J. Bamboo and Rattan, Vol. 16, Nos. 2, pp. 77-96 (2017)

Natural history, traditional agronomy and sociocultural aspects of *Dendrocalamus stocksii* (munro) from sahyadri mountains, India

Milind Digambar Patil
University of Mumbai, M. G. Road, Fort, Mumbai - 400032, Maharashtra, India.

Abstract: Exploring indigenous traditional methods of crop production provides new perspectives and insights to its conservation and improvement. Though there are several publications on modern bamboo cultivation aspects, records on age-old practices of cultivation and clump management are rare. To study the traditional aspects of cultivation, management and utilization of *Dendrocalamus stocksii* (Munro), a study was conducted in Sindhudurg district, the south Konkan region of Maharashtra state. *D. stocksii* is one of the endemic bamboo species having its germplasm exclusively conserved in farmers' fields. Cultivation of *D. stocksii* is an excellent example of tree based land use system which derives sustainable benefits through protection of natural ecosystem. Farmers do not clear fell the existing natural vegetation at plantation site; large trees (>30cm diameter) are preferably retained. *D. stocksii* is traditionally being propagated only by vegetative means through rhizome-offsets as it does not produce seeds. The period of detachment and planting of offsets is confined during early fortnight of June with the progress of S-W monsoon in the Western Ghats. Long length offsets (>2.5m) are planted by staking them to the tree trunks for stability. Offsets are strictly planted at around 70^0 of inclination such that its tip faces towards south which minimizes the southern heats of winter solstice. No synthetic chemical fertilizers were used other than organic. Farmers are following a unique 'clear felling and light burning practice to rejuvenate the flowered clumps. Indigenous crop protection measures against wildlife such as use of dead and decaying fish-waste for Langurs, use of human hairs for wild boars were reported. Harvesting of mature culms was found to be associated with low tidal events and lunar phases which make poles less susceptible to the insect attack. Harvested poles are then kept submerged in water for 6 to 10 weeks which enhances its durability up to 20 years. More than 40 different local uses and sociocultural customs associated with the species were documented.

Key words: bamboo farming, bamboo flowering, bamboo preservation, clump rejuvenation, vertebrate-pest management, Western Ghats

INTRODUCTION

Bamboo is a tall, arborescent grass belonging to sub-family Bambusoideae, family Poaceae. Wide adaptability, extraordinary fast growth, sustainable harvesting and multiple end uses are major advantages of bamboo over other forestry species. There are more than 1600 described bamboo species in 120 genera distributed worldwide, of

*To whom correspondence should be addressed: milindp771@gmail.com

which around 93% are woody bamboos (Kumar, 2011). Indian bamboo resources contributes nearly 136 species under 29 genera (Kumar, 2011). The north-east region, part of central India and the Western Ghats (Sahyadri Mountains) are the major bamboo growing regions in India. Kumar (2009) has documented 22 species and two varieties belonging to seven genera from peninsular India of which *Ochlandra*, *Bambusa*, *Dendrocalamus* and *Oxytenanthera* are dominant genera (Yeasmin et al. 2015). Out of 22 species, 17 species are endemic to the Sahyadri region (Kumar, 2011).

Dendrocalamus stocksii (Munro) M. Kumar, Remesh & Unnikrishnan, 2004 Syn: *Oxytenanthera stocksii* Munro, 1868; *Pseudotenanthera stocksii* (Munro) R. B. Majumdar, 1989; *Gigantochloa stocksii* (Munro) T. Q. Nguyen, 1990; *Pseudoxytenanthera stocksii* (Munro) Naithani, 1991 is medium sized, deciduous bamboo species with pachymorph, short necked, caespitose rhizomatous systems. Culm sheath is pubescent with brownish-red coloured bristles with prominent auricle. Culms are strong, loosely spaced, almost solid and thornless with minimal lower branching, distally dense white or gray deciduous tomentum and green to dark green in colour. Mature culms are erect, self-supporting and rarely erect with pendulous tips. Culms can attain height up to 15m with internodal length of 20 to 38cm and diameter 2.5 to 4cm. Sporadic flowering is commonly observed in this species (Kumar, 2009). Inflorescence is a large panicle, terminal and axillary as verticillate clusters or large globose heads on the nodes. Though it flowers profusely, it does not produce seeds (Seethalakshmi and Kumar, 1998) probably due to protogyny and dichogamy (Beena 2011).

D. stocksii is the third most preferred bamboo species in agriculture sector in peninsular India (Rao et al. 2008). It is endemic to the central Western Ghats, distributed from northern Kerala, Karnataka, Goa and the Konkan coasts of Maharashtra (Kumar et al. 2004). It is commonly known as Managa in Marathi language and also popular by the names Bharadi, Chiva, Heshi, Godi, Kapshi, Tandali, and Dar bet (bet = clump) in the Konkan region based on phenotypic expressions. It is traditionally being planted in home gardens, farm bunds, farm borders, block plantations and as a bio-fencing (fig. 1a, b). Farmers highlighted that Managa is only found adjoining to the human settlements and unlike other bamboo species it was not observed in the forest area.

National Bamboo Mission (NBM), Government of India recently prioritized Managa as one amongst 18 industrially important bamboo species in India and recommended its large scale cultivation. Institute of Wood Science and Technology (IWST), Bengaluru, Karnataka initiated research work on the species since last decade and published the first technical booklet in the year 2012. Besides, many authors studied *D. stocksii* in different aspects like germplasm and genetic diversity, niche and distribution, agroforestry aspects, propagation techniques, economics of cultivation,

marketing potential and modern utilization, C sequestration and climate change mitigation/adaptation approaches etc. (Sanjaya et al. 2005; Viswanath et al. 2012; Rane et al. 2013; Anonymous 2014; Viswanath et al. 2014; Dhavala et al. 2015; Rane 2015, Patil et al. 2016a). However the age-old farming practices of the species were largely unnoticed.

Indigenous crop cultivation methods are based on experiences gain by the local communities over a period of time. The methods are tested over centauries reflecting indigenous perspectives of crop production and the strong bond between environment and community. It is thus essential to understand the roots of local agricultural history and link it with advanced agronomic practices (David et al, 2012). The paper described one such sophisticated knowledge system developed over generations by the local communities in the central Western Ghats. To explore the traditional aspects of cultivation, management and utilization aspects of *D. stocksii*, a study was conducted in Sindhudurg district, the south Konkan region of Maharashtra state.

