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Field performance of Micro- and macro- propagated planting stock of five commercially important bamboo species

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Contents

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ABSTRACT

Sustainable supply of bamboo raw material is the prime requirement for the successful functioning of many new industries established by Government of India during last decade for development of bamboo sector. Intensive research has been carried out by many R&D institutions and private laboratories for large scale production of planting stock through different methods of propagation and successful protocols for micro-propagation have been developed for about half a dozen priority species. However, there have been no sufficient field trials with the micro-propagated planting stock of many species. In this context, Department of Biotechnology initiated network programmes to evaluate the field performance of planting stock raised t both macro and micro propagation methods. Kerala Forest Research Institute was selected as a nodal agency to implement this programme in Southern India along with Institute of Wood Science and Technology, Bangalore and Institute of Forest Genetics and Tree Breeding, Coimbatore as partners.

The objective of the KFRI component was to evaluate the field performance of micro- and macro- propagated planting stock of five commercially important species, viz., *Bambusa bambos, Dendrocalamus strictus, Dendrocalamus asper, Dendrocalamus stocksii* (*Pseudoxytenanthera stocksii*) and *Ochlandra travancorica.* Since micro-propagated planting stock of *O. travancorica* was not available, *Bambusa balcooa* was included in the plantation trials.

A trial plantation of 41.19 ha was established at Moolagangal, Attappadi, Palakkad District and 2 ha at Puthenkurizu, Ernakulam District in collaboration with private planters. The planters provided the land after establishing solar fencing for protection and facilities for drip irrigation. Two ha was planted as a

part of the riverbank stabilization programme on the banks of Kalpathy River Basin at Palakkad. Totally five species viz. *Bambusa balcooa, B. bambos, Dendrocalamus asper, D. strictus* and *D. stocksii* were planted. The experimental plots of 3 ha each were laid out for *B. balcooa* and *D. asper* with macro and micro propagated planting stock. Two spacing (5 x 5 m and 6 x 6 m) and three fertilizer doses, FYM, NPK and FYM+NPK and a control were included in the experimental plots.

Both the planting stocks were found to perform similarly. Spacing and fertilizer addition influenced the survival and growth of the seedlings positively. However, observations need to be continued for at least five years to reach a definite conclusion.

INTRODUCTION

Sustainable supply of bamboo raw material is the prime requirement for the successful functioning of many new industries recently initiated by the Government of India during last decade for the development of bamboo sector. Expansion of area under bamboo through establishment of new plantations with suitable species is one of the priority areas of National Bamboo Mission. Intensive research has been carried out by many R&D institutions and private laboratories for large scale production of planting stock through different methods of propagation. Of these, tissue culture has emerged as one of the promising methods to meet the requirement of planting stock in large quantity.

The use of tissue culture techniques for large scale cloning is known as micro-propagation. This technique uses synthetic nutrient media for growing tissues under sterile conditions and has advantages of very high multiplication rates and the feasibility of producing uniform, disease and pest free plants throughout the year. It is often the only solution to overcome the shortage of high quality planting stock when demands for large numbers exist.

Bamboo micropropagation technology is several decades old and the list of species that are successfully propagated in tissue culture is growing. But most of the reports in literature are limited to standardization of tissue culture protocols which give no indication of the feasibility for large scale propagation. Several commercial firms however produce bamboo plantlets around the world and large scale plantations are envisaged under the National Bamboo Mission in different states. Before undertaking plantations of bamboo with micropropagated planting stock, it would be desirable to be aware of the advantages and disadvantages, if any, *vis-à-vis* conventional seedlings or vegetatively propagated plants.

Micropropagation does not by itself confer any specific advantages in the quality of plantlets except for uniformity and disease free nature. The selection of the mother plant used for propagation is of paramount importance since clones would carry the same genetic complement as the plant from which explants are taken for establishing the culture. Selection of elite genotypes after adequate testing is thus a requirement if quality has to be established.

There is a danger of genetic variability resulting from the tissue culture procedure depending on the choice of method of culture and regeneration. In general the procedure that uses sprouting of axillary buds and enhanced multiple shoot formation followed by rooting of shoots, is considered safe and dependable for mass multiplication. The procedure using somatic embryogenesis on the other hand is prone to genetic instability. There is also the possibility of epigenetic changes occurring due to altered gene expression in tissue cultures which might also result in altered behavior of plantlets in the field.

Although successful protocols for micro-propagation were developed for about half a dozen priority species there were no sufficient field trials with the micro-propagated planting stock of many species except a few like *Bambusa bambos* and *Dendrocalamus strictus.* In this context, Department of Biotechnology initiated network programmes to evaluate the field performance of planting stock raised by both macro and micro propagation methods. Kerala Forest Research Institute was selected as a nodal agency to implement this programme in Southern India along with Institute of Wood Science and Technology, Bangalore and Institute of Forest Genetics and Tree Breeding, Coimbatore as partners.

The objective of the KFRI component was to evaluate the field performance of micro- and macro-propagated planting stock of five commercially important

species, viz., *Bambusa bambos, Dendrocalamus strictus, Dendrocalamus asper, Dendrocalamus stocksii* (*Pseudoxytenanthera stocksii*) and *Ochlandra travancorica*. Since micro-propagated planting stock of *O. travancorica* was not available, *Bambusa balcooa* was included in the plantation trails. The details are presented in this report.

MATERIALS AND METHODS

Selection of sites

The major area (about 40 ha) was selected in Moolagangal, (N- 11^0 02′ 49″ E 76^0 46′ 65″) Agali Forest Range, Mannarkkad Forest Division, Palakkad District in collaboration with two private planters, Navanirman Trust and AC Agro Farm for the experimental trails. An agreement was executed with the planters for sparing their land for five years with protection and drip irrigation facilities.

Terrain comprised flat and sloping areas (angle of slope about 40-45^o). It was a rain shadow region receiving major part of the rain during September-December (North-east monsoon). Dominant species in the area included of *Bambusa bambos*, *Dendrocalamus strictus*, *Santalam album, Dalbergia latifolia, Psidium guaoa, Citrus* spp. etc. Many herbs and perennial grasses were also seen. Soil was clayey. Another 2 ha was planted as a part of Kalpathy river bank stabilization programme of Akathethara Panchayath, Palakkad District. An additional 2 ha was planted with one species – *D. asper* by Navanirman Trust at Puthen Kurizhu, Ernakulam District. Both the areas were level ground.

Preparation of land

When the area was handed over to KFRI, it had solar fencing all around, a water harvesting pond and all arrangements for drip irrigation. As soon as the land was taken over a complete knife weeding was carried out. Except for one of the spacing trials of 6 x 6 m, for all other planting trials alignment and staking were carried out at 5 x 5m spacing and pits were dug using augurs. Experimental layout for different field trials is given Appendix 1.

Experimental plots

1. Effect of different types of planting stock

In order to find out the effect of different planting stock on the performance of the bamboo species, three types of planting stock, viz., micro-propagated (TC), Rooted Cuttings (RC) and Seedlings were planted in the field. The spacing adopted was 5 m x 5 m (400 plants/ha). Each treatment had 3 blocks with 16 plants. Micropropagated plants of *B. balcooa* were procured from Grow More Biotech, Hosur; and *D. asper* from Tata Energy Research Institute (TERI), Delhi, *D. stocksii* from Institute of Wood Science and Technology (IWST), Bangalore, *B. bambos* and *D. strictus* from National Chemical Laboratory (NCL) Pune. Seedlings and rooted cuttings were produced in KFRI Field Research Centre Nursery at Velupadam. The details of planting stock used and experiments are given in Table 1.

Table 1. Species and types of planting stock used for planting

Trt.	Code	Species	Type of planting stock	Trt.	Code	Species	Type of Planting stock
T1	S^1TC	*B. balcooa*	TC plants	T7	S^3RC		Rooted cuttings
T2	S^1RC		Rooted cuttings	T8	S^4TC	*D. stocksii*	TC plants
T3	S^2TC	*B. bambos*	TC plants	T9	S^4RC		Rooted cuttings
T4	S^2RC		Rooted cuttings	T10	S^5TC	*D. strictus*	TC plants
T5	S^2SE		Seedlings	T11	S^5RC		Rooted cuttings
T6	S^3TC	*D. asper*	TC plants	T12	S^5SE		Seedlings

Observations were recorded on percentage of survival at one and two months after planting. Percentage of survival and growth attributes such as number of tillers and internodes, height and diameter of tillers were measured at 6 months

Fig. I. 1 & 2. General view of the planting sites. 3. Grazing in the plot 4. Solar fencing provided for protection from grazing and elephant damage 5. Heavy infestation with weeds during initial stages of planting . 6. Weeding operations

and one year after planting. The experimental plot of *B. balcooa* was damaged due to the removal of solar fencing, hence the area was replanted after establishing protection and observations were recorded for another one year.

2. Effect of spacing and fertilizer applications

Source of planting material

Both Tissue culture and conventional planting stock were used to conduct different trials. The tissue culture plants of *B. balcooa* were obtained from M/s Grow More Biotech, Hosur from the explants collected from Kerala Forest Research Institute bambusetum (B-89 KFRI). During initial stages, the plants were hardened in the nursery of Grow More Biotech and acclimatization for about 3 months was done at the satellite nursery at the planting site - Mulagangal, Sholayur village, Palakkad. TC plants of *D. asper* were procured from Century Laminations, New-Delhi. The seedlings were air lifted and hardened initially in the nursery at Field Research Centre, Kerala Forest Research Institute and proliferated. Three months prior to field planting they were transferred to satellite nursery at Mulagangal, Sholayur village, Palakkad, hardened and proliferated once again.

