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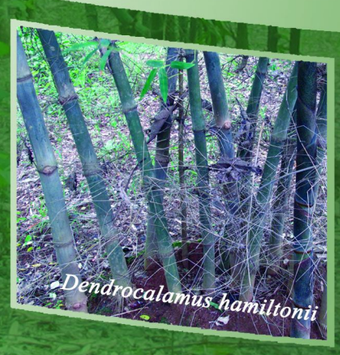

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(An Institution of Kerala State Council for Science, Technology and Environment)
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Abstract of the project proposal

Project Code	KFRI 494/05
Title	Multilocational field trials for selected bamboo species in Kerala
Objective	1. Multilocational species trials: Performance of eight species viz. *Bambusa bambos* , *B. tulda*, *B. nutans*, *B. balcooa*, *Dendrocalamus hamiltonii*, *D. asper*, *Guadua angustifolia* and *Ochlandra travancorica* 2. Spacing trials: Effect of different spacing on growth and performance of *Ochlandra travancorica* 3. Bamboo-based cropping systems: Intercropping in *Bambusa bambos* plots 4. Clump management: Adoption of different practices for management of congested *Bambusa bambos* clumps.
Principal Investigator	V. P. Raveendran
Associate	K. K. Seethalakshmi and K. K. Unni
Duration	Five years (2005-2010)
Funded by	National Mission on Bamboo Applications (NMBA)

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ABSTRACT

The bamboo multilocational trials in Kerala under NMBA were undertaken by KFRI in the private farm land and Government non-forest lands in Palakkad district. The details of the trials carried out were: 1. Multilocational species trial: Performance of eight species, viz., *Bambusa bambos , B. tulda, B. nutans, B. balcooa, Dendrocalamus hamiltonii, D. asper, Guadua angustifolia* and *Ochlandra travancorica.* 2. Spacing trials: Effect of different spacing on growth and performance of *Ochlandra travancorica* 3. Bamboo-based cropping systems: Intercropping in *Bambusa bambos* plots 4. Clump management: Adoption of different practices for management of congested *Bambusa bambos* clumps. Plantations were raised in an area of 2.97 ha at different locations in Palakkad district Multilocational species trials: 9600 sq. m. at Vilayannur, Spacing trials: 11463 sq. m. at Dhoni, Bamboo-based cropping systems: 3888 sq. m. at Kinassery and Clump management: 4725 sq. m. at Nellikkad. Observations were recorded at six monthly intervals for a period of four years. When the performance of three different types of planting stock was compared, rooted cuttings (*B. balcooa, B. nutans* and *D. hamiltonii*) performed better than seedlings and TC plants. The highest biomass per culm was observed in *B. balcooa*. From the observations made for three years on spacing trial of *O. travancoria,* it is clear that the seedlings planted at 9m x 4.5m x 4.5 m and 5m x 5 m produced the highest number of culms and thereby the maximum yield. The intercropping with *B. bambos* was found to be promising in the initial years. The clump management plots are ready for initiating the management activities and further studies are required for arriving at more meaningful conclusions.

INTRODUCTION

Bamboo stands occupy an area of 36 million hectares worldwide which is equivalent to 3.2 percent of the total forest area in the world. According to the FAO/INBAR global thematic study, over 63 percentage of bamboo resources are privately owned and the remaining 36 percentage bamboo plantations are owned by Governmental entities. In comparison 80 percentage of all world forests are public owned. In Asia, India is the major bamboo producing country (almost 11.4 million hectares) which accounts for roughly half the total area of bamboo reported for Asia. There are different reports on the number of genera and species of bamboo found in India. As per the latest compilation, 18 genera and 128 species were reported (Seethalakshmi and Kumar, 1998). Of the total species found in India, about 20 are commercially used. Kerala is one among the major diversity centres of bamboo in the country and 22 species of bamboos under seven genera have been recorded from this region. The total standing crop of bamboo in homesteads was estimated as 13.61 million culms and its green weight was estimated to be 0.331 million tonnes during 2004-2005 (Muraleedharan *et al.*, 2007), whereas the bamboo resource in the forest areas was estimated as 2.63 million tonnes based on the satellite imagery taken in 1997.

The most serious issue concerning bamboo entrepreneurs and industries is the sustainable supply of raw material. Bamboo has been exploited in the past without scientific management. For enhancing the resources, no concerted efforts were made for cultivation. To meet the ever-increasing demands, large-scale plantations with traditional high-yielding species and clones should be introduced. With this objective several projects supported by IDRC (1987), DCH & UNDP (2000), have been implemented. The efforts are now concentrated on the replenishment of the bamboo resources with the establishment of two bamboo missions by Government of India viz., National Mission on Bamboo Applications (NMBA) and the National Bamboo Mission (NBM) under Ministry of Science and Technology and Ministry of Agriculture and Co-operation respectively. The National Mission on Bamboo Applications, structured as a Technology Mission, is one of the first initiatives of Government of India under Department of Science & Technology for the Tenth Five Year Plan.

The NMBA has been given the task of creating the basis for improvement of the bamboo sector and supporting the efforts of the Government of India towards augmenting economic opportunity, income and employment.

While making an effort to prepare the Package of Practices (POP) for the 16 priority species to be taken for cultivation in India, NMBA observed that species-specific data is lacking except for a few like *Bambusa bambos* and *Dendrocalamus strictus.* A network project covering all the three zones (North, South and East) of the country was developed during the Round Table Meeting held at GB Pant University of Agriculture & Technology, Pantnagar. For the plantation trials, six species were selected (*Bambusa balcooa, B. bambos, B. tulda, B. nutans, Dendrocalamus hamiltonii,* and *D. asper)* and the collaborating institute was permitted to add two species of local importance. Totally 13 organizations collaborated with the project. Six partners from North (1. AFRI, Jodhpur 2. Allahabad Agricultural Institute, Allahabad 3. Bamboo Centre, GB Pant University of Agriculture & Technology, Pantnagar, 4. Institute of Himalayan Bioresource Technology (IHBT), Palampur, 5. Merino Century Laminating Co. Ltd., Hapur and 6. National Botanical Research Institute (NBRI), Lucknow), five partners from South (1. Kerala Forest Research Institute (KFRI), Kerala. 2. Growers, Salem. 3. Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore. 4. Institute of Wood Science and Technology (IWST), Bangalore. 5. Jain Irrigation Systems Ltd., Maharashtra.) and two partners from East (1. Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani. 2. Uttar Banga Krishi Viswavidyalaya, Koch Behar) participated.

As one of the collaborating centers, KFRI agreed to implement four components of this mega project, viz.,

1. Multilocational species trials: Performance of eight species viz. *Bambusa bambos , B. tulda, B. nutans, B. balcooa, Dendrocalamus hamiltonii, D. asper, Guadua angustifolia* and *Ochlandra travancorica*
2. Spacing trials: Effect of different spacing on growth and performance of *Ochlandra travancorica*

3. Bamboo-based cropping systems: Intercropping in *Bambusa bambos* plots
4. Clump management: Adoption of different practices for management of congested *Bambusa bambos* clumps.

To carry out the above trials a project entitled 'Multilocational field trials of selected bamboo species of Kerala' was initiated in 2005. Plantations were raised in an area of 2.97 ha at different locations in Palakkad district (Multilocational species trials: 9600 m^2 at Vilayannur, Spacing trials: 11463 m^2 at Dhoni, Bamboo-based cropping systems: 3888 m^2 at Kinassery and Clump management: 4725 m^2 at Nellikkad). Observations were recorded at six monthly intervals for a period of four years on culm height, culm girth, number of culms, number of internodes and internodal length.

MATERIALS AND METHODS

Materials

The species selected for the present investigation were *Bambusa balcooa, B. bambos, B. nutans, B. tulda, Dendrocalamus asper, D. hamiltonii, Guadua angustifolia* and *Ochlandra travancorica.* Brief descriptions about the eight species are given below.

***Bambusa balcooa* Roxb:** *B. balcooa* is a tall clumping bamboo forming distinct tufts, groups or clumps. The culms are 20–24 m long, 8–15 cm in diameter, thick walled (2–2.5 cm), nodes prominent with white ring above the node and internodes 30–45 cm long (Fig. 1.1). It is indigenous to the North-east India, Bihar, Jharkand, Uttaranchal, West Bengal and Bangladesh. It is cultivated in villages of different states in India and is introduced to Kerala owing to its non-thorny nature and strength properties. The most common use of this sturdy and strong bamboo is in construction, thatching, walling, roofing, handicrafts and for making novelty items. It is a good bamboo for scaffolding, making ladders and also for pulp, paper, rayon and agarbathi sticks. Shoots are edible.

***Bambusa bambos* Voss:** A very densely tufted bamboo, producing large dense clumps of closely packed culms. The culms are strong, green coloured, grow up to 30 m in height and 18-25 cm in diameter (Fig. 1. 2). Walls are 3 cm thick at the base. Branching is observed at all the nodes, central dominant branch being produced first, with one or two laterals. Branches bear spines. This species is widely distributed in moist deciduous forests, occupying 15 per cent of bamboo area of India and one of the most common species in homesteads in Southern India. It prefers rich, moist, alluvial soil and grows along perennial rivers and valleys up to an altitude of 1000 m receiving a rainfall of 2000 to 2500 mm. *B. bambos* is highly productive with strong rhizome.

There are several uses which include pulp and panel production, handicrafts, scaffolding, thatching, roofing, baskets, mats, bows and arrows, furniture, floating timber and rafting, cooking utensils, fencing, fodder, medicine, etc. Young shoots are edible. The most common use of this sturdy and strong bamboo is in construction, thatching, walling, roofing, and making handicrafts and novelty items. It is a good bamboo for scaffolding and ladders and also used for pulp, paper, rayon and agarbathi sticks. Vitamins and minerals are extracted from leaves and rhizome. Leaves and stems are used in ayurvedic system of medicine as a blood purifier, in treatment of leucoderma and inflammatory conditions. The burned root of this species is applied for controlling Ringworm, for treating bleeding gums and joint pains.

Bambusa nutans* Wall. ex. Munro:* A medium-sized bamboo with culms reaching a height of 6 to 15 m with a diameter of 5-10 cm and an internode length of 25-45 cm (Fig. 1. 3). It is a loose, clump-forming species, usually unbranched below and branched above, culms straight, green and smooth, not shining, white-ringed below the nodes, node slightly thickened often hairy and lower nodes bear rootlets. *B. nutans* naturally occurs in Sub-Himalayan region from Yamuna eastwards to Arunachal Pradesh and is common in the Brahmaputra valley. It is commonly cultivated in North-west India, especially in and around Dehra Dun, and in Orissa and West Bengal. It grows in moist hill slopes and flat uplands in well-drained sandy loam to clayey loam at an elevation between 600 and 1500 m. It is a graceful bamboo worth growing as ornamental and one among the six species commonly used in Indian paper industry. It is commonly used in structural and construction application and also used for thatching, walling, roofing, handicrafts and novelty items. It is also used to make agricultural implements and big size containers for storing food grains.

