



# Development of a Dwarf x Tall coconut hybrid 'Kalpa Samrudhi'

**B. Augustine Jerard\*, V. Niral, K. Samsudeen, R.V. Nair, C. Jayabose and George V. Thomas**

*ICAR-Central Plantation Crops Research Institute, Kasaragod-671124, Kerala, India*

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## Abstract

An evaluation trial conducted over 28 years on coconut hybrid combinations has resulted in identification of a superior, high yielding Dwarf x Tall hybrid, named as 'Kalpa Samrudhi' involving IND 058S as female parent and IND 069S as male parent. The results revealed that the hybrid is better performing over other hybrids and local control with higher fruit yield (117 fruits palm<sup>-1</sup> year<sup>-1</sup>), high copra out turn (25.72 kg palm<sup>-1</sup> year<sup>-1</sup> or 4.5 t ha<sup>-1</sup> year<sup>-1</sup> copra) and estimated oil recovery of 3.04 tonnes ha<sup>-1</sup> under rainfed conditions of Kerala. The palms of the hybrid are semi tall, take an average of 45 months for initiation of flowering under rainfed conditions, possess good tender nut water quality (TSS 6° Brix) and higher quantity (346 mL per tender nut). The tender nut water has Na content of 35.1 ppm and K content of 2370 ppm. The hybrid recorded 30.27 per cent more nut yield, 66.05 per cent more copra yield and 73.71 per cent more oil yield over another released Dwarf x Tall hybrid 'Chandra Sankara'. The seedlings of the hybrid are more vigorous, producing higher number of leaves within 12 months, having higher leaf area and dry weight indicating precocity in growth and development. The flowering, morphological and fruit component traits of the hybrid were compared with parental palms. The characteristics of this hybrid and its performance indicate potential to increase the production and productivity of coconut.

*Keywords:* Coconut breeding, *Cocos nucifera*, hybrid evaluation, copra, tender nut

## Introduction

Coconut is an important multi-purpose palm grown widely in the humid tropics and is known as 'Kalpavriksha' in India which provides nutritious food and refreshing drink, oil for edible and non-edible uses, fibre of commercial value, shell for fuel and industrial uses, timber and a variety of miscellaneous products for domestic and industrial use. In recent years, coconut is being increasingly considered as a health food, with virgin coconut oil, tender coconut water and inflorescence sap being promoted for consumption. Perennial nature of palms, higher level of heterozygosity, long juvenile phase, need for larger area and longer time for experimentation and lack of technologies for mass propagation of palms with targeted traits are the impeding factors in successful breeding efforts. The breeding efforts are mostly confined with

conventional approaches such as mass selection and hybridization besides attempts to use individual palm selection for novel traits. The major classification of coconut is based on stature and breeding behaviour which groups coconut broadly into two groups or types *viz.*, Tall and Dwarf. The Tall type is primarily out-crossing while the Dwarf type is mainly self pollinating (with a few exceptions). The Tall cultivars are the most common, commercially cultivated in all coconut growing regions of the world while the Dwarf varieties are usually grown for ornamental and breeding purpose. The Tall and Dwarf types have been utilized for development of hybrid varieties, combining the early flowering trait of dwarfs with the hardiness and high yielding character of Tall parents and also exploitation of hybrid vigour. The present day varieties grown in different coconut

\*Corresponding Author: [jerardba@yahoo.com](mailto:jerardba@yahoo.com)

growing regions are mostly selections from the Tall cultivars or Dwarf cultivars or hybrids among the selected Dwarf and Tall types.

The discovery of hybrid vigour in coconut by Patel (1937) in a cross between West Coast Tall and Chowghat Green Dwarf made in 1932 at Coconut Research Station, Nileshwar was a significant landmark in the history of crop improvement in coconut. This important finding paved the way for the successful breeding programmes in coconut not only in India but also in other countries like the Philippines, Indonesia, Sri Lanka, Côte d'Ivoire and Jamaica. Superior varieties selected after evaluation of germplasm have been utilized in crosses to develop high yielding hybrids. The inter-varietal hybridization in coconut breeding, demonstrated the usefulness of heterosis in coconut. Most of the hybrid tests that were conducted involved inter-varietal crosses of Dwarf x Tall and Tall x Dwarf types and the superiority of hybrids over local tall cultivars were established.

The present investigation was carried to select a better performing coconut hybrid from the crosses that were planted at Kasaragod, Kerala during 1981 and evaluated for yield attributes.