The vegetatively propagated planting stock (rooted cuttings) were produced in the KFRI Field Research Centre, Velupadam. The Age of the plants at the time of planting was 7 months and other growth parameters at the time of planting are given in Table 2.

Design and Planting of experimental plants

The planting was carried out during October 2006 as per the guidelines given by Department of Biotechnology for the network programme.

Table 2. The average size of the planting stock at the time of planting

Type of planting stock	Micro-propagated	Rooted cutting
Average height	36.3 cm	42.5 cm
Diameter	0.29 cm	0.36 cm
No of tillers	2-3	2
No of nodes	3-4	4-5

Design for TC plants

Each experimental plantation had 3 replicates and for each replicate there were two planting distances and 4 fertilizer dosages. There were two main plots for two different spacing.

- Main plot (S1) : 5 m x 5 m
- Main plot (S2) : 6 m x 6 m

Each main plot was divided into 4 subplots of equal size; each subplot represented one fertilizer dosage. The following fertilizer treatments were recommended. All the dosages were applied during pit filling.

F1 – No Fertilizer

F2 – FYM (10kg)

F3 – NPK (50g N + 50g P + 25g K)

F4 – FYM + NPK (5kg FYM + 50g N + 50g P + 25g K)

Design for vegetatively propagated plants

There was only one main plot with a spacing of 5 m x 5 m. The main plot had 4 sub-plots of equal size (15 m x 15 m) for 4 different fertilizer treatments. There were three replications for each subplot. Each treatment had 9 plants. The plots/replications were distributed across the fertility or other environmental gradients existing in the experimental area. Planting was carried out in March 2008.

Fig. II 1. Nursery with sprouted cuttigs. 2. Rooted cuttings of *D. asper* at FRC, Velupadam. 3. Synchronous flowering of rooted cuttings of *D. stocksii* in nursery beds. 4. TC plants of *D. asper* with transplanting shock 5 and 6. *D. asper* and *B. bambos* after hardening. 7. Acclimatization at planting site 8. Single TC plant in root trainer.

River Bank Stabilization Programme at Kalpathy

The details of the species, type of planting materials and number of plants planted during the river bank stabilization programme (RBS) are given below. Planting was replicated in two blocks.

Table 3. Species, type of planting materials and number of plants used for RBS

Species	Type of plant. stock	No. of plants	Species	Type of plant. stock	No.of plants
B. bambos	Seedling	255	*D. asper*	TC plants	210
B. tulda	"	100	*D. strictus*	"	225
B. striata	Cutting	130	*D. hamiltonii*	Seedling	130
B. vulgaris	"	50	*O. nigroceleata*	"	110
			O. travancorica	"	2040
Total					3250

The observations on survival, height, number of internode and length were noted six months after planting.

Fig III. River bank stabilization programme at Kalpathy 1.A view o the planting area, 2-4 planting operations involving Kudumbasree and student volunteers.5 & 6 Sri Paloli MohammedKutty Hon. Minister for Local Self Govt and Rural Development inaugurates the planting

RESULTS

A total area of 45.19 ha was planted with five species. This includes 18 ha of *B. balcooa*, 2 ha of *B. bambos,* 20 ha of *D. asper,* 1.75 ha of *D. stocksii,* 1.44 ha with different species. The details are given in Table 4.

Table 4. Details of species, location, area and nature of planting

Species	**Location**	**Area (ha)**	**Details of planing**
B. balcooa	Moolagangal, Palakkad	18	Three ha experimental plots and the rest of the area was block planted at a spacing of 5x5 m
B. bambos	Kalpathi, Palakkad	2	Planted as part of the river bank stabilization programme.
D. asper	Moolagangal, Palakkad and Puthankurish, Eranakulam	20	Three ha experimental plots and the 15 ha block planted at a spacing of 5x5 m at Moolagangal. Two ha of the plantation was established at Puthankurish, Eranakulam at a spacing 5 m x 5 m
D. stocksii	Moolagangal, Palakkad	1.75	The vegetatively propagated plants flowered synchronously with mother clump and died.
D. strictus	Kalpathi, Palakkad	2 ha	Planted as part of the river bank stabilization programme.
Species trial	Moolagngal, Palakkad	1.44	The trial was conducted with 5 species before the guide lines of DBT for network programme were issued and hence it was not followed.
Total		**45.19**	

Performance of different types of planting stock

In general, rooted cuttings recorded a higher survival compared to tissue cultured planting stock. Rooted cuttings also recorded higher number of tillers and larger height. *B. balcooa* recorded a higher survival compared to other four species. The details are given in Table 5.

Table 5 Survival, number of tillers and average height of different planting stock

Treatment Code	Survival (%)	Number of tillers	Average ht (cm)
Bambusa balcooa			
T1 - S^1TC	88	3	78
T2 - S^1RC	96	4	125
Bambusa bambos			
T3 - S^2TC	73	2	69
T4 - S^2RC	75	3	78
T5 - S^2SE	NA	NA	NA
Dendrocalamus asper			
T6 - S^3TC	88	3	39
T7 - S^3RC	92	2	42
Dendrocalamus stocksii			
T8 – S^4TC	NA	NA	NA
T9 – S^4RC	75	2	106
Dendrocalamus strictus			
T10 – S^5TC	NA	NA	NA
T11 – S^5RC	83	4	79
T12 – S^5SE	NA	NA	NA

NA = Not available

Fig. IV 1. General view of the experimental plot with road in the middle. 2. Natural growth of *B. bambos* in the area. 3. Flowering and death of natural bamboo. 4. Planting operations 5. Ponds made for water harvesting from perennial streams found in the plots. 6. *D. asper* one year after planting.

Effect of spacing and fertilizer applications on initial growth of *B. balcooa* and *D. asper*

The observations were made after first, second, sixth and twelfth months after planting. Only percentage of survival was recorded during first two observations (first and second months).

Bambusa balcooa

Percentage of Survival

Although 100 percent survival was observed during the first two months, it varied from 80 to 100 percent in the subsequent observations. The rooted cuttings showed 100 per cent survival except in control at 6 and 12 months. Among TC plants, control (without) fertilizer showed lowest survival ranging from 80 to 83.3 per cent. The survival percentage was lowest (80) in spacing 6 m x 6m with out any fertilizer applications (Table 6).

Table 6. The survival at 6th and 12th months after planting

Treatment	Survival (%)		Treatment	Survival (%)	
	6 months	12 months		6 months	12 months
Spacing 5 x 5 m; TC Plants					
S^1F^1	83.3	83.3	S^2F^3	94.4	94.4
S^1F^2	92	92	S^2F^4	92	92
S^1F^3	89	89	Conventionally propagated spacing 5 x 5 m		
S^1F^4	92	92	C F^1	100	92
Spacing 6x 6 m			C F^2	100	100
S^2F^1 - Control	80	80	CF^3	100	100
S^2F^2 - FYM	92	92	CF^4	100	100

S^1 = spacing 5x 5; S^2 = Spacing 6 x 6 ; F^1= No Fertilizer; F^2 = FYM; F^3 = NPK; F^4 + NPK + FYM; C = Conventionally propagated plants.

Number of culms per clump

The number of culms (tillers) per clump varied (1.2 to 4.2) among different treatments at both the periods of observations. At the end of the observation, treatment S^1F^4 (spacing 5 x 5 m and Farm yard manure and NPK) recorded the maximum number of tillers (Fig. 1).

Height of culms

At the end of the 12 months, maximum height was observed in rooted cuttings (CF^3) treated with inorganic fertilizers (125.2 cm) followed by CF^4 (118.2 cm) and CF^2 (116.5 cm). Seedling height was the minimum (72.5 cm) in S^1F^1 (Fig. 2).

Collar girth

Collar girth of the seedlings varied due to different treatments at different periods of growth. At the end of 12 months, largest collar girth (1.02 cm) was observed in the rooted cuttings treated with inorganic fertilizers and FYM (CF^4) which was followed by the CF^2 and S^1F^3 (Fig. 3). The collar girth was minimum in control (S^1F^1 and S^2F^1).

Internodal length

At the end of 12 month the highest internodal length (14.5 cm) was observed in rooted cuttings treated with FYM and NPK (CF^4) and it was lowest (5.6 cm) in S^2F^{23} (Fig. 4).

Number of nodes per culms

The highest number of nodes was observed in S^2F^3 (12) and the lowest in S^2F^1(4) at the end of one year (Fig. 5).

The observations in the experimental plot were interrupted due to some unforeseen reasons. This necessitated replanting in a portion.

Fig. V. 1. *B. balcooa* TC plants one year after planting. 2. Drip irrigation facilities. 3 *D. asper* 4– 6. General view of the planted sites.

