect of Season (S) and Treatments (T)

Sprouting parameters:-

The interactive effect of Season and Treatment on mean sprouting percent showed significant variation at P<0.01 in all seasons (Table-1). In summer season, a maximum of 68.3% sprouting was discernible in the cuttings treated with IAA 500 ppm followed by IBA 500 ppm (66.7%) and minimum (57.3%) in NAA 500 ppm. On the other hand, the rainy season depicted a maximum of 78.3% sprouting in the cuttings treated with IBA 500 ppm while, minimum (60.3%) sprouting were recorded in the cuttings treated with NAA 500 ppm. No sprouting was recorded during winter season (November-February) planted cuttings in any of the treatments. Overall, the maximum sprouting percentage (78%) was recorded in rainy season with IBA 500 ppm. Interactive effect of season and treatment had significant influence (P<0.05) on mean number of sprouts with maximum (7.50) numbers of sprouts in IAA 500 ppm treated cuttings in Summer season and minimum (3.00) in NAA 500 ppm in the Rainy season. No sprouting in winter was obvious. Highly significant (P<0.001) variation was discernible on mean sprout length per cutting in relation to

Season and Treatment (Table-1). The maximum sprout length (17.21 cm) was recorded in rainy season when treated with IBA 500 ppm in contrast to 13.24 cm in untreated cuttings in summer season.

Rooting parameters:-

The interactive influence of Season and Treatment in relation to rooting and allied parameters revealed highly significant response with maximum (57%) rooting discernible in IAA 500 ppm in summer season at par with control of rainy season in contrast to minimum 40% rooting in NAA 500 ppm in the same season (Table-1), however the cuttings did not respond in winter months. Similarly, the interactive effect of season and treatment revealed a highly significant (0.01% level) effect on the mean number of roots in all seasons except November planted cuttings (winter season) with maximum 7.93 roots in rainy season with IBA 500 ppm treated cuttings. (Table-1) while minimum (3.45) roots were recorded in the untreated cuttings in Summer. The treatment effect is significant (5 % level) in all seasons with regard to mean root length (Table-1). Overall, the maximum root length (10.42 cm) was recorded in rainy season with IAA 500 ppm at par with the same treatment in summer season.

Table 1. Interactive effect of SxT on rooting and allied parameters

Season	Treatment	Characters					
		Mean sprouting (%)	Mean No. of Sprouts	Mean sprout Length (cm)	Mean rooting %	Mean No. of roots	Mean root Length (cm)
March-June	Control	65.33	4.00	13.24	43.33	3.45	8.66
	IAA500ppm	68.33	7.50	14.51	56.70	4.50	7.94
	IBA500ppm	66.67	5.00	16.93	51.66	5.66	10.22
	NAA500ppm	57.30	4.00	13.57	40.00	4.00	7.14
July-October	Control	73.66	4.00	14.14	56.66	4.00	7.53
	IAA500ppm	69.67	4.50	15.62	41.66	6.55	10.42
	IBA500ppm	78.33	5.50	17.21	53.33	7.93	9.12
	NAA500ppm	60.33	3.00	13.67	43.33	5.12	7.72
Nov.- Feb.	Control	0	0	0	0	0	0
	IAA500ppm	0	0	0	0	0	0
	IBA500ppn	0	0	0	0	0	0
	NAA500ppm	0	0	0	0	0	0
Significance		**	*	***	***	***	*
CD		6.520	1.075	1.215	5.731	0.805	1.104

NS=Non Significant, *=Significant at 5%, ** = Significant at 0.1 %, ***= Significant at 0.01%

Effect of Treatment

Sprouting parameters :-

The statistical analysis with regard to hormonal application depicted variation in sprouting percentage and number of sprouts among different treatments at 5% level (Table-2). The maximum (72.5%) effect in sprouting was visible with IBA 500ppm while maximum sprouts (6.00) were discernible in the cuttings treated with IAA 500 ppm. **Variation for sprout length was highly significant ($P<0.001$)** for mean sprout length with maximum (17.07 cm) sprout length recorded in the cuttings treated with IBA 500 ppm and minimum (13.62 cm) in NAA 500ppm.

Rooting parameters :-

The maximum (52.5%) significant rooting was discernible in IBA 500 ppm while minimum (42%) in the cuttings treated with NAA 500 ppm. Highly significant values (0.01% level) among treatments with regard to mean number of roots and root length depicted maximum 6.80 nos. and 9.67 cm respectively with IBA 500 ppm. (Table-2).

