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Genetics and Improvement of Coconut in India

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India is the largest producer of coconut in the World. However, the annual productivity per palm is low when compared to the potential. There is a vast scope of improving coconut yield through selection and breeding. First organised coconut breeding was started in 1916 at the Coconut Research Stations at Kasaragod and Nileshwar. CPCRI has undertaken extensive explorations and it now maintains world's largest collection of coconut germplasm. Based on multilocation trials, promising cultivars have been selected and released for different parts of the country. Eleven hybrids have been released for cultivation with yield potential of 95 - 141 nuts/palm/year. Drought tolerant and disease resistant varieties have been identified and are being used to develop high yielding hybrids. Biotechnological research is in progress for clonal propagation, gene transfer and use of molecular markers for fingerprinting germplasm.

The coconut palm, *Cocos nucifera* Linn., an important cultivated palm, is an oil crop but is also ranked as an important food crop. The palm not only supplies food, drink and shelter, but also provides raw materials for a number of important industries. The palm is referred to as "The Tree of Wealth" and "The Tree of Life", as it provides all the necessities of life.

The coconut palm is cultivated in the tropical region between latitudes 22° N and 22° S. Though it is a sea-side plant, it grows far away from the sea also. The main coconut growing areas are located in Asia, Oceania, West Indies, Central and South America, and West and East Africa.

In India, the coconut palm is grown in an area of 1796 million hectares. Kerala, Tamil Nadu and Karnataka account for about 88% of this area, while Andhra Pradesh, Orissa, West Bengal, Maharashtra, Goa, Diu and Daman, Assam, Pondicherry, Tripura, Andaman and Nicobar Islands and Lakshadweep account for the remaining 12% of the coconut area in the country.

India has been in the forefront in research on coconut improvement and the first organized coconut breeding in the world was started in 1916 at the erstwhile Coconut Research Stations in Kasaragod and Nileshwar (Pilicode) of the former Madras Presidency, now in Kerala State. Substantial advancement in knowledge has been achieved since then. This paper reviews the various aspects of coconut improvement in the country.

ORIGIN AND DISTRIBUTION

Martius (1850) considered the West Coast of Central America as the centre of origin of coconut. This was supported by Cook (1901). On the other hand, de Candolle (1886) considered coconut to be of Asiatic origin. A lot of controversies are there pertaining to the origin of coconut. Whichever the place of origin of coconut, it is presently disseminated throughout the tropics.

VARIETAL CLASSIFICATION

The coconut palm, *Cocos nucifera*, belongs to the monotypic genus *Cocos* with no known wild or domesticated relatives. However, the present day population of this palm presents a wide range of variability and a number of workers have attempted a classification of the various forms of coconut. A widely accepted classification groups cultivars into two groups - Talls and Dwarfs, on the basis of a few important characters like stature, growth characteristics of the palm, precocious nature in flowering, and nut and copra characters.

In addition, certain variants have also been observed. One is the seedless coconut or male coconut tree, which produces only male flowers and another is spikeless coconut palm or

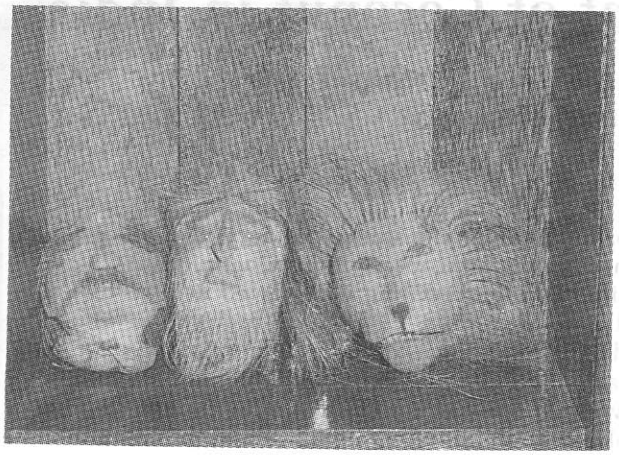

Fig. 1 : Handicrafts sculpted from the whole coconut

spicata, wherein the inflorescence does not carry spikelets (the male and female flowers borne directly on the primary spike).