### Materials and methods

The experiment was conducted at Indian Council of Agricultural Research-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod situated at latitude of 12°31' 47.4517" N and longitude of 74° 58' 5.9568" E at an altitude of 18 m from mean sea level. The average maximum temperature is 40 °C in summer and 33 °C in winter while the average minimum temperature is 24 °C

in summer and 18 °C in winter. The annual rainfall varied between 2800 and 4200 mm.

The experimental material consisted of four cross combinations including released hybrids *viz.*, Chandra Sankara (COD x WCT), MAWA (MYD x WAT), IND 376 (IND 058S x IND 069S), Kera Sankara (WCT x COD) along with WCT (West Coast Tall) as local control. The details of parents are presented in Table 1. Hybrid seed nuts were produced through emasculation and pollination method. The F<sub>1</sub> hybrid seedlings were selected and planted at ICAR-CPCRI, Kasaragod during 1981 and evaluated for yield performance. The hybrids along with control were planted in a replicated trial in completely randomized design with five replications having six palms each. Spacing adopted was 7.5 x 7.5 m with palm density of 175 palms per hectare. The trial was under rainfed conditions till 2008 and the yield data in terms of nut production, estimated copra out turn, tender nut traits recorded from 1999 to 2008 (ten years) was used for assessing the performance of the hybrids for fruit yield. The high yielding hybrid in the trial was selected and the observations on morphological, tender fruit traits *viz.*, tender fruit weight (g), volume of water (mL), total soluble solids (° Brix), total sugars (g 100 mL<sup>-1</sup>), amino acids (mg 100 mL<sup>-1</sup>), sodium (ppm) and potassium (ppm) content were recorded. The morphological traits of the palms of selected hybrid IND 376 were recorded through standard procedures (IPGRI, 1995) and the DUS traits were recorded as per the guidelines notified by PPV&FR Authority (Anon., 2011). The fruit yield, copra content and copra yield were estimated and the description of the hybrid IND 376 were recorded. The information generated from earlier studies on

**Table 1. Details of parental palms used in the crossing**

SI No	Hybrid	Parental information	Abbreviation
1	Chandra Sankara	Selection from Chowghat Orange Dwarf as female parent and selection from West Coast Tall as male parent	COD x WCT
2	MAWA	Selection from Malayan Yellow Dwarf as female parent and selection from West African Tall as male parent	MYD x WAT
3	IND 376	Selection from Malayan Yellow Dwarf as female parent and selection from West Coast Tall as male parent	MYD x WCT
4	Kera Sankara	Selection from West Coast Tall as female parent and selection from Chowghat Orange Dwarf as male parent	WCT x COD
5	West Coast Tall	Selection from West Coast Tall	WCT

the fatty acid profile, reaction to environmental stresses, biochemical constituents of seedlings of the hybrid combination (CPCRI, 1991, 1992 and 1994; Shivasankar and Chempakam, 1999; Voleti *et al.*, 1991; Rajagopal *et al.*, 1991; Shivasankar and Kasturi Bai, 1988; Thomas *et al.*, 1993) were collected and used. The seedling parameters such as the height, girth, number of leaves and split leaves were assessed by producing hybrid seedlings using the selected parental palms during 2007 to 2008. The data on the morphological and fruit component traits of parental palms were also recorded for comparison.

## Results and discussion

Earlier experiment conducted in Côte d'Ivoire in 1971 to test the three possible hybrids between Malayan Yellow Dwarf (MYD), Malayan Red Dwarf (MRD) and Brazil Green Dwarf (BGD with MYD as control (Le Saint and Nuce de Lamothe, 1987), revealed that the hybrid MYD x MRD produced an average of 3.8 tonnes copra per hectare which was comparable to the production level of a good D x T hybrid. This method, initially developed by CIRAD in the 1970s, was applied mainly in Côte d'Ivoire and Vanuatu on D x T and T x T hybrids using the West African, Rennell Island, Tahiti and Vanuatu populations of Talls. In India, the hybrids, MYD x WCT and MYD x WAT were compared with the released hybrids *viz.*, 'Chandra Sankara' (COD x WCT) and 'Kera Sankara' (WCT x COD).