Table 2. Effect of phyto hormones on rooting of *Sinarundinaria falcata*

	Characters					
	Sprouting%	Mean No. Sprouts	Mean sprout Length (cm)	Rooting %	Mean No. of roots	Mean root Length (cm)
Control	69.49	4.00	13.69	50.00	3.72	8.09
IAA500ppm	69.00	6.00	15.06	49.16	5.52	9.18
IBA500ppn	72.50	5.25	17.07	52.49	6.80	9.67
NAA500ppm	58.81	3.50	13.62	41.66	4.56	7.43
Significance	*	*	***	*	***	***
CD	5.761	0.726	0.923	3.726	0.682	0.925

*=Significant at 5%, ***=Significant at 0.01%, NS= Non significant

Effect of Season:-

Sprouting parameters:-

The statistical analysis revealed 0.05% variation in sprouting percentage among different seasons with maximum (67%) sprouting in cuttings planted in rainy season while maximum (5.11) sprouts were noticed in the cuttings planted in summer season which was significant at 0.01% level. Season had significant influence ($P<0.05$) on mean sprout length per cutting. Maximum (14. 82 cm) sprout length was noticed in the cuttings planted in rainy season. No sprouting was recorded during winter (November - February) planted cuttings.

Rooting parameters:-

Maximum (48%) rooting was discernible in cuttings planted in Rainy season at par with Summer season. Similarly, maximum number (5.07) of roots were noticed in the same season which was significant at 0.01% level. The root length was significantly (0.05 %) maximum (8.61 cm) in rainy season. There was absolutely no response in rooting in the cuttings planted in winter season.

Table 3. Effect of seasons on rooting and allied parameters in culm cuttings of *Sinarundinaria falcata*

Season	Characters					
	Sprout (%)	Mean No. of Sprouts	Sprout Length (cm)	Rooting (%)	Mean No. of Roots	Root Length (cm)
March-June	64.40	5.11	14.56	47.90	4.40	8.49
July-October	67.11	4.73	14.82	48.28	5.07	8.61
Nov.-February	0	0	0	0	0	0
Significance	*	***	*	*	***	*
CD	0.768	0.621	0.39	0.584	1.154	3.714

***=Significant at 0.01%,   *=Significant at 0.05%,

Macroproliferation of Rooted Cuttings:-

The proliferation of rooted cutting was assessed through macroproliferation. Table 4. depicts the various stages of separation along with the number of propagules produced from each nodal cutting. It was evident that sprouting initiated after 12-16 days of planting of cuttings followed by root initiation which was completed in 90 days. Nearly 40 % (23) of the cuttings produced sprouts at both nodes. The multiplication rate was 5.0 sprouts in the initial stage. When rooted cuttings were transplanted in polybags after separation in the month of July (Monsoon), with 80% survival, 75 propagules were generated. Propagation of 100 binodal cuttings resulted in 450 propagules at this stage. The propagules were separated again and planted in the field. After 12 months of planting with survival of 80% and multiplication rate of 6.0 nearly 360 propagules were generated which were planted in the field. The tiller number increased gradually with the passage of time and reached an average number of 9.0 sprouts after 20 months of planting (8 months after separation). The maximum culm length was 125 cm and average collar diameter was 4.2 mm (Table 4). With a multiplication rate of 9.0, the expected propagules would be 3240 after two multiplication cycles.

Table 4. Number of propagules produced at various stages of culm cuttings with macroproliferation in *S. falcata*

A	No. of two noded culm cuttings planted	100 (200 nodes)
B	Planting period	March
C	Maximum % of cuttings rooted	57%
D	Number of cuttings rooted at both nodes	23(40%)
E	Number of cuttings rooted at one node	34 (60%)
F	Total number of rooted nodes (D+E)	80
G	Average number of sprouts at each node	5
H	Number of nodes separated and planted in polybags	80
I	Period of planting	July
J	Number of propagules survived in polybags	75 (80%)
K	Average number of sprouts/node at 9 months period in polybags	6.0
L	Period of separation	Next February (11 months after planting)
M	Total number of survived new propagules separated out of culm cuttings	450
N	Number of survived new propagules separated out of culm cuttings after planting in field	360 (80%)
O	Average number of sprouts/propagule in the field	9.0
P	Average height	125 cm
Q	Average collar diameter	4.2 mm
R	Duration of observation	20 months after cutting planting
S	Expected number of survived new propagules separated out of propagules proliferating in beds (N x O)	3240 propagules

Discussion

Bamboos are traditionally propagated by rhizome, offset cuttings, Part clump planting etc., however, these conventional methods are not practical and economical, leading to non-availability of required propagating material of bamboos. This is evident when one finds a yawning gap between production and consumption of bamboos in India.