CYTOLOGICAL STUDIES

Palms are difficult objects for cytological studies and hence have received little cytological attention in spite of their economic importance and biological and ecological significance. The first detailed study on cytology of *Cocos nucifera* was by Santos (1929), who reported the chromosome number of coconut as n = 16. In India, the chromosome number (n = 16) was reported in several publications (Janaki Ammal, 1945; Venkatasubban, 1945; Sharma & Sarkar, 1956; Ninan et al., 1960; Abraham et al., 1961). These studies and those of several others (Nambiar & Swaminathan, 1960; Swaminathan & Nambiar, 1961; Raveendranath & Ninan, 1973) have confirmed the somatic chromosome number of 2n = 32.

KARYOMORPHOLOGICAL STUDIES

A comparison of the gross features of chromosome complements of Tall (WCT) and Dwarf varieties reveals certain interesting facts. Raveendranath and Ninan (1973) observed that secondary constrictions were present on long arm of chromosome VI in Talls and long arm of chromosome III in Dwarfs. However, these differences were not consistent and additional satellites were observed on chromosome II (long arm), chromosome I (short arm), short arm of chromosome XII (Raveendranath & Ninan, 1973), long arm of chromosome XII (Thankamma Pillai et al., 1983) and IX (Nambiar & Swaminathan, 1980) in Talls and in chromosome VI (long arm) in Dwarfs (Raveendranath & Ninan, 1973).

Nambiar and Swaminathan (1960) observed that in Talls, majority of the chromosomes had submedian centromeres, with two pairs of chromosomes much longer and three pairs relatively short. On the other hand, Raveendranath and Ninan (1973) observed that Talls as well as Dwarfs had a preponderance of chromosomes with median centromeres, with four submedian chromosomes (II, IV, VII, XIV) in WCT, three (chromosome II, VII, XII) in Dwarf Orange (DO) and only one (chromosome II) in Dwarf Green (DG). In higher plants, karyotypic evolution has been from complete symmetry to asymmetry (Stebbins, 1950). From this angle, WCTs show a more evolved karyotype than DO and DG.

