Advances in Horticulture Vol. 9 – Plantation and Spice Crops Part 1 (1994). Eds: *K.L. Chadha and P. Rethinam* © 1994 Malhotra Publishing House, New Delhi-110 064, India

Improvement of Coconut

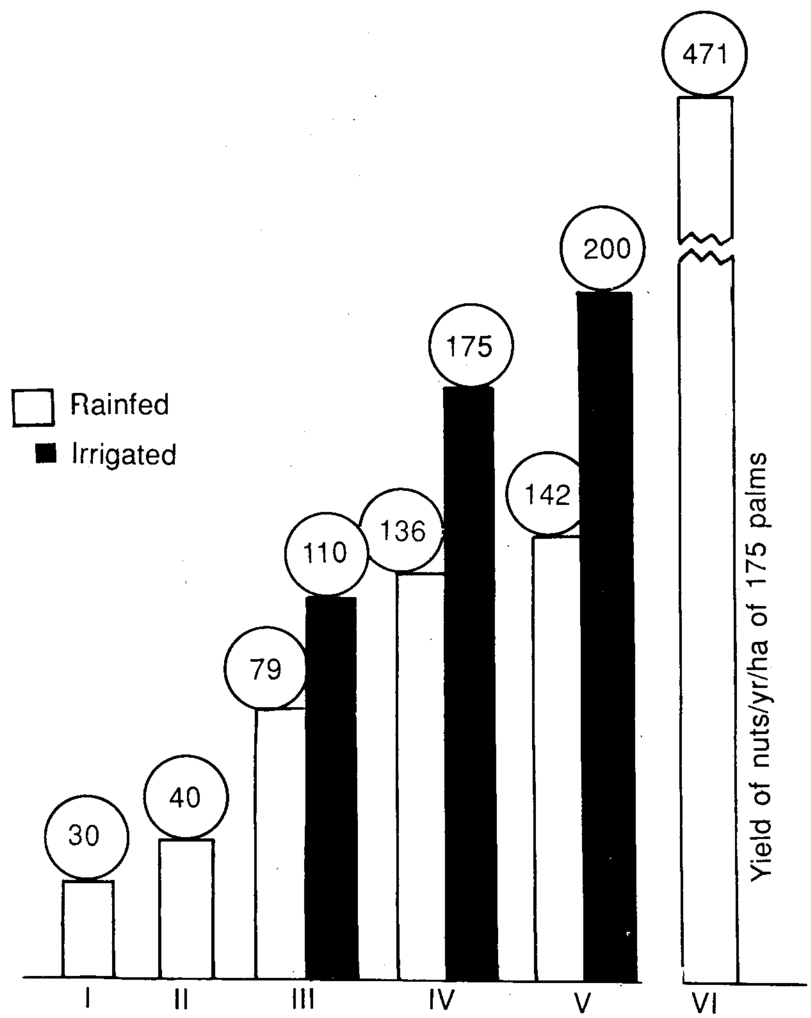
R.D. IYER AND S. DHAMODARAN

1. INTRODUCTION

Improvement of perennial crops in general and coconut in particular is a long-drawn, slow and difficult process, because of : (i) palm's unique floral biology, (ii) its long juvenile phase before flowering, (iii) prolonged interval between generations, (iv) heterozygous nature of the crop, (v) long period of experimentation required to obtain results, (vi) lack of a reproducible asexual method of rapid multiplication, (vii) its low rate of sexual propagation, and (viii) vast land area required for its experimentation because of low planting density. All these handicaps get compounded by the fact that the bulk of the coconut farming is in the small farmers holdings of 0.25 ha average size. Inspite of all these limitations, India has been in the forefront of coconut breeding and crop improvement researches, where organized coconut breeding was started for the first time in the world in 1916 at the erstwhile Coconut Research Stations at Kasaragod and Nileshwar (Pilicode) of former Madras Presidency, now in Kerala State. Though the progress has been slow till the the early 1970s, substantial advancement in knowledge has been achieved in India since then.

Although the precise centre of origin of coconut is still a controversial issue with two distinct zones of diversity, namely, South Pacific Islands of Polynesia and Melanesia, and South East Asia and South America often quoted as the possible home of the coconut palm (Purseglove, 1972; Child, 1974), its pan-tropical distribution is limited to 23°N and S of the equator.

India, with 1.514 million ha under this crop with an annual production of 9700 million nuts, is the third largest coconut producer in the world, after the Philippines and Indonesia. As it stands, the gap between the national average (36 nuts/palm/year) and the best yield realized by a progressive farmer (110 nuts/palm/year) and research station (175 nuts/palm/year for TxD hybrid) is quite wide and needs immediate steps to bridge it (Swaminathan, 1983, Fig. 1). Identification of some of the individual palms capable of yielding 471 nuts/year even in root (wilt) disease affected area under rained condition (Iyer *et al.*, 1979) indicates that we have not fully exploited the biological potential of this wonderful palm, which clearly calls for a more systematic approach for coconut yield improvement. The fact that coconut belongs to a monotypic genus with a single species *Cocos nucifera* L. and a rather restricted genetic base with no known wild or domesticated



TEXT FIG. 1. YIELD GAP PROJECTION IN COCONUT

Fig. 1 : A projection of yield gaps in coconut (mean yield/palm/year shown in circles).

(i) WCT state average yield - 30 nuts/palm/year : rainfed
(ii) WCT farmer's average under suboptimal level of management : 40 nuts/palm/year : rainfed
(iii) WCT farmer's best average rainfed well managed : 79 nuts/palm/year.
-do irrigated well managed : 110 nuts/palm/year.
(iv) TxD Research Farm Rainfed well managed : 136 nuts/palm/year
" Irrigated " 175 "
(v) DxT " Rainfed " 142 "
" " Irrigated " 200 "
(vi) Elite palm average yield (Thazhava Village) : 471 "
Projections for yield/ha based on 175 palms density.

relatives, limits the possibilities for tapping gene pools from related sources. Due to the indiscriminate and large scale replanting that is going on, total erosion of native gene pools is taking place, which calls for a concerted effort to conserve this limited available variability.

2. CROP IMPROVEMENT

The various methods adopted for genetic improvement of coconut, namely, introduction of germplasm and their utilization, mother palm selection, seedling selection, selection of prepotent palms, exploitation of hybrid vigour, and tissue culture, will be discussed at length in the following paragraphs.

2.1 Genetic Variability and Germplasm Introductions

In coconut, the natural populations consist of two morphological forms, the *talls* and the *dwarfs*. The tall varieties are the most commonly cultivated in all the coconut growing countries of the world. The tall varieties grow to a height of 15-18 metres with a pre-bearing period of 6 to 10 years. They are largely cross-pollinated and hence heterozygous in nature. The palms are heavy yielders with nut size ranging from medium to large. The talls are identified by the geographical location of their collection or cultivation. Dwarfs are characterized by their short stature, thin non-tapering trunks having closely spaced internodes, shorter leaves and earliness in bearing. They attain bearing in 3-4 years and are predominantly self-pollinated due to nearly total overlap of male and female phases. The dwarfs are invariably known by the colour of the nuts in addition to the place of their collection/cultivation, such as Chowghat Orange Dwarf, Malayan Yellow Dwarf, etc.

The coconut germplasm collection programme in India dates back to 1924 when some of the cultivars were introduced at the Central Coconut Research Station, Pilicode (now under KAU), Kerala, from important coconut producing countries like the Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Cochin China (Vietnam). These introductions formed the nucleus populations for many of the subsequent research programmes. The open-pollinated and selfed progenies of these introductions were later planted at the Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala state in 1940s. Systematic introduction of coconut germplasm was further intensified in 1952, and in 1958, survey for collection of indigenous germplasm was started. At present, CPCRI is maintaining the largest assemblage of 86 exotic and 4 indigenous collections (Table 1). Sub-samples of some of these collections are also being maintained at twelve centres under the All India Co-ordinated Project on Palms, namely, Aliyarnagar (Tamil Nadu), Coimbatore (Tamil Nadu). Veppankulam (Tamil Nadu), Ambajipet (Andhra Pradesh), Arsikere (Karnataka), Konark (Orissa), Jagadalpur (Madhya Pradesh), Jalalgarh (Purnea, Bihar)., Mondouri (Kalyani, West Bengal), Ratnagiri (Maharashtra), Pilicode (Kerala) and Andamans to assess their regional adaptability.

Usually, the performance of an introduction can be evaluated only after the stabilization of yield, i.e., after 15 years of age. However, as the cumulative yield of

Table 1 : Coconut Germplasm Holdings at CPCRI, Kasaragod (Kerala) and Sipighat, Andamans)

	Region	Exotic				Indigenous				
		Tall	Semi-tall	Dwarf	Total	States/Union Territories	Tall	Semi-tall	Dwarf	Total
I	South East Asia	16	1*	3	20	Kerala	3	—	3	6
II	Central South America and Atlantic Region	6	—	1	7	Tamil Nadu	4	—	4	8
III	African Region	4	1**	2	7	Karnataka	1	—	1	2
IV	Pacific Region Is.	40	—	5	45	Andhra Pradesh	4	—	1	5
V	Indian Ocean Is.	4	—	3	7	Goa	3	—	—	3
						Gujarat	1	—	—	1
						Orissa	1	—	—	1
						Andamans	10	—	1	11
						Lakshadweep	2	—	1	3
	Total :	70	2	14	86		29	—	11	40

*SS Green
**MAWA Hybrid
Source : MK Nair (1992)

first eight years of bearing had shown high correlation (R^2 = 0.95) with that of stabilized yield (Rao, *et al.*, 1978), it is possible to make preliminary evaluations after eight years of bearing. For further details on genetic resources, the reader may refer to Chapter on "Coconut Genetic Resources".

