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Silvicultural management for seed setting in sporadically flowered *Bambusa tulda* Roxb.

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Abstract: Inventories on flowering bamboo is not adequate in our country for ensuring seed availability and maintenance of bamboo germplasm.In the present article the flowering behaviour of *Bambusa tulda* Roxb., a sympodial bamboo species endemic to eastern and north-eastern parts of India has been studied from the bamboo *ex-situ* conservation garden, Bambusetum and vegetative propagation nursery established at the Institute of Forest Productivity, Ranchi, Jharkhand, during 2008 to 2010. Morphological features of the inflorescence and that of seeds have been discussed. The effect of soil work, irrigation and manuring on seed setting in flowered clumps has also been illustrated. Seed setting has been recorded from planted propagules developed vegetatively from the mother clump but not from those in nursery beds during propagation. Irrigation and manuring have shown positive influence in number of spikelets, fertile florets per spikelet and setting of seeds. The caryopsis seeds showed 97% germination in Petri dishes. Few seedlings have been found regenerated near the clump base. Flowering and seed setting in individual clump in the present study supported self pollination in *B. tulda* in Jharkhand. Thus sporadic flowering may give rise to viable seeds in isolated clumps which could be utilized initially for macropropagation and subsequently for future plantations and clonal propagation with appropriate flowering inventory.

Keywords: Sporadic flowering, culm flowering pattern, seed setting, silvicultural management, *Bambusa tulda*

INTRODUCTION

Bambusa tulda Roxb. is a sympodial bamboo species endemic to north-eastern states and eastern parts of India, especially in West Bengal. It grows well in humid tropical and subtropical regions and prefers fine textured moist alluvial soil in good rainfall areas in semi-evergreen forests (Seethalakshmi and Muktesh Kumar, 1998; Anon, 2005; Nautiyal *et al*., 2008; Singh *et al.,* 2010).The species is locally known as *Taral* in West Bengal, *Jati* in Assam, *Wati* (*Owati*) in Garo, *Mirtinga* in Tripura, and *Taleda* in Orissa.

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Flowering cycle of *B. tulda* generally varies from 30-60 years (Seethalakshmi and Muktesh Kumar, 1998; Anon, 2005). However, flowering cycle of 25-30 years have also been reported by Nautiyal *et al*. (2008). In Mizoram, *Melocanna baccifera* and *B. tulda* both have life cycle of 48 years (Anon, 2006). Both sporadic and gregarious flowering of the species have been reported over considerable areas. In Mizoram, a few plants of *B. tulda* flowered in the first and the third year but the vast majority flowered in the second year. Flowering was recorded from Bengal during 1867-68, 1872, 1884, 1919, 1930, and 1936; from Assam during 1886, 1910, and 1930; in Myanmar during 1892, 1903, 1908, 1911 and 1914 and in Bangladesh in 1876, 1886, 1929-30, 1976-77, 1978-79, 1982-83 and 1983-84 and also at Dehra Dun in 1986 (Seethalakshmi and Muktesh Kumar, 1998). Brandis (1899) also reported sporadic flowering in *B. tulda* from Bengal. Many clumps of the species flowered and ultimately died during 1977 in Shishak area of Chittagong hill tracts, during 1978-79 in Sagoolal block of Pathoria Reserve of Sylhet forest and also during 1983-84 at the bambusetum of FRI Chittagong, Bangladesh (Banik, 1988). In Bangladesh, flowering was initiated in February and seed setting during May and June. Mohan Ram and Harigopal (1981) reported sporadic flowering of *B. tulda* in the year 1976 in Mizoram followed by mast flowering until 1979 and they arrived at the conclusion that the inter-mast period was of about 48 years. Sporadic flowering was noticed in one out of four clumps at Dighra, Hoogly, West Bengal, India by Bhattacharya *et al*. (2006). Gregarious flowering in *B. tulda* along with *B. bambos* and *M. baccifera* has been noticed during early March to late May in 2008 in the lowland forests of Bajali area of the Indo-Burma hot spot region (Sarma *et al*., 2010).