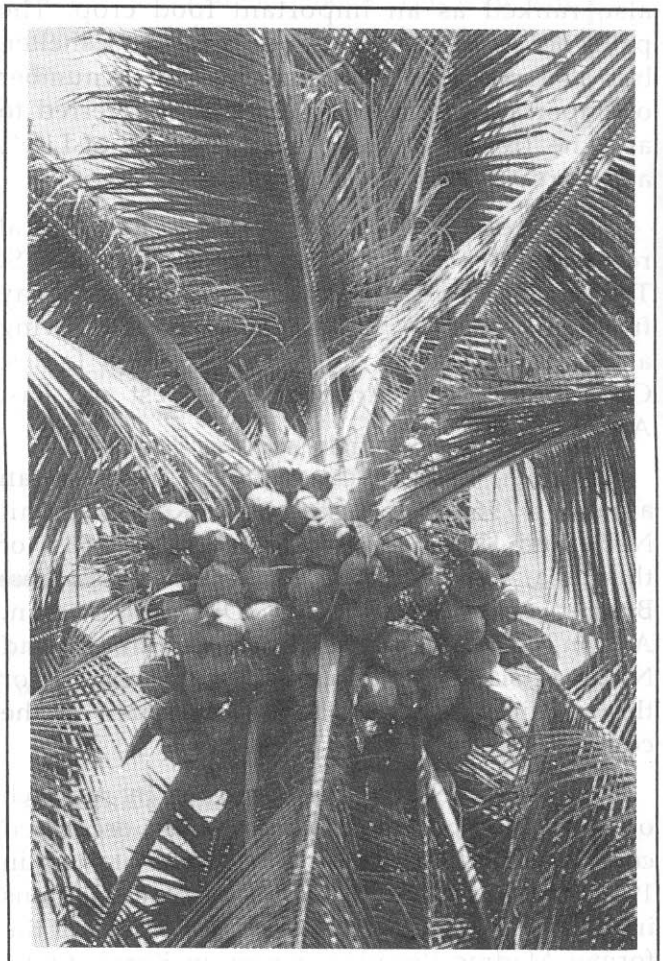

Fig. 2 : Chandra Tara - A promising variety

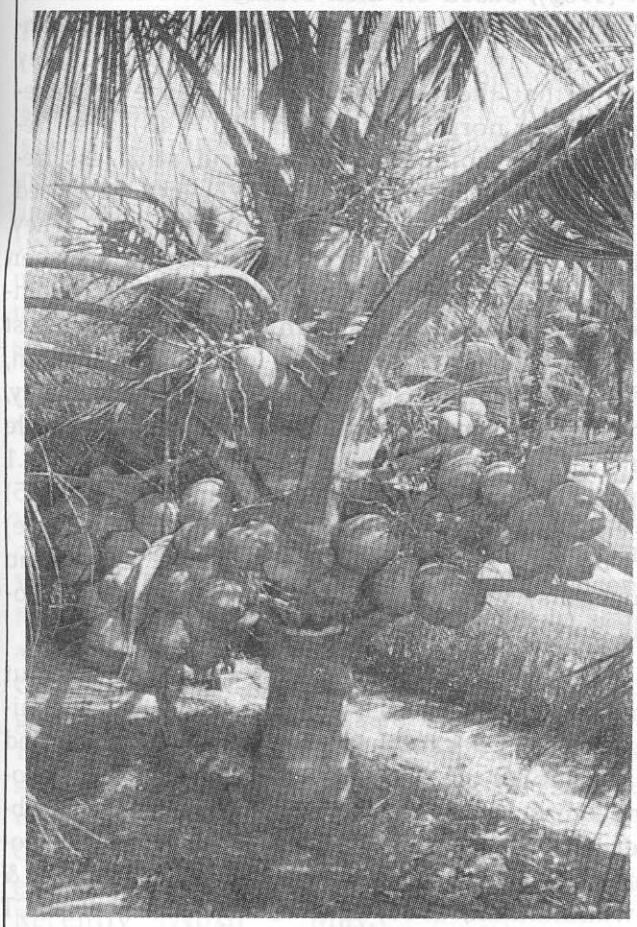

Fig. 3 : A prolific hybrid CGD x WCT

Total chromatin content is found to be greater in DG than WCT (Raveendranath & Ninan, 1973). Sharma and Sarkar (1956) have observed that total chromatin content is more in wild species than cultivated ones. Therefore, DG appears to be the most primitive among the three cultivars studied. However, evidences from morphology, breeding system and meiotic behaviour support the possible evolution of Dwarfs from Talls.

MEIOTIC STUDIES

The different varieties of Talls and Dwarfs, open pollinated and inbred populations, show significant differences in their meiotic behaviour. The Dwarfs show less stable meiosis than Talls, and it has been proposed that ancestral types show more stable meiosis (Lindquist, 1960). In general, microsporogenesis is more regular in open pollinated than inbred progenies.

Nambiar et al. (1970) studied cytological behaviour of Laccadive Ordinary (LO), Philippines Ordinary (PO), Andaman, New Guinea and Cochin China varieties of coconut and observed that microsporogenesis was relatively regular in both inbred and open pollinated progenies of Laccadive variety, while comparatively higher frequencies of chromosome aberration and pollen sterility was observed in inbred as well as open pollinated progenies of Cochin China and New Guinea and inbred progenies of Philippines and Andaman varieties. The lack of inbreeding depression only in Laccadive variety may either be due to differences in intensity of inbreeding and selection between these geographically distinct varieties, or due to the Laccadive genotype being comparatively less sensitive to inbreeding.

Nambiar and Swaminathan (1960) observed many meiotic irregularities in Apricot from Straits Settlements and Dwarf Red forms which are derived from the Dwarfs, while meiosis was regular in Laccadive Ordinary. Consequently, higher pollen sterility occurred in these two Dwarf derivatives in comparison to Laccadive Ordinary. Thankamma Pillai et al. (1983) studied meiosis in nine cultivars and hybrids and indicated that percentage of abnormalities was highest in DG and DO, while chromosome abnormalities and sterility were very low in D x T and T x D hybrids. They concluded that the higher degree of inbreeding in Dwarfs may be the reason for higher chromosome aberrations and sterility in them. Cytological studies on Spicata variety (Ninan et al., 1960; Ninan & Satyabalan, 1963; Ninan & Nambiar, 1974) showed that meiosis was irregular with inversions, translocations and many other abnormalities. Spicata palms, being predominant outbreeders, are believed to have arisen from Talls through mutation.

Further, cytological studies have been undertaken on abnormal palm, bulbiferous palm and root wilt affected palms. Nambiar and Prasannakumari (1964) studied the effect of root (wilt) diseases on microsporogenesis in coconut and observed low frequency of cytological aberrations, high pollen fertility and seed set. Thankamma Pillai and Vijayakumar (1972) studied the course of microsporogenesis in the prog-

eny of a self pollinated New Guinea palm which produced defective nuts and observed aberrant meiosis. The sterility in this palm was attributed to inbreeding. Raveendranath et al. (1975) found no appreciable karyological differences between the Tall and abnormal coconut palm producing bulbils in the place of inflorescences and opined that cryptic structural changes or genetic mutations might be responsible for the appearance of this type of coconut palm.