S. falcata has been eroding fast from the nature because of over usage and lot other factors resulting in scarcity of material affecting lives of many people solely dependent on this commodity. Like other hill bamboos, this species also has thin culms which are difficult to propagate thus other methods viz. air layering and ground layering etc. also needs to be explored. Stapleton (1994) noted spontaneous production of aerial roots on branch bases in ***Thamnocalamus falconeri***. To cope up with the situation, a modest approach has been made in present context by pursuing investigation on seasonal behavior of adventitious root induction in culm cuttings of *S. falcata* .

Although there was not much difference in Summer and Monsoon planting but winter severely affected rooting. This influence is probably due to changes in the temperature which prevail at the time of collection and planting of cuttings. Low temperature during Winter completely inhibits the rooting as well as sprouting because of low metabolic activities and growth resumed on onset of favorable temperature. Stored energy like carbohydrate, protein contents and minerals play key role in rhizogenesis process and their concentrations are variable during different seasons. Raveendran et al. (2010a) observed rooting throughout the season in *Dendrocalamus. brandissi* but maximum during Summer months. Kumar *et al.* (1997) reported that *Bambusa tulda* produces adventitious roots almost whole year, except in the month of December, whereas, *D. strictus* did so for six months i.e. from February to July only. Agnihotri and Ansari (2000) exhibited significantly maximum root induction and growth of adventitious roots in cuttings collected in February and April in *B. bambos* and *D. strictus.* They observed a steep decline in rooting in *D. strictus* from April to July while cuttings collected in December in *B. vulgaris* did not induce rooting, however no root induction was observed from the cuttings collected during August to January in *D. strictus.* In *S. falcata* on the onset of warm season, the rooting is assumed. This is possible due to resumption of active growth by rhizome which are the store houses of photosynthates and auxiliary substances. These substances become available to new culms and culm branches which also incidentally developed during March to September in most bamboos in India. In fact, a plenty of literature is available citing the influence of season on adventitious rooting (Raveendren et al. 2010 a & b; Nautiyal et al. 1991 ; Bakshi et al. 2012).

The effect of auxins on rooting cannot be ignored. It is well established that all auxins IAA, IBA and NAA generally stimulated adventitious root formation. The effectiveness of these auxins in *S. falcata* followed a pattern IBA> control> IAA>NAA. Similar comparison of exogenous hormones was also reported in bamboos indicating improvement in rooting by application of one or the other auxin e.g. IBA in *Bambusa vulgaris* by Uchimura (1997), IAA in *B. balcooa, D. hamiltonii* and *B. vulgaris* (Nath et al. 1986), NAA in *B. arundinacea* and *D. strictus* (Surendran et al. 1983), *Bambusa tulda* (Adarsh Kumar 1989; Nath et al. 1986) and IBA in *Bambusa arundinacea* and *Dendrocalamus strictus* (Surendran et al. 1989) were found fruitful. Bakshi and Prakash (2008) vegetatively propagated *B. vulgaris* var striata through branch cuttings. The maximum rooting and sprouting were observed in the cuttings treated with IBA 500 ppm. The cuttings treated with IBA 500 ppm showed maximum root and sprout by Razvi and Nautiyal (2009). Several attempts were made earlier by Nautiyal et al. (1991); Nautiyal and Rawat (1994); Sorin et al. (2005) on rooting behavior of cuttings. The precedence of control over other hormones was also reported by Nautiyal et al. (2007) in *Dendrocalamus giganteus,* Razvi and Nautiyal (2009) in *Bambusa vulgaris* var. striata and Razvi et al. (2011) in *Bumbusa vulgaris* cv wamin, however the efficacy of hormones was noticed in other rooting parameters where maximum number of roots and root length were discernible in auxin treated cuttings.