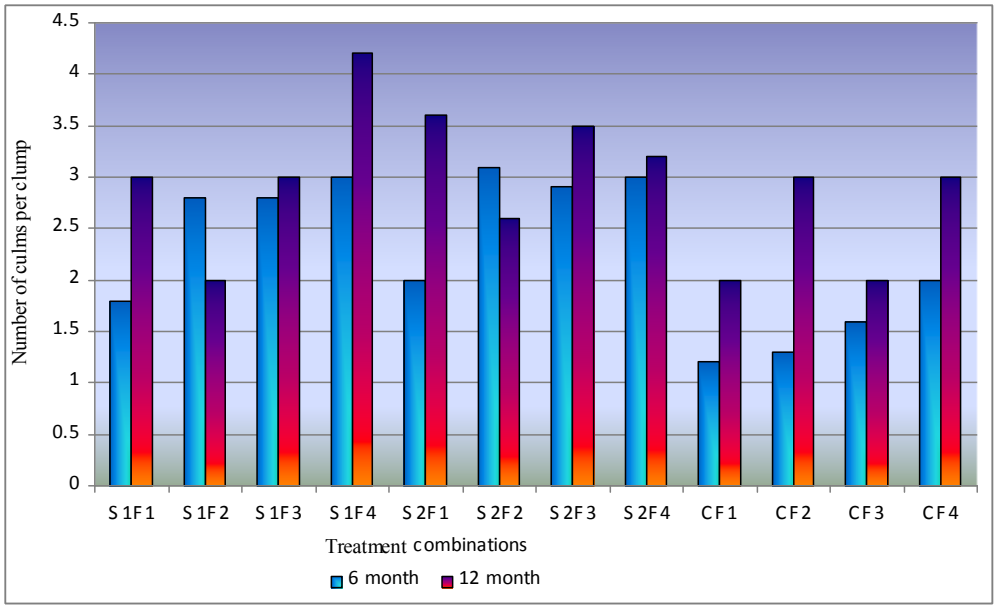

Fig 1. *B. balcooa*. Number of tillers per clump at different spacing and fertilizer applications

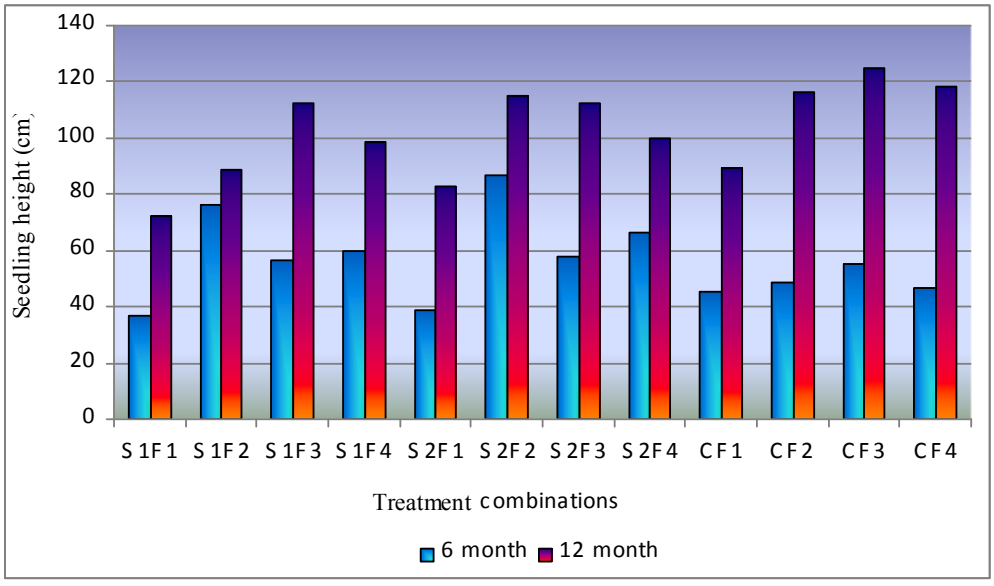

Fig 2. *B. balcooa*. Height of seedlings at different spacing and fertilizer applications

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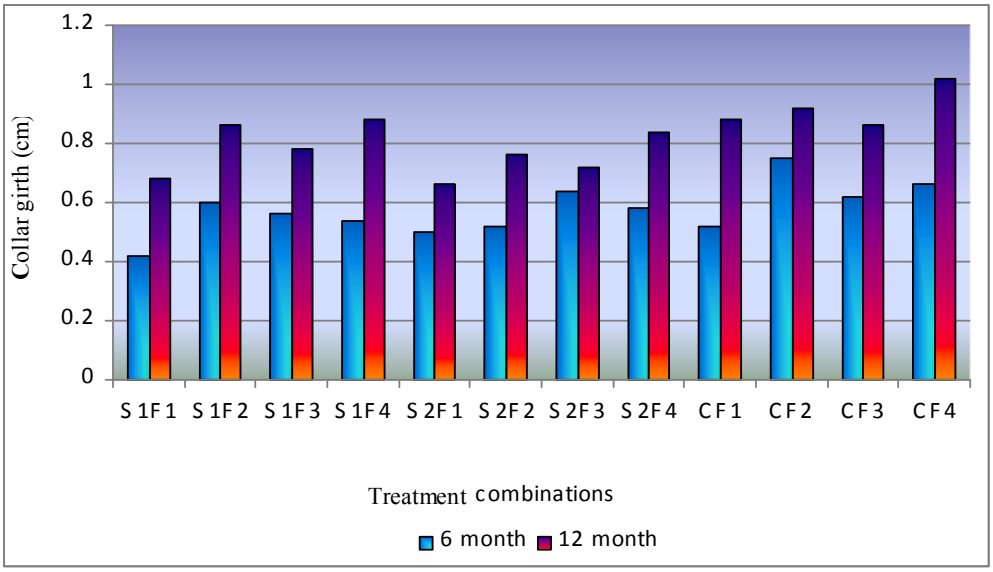


Fig 3. *B. balcooa*. Collar girth seedlings at different spacing and fertilizer applications

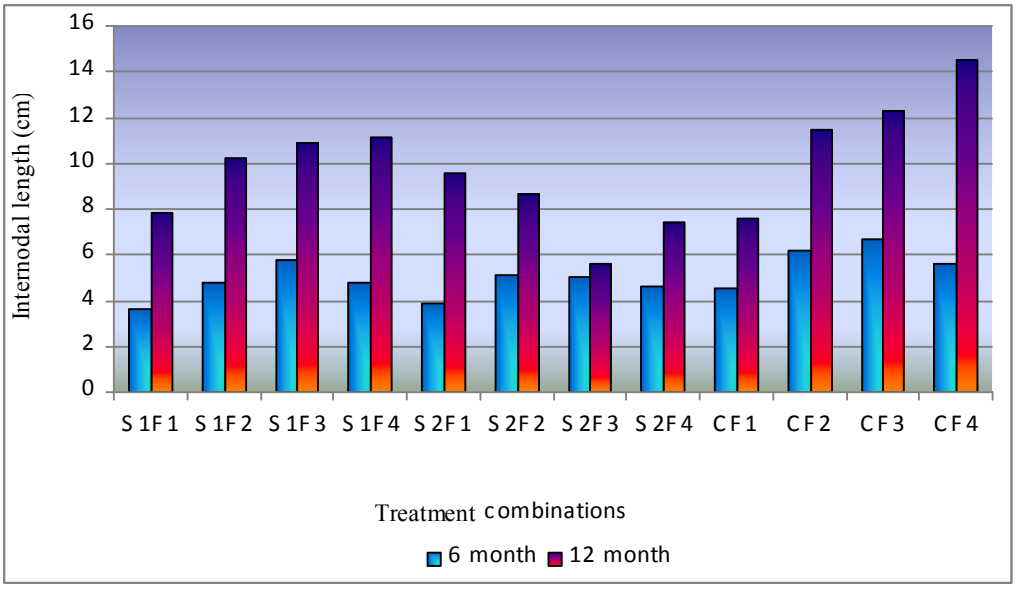


Fig 4. *B. balcooa*. Internodal length seedlings at different spacing and fertilizer applications

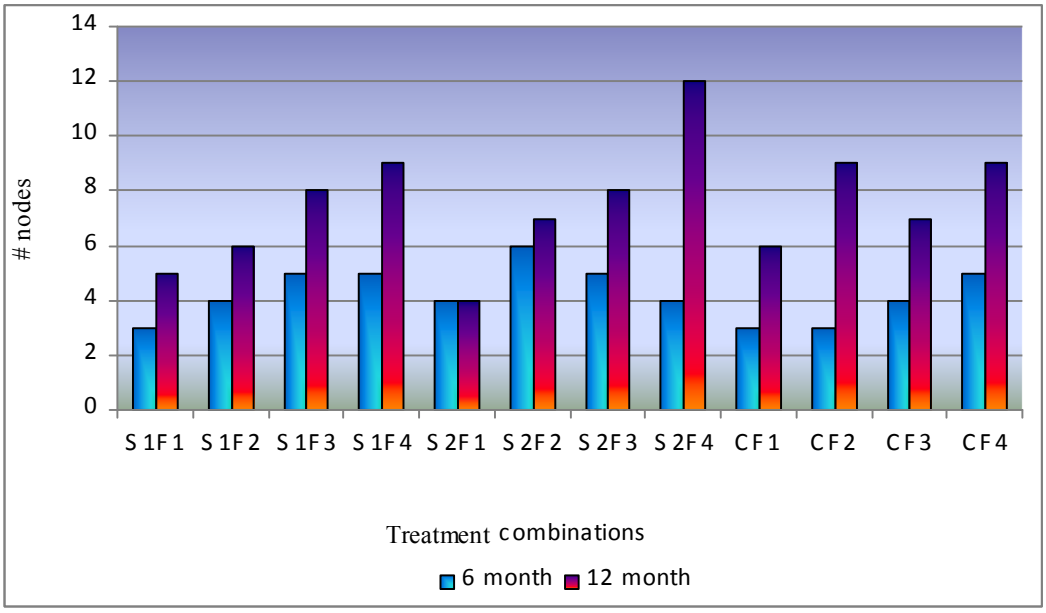


Fig 5. *B. balcooa*. Number of nodes seedlings at different spacing and fertilizer applications

Observations in the Replanted plot

Growth and survival of seedlings after sixth and twelfth month

Survival percentage

The survival percentage of the seedlings was higher in micro-propagated plants than the conventional planting stock(Table 7).