Inventories on flowering bamboo is not adequate in our country so as to ensure seed availability and maintenance of bamboo germplasm in one hand, and proper identification on the other. During the field survey for bamboo resource assessment of Jharkhand during the last 5-6 years, attempts have also been made to record bamboo flowering in the State. Besides *B. bambos*, *B. nutans* and *Dendrocalamus strictus*, no other species have shown flowering during that period, except in a few sporadic *B. tulda* clumps encountered outside Chhotanagpur plateau region of Jharkhand. However, during vegetative propagation and at the *ex-situ* conservation garden and bambusetum established at the Institute of Forest Productivity (IFP), Ranchi, Jharkhand flowering in *B. tulda* has been noted. The present article deals with the flowering pattern, flower and seed character and the effect of soil work, irrigation and manuring on seed setting in the species.

MATERIAL AND METHODS

The study sites at Ranchi and Mandar (about 30 km away from Ranchi) within Ranchi district of Jharkhand are situated in Chhotanagpur Plateau (21°58' to 25°30' N latitude and 83°22' to 87°40' E longitude) and are within Northern Tropical Dry Deciduous Forest (Champion and Seth, 1968) having agro-climatic zone 7 i.e., 'Eastern Plateau and Hills Region'. Annual precipitation, mean maximum and mean minimum temperatures vary from 1246 to 1400 mm, 37.5 to 43.3° C and 5.6 to 11.5° C respectively. The two sites are about 600 masl. The major soil group associated is of lateritic type having shallow depth, low water retention capacity, acidity, low levels of organic matter, available nitrogen, phosphorus and some of the micronutrients.

Field trial and laboratory observation

Offsets of *B. tulda* from selected clumps based on apparent health and better growth

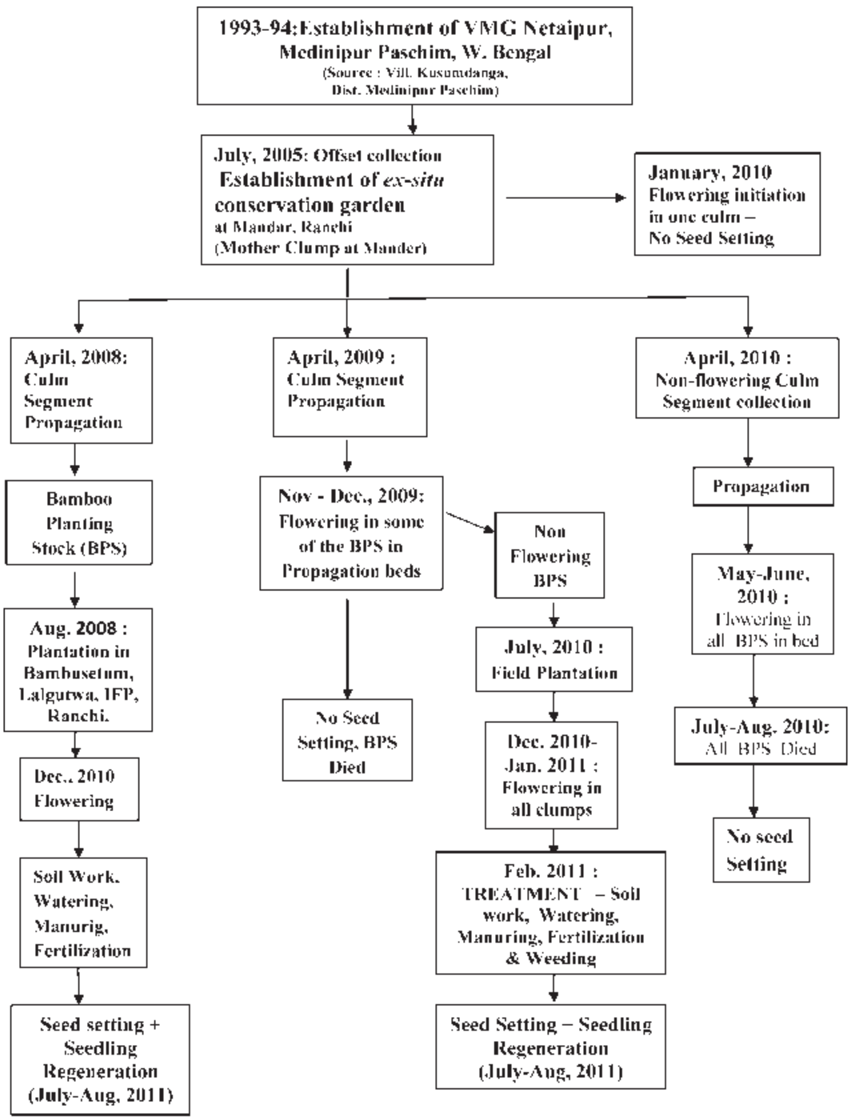

Figure 1. Flow chart on flowering sequence in *B. tulda*.