***Bambusa tulda* Roxb:** This species is an evergreen or deciduous, tufted and gregarious bamboo. Culms reach a height of 7-23m, internodal length of 40-70 cm and diameter of 5-10cm (Fig. 1. 4). The large, straight, thick-walled culm makes it one of the most useful bamboos. In India, it is found naturally in the states of Assam,

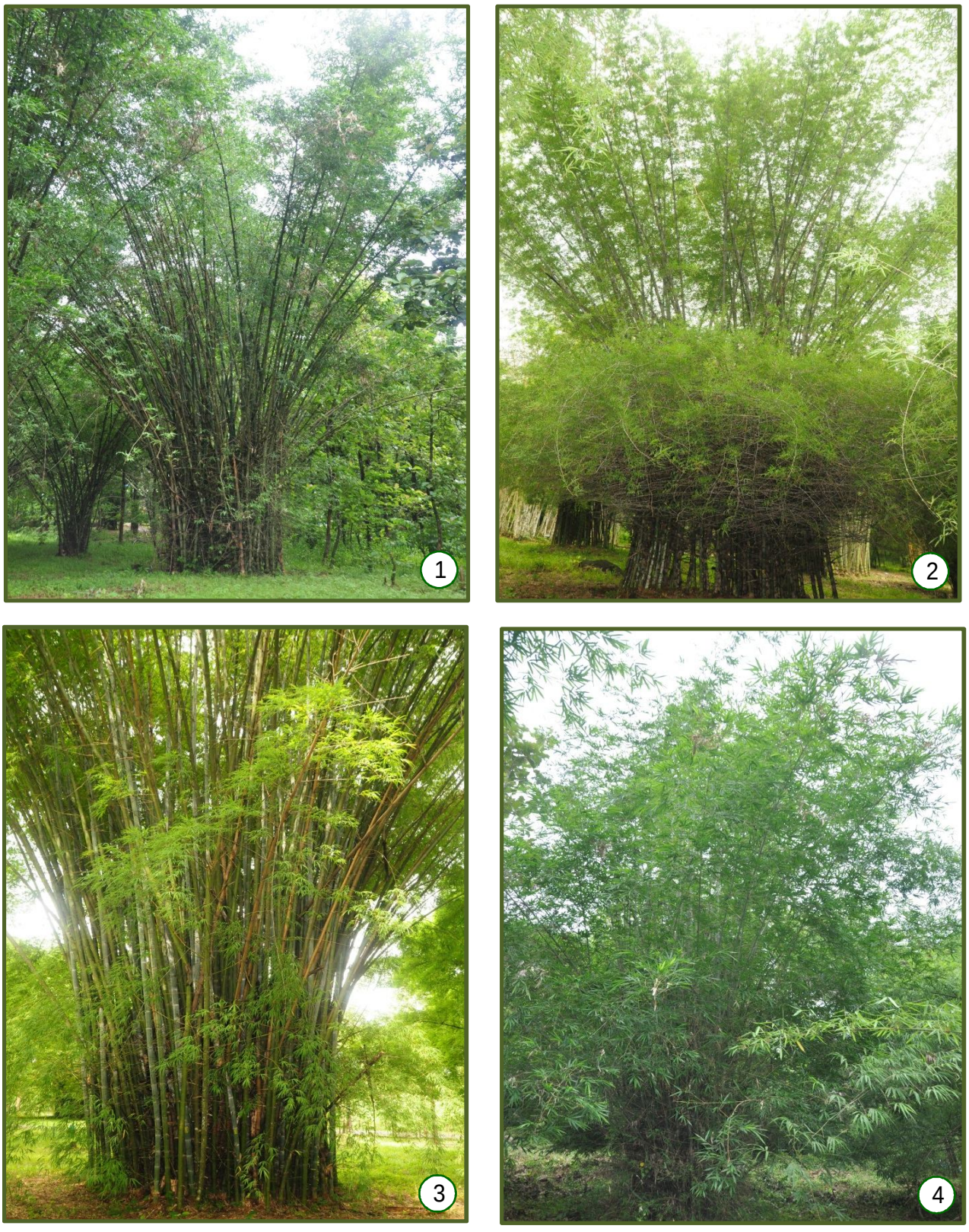

Fig. 1. 1. Habit of *B.balcooa* , 2. Habit of *B. bamboos,* 3. Habit of *B. nutans* and 4. Habit of *B. tulda*

Bihar, Meghalaya, Mizoram, Nagaland and Tripura and cultivated in Arunachal Pradesh, Uttar Pradesh, Karnataka and Bengal. The species is extensively grown in low hills of Central Assam. The species also occurs in Bangladesh, Myanmar and Thailand. It is used throughout North-east India for thatching and scaffolding. The tender shoots are used for making pickles. It is suitable for the manufacture of wrapping, writing and printing paper. It is used in Tripura for making toys, mats, screens, wall plates, wall hangers, hats, baskets, food grain containers, etc. It has long been exported to Europe and the United States of America under the names 'Calcutta cane' or 'East India Brown Bamboo'. This is one of the five quick-growing species of bamboos preferred for raising plantations in India. It can also be used as reinforcement in cement concrete.

***Dendrocalamus asper* Backer**: It is one of the giant bamboo species from Indonesia. It reaches between 25 to 30 m in height with 25 to 30 cm in girth of culms (Fig. 2. 1). It grows at high altitudes and also able to withstand frost. This fast growing species is cultivated in many parts of South-east Asia for its excellent quality edible shoots and construction and craft. The large culms are also used as outriggers on fishing boats and percussion instruments. Two varieties are available: one is Javanese and other one is the smaller Thai shoot variety. The internodes are black and the nodes have a white band. It is highly valued in Java. There is paucity of information related to cultivation and productivity aspects under domesticated situation.

***Dendrocalamus hamiltonii* Nees and Arn. Ex Munro:** *D. hamiltonii* is a large clump forming bamboo sometimes growing tall and erect; culms often at an angle or curved downwards. Culms reach a height of 12 to 25 m with an internodal length of 30-50 cm and a diameter of 10 to 18.5 cm (Fig. 2. 2). It is naturally found in North-west Himalayas and North-east India.

It is a multipurpose, fast growing bamboo species with strong culms and is commonly used in the Western Himalayan Region for its leaves as good quality cattle fodder particularly during winter months and holds considerable promise in Central Himalaya also as a green fodder. Moreover, its use in paper production,

house building, making furniture, agricultural implements, mat boards, baskets, handicrafts and numerous traditional uses is well known. Thus, this bamboo has a great potential for hilly regions of the Central Himalaya. The tribals of Arunachal Pradesh use the tender shoot for preparation of '*hiyup*', a sour pickle. Recently, it was observed that the skin of this bamboo was being used in cottage industry for binding and caning of chairs.

***Guadua angustifolia* Kunth:** *G. angustifolia* is a large sympodial bamboo, found naturally in Colombia. The culms are dark green with white bands at nodes with short internodes and thorny branches, attaining a maximum height of 30 m and over 20cm in diameter (Fig. 2. 3)**.** It is one of the most valuable multipurpose bamboos used for scaffolding, as building material, as a source of pulp for paper industry and furniture making. *G. angustifolia* is considered to be outstanding in its physical and mechanical properties as well as durability and hence it is perceived to boost local economy wherever it is grown. It is also one of the fast growing bamboos. Its shoots are edible.

***Ochlandra travancorica* Benth:** It is an erect, shrubby, reed like, gregarious bamboo. Culms reach a height of 2-6 m with an average intermodal length of 45 - 60 cm and sometimes up to 150 cm in ideal growing conditions with a diameter of 2.5-5 cm (Fig. 2. 4). This species is distributed throughout the Western Ghats and is more abundant in South Kerala. It occurs widely as undergrowth in the low level evergreen and semi evergreen forests. Pure patches which grow as impenetrable thickets are also found along the sides of rivers and streams where other tree species are not allowed to come up.

It is an integral part of rural economy. It is an ideal raw material for paper manufacture. Culms are used for mat and basket making, umbrella handles, fishing rods and handicrafts. The mats made out of this species are used for making bamboo plywood. Leaves are used for thatching. Fruits are used as cattle feed.

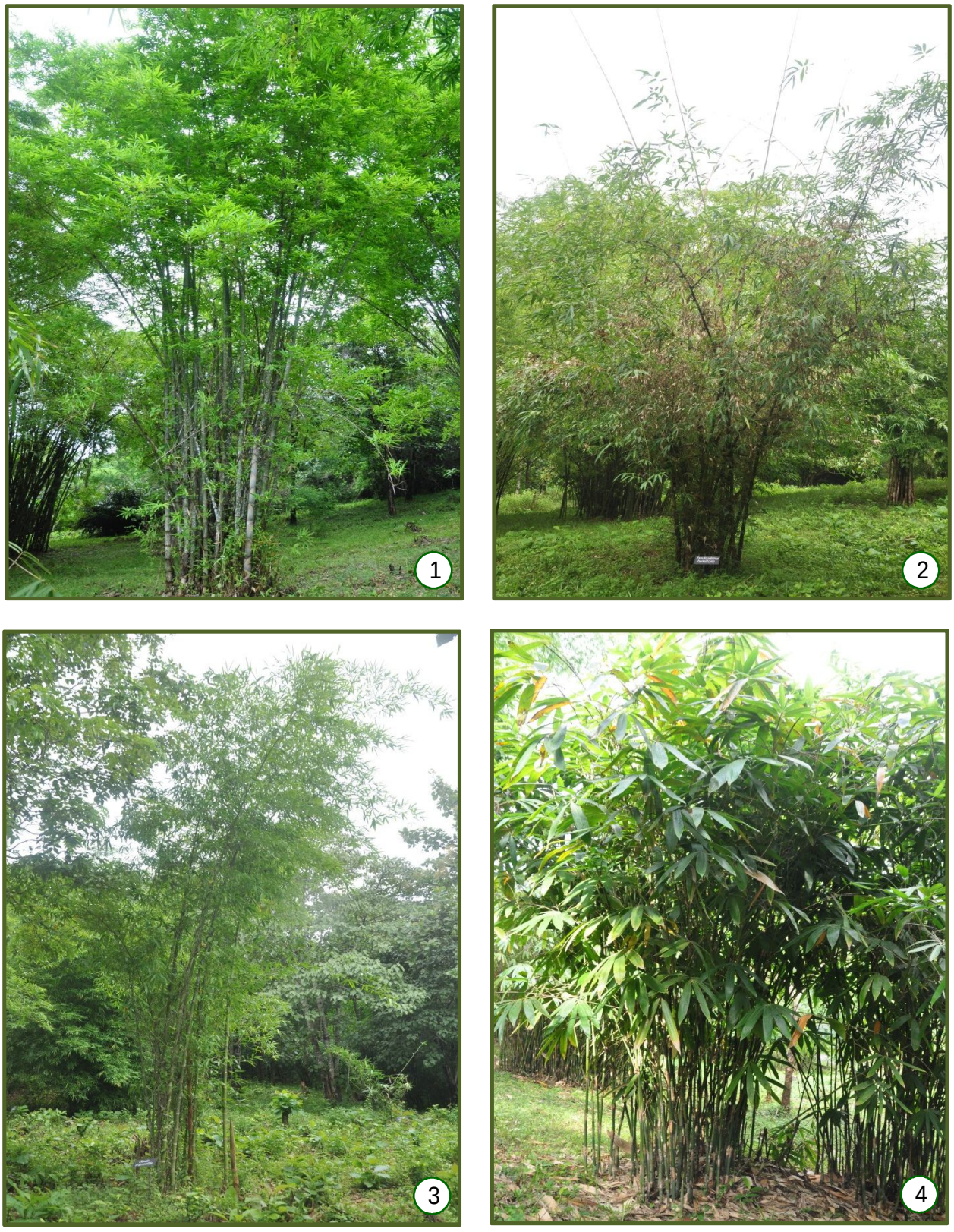

Fig. 2. 1.Habit of *D.asper* , 2. Habit of *D.hamiltonii*, 3. Habit of *G. angustifolia* and 4. Habit of *O. travancorica*

Methods

Four different experiments of the network programme were taken up as KFRI component and they were 1. Multilocational species trials 2. Spacing trials of *O. travancorica* 3. Bamboo-based cropping systems 4. Clump management of *B. bambos.* The type of planting stock used in the study is given in Table 1.