CYTOLOGICAL STUDIES ON ENDOSPERM AND EMBRYO

Dutt (1953) and Abraham and Thomas (1962) reported free nuclear divisions in coconut water (liquid endosperm). But, this was disputed by Mondal et al. (1970) based on the biochemical analysis of coconut water.

Abraham and Mathew (1963) and Abraham *et al.* (1966), based on their studies of 6 month old nuts, observed that size of nuclei varied considerably in the developing endosperm. They found that the tissues adjacent to the endothelium were normally triploid (3x = 48), less frequently hexaploid (6x = 96) and still less frequently dodecaploid (12x = 192) and proposed that higher ploidy levels arise by C-mitosis. They also recorded an inverse relationship between ploidy and percentage oil content, with the inner part of the endosperm having the highest ploidy level and lowest oil content (Abraham, 1963; Abraham et al., 1965). In the Tall variety, the percentage oil content in the outer, middle and inner layers of endosperm was 75.7, 54.1 and 41.4, respectively. Abraham et al. (1965) recorded higher ploidy levels (48x and above) in buttery endosperm (Philippines Makapuno coconuts) which they felt arose through amitosis and nuclear fusion.

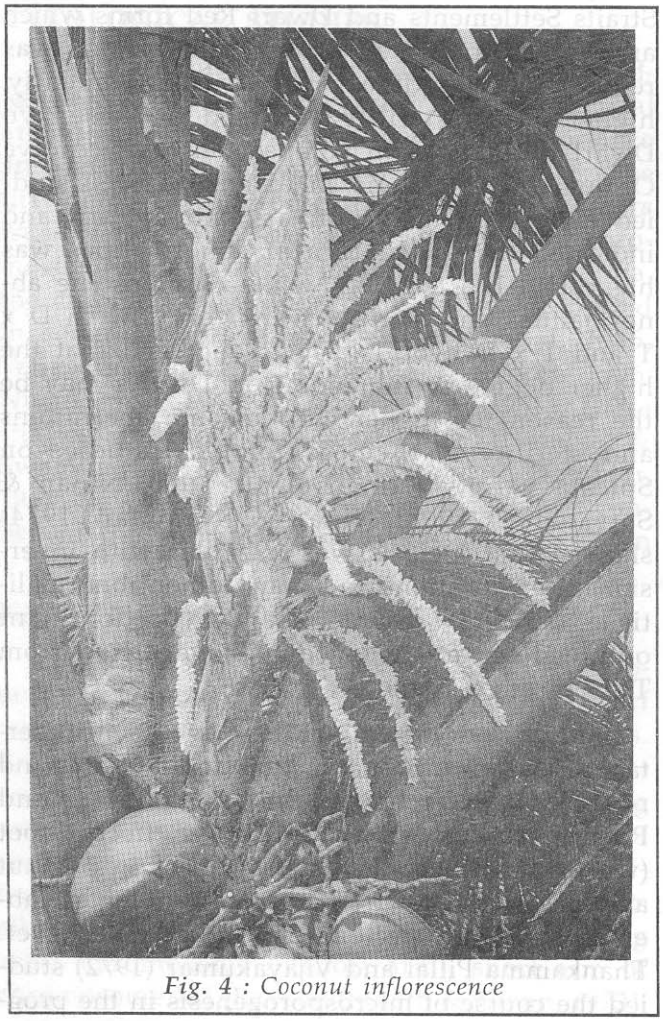

Fig. 4 : Coconut inflorescence

Unlike the endosperm, the young coconut embryos are diploids and divide by normal mitosis. Raveendranath and Ninan (1973) studied karyomorphological features of somatic chromosomes from six month old embryos and observed an essential uniformity in relative chromosome length from root tip (Nambiar & Swaminathan, 1960) and embryo cells of WCT palms. Ninan and Raveendranath (1965) reported occurrence of a haploid embryo in a WCT palm.

CROP IMPROVEMENT

India tops the world in coconut production, with an annual yield of 13,299 million nuts. However, the average annual productivity is 36 nuts/palm. This contrasts sharply with the yield of 110 nuts/palm/year realized by a progressive farmer, 175 nuts/palm/year for T x D hybrids at research stations (Swaminathan, 1983) and 471 nuts/palm/year recorded in certain elite palms (Iyer et al., 1979), indicating the vast scope available for coconut improvement.