2.2 Selection

2.2.1 *Mother Palm Selection*

Upgrading of the existing tall populations through the selection of consistently high yielding palms and marking these palms for seednut collection was the main method adopted earlier for yield improvement in almost all the coconut growing tracts of the world. Such a selection of mother palm involves identification of potential yielders using some of the easily observable morphological characters like straight stout trunk, spherical or hemispherical crown, number of leaves and inflorescences produced, high and consistent yield of nuts, high copra yield and freedom from pests and diseases (Menon and Pandalai, 1958). Of all these characters, yield of nuts is usually given the maximum importance. In India, palms yielding 80 nuts and more with a copra out-turn of 20 kg per palm per year consistently over a period are usually considered as mother palms. Through such a selection of mother palms based on yield of nuts, it was estimated that yield improvement of only up to 15% (Charles, 1961) could be achieved. This is mainly because of the low heritability of about 50% for yield of nuts (Lakshmanachar, 1959; Liyanage and Sakai, 1961; Nambiar and Nambiar, 1970), and low percentage distribution of high yielding palms (Table 2) in nature (Satyabalan, 1982). Studies indicated that the mean weight of copra per nut and weight per husked nut showed high heritability values of 0.67 and 0. 95 respectively (Liyanage and Sakai, 1961). Hence, selection pressure should be exercised towards weight of copra in addition to yield of nuts (Bavappa and Sukumaran, 1983). The yield in coconut being a complex character controlled by a number of components and their interaction, studies on path coefficient and regression analyses indicated that the average number of female flowers, number of functional leaves on the crown, internodal distance at fixed mark, total leaf production upto 3 years after sowing and the time taken for flowering are the important components that showed the largest direct influence on yield, and thereby indicating their value in selection programmes (Sukumaran, *et al.*, 1982). It was also stressed that the number of leaves on the crown, number of female flowers per palm, number of spikes, distribution of one female flower per spike, and setting percentage (Louis, 1981; Nambiar, *et. al.*, 1970; Nambiar and Ravindran, 1974), are also to be given importance while exercising selection.

Such a method of mother palm selection would constitute an imperfect form of mass selection. Since the pollen donor is unknown and the female parent is so heterogeneous, it is not certain that a genuinely high yielding palm would yield true to mother progeny. Bourdeix (1988), reviewing the effectiveness of mass selection methods based on yield components in coconut, has concluded that methods based on between-ecotype heterosis guarantee faster genetic advance.

Table 2 : Distribution of Palms in various yield groups

Location	No.of palms studied	Yield group (No. of nuts)	Percentage age of palms in the group	Percentage contribution to yield	References
Kasaragod (Kerala)	1400	Below 40	32.0	17.3	Menon & Pandalai (1958)
		40-80	59.4	66.9	
		Above 80	8.6	15.8	
Kasaragod (Kerala)	4347	Below 40	31.3	17.2	Mathew *et al.* (1978)
		40-80	60.3	67.6	
		Above 80	8.4	15.3	
Pilicode (Kerala)	150	Below 40	29.3		Kannan (1982)
		40-80	54.0		
		Above 80	16.7		
Veppankulam (Tamil Nadu)	1668	Below 40	66.9	34.1	Venkateswaran *et al.* (1975)
		40-80	27.2	47.4	
		Above 80	5.9	18.5	

From: Satyabalan (1982)

2.2.2 *Seedling Selection*

Since seednuts may not be genetically pure or uniform, roguing out inferior and unthrifty seedings in the nursery is as vital as selecting mother palms and seednuts. This is the most important step in producing quality planting materials. Nursery selection is based on characters that have been seen to be correlated with high yield of adult palms, such as early sprouting, faster growth rate, early splitting of the unexpanded leaf into leaflets, seedling vigour in terms of girth at collar, height and number of leaves besides freedom from pests and diseases (Menon and Pandalai, 1958).

Liyanage (1953) has shown clearly the breeding value of seedling selection in the nursery. Thus, the selected seedlings produced palms that yielded 12 per cent more copra compared to the unselected group comprising all types of seedlings ranging from good to bad (Table 3). He also noted that the period taken for germination is an important factor. Early germination gave early bearing and more productive palms.

Table 3 : Average yield/acre according to seedling selection (Liyanage, 1953)

Material	Nuts	Difference	Copra (lb)	Difference
Selected seedlings	2646		1273	
Unselected seedlings	2358	288	1136	137
CD P= 0.05	142		127	

The wastage of seedlings in the process of screening for vigour is large and it could be reduced, if not largely eliminated by rejecting parental palms giving inferior offspring. This correlation between seedling characters and adult palm performance is the most valuable tool in coconut improvement for providing superior planting material. Since seedling selection involves also the possible destruction of rare but superior types, especially slow growing palms carrying valuable genes, correlation of juvenile morphological traits with adult palm potential should be further fortified by taking physiological and biochemical traits like leaf area, chlorophyll content and nitrate reductase activity (Shivashankar *et al.*, 1985; Shivashankar and Kasturi Bai, 1988).

2.2.3 *Identification and Selection of Prepotent Palms*

As we have seen earlier, the percentage of high yielders in a coconut population is very low (Satyabalan, 1982), and the chances of recovering high yielding progenies from these is much lower. Hence, if we can identify those rare palms which exhibit a consistently higher rate of transmission of their characters to the progeny, then such palms would prove valuable for yield improvement. It was Harland (1957) working at the Coconut Research Institute in Sri Lanka who first proposed in his classic paper the concept of prepotency for coconut, based on his experience with open pollinated cacao trees that differed in their power of transmitting high yield to their progenies. Some transmit strongly probably due to a favourable combination of dominant genes, i.e., they are prepotent. Harland also drew analogy with animal breeding systems, where the value of a pedigree bull is assessed by the amount he can raise the mean milk yield of the daughters over that of their dams (Lush, 1949). Harland (1957) defined "prepotent palms as mother palms which, inspite of having been indiscriminately pollinated by miscellaneous males, are sufficiently possessed of dominant yield factors to ensure that their offsprings are also high yielding". Thus, a prepotent palm would be one where the stable gene combinations, particularly those controlling polygenic quantitative traits like yield which may be located on different chromosomes, tend to cohere but do not recombine, thus resulting in the '*en bloc*' transmission of parental characters to the progeny even under random mating. It is this coherence mechanism that enables a prepotent palm to function as reservoirs for potential variability. Once an equilibrium between coherence and variation becomes established, the organism is enabled to adjust to its dynamic environment. (Clausen and Hiesey, 1960). This would apparently lead to some sort of 'functional homozygosity of a complex heterozygote' like the tall variety of coconut, constituting a 'prepotent' palm (Iyer *et al.*, 1982b). But for the existence of such a mechanism, we would have lost much of the valuable reservoir of high yielders under random mating during the long evolutionary history of coconut.

2.2.4 Seedling Score for Prepotency

Since the identification of prepotent talls based on progeny yield performance would take several years, nursery selection methods to correlate seedling characters with adult palm potency have been attempted by several workers. Ninan and Pankajakshan (1961) have shown that it is possible to distinguish high yielders which would give superior progenies, from those showing inferior progeny performance on the basis of seedling performance in nursery. Ninan *et al.* (1964) found that differences in vigour and growth rate of seedlings between families were highly significant in comparison to variation within families. This indicates possibilities of locating prepotent mother palms on the basis of their progeny performance in nursery. Satyabalan *et al.* (1975) studied seedling characters such as collar girth and leaf production, which are reported by Nampoothiri *et al.*, (1975) to be genetically correlated with adult palm yield (open-pollinated progenies of high yielding palms). These were compared with their performance as adult palms for identifying prepotent palms based on seedling characters.

Satyabalan and Jacob Mathew (1983) analysed the correlation of growth rate and seedling vigour in terms of collar girth and leaf production in open-pollinated progenies of high yielding families, from the first to the ninth month, with those of the tenth month following seed germination. This indicated possibilities of identifying palms of superior genetic value even at 5th month based on those two characters of seedling progeny. Their studies also showed that in the palms identified as prepotent, irrespective of months (January to May) of seednut harvest, and of the month (July-November) when they germinate, the growth of these seedlings was more vigorous than those of other palms. Moreover, a higher percentage of seedling progenies of the two palms identified as prepotents (Table 4) exhibited growth characters, namely, collar girth and leaf production, above the general mean of all other seedling progenies, thus confirming the prepotency of these two mother palms (Satyabalan, 1983).