Table 1: Species and type of planting stock used for planting

Sl. No.	Species	Planting material	Source
1.	*Bambusa balcooa*	Rooted Cuttings	KFRI, Peechi
2.	*Bambusa bambos*	Seedlings	KFRI, Peechi
3.	*Bambusa nutans*	Rooted Cuttings	SFRI, Itanagar
4.	*Bambusa tulda*	Seedlings	KFRI, Peechi
5.	*Dendrocalamus asper*	Tissue Culture	TERI, Gurgaon
6.	*Dendrocalamus hamiltonii*	Rooted Cuttings	IHBT, Palampur
7.	*Guadua angustifolia*	Tissue Culture	IWST, Bangalore
8.	*Ochlandra travancorica*	Seedlings	KFRI, Peechi

1. Multilocational species trial

The experiment was conducted at Kollappankad, Vilayannur, Palakkad district using all species arranged in randomized block design in three replicates. The details of experiment are given below.

- No of treatments : 8
- Design: RBD
- No of replications = 3
- No of plants / replications = 16
- Spacing = 5x5m
- Total area = 9600 m^2
- No of clumps for data recording = 4 per treatment

The species trial was initiated during December 2005. Pits of 60 cm^3 were dug and were filled with10 kg FYM + 1kg groundnut cake + 25 g P + 50 g K/plant. The seedlings were irrigated twice a week from December to May for the first two years. Two weeding operations were conducted in the first year and one each in second and third years. Observations on culm height, culm girth, number of culms, number of internodes and intermodal length were recorded after six months of planting and thereafter at every six month interval.

2. Spacing trials of *O. travancorica*

The study was conducted at Dhoni Farm in Palakkad district of Kerala. Seeds were collected from Neriamangalam in Idukki district during May 2005, brought to nursery and germinated on standard nursery beds. Three weeks after germination, the seedlings were polypotted in a medium containing sand, soil and cow dung in the ratio 3:1:1 and kept in the nursery for one year. The seedlings were planted in the field in pits of 45 cm x45 cm x 45 cm during June 2006 and a basal dose of FYM (10 kg), groundnut cake (1 kg), P (25 g) and K (50 g) was given. The different planting densities adopted were 400 (5mx5m), 204 (7mx7 m) 122 (9mx9m), 247 (9mx4.5m), 329 (9mx4.5mx4.5m) and 476 (9mx5mx3 m) plants per hectare. Each treatment was replicated thrice and 16 plants constituted one replication. Two weeding operations were conducted in the first year and one each in second and third years. The growth measurements like culm height, culm girth, number of culms, number of internodes and internodal length were recorded after six months of planting and thereafter at every six month interval.

3. Bamboo-based cropping systems

The experiment was conducted at Kinasseri, Peruvemb, Palakkad district of Keala. The crops integrated with bamboo (*B. bambos*) were ginger, cowpea, banana, coconut, gooseberry, papaya, mango and bael. The layout of the experimental plot is given in Fig 3. (a). The spacing adopted for bamboos was 9 m x 9 m and the pit size was 60 cm X 60 cm X 60 cm. Annual crops like ginger and cowpea were planted in raised beds and banana plants (micropropagated) were planted in the open space

available between the other crops, the pit size was 45 cm X 45 cm X 45 cm. The pit sizes for other perennial plants like gooseberry, papaya, mango and bael were 30cm X 30 cm X 30 cm.

4. Clump management trials

The clump management trials were conducted for *B. bambos* at Nellaikkad, Koyalmandam, Palakkad district. The trial was initiated during December 2005, pits of 60 cm X 60 cm X 60 cm were dug and were filled with 10 kg FYM + 1kg neem cake + 25 g P + 50 g K/plant. The spacing adopted was 5mx5 m; nine plants constituted one plot and 21 such plots were established in three blocks. The seedlings were irrigated twice a week from December to May for the first two years. Two weeding operations were conducted in the first year and one each in second and third year. The growth measurements like culm height, culm girth, number of culms, number of internodes and internodal length were recorded after six months of planting and thereafter at every six month interval. As part of the management programme, to avoid congestion in the clumps, pruning of thorns were carried out during March-April 2009.

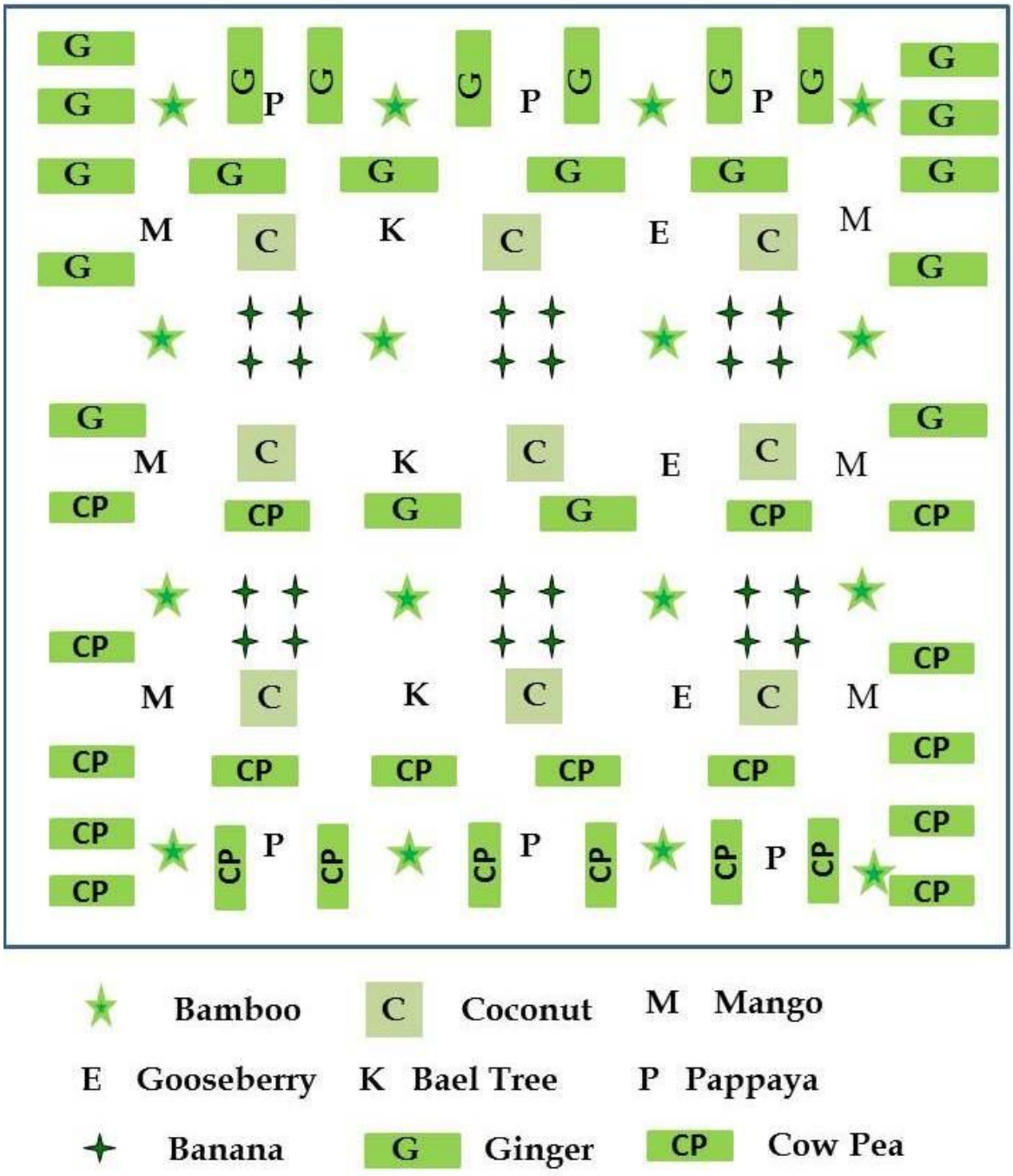

Fig: 3. (a). Layout of the Experimental Plot

Fig. 3. (b). Different view of the bamboo based cropping system

RESULTS

1. Multilocational species trial

The growth attributes of different bamboo species up to 48 months after planting are given in the Tables 2-10. In general, hundred percent survival was observed after 48 months of planting in *B. balcooa* and *B. nutans.* The lowest survival percentage was recorded in *D. hamiltonii*. The highest number of culms were observed in *B. tulda* (11,545 culms per ha) followed by *O. travancorica* (11,337) and *D. asper* (10, 354) and the culm production was the lowest in *D. hamiltonii* (2074). Similarly, the production of new culms was the highest in *B. tulda* (2990 culms per ha) followed by *O. travancorica* (2816) and *D. asper* (2033) after 48 months of planting. The new culm production was the lowest in *D. hamiltonii* (800). Height of the culms was maximum in *B.nutans* (12.42 m) followed by *B. balcooa* (10.92 m) and the lowest height were observed in *G. angustifolia* (3.69 m). Culm girth was the highest in *B. balcooa* (17.7 cm) followed by *D. hamiltonii* (16.8 cm) and *B. nutans* (13.2 cm) and the lowest girth were recorded in *G. angustifolia* (4.5 cm). Highest internodal length was observed in *O. travancorica* (46 cm) followed by *B. nutans* (39 cm) and *B. tulda* (35 cm) and the lowest were in *G. angustifolia* (18 cm). The growth performance of the species (Figs. 4-8), different stages of growth (Figs. 9-16) and growth attributes of each species in the experimental plot is given in detail below.

1. Bambusa balcooa

The growth attributes of *B. balcooa* are presented in the Table 2. The survival of seedlings after sixth months was 96 percent and after casualty replacement was done the survival continued to be cent percent till the end of the observation period. The number of culms per ha increased from 633 to 3931 during the growth period. The emergence of new shoots also increased with age of the clump and after 48 months of planting, 1358 new shoots were produced per ha. The average height, girth and internodal length of *B. balcooa* were 10.92 m, 17.7cm and 25 cm respectively.