Table 7. The survival at 6th and 12th month after planting in the replanted plot

Treatment	Survival %		Treatment	Survival %	
	6 months	12 months		6 months	12 months
Spacing 5 x 5 m; TC Plants					
S^1F^1	100	86	S^2F^3	100	91
S^1F^2	100	92	S^2F^4	100	100
S^1F^3	100	92	Conventionally propagated spacing 5 x 5 m		
S^1F^4	100	100	C F^1	66.66	66.66
Spacing 6x 6 m			C F^2	100	100
S^2F^1 - Control	100	96	CF^3	100	100
S^2F^2 - FYM	100	78	CF^4	100	100

S^1 = spacing 5x 5; S^2 = Spacing 6 x 6 ; F^1= No Fertilizer; F^2 = FYM; F^3 = NPK; F^4 + NPK + FYM; C = Conventionally propagated plants

Number of culms per clump and seedling height

When the out planted propagules were 6 and 12 months old in the field, the highest number of clumps was observed in the treatment S2F2, 3.2 followed by S2F1, 3.1 (Fig. 6). Tallest seedlings (83.5 cm) were observed in the treatment S2F1 (Fig. 7) followed by S2F2 (77.2 cm). The lowest height was observed in the treatment S1F2 (36.5).

Collar girth

Collar girth of the seedlings varied in different treatments (Fig. 8). The highest collar girth was recorded in treatment S2F1 (1.89cm) followed by S2F2 (1.65 cm). The least collar diameter was observed C F1 (0.9 cm).

Internodal length

Internodal length of the seedlings varied in different treatments (Fig. 9). The highest internodal length was recorded in the treatment S1F1 (16.5 cm) and lowest in C F4 (7.2cm).

Number of nodes per culm

Twelve months after planting, the number of nodes of the seedlings also varied due to different treatments (Fig. 10). The highest number of nodes were present in the treatment CF2 (8) and CF4. The lowest number of nodes was observed in S2F2 (4).

Erratic flowering

Erratic flowering of two TC plants was observed one year after planting. Seed formation or growth of wildings under flowered plant was not observed. During the next growing season vegetative growth was resumed.

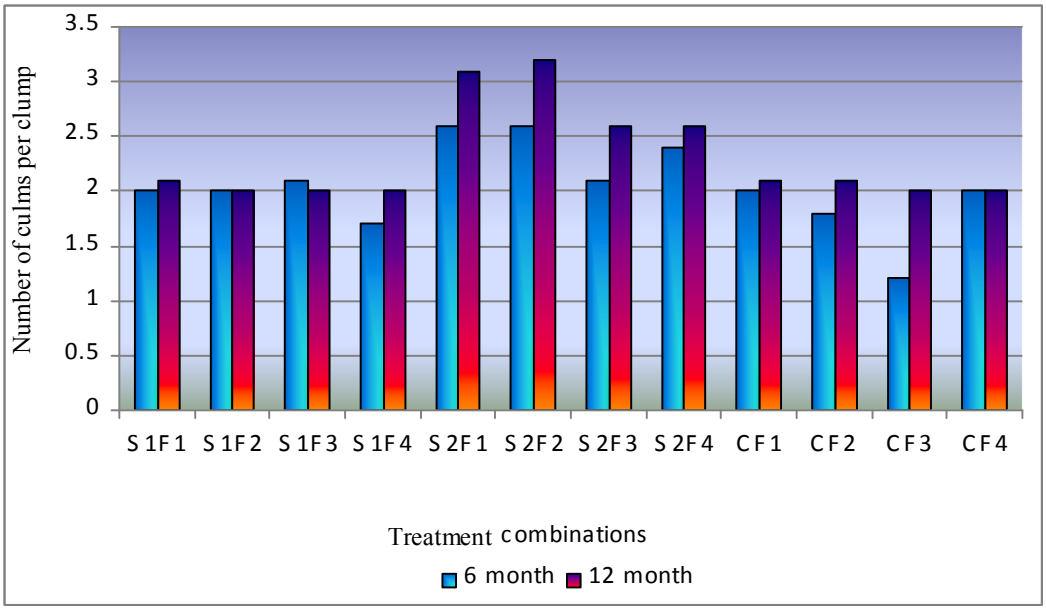


Fig 6. *B. balcooa*. Number of tillers per clump at different spacing and fertilizer applications in replanted plot

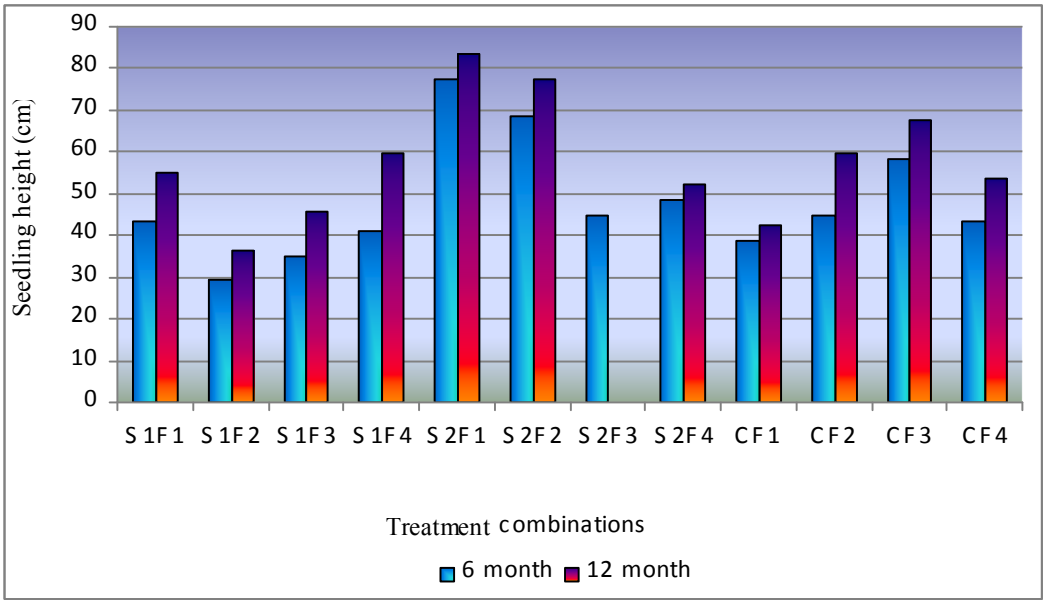


Fig 7. *B. balcooa*. Height at different spacing and fertilizer applications in replanted plot

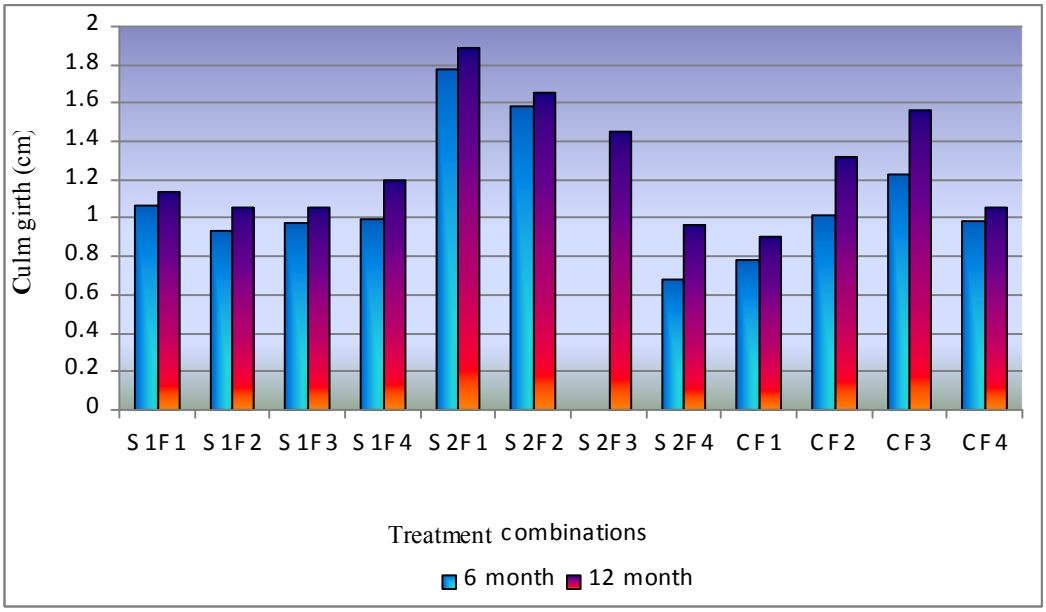


Fig 8. *B. balcooa*. Collar girth of plants at different spacing and fertilizer applications in replanted plot