Table 4 : Nursery Score of six high yielding palm progenies (each value is an average of 20 seedlings)

Mother palm No.	Total No. of leaves emerged at			Girth at collar (cm) at		
	Ist month	5th month	10th month	Ist month	5th month	10th month
VII/27	0.8	4.0	7.1	5.2	9.2	13.8
VIII/112	0.4	3.6	6.3	4.7	8.5	12.6
*OC-19	1.1	4.7	7.4	5.5	10.0	14.8
OC-6	0.3	3.4	6.3	4.9	8.4	12.4
VIII/23	0.2	3.6	6.5	4.6	8.7	13.3
*41-588	0.4	4.3	7.4	5.1	9.6	14.4

*Prepotent palms.

While selecting prepotents, caution is to be exercised to ensure that the palm shows regular bearing and its high yielding capacity is not influenced by temporary changes in weather, or by other favoured location of the palm in the field, manurial or cultural conditions. Such palms are to be selected on the basis of low c.v. for nut yield and annual out-turn of copra. The coconut breeder can routinely use the seedling index method for locating genetically superior prepotent palms in natural populations of West Coast Tall, which can transmit their high yielding potential to their offspring at a high frequency even under random mating irrespective of the pollen donor. In view of the rapid replanting going on with the advent of new hybrids, there is every chance of our losing native genotypes, some of which could be prepotents. Hence, the identification and utilization of prepotent palms in coconut breeding should form an important continuing programme in all future crop improvement research in coconut.

In order to ascertain whether open-pollinated second generation progenies of such genetically superior palms, identified as prepotents, continue to retain their superiority, seedling progenies of three such palms (R.S.39-2-1/205, 29S/346 and 29N/387) were analysed for collar girth and leaf production at 5th month after germination. Data showed that only in the prepotent palm 39-2.1/205, two out of three first generation palm progenies, that is 60% and above progenies were superior and only one out of 5 in the case of 29S/346 palm exhibited this superiority (Satyabalan, 1984). Thus, it appears that prepotency is not transmitted at the same frequency in all such palms. Analysis of greater number of progenies would be needed to confirm this.

2.2.5 Varieties Evolved out of Selection

Based on the preliminary evaluation of cultivars available at Kasaragod, a multilocational trial was started in 1972 in different states with six cultivars and local WCT as the control. Based on the overall superior performance of Lakshadweep Ordinary in various research centres located in Andhra Pradesh, Tamil Nadu, Kerala and Maharashtra, the cultivar Lakshadweep Ordinary has been selected and released by CPCRI in 1985 (Anon., 1985) for commercial cultivation in these four states under the name "Chandrakalpa". (Fig.2).

Recently, another cultivar, Banawali Green Round, from Goa region has been selected and released in 1987 by Konkan Krishi Vidyapeeth, Dapoli (Anon. 1987) for cultivation in Konkan Coast under the name 'Pratap'.(Fig.3). The performance of these two indigenous selections is given in Table 5.

2.3 Exploitation of Hybrid Vigour

2.3.1 *Tall x Dwarf Hybrids*

The discovery of hybrid vigour in coconut by Patel (1937) between the West Coast Tall (female) x Chowghat Green Dwarf (male) crosses made in 1932 at the Nileshwar Coconut Research Station (now under KAU) was a significant land mark in the history of coconut improvement. He found that these hybrid seedlings showed early germination, increased collar girth and higher leaf number as compared to the progenies of the female parent. This important finding paved the way for the successful exploitation of this phenomenon in many of the coconut growing countries. John and Narayana (1943) found that these Tall x Dwarf hybrids gave higher yields, combining the nut and copra characters of Tall with early bearing of the Dwarf parent. Rao and Koyamu (1952) confirmed this hybrid vigour in one year old seedlings by measurable traits such as time taken for seed germination, collar girth, height and leaf number. Bhaskaran and Leela

Fig.2 : Laccadive Ordinary (L.O.), also called "Chandrakalpa" released by CPCRI in 1985 for Kerala, Andhra Pradesh, Tamil Nadu and Maharashtra exhibits drought tolerance and gives an average yield of 97 nuts/palm/year.

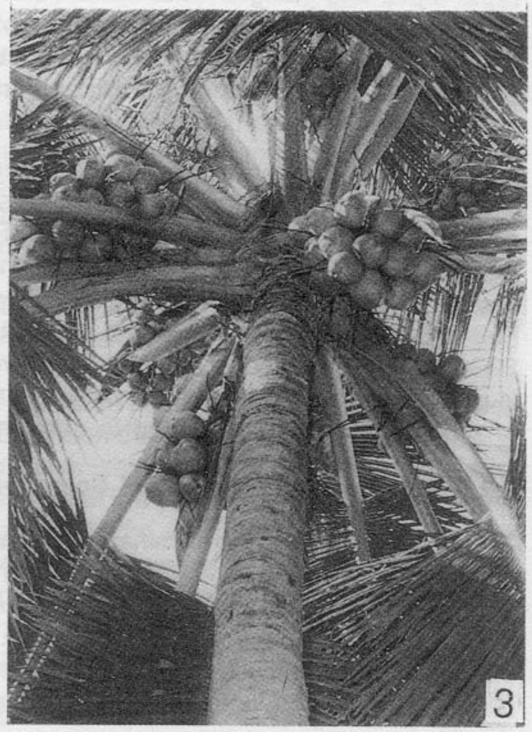


Fig.3 : Benaulim, also called "Pratap" or Banawali Green Round of Goa was released by Konkan Krishi Vidyapeeth, in 1987 for Coastal Maharashtra. Yields 151 nuts/palm/year.

Table 5 : Performance of released indigenous coconut cultivars.

Cultivar	Mean yield of nuts/pam/year		Copra yield		
	No.	Percent over WCT	Mean/ nut	Mean palm/year (g)	Percent over WCT (kg)
Lakshadweep Ordinary	97	21.3	195	18.9	32.3
Banawali Green Round	151	88.8	250	22.7	57.6
West Coast Tall	80	—	180	14.4	—

(1964) on a comparison of 25 years old TxD (WCT x CGD) hybrids planted in 1935-36 at Nileshwar showed that they were early bearing, high yielding and attained steady bearing earlier than the Tall parent with higher number of functional leaves, and rate of leaf production. Bavappa *et al.* (1973), based on their studies with different Tall x Dwarf hybrids suggested proper choice of Tall and Dwarf parents for efficient exploitation of hybrid vigour in coconut, since undefined Tall parents used in TxD hybrid production lead to wide variation in yield of nut and copra. The variable performance of different hybrids in different countries also clearly indicates the need for careful selection of parents for hybrid production.

Later studies on the performance of Tall x Dwarf hybrids by Satyabalan (1976) using the two common dwarf parents, namely, Chowghat Orange Dwarf (COD) and Chowghat Green Dwarf (CGD) as male parents have indicated that COD is a better pollen parent than CGD for the production of promising hybrids (Table 6).

The superiority of WCT x COD was further established in the trials planted at Kasaragod in 1966 and at Ratnagiri in 1957. In view of its superior performance, the IXth Workshop on All India Coordinated Research Project on Palms recommended this hybrid named as Kera Sankara (Fig. 4) for release in Kerala, coastal Maharashtra and coastal Andhra Pradesh.

Table 6 : Performance of the WCT × Dwarf hybrids planted in 1965

Hybrids	Mean Yield of nuts/palm per year (1970-74)	Mean copra weight/nut (g)	Mean Copra out-turn/palm/ year (kg)
WCT x COD	140	197	28.0
WCT x CGD	142	135	19.0
WCT progenies of selected mother palms for comparison	96	176	17.0

Source : Satyabalan, 1976.

In a comparative analysis of nursery growth parameters and later nut and copra characters of WCT x CGD, WCT x COD and WCT x Gangabondam (a green dwarf from Andhra Pradesh). Satyabalan *et al.*, (1964,1970) found that the latter two hybrids showed hybrid vigour in the weight of husked nut, nut water and kernel as compared with those of the female parent, the West Coast Tall. The studies indicated that COD and GB are the desirable pollen parents. Trials laid out at different coordinating centres have also indicated the superiority of hybrids under good management conditions. In a comparative trial on the performance of different dwarfs as pollen parents, the superiority of GB as a male parent with good combining ability was reported from Nileshwar by Kanan and Nambiar (1974). The superior performance of Gangabondam as male parent has been reported from Kasaragod, Mahuva and Coimbatore (Anon.,1981). In another comparative trial involving WCT and LO as female parent and COD and GB as male parents, the superior performance of LO × COD and LO × GB at Kasaragod has been reported (Anon., 1985). In view of the superior performance of LO x COD and LO x GB at Kasaragod and LO x GB at Pilicode, the VIIth workshop on All India Coordinated Research Project on Palms (AICRPP) held at Trivandrum during 1985 recommended the release of these two hybrids under the name Chandra Laksha (LO x COD) (Fig. 5) and Laksha Ganga (LO x GB) (Fig. 6) for general cultivation in Kerela.

Fig. 4 : West Coast Tall (WCT) x Chowghat Orange Dwarf (COD), also called "Kerasankara", released by CPCRI in 1989, for Kerala, Coastal Maharashtra and Andhra Pradesh. Yields 108 nuts/palm/year.

Fig. 5 : L.O. x COD, also called "Chandralaksha" released by CPCRI in 1985 for Kerala, yields 109 nuts/palm/year.