The interactive effect of season and hormone depicted a maximum of 57 % rooting in summer with IBA 500ppm at par with Control in Rainy season suggesting that the cuttings had sufficient endogenous auxins during rainy season. Singh et al. (2002) showed that single nodal culm and 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), they observed maximum (52.2%) rooting with IBA 200 ppm and minimum (21.83%) with NAA 200 ppm. In winter season, no sprouting was recorded which is confirmatory to our findings. In contrast to our findings, Surendran and Seethalakshmi (1985) reported 100ppm NAA as the best for *B. arundinacea* during March and 100ppm NAA for *D. strictus* during Feb-March . Kumar et al. (1988) carried out studies on the effect of season on rooting percentage in *B. tulda*. They found that cuttings treated with growth regulators like Coumarin, NAA and boric acid and planted in Summer season (May) were found better than rainy season (August) in terms of sprouting, rooting and rhizome formation. Razvi et al. (2011) vegetatively propagated *Bambusa vulgaris* cv. wamin through juvenile branch cuttings and reported maximum rooting in untreated cuttings (Control) followed by IBA and NAA 500 ppm while minimum was observed in the cuttings treated with Boric acid.

Bamboo possesses inherent proliferating capacity of reproducing itself which can be captured for large scale multiplications. The propagation of bamboo through seedlings proliferation has been found to be one of the most dependable techniques. Adarsh Kumar (1991) reported that the nursery stock of *Dendrocalamus strictus* could be multiplied sixteen times the initial stock by using the improved method of macroproliferation. He employed this schemes for the multiplication of *Dendrocalamus hamilttonii* (Adarsh Kumar *et al.* 1992) and *Bambusa tulda* (Kumar and Pal 1994) seedlings for mass production of field planting stock. Kumar and Pal (1994) reported production of 25 propagules from one mother sapling of seed origin after two multiplications in a year in *B. tulda* while Dubey *et al.* (2008) reported on an average 180, 165, 160,159,149 and 60 numbers of propagules / node in respect of *B. vulgaris*, *B. bambos, B. balcooa*, *D. hamiltonii*, *B. nutans* and *B. tulda* respectively after 4 multiplications. Banik (1985) reported three-fold increase in initial stock of seedlings of *Bambusa tulda* every year.

In all these above studies, the propagating material was seedlings, however, there are no reports of macroproliferation in context to cutting raised plantlets which is the context of this work. During the presnt study it was observed that starting with 100 binodal cuttings, we can finally generate 3240 propagules in 20 months period. Out of these 3/4th can be used for field plantings while 1/4th can be retained for further multiplications . Thus dependency on seeds can be eliminated right from 6 months growth enabling the forester/researcher to grow this Ringal species for innumerable number of years which is the prime objective of this work.

Conclusion

Assessment of requirement of Ringal (*S. falcata*) in hills of Uttarakhand points out to heavy demands which cannot be met through seeds as the gestation period of this species resides between 28-30 years (Troup 1921; Campbell 1988). Therefore alternative techniques of multiplication and conservation were explored. To produce limited plantlets, conventional techniques like offset, Part clump and rhizome planting were feasible, however, to generate enormous planting material in short span of time, planting through culm cuttings followed by macroproliferation is the most suggestive approach. For *In situ* conservation of Ringal resources in nature, an innovative technique through pinning down was reported for the first time in this species. The techniques developed in the present approach were friendly, cost effective, easy and accessible for sustainable produce of *S. falcata* , a socio-economic species in hills of Uttarakhand. The villagers were apprised with these techniques for availability of raw material in their vicinity. Indigenous availability of Ringal to the artisans and villagers would be of great significance to upgrade their socio economic status, at the same time save our forests and women from drudgery.

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Captions of figures

Figure 1a. Part clumps collected from nature

Figure 1b Clumps growth after 1 year

Figure 2a. Offsets prepared for planting

Figure 2b. Planted offsets after 8 months

Figure 3a. Separated rhizome pieces

Figure 3b. Plantlet from rhizome after 8 months

Figure 4a. Separated culms after rooting

Figure 4b. Separated propagules

Figure 4c. Propagule planting in polybag

Figure 5a. Binodal culm cuttings in bundle

Figure 5b. Planting of treated cuttings in trays

Figure 5c. Planting of cuttings in the field

Figure 5d. Sprouting in 6 weeks period

Figure 5e. Rooting after 10 weeks

Figure 5f. Rooted Propagule in Polybag

Figure 6a. Proliferated plant from cutting

Figure 6b. Separation of propagules

Figure 6c. Separated propagules

Figure 6d. Replanting of propagules in polybags

Figure 7a. Preparation of trenches

Figure 7b. Burying of intact culms in trenches

Figure 7c. Root formation from nodes