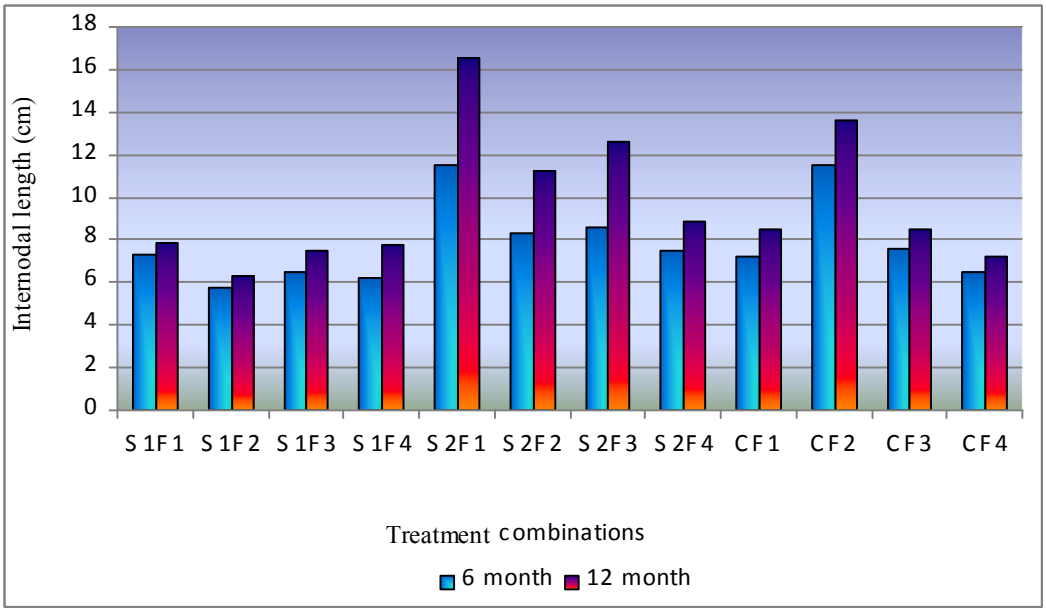


Fig 9. *B. balcooa*. Internodal lengthof plants at different spacing and fertilizer applications in replanted plot

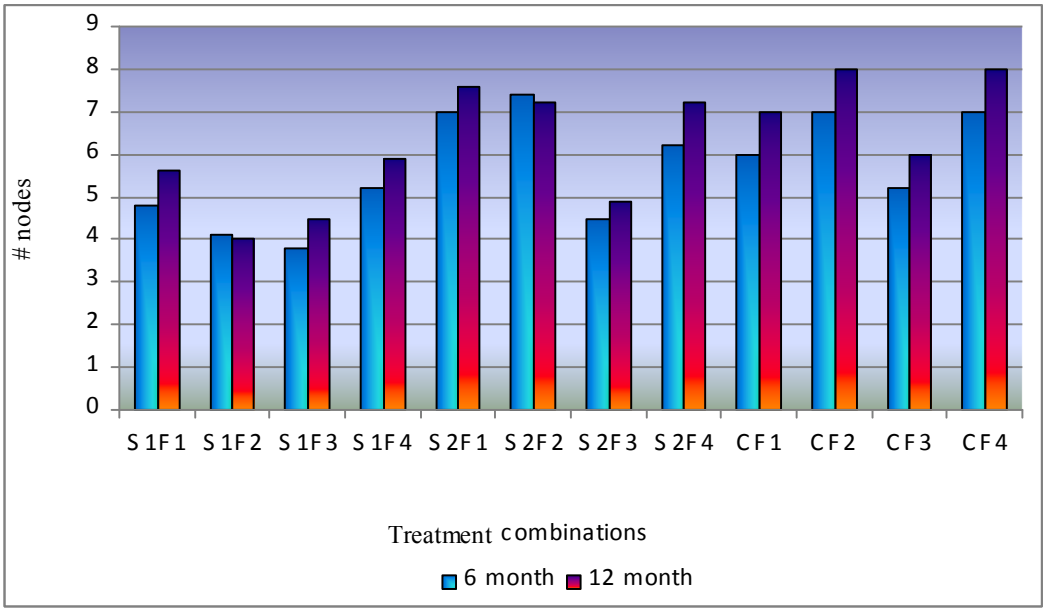


Fig 10. *B. balcooa*. Number of nodes seedlings at different spacing and fertilizer applications in replanated plot

Dendrocalmus asper

Observations were recorded at one, two, six and twelve months after planting. During first two observations only percentage of survival was recorded. One hundred per cent survival was observed in all the treatments.

Six months after planting: Observation made six months after planting showed that percentage of survival and growth attributes varied due to spacing and fertilizer applications. The highest percentage survival was recorded for the treatment combination CF^3 (97.6%). The number of culms per clump was highest in the treatment S^2F^4 (4.1) and the seedling height was the maximum in the treatment CF^3 (77.6 cm). Maximum collar girth was observed in the treatment CF^2 (1.32 cm). The internodal length and number of nodes were highest in the treatment CF^2 (11.2 cm and 7.1 respectively). Generally rooted cuttings showed better performance over TC plants (Table 8).

Table. 8. Growth attributes as influenced by spacing and fertilizer at sixth months after planting.

Treatment	Survival (%)	No.culms /clump	Height (cm)	Culm girth (cm)	Internode length (cm)	No. nodes
S^1F^1	92.25	2.8	56.3	0.28	8.50	3.6
S^1F^2	90.07	3.2	61.2	0.31	8.23	4.8
S^1F^3	88.80	3.2	32.9	0.19	6.5	3.7
S^1F^4	88.80	2.9	40.13	0.23	7.74	3.4
S^2F^1	86.10	2.2	31.2	0.20	3.6	2.5
S^2F^2	93.50	2.5	30.8	0.21	6.1	3.2
S^2F^3	85.10	1.7	20.5	0.12	4.35	1.8
S^2F^4	92.25	4.1	40.86	0.23	7.8	3.9
CF^1	88.8	1.2	74.5	1.20	7.5	6

CF^2	89.5	2.1	68.9	1.32	11.2	7.1
CF^3	97.6	1.8	77.8	0.98	10.5	6.2
CF^4	92.3	2.1	64.5	0.97	6.8	6.7

One year after planting: Maximum percentage of survival was obtained in the treatment CF^3 (97.6%) followed by S^2F^2 (93.5%) while lowest survival percentage was observed in S^1F^1 (82.5 %). The highest number of culms was obtained in the treatment S^2F^{24} (4.1).

The height of the plants at the end of the observation ranged from 76.3 to 162 cm. Maximum height was observed in the treatment CF^2 (Fig. 11). The lowest height was observed in the control seedlings at spacing 5x5 (S^1F^1).

Collar girth of the seedlings varied due to different treatments (Fig. 12). The highest collar diameter was recorded in the treatment CF^3 (1.46 cm) followed by CF^4 and S^1F^2. The lowest collar girth was observed S^2F^1 (1.2 cm).

Internodal length of the seedlings varied due to different treatments (Fig. 13). The highest internodal length was recorded in the treatment S^1F^3 (16.5 cm) followed by CF^3 (14.5 cm). The lowest internodal length was observed S^2F^3 (6.8 cm).

At the end of the observation, the number of internodes of the seedlings also varied due to different treatments (Fig. 14). The largest number of nodes was present in the treatment $S^1F^4$and S^2F^3 (2). The least number of internodes was observed in CF^1 (5).

Table 9. Variation in survival percentage and number of culms per clump of *D. asper* due to spacing and fertilizer application at twelfth month after planting.

Treatment	Growth		Treatment	Growth	
	Survival	No. Culms		Survival	No. Culms
Spacing 5 x 5 m; TC Plants					
S^1F^1	82.25	2.8	S^2F^3		1.7
S^1F^2	90.07	3.2	S^2F^4	92.25	4.1
S^1F^3	88.80	2.9	Conventionally propagated spacing 5 x 5 m		
S^1F^4		100	C F^1	88.8	1.2
Spacing 6x 6 m			C F^2	89.5	2.1
S^2F^1	86.10	2.2	CF^3	97.6	1.8
S^2F^2	93.50	2.5	CF^4	92.3	2.1

S^1 = spacing 5x 5; S^2 = Spacing 6 x 6 ; F^1= No Fertilizer; F^2 = FYM; F^3 = NPK; F^4 + NPK + FYM; C = Conventionally propagated plants