have been collected from Kusumdanga village, Medinipur Paschim district, West Bengal during July 2005 and planted at Mandar, Ranchi as *ex situ* conservation garden. The established clumps, as introduced in Chhotanagpur plateau for the first time, henceforth is termed as the *Mother Clumps* (Fig. 1). Culm segments of the mother clump have been propagated (April, 2008) and the bamboo planting stock (BPS) developed have been planted at the Bambusetum of IFP, Ranchi in August, 2008.

Figure. 2a

Figure. 2b

Figure. 2c

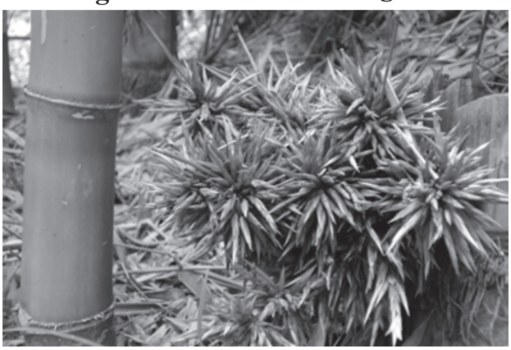

Figure. 2d

Figure. 2e

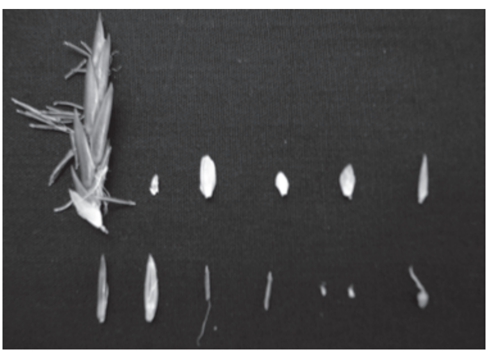

Figure. 2f

Figure. 2g

Figure.2a Flowering clumps of *B. tulda*, b. Flowering of *B. tulda* – advanced stage, c. Flowering in propagation bed, d. Inflorescence in stump of removed culm, e. Inflorescence of *B. tulda*, f. Different floral parts of *B. tulda*, g. *B. tulda* seed

Figure. 2h

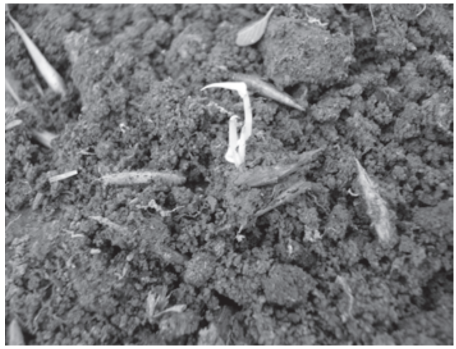

Figure. 2i

Figure. 2j

Figure. 2k

Figure. 2l

Figure 2h. Soil work, manuring and irrigation in flowered clumps, i. Germination of seed at clump base, j&k. Development of seedlings at base of clump, l. Potted seedlings from under flowered clump

Culm cuttings of the same mother clump have also been propagated during April, 2009 and the raised BPS showing no inflorescence in propagation beds have been transplanted in field during July, 2010 at Ranchi maintaining spacing of 5m x 5m.

Field trial and laboratory observations on inflorescence in *B. tulda* have been taken up after the incidence of flowering in one of the clumps each at *ex situ* conservation garden and bambusetum (Fig. 2a and 2b). Twelve outplanted clumps (July, 2010) developed from culm segments have been selected for the field trial to study the flowering characteristics and the effect of soil work, irrigation and manuring on seed setting after simultaneous appearance of inflorescence during December, 2010 and January, 2011 (Fig. 2h).

The clumps were treated during February, 2011 as shown below taking 3 clumps as 3 replications.