Figure 1. Cultivation of *D. stocksii* ***(a.)*** Farm bunds and ***(b.)*** Bio fencing in Sindhudurg district, India

MATERIALS AND METHODS

Study area

Sindhudurg (15°37'-16°40'N and 73°19'-74°18'E) is the southernmost coastal district in Maharashtra state, popularly a part of Konkan region. (Fig.2). It has five major physiographic units viz. coastline, estuarine plains, lateritic plateaus, residual hills and scrap faces of Sahyadri Mountains. The major rock formations are laterite and Deccan trap which are poor in phosphorous and rich in nitrogen and potassium. The total geographical area of Sindhudurg is 5207km^2 having 121km of coastline. Around 50% of the geographical area of Sindhudurg is covered with moist deciduous and semi-evergreen type of forests of which a large extent of forests (89%) is either

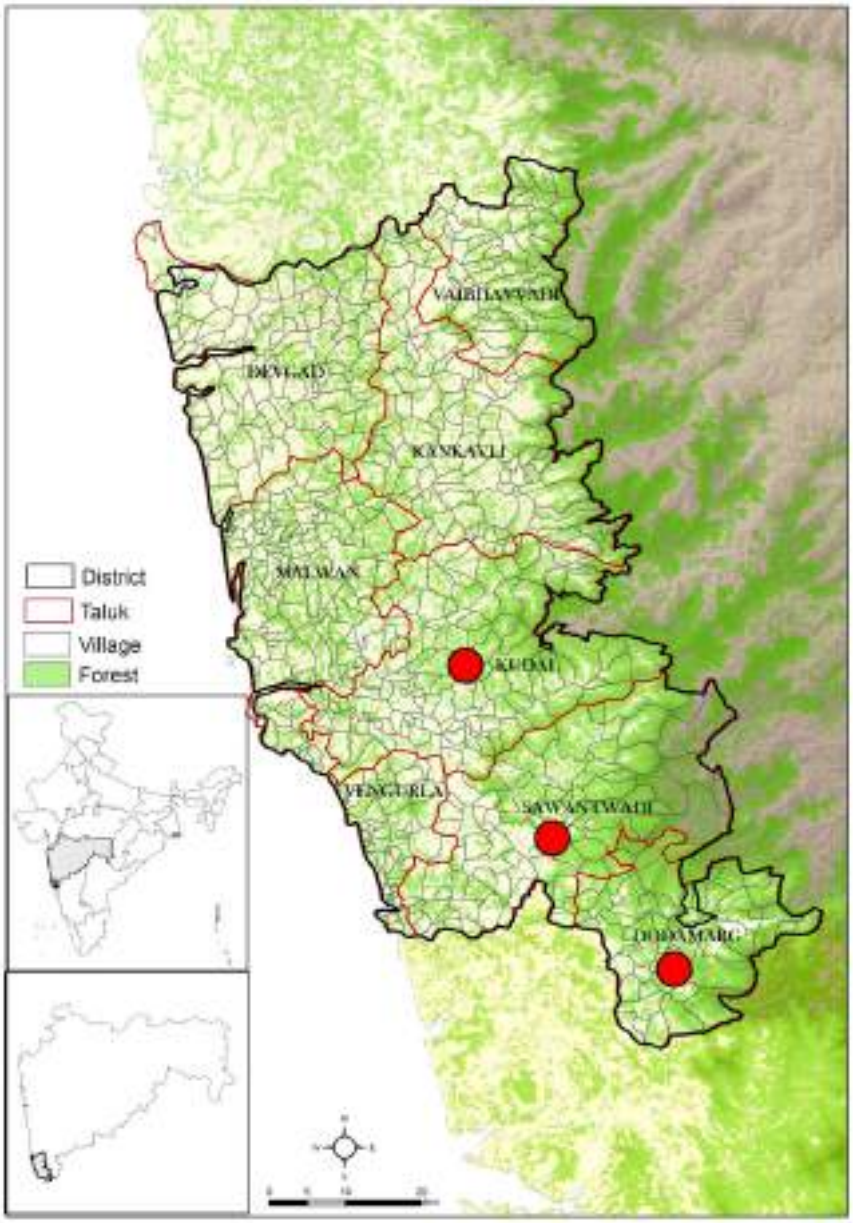

Figure 2. The map representing surveyed talukas in Sindhudurg district, India

privately owned or the community forests. Only 11% of the forest area is administered by the State Forest Department. The study area exhibits three distinct climatic seasons viz. summer (February to May), monsoon (June to September) and a diffused winter (October to January). It receives >3200mm of annual rainfall. An annual minimum and maximum average temperature of Sindhudurg is 13°C and 38°C and the minimum and maximum average humidity is 25% and 97% respectively.

Sindhudurg is politically sub divided into eight units called taluka viz. Vaibhavvadi, Devgad, Kankavli, Malwan, Kudal, Vengurla, Sawantwadi and Dodamarg. There are total 748 villages spread across all these talukas. As per Census 2011, the total population of Sindhudurg is 868,825 with the population density of 167 people per km^2. It is the least populated district but having the highest sex ratio (1036) in Maharashtra state. Around 87% is engaged in agriculture with an average landholding of one hectare. Home garden is traditionally adopted agroforestry system in this region. Major agricultural crops include rice, some millets and pulses. A large proportion of land has been brought under orchards of mango, cashew, coconut, areca palms, bamboo and banana.

D. stocksii has relatively stable and perennial inter- and intra-state bamboo markets. Indeed, there was no trend for large scale cultivation of the species till late 1990s. This onwards, increasing demand for bamboo poles tempted farmers to establish block plantations of the species. As per the government records (2015), Sindhudurg district produces around 2500 truckloads of marketable bamboo harvest per annum. Each truckload bears 1200 to 1400 harvested poles. If we extrapolate the values with present average on-farm prize of each pole i.e. ₹ 50 or $ 0.75 (1 USD = 67 INR), farmers in Sindhudurg are actually earning more than 162.5 million INR or 2.4 million USD per annum. Besides, the Benefit Cost Ratio of *D. stocksii* plantations from fifth year onwards is around 3.4, which can potentially be comparable with the major horticultural crops cultivated in the Konkan region like cashew and mango (author's unpub. work).