Fig. 6 : L.O. x Gangabondam (GB), also called "Lakshaganga", released by Kerala Agricultural University for Kerala. Yields 108 nuts/palm/year.

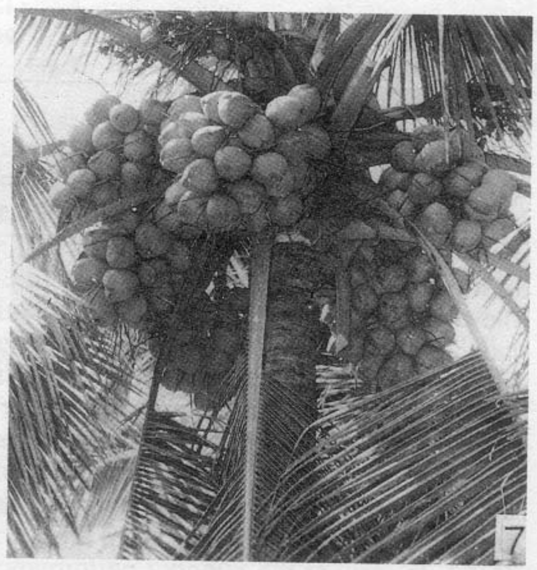


Fig. 7 : COD × WCT (D x T hybrid) known as 'Chandra Sankara' released by CPCRI, Kasaragod in 1985 yields 116 nuts/palm/year.

In the earlier studies , the performance of GB as male parent was proved better than other dwarfs like CGD. Concerted efforts were made at the Pilicode centre to ascertain the combining ability of GB by crossing it with six tall female parents. Among the six hybrids LO x GB, AO x GB and WCT X GB were found to be superior in respect of copra yield per palm and copra out-turn per hectare (Table 7).

Table 7 : Yield performance of hybrids involving Gangabondam as the male parent (mean of 1963-65)

Hybrid	Nut yield/ palm	Copra content per nut (g)	Copra yield/ palm (kg)	Copra out-turn per ha (kg)
Laccadive Ordinary x GB	108.3	194.5	21.1	3728
Laccadive Small x GB	125.4	158.0	19.8	3506
Andaman Ordinary x GB	95.2	216.0	20.6	3639
Cochin China x GB	84.1	203.6	17.1	3030
West Coast Tall x GB	100.2	201.0	20.1	3602
Java x GB	93.4	175.6	16.4	2903

Source : Balakrishnan *et al.*, 1988.

These studies ultimately culminated in the release of three Pilicode hybrid coconuts, namely, PHC-1 (LO x GB). PHC-2 (AO x GB) and PHC-3 (WCT x GB).

Studies carried out at Veppankulam in Tamil Nadu by Ramanathan *et al.*(1982, 1984) on different Tall x Dwarf crosses involving East Coast Tall with different Dwarf pollen parents have established the superiority of ECT x Dwarf Green over other combinations in yield of nuts, weight of whole nut, dehusked nut, kernel and copra. This has led to the release of this as Veppankulam Hybrid Coconut-1 (VHC-1) for large scale cultivation in Tamil Nadu. A second TxD hybrid (ECT x MYD) has also been released by them as VHC-2 for large scale cultivation in Tamil Nadu.

So far, nine Tall x Dwarf hybrids have been recommended for large scale cultivation in the country (Table-8).

Although the cross combinations between Tall x Dwarf hybrids are high yielding and precocious, there are some limitations with regard to their selection and production. It is imperative that to produce TxD hybrids of promising nature, the male and female parents have to be carefully selected based on wide genetic distance, combining ability and high recovery of heterotic hybrids. In the absence of a colour marker in TxD hybrids, the hybrids are to be selected based on growth parameters in the nursery. Large scale production of TxD hybrids is a labour intensive and expensive operation since hand pollination by trained climbers is involved. Hence, in most countries, DxT hybrids are produced on a commercial scale because of the ease with which the hybrids can be identified in the nursery by colour marker and vigour of the seedlings and also by their superior performance.

Table 8 : Performance of released coconut hybrids

Hybrids	Nut yield/ palm/ year	Copra yield Mean/ nut (g)	Copra yield Mean/ palm (kg)	Oil content (%)	State for which recommended	Agency responsible for release
Chandrasankara (COD x WCT)	116	215	24.9	68	Kerala	CPCRI
Kerasankara (WCT x COD)	108	187	20.2	68	Kerala, Coastal Maharashtra & Coastal Andhra Pradesh.	CPCRI
Chandralaksha (LO x COD)	109	195	21.2	89	Kerala	CPCRI
Lakshaganga (LO x GB)	108	195	21.1	70	Kerala	KAU
Anandaganga (AO x GB)	95	216	20.5	68	Kerala	KAU
Keraganga (WCT x GB)	100	201	20.1	69	Kerala	KAU
Kerasree (WCT x MYD)						
VHC-1 (ECT x DG)	98	135	13.2	70	Tamil Nadu	TNAU
VHC-2 (ECT x MYD)	107	152	16.3	69	Tamil Nadu	TNAU
ECT x GB	140	150	21.0	68	Andhra Pradesh	APAU
WCT	80	176	14.1	68	Control	

2.3.2 *Dwarf x Tall Hybrids*

Although the DxT hybrids have been found to be of higher production potential than TxD hybrids, they were originally discovered by accident, as it were, when open pollinated progenies of Chowghat Orange Dwarf (COD) were studied. These natural hybrids of Orange Dwarf carry a characteristic bronze colour in the seedling petioles, which renders them easy for scoring at nursery stage. Rao and Koyamu (1955) observed 'off type' progenies to the extent of 20% in the Dwarf nurseries and later Satyabalan (1956) indicated that these 'off types' could be the 'natural cross' hybrids between the Dwarf female and Tall male parents. Ninan and Satyabalan (1964)also obtained these 'off-types'after controlled pollination of COD which are similar to naturally occurring off types and they called these as heterozygous segregants of COD with "Imposed Hybridity". Subsequently, Ninan (1983), and Bavappa and Sukumaran (1983) brought out evidence to show that these off-types are segregants arising due to the inherent heterozygosity of the dwarfs. The excellent performance of these natural cross dwarfs of Chowghat Orange Dwarf palms encouraged the breeders to attempt more and more DxT hybrids. The DxT hybrids produced by controlled pollination between COD as the female parent and WCT as the male parent were markedly superior, both in nut production and copra out-turn (Satyabalan and Vijayakumar, 1982). The survey conducted on the field performance of coconut varieties and hybrids in Kerala State during 1978-79 indicated that among TxD and DxT hybrids, the latter was definitely superior to the former

(Anonymous, 1979). It was also noticed that tree to tree variation was minimum in this hybrid. The COD x WCT hybrids were also found to have better nutrient utilization ability and responded well to lower levels of applied fertilizers (Hameed Khan *et al.*, 1986). As the performance of COD x WCT was found to be superior, the Seventh AICRPP recommended the release of this hybrid under the name 'Chandrasankara' for general cultivation in Kerala (Fig. 7).

However, the production of COD x WCT hybrids has not been successful to the extent desired as the hybrid recovery as scored in the nursery of COD x WCT was 30% on an average, although the recovery ranged from 10 to 100% when different COD palms were used with a common source of WCT pollen (Sukumaran and Iyer, unpublished). This clearly indicates the variable genetic make-up of COD palms and the need for selecting high combiners. Satyabalan and Rajagopal (1987) have shown that by proper selection of parents based on nut characters (Dwarf palms having shell content less than 20% of husked nut weight as female parents and pollinating with tall palms having more than 150 g copra/nut and husk content of less than 50%), the hybrid recovery could be improved to an extent of 28.6 to 78.1%.

Although there is good response and high demand for hybrid coconut seedlings, in view of their superior performance, one of the apprehensions among the coconut growers is the shorter economic life span of these hybrids. Studies carried out at CPCRI by Pillai (1991) have shown that DxT and TxD hybrids continue to give heavy yields even after 49 years.

2.3.3 *Tall x Tall Hybrid*

In a comparative trial involving five Tall x Tall hybrids planted at CPCRI in 1966, there was no significant difference between the hybrids for cumulative yield of nuts/palm and annual nut yield/palm. The poor yield in all the Tall combinations may be due to the poor combining ability of the parents. (Anon., 1992). This emphasizes the need to select promising tall parents based on combining ability tests. In another trial of 36 hybrids planted in a Diallel series involving 9 parents (8 Talls and 1 Dwarf), LO x GB recorded the highest cumulative yield of nuts followed by LO x Jamaica (Anon., 1992).

2.3.4 *Other Hybrids*

Encouraged by the superior performance of DxT and TxD hybrids, different inter-varietal crosses involving promising exotic and indigenous varieties were made. In India, production and evaluation of different hybrid combinations is being carried out at the Central Plantation Crops Research Institute (CPCRI) Kasaragod, Kerala Agricultural University and four other research centers. At CPCRI, 95 cross combinations involving Tall and Dwarf cultivars (22 TxDs, 18 DxTs, 51 TxTs and 4 DxDs) are currently under evaluation.