The hybrid PB121 (MYD x WAT), a cross between the MYD and a selected population of WAT was reported as better performing in Côte d'Ivoire (Bourdeix *et al.* 1992). Forty-five WAT parent palms were selected based on phenotype and individually crossed with the same MYD population. The 45 progenies thus obtained were

considered half-sib families. In only one generation of breeding, it was possible to improve the yield of the earlier PB121 hybrid from 15 to 25 per cent (Bourdeix *et al.* 1992). In the present study, a better performing hybrid could be identified with a selection of MYD (IND 058S) crossed with a selection of WCT (IND 069S) which is a predominant local tall population with high adaptability. The better performance of IND 376 (IND 058S x IND 069S) over MYD x WAT in the present study may be attributed to the WCT's performance as a pollen parent or specific combining ability of MYD x WCT. An earlier study at ICAR-CPCRI has indicated Gangabondam Green Dwarf (GBGD) to be a good general combiner and LCT x GBGD as a good specific combiner (Nampoothiri *et al.*, 1999).

In the present investigation, the average fruit yield recorded over ten years from 1999 to 2008 and the estimated mean copra yield of hybrids and WCT are given in Table 2. The average fruit yield over ten years among the hybrids and WCT ranged from 89.88 fruits per palm per year (WCT) to 117.2 fruits per palm per year (IND 376). The hybrid IND 376 performed significantly better than other hybrids and WCT for fruit yield and this hybrid with copra content of 219.46 g also recorded the highest values compared to other hybrids and local control. The comparative performance of the hybrid IND 376 was assessed based on the performance of the released hybrid 'Chandra Sankara' in terms of mean fruit yield, copra yield and oil yield (Table 3). It was estimated that the hybrid gives 30.27 per cent more fruit yield, 66.05 per cent more copra yield and 73.71 per cent more oil yield over the released hybrid 'Chandra Sankara'. The potential yield was estimated based on the average yield of the top 50 per cent selected high yielding palms in each

**Table 2. Mean performance of hybrids over ten years from 1999 to 2008**

Variety	Fruit yield (No. palm <sup>-1</sup> year <sup>-1</sup> )	Copra content (g fruit <sup>-1</sup> )	Copra yield (kg palm <sup>-1</sup> )	Copra out turn (t ha <sup>-1</sup> )	Oil in copra (%)	Oil yield (t ha <sup>-1</sup> )
Chandra Sankara	89.97	172.12	15.49	2.71	64.5	1.75
MAWA	90.57	196.48	17.80	3.11	66.0	2.06
IND 376	117.20	219.46	25.72	4.50	67.5	3.04
Kera Sankara	92.47	168.56	15.59	2.73	66.1	1.80
WCT	89.88	178.32	16.03	2.80	66.4	1.86
CD 5%	9.73	19.63	2.45	0.43		

**Table 3. Comparative performance of the hybrid IND 376 under rainfed conditions**

Particulars	Mean fruit yield (No. palm <sup>-1</sup> year <sup>-1</sup> )	Copra yield (t ha <sup>-1</sup> )	Oil yield (t ha <sup>-1</sup> )
IND 376	117.20	4.50	3.04
Chandra Sankara	89.97	2.71	1.75
Per cent increase over Chandra Sankara	30.27	66.05	73.71

hybrid and control and the potential for copra out turn and oil yield were estimated. The hybrid IND 376 exhibited potential yield of 25025 fruits per ha per year which will deliver 5.49 tonnes of copra per ha containing about 3.70 tonnes of oil per ha (Table 4). Based on the flowering data recorded earlier, the hybrid palms were reported to be regular bearers and commenced flowering in 45 months after planting under rain-fed conditions at ICAR-CPCRI, Kasaragod. Time taken for flowering of 50 per cent of the palms in the hybrid population was 60 months (CPCRI, 1994). The oil extracted from the copra of this hybrid was reported to have 45.4 per cent lauric acid (Naresh Kumar *et al.*, 2004). Based on the average and potential fruit yield, copra content, copra out turn and oil yield, the hybrid IND 376 was selected for further study, and the palms of this hybrid and the parental accessions of this hybrid were subjected to other observations.