Data collection

The study was conducted during January, 2015 and June, 2016. Based on pilot survey and discussions with District Agricultural Department personnel, foot-hill region of Sahyadri Mountain was identified as the core bamboo producing region in Sindhudurg includes three talukas viz. Kudal, Sawantwadi and Dodamarg. The final survey was conducted in 12 villages from the selected talukas viz. Kudal (Digas, Hirlok, Naneli and Wados), Sawantwadi (Dingne, Otavane, Padlos and Sonurli) and Dodamarg (Bambarde, Hewale, Kalane and Mangeli). Door-to-door interviews were conducted during December, 2015 and February, 2016. Total 180 bamboo farmers (15 in each village) were personally interviewed using semi structured descriptive type questionnaire. Semi structured questionnaires contains a pre fixed set of questions; some flexibility is given to guide and persist with the conversations with respondents. Group discussions were also organized in Kudal taluka each with a group size of 30 ($\pm$5)respondents. Each interview lasted for around 30 minutes. Around 60 bamboo farms were visited to confirm field management practices and the ground facts. Detailed explanatory notes were also maintained on each sub-topic. Data were recorded in a local language Marathi and later translated into English. Bamboo cultivation is exclusively a male activity and therefore the interactions were chiefly

restricted to men only. Women participated in group discussions and significantly contributed to documenting the uses of *D. stocksii*.

RESULTS AND DISCUSSION

General profile of respondents

Age of respondents ranged from 20 to 95 years. Most of the respondents represented the age class 60-69 years. Around 82% of respondents had educational qualification below Secondary School Certificate (SSC) examination whereas 5% were uneducated. Most of the respondents (89%) reported farming as their sole occupation whereas only 9% had another source of income along with farming. The reported annual income of 86% of the respondents was less than ₹ 50,000 and only 10% earned more than ₹ 100,000 per annum. The households resided in kachcha (earthern) and pakka (lateritic stones) houses in approximately equal proportions. Around 80% of the respondents had less than six members in their household. Average land-holding of the surveyed respondents was 5 ha which comprised of average 1 ha and 2.7 ha land under agriculture and horticulture respectively. It was found that highest proportion of land under agriculture (which is mostly rice) was in Sawantwadi taluka. The same for land under horticulture was in Kudal taluka. Dodamarg is a largely hilly taluka and hence proportion of uncultivated privately owned land is very high there. All the farmers were cultivating *D. stocksii* as one of the major source of income. They have the legacy and culture of bamboo farming established over generations.

Description of the system

Selection of site

Farmers cultivate *D. stocksii* on variety of soils ranging from rich alluvium to lateritic carps. Successfully established clumps of *D. stocksii* in the crevices of igneous rocks were observed in Mangaon village (fig. 3). Farmers highlighted the scope for establishing block plantations on rocky or lateritic plateaus by putting 75cm of soil layer over it. Seasonally waterlogged soils or paddy fields facilitate planting opportunity by constructing mounds/ridges. Successfully established clumps were observed effectively tolerating waterlogged conditions for 10 to 15 days.

Being a surface feeder with shallow and sturdy root system *D. stocksii* generally requires minimum of 40cm soil depth for clump establishment which was confirmed after observing four excavated rhizome systems. In general the rhizome system of older clump is more convex; appeared slightly above the ground; more looks like an upturned saucer on a table-top. In contrast, rhizome grows differently on extreme gradient soils e.g. on the river banks where the rhizome neck (a long thin portion of rhizome attached with parent rhizome, usually bear minimum or no roots, also known as pseudowhips or rhizoids) first goes deeper into the soil sometimes more than 60cm

depth, entwined with the older rhizomes and then abruptly turned upward. This typical behaviour of rhizomes made it suitable for planting on banks of seasonal streams and/or river embankments to check the soil erosion.

It is generally believed that planting bamboo under trees leads to failure of plantation. BTSG-KFRI Manual of Bamboo Plantations (2015) recommended removal of large trees at the plantation site. Paradoxically, farmers cultivate *D. stocksii* as a component of tree based landuse system in Sindhudurg. Farmers do not clear-fell the existing natural vegetation for establishing bamboo plantations. Only the shrubs, bushes and climbers are removed, while already existing large trees (>30cm diameter) are preferably retained (Fig. 4). Around 28 different indigenous tree species from 18 different families were recorded (table 1). Farmers highlighted that competition with already existing arboreta for sunlight makes new culms taller and erect. Such culms sometimes reach up to height of 12m with a diameter of 60mm at 5th internode which is much higher than usual. Tree branches provide physical support and stability to the culms and avoid dropping tops. Trees derived the nutrients from deeper layer of soil and deposited them on the surface in the form of leaf litter. Those mineral nutrients are readily available for the bamboo clumps. It was also noticed that culms under tree canopy exhibits hardly any lower branches; thus are easy to harvest and produces minimal post-harvest residue. Rane et al. (2014) demonstrate that *D. stocksii* performs well as mixed forest component since forests soils contained more available N, P, K and organic carbon, which facilitates production of thicker and taller culms.

Figure 3. Successfully established clumps of *D. stocksii* in the crevices of igneous rocks were observed in Mangaon village, Sindhudurg district, India

Figure 4. Cultivation of *D. stocksii* clumps under tree canopy, Sindhudurg district, India

Table 1. Tree species (>30cm diameter) recorded in *D. stocksii* plantations, Sindhudurg district, India.