Table 2. Growth attributes of *Bambusa balcooa*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	96	633	108	47	2.7	20
12	98	916	375	182	4.1	22
18	100	1316	400	295	7.2	21
24	100	3065	825	495	11.6	23
30	100	2115	367	533	11.7	22
36	100	2865	1083	842	14.7	26
42	100	3315	483	1002	17.1	24
48	100	3931	1358	1092	17.7	25

2. Bambusa bambos

The growth attributes of *B. bambos* are presented in the Table 3. The survival of the seedlings after sixth month was 100 percent till 42 months after planting and after 48 months of planting, it was 98 percent. The number of culms per ha increased from 1808 to 4190 during the growth period. The new shoot emergence also increased with age of the clump and at the end of the observation 858 new shoots were produced per ha. The average height, girth and internodal length of the *B. bambos* culms were 4.48 m, 9.3cm and 19 cm respectively after 48 months of planting.

Table 3. Growth attributes of *Bambusa bambos*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	100	1808	100	69	1.0	15
12	100	2024	541	140	2.5	16
18	100	1816	516	167	3.5	17
24	100	4007	1150	246	5.9	19
30	100	3065	741	266	5.7	17
36	100	3282	800	339	7.7	20
42	100	3907	641	390	8.3	21
48	98	4190	858	448	9.3	19

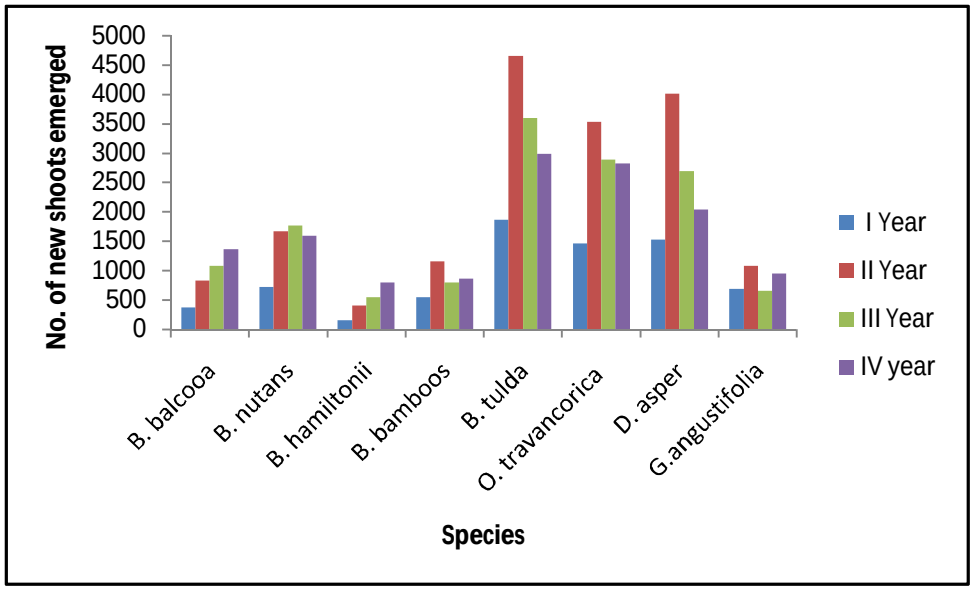

Fig: 4. New shoots emerged per ha. during the years

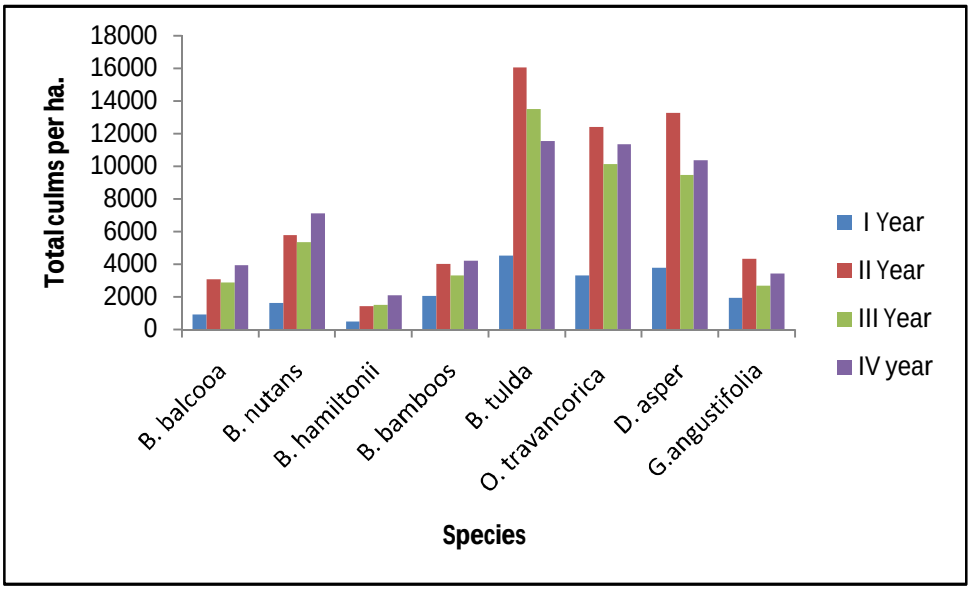

Fig: 5. Total culms produced per ha. during the years

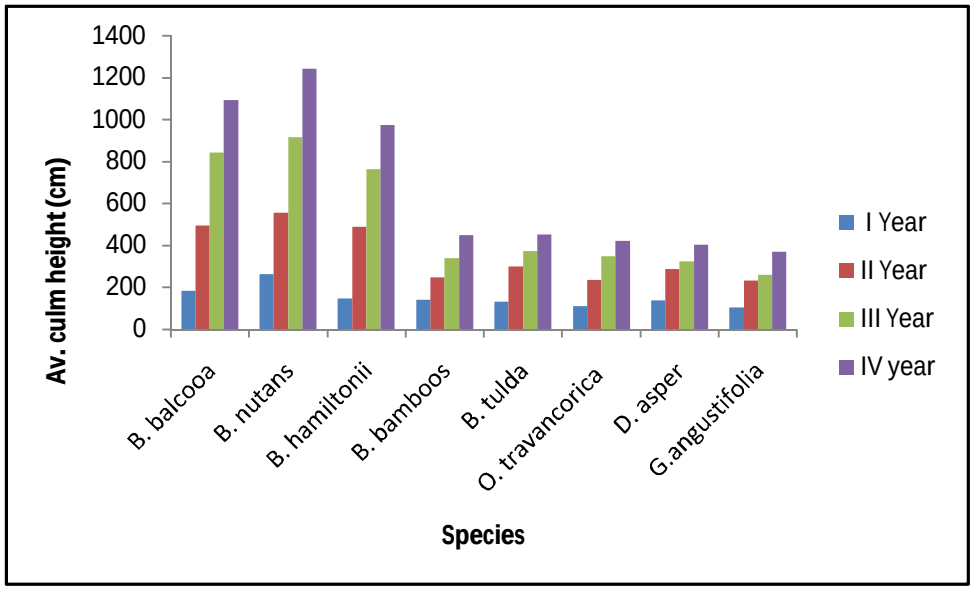

Fig: 6. Average culm height

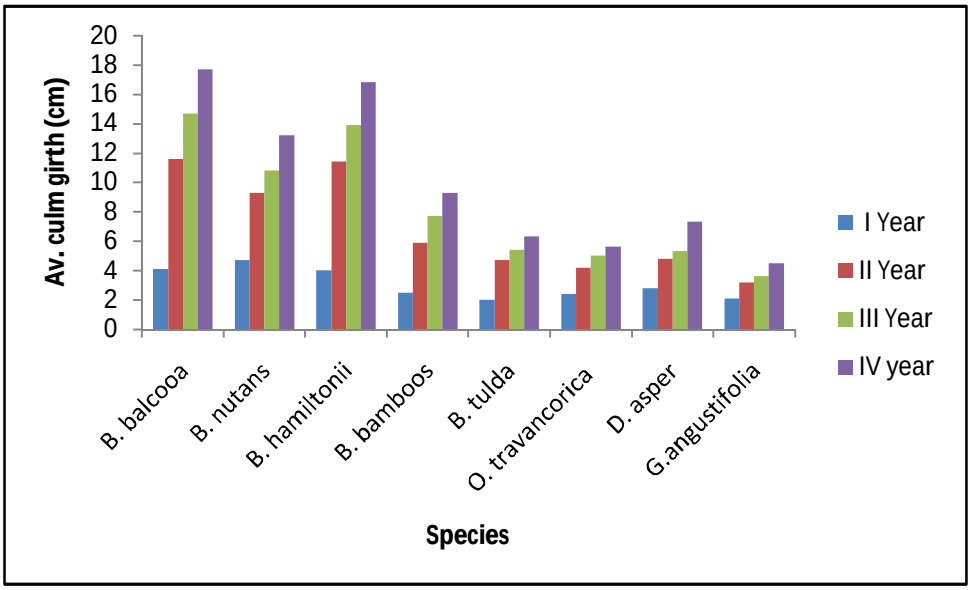

Fig: 7. Average culm girth

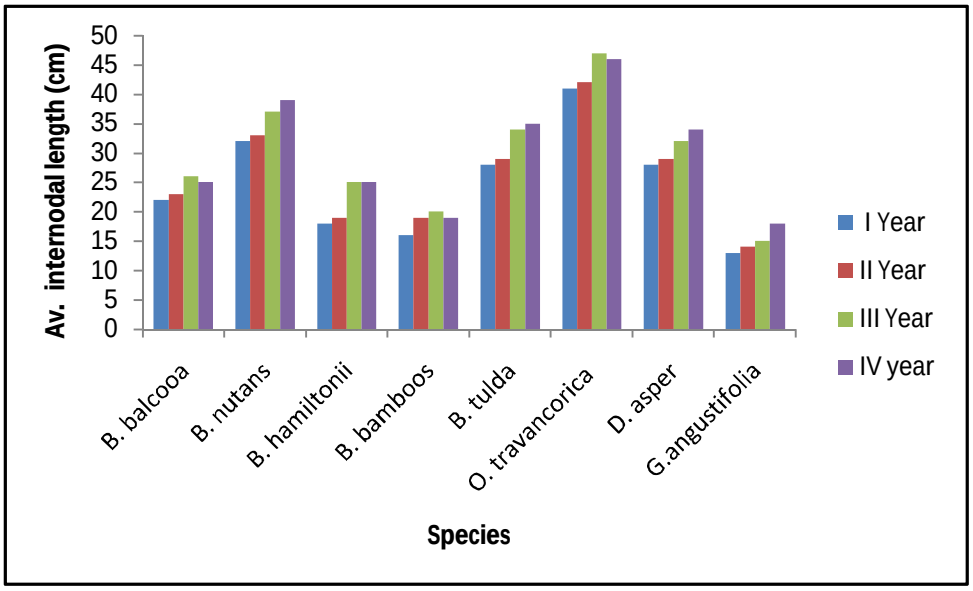

Fig: 8. Average internodal length

3. Bambusa nutans

The growth attributes of *B. nutans* at different stages of growth are presented in Table 4. The survival was 100 per cent till the end of the observation. The number of culms per ha increased from 1125 to 7114 per ha during the growth period. The new shoot emergence also increased with age of the clump and at the end of the observation, 1591 new shoots were produced per ha. The average height, girth and internodal length of the *B. nutans* culms were 12.42 m, 13.2 cm and 39 cm respectively after 48 months of planting.