The morphological traits of the parental and hybrid palms are shown in Table 5. The palms of IND 376 are semi-tall and attain an average height of 733.82 cm, 28 years after planting. The palms are without prominent bole. The colour of the petiole is green and bears green coloured, oval fruits and the husked fruits are round in shape. The selected, typical, seedlings of this hybrid are vigorous, producing more number of leaves, higher collar girth within 12 months, and have more leaf

area and shoot dry weight when compared to the selected seedlings of released hybrid Chandra Sankara (Table 6). The palms of the female parent are dwarf, take average of 66 months for flowering under rainfed conditions, bear bright yellow fruits and have yellow petiole colour. The palms of male parent are tall, bear green fruits and take about 98 months for flowering under rainfed conditions. The hybrid palms exhibited desirable values for weight of fruits, fruit yield, weight of kernel and copra content besides many morphological traits such as earliness for flowering, shorter inflorescences and higher number of female flowers. The tender nut traits of the hybrid IND 376 (Table 7) showed the potential of the hybrid for tender nut purpose. The average quantity of tender nut water was 346 mL. Based on the organoleptic test; the tender nut water is classified as “good” in taste with a TSS of 6° Brix. The tender nut water recorded Na content of 35.1 ppm and K content of 2370 ppm.

The hybrid IND 376 was reported to exhibit higher level of drought tolerance owing to the different physiological and biochemical traits, epicuticular wax content and also VAM association (CPCRI, 1991, 1992, 1994; Voleti *et al.*, 1991; Rajagopal *et al.*, 1991; Shivasankar and Kasturi Bai, 1988; Thomas *et al.*, 1993; Shivasankar and Chempakam, 1999). The studies conducted at CPCRI revealed that the desirable levels of leaf water potential, stomatal resistance and specific leaf weight measured during pre stress and stress periods indicated better conservation of water by IND 376 than ‘Chandra Sankara’. It was reported that IND 376 exhibited six to seven fold increase in stomatal resistance during severe stress as compared to pre-stress, thus checking the transpirational loss of water. IND 376 was reported to maintain relatively higher leaf water potential during stress (-7.6 bars) as compared with ‘Chandra Sankara’ (-10.00 bars).

**Table 4. Mean and potential yield of IND 376 compared with released hybrids and WCT**

Performance	Chandra Sankara	MAWA	IND 376	Kera Sankara	WCT
Mean fruit yield per ha (Nos)	15745	15850	20510	16183	15729
Mean copra yield per ha (t)	2.70	3.11	4.50	2.73	2.80
Mean oil yield per ha (t)	1.75	2.06	3.04	1.8	1.86
Potential nut yield per ha (Nos)	21350	20825	25025	23100	22750
Potential copra per ha (t)	3.67	4.09	5.49	3.89	4.06
Potential oil yield per ha (t)	2.37	2.70	3.70	2.57	2.69

**Table 5. Morphological and fruit component traits of IND 376 compared with parental palms**

SI No.	Parameters	Male parent IND 069s	Female parent IND 058s	IND 376
1	Age of measurement (years)	26	22	28
2	Category	Tall	Dwarf	Semi Tall
3	Crown shape	Circular	Circular	Circular
4	Presence of bole	Present	Absent	Absent
5	Plant height (cm) at 28 years of age	750.3	376.8	733.82
6	Girth of trunk (cm)	79.3	62.9	69.36
7	Total number of leaves	36	31	33
8	Length of petiole (cm)	136.9	109.9	122.27
9	Length of leaflet bearing portion (cm)	421.1	326.1	376.45
10	Number of leaflets	122	90	109
11	Length of leaflet (cm)	122	105	122.73
12	Breadth of leaflet (cm)	5.9	4.68	6.01
13	No. of leaf scars in 1 m length	15.2	33.5	25
14	Length of 10 internodes (cm)	51.5	31.0	39.18
15	Age at 50% flowering (months)	98	66	60
16	Length of inflorescence (cm)	105	81.1	88.64
17	Length of spikelet bearing portion (cm)	47.4	42.8	40.36
18	Length of stalk (cm)	57.6	38.5	48.27
19	Length of spikelet (cm)	40.1	30.9	41.09
20	No. of spikelets in the inflorescence	37.67	39.5	37.18
21	Number of female flowers	18.8	22.5	26
22	Number of inflorescences on the crown	12	10	14
23	Colour and shape of fruit	Green, Oval	Yellow, Oval	Green, Oval
24	Length of fruit (cm)	25.9	18.3	19.38
25	Breadth of fruit (cm)	14.5	14.5	15.44
26	Weight of fruit (g)	1196.12	565.0	1032.33
27	Thickness of husk (cm)			
	Apical	7.25	5.25	6.00
	Distal	3.25	2.75	2.75
	Equatorial	3.00	2.00	2.35
28	Shape of husked fruit	Round	Round	Round
29	Weight of husked fruit (g)	566.38	382.11	681.33
30	Per cent of husk to whole fruit weight	52.31	32.37	34.0
31	Thickness of kernel (cm)	1.2	1.2	1.77
32	Weight of kernel per fruit (g)	283	244.99	359.67
33	Weight of copra per fruit (g)	178	129	219.46