Family	Botanical Name	Local Name
Anacardiaceae	*Anacardium occidentale*	Kaju
Anacardiaceae	*Buchanania lanzan*	Charoli
Anacardiaceae	*Mangifera indica*	Amba
Anacardiaceae	*Semecarpus anacardium*	Bibba
Apocynaceae	*Alstonia scholaris*	Satvin
Arecaceae	*Caryota urens*	Bherali-mad
Bombacaceae	*Bombax ceiba*	Kate-savar
Combretaceae	*Terminalia arjuna*	Pandhara Ain
Combretaceae	*Terminalia bellerica*	Bhela
Combretaceae	*Terminalia chebula*	Hela
Combretaceae	*Terminalia elliptica*	Kala Ain
Combretaceae	*Terminalia paniculata*	Kinjal
Euphorbiaceae	*Bridelia retusa*	Kate-asan
Fabaceae	*Pterocarpus marsupium*	Pale-asan
Fabaceae	*Butea monosperma*	Palas
Guttiferae	*Garcinia indica*	Ratamba
Lecythidaceae	*Careya arborea*	Kumbha
Lecythidaceae	*Lagersroemia microcarpa*	Nana
Loganiaceae	*trychnos nux-vomica*	Kajara
Mimosaceae	*Acacia catechu*	Khair
Moraceae	*Artocarpus heterophyllus*	Fanas
Myrtaceae	*Syzygium cumini*	Jambhul
Rutaceae	*Zanthoxylum rhetsa*	Tirphal
Sapindaceae	*Schleichera oleosa*	Kusum
Sapotaceae	*Mimusops elengi*	Bakul
Tiliaceae	*Grewia tiliaefolia*	Dhaman
Verbenaceae	*Gmelina arborea*	Shivan
Verbenaceae	*Tectona grandis*	Sag

Detachment of rhizome-offset

Offset planting is the traditional method of propagation of the species. Detachment of rhizome-offsets from the parent culm is carried out during early fortnight of June, locally known as Mriga nakshatra, the 5th lunar mansion in Hindu astrology, indicating progress of S-W monsoon. Even though it has no direct correlation, however the period is confined with seasonal spawning migration of freshwater fishes through flooded rivers and streams. This upstream migration looks like several wavy iron hawsers moving through a river, thus the phenomena is also known as Sakhali khel (literally meaning chain sports).

The thickened portion of rhizome bears hundreds of fibrous roots and 6 to 10 dormant vegetative buds from which one or more new culms will be produced. Farmers said that growth and development of dormant buds begins in this period. Wet soils also enable easy detachment of underground rhizomes and the progressive growth of roots after planting. If detachment operations get delayed by a month or two, the new emerging shoots will be prone to damage during excavation and none of them are likely to establish well. But such rhizomes always again sprouts in the following monsoon from remaining dormant buds.

Separation of bamboo rhizome requires special skills. Firstly, one year old culms in a clump are identified based on various morphological cues e.g. presence of nodal culm sheath, colour of the culm etc. Then a transverse cut is given at 4.5 to 5.5m (sometimes at minimum 1.2 to 2m) height, 2cm above the nodal portion. A small trench is dug around by *pikav* (pickaxe) so that neck of the daughter rhizome should be clearly visible. Rhizome is then detached from its neck portion using *kurhad* (axe) or *pahar* (broad-blade crow bar) or *pal koyta* (scythe).

Planting

Offsets should be planted within 24 hours after detachment**.** If the numbers of offsets to be planted are few, pits are dug out after separation of offsets from the mother clump. This avoids stagnation of water into pits. For establishing large plantations, pits are preferably dug prior to the rainy season and refilled with dung manure, goat manure, rice husk, leaf litter and other organic residue. An average pit size for planting bamboo rhizomes-offsets is 50cm x 50cm x 30 cm Farmers prefer minimum of 3m to 5m spacing for block plantations. Long length offsets (>2.5m) are planted by stacking them adjacent to the trees. Keeping long length of an offset has future economic perspective. Farmers harvest those long poles after successful establishment of daughter rhizome, generally two years after planting and sell them at market price.

Offsets are strictly planted in slanting position (at around 70^0 of inclination) such that the tip faces towards south. It helps to minimize the southern heat during winter solstice locally referred to as *Dakshin tapa,*. Mound planting (50-60cm height) is

practiced in flood prone regions and areas which frequently exhibits prolonged water stagnation in rainy season. For establishing boundary plantations, ridge method is used. Here the two adjacent planted at 2m spacing and tied together in 'X' position for physical stability. In recent times, farmers are using bulldozers to make continuous ridges with 1m height and 2m wide at base. Ridge/mound planting has many advantages over the pit method like early clump establishment, vigorous growth etc. If newly planted offsets survive the first growing season, it will sprout a minimum of one and occasionally two or more culms in the following monsoon.

Irrigation

Most of the farmers (98%) do not provide post-monsoon irrigation to the newly planted offsets. Such offsets require at least two years for their successful establishment. A farmer (Mr. Baba Kumbhar, Pinguli village) said that in rare cases, newly planted offsets under non-irrigated conditions may have a delay of two years in producing the first shoot(s) due to certain unknown factors. Thus offsets producing no new culms, should not be removed at least for initial two years.

Unseasonal rains (during December to February) usually accelerate the growth and development of rhizomes as well as the new shoots. And the same clump always, shoots-up again in the following rainy season (June to August). Offsets provided with artificial irrigation were observed producing more number of culms in two folds; first during June-July and again in January-February. One such irrigated clump was observed with 21 culms within a year after planting in which four culms were of commercial size. Two farmers in Kudal taluka were cultivating vegetables like Karali (*Momordica charantia*), Kakdi (*Cucumis sativus*) etc. under newly planted offsets for initial two years as an additional income source (fig. 5). Intercropping under newly established plantations provides both water and nutrients to the developing rhizomes which increases the productivity and economic returns (Mera and Xu, 2014). Though artificial irrigation confirms an early establishment of daughter offsets, it significantly reduces the diameter and height of new shoots. Thus it was suggested that irrigation should be provided for the first year only to achieve the early clump establishment.

IWST, Bangaluru, Karnataka and DBSKKV, Dapoli, Maharashtra have developed micro- and macro- propagation protocols of *D. stocksii*. Two of the respondents had planted the plantlets on their farms. A farmer (Mr. Madhukar Rane, Kasal village) has observed the growth and performance of the plantlets on his farm. He said that irrigation should not be provided to those planted under tree canopy since irrigated water and dissolved soil nutrients are used up by adjoining trees; especially during the dry spell of the year. Tree roots make a mesh-like structure below the sapling's rhizome and hinder the growth of saplings. I also confirmed this after observing six saplings with poor growth. On the contrary, non-irrigated saplings under trees always show better growth which can be comparable with non-irrigated rhizome-offsets from the

third year, provided that there should be minimum 50% of the active sunlight available for the photosynthesis (auth. per. comm.).