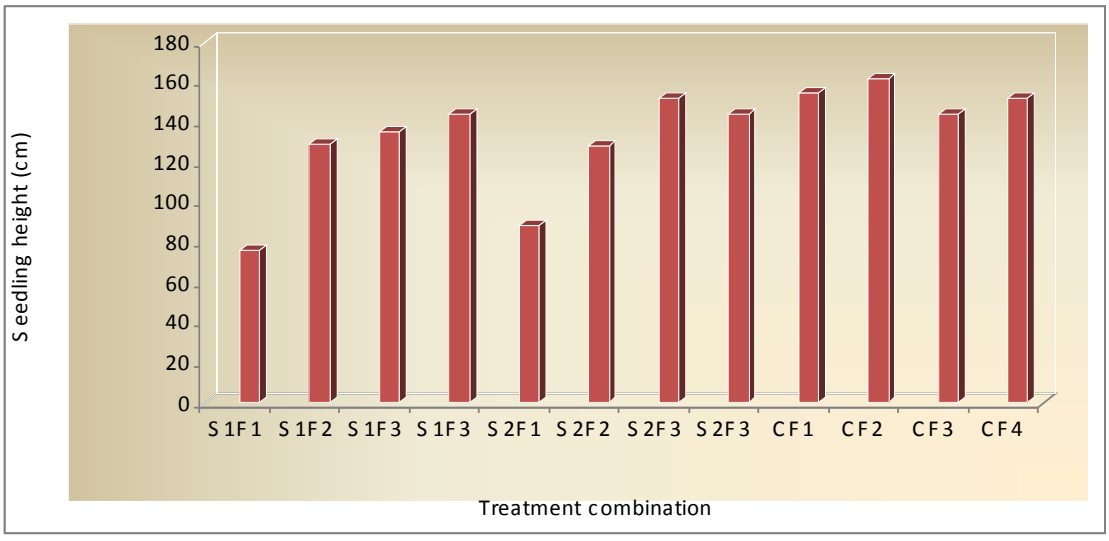


Fig. 11. Variation in height of *D. asper* seedlings due to spacing and fertilizer application at twelfth month after planting.

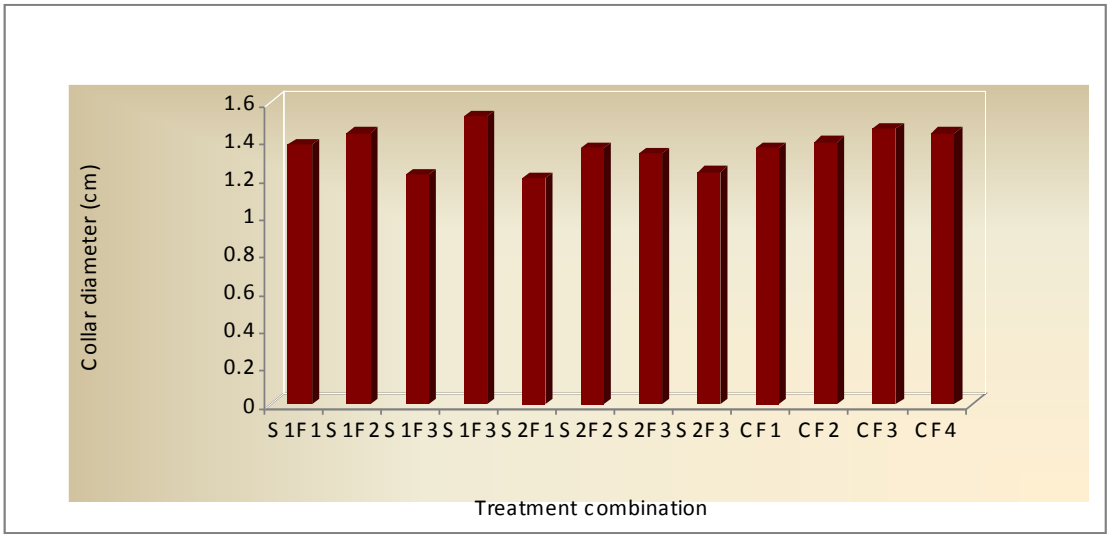


Fig. 12. Variation in collar girth of D. *asper* seedlings due to spacing and fertilizer application at twelfth month after planting.

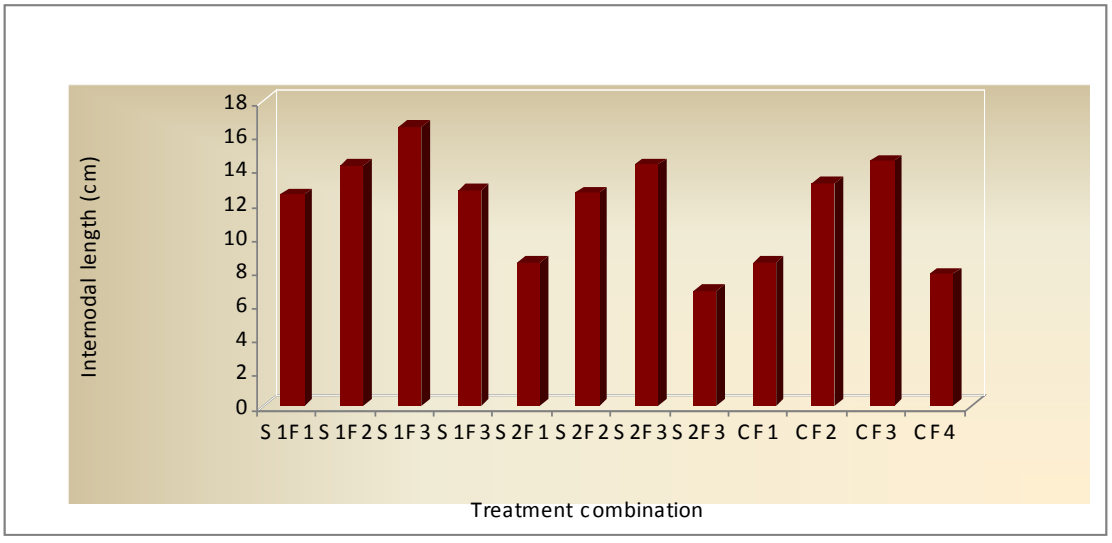


Fig. 13. Variation in internodal length of D. *asper* seedlings due to spacing and fertilizer application at twelfth month after planting.

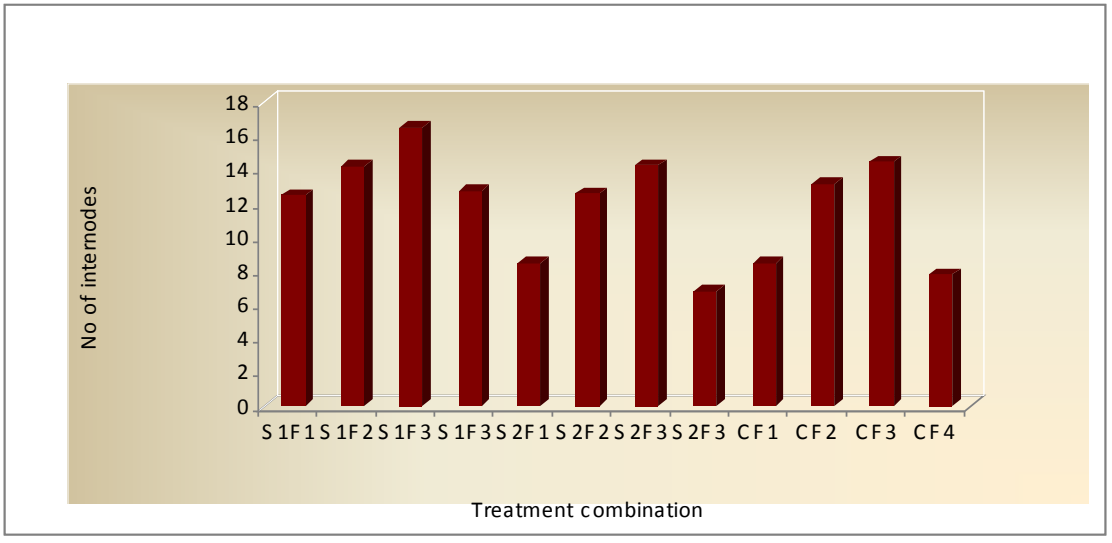


Fig. 14. Variation in number of nodes of *D. asper* seedlings due to spacing and fertilizer application at twelfth month after planting.

Fig. VI. 1 & 2. Views of the *B. balcooa* TC plants three year after planting. 3. Close up of the clump 4. Irregular flowering of one TC plant of *B. balcooa* 5. A view of the plantation of *D. asper*. 6. Close-up of *D. asper* plants three years after planting

The initial observations indicate that of the two species tried, *B. balcooa* exhibited better growth when compared to *D. asper* in Moolagangal (Both rooted cuttings and TC plants). Long-term observations are being continued on block planting.

DISCUSSION

In *B. balcooa,* initially the survival and growth of the seedlings from tissue cultured and conventional rooted cuttings were similar. However at the end of the first year, in the first trial the rooted cuttings showed a higher survival percentage compared to tissue cultured planting stock. Plants were taller with higher collar girth and internodal length. Both spacing and fertilizer applications also influenced the growth of the seedlings. The observations carried out after replanting showed a higher survival for tissue cultured planting stock compared to rooted cuttings. The treatment combinations $S^2F^1$and S^2F^2 (spacing 6 x 6 m fertilizer control and FYM) showed higher growth attributes compared to other treatments. When replanting was done TC plants were one-year-old.

From the data collected for one year indicated that both TC and vegetatively propagated plants of *B. balcooa* survived equally well in this locality. The growth for initial years was satisfactory. Erratic flowering was found in some of the TC plants which is reported as common in tissue culture plants. Although synchronous flowering is reported in vegetatively propagated planting stock using conventional methods of vegetative propagation such as offset planting, rooting of cuttings, etc there is no information of flowering of TC planting stock. Long-term observation for a minimum of five years is required for any critical assessment about the performance of the species. Probably the drip irrigation provided in the plot, resulted in the higher per cent survival. The performance under rain fed condition needs to be studied.