T_1 - Control - only soil work or tillage operation surrounding the base of clumps at a radius of 1.0 m

T_2 - T_1 + Irrigation (fortnightly)

T_3 - T_2 + Manuring and fertilization @ 2.0 kg FYM + 0.25 kg DAP per clump

T_4 - T_2 + Manuring and fertilization @ 5.0 kg FYM + 0.50 kg DAP per clump

Clump parameters *viz*., culm number, length, collar diameter, number of nodes and number of branching nodes per culm of the selected clumps have been recorded at the outset of the trial. Among flowering culms of each clump, the tallest one was selected and three nodes of that culm at mid-height have been marked to study the inflorescence and seed setting. The number of spiketlets bearing rachis or sub-branchlets and spikelets per node and fertile florets per spikelet have been recorded from marked nodes of the selected flowering culms during April-May 2011. Regular observation have been made to ascertain the seed setting since April 2011 and during May-June 2011 and after browning of the spikelets, seeds were collected and counted separately from each marked node.

Morphological features of the inflorescence have been recorded in the laboratory from specimen collected from *ex-situ* conservation garden, bambusetum and nursery propagation beds. Immediately after collection, seed dimensions have been recorded and seed germination test was conducted on Whatman 1 Filter paper in Petri dish.

RESULTS AND DISCUSSION

Inflorescence

Inflorescence is a leafless panicle and its many features studied (Fig. 2e.) are similar to those observed by Bhattacharya *et al*. (2006). Rachis smooth and striate, spikelets variable in length 20-40 mm, 6-7 mm broad, sessile, glabrous, cylindrical, acute when young; after that they divide into 7-9 bisexual flowers or florets separated by conspicuous rachillae. The spikelets are subtended first by 1-2 bracts, 20-40 mm long, the 5 lowermost florets are reduced to empty glumes 5-9 mm long, acute and many nerved; followed by 4-6 fertile florets, 17-20 mm long and 2 mm broad at the base, acuminate, mucronate, glabrous, many nerved. Lemma 11 mm long acuminate, mucronate, concave, bright green when fresh, overlapping with palea. Palea shorter than lemma 9-10 mm long, 3-4 mm broad, boat shaped, 2- keeled, with long ciliae on keels, membranous, subtending a bisexual florets. Stamen 6 in numbers, long and exserted, anthers 4.5-6.0 mm long, purple in colour, basifixed, blunt at tip, with a linear dehiscence, filament thread like (Fig. 2f). However, Bhattacharya *et al.* (2006) reported bisexual florets of 15-22 mm long and 5-7 mm broad, palea of 9-15 mm long, 3-5 mm broad at the base and 3.5-6.0 mm long anthers in *B. tulda* observed from Dighra, Hooghly, West Bengal. Ovary obovate 1-2 mm long, short style 1-2 mm long, divided into 3 plumose wavy stigma. Lodicules 3 found at base of ovary, 2.5-3.5 long cuneate, oblong, hyaline, upper part long, white fimbriate, 5 nerved.

Seed

The seed is a caryopsis 0.94-1.05 cm long, oblong, hirsute at apex and furrowed (Fig. 2g). The mid width of seeds ranges from 0.23-0.29 cm and thickness of 0.17- 0.20 cm. Dry weight of 10 seeds is 0.422 g, i.e., 23696 seeds kg^{-1}. Laboratory tests showed

97% germination of these seeds collected from the flowered and treated plants. Sarma *et al.* (2010) have studied gregarious flowering in *B. tulda* from Bajali area of Indo-Burma hotspot region and reported 75% viability of seeds that had the potential for mass regeneration of the species.

Flowering sequence and behaviour

The flowering sequence of *B. tulda* in Jharkhand has been presented in the flow chart (Fig.1). Some of the BPS developed during April-June 2009 started flowering during Nov-Dec 2009 in mother beds (Fig. 2c), and these were kept in sand beds for further observation. This might be the first incidence of flowering in *B. tulda* from Jharkhand (Suraj Kumar and Nath, 2011). The non-flowering BPS have been transplanted in field after one year (July 2010) to examine the flowering behaviour of the species under field conditions.