At Nileshwar, attempts to combine the high female flower production of 'spicata' with high setting percentage of West Coast Tall was not successful (Anon., 1977).

2.3.5 *Seed Production*

It has been estimated that the annual demand of improved/released hybrids and varieties in the country is 15 million seedlings for new planting, replanting and under planting. However, the annual production of Talls is 2.17 million and hybrids is 0.93 million seedings, revealing a wide gap between demand and supply. This gap could be bridged by increasing the hybrid seed production of the 24 existing seed gradens spread over 1258 hectares and establishing additional seed gardens in the country. The parental materials necessary for the production of recommended hybrids in different states of the country have been identified in the National Group Discussion on Strategy for Planting Materials held during 1988 and the Seed Garden should be replanted with the parental materials suggested (see Table 9 of Pillai, 1990) for each agroclimatic zone.

2.4 Tissue Culture

Another recent approach that has engaged the attention of research workers for coconut improvement is tissue culture. Currently, some ten different centres in India are engaged in this work on the following three main areas:

(i) Culture of vegetative tissues such as root, leaf, meristem and leaf bases to induce somatic embryogenesis for clonal propagation;

(ii) Culture of floral primordia from immature inflorescences for induction of bulbil shoots; and

(iii) Embryo culture, both as a source of sterile explants, for inducing multiple shoots or suckers and for standardizing field collection, storage, transport and retrieval of coconut germplasm in future expeditions.

In addition to the above, there have been attempts to culture immature anthers for obtaining androgenic haploids.

The first successful production of clonal plantlets from seedling spindle leaf segments of WCT through somatic embryogenesis was reported from CPCRI by Raju *et al.* (1984). They could obtain from a single leaf explant measuring 5 mm as many as 48 somatic embryoids. However, the response was found to be erratic and repeatability was found to be extremely low. Four of these clones have been field planted in 1989 and are progressing well. Current emphasis is on obtaining repeatable results with adult palm tissues. Rachilla explants have so far yielded only shoot-like structures without roots. Although ten centres are working on clonal multiplication through tissue culture, so far, except for the report by Raju *et al.* (1984), there have been no other successful attempts (Iyer, 1991) in India.

Bulbil formation is a known phenomenon in certain freak mutants of coconut (Davis, 1948), but these do not strike roots in nature. Davis *et al.*, (1981) have reported successful airlayering of bulbils and raising the clonal palms in soi, although they have

Table 9 : Parents suggested for different states for establishing elite seed gardens

State & Union Territory (1)	WCT (2)	LO (3)	AO (4)	ECT (5)	TT (6)	BEN (7)	COD (8)	MYD (9)	GB (10)	GD (11)
Andamans	-	+	+	+	-	-	+	+	-	-
Andhra Pradesh	-	+	+	+	-	-	+	+	+	-
Assam	-	+	+	-	-	-	+	+	-	-
Bihar & Madhya Pradesh	+	+	+	+	-	-	+	+	+	-
Gujarat	+	+	-	-	-	-	+	+	-	+
Karnataka	+	+	-	-	+	-	+	+	-	-
Kerala	+	+	+	-	-	-	+	+	+	-
Lakshadweep	+	+	-	-	-	-	+	+	-	-
Maharashtra & Goa	+	+	-	-	-	+	+	+	+	-
Orissa	+	+	+	+	-	-	+	+	+	-
Pondicherry	-	+	+	+	-	-	+	+	+	-
Tamil Nadu	+	+	+	+	-	-	+	+	+	-
Tripura	+	+	+	-	-	-	+	+	+	-
West Bengal	-	+	+	+	-	-	+	+	+	-

WCT = West Coast Tall LO = Laccadive Ordinary; ECT = East Coast Tall AP = Andaman Ordinary; BEN = Benaulim; TT = Tiptur Tall; COD = Chowghat Orange Dwarf; GB = Gangabondam; GD = Goodajali Dwarf.

not produced normal flowers. Attempts to culture immature rachillae explants *in vitro* to convert the floral primordia into vegetative shoots were made at CPCRI. Although shoot-like outgrowths were obtained, no viable plantlet could be realized from floral primordia *in vitro* (Kuruvinashetti and Iyer, 1979, 1980; Iyer *et al.*, 1982a).

Although anther culture offers much hope for coconut yield improvement, work carried out at CPCRI has so far yielded only multicelled pollen embryoids (Iyer, 1982).

The earliest report on coconut zygotic embryo-culture was by Abraham and Thomas (1962). Gupta *et al*., (1984) successfully transferred embryo-culture plantlets to polybags containing 3 : 3 : 1 mixture of soil:sand:compost. These plantlets survived for four weeks in glass-house condition and later died. Successful field planting of zygotic embryo cultured plantlets has been reported from CPCRI (Anon., 1989), St. Aloysius College, Mangalore (D'Souza *et al.*, 1988), Madurai Kamaraj University, Madurai (Jegadeesan and Padmanabhan, 1982). The field planted saplings at CPCRI are progressing well. At JNU, New Delhi, Sipra-Guha Mukherjee and colleagues have obtained callus from 8-10 months old zygotic embryos on B5 medium supplemented with IAA-amino acid conjugates and complete plantlets were obtained on B5+NAA+BAP+PVP, but the plants did not survive on transfer to soil due to poor root growth (Neera Bhalla-Sarin *et al.*, 1986).

3. BREEDING FOR SPECIAL CHARACTERISTICS

3.1 Drought Tolerance

As a rainfed crop, coconut is exposed to the vagaries of weather, and rainfall has a great influence on nut production. An average monthly rainfall of 150 mm is necessary for ideal growth and nut yield of the palms. Any erratic distribution and low average rainfall resulting in prolonged dry spell for 5 to 7 months, adversely affects the yield of the palm. The four southern states of India (Andhra Pradesh, Tamil Nadu, Kerala and Karnataka) which account for 90% of the area under coconut are periodically exposed to low rainfall or delayed onset of monsoon or both resulting in poor yield during drought. The impact of drought on coconut yield is well documented. Prasada Rao (1988) reported an average decline of about 48% in a 25 ha farm at Pilicode during 1983 drought. Unlike annuals, the adverse effect of drought on coconut persists even for the subsequent 2 to 3 years. Under these circumstances, evolving drought-tolerant varieties/hybrids is the only solution towards increasing coconut production in drought affected areas.

Studies carried out at CPCRI have revealed the possibility of identifying desirable traits of drought-tolerant cultivars in coconut field conditions (Rajagopal *et al.*, 1988a). Among these criteria, accumulation of epicuticular wax on the leaf surface (ECW), low stomatal frequency (SF), low stomatal resistance(s) and leaf water potential (ψ) are important. The pattern of soil moisture depletion and the stability of the activity of certain enzymes lke glutamate oxalacetic transaminase (GOT) and acid phosphatase (APH) are also found to have their influence on drought tolerance (Rajagopal *et al.*, 1988a). A soil water deficit (SDW) of 115 mm was found to be the critical level at which coconut expresses stress symptoms in sandy loam soil as indicated by the stomatal closure.

Rajagopal *et al.*, (1990) screened some twenty-three genotypes of coconut for drought tolerance using the above sensitive parameters and found that WCT x WCT, Federated Malay States (FMS), Java Giant, Andaman Giant and LO x COD are drought tolerant (Table 10). Recent studies on the changes in the ψ and the activity of GOT and APH under laboratory conditions in dehydrated leaves of eight genotypes indicated that the hybrids LO x COD and LO x GB are more drought tolerant (Rajagopal, 1988b). Further evidence of the drought tolerant nature of LO x GB and LO x COD was provided by Rao, *et al.* (1991) in their study of yield performance during drought situation. The reduction in overall yield during drought affected years for LO x COD and LO x GB was 15% and 44% respectively compared to 75% in drought susceptible COD x WCT hybrids. All the identified drought-tolerant varieties are currently being utilized in the breeding programme at CPCRI, Kasaragod to evolve high yielding hybrids possessing drought tolerance.

Table 10 : Effect of moisture stress (during March) on the leaf water potential (ψ) and epicuticular wax content (ECW) in different coconut genotypes. (MPa = Mega Pascals)

	S.No.	Genotypes	ψ (MPa)	ECW (μg/cm²)	Rank
Talls	1.	West Coast Tall (WCT)	–1.48	109.0	11
	2.	SS Apricot	–1.14	102.1	12
	3.	Andaman Ordinary	–1.24	91.9	14
	4.	Laccadive Micro	–1.41	96.2	15
	5.	Andaman Giant	–1.13	99.2	5
	6.	Federated Malay States (FMS)	–1.10	116.7	2
	7.	Fiji	–1.23	104.7	4
	8.	Philippines Ordinary	–1.32	113.4	6
	9.	Cochin China	–1.27	110.4	8
	10.	Java Giant	–1.41	116.2	3
			–1.27	105.9	
Dwarfs	11.	SS Green	–1.32	98.4	17
	12.	Malayan Green Dwarf (MGD)	–1.36	94.0	18
	13.	Malayan Orange Dwarf (MOD)	–1.52	77.0	21
	14.	Malayan Yellow Dwarf (MYD)	–1.49	79.0	20
	15.	Gangabondam (GB)	–1.46	90.3	19
	16.	Chowghat Orange Dwarf (COD)	–1.01	87.6	13
		Mean	–1.36	87.8	
Hybrids	17.	WCT x COD	–1.19	116.7	10
	18.	COD x WCT	–1.25	110.5	16
	19.	WCT x WCT	–1.17	117.4	1
	20.	COD x COD	–1.36	109.2	7
	21.	WCT x GB	–1.16	109.6	9
	22.	LO x GB	–1.32	132.6	11
	23.	LO x COD	–1.26	120.7	5
		Mean	–1.24	116.7	
		SE/plot	±1.82	15.49	
		GEN.Mean	–1.29	104.5	
		CV (%)	1.41	14.83	
		CD (p=0.05)	2.08	11.42	

Source : Rajagopal *et al.* (1990). Values are mean of six palms.
Ranking of genotypes was done on the basis of SF, rs y and ECW and rank sums computed to allot ranking.