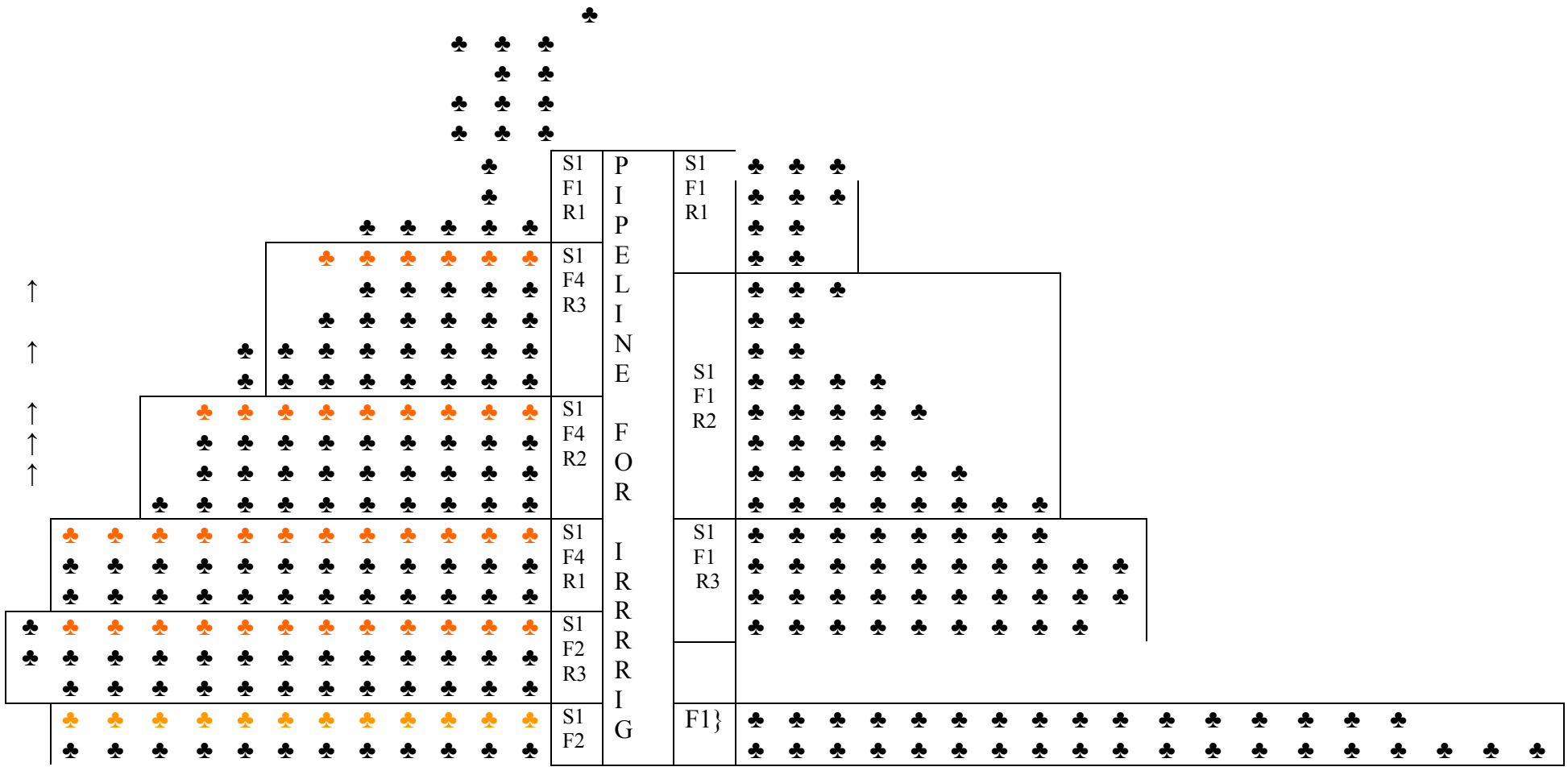
D. asper was not very promising in this location as compared to *B. balcooa.* The plants appeared stunted and yellowish. Further observations are continued after application of FYM.

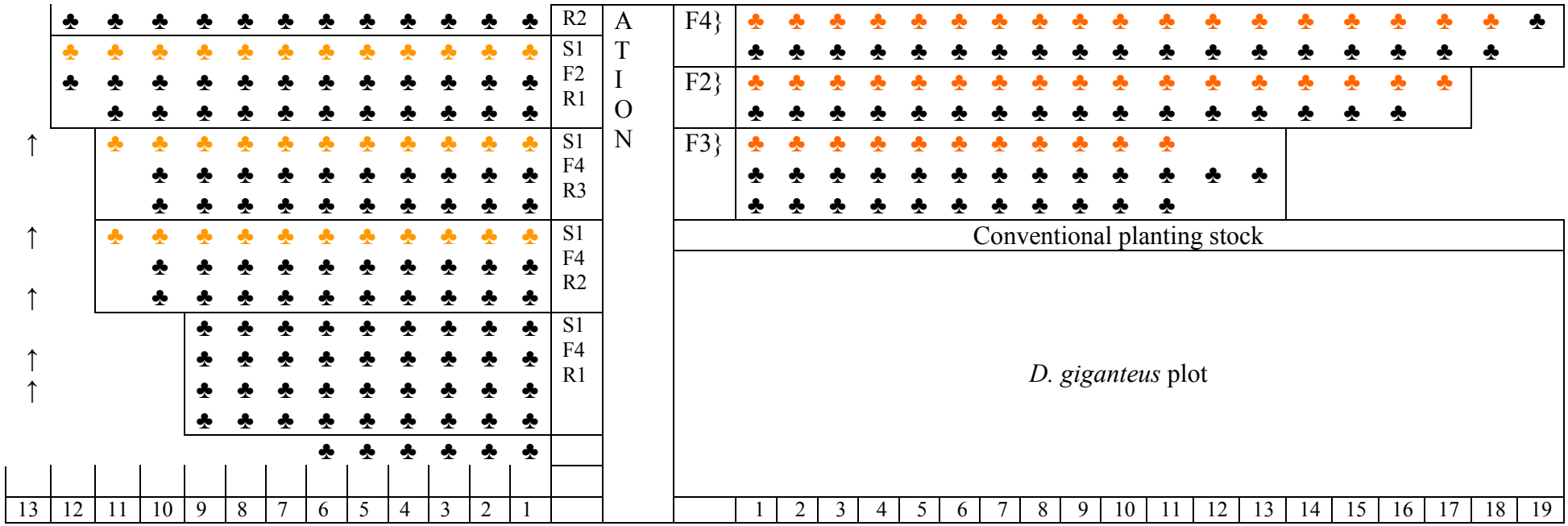
Out of five species proposed for the project, the experimental plantations could be established for only two species. However, small scale planting of two species was done under the riverbank stabilization programme. As per the guidelines, the tissue cultured

plants and vegetatively propagated plants are required to be from the same mother plants. In *B. bambos* and *D. strictus* no TC plants from auxiliary buds were available. Further, the plantations were established in collaboration with a private planter and these two species since locally available it was of no interest to them. Generally species without thorns are preferred by farmers. *D. stocksii* vegetative propagation materials were raised in a nursery in Kasaragode District and brought to planting site. Although planting was carried out, it flowered and died. Although TC plants were supplied there was mixing up with *B. bambos*. Further supply of TC seedlings was not obtained.