Flowering in the established mother clump in *ex situ* conservation garden at Mandar has subsequently been noted and that too in a single culm during January 2010. Gradually other culms manifested inflorescence one after another. Even after flowering in only few culms of the mother clump, vegetative propagation continued during April 2010 utilizing the non-flowering culms. Initiation of flowering has been noticed in all planted culm cuttings within one month after sprouting. However, flowering continued for a short period of two months (May to June 2010) before all the BPS died after root formation in beds. In the bambusetum, only one clump out of total eight started flowering during December 2010 and continued flowering till July 2011.

In all the above situations, no seed setting has been noticed in the flowering plants without any treatment. Absence of seed-set has also been reported earlier by Bhattacharya *et al.* (2006) in *B. tulda*, Koshy and Harikumar (2000) in *B. vulgaris* and Singha *et al.* (2003) in *B. cacharensis.* Absence of seed-set may be attributed to the short height of pistil coupled with tight overlapping of lemma and palea, which prevent the pistil from coming out, thereby reducing the chances of cross-pollination. The soil moisture and nutrient regime may be the other factor for seed setting.

According to Anantachote (1988), who studied flowering pattern in many species other than *B. tulda*, the earliest flowering period from flower initiation to seeding starts in October and ends in February in Thailand. In general, bamboo starts flowering by late November or early December which continues till March/April. In the present study, however, propagated BPS in nursery beds flowered during November-December while the established clumps at *ex situ* garden started flowering during December 2009 and January 2010 and continued for more than one year till May-June 2011. Some culms of the mother clump flowered and died, while the other culms grow as usual with subsequent flowering and the whole clump died after every culm has flowered. Only one clump of the bambusetum which had flowered during late

Table 1. Clump parameters of flowering *Bambusa tulda* and seed setting as influenced by soil work, irrigation and manurial treatment

Treatments		Clump No.	Clump parameters					No. of Rachis/ Branch-lets/ node	Spikelets per node at Mid height				Fertile Florets/ Spikelets				No. of Seeds collected			
			No of Total Culms	Culm length (m)	Coll. Dia (cm)	No. of Nodes	No. of branch-ing nodes		1st Node	2nd Node	3rd Node	Mean	1st Node	2nd Node	3rd Node	Mean	1st Node	2nd Node	3rd Node	Total in 3 nodes
T_1	**Only Soil**	1	12	3.34	2.55	15	9	3	35	25	36	**32.0**	4	3	4	**3.7**	0	0	4	4
	Work (no	2	7	2.83	2.14	12	7	4	25	21	42	**29.3**	5	4	5	**4.7**	2	0	1	3
	irrigation)	3	10	2.47	1.86	11	6	3	30	38	26	**31.3**	4	5	4	**4.3**	2	3	0	5
			Mean	**2.88**	**2.18**	**12.7**	**7.3**	**3.3**	**30.0**	**28.0**	**34.7**	**30.9**	**4.3**	**4.0**	**4.3**	**4.2**	**1.3**	**1.0**	**1.7**	**4.0**
T_2	**T_1 +**	1	11	3.25	2.23	14	8	3	26	48	39	**37.7**	4	6	3	**4.3**	13	9	6	28
	Irrigation	2	13	3.45	2.65	15	9	3	52	42	29	**41.0**	5	5	6	**5.3**	9	5	6	20
		3	8	2.63	2.17	13	7	5	43	52	36	**43.7**	5	3	5	**4.3**	6	8	7	21
			Mean	**3.11**	**2.35**	**14.0**	**8.0**	**3.7**	**40.3**	**47.3**	**34.7**	**40.8**	**4.7**	**4.7**	**4.7**	**4.7**	**9.3**	**7.3**	**6.3**	**23.0**
T_3	**T_2 + 2.0 kg**	1	6	3.54	2.55	16	9	6	56	47	46	**49.7**	6	3	7	**5.3**	9	13	15	37
	FYM + 0.25	2	8	2.75	1.86	12	6	4	42	49	53	**48.0**	4	5	6	**5.0**	12	11	7	30
	kg DAP	3	13	2.87	2.2	11	8	3	54	43	38	**45.0**	4	7	7	**6.0**	9	5	11	25
			Mean	**3.05**	**2.20**	**13.0**	**7.7**	**4.3**	**50.7**	**46.3**	**45.7**	**47.6**	**4.7**	**5.0**	**6.7**	**5.4**	**10.0**	**9.7**	**11.0**	**30.7**
T_4	**T_2 + 5.0 kg**	1	11	3.21	2.32	12	7	4	55	47	43	**48.3**	7	5	7	**6.3**	11	19	12	42
	FYM +	2	10	2.88	2.25	10	8	3	45	54	48	**49.0**	6	5	8	**6.3**	9	11	9	29
	0.50 kg	3	11	2.75	1.86	11	6	5	52	47	51	**50.0**	5	5	3	**4.3**	12	7	8	27
	DAP		Mean	**2.95**	**2.14**	**11.0**	**7.0**	**4.0**	**50.7**	**49.3**	**47.3**	**49.1**	**6.0**	**5.0**	**6.0**	**5.7**	**10.7**	**12.3**	**9.7**	**32.7**