3.2 Disease Resistance

Although coconut is ravaged by a number of diseases, the root (wilt) disease is the most serious problem causing an annual production loss of 968 million nuts in eight districts of Kerala (Anon., 1985). The disease is prevalent in a contiguous manner in eight southern districts of Kerala and in isolated pockets in northern districts and in areas of Tamil Nadu adjacent to Kerala. The disease occurs in all soil types and palms of all age groups are affected. The characteristic symptom of this disease is flaccidity, yellowing and necrosis of leaflets (Menon and Pandalai, 1958) followed by a progressive decline in yield. Systematic studies carried out at CPCRI have conclusively shown the presence of mycoplasma like organisms (MLOs) in the sieve tubes of roots, tender stem, inflorescence and petioles of diseased palms (Solomon, *et al.*, 1983). The mycoplasmal etiology was further confirmed by the successful transmission of the disease using vector lace-wing bug, *Stephanitis typica* Distant-Tingidae under insect-proof conditions. As no control measures are available for this disease, developing resistant/tolerant genotypes is the only long-lasting solution for this malady.

The first step in developing resistant/tolerant genotypes is the identification of sources of resistance. The screening of available coconut germplasm (48 cultivars and 25 hybrids) has not yielded any resistant type. Hence, survey for the identification of disease-free palms in the heavily diseased tracts (hot spots) was undertaken and 162 high yielding apparently healthy WCT palms were initially selected, and subjected to serological and physiological (stomatal resistance) tests. Of these 26 palms were selected as disease-free palms as they showed negative reaction to both these tests. In view of the reported field tolerance of Chowghat Green Dwarf (CGD) palms to root (wilt) disease (Anon., 1972), a survey was conducted in hot spot areas to identify high yielding and disease-free palms. Thus, 19 CGD palms were identified as disease-free palms. Having identified the source of resistance, the next step would be to involve these identified disease-free palms (26 WCT and 19 CGD) in the breeding programme.

The cross combinations in progress are : (1) WCT x WCT, (2) CGD X WCT, (3) WCT x CGD and (4) WCT (self). The first batch of 32 progenies of WCT selfed and 48 progenies of CGD x WCT produced have been planted during July 1989 for screening against root (wilt) disease (Jacob and Rawther, 1991).

The other diseases of importance are bud rot caused by *Phytophthora palmivora* Butler, stem bleeding disease and Thanjavur wilt/Ganoderma disease. Bud rot is a fatal disease characterized by rotting of the apical bud and surrounding tissues. Palms of all age groups, especially the younger palms, are the most affected. The disease can be controlled if detected at the early stage by application of 1 per cent Bordeaux paste on the affected bud portion. Since this disease can be controlled by conventional plant protection measures, at present no breeding work is being done to develop a resistant genotype for this disease. In the stem bleeding disease caused by *Thielaviopsis paradoxa*, the affected palms show exudation of a brown liquid on the lower portion of the trunk through the cracks that develop. The disease can be controlled by stem injection and root feeding of Calixin at 5 mg/100 ml of water. The available germplasm are at present being screened to identify a resistant/tolerant genotype for this disease. Thanjavur disease/Ganoderma disease is caused by *Ganoderma lucidum* and *Ganoderma aplanatum*. The characteristic symptom of the disease is yellowing and withering of outer whorls of the leaves, which subsequently dry and hang around the trunk. In advanced stage of the disease, 'bracket' formation takes place. Since the disease can be controlled by root feeding/drenching with 5% Calixin, no attempt is being made at present to develop resistant genotypes through breeding.

3.3 Pests

The coconut palm is susceptible to a large number of pests. Among them, the rhinoceros beetle and the red palm weevil are the most important ones. The rhinoceros beetle(*Oryctes rhinoceros* L.) bores into the soft tissue of the 'cabbage' by cutting and chewing the tender unopened leaves. The affected leaves on emergence show the characteristic geometric cuts. Effective control measures are available for this pest such as axil filling with pesticides like Furadan. The red palm weevil, *Rhynchophorus ferrugineus* is the most dangerous pest capable of killing the palm if not detected at the early stage. As for the rhinoceros beetle, effective control measures are available for this pest also. Since these two pests can be controlled by conventional plant protection measures, no breeding work for developing resistant genotypes is being done at present.

3.4 Nut Water Quality

In recent years, the consumption of coconut as tender nuts, especially during summer, is becoming increasingly popular as a natural, nourishing, refreshing and satisfying drink. In order to meet this very high demand, tendernuts are harvested from almost all the tall varieties of coconut, sacrificing the quality of nut water, and at the cost of the valuable copra and oil source. In Tamil Nadu alone, which ranks second in coconut production in the country, it is estimated that five per cent of all the coconuts

Table 11 : Biochemical constituents of Tender-nut water and nut yield in 12 coconut cultivars (mean values for 1988-91)

Cultivar	Volume of water (ml)	Sugars: Total (g/100 ml)	Sugars: Reducing (g/100 ml)	Free amino acids (mg/100 ml)	K (mg/l)	N (mg/l)	Mean annual yield of nuts/palm
New Guinea	358	5.8	3.0	1.4	2258	21	73
Philippine Ordinary	457	5.8	3.7	1.3	2273	24	113
Fiji Long Tongwan	390	4.9	3.6	1.4	2641	29	105
Spikeless	275	5.3	3.2	1.7	2617	38	149
WCT	240	5.6	3.2	1.3	2797	37	92
Andaman Ordinary	274	5.3	3.3	2.1	2272	27	94
Jamaica Sanblas	263	6.0	3.4	1.7	2703	28	65
MYD	238	6.2	3.8	1.7	1998	36	53
MOD	303	6.7	4.1	1.8	2142	35	75
GB	267	5.6	3.5	1.7	2125	28	68
COD	351	7.0	4.7	1.8	2003	20	67
Guam III	278	6.0	3.7	2.0	2434	34	96
General Mean	307	5.9	3.6	1.7	2355	30	
SE/Plot	101.7	1.2	0.79	0.51	258.0	9.0	
CD	73.0	0.89	0.56	0.36	185.1	6.4	

produced is being consumed as tender nuts (Thomas Mathew, 1991). A study to find out a suitable cultivar for tender nut purpose was hence unde taken at CPCRI (Dhamodaran *et al.*, 1991). Initially, 46 cultivars were organoleptically screened for nut water quality, and twelve cultivars selected out of this screening were further evaluated biochemically. Biochemical evaluation indicated that Chowghat Orange Dwarf (COD), a dwarf cultivar from the Chavakkad village in Trichur District of Kerala, had the maximum amount of total sugars (7.0 g/10ml), reducing sugars (4.7 g/100ml), and low sodium and potassium contents (Table 11). The superior quality of the tender nut water of COD was further confirmed by organoleptic evaluation following a non-parametric statistical method. In view of its superior quality of nut water, the Tenth Workshop of the All India Co-ordinated Project on Palms held in September 1991, at Kasaragod, has recommended this cultivar for release as a tender nut variety in Kerala (Anon., 1991).

REFERENCES

Abraham, A. and Thomas, K.J. 1962. A note on the *in vitro* culture of excised coconut embryos. *Indian Cocon. J.*, **15** : 84-88.

Anonymous, 1972. Annual Report for 1971. Central Plantation Crops Research Institute, Kasaragod, 212 p.

Anonymous, 1977. Reports and papers. Coconut Convention, 9th and 10th October 1975, Directorate of Extension Education, Kerala Agricultural University, Mannuthy, India. pp.44.

Anonymous, 1979. Survey report on the performance of coconut varieties and hybrids in Kerala State-survey organised jointly by Kerala Agriculture Department, Kerala Agricultural University, Directorate of Coconut Development and Central Plantation Crops Research Institute during 1978-79 (Mimeographed), pp. 38.

Anonymous, 1981. Progress Report for 1979-80. All India Co-ordinated Coconut and Arecanut Improvement Project. Central Plantation Crops Research Institute, Kasaragod, India. pp. 45.

Anonymous, 1985. Proceedings of the Seventh Workshop, All India Co-ordinated Coconut, Arecanut, Spices and Cashew Improvement Projects. Trivandrum, 6-9 November 1985. Central Plantation Crops Research Institute, Kasaragod, India. pp. 182.