Appendix I

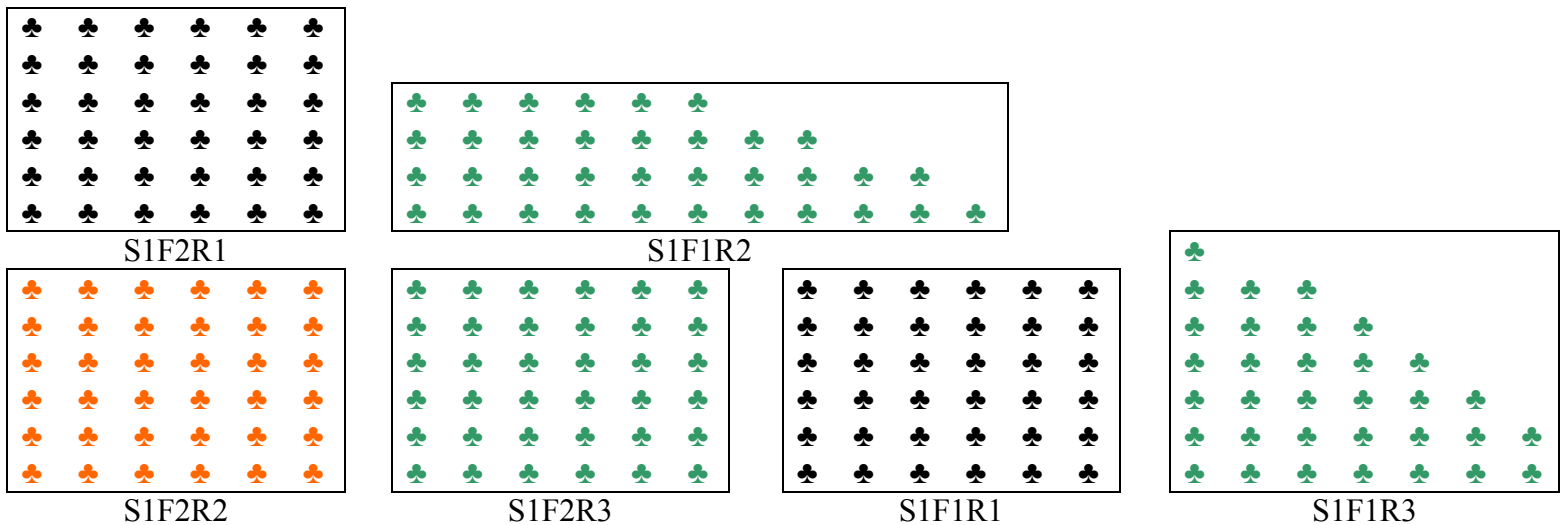
DENDROCALAMUS ASPER EXPERIMENTAL PLOT AT MOOLAGANGAL





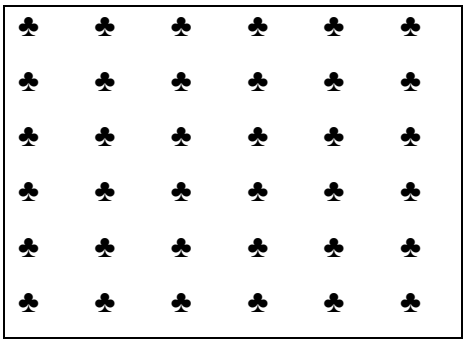
S1: 5x5 m, F1: control, F2 : FYM F3: NPK and F4: NPK+FYM

BAMBUSA BALCOOA EXPERIMENTAL PLOT 1

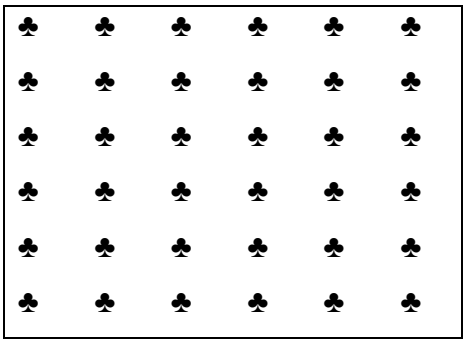


(S1: 5x5 m, F1: control, F2 : FYM)

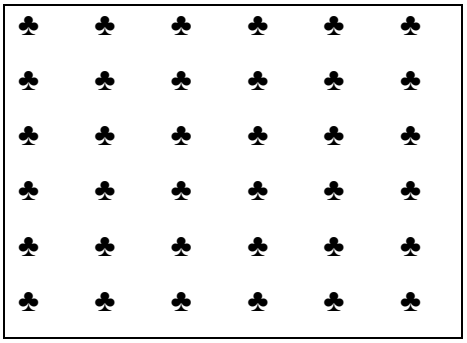
BAMBUSA BALCOOA EXPERIMENTAL PLOT 1I



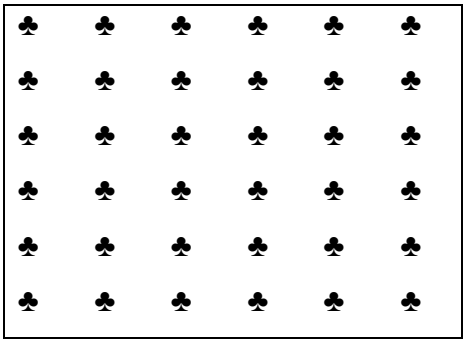
S1F3R3



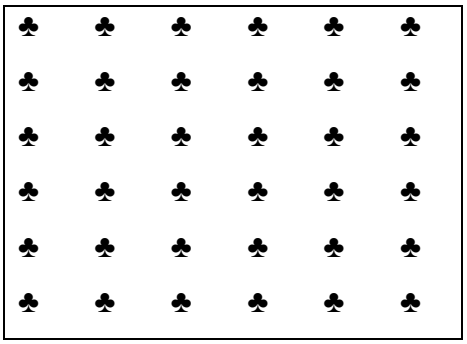
S1F4R3



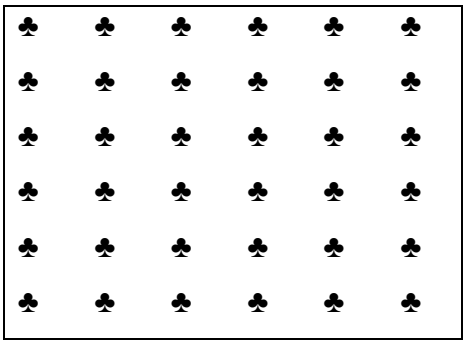
S1F3R2



S1F4R2



S1F3R1



S1F4R1

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ROAD ► ►

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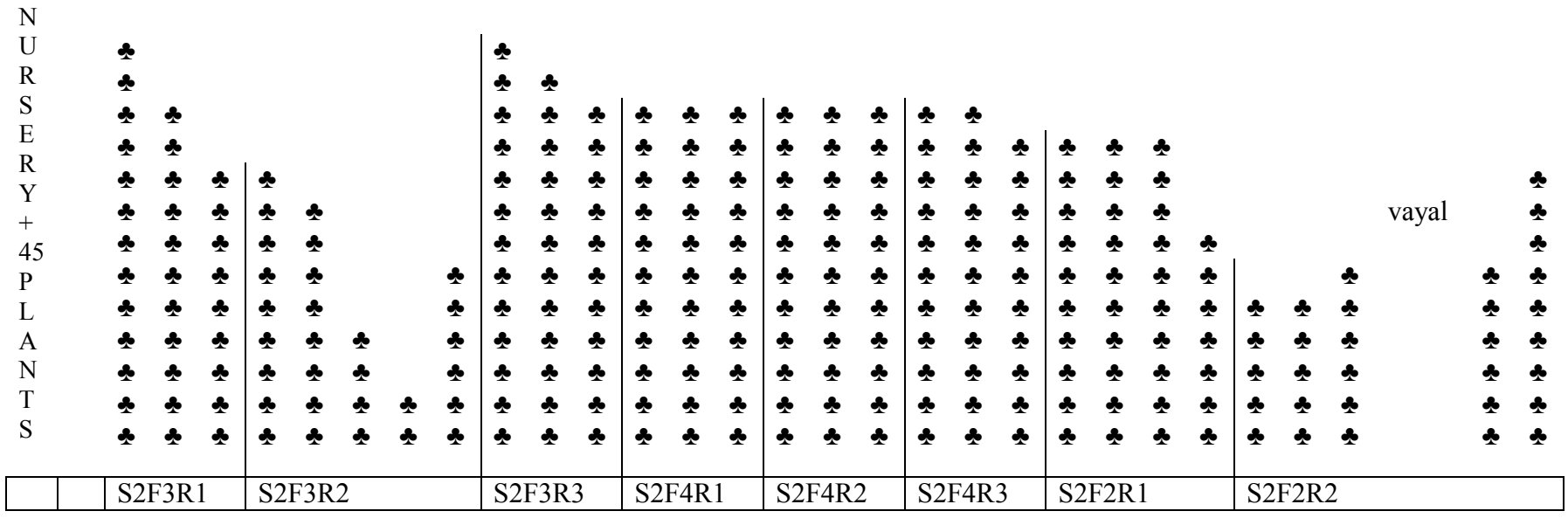
(S1=5x5 m F3: NPK and F4: NPK+FYM)

BAMBUSA BALCOOA EXPERIMENTAL PLOT III



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ROAD ► ►

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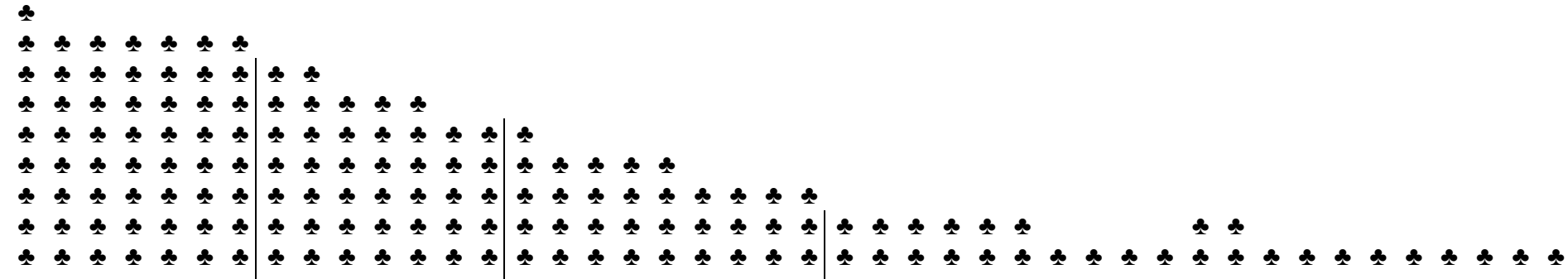
(S2=6x6 m, F2=FYM, F3: NPK and F4: NPK+FYM)

BAMBUSA BALCOOA EXPERIMENTAL PLOT IV



S2F2R3	S2F1R1	S2F1R2	S2F1R3

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ROAD ►

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(S2: 6x6 m, F1: control, F2 : FYM)