Figure 5. Intercropping under newly planted rhizome-offsets plantations, Ranbambuli village, Sindhudurg district, India

Mulching

Mulching is practiced during early monsoon season. Leaf litter available from around the clump is used as mulch. Sometimes farm yard manure are added. Mulching is followed by mounding of earth at the base of clump. It protects adventitious roots and prevents leaching of supplementary nutrients during heavy rains. None of the farmer was reported using synthetic chemical fertilizers for bamboo cultivation. Branches and other residue after harvesting of clump are also used as mulch.

Flowering and clump rejuvenation

Farmers mentioned that *D. stocksii* flowers at the age between 40 to 60 years. Flowering is exclusively observed in post-monsoon season i.e. during October-December; however the older culms show symptoms of early flowering. Here, older culms produce new leaves as well as floral spiklets at the terminal portion of branches in the rainy season. The clump also produces one or more new shoots however instead of leaves it produces flowers in the post monsoon season. Sometimes few fresh leaves can be seen on flowered culms. But otherwise in most of the cases, new culms remain almost leafless.

All culms in a clump do not always flower at the same time. There may be one or few older culms in a clump remain un-flowered and the new vegetative shoots may be expected from the same non-flowered culms in the next monsoon. Ramanayake (2006) similarly reported that *Bambusa atra* and *Schizostachyum brachycladum* in Sri Lanka constantly flower but with no seed set and continue to grow from new vigorous shoots. Koshy & Pushpangadan (1997) recorded two forms of flowered clumps of *Bambusa vulgaris* viz. (i) gregariously flowered clumps with no leaves and (ii) partly flowered clumps in healthy vegetative phase. The former clumps were died after flowering whereas new shoots were produced in later case.

Farmers are following a systematic protocol for the rejuvenation of flowered clumps. First, all the above ground biomass is clear felled when culms are in a green condition. A thin layer of dried leaves and grasses is spread over clear felled clump and lit up to establish light fire. This practice is locally known as *dhagavani*. Rhizome gets immediately irrigated with plenty of water after complete incineration of fuel. Sometimes fresh cow dung is placed over it. It is believed that this practice reduces the concentration of *pitta* (enzymes and hormones responsible for flowering) in the flowered rhizome.

New sprouts/branches having diameter of 0.5-1cm and 1-1.5m of height appears 25-30 days after *dhagavani* (Fig 6). If the new flush comprised with both flowered and non-flowered twigs, flowered twigs are selectively removed while non-flowered twigs are retained. But if all the twigs are flowered again; the whole earlier procedure is repeated. Rejuvenation is confirmed with the emergence of new vegetative shoots in the following rainy season.

Figure 6. Rejuvenation of *D. stocksii* after clear felling and light burning practice, Sindhudurg district, India

Newly planted rhizome-offsets occasionally flowers immediately or a year after planting even though the parent clump is in vegetative phase. In such situations offsets could not be rejuvenated by the above method. Farmers highlighted that around 80% of the completely flowered clumps can successfully rejuvenate after *dhagavani* while the remaining 20% does not revert back to its vegetative phase and subsequently dies.

A farmer (Mr. Dattaram Khot, Ranbambuli village) observed that in partially flowered clumps (clumps containing both flowered and non-flowered culms) successful natural rejuvenation is from the older rhizomes of non-flowered culms. Thus he recommended to retain minimum two or three older culms (>3 years) at each felling cycle if flowering is expected in near future. He also highlighted that as the underground rhizome ages; culms will get hollower with longer internodes and hollowness may be more pronounced in the lower-middle portion of the culms.

Usually the death of bamboo after flowering is highly correlated to the reproductive exhaustion of underground rhizomes and clump is able to revert back to its vegetative phase if rhizome is left with sufficient food resources although all the above ground culms were flowered to die (Ramanayake 2006; Beena 2011). Nath et al. (2014) studied gregarious flowering and post-flowering regenerative ability of rhizomes in *Schizostachyum dullooa* in the north-east region of India. They observed emergence of new vegetative shoots from three per cent of clumps; three years after gregarious flowering. There examination revealed that reserved food was not exhausted fully in the rejuvenated rhizomes and new culms were emerged from the rhizome neck.

Fire

D. stocksii is a deciduous bamboo species in which leaf shading occurs during January-February and new leaves appeared in March. The new flush is locally known as *Chaitra palavi*. Thus during summer season (February to May) bamboo plantations are at high risks of fire injury. Farmers mentioned that ground fires in bamboo plantations potentially destroy all the culms however it does not be fatal for underground rhizomes. In contrast, fire-damaged bamboo clumps vigorously produces more number of new shoots little earlier in the rainy season than the normal clumps. Few of the farmers were deliberately following 'light burning practice' under live vegetative clumps in the month of May to increase the number of new shoots. Most of the respondents (76%) were against this practice since it is unscrupulous to burn any living plant. Besides, fire-damaged bamboo poles fetch lower prize in the market. Two farmers from Kudal taluka had established 4m wide fire belts around their plantation to minimize the summer fire hazards.

Insect-pests and diseases

Farmers recorded various symptoms and signs of insect-pests attack in bamboo groves however, according to them; none of the infestation is fatal for the entire clump. Surprisingly none of the farmers was using any protective, preventive or remedial

measures against insect-pests or diseases in bamboo plantations. In case of termites, farmer reported that it playing a vital role in decomposition of dead stumps, dead underground rhizomes etc. and recycling the nutrients in the rhizosphere. Termites do not cause any harm to the living tissues of bamboo clumps.

Viswanath et al. (2012) first systematically recorded the pest and diseases on *D. stocksii* from various regions of Western Ghats viz. scale insects (*Antonina* sp.), Leaf spot disease (caused by *Colletotrichum* and *Rhizoctonia*), 'Witches Broom' disease (caused by mycoplasma like organisms), Leaf Rust (caused by *Dasturella* sp.) and Leaf Blight diasease in the species at various growing phases. Patil et al. (2016b) documented heavy infestation of Bamboo weevil (*Cyrtotryachilus* sp.) on *D. stocksii* where >60% of the new growing shoots were damage by the weevils. Harvested culms are susceptible to *barad* (Powderpost beetle) and *bhunga* (Ghoon borer), where the later causes 90% of the total insect damage to the harvested poles (Viswanath et al. 2012).