Table 4. Growth attributes of *Bambusa nutans*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	100	1125	425	72	1.2	30
12	100	1599	716	263	4.7	32
18	100	2407	975	321	6.3	33
24	100	5781	1666	554	9.3	33
30	100	4590	933	574	9.5	31
36	100	5315	1766	914	10.8	37
42	100	6414	1166	1100	12.5	36
48	100	7114	1591	1242	13.2	39

4. *Bambusa tulda*

The growth attributes of *B. tulda* at different stages of growth are presented in Table 5. The survival was 100 percent till 42 months after planting and at 48 months after planting, 94 percent survival was observed. The number of culms per ha increased from 2357 to 11545 per ha during the growth period. The new shoot emergence also increased with age of the clump and after 48 months of planting 2990 new shoots were produced per ha. The average height, girth and internodal length of the *B. tulda* culms were 4.50 m, 6.3 cm and 35 cm respectively at the end of the observation.

Table 5. Growth attributes of *Bambusa tulda*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	100	2357	1241	46	0.9	26
12	100	4507	1858	130	2.0	28
18	100	6231	2616	188	3.3	28
24	100	16035	4656	298	4.7	29
30	100	10554	1216	326	4.6	30
36	100	13502	3599	372	5.4	34
42	100	17368	3915	440	6.3	32
48	94	11545	2990	450	6.3	35

Dendrocalamus asper

The growth attributes of *D. asper* at different stages of growth are presented in Table 6. The survival was 94 percent after 48 months of planting. The number of culms per ha increased from 1716 to 10354 per ha during the growth period. The new shoot emergence also increased with age of the clump and after 48 months of planting 2033 new shoots were produced per ha. The average height, girth and internodal length of the *D. asper* culms were 4.02 m, 7.3 cm and 34 cm respectively at the end of the observation.

Table 6. Growth attributes of Dendrocalamus *asper*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	100	1716	408	77	1.2	27
12	100	3782	1524	136	2.8	28
18	100	4390	1349	184	3.5	28
24	98	13261	4007	286	4.8	29
30	98	9538	900	313	4.9	28
36	98	9463	2691	324	5.3	32
42	98	11337	1874	380	6.2	30
48	94	10354	2033	402	7.3	34

Dendrocalamus hamiltonii

The growth attributes of *D. hamiltonii* at different stages of growth are presented in Table 7. The survival was 61 per cent after 48 months of planting. The number of culms per ha increased from 342 to 2074 per ha during the growth period. The new shoot emergence increased with age of the clump but the emergence varied with growing season and after 48 months of planting, 800 new shoots were produced per ha. The average height, girth and internodal length of the *D. hamiltonii* culms were 9.72 m, 16.8 cm and 25cm respectively after 48 months of planting.

Table 7. Growth attributes of *Dendrocalamus hamiltonii*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	83	342	42	68	3.5	17
12	71	475	150	146	4.0	18
18	77	575	158	297	6.4	19
24	64	1424	408	489	11.4	19
30	64	1125	200	536	11.8	20
36	61	1499	550	762	13.9	25
42	61	1791	292	877	14.8	23
48	61	2074	800	972	16.8	25

Guadua angustifolia

The growth attributes of *Guadua angustifolia* at different stages of growth are presented in Table 8. The survival was 85 per cent after 48 months of planting. The number of culms per ha increased from 1333 to 3399 per ha during the growth period. The new shoot emergence increased with age of the clump but the emergence varied with growing season and after 48 months of planting, 950 new shoots were produced per ha. The average height, girth and internodal length of the *G. angustifolia* culms were 3.69 m, 4.5 cm and 18 cm respectively after 48 months of planting.

Table 8. Growth attributes of *Guadua angustifolia*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	96	1333	425	61	1.1	12
12	100	1924	683	105	2.1	13
18	96	2207	533	171	2.7	13
24	98	4298	1083	232	3.2	14
30	92	3065	342	267	3.2	14
36	87	2649	658	258	3.6	15
42	87	3274	625	295	4.1	15
48	85	3399	950	369	4.5	18

Ochlandra travancorica

The growth attributes of *Ochlandra travancorica* at different stages of growth are presented in Table 9. The survival was 98 per cent after 48 months of planting with causality replacement at initial stages. The number of culms per ha increased from 1524 to 11337 per ha during the growth period. The new shoot emergence increased with age of the clump but the emergences varied with growing season and after 48 months of planting 2816 new shoots were produced per ha. The average height, girth and internodal length of the *Ochlandra travancorica* culms were 4.21 m, 5.6 cm and 46 cm respectively after 48 months of planting.

Table 9. Growth attributes of *Ochlandra travancorica*

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	94	1524	250	46	1.0	40
12	98	3299	1458	111	2.4	41
18	100	4557	1749	136	3.1	42
24	100	12378	3524	234	4.2	42
30	98	8438	2183	250	4.5	41
36	96	10104	2891	348	5.0	47
42	96	12120	2041	385	5.8	45
48	98	11337	2816	421	5.6	46

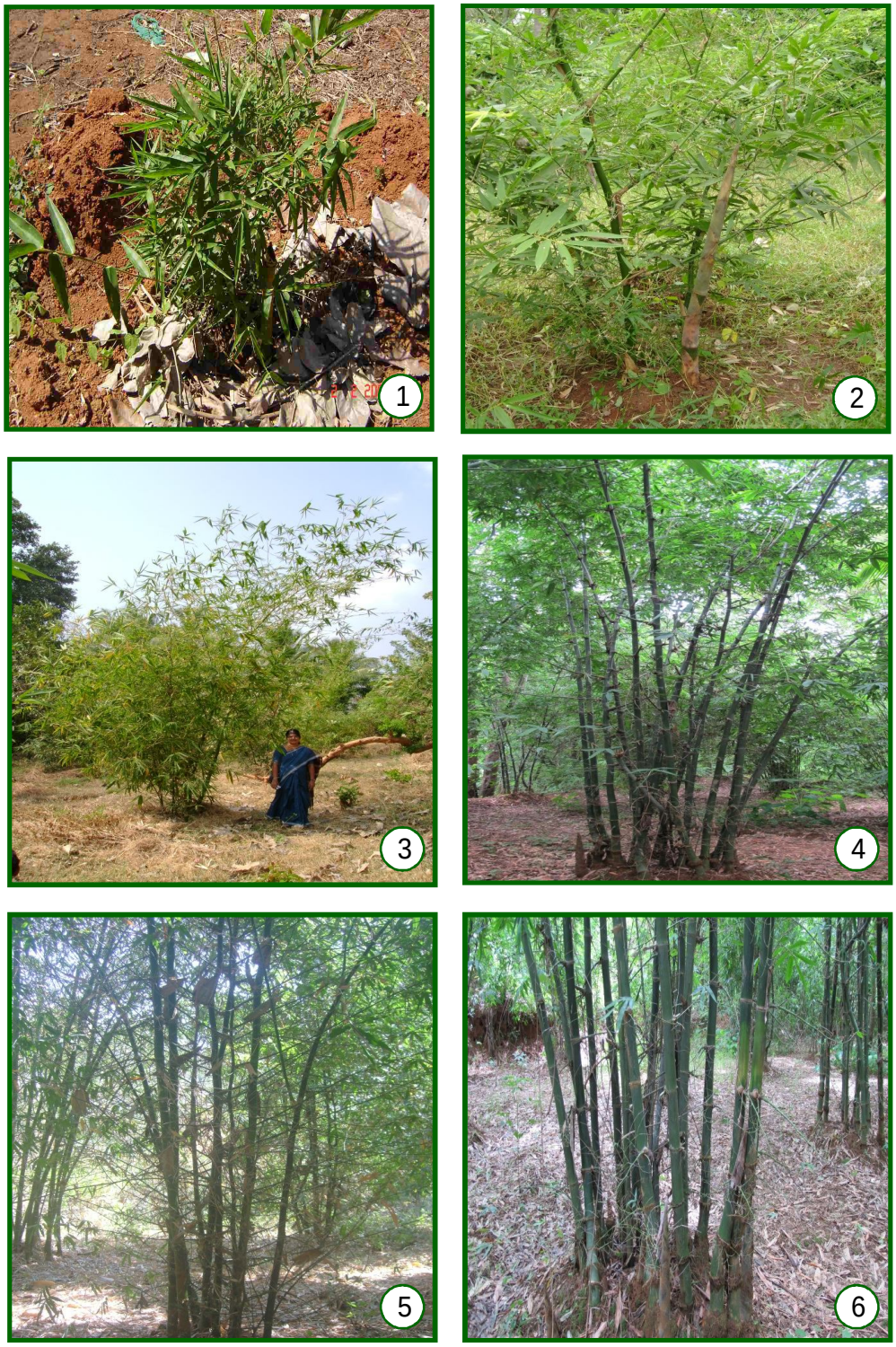

Fig. 9. Different growth stages of *B.balcooa*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