Anonymous, 1987. Proceedings of Eighth Biennial Workshop of All India Co-ordinated Project on Palms, OUAT, Bhubaneswar, 24-27 October 1987. Central Plantation Crops Research Institute, Kasaragod. pp. 74-76.

Anonymous, 1989. Annual Report for 1988. Central Plantation Crops Research Institute, Kasaragod, India. pp. 30-31.

Anonymous, 1991. Proceedings of the Tenth All India Co-ordinated Project on Palms. 26-28 September, 1991, Kasaragod. pp. 36.

Anonymous, 1992. Annual Report for 1991-92. Central Plantation Crops Research Institute, Kasaragod, India. pp. 188.

Balakrishnan, P.C., Sukumaran Nair, S. and Kumaran, K. 1988. Coconut Improvement. In *Six Decades of Coconut Research* (Aravindakshan, M., Nair, R.R. and Wahid, P.A., Eds.). Kerala Agricultural University, Mannuthy, pp. 7-36.

Bavappa, K.V.A. and Sukumaran, C.K. 1983. Coconut improvement by selection and breeding—A review in the light of recent findings. In *Coconut Research and Development*, Proc. Internatl. Symp. Cocon. Res. & Dev. CPCRI, Kasaragod, 27-31 December 1976. (Nayar, N.M., Ed.). Wiley Eastern Ltd., New Delhi. pp. 44-55.

Bavappa, K.V.A., Sukumaran, C.K. and Mathew, J. 1973. A study of F1 hybrids of Tall x Dwarf Coconut and its bearing on the genetics of dwarfness. *J. Plantn. Crops*, **1** (Suppl.) : 1-6.

Bhaskaran, U.P. and Leela, K. 1964. Hybrid coconut Tall x Dwarf—A comparative study with parental types. *Agric. Res. J. Kerala*, **1** (2) : 67-84.

Bourdeix, B. 1988. Effectiveness of mass selection based on yield components in coconut. *Oleagineux*, **43** : 291-295.

Charles, A.E. 1961. Selection and breeding of coconut palm. *Trop. Agric. (Trin.)*, **38** : 283-296.

Child, R. 1974. *Coconuts*, 2nd edn. Longman Group Ltd., London. pp. 335.

Clausen, J. and Hiesey, W.M. 1960. The balance between coherence and variation in evolution. *Proc. Natl. Acad. Sci. (USA)*, **46** : 494-506.

Davis, T.A. 1948. Abnormal palms of Travancore. III. A bulbiliferous coconut palm (*Cocos nucifera* L.) *J. Bombay Nat. Hist. Soc.*, **47** : 527-529.

Davis, T.A., Sudasrip, H. and Azis, H. 1981. Bulbil shoot production from clonally propagated coconuts. *Principes*, **25** (3) : 124-129.

Dhamodaran, S., Ratnambal, M.J., Chempakam, B., Pillai, R.V. and Viraktamath, B. C. 1991. Evaluation of coconut cultivars for tender nut water. In *Proc. Internatl. Symp. on Cocon. Res. & Dev.* II. Abst. No. 34. 26-29 November 1991, CPCRI, Kasaragod. pp. 26.

D'Souza, L., Paily, J. and Arokiadoss, V. 1988. Coconut embryo and tissue culture : Potentialities, problems and applications. *Proc. Natl. Sem. Plant Tissue Culture*, CPCRI, Kasaragod. 2-4 March 1993. CPCRI, Kasaragod, ICAR, New Delhi. pp. 140-145.

Gupta, P.K., Kendurkar, S.V., Kulkarni, V.M., Shirgurkar, M.V. and Mascarenhas, A.F. 1984. Somatic embryogenesis and plants from zygotic embryos of coconut (*Cocos nucifera* L.) *in vitro Plant. Cell Rep.*, **3** : 222-225.

Hameed Khan. H., Gopalasundaram, P., Joshi, O.P. and Nelliat, E.V. 1986. Effect of NPK fertilization on the mineral nutrition and yield of three coconut genotypes. *Fert. Res.*, **10** : 185-190.

Harland, S.C. 1957. The improvement of coconut palm by breeding and selection. Circulation Paper No. 7/57. Coconut Res. Inst. Ceylon. Bull. No.15, pp. 14.

Iyer, R.D. 1982. Embryo and tissue culture for crop improvement, especially of perennials, germplasm conservation and exchange—Relevance to developing countries. *Proc. COSTED Symp. on Tissue Culture of Economically Important Plants* (A.N. Rao, Ed.). Singapore, 1981. pp. 219-230.

Iyer, R.D. 1991. Current status of coconut tissue culture in India. In : *Abst. 39, Internatl. Symp. on Coconut Res. & Dev.* II, 26-29 November 1991, CPCRI, Kasaragod. pp. 31-32.

Iyer, R.D., Kuruvinashetti, M.S., Mini, P.S., Prakash, P. and Raju, C.R. 1982a. Some applications of tissue culture in coconut improvement. *Abst. V. Internatl. Cong. on Plant Tissue and Cell Culture.* Tokyo, Japan.

Iyer, R.D., Rao, E.V.V.B. and Govindankutty, M.P. 1979. Super yielders in coconut. *Indian Farming*, **28** : 3-5.

Iyer, R.D., Satyabalan, K., Rao, E.V.V.B., and Sukumaran, C.K. 1982b. Breeding methodology as applicable to coconut improvement. In *Advances in Cytogenetics and Crop Improvement* (Singh, R.B., Sing, R.M., Singh, B.D., Eds.). Kalyani Publ. New Delhi, pp. 283-289.

Jacob, P.M. and Rawther, T.S.S. 1991. Varietal resistance. In Monograph series No. 3. *Coconut root (wilt) disease* (Nair, M.K., Nambiar, K.K.N., Koshy, P.K. and Jayasankar, N.P. Eds.). pp. 92.

Jegadeesan, M. and Padmanabhan, D. 1982. Studies on coconut embryo culture. Abst. 31, *PLACROSYM-V* (CPCRI, Kasaragod, 15-18 December 1982, pp. 22.

John, C.M. and Narayana, G.V. 1943. Note on the improvement of coconut by cross breeding. *Madras Agric. J.*, **31** : 75-77.

Kannan, K. 1982. West Coast Tall. How to improve its production potential? *Indian Cocon. J.*, **12** : 5-8.

Kannan, K. and Nambiar, P.K.N. 1974. A comparative study of six tall types (var. typica) of coconut crossed with semi-Tall 'Gangabondam' var. Javanica). *Agric. Res. J. Kerala*, **12** (2) : 124-130.

Kuruvinashetti, M.S. and Iyer, R.D. 1979. *In vitro* studies for vegetative propagation in coconut. *Fifth FAO Tech. Wkg. Party Cocon. Prodn. Protn and Processg.* Manila, The Philippines.

Kuruvinashetti, M.S. and Iyer, R.D. 1980. Tissue culture studies on coconut palm for its clonal propagation. In *Proc. Natl. Symp. on Tissue Culture, Genetic Manipulation and Somatic Hybridization of Plant Cells,* (Rao, P.S., Heble, M.R. and Chadha, M.S. Eds.). BARC, Bombay. pp. 184-191.

Lakshmanachar, M.S. 1959. A preliminary note on the heritability of yield in coconuts. *Indian Cocon. J.* **12** : 65-68.

Liyanage, D.V. 1953. Selection of coconut seednuts and seedlings. *Ceylon Coconut Quart.*, **4** : 127-129.

Liyanage, D.V. and Sakai, 1961. Heritabilities of certain yield characters of the coconut palm. *J. Genetics,* **57** : 245-252.

Louis, I.H. 1981. Genetic variability in coconut palm *(Cocos nucifera* L). *Madras Agric. J.*, **68** : 588-593.

Lush, J.L. 1949. *Animal Breeding Plans.* Iowa State Coll. Press., Ames, Iowa, 443 p.

Mathew, J., Rao, E.V.V.B., and Satyabalan, K. 1978. Sampling procedure for coconut germplasm collection. Paper presented at the *National Symposium on Plant and Animal Genetics Research.* 28-30 December 1978. IARI, New Delhi. India.

Menon, K.P.V. and Pandalai, K.M. *The coconut palm—A monograph.* Indian Central Coconut Committee, Ernakulam. 384 p.

Nair. M.K. 1992. Recent trends in evolving coconut varieties. *Vatika* from the seed and Plant people. Summer **2** : 11-17.

Nambiar, M.C. and Nambiar, K.P.P. 1970. Genetical analysis of yield attributes in *Cocos nucifera* var. West Coast Tall. *Euphytica,* **19** : 543-551.

Nambiar, M.C. and Ravindran, P.S. 1974. Pattern of genetic variation in reproductive characters of coconut. *Indian J. Genet.*, **34A** : 75-82.

Nambiar, M.C., Mathew, J. and Sumangalakutty, S. 1970. Inheritance of nut production in coconut. *Indian J. Genet.*, **30** : 599-603.

Neera Bhalla-Sarin, Suman Bagga, Sopory, S.K. and Guha-Mukherjee,S. 1986. Induction and differentiation of callus from embryos of *Cocos nucifera* L. by IAA-conjugates. *Plant Cell Reports,* **5** : 322-324.