The fact that coconut belongs to a monotypic genus with no known wild/domesticated relatives limits the possibilities of tapping gene pools of related sources. Moreover, the available variability within coconut is being slowly depleted through large scale replanting programmes, thereby necessitating immediate

collection and conservation of existing native populations.

The first organized coconut breeding was started in 1916 at the erstwhile Coconut Research Stations at Kasaragod and Nileshwar, now under Central Plantation Crops Research Institute (CPCRI) and Kerala Agricultural University, respectively. However, genetic improvement of perennial crops, in general, and coconut in particular is very tedious and time consuming.

GERMPLASM COLLECTION AND CONSERVATION

In India, germplasm collection began in 1924 with the introduction of cultivars from Fiji, Indonesia, Malaysia, Philippines, Sri Lanka and Vietnam (Cochin China) at the Central Coconut Research Station, Pilicode. Subsequently selfed and open pollinated progenies were planted at CPCRI (then CCRS), Kasaragod, in 1940s. The germplasm collection was further intensified in 1952 and in 1958 the first indigenous germplasm survey and collection was started. In 1981, survey and collection was made from six Pacific Ocean countries under an FAO/IBPGR funded expedition, which added 24 exotic collections. Recently (April - May, 1997) an Asian Development Bank funded germplasm collection was undertaken by CPCRI, Kasaragod, and 15 accessions (including three dwarfs) were collected (in the form of embryos) from the three Indian Ocean Islands of Mauritius, Madagascar and Seychelles. Presently, CPCRI has the world's largest collection of coconut germplasm with 147 accessions from 25 countries of South and South East Asia, Caribbean Islands, Indian Ocean Islands, Pacific Ocean Islands and African countries, and indigenous collections from Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Goa, Gujrat, Orissa, West Bengal, Andaman and Nicobar Islands and Lakshadweep Islands. Among these, 62 exotic and 40 indigenous accessions are maintained at Kasaragod and the rest (24 Pacific Ocean collections and 6 Nicobar collections) at the World Coconut Germplasm Centre (WCGC), Andamans. In addition, subsamples of these collections are maintained at Pilicode, and the centres under the All India Coordinated Project on Palms, namely, Aliyarnagar, Coimbatore and Veppankulam in Tamil Nadu, Ambajipet in Andhra Pradesh, Arsikere in Karnataka, Konark in Orissa, Jagadalpur in Madhya Pradesh, Jalagarh in Bihar, Moudouri in West Bengal and Ratnagiri in Maharashtra, for testing their regional adaptability. Germplasm characterization is undertaken using the IBPGR descriptor (Anonymous, 1978). CPCRI has so far prepared a descriptor for 48 different coconut accessions (Ratnambal et al., 1995).

VARIETIES RELEASED THROUGH SELECTION

Screening of the available coconut cultivars for their performance under different ecological conditions is a promising method of obtaining ecotypes suited for the different regions of

Fig. 5 : Coconut shell and wood handicrafts

Fig. 6 : A coconut plantation

our country.

At CPCRI, on the basis of a preliminary evaluation of available coconut cultivars, promising cultivars were selected for further multilocation trials. Laccadive Ordinary was found to be a superior yielder in the States of Andhra Pradesh, Kerala, Tamil Nadu and Maharashtra and was therefore released by CPCRI in 1985 under the name 'Chandra Kalpa' (Anon., 1985). Similarly another promising exotic cultivar, Philippines Ordinary, has been recommended for release as a National Variety (Chandra Tara) by the XII Workshop on AICRPP (December, 1995) for commercial cultivation in the West Coast, including Konkan regions, coastal Andhra Pradesh and West Bengal (Anon., 1996). The Konkan Krishi Vidyapeeth, Dapoli has selected and released a local cultivar 'Banawali Green Round' (Benaulim), for cultivation in the Konkan coast under the name 'Pratap' (Anon., 1987). The yield performance of the released coconut cultivars is given in Table 1.

HYBRIDIZATION

Hybridization work was first started in Fiji (Marechal, 1928) but was discontinued due to economic crisis. In India, hybridization was initiated in 1932, followed some 15 years later by Sri Lanka. In the early 1960s, IRHO and its partners started their hybridization work while other coconut growing countries undertook hybridization work much later.