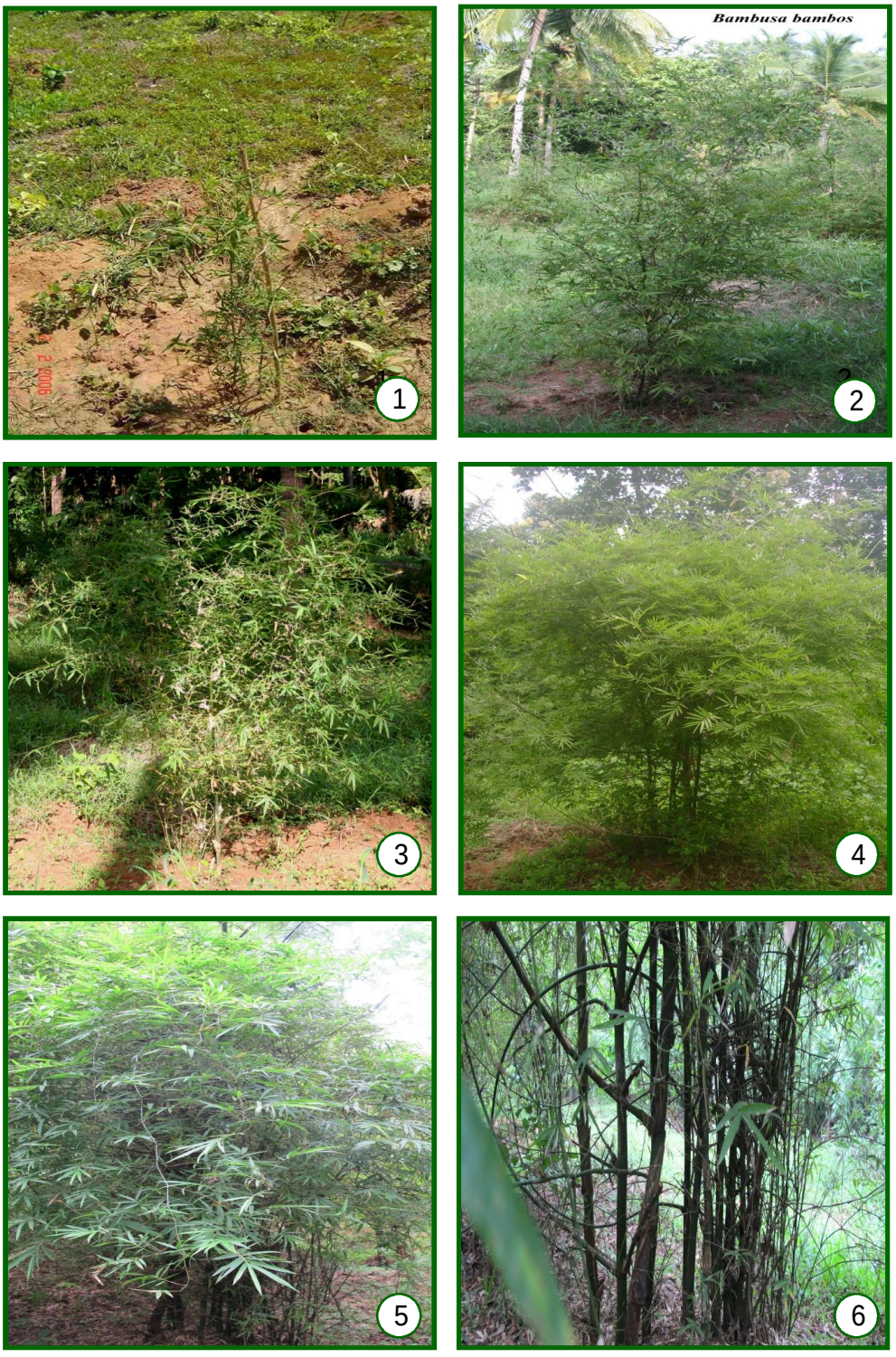

Fig. 10. Different growth stages of *B.bambos*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

Fig. 11. Different growth stages of *B.nutans*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

Fig. 12. Different growth stages of *B.tulda*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

Fig. 13. Different growth stages of *D. asper*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

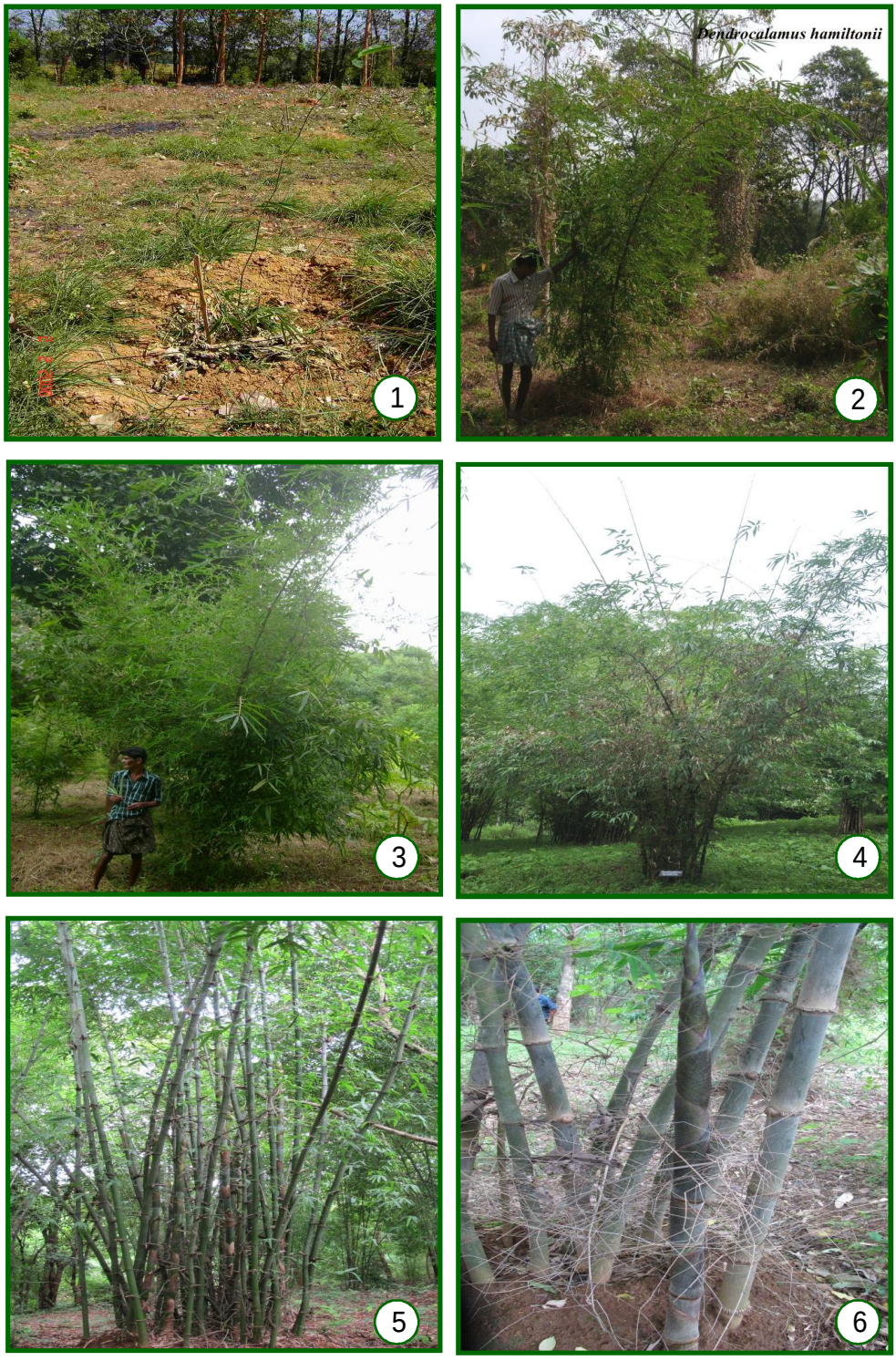

Fig. 14. Different growth stages of *D. hamiltonii:* 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

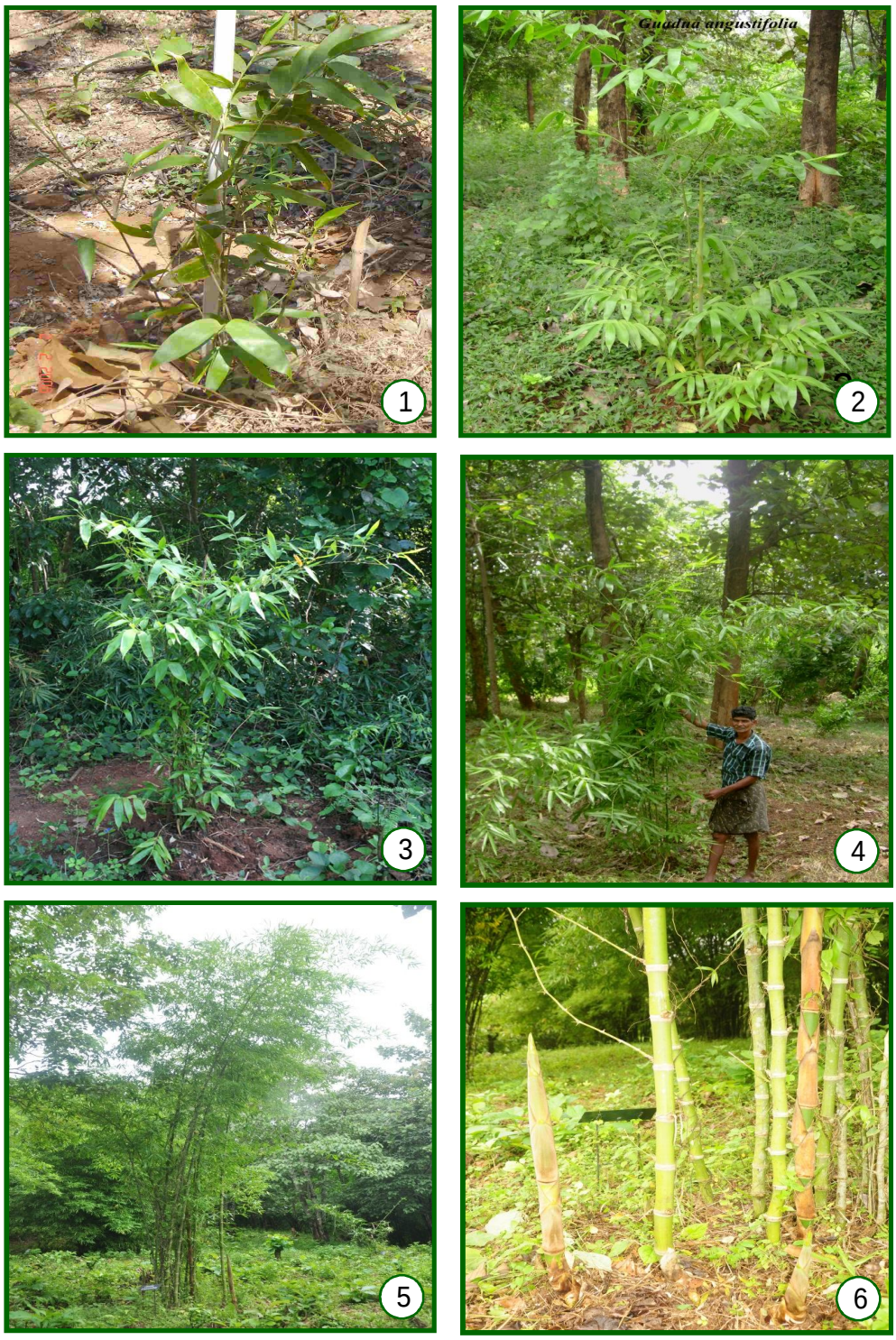

Fig. 15. Different growth stages of *G.angustifolia*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