December 2010 continued to flower up to July 2011.

Field inspection has also been conducted at the locality of the origin of the species in Medinipur Paschim, West Bengal and it was observed that the selected clump from which the BPS were collected for introduction at Mandar, Ranchi in 2005 had died in 2009 after two years of continuous flowering. Few other clumps of *B. tulda* have also flowered during that period but not in the same village, supporting earlier findings of Bhattacharya *et al*. (2006) from Hoogly district of West Bengal.

In view of these irregularities and flowering in only few of the individual clumps, *B. tulda* in Jharkhand showed 'sporadic' type of flowering with 'culm flowering pattern' (Anantachote, 1988). Even the stumps produce inflorescence after removal of culms for vegetative propagation (Fig. 2d). All the flowering clumps at *ex situ* conservation garden as well as in bambusetum died after every culm has flowered. The early flowering in propagation beds may be due to the stress induced by non-availability of nutrient minerals in sand beds. Anantachote (1988) observed culm flowering in *D. asper* and *Thyrsostachys siamensis*.

Silvicultural management

Table 1 depicts the clump parameters of the selected clumps and there is very little variation in culm length, culm collar diameter, number of nodes and branching nodes. However, the number of rachides at the mid nodes of the culms has increased to a smaller extent due to irrigation and manuring. Spikelet count in the clumps, however, manifested significant response to the clump treatments. On an average, more than thirty per cent increase in number of spikelets has been recorded due to irrigation. Manurial and fertilizer application in the form of FYM and DAP further accentuated the effect of irrigation on numerical preponderance of spikelets. Similar trends have been observed for seed setting but not for fertile florets per spikelet. Irrigation and manuring have shown very little influence in the number of fertile florets per spikelet. On the other hand, 8- 10 fold increase in seed setting have been achieved due to the treatments as reflected from the number of seeds collected separately from the marked nodes (Table 1). However, the increase in number of spikelets and setted seeds with higher dose of manure and fertilizer compared to their lower dose is negligible.

Sporadic flowering in isolated clumps resulted in little or no seed as reported by Gamble (1904) and Janzen (1976). McClure (1966) also reported flowering without seed setting in some introduced or cultivated bamboos. Approximately 40 introduced bamboo species rarely set seeds during sporadic flowering (Wang and Chen, 1971; 1972). The present study showed that assured seed setting in bamboos can be achieved through silvicultural intervention.

It has also been noted that the lone flowering *B. tulda* clump in the bambusetum started seed setting only after clump treatments of soil work, irrigation and manuring since May 2011. Subsequently, it was possible to collect a few grams of seed from the clump and seedlings could be regenerated (Fig. 2i) at the base of the clump during July-August 2011. Thus, it is clear that a threshold level of soil nutrients is essential for seed setting in addition to soil working and irrigation.

Seeds collected from the flowering *B. tulda* due to treatments have shown 97% germination and seedlings have been raised for future utilization. At the base of the flowered clumps, under treatments and that in the bambusetum, tiny seedlings (10-30 per clump) have been seen regenerated (Fig. 2j and 2k). This may be due to maintenance of adequate soil moisture and nutrient supply to the clump during flowering period. These have been potted (Fig. 2l) for macro-propagation with strategic view of subsequent clonal propagation and future plantation with materials having appropriate flowering inventory.

Since the individual clumps in *ex situ* conservation garden and bambusetum that flowered are far apart from one another, it can be concluded that the seed setting is due to self-pollination rather than cross-pollination which is common in bamboos.