In India, Patel initiated the hybridization programme with three intra-varietal and one inter-varietal cross at the Coconut Research Station, Nileshwar, in the year 1932, and was the first to report hybrid vigour in coconut (Patel, 1937). Over the years, more than 95 hybrid combinations have been evaluated at CPCRI and the various coordinating centres and so far 11 hybrids have been released for cultivation, the yield potential of which varies from 95 - 141 nuts/palm/year and 13.20 - 26.40 kg copra/palm/year (Table 2).

BREEDING FOR SPECIFIC TRAITS

Coconut breeding programmes, in addition to yield improvement, are also aimed at development of drought tolerant and pest resistant varieties. Further, qualitative parameters of tendernut water are studied for selection of the best tendernut varieties.

DROUGHT TOLERANCE

Coconut palm requires an average monthly rainfall of 150 mm for ideal palm growth and good nut yield and, unlike annuals, the adverse effect of drought persists for the subsequent two to three years. In India, coconut is cultivated mainly as a rainfed crop in peninsular India, which accounts for 90% of the coconut area in the country, and is exposed to the vagaries of monsoon, resulting in poor yields. Therefore, there is a need to evolve drought tolerant hybrids/varieties.

Rajagopal et al. (1991) and Chempakam et al. (1993) revealed the possibility of identifying

drought tolerant cultivars based on different physiological and biochemical parameters. Subsequently, Rajagopal et al. (1988, 1990) screened different coconut cultivars for drought tolerance and found WCT x WCT, Federated Malay States (FMS), Java Gaint, Fiji, Andaman Gaint, LO x GB and LO x COD to be drought tolerant.

The identified drought tolerant cultivars are currently being used in the breeding programs at CPCRI, Kasaragod, to evolve high yielding, drought tolerant hybrids.

INSECT RESISTANCE

A number of insect pests attack coconut palms, of which, rhinoceros beetle and red palm weevil are the two major ones. These respond to conventional plant protection measures and therefore no specific breeding programmes for developing resistant genotypes have been initiated. Preliminary screening of cultivars/hybrids against leaf eating caterpillar, *Nephantis serinopa* Meyr. (Kapadia, 1981) and rhinoceros beetle, *Oryctes rhinoceros* Linn. (Sumangala Nambiar, 1991) indicated variations in susceptibility among cultivars, though no resistant variety was observed.

DISEASE RESISTANCE

Coconut is affected by a number of diseases, of which the major ones are *Phytophthora* bud rot, stem bleeding, Thanjavur wilt/Ganoderma disease and root (wilt) disease. Among these, root (wilt) disease is the most serious and in the absence of effective control measures against the disease, evolving resistant cultivars is of utmost importance.

Studies on identifying coconut genotypes resistant/tolerant to root (wilt) disease were initiated by Varghese in 1934. Since 1961, the CPCRI Regional Research Station, Kayangulam, has made considerable efforts to screen the available cultivars for tolerance to root (wilt) disease. However, all the cultivars/hybrids screened were found susceptible to the disease (Menon et al., 1981). Only the cultivar CGD, has been found to have field tolerance of over 90% to the disease (Anon., 1972). A survey of the disease affected areas ('hot spots') identified some high yielding, disease free WCT and CGD palms (Iyer et al., 1979). Presently, phenotypically and serologically disease-free WCT and CGD palms are used in the breeding programme to produce different cross combinations - WCT × WCT, WCT × CGD, CGD × WCT, WCT self, CGD self. In addition, mixed pollen from all selected healthy palms in the diseased tract is also used for pollination to develop a gene pool of field tolerant palms. So far 2455 seedlings have been planted in the disease affected areas for screening against root (wilt) disease (Anon., 1997). A few progenies of the cultivar 'Gudanjali' from Gujrat have also been planted for screening (Anon., 1994). Subsequently, healthy COD mother palms in the 'hot spots', have also been

Table 1 : Yield performance of released coconut varieties

Cultivar	Varietal Name	Mean yield nuts/ palm/ year	Copra yield		State for which recommended	Year of release	Agency responsible for release
			Mean/ nut (g)	Mean/ palm/ year (kg)			
Laccadive Ordinary	Chandra Kalpa	97	195	18.9	Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra	1985	CPCRI
Banawali Green Round	Pratap	151	250	22.7	Goa, Coastal Maharashtra	1987	Konkan Krishi Vidyapeeth
Philippines Ordinary	Chandra Tara	110	189	20.8	West Coast, Coastal Andhra Pradesh, West Bengal	1995	CPCRI
WCT	-	80	176	14.1			