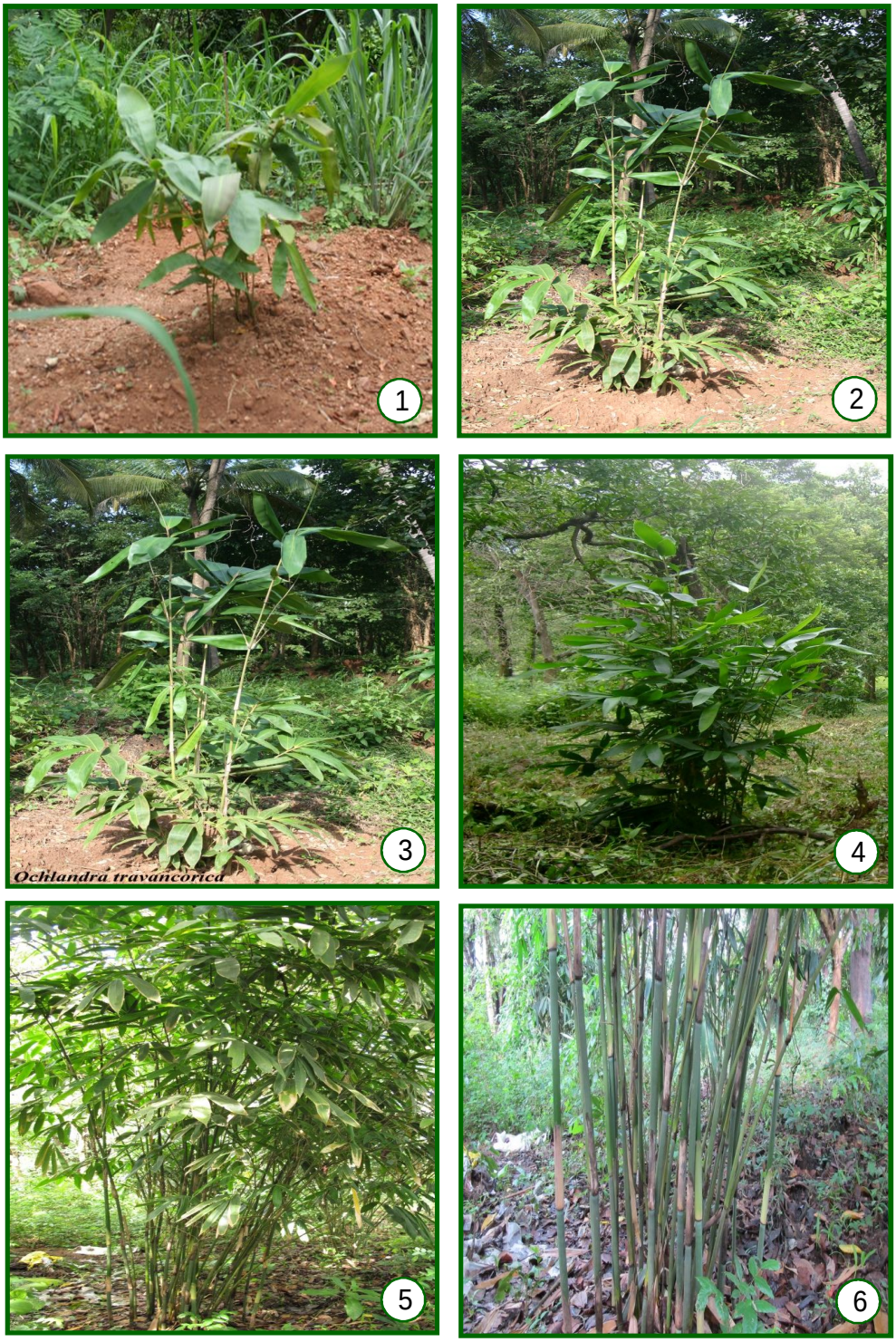

Fig. 16. Different growth stages of *O. travancorica*: 1. Six months after planting, 2. One year after planting, 3. Two year after planting, 4. Three year after planting, 5. Four year after planting and 6.Basal portion of the clump after four years.

The biomass per culm of different bamboo species after 48 months of planting is given in Table 10. The average green weight and dry weight of the bamboos varied with species. The highest green and dry weight was reported for *B. balocooa* (15.0 and 9.9 kg respectively) followed by *D. hamiltonii* (12.8 and 6.9 kg respectively). The lowest weight (green and dry weight) was recorded in *B. bambos* (5.6 and 2.1 kg respectively).

Table 10. The clum and clump attributes of different bamboo species after 48 months of planting.

Species	Clump		Culm			
	Girth (m)	Total Culms per Clump	Height (m)	Girth (cm)	Green Weight (kg)	Dry weight Dry (kg)
B. balcooa	2.3	6	10.92	17.7	15.0	9.9
B. bambos	1.7	8	4.48	9.3	5.6	2.1
B. nutans	3.3	14	12.42	13.2	7.6	4.2
B. tulda	1.6	22	4.5	6.3	6.8	3.9
D. asper	2.2	21	4.02	7.3	7.5	3.9
D. hamiltonii	2.7	4	9.72	16.8	12.8	6.9
G. angustifolia	1.3	6	3.69	4.5	7.0	3.9
O. travancorica	1.7	21	4.21	5.6	7.1	4.0

Changes in soil associated with bamboo planting

The soil gravel content, pH and organic carbon content of the soil at different depths before and after planting are given in Table 11. There was a slight change in the organic matter content of the soil due to bamboo planting as shown in Table 12.

Table 11. Soil characteristics of the site before and 48 months after planting bamboos.

Soil particulars	Gravel (%)	PH	OC (%)
Before Planting (0-20 cm)	10.38	6.65	0.81
Before Planting (20-40 cm)	28.96	6.15	0.78
Before Planting (40-60 cm)	33.37	6.43	0.72
B.balcooa (0-20 cm)	35.51	5.94	0.90
B. balcooa (20-40 cm)	23.77	5.66	0.78
B. balcooa (40-60 cm)	34.96	6.38	0.60
B. bambos (0-20 cm)	40.23	6.02	1.05
B. bambos (20-40 cm)	45.89	5.78	0.87
B. bambos (40-60 cm)	45.72	6.23	0.60
B. nutans (0-20 cm)	33.10	5.98	1.05
B. nutans (20-40 cm)	34.70	5.7	0.72
B. nutans (40-60 cm)	44.79	6.5	0.69
B. tulda (0-20 cm)	12.90	5.29	0.90
B. tulda (20-40 cm)	33.44	5.1	0.60
B. tulda (40-60 cm)	42.74	5.75	0.39
D. asper (0-20 cm)	29.53	5.87	0.81
D. asper (20-40 cm)	12.52	5.99	0.42
D. asper (40-60 cm)	48.47	6.18	0.24
D. hamiltonii (0-20 cm)	16.92	6.53	0.93
D.hamiltonii (20-40 cm)	6.98	6.05	0.75
D.hamiltonii (40-60 cm	34.58	6.74	0.33
G.angustifolia (0-20 cm)	6.53	5.56	0.84
G.angustifolia (20-40 cm)	24.69	6.31	0.78
G.angustifolia (40-60 cm	43.81	5.64	0.30
O.travancorica (0-20 cm)	27.25	6.32	0.57
O.travancorica (20-40 cm)	4.39	6.23	0.81
O.travancorica (40-60 cm)	34.12	5.75	0.48

Table 12. Changes in the percentage of organic carbon before and 48 months after planting

Species	Soil depth					
	0-20 cm		20-40 cm		40-60 cm	
	Before	After	Before	After	Before	After
B. balcooa	0.81	0.90	0.78	0.78	0.72	0.60
B. bambos	0.81	1.05	0.78	0.87	0.72	0.60
B. nutans	0.81	1.05	0.78	0.72	0.72	0.69
B. tulda	0.81	0.90	0.78	0.60	0.72	0.39
D. asper	0.81	0.81	0.78	0.42	0.72	0.24
D. hamiltonii	0.81	0.93	0.78	0.75	0.72	0.33
G.angustifolia	0.81	0.84	0.78	0.78	0.72	0.30
O.travancorica	0.81	0.57	0.78	0.81	0.72	0.48

2. Spacing trials of *O. travancorica*

In general, the variation in clump density influenced the growth of the *O. travancorica* seedlings and those planted at a wider spacing showed better growth (Figs. 17-21). At the end of the observation, the seedlings planted at a spacing of 9 m x 9 m (clump density = 122 plants per ha) produced the largest number of culms per clump (61.54), culm height (415.45 cm), collar diameter (7.11 cm), number of internodes (9.64) and internodal length (51.27 cm). Meanwhile, lowest number of culms (26.19) per clump was obtained for the spacing 9mx5mx3 m (476 plants per ha). The present results are contradictory to the observations by Patil and Patil (1990) who obtained a higher number of culms and growth for closely spaced *D. strictus* seedlings. This might be due to the fact that at a wider spacing, new shoots of *O. travancorica* utilize the maximum growing space and resources available to them and establish easily leading to the maximum survival in the field. However, on a per hectare basis, the plants spaced at 9 m X4.5 m X 4.5 m gave the maximum number of culms (18, 972) followed by 5 m X 5 m (18, 650) and the least number of culms were obtained for spacing 9 m X 9 m (7, 508).

In summary, from the three year observations on growth of *O. travancoria,* it can be concluded that the seedlings spaced at 9 m X 4.5 m X 4.5 m and 5 m X 5 m produce the highest number of culms, and hence maximum yield.

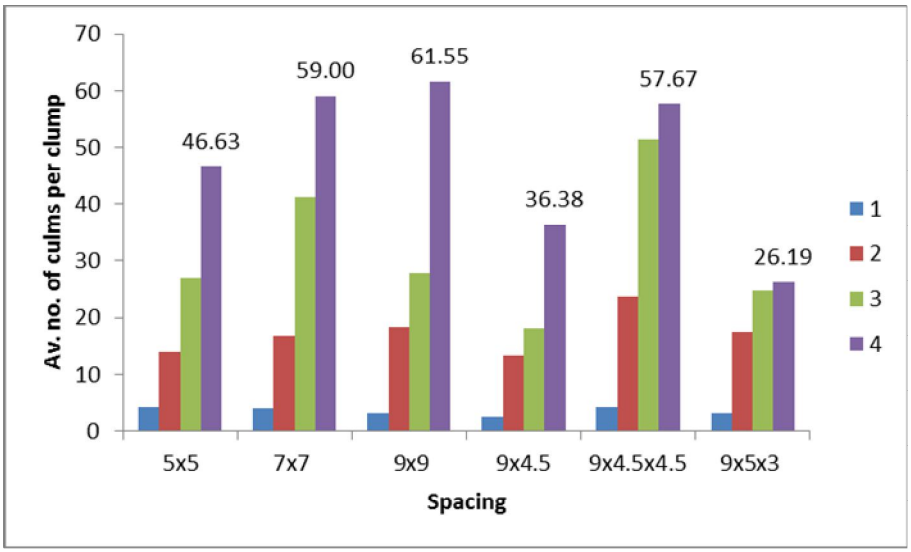

Fig 17. Number of culms per clump of *O. travancorica* as influenced by different spacing