Vertebrate-pests management

Bamboo is one of the highly damaged (or preferred) crops by the wild life. Unfortunately, bamboo crop is not included in the crop compensation scheme of the Government of Maharashtra. The wild animals causing significant damage in bamboo plantations include common Langur (*Semnopithecus entellus*), Wild boar (*Sus scrofa*), Gaur (*Bos gaurus*), Indian crested porcupine (*Hystrix indica*), Sambar deer (*Rusa unicolor*) and the Asian elephant (*Elephas maximus*). Growing shoots in the monsoon are always at high risk of being eaten or damaged by the above wild animals. Langurs, deer and gaurs prefer the tender fraction of young growing shoots, although sometimes they just adore to destroying them. Wild boars and porcupines excavate the earth around the clump especially during monsoon in search of new emerging shoots. Leaves, tender branches and immature culms are the true delicacy for Asian elephants.

Farmers are following various crop protection measures against wildlife. The dead and decaying fish-waste is tied in a clump which acts as a repellent for langurs, but it may lures wild bores and/or porcupines. Thus it is used in areas where langurs are the only problem animals. Human hairs are brought from barber's shop and broadcasted along the periphery of the clump which was always found to be effective against wild bores. Baited explosives are also sometimes kept under clumps if there is intensive damage. Besides wildlife, stray cattle may cause severe damage to newly established bamboo plantations. Thus thorny branches of Karvand *Carissa congesta* are used to encircle the clumps.

Farmers from Dodamrg taluka are using a simple measure of crop protection against gaurs. A single aluminium string tied around the bamboo plantation at around 50cm height above the ground. It has no electric current passing through or any olfactory or any other repellents smeared over. A farmer (Mr. Zila Patyekar, Zare village) was

using this technique since last five years. He said that though being the largest and the strongest Bovide on the earth, gaurs are always suspicious about man-made things in the vicinity and are always afraid to cross or leap over these 'quail-feather' hurdles. Instead of aluminium string, farmers from Bhadgaon village were using long vertically split bamboo slivers (>5m in length) with sharp edges, and found to be successful. Firing blank cartridges in the air is very effective; however, results may vary with different locale. Two farmers from Mangeli village were using innovative and modern techniques for crop protection e.g. small pouches of phorate 10% CG were tied at the base of clump to ward off wild boars. Sometimes two to four naphthalene balls were observed under a clump as an effective repellent for porcupines. Interestingly farmers observed that emerging shoots damaged by wild boars do not die and are always sprout again but with smaller diameter. Culms damaged at around 50cm or above can also be used as offsets planting in the following rainy season. All the respondents underlined the importance of crop guarding (physical surveillance) during June to August. Yet it could be effectively managed since farmers are already occupied in the paddy cultivation during same period.

Farmers said that though wildlife crop damage is an age-old conundrum, it increased by multifold since 1990s. Now there are little or no food resources inside the forests available for wild herbivores due to invasion of exotic alien plants like Ghaneri (*Lantana camara*) and Ranmodi (*Eupatorium odoratum*). A strong allelopathic effect and the resultant proliferation of these two species significantly depleted most of the ground cover (space) available to the local grass species and other native herbs and shrubs including regeneration classes of native tree species (Sundaram et al. 2012, Ramaswami & Sukumar 2013). For example in BRT Wildlife Sanctuary, Karnataka there is very little grass and bamboo left now. Many animals are in an unhealthy condition and resort to crop-raiding to augment their diet (Sundaram et al., 2012). As wild herbivores are so fond of bamboo, farmers also suggested planting bamboo inside the forests exclusively as a food for wildlife.

Harvesting

Successful establishment of newly planted offsets is marked when it produces new culms having diameter and height equal to or more than the culms in a parent clump. Such clumps can produce 10-20 culms/clump/year, 5th year onwards. One year old culm is referred as immature, whereas culm having age of more than two years is mature. Farmers preferably harvest mature culms at two to three years of felling cycle. Mature culms are harvested below the first node to avoid profuse branching from the stump during following monsoon. All the mature culms get harvested whereas immature and current year culms are preferably retained. Mature culms could be harvested throughout a year; however a peak period of harvesting is November-April. Most of the farmers (72%) do not allow the 'cut' during monsoon as it is the growing period for bamboo. Harvesting operations during this period may cause damage to the

new emerging shoots. Moreover the immature culms get pendulous in appearance due to lack of lateral support.

Harvesting is correlated with the low tidal events and lunar phases. Farmers stated that these two factors significantly regulate sap flow in the culms. Lower the sap flow, culms will be less susceptible to the insect-pest attack and ultimately will be more durable. Harvesting of mature culms during rainy season also significantly reduces its susceptibility to powder post beetle. Kumar et al. (1994) reported that amount of soluble sugars principally varies with season and the age of culm. More concentration of sugar attracts borers and other insect-pests. Thus felling of culms at low concentration level of carbohydrates e.g. harvesting during post monsoon period (August-December) or harvesting of mature culms (3-4 years old) is recommended.

Post-harvest management

Branches and other post-harvest residue are collected at the base of clump after harvesting. It serves two important functions viz. protection to new emerging shoots from wild herbivores during rainy season and conservation of moisture in the dry season. Sometimes an open space of 2-4 are (in ha) is kept adjoining the plantation site as a collection and disposal site of the post-harvest residue. Well-established bamboo plantations prohibit the invasion of other plant species; hence it does not require any additional intercultural operations like weeding, climber cutting etc.

Preservation

Vertically split bamboo culms are used for construction of roof (*kadani*). For this, the two long tiles are kept submerged in water for 6 to 10 weeks. This practice enhances its life up to 20 years, provided that roof should having the desired gradient. Outdoor-use baskets and containers made up of bamboo strips (*bela*) are treated with cow or buffalo urine and dung slurry. Kumar et al. (1994) mentioned a traditional method of water soaking of harvested bamboo poles for 4-12 weeks where most of the sugars get leached out and the pole becomes less susceptible to the insect-pest. Seethalakshmi and Kumar (1998) similarly reported that soaking of freshly harvested poles in muddy pond for 1-8 weeks which significantly reduced the attack of insects in *Bambusa balcooa*, *B. bambos*, *B. tulda*, *Dendrocalamus giganteus* and *D. strictus*.