Maintenance of water balance through effective stomatal regulation and wax content coupled with the activities of the stress responsive enzymes indicate the drought tolerant nature of the hybrid IND 376. Induced NR activity and MDH was higher

in IND 376 whereas the activity of degenerative enzymes APH and GOT was lesser as compared with 'Chandra Sankara'. The deposition of wax on leaf surface showed differences between wet and dry season among coconut hybrids. IND 376 had



**Table 6. Seedling parameters of hybrid IND 376 (12 month old) compared with Chandra Sankara**

Parameter	IND 376	Chandra Sankara	't' value
Seedling Height (cm)	164.40	145.40	2.65**
Seedling girth (cm)	17.80	13.40	2.95**
No of leaves	9.00	7.00	3.67**
Leaf area (m <sup>2</sup> )	1.011	0.619	4.12**
Shoot dry mass (g)	197.90	130.67	4.05**

the tendency to accumulate relatively higher epicuticular wax content when compared to 'Chandra Sankara' during both wet and dry seasons.

A positive relationship of vesicular arbuscular mycorrhiza (VAM) colonization was reported with stomatal resistance and leaf water potential, the two characters directly associated with drought tolerance (Thomas *et al.*, 1993). Comparison of VAM colonization pattern during and after stress revealed the superiority of IND 376 over 'Chandra Sankara' in harbouring highest level of VAM colonization in roots during stress period. The relative drought tolerant nature of WCT x COD hybrid was reported earlier, in comparison with COD x WCT by Kumaran *et al.* (2006). Earlier workers concluded that Dwarf x Tall hybrids could boost yield in input intensive situations, while Tall x Dwarf hybrids could be a good alternative for marginal input deficient situations (Liyanage and Luntugan, 1978; Kumaran *et al.*, 2006). The present study indicates that such generalization may not apply in coconut. IND 376, a Dwarf x Tall hybrid has shown better performance under moisture deficit and rainfed conditions in comparison to COD x WCT as detailed in the present day, indicating the possibility of identification of more such Dwarf x Tall hybrids suitable for low moisture (or) rainfed cultivation.

The results on yield performance, tender nut traits, seedling parameters, association with drought tolerance showed the superiority of IND 376 and aided in identification of the hybrid for commercial exploitation. The selected hybrid was named as 'Kalpa Samrudhi' and allotted national identity of IC574568.

The comparison using DUS traits of the hybrid 'Kalpa Samrudhi' with hybrids 'Chandra Sankara' and 'Chandra Laksha' revealed that the hybrid

**Table 7. Tender nut traits of hybrid IND 376**

Parameter	IND 376
Tender Fruit weight (g)	1824.10
Volume of water (mL)	346.36
TSS (° Brix)	6.00
Total sugars (g 100 mL <sup>-1</sup> )	4.17
Amino acids (mg 100 mL <sup>-1</sup> )	2.08
Sodium (ppm)	35.10
Potassium (ppm)	2370

'Kalpa Samrudhi' has distinguishable characters of green petiole, high collar girth, medium inflorescence length, thick inflorescence stalk girth, medium number of female flowers, green fruits, medium fruit length, thick fresh endosperm and high shell weight when compared to reference varieties 'Chandra Sankara' and 'Chandra Laksha'.

Owing to the superior performance of coconut hybrids, there is heavy demand for hybrid varieties which are early and heavy bearing. According to Bourdeix (1999), before 1993, about 400 coconut hybrids were created around the world in national research programmes; however, less than ten of these coconut hybrids have been tested internationally under various ecological conditions. There is potential for 'Kalpa Samrudhi' to be evaluated under different coconut growing zones to upgrade it to an international variety for coconut communities in different coconut growing zones as it is evident that the realisable yield of coconut could be improved through cultivation of improved varieties. The hybrid is superior to the already

**Fig. 1. Kalpa Samrudhi**

released hybrids from ICAR-CPCRI in terms of yield and drought tolerance and hence acceptable to the growers. It is a dual-purpose variety, suitable for copra production and tender nuts. The palms are regular bearers and early flowering. The variety is superior to Chandra Sankara, the earlier released D x T hybrid in terms of annual average nut, copra and oil yield per hectare. For large scale hybrid seed production, hybrid seed gardens are to be established in isolated locations by planting both the parents in a suitable manner to facilitate natural hybrid seed production with regular emasculation in female parental palms. If such gardens are surrounded with other coconut cultivars, then artificial pollination technique (Niral *et al.*, 2009) should be followed for production of hybrids. The hybrid 'Kalpa Samrudhi' if cultivated in large scale, would help in enhancing the product diversification efforts considering its suitability for tender nut consumption, besides helping in sustaining the coconut production under drought situations.