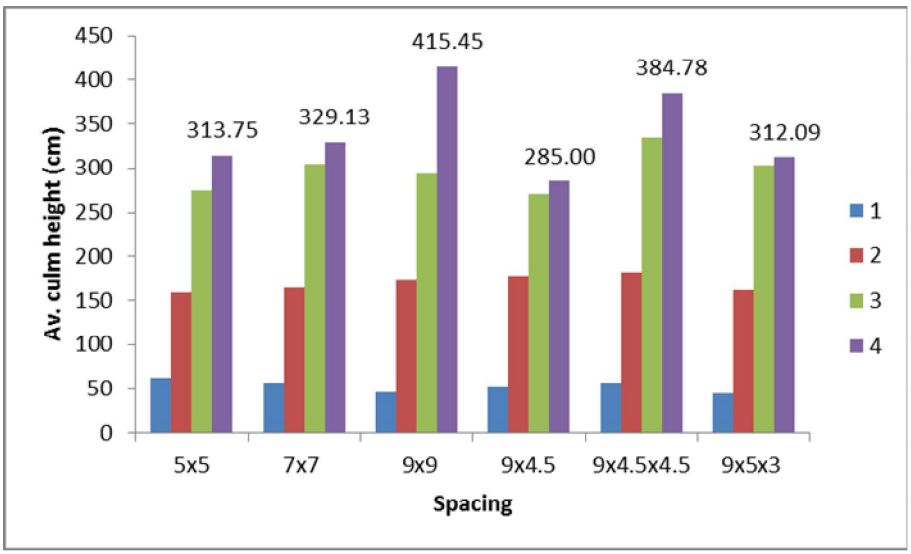

Fig 18. Height of the *O. travancorica* culms as influenced by different spacing

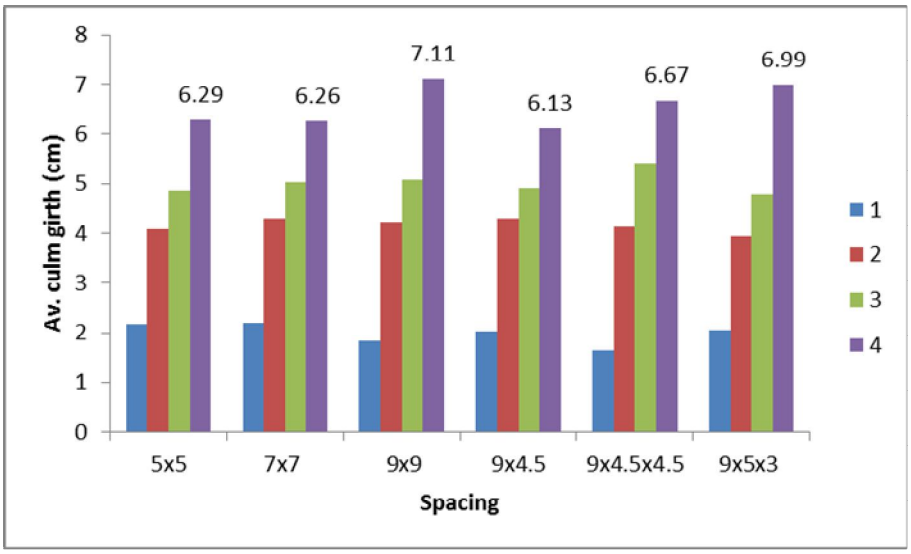

Fig 19. Girth of *O. travancorica* culms as influenced by different spacing

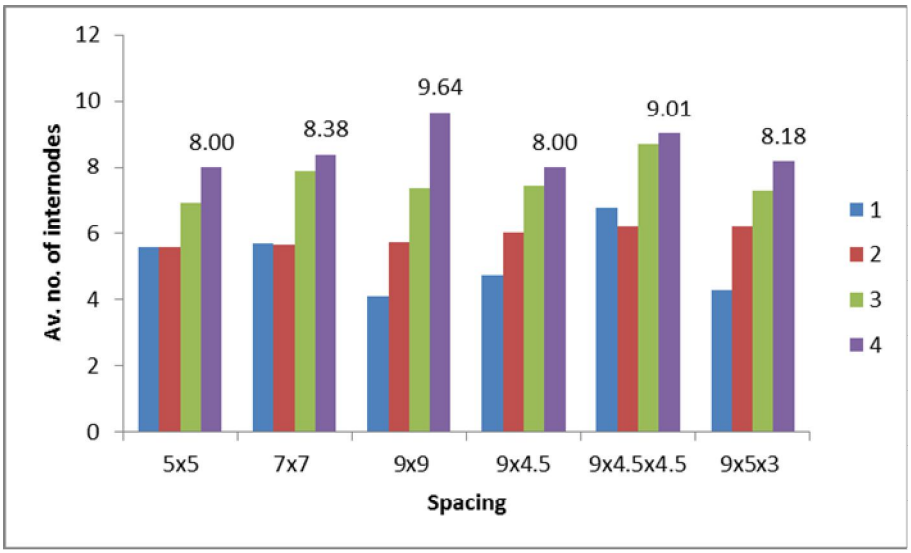

Fig 20. Number of internodes of *O. travancorica* culms as influenced by different spacing

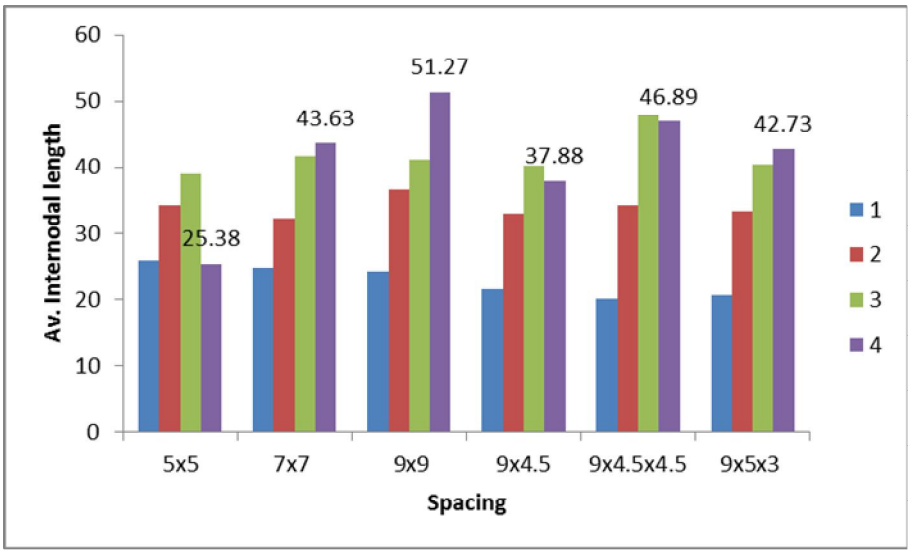

Fig 21. Internodal length *O. travancorica* culms as influenced by different spacing

3. Bamboo-based cropping systems

The trials on Bamboo-based cropping systems were established in the farmers' field as indicated in the plot diagram (Fig. 1) during December 2005 at Kinasseri, Peruvemb panchayath of Palakkad district. Knife weeding, soil mounting and leaf mulching works were carried out during December every year. The data on growth attributes of the bamboo at different stages of growth is given in the Table 13. The details of intercropping are as follows.

Table 13. Growth attributes of *Bambusa bambos* during the study period

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	100	1327.84	-	36.42	1.73	-
12	92	1127.12	370.56	74.24	1.54	-
18	69	880.08	223.88	106.37	3.00	-
24	96	2346.88	579.00	172.43	3.70	-
30	71	1065.36	162.12	223.00	4.63	18.67

First year

During April, 2006, 25 kg of ginger rhizomes were planted in the raised nursery bed and it was harvested during January 2007 and 250 kg ginger was obtained from an area of 0.01 ha of land. The yield was moderate because the area was rainfed and the intensity of drought was very high during the summer season. During June 2006, 500 g seeds of cowpea were planted in the raised beds and the harvesting was carried out during August – September 2006. On an average, 400 kg of cow pea was obtained from the same area. The yield was good as it was planted during rainy season and supplemental irrigation was not done during the growth period. Similarly, 200 numbers of tissue cultured banana (Robusta) were planted during June 2006 in the open space in between the bamboos and other perennial plants and harvested during March 2007. On an average the total bunch weight was 20 kg per plant.

Second year

Similar planting activities were repeated during 2007-2008. However, the cropping area was interchanged. The ginger was sown in the area where the cowpea was cultivated during the previous year and *vice versa*. During the harvest, 350 kg ginger was obtained from the area and the yield was 100 kg more compared to the previous year. The yield of cowpea was almost the same (410 kg). Banana was not planted during the period because of the scarcity of water. The growth performance of the bamboos during the study period is given in the Table 13. However the observations on trial could not be completed as the field caught fire during the summer of 2008.

4. Clump management trial

The clump management trial with *Bambusa bambos* was done at Nellikkad, Koyalmandam panchayath of Palakkad district during December 2005. The data on growth attributes of the bamboo at different stages of growth is given in the Table 14. The clump management operations are about to start as the clumps had obtained maturity. As an initial trial, the thorny branches were collected from the bamboo plots. The dead and dried culms and side branches were removed from the plot.

Thorn removal was carried out during the month of March-April both in 2009 and 2010. On an average, 13 bundles of thorns per plot were obtained, each bundle 8.72 kg (equivalent to 578 kg per ha). The cost of one bundle in the local market was around Rs. 60.

Table 14. The growth attributes of the *Bambusa bambos* during different stages of growth.

Months after planting	Survival Percentage	Total culms (per ha)	New shoots emerged (per ha)	Culm Height (cm)	Culm Girth (cm)	Inter-nodal Length (cm)
6	94.24	1426.76	205.64	71.90	1.16	-
12	99.48	2162.40	684.76	142.22	3.31	-
18	98.43	1859.24	686.88	168.16	4.46	-
24	96.86	3593.40	1038.80	262.39	7.12	-
30	96.33	3188.48	678.40	287.05	7.34	19.19
36	95.29	3355.96	705.96	325.43	8.60	19.24
42	95.29	2753.88	385.84	285.43	8.02	18.76
48	94.76	3283.88	415.52	316.33	8.67	19.57

Fig.22. Silvicultural practices in the plots –Different stages of weeding (1-5) and clump management-removal of thorns (6)

Fig. 23.Visits of the officials and trainees from NMBA & NBM

CONCLUSION

The present investigation on bamboo multilocational trials was conducted in Palakkad district of Kerala. The bamboo plantations were established both in farmers' field and on government land. The results on the multilocational species trial indicate that at the end of fourth year all the species raised from the rooted cuttings (*B. balcooa, B.nutans* and *D. hamiltonii*) had a higher growth performance compared to those raised from tissue culture planting stock and seedling propagules. The highest biomass production per culm was obtained in *B. balcooa*. Nowadays, farmers are interested in growing bamboos on their farmlands. Most of those farmers are concerned about the species suitability for their climatic and edaphic conditions, the yield and economic benefit from the plantation. The present investigations indicate the suitability of bamboos in the farm land and the growth of bamboos were found to be promising. Although definite conclusions can't be made at this stage the multi species bamboo plantation can act as a demonstration plantation for the farmers who are interested to incorporate bamboo into their farming practices. The three year observations on spacing trials of *O. travancorica,* indicate that the seedlings spaced at 9 m x 4.5 m x 4.5 m and 5 m x 5 m produce the highest number of culms and thereby the maximum yield. This indicates the possibility of intercropping with the bamboos leading to optimum utilization of the site and additional income to the farmers. Intercropping with *B. bambos* was found to be promising in the initial year. However, definite conclusions could not be drawn as the plots caught fire during the summer season. However, the initial results indicate the possibility of intercropping among the bamboo species. The clump management plots are ready for initiating the management activities; further studies are required for drawing any conclusions.

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