Utilization

D. stocksii is traditionally being used for making *Soop* or *Soopli* (winnowing fan), *Topli* (small basket), *Zap* or *Dalgya* (large baskets used for collection of dried leaves), *Rovli* (container having square base and rounded top), *Pushpa paradi* or *Fuladani* (flowerpot), *Hat Pankha* (hand fans), *Daali* (sleeping/seating mat), *Kanagi* (large, round bottom bins, 3-4ft height for grain storage), *Sathi* or *Tato* (large cylindrical bins, 5-6ft height for grain storage) etc. The above different bamboo artifacts are collectively termed as *Aidan*. For this, medium sized, one or two year old culms with

long and hollow internodes are preferred. Black and dark pink colour combinations are used to decorate the above artifacts. The colours are extracted from the roots of *Bondagi* plant (*Pandamus* sp.).

The species is also use for manufacturing *Paalna* (baby cradle), *Saanshi* (a purse like structure for putting child medicines), *Aakash Kandil* (sky lantern), *Patanga* (kite), *Murali* (flute), walking sticks, construction of *Irla* (a water proof hood use in the fields during paddy cultivation), *Khatari* (bullock carts), *Machan* (traditional watch towers), *Padvi* or *Khop* (temporary farm shelters), *Shidi* or *Nishan* (ladder), *Gavaani* (a part of cattle shade), *Pan* and *Karando* (temporary poultry screens) etc. Long poles of *D. stocksii* are used as oars to row the country boats. Slivers are used for making traditional fishing gears e.g. *Khoon* (V shaped conical trap for capturing crabs or fishes), *Domya* (a typical fishing trap) etc. Slender and flexible culms (1-1.5cm diameter) are used for making *Gari* (fishing rod).

Poles are used as handle of *Jaate* (traditional grinding mill made up of stone), making *Tatki* (a typically weaved gate), *Akhanda* (gate with 3 or 5 long bamboo poles), *Vay* or *Aado* (compound or fencing), construction of *Matav* (pendol-like structure in the summer). Dried coconut leaves called *Saple* (raw leaf) and *kadan* (an aesthetically weaved coconut leaf) are tied in between vertically split poles to make *Kood* or *Koodawal* (curtain like structure) and *Zadi* (an extended lid of the roof). These structures protect earthen walls of houses in the heavy rains.

Solid culms are used for making handle of several agricultural implements e.g. spade, pickaxe, garden rake etc. It is used to support/prop grape vines, banana, tomato, clustered apple etc. Upper noncommercial portion of culm is used to stake climbing vegetables like Karali (*Momordica charantia*), Wal (*Vigna unguiculata*), Dodaki (*Luffa acutangula*), Dudhi (*Lagenaria siceraria*), Padawal (*Trichosanthes cucumerina*), Kakdi (*Cucumis sativus*) etc. Today, villagers in Sindhudurg are using *D. stocksii* culms for the construction of biogas domes (See: (http://www.youtube.com/watch?v=STkOgy4sdkw).

Bamboo leaves are sometimes used as fodder for cattle during the dry season. However it should strictly avoided during the pregnancy period since consumption of larger quantity of bamboo fodder may cause abortion. Bamboo leaves are typically feed after parturition to remove the *war*. Young shoots of *D. stocksii* are safe for the human consumption (Chandramouli et al. 2014), By anticipating the future market prize of mature culms, they are seldom cooked in the village kitchens. Here, shoots of Kalak bamboo (*Bambusa bambos*) are commonly used for consumption purpose.

Sociocultural values

Besides numerous uses and applications, *D. stocksii* has a strong socio-cultural bond with the local society. It is used in various religious functions. *Vasa* or *Vaushe* is a post marriage function, performed during *Gauri pooja* in the *Ganesh Chaturthi* (the

festival of Hindu God Ganesha) where different *Aidan* are used to serve the god for well-being and prosperity of the family. Various ritual customs are performed at fifth day of child birth called *Pachavi pooja*. Here, small *Dhanushya* (bow) is prepared using small slivers of *D. stocksii* as a symbol of courage. *Upanayana* or *Munj* is a ritualistic ceremony where a *Batu* (boy) invests with *Janhave* (sacred thread) by holding a bamboo staff in his right hand. Here the bamboo staff (diameter 3cm and height 1.4m) is known as *Dand* (a self-defense weapon). *Zadu* (broom) typically made from *D. stocksii* is used during *Grihapravesha* (ceremony of entry in a new home). *Gudhi padava* is celebrated on *Chaitra Shukla Pratipada* as the beginning of Hindu New Year. *Gudhi* representing the flag of God Brahma, hoisted on a long pole of *D. stocksii* as a symbol of victory of good over evil. Moreover, the poles are also used in Hindu cremation ceremony. After the death, corpse is placed on *Tiradi* (ladder-like structure) prepared from the solid poles of *D. stocksii*, which is then borne up to the cremation-ground.

CONCLUSION

Bamboo serves numerous socioeconomic, sociocultural and ecosystem services to the world. It is thus important to record indigenous farming practices and location-specific sociocultural values for its conservation and improvement. Unlike other bamboo farming systems described elsewhere, the present system has many unique features. *D. stocksii* is one such endemic bamboo species whose germplasm is exclusively conserved by the farmers. Their vision of preserving large trees in bamboo plantations has modern-day conservation value which also gratifies their supplementary needs. Farmers' observations on flowering behaviour and its correlation with length and internodal solidness, the rejuvenation techniques of flowered clumps, significance and effect of fire on life history of bamboo, the traditional low coast preservation methods of harvested poles etc. highlighted new research avenues in tropical sympodial Bambusoidae. Moreover, the effective use of animal specific indigenous crop protection measures showing acquaintance of the society with deep seated natural history and provides new insights towards human-wildlife coexistence. Their knowledge of harvesting bamboo poles based on lunar calendar and how it regulates the sap flow in plant was really astonishing. Certainly the traditional aspects of *D. stocksii* cultivation could be entitled as the sustainable bamboo based agroforestry system; nevertheless each of its aspect requires further comprehensive evaluation and quantitative assessment.