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### References

- Anonymous, 2011. Guidelines for the conduct of test for Distinctiveness, Uniformity and Stability on Coconut (*Cocos nucifera* L.). *Plant Variety Journal of India* **5**(2&3): 33-47.
- Bourdeix, R. 1999. Coconut selection and breeding. In: *Modern Coconut Management*. (Ed.) Ohler, J.G. Intermediate Technology Publications, FAO, Universiteit Leiden. pp. 117-196.
- Bourdeix, R, N'Cho, Y.P., Sangare, A., Baudouin, L. and de Nuce de Lamothe, M.W. 1992. The improved PB121 coconut hybrid, a cross between the Malayan Yellow Dwarf and selected West African Tall parents. *Oléagineux* **47**(11): 619-633.
- CPCRI, 1991. *Annual Report 1990-91*, Central Plantation Crops Research Institute, ICAR, Kasaragod. 154p.
- CPCRI, 1992. *Annual Report 1991-92*, Central Plantation Crops Research Institute, ICAR, Kasaragod. 188p.
- CPCRI, 1994. *Annual Report, 1993-94*, Central Plantation Crops Research Institute, Kasaragod. 193p.
- Kumaran, P.M., Arunachalam, V., Nampoothiri, K.U.K., Pillai, R.V., ratnambal, M.J., Niral, V., Namboothiri, C.G.N. 2006. Performance of coconut hybrids in rainfed conditions. *Journal of Plantation Crops* **34**(1): 11-14.
- IPGRI, 1995. *Descriptors for Coconut (Cocos nucifera L.)*. International Plant genetic Resources Institute, Rome, Italy.
- Le Saint, J.P. and de Nuce de Lamothe, M.W. 1987. Les hybrides de cocotiers nains: performance et intérêt. *Oléagineux* **42**(10): 353-362.
- Liyanage, D.V. and Luntungan, H.T. 1978. Choice of coconut seed for planting in small holdings in Indonesia. *Pemberitsan - Lembaga Penelitian Tanaman Industri*, **29**: 1-11.
- Nampoothiri, K.U.K., Kumaran, P.M., Jerard, B.A. and Ratnambal, M.J. 1999. Combining ability in coconut (*Cocos nucifera* L.). *CORD* **15**(2): 68-75.
- Naresh Kumar, S., Chempakam, B, and Rajagopal, V. 2004. Variability in coconut cultivars for lipid and fatty acid composition of oil. *Tropical Agriculture* **81**(1): 34-40.
- Niral, V., Jerard, B. A., Samsudeen, K. and Nair, R. V. 2009. Hybridization Technique in Coconut. Technical Bulletin, CPCRI, Kasaragod, 26p.
- Patel, J.S. 1937. Coconut breeding. *Proceedings of Association of Economic Biologists* **5**: 25.
- Rajagopal, V., Kasturi Bai, K.V. and Shivasankar, S. 1991. Physiological and biochemical basis of coconut production. *CORD* **7**(2): 12-30.
- Shivasankar, S. and Chempakam, B. 1999. Germination and early seed growth. In: *Advances in Plant Physiology and Biochemistry of Coconut Palm*. (Eds.) Rajagopal, V. and Ramadasan, A., Asian and Pacific Coconut Community, Indonesia. pp. 11-14.
- Shivasankar, S and Kasturi Bai, K.V. 1988. A comparative study of the growth and nitrogen accumulation capacity of hybrid coconut (*Cocos nucifera* L.) seedlings. *Philippines Journal of Coconut Studies* **13**(1): 24-30.
- Thomas, G.V., Rajagopal, V. and Bopaiah, B.M. 1993. VA-mycorrhizal association in relation to drought tolerance in coconut. *Journal of Plantation Crops* **21**(Suppl.): 98-103.
- Voleti, S.R., Shivasankar, S. and Rajagopal, V. 1991. Comparison of physiological and biochemical parameters of coconut hybrid seedlings. *Journal of Plantation Crops* **18**(Suppl.): 104-107.