Table 2 : Performance of released coconut hybrids

Sl. No.	Hybrid	Parentage	Nut yield/ palm/ year	Copra yield		Oil content	States for which re-commended	Year of release	Agency respon-sible for release
				Mean nut (g)	Mean/ palm (kg)				
1.	Chandra Sankara	COD × WCT	116	215	24.9	68	Kerala	1985	CPCRI
2.	Laksha Ganga (PHC1)	LO × GB	108	195	21.1	70	Kerala	1987	KAU
3.	Chandra Laksha	LO × COD	109	195	21.3	69	Kerala	1985	CPCRI
4.	Kera Ganga (PHC3)	WCT × GB	100	201	20.1	69	Kerala	1988	KAU
5.	Ananda Ganga (PHC2)	AO × GB	95	216	20.5	68	Kerala	1988	KAU
6.	Kera Sankara	WCT × COD	108	187	20.2	68	Kerala, Coastal Maharashtra, Coastal Andhra Pradesh	1991	CPCRI
7.	Kera Sree	WCT × MYD	141	187	26.4	66	Kerala	1992	KAU
8.	Kera Sowbhagya	WCT × SS	116	196	22.7	65	Kerala	1994	KAU
9.	VHC 1	ECT × DG	98	135	13.2	70	Tamil Nadu	1982	TNAU
10.	VHC 2	ECT × MYD	107	152	16.3	69	Tamil Nadu	1988	TNAU
11.	Godavari Ganga	ECT × GB	140	150	21.0	68	Andhra Pradesh	1992	APAU
	WCT	-	80	176	14.1	68			

used in the resistance breeding programme (Anon., 1996).

A few exotic cultivars screened against root (wilt) disease were found susceptible to the disease, though significant differences in disease intensity between cultivars was observed (Mathai et al., 1985, 1991). However, since no tolerant variety has been identified, exotic cultivars are presently not being utilized in the root (wilt) disease resistance breeding programme. Meanwhile, *inter se* and selfed nuts of the 24 exotic accessions from the South Pacific Ocean Islands being evaluated at the WCGC, Andamans, have been planted in the 'hot spot' areas for screening for resistance/ tolerance to root (wilt) disease (Jacob & Rawther, 1991).

At the CPCRI Regional Research Station, Kayangulam, the CGD x WCT hybrid progenies planted in 1991 have started bearing and have so far not taken up the root (wilt) disease (Anon., 1995, 1996, 1997; Nair et al., 1996). The relative tolerance/resistance to the disease of these D × T hybrids, coupled with their high yield potential has highlighted the scope of developing this hybrid as a suitable planting material for the disease endemic areas.

NUT WATER QUALITY

The consumption of tendernuts as a natural, nourishing and refreshing drink is becoming increasingly popular in our country. As a result of the high demand, tendernuts are being harvested from the existing Talls, sacrificing the quality of nut water and at the cost of valuable copra and oil. Therefore, at CPCRI, a study was initiated to identify a suitable cultivar for tendernut purpose (Dhamodaran et al., 1993). Among the cultivars evaluated, the cultivar COD, from the Chavakkad village in Trichur District of Kerala, had the maximum total sugars (7.0%) and reducing sugars (4.7%) coupled with low sodium and potassium levels (Table 3). On the basis of the superior nut water quality, the X Workshop of the All India Coordinated Project on Palms (September, 1991), recommended the release of COD as a tender nut variety in Kerala (Anon., 1991).

Table 3 : Biochemical constituents of tendernut water and nut yield in 12 coconut cultivars (mean values for 1988-91)

Cultivar	Volume of water (ml)	Sugars (g/100 ml)		Free amino acids (mg/ 100 ml)	K (mg/l)	Na (mg/l)	Mean yield nuts/palm/ (l) year
		Total	Reducing				
New Guinea	358	5.8	3.0	1.4	2258	21	73
Philippines 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
Jamaican 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

BIOTECHNOLOGY

Clonal propagation of coconut through tissue culture would accelerate progress in coconut breeding programmes. Palms selected on the basis of yield, tolerance to drought, pest and diseases, and other unfavourable conditions could be vegetatively propagated for producing elite parental lines for use in breeding programmes or for establishing high yielding, elite commercial plantations.