ACKNOWLEDGEMENT

I thank Dr. Ajay Rane (Professor), College of Forestry, Dapoli, Maharashtra and Dr. Syam Viswanath (Scientist-F), IWST, Bangaluru, Karnataka for encouragements. I thank bamboo farmers in Sindhudurg for sharing their experiences and knowledge.

REFERENCES

Anon. 2014. Culm cutting technique for mass multiplication of Managa bamboo (*Dendrocalamus Stocksii*). Technology recommended by Dr. B. S. Konkan Krishi Vidyapeeth (Agricultural University), Dapoli at Joint Agresco-2014, Maharashta, India.

Beena, V. B., 2011. Reproductive biology and biochemical changes associated with flowering of *Dendrocalamus stocksii* and *Ochlandra travancorica*. Ph.D. Thesis, Cochin University of Science and Technology, Kerala, India.

Chandramouli, S., Viswanath, S. and Nidoni, U., 2014. Potential for exploitation of *Dendrocalamus stocksii* (Munro) shoots: New report from Peninsular India. *Tropical Plant Research*, 1:89–91.

David, W., Widianingsih, N. N., Kasim, A. and Ploeger, A., 2012. Role of indigenous knowledge in traditional farming system on natural resources management, 2nd International Conference on Biodiversity. doi: 10.13140/RG.2.1.5 119.6960

Dhavala, A., Muyeed, A. S. and Viswanath, S., 2015. Morphological and genetic diversity analysis in a germplasm bank of *Dendrocalamus stocksii* (Munro) - Implications on conservation. *International Journal of Molecular Ecology and Conservation*, 5:1–8. doi:10.5376/ijmec.2015.05.0003.

Koshy, K. C. and Pushpangadan, P., 1997. *Bambusa vulgaris* blooms, a leap towards extinction. *Current Science*, 72:623–624.

Kumar, M. S. M., 2009. Revisionary studies on four genera of Indian bamboos. KFRI Research Report No. 330, Peechi, Kerala, India.

Kumar, M. S. M., 2011. Bamboos of Peninsular India (Part-II). KFRI Research Report No. 399, Peechi, Kerala, India.

Kumar, M. S. M., Ramesh, M. N. and Unnikrishnan, N., 2004. A new combination in *Dendrocalamus* (Poaceae: Bambusoideae). SIDA 21:93–96.

Kumar, S., Shukla, K. S., Dev, T. and Dobriyal, P. B., 1994. Bamboo preservation techniques: a review. published jointly by INBAR, China and ICFRE, India.

Mera, F. A. T., Xu, C., 2014. Plantation management and bamboo resource economics in china. *Ciencia Y Tecnología*, 7:1–12.

Nath, A. J., Das, M. C. and Das, A. K., 2014. Gregarious flowering in woody bamboos: does it mean end of life? *Current Science*, 106:12–13.

Patil, M. D., Indulkar, S. R., Patil, V. K. and Rane, A. D., 2016a. Bamboo especially *Dendrocalamus stocksii* as a potential climate change mitigation resource in Konkan region of Maharashtra. In Kinhal, G. A., Dharni, A. K., Upadhyay, A. P. and Dugaya, D., (Eds), Climate Change Combating Through Science and Technology, M/S Bishen Singh Mahendra Pal Singh, Dehradun. pp. 141-153.

Patil, M. D., Rane, A. D., Mehendale, S. K. and Narkhede, S. S., 2016b. Bamboo weevil *Cyrtotrachelus* sp. (Coleoptera: Curculionidae): A new insect pest on

Managa bamboo *Dendrocalamus stocksii* (Munro), Ratnagiri District, Maharashtra. In National Seminar on Bamboo Reserve Management and Advances in Utilization Options at IWST, Bengaluru, India p. 40.

Ramanayake, S. M. S. D., 2006. Flowering in bamboo: an enigma! *Ceylon Journal of Science (Biological Sciences)*, 35:95–105.

Ramaswami, G. and Sukumar, R., 2013. Long-term environmental correlates of invasion by *Lantana camara* (Verbenaceae) in a seasonally dry tropical forest. PLoS ONE 8:e76995. doi: 10.1371/journal.pone.0076995

Rane, A. D., 2015. Morphological, physiological and genetic variation in *Dendrocalamus stocksii* (Munro) M. Kumar, Ramesh and Unnikrishnan along the central Western Ghats. PhD thesis, Forest Research Institute (deemed) University, Dehara Dun, Uttarakhand.

Rane, A. D., Chandramouli, S. and Viswanath, S. 2013 Diversity of the solid bamboo *Dendroclamus stocksii* along the Central Western Ghats of India. In International Conference on Biodiversity 2013 (online) at Malabe, Sri Lanka pp. 20–27.

Rane, A. D., Chandramouli, S. and Viswanath, S., 2014 Culm emergence and soil properties in *Dendrocalamus stocksii* under different landuse systems in central Western Ghats. *Journal of Tree Sciences*, 33:48–52.

Rao, R. V., Gairola, S. C., Shashikala, S. and Sethy, A. K., 2008. Bamboo utilization in southern India. Indian Forester, 134:379–386.

Sanjaya, Rathore, T. S. and Ravishankar Rai, V., 2005. Micropropagation of *Pseudoxytenanthera stocksii* Munro. *In Vitro Cellular and Developmental Biology - Plant*, 41: 333–337. doi:10.1079/IVP2004625

Seethalakshmi, K. K. and Kumar, M. S. M., 1998. Bamboos of India: a compendium, Technical Report No. 17, jointly published by INBAR, China and KFRI, India.

Sundaram, B., Krishnan, S., Hiremath, A. J. and Joseph G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in south India: perspectives from local knowledge. *Human Ecology*, 40:931-42. doi: 10.1007/s10745-012-9532-1

Viswanath. S., Joshi, G., Somashekar, P. V., Rane, A. D., Chandramouli, S. and Joshi, S.C., 2012. *Dendrocalamus stocksii* (Munro): A potential multipurpose bamboo species for Peninsular India. Technical Bulletin No.10, IWST, Bangalore, India.

Yeasmin L., Ali M. N., Gantait S. and Chakraborty S., 2015. Bamboo: an overview on its genetic diversity and characterization. *3 Biotech*, 5:1–11. doi: 10.1007/s 13205-014-0201-5