It may be concluded that sporadic flowering may give rise to seed setting in isolated clumps which could be utilized for future propagation and subsequent establishment of plantations. Further, for seed setting in such situations of sporadic flowering, silvicultural management of clumps is obligatory with proper irrigation and manuring/ fertilization.

REFERENCES

Anantachote, A. 1988. Flowering characteristics of some bamboos in Thailand. *In*: I. V. Ramanuja Rao, R. Gnanaharan and C. B. Sastry, (Eds.). Bamboos: Current Research. Kerala Forest Research Institute, India and International Development Research Centre, Canada: 66-75.

Anonymous 2005. Orissa Bamboo Development Agency, http:// www.odishabamboo.org/btulda.html

Anonymous 2006. Bamboo Resources In Mizoram. Environment and Forest Department, Govt. of Mizoram, http:// env for mizo .in /forest/ bamboo-_flower.htm.

Banik, R. L. 1988. Management of Wild Bamboo Seedlings for Natural Regeneration and Reforestation. *In*: I. V. Ramanuja Rao, R. Gnanaharan and C. B. Sastry, (Eds.). Bamboos: Current Research. Kerala Forest Research Institute, India and International Development Research Centre, Canada: 92-95.

Bhattacharya, S., Das, M., Bar, R. R. and Pal, A. 2006. Morphological and Molecular

Characterization of *Bambusa tulda* with a Note on flowering. *Ann.Bot.* 98: 529-535.

Brandis, D. 1899. Biological Notes on Indian Bamboos. *Indian Forester* 25: 1-25

Champion, H. G. and Seth, S. K. 1968. A revised survey of the Forest Types of India. Govt. of India, New Delhi: 189-205

Gamble, J. S. 1904. The flowering of the bamboo. *Nature* 70: 423p.

Janzen, D. H. 1976. Why bamboos wait so long to flower. *Ann. Rev. Ecol. Systematics* 7: 347-391

Koshy, K. C. and Harikumar, D. 2000. Flowering incidences and breeding system in *Bambusa vulgaris*. *Curr. Sci.* 79: 1650-1651.

McClure, F.A. 1966. The Bamboos: A Fresh Perspective. Cambridge, Massachusetts. Harvard University Press: 86p.

Mohan Ram, H. Y. and Harigopal, B. 1981. Some observations on the flowering of bamboos in Mizoram. *Curr. Scie.* 50: 708-710.

Nautiyal, D. P., Nautiyal, S. and Chaukiyal, S. P. 2008. Indication of gregarious flowering In *Bambusa tulda* in North-Eastern states of India. *Indian Forester* 134 (7):985-986.

Sarma, H., Sarma, A. M., Sarma, A. and Borah, S. 2010. A case of gregarious flowering in bamboo, dominated lowland forest of Assam, India: Phenology, Regeneration, Impact on Rural Economy and Conservation. *J. For. Res.* 21 (4): 409-414.

Seethalakshmi, K. K. and Muktesh Kumar, M. S. 1998. Bamboos of India- A Compendium, Kerala Forest Research Institute (KFRI), INBAR. (ISBN 81-86247-25-4): 79-83.

Singh, P. K., Sorokhaibam, P. D., Keisham, K. D., Ningombam, D. S. and Athokpam, P. 2010. *Bambusa tulda* Roxb. in Manipur State, India: Exploring The Local Values and Commercial Implications. *Notulae Scientia Biologicae*. 2 (2): 35-40.

Singha, L. B., Bhatt, B. P. and Khan, M. L. 2003. Flowering of *Bambusa cacharensis* Mazumder in the southern part of N E India : A case study. *J. Bamboo Rattan* 2 : 57-63.

Suraj Kumar and Nath, S. 2011. Flowering in *Bambusa tulda* Roxb. at Ranchi, Jharkhand. *Indian Forester* 137 (6): 802-03.

Wang, T. T. and Chen, M. Y. 1971. Studies on Bamboo Flowering in Taiwan. *Tech. Bull. Experimental Forests, Taiwan University* 87: 27

Wang, T. T. and Chen, M. Y. 1972. Flowering and seeding of giant bamboo (*Sinocalamus latiflorus*). *Silvae Genetica* 21: 251-252