Tissue culture work in India began in the late 1970s and early 1980s and ten different centres across the country were engaged in tissue culture research (Nair, 1994; Iyer, 1995). Presently, organised research on coconut biotechnology is being carried out only at CPCRI, Kasaragod. The main areas of research are : (i) culture of vegetative tissues for induction of somatic enbryogenesis; (ii) culture of immature inflorescence explants for direct shoot induction and plantlet production; (iii) embryo culture for standardization of field collection, storage, transportation and retrieval of germplasm from different coconut growing regions and also as a source of sterile explants for induction of multiple shoot formation and plantlet production; and (iv) application of biochemical and molecular markers like isozymes, RFLPs, RAPDs, DAF, for character tagging and fingerprinting germplasm.

Work on leaf tissue culture was initiated by Raju et al. (1982) at CPCRI. From spindle leaf explants of WCT seedlings the first clonal plantlet was obtained in 1984 (Raju et al., 1984). Subsequently, four such clonal plantlets were field planted and have established well. However, consistent and repeatable success has not been achieved. The emphasis now is on using adult palm tissue for culture. So far, no successful attempts have been reported in India (Iyer, 1993). Bhaskaran (1985), at the Tissue Culture Laboratory of Hindustan Lever Ltd., Mumbai, obtained direct and indirect somatic embryogenesis via callus from immature leaf explants in culture. However, only embryos arising from callus germinated into plantlets on a high cytokinin medium.

Immature rachilla explants have produced shoot-like structures, but without roots (Kuruvinashetti & Iyer, 1979, 1980; Iyer et al., 1982). Shirke et al. (1993) at the National Chemical Laboratory, Pune, obtained repetitive embryogenesis from rachilla tissue in culture. The embryo-like structures turned green on expo-

sure to light.

Anther culture work carried out at CPCRI, Kasaragod (Iyer, 1982) and St. Aloysius College, Mangalore (D'Souza & Mallya, 1993), has yielded only multi-celled pollen embryoids.

Tissue culture and embryo culture work on coconut was initiated at the School of Life Sciences, Jawaharlal Nehru University, New Delhi, in the early 1980s by a team of scientists headed by Prof. Sipra Guha-Mukherjee. They cultured explants from endosperm (semi-solid and solid), apical meristems, leaf and leaf base, male flowers, inflorescence, anthers and rachillae, but could not obtain a repeatable response (Neera Bhalla-Sarin & Suman Bagga, 1988). They also tried protoplast culture and obtained a few divisions with viable protoplasts.

Zygotic embryo culture was first attempted by Abraham and Thomas (1962) in the Department of Botany, Kerala University. They obtained fully developed plantlets six months after culture, but their root growth was rudimentary. Gupta et al. (1984) and Mascarenhas et al. (1988) obtained complete plantlets from cultured zygotic embryos but these plants did not survive transplantation. Subsequently, field planting of embryo-cultured plantlets has been reported from CPCRI, Kasaragod (Anon., 1989), St. Aloysius College, Mangalore (D'Souza et al., 1988), and Madurai Kamaraj University, Madurai (Jegadeesan & Padmanabhan, 1982). Embryo-cultured plantlets have also been obtained at Tamil Nadu Agricultural University, Coimbatore (Kalamani & Sree Rangaswamy, 1990). Presently embryo culture is being used at CPCRI as a tool for germplasm collection (Anitha Karun et al., 1993). At Jawaharlal Nehru University, New Delhi, Sipra Guha-Mukherjee and co-workers obtained callus from 8 to 10 month old zygotic embryos, which regenerated into plantlets. However, the plantlets did not survive in soil due to poor root growth (Neera Bhalla-Sarin et al., 1986).

Bajaj (1984) at Punjab Agricultural University, Ludhiana, reported the possibility of long term cryopreservation of coconut embryos by freezing in liquid Nitrogen.

Research on coconut biotechnology is also being carried out in a few laboratories in Sri Lanka, Philippines, France and U.K.

CONCLUSION

From the foregoing discussion, it is clear that the research on genetics and breeding of coconut is going on for the past seven decades and the major research is being carried out in India. Considering the importance of the crop and the pioneering role played by India it is our endeavour to preserve the coconut germplasm available in all the coconut growing countries of the world. It is in this direction a Coconut Regional Gene Bank is proposed to be set up under CPCRI. This would prevent coconut varieties from becoming extinct. Some of the other areas in which research has to be carried out more intensely are as follows :

1. Conserving and cataloguing of coconut germplasm.
2. Breeding for resistance to root wilt.
3. Breeding varieties for tolerance to drought.
4. Intensive biotechnological research for clonal propagation, gene transfer and use of molecular markers for fingerprinting germplasm.

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