Nampoothiri, K.U.K., Satyabalan, K. and Mathew, J. 1975. Phenotypic and genotypic correlation of certain characters with yield in coconut. *Fourth FAO Tech. Wkg. Party Cocon. Prodx. Protx. and Processg.* Kingston, Jamaica (AGP : CNP/75/44).

Ninan, C.A. 1983. Improvement of dwarf coconuts with special reference to Indian Dwarf Orange palms and their natural hybrids. In *Coconut Research and Development.* (Nayar, N.M., Ed.). Proc. ISOCRAD-I, 28-31 December 1976, Kasaragod. Wiley Eastern Ltd., New Delhi. p. 30-37.

Ninan, C.A. and Pankajakshan, A.S. 1961. Progeny studies in coconut. 1. Relationship between parent yield and seedling characters of progeny with special reference to open pollinated and hybrid progenies of West Coast Tall and its bearing on the concept of prepotency in coconut. *Indian Cocon. J.*, **14** : 100-109.

Ninan, C.A., Pankajakshan, A.S. and Abdu, K.M. 1964. Some observations on growth rate and vigour of coconut seedlings. *Indian Cocon. J.*, **18** : 12-17.

Ninan C.A. and Satyabalan, K. 1964. A study of natural. self and cross (Dwarf x Tall) progenies of Dwarf coconuts of the West Coast of India and its bearing on the genetics of Dwarfs and the putative hybridity of their off-type progenies. *Caryologia*, **17** : 77-91.

Patel, J.S. 1937. Coconut breeding. *Proc. Assoc. Biol.*, **5** : 1-16.

Pillai, R.V. 1990. Establishment of elite coconut seed garden and commercial production of hybrids, Tech. Bull. 22 (Nair, M.K. and Rohini Iyer, Eds.). CPCRI, Kasaragod. pp. 12.

Pillai, R.V. 1991. Economic life span of coconut hybrids. *Indian Cocon. J.*, **21** (6) : 2-6.

Prasada Rao., G.S.L.H.V. 1988. Agrometeorology of coconut. In *Six Decades of Coconut Research,* (Aravindakshan, M., Nair, R.R. and Wahid, P.A., Eds.). Kerala Agricultural University, Mannuthy. pp.81-93.

Purseglove, J.W. 1972. *Tropical Crops—Monocotyledons.* Longman Group Ltd., London. pp.607.

Rajagopal, V., Kasturi Bai, K.V. and Voleti, S.R. 1990. Screening of coconut genotypes for drought tolerance. *Oleagineux,* **45** : 215-223.

Rajagopal, V., Kasturi Bai, K.V., Voleti, S.R. and Shivashankar. S. 1988b. Leaf water potential as an index of drought tolerance in coconut. *Plant Physiol. and Biochem.,* **15** : 80-86.

Rajagopal, V., Voleti, S.R., Kasturi Bai, K.V. and Shivashankar, S. 1988a. Physiological and bio-chemical criteria for breeding for drought tolerance in coconut. *Proc. National Symposium on Coconut Breeding and Management* (Silas, E.G., Arvindakshan, M. Jose, A.I. Eds.). Kerala Agricultural University, 23-26 November 1988. pp. 136-143.

Raju, C.R., Prakash Kumar, P., Mini Chandran and Iyer, R.D. 1984. Coconut plantlets from leaf tissue culture. *J. Plantn. Crops.,* **12** (1) : 75-78.

Ramanathan, T., Henry Louis, I. and Navakodi, K. 1984. High yielding VHC-1 coconut hybrid. *Proc. Fifth Annu. Symp. Plantn. Crops* (PLACROSYM-V 1982). K.V.A. Bavappa, R.D. Iyer, P.K. Das, M.R. Sethuraj, V. Ranganathan, K.K.N. Nambiar and M.J. Chacko, Eds.). CPCRI, Kasaragod, 15-18 December 1982. pp. 125-130.

Ramanathan, T., Henry Louis, I. and Venkateswaran, A.N. 1982. Genetic diversity and exploitation of heterosis in coconut. Abstracts of papers. *5th Ann. Smp. on Plant Crops.* 15-18 December 1982. pp. 20-21.

Rao, E.V.V.B., Pillai, R.V. and Mathew, J. 1991. Relative drought tolerance and productivity of released coconut hybrids. In *Coconut Breeding and Management* (Silas, E.G., Aravindakshan, M. and Jose, A.I. Eds.). pp. 144-149.

Rao, E.V.V.B., Satyabalan, K. and Mathew, J. 1978. Evaluation of ten cultivars of coconut germplasm. Abstracts of papers presented at All India High Level Symposium on Researches in Plant Cytogenetics at Andhra University, Waltair, India. 9-12 Feb. 1978. pp. 9.

Rao, M.B.S. and Koyamu, K. 1952. Hybrid vigour in coconut seedlings. *Indian Cocon. J.,* **6** : 41-44.

Rao, M.B.S. and Koyamu, K. 1955. The dwarf coconut. *Indian Cocon. J.,* **8** : 106-112.

Satyabalan, K. 1956. A note on the performance of National Cross Disarf (female) x Tall (male) in coconut. *Indian Cocon. J.,* **9** : 166-173.

Satyabalan, K. 1976. Coconut hybrids. *Indian Farming,* **27** (9) : 13-16.

Satyabalan, K. 1982. Yield capacity and transmitting power of mother palms in coconut. *Indian Cocon. J.,* **13** (4) : 5-13.

Satyabalan, K. 1983. Review on coconut hybrids. Tall x Dwarf. *Coconis. Review Series,* Coconut Infor. Centre: Cocon. Res. Inst., Lunuwila, Sri Lanka. pp. 25.

Satyabalan, K. 1984. Nursery studies on West Coast Tall coconut to select seedlings for early transplanting. *J. Plant. Crops.,* **12** (2) : 112-118.

Satyabalan, K., George, M.V. and Radhakrishnan, V. 1964. Coconut breeding : A comparative study of 'Tall'x 'Dwarf', 'Tall' x 'Gangabondam' and 'Tall'x 'Tall' hybrid seedlings in the nursery for maximum expression of vigour. *Indian Cocon. J.,* **17** : 155-164.

Satyabalan, K. and Mathew, J. 1983. Identification of prepotent palms in West Coast Tall coconut based on the early stages of growth of the progeny in the nursery. In *Coconut Research and Development* (Nayar, N.M., Ed.). Wiley Eastern Ltd., New Delhi. pp. 15-22.

Satyabalan, K. and Rajagopal, K. 1987. Genetic improvement of coconut palm—Combining ability of palms in Dwarf x Tall hybrids. *J. Plantn. Crops,* **15** (1) : 23-30.

Satyabalan, K., Nampoothiri, K.U.K. and Mathew, J. 1975. Identification of prepotent West Coast Tall palms based on progeny performance. Fourth *FAO Tech. Wkg. Party. Cocon. Prodn. Protn. and Processg.* Kingston, Jamaica, (AGP : CNP/75/45).

Satyabalan, K., Ratnam, T.C. and Kunjan, P.V. 1970. Hybrid vigour in nut and copra characters of coconut hybrids. *Indian J. agric. Sci.*, **40** : 1088-1093.

Satyabalan, K. and Vijayakumar, G. 1982. Comparative performance of progenies from Chowghat Dwarf Orange coconut. In Proceedings, PLACROSYM IV (Vishweswara, S., *etal.*, Eds.). C.F.T.R.I. Mysore 3-5 December 1981. pp. 289-294.

Shivashankar, S. and Kasturi Bai, K.V. 1988. A comparative study of the growth and nitrogen accumulation capacity of hybrid coconut (*Cocos nucifera* L.) seedlings. *The Philip. J. of Coconut Studies,* **XII** (1) : 24-29.

Shivashankar, S., Rajagopal, K. and Ramadasan, A. 1985. Chlorophyll and nitrate reductase activity in relation to heterosis in coconut seedlings. *Ann. Bot.*, **55** : 755-758.

Solomon, J.J., Govindankutty, M.P. and Nienhaus, F. 1983. Association of mycoplasma-like organisms with the coconut root(wilt) disease in India. *Z. Pflkrankh. Pflschutz.*, **90** : 295-297.

Sukumaran, C.K., Narasimhayya, G. and Kumar, G.V. 1982. Path co-efficient analysis in coconut. In *Proceedings of PLACROSYM IV* (Vishveshwara, S. *et al.*, Ed.). CFTRI, Mysore 3-5 December 1981. pp. 191-199.

Swaminathan, M.S. 1983. Keynote address—Coconut Research The next phase, In : *Coonut Research and Development.* Nayar, N.M., Ed.) : Wiley Eastern Ltd., New Delhi. pp. 3-11. *Proc. Int. Symp. Cocon. Res. Dev.* Dec. 1976, CPCRI, Kasaragod.

Thomas Mathew, 1991. A study on the consumption of tender nut coconuts in Tamil Nadu. *Indian Cocon. J.*, **22** (5) : 5-8.

Venkateswaran, A.N., Rajagopal, R., Ramachandran, M. and Sridharan, C.S. 1975. A study on coconut plantations in Tamil Nadu. *Coconut Bull.*, **5** : 3-4.