

HIGH PRODUCTION TECHNOLOGY IN COCONUT

M.K. Nair*, H.H. Khan** and P. Gopalasundaram**

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

INTRODUCTION

India ranks third in the world in area and total production of coconut. Present estimated area under coconut is 1.51 million ha with an annual estimated production of 10043.2 million nuts. Kerala State accounts for 55.75 per cent area and 41.88 per cent production of nuts. Though Karnataka with 0.233 million ha under coconut is second in area to Kerala, in terms of production, Tamil Nadu ranks next to Kerala with 2358 million nuts.

The Central Plantation Crops Research Institute (CPCRI) is the premier research institute in the country with a mandate to conduct basic and applied research on various aspects of improving productivity in coconut in the country. The Institute also co-ordinates the research being done on coconut by the State Agricultural Universities and other agencies in India. The current status of coconut research pertaining to high production technology excluding plant protection measures is briefly reviewed below.

CROP IMPROVEMENT

Germplasm

The earliest exotic introductions into India were in 1914 from the Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam which formed the nucleus population for many of the research

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programmes. The germplasm collection programme was further intensified in 1952. The first indigenous survey for germplasm collection was started during the year 1958. At present the Central Plantation Crops Research Institute (CPCRI) is maintaining the world's largest assemblage of germplasm of 41 indigenous and 86 exotic accessions (Table 1).

These 86 exotic cultivars represent collections from 22 countries of South and South-East Asia, Carribean, Indian Ocean, Pacific Ocean Islands and African countries, comprising of 52 Talls, 8 Dwarfs, one semi tall and one Hybrid. Of the earlier collections, 24 exotic collections (20 Talls and 4 Dwarfs) are from six countries in the Pacific Ocean region, made during the year 1981 under the FAO/IBPGR funded expedition.

These germplasm are being systematically evaluated for their yield, tolerance to pests and dis-

eases in comparison with local Talls.

Among the exotic cultivars, Fiji Tall, Fiji Long Tongwan, Philippine Ordinary, Philippine Laguna and SS Green from Malaysia were found superior to others. Performance of these promising exotic accessions are given in Table-2.

Among the indigenous cultivars evaluated, Kappadam, Andaman Ordinary, Laccadive Ordinary and Benaullim Green Round were found to have higher yield potential than the local West Coast Tall. Based on the overall performance of these indigenous types, Laccadive Ordinary has been recommended for release under the name "Chandrakalpa" for four states, viz., Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra. This cultivar gave 25 per cent more yield in terms of nut and 33 per cent more copra yield at stabilised bearing period. Benaullim Green Round with an

Table 1. Coconut germplasm holding at CPCRI

Regions	Exotic		Indigenous	
	No. of accessions	States/ UT	No. of accessions	
Asia & S.E. Asia	21	Andaman & Nicobar	11	
Africa	9	Andhra Pradesh	4	
Carribean	5	Gujarat	1	
Pacific	48*	Goa	3	
South America	1	Karnataka	3	
Indian Ocean Islands	2	Kerala	6	
		Lakshadweep	4	
		Orissa	1	
		Tamil nadu	8	
Total	86		41	

* Including 24 accessions collected under FAO/IBPGR/CPCRI programme.

Table 2. Performance of promising exotic cultivars of coconut

Cultivar	Mean annual yield (nuts/palm)		Copra	
	9th and 10th yr.	17th - 20th yr.	per nut (g)	per palm (kg/yr.)
<i>Exotic</i>				
Fiji Tall	37.4	106.1	180	19.1
Fiji Long Tong Wan	19.9	104.3	181	18.9
Philippine Ordinary	37.3	107.7	210	22.6
Philippine Laguna	25.3	87.5	261	22.8
SS Green	46.8	108.1	196	21.2

yield of 151 nuts/palm/year was recommended for release in Maharashtra.

HYBRIDS

Discovery of manifestation of Hybrid vigour in crosses between West Coast Tall and Chowghat Dwarf Green by Dr.J.S. Patel in 1937 added a new dimension to the coconut improvement programme in the country. Subsequently, many workers confirmed heterotic effects in the inter-varietal and intra-varietal crosses of coconut. Till the middle of 50s the

emphasis was given on the production of hybrids with Tall as the female parent. These hybrids were precocious and had high yield compared to West Coast Tall under good management. In subsequent years, Dwarf as mother palm was found to be superior to both the parents as well as its reciprocals in yield of nut and out-turn of copra. More than 80 hybrid combinations have been evaluated over the years at CPCRI, Kasaragod and various Co-ordinating Centres of All India Co-ordinated Research Project on

Palms. In view of the superior performance, the hybrids COD x WCT (Chandrasankara) and LO x COD (Chandralaksha) developed at CPCRI were recommended for release in Kerala during the year 1985. Laccadive Ordinary x Gangabondam hybrid developed by the Kerala Agricultural University was also recommended for release under name Laksha Ganga during the year 1985. Two Tall x Dwarf hybrids developed at Veppankulam Centre of the Tamil Nadu Agricultural University was recommended for release under the name VHC-1 and VHC-2 for Tamil Nadu. Another hybrid WCT x COD developed at CPCRI was recommended for release in whole of Kerala, coastal Maharashtra and coastal Andhra Pradesh and Karnataka during the year 1989 based on its superior performance. So far nine hybrids have been recommended for release for large-scale cultivation in various parts of the country. The details are given

Table 3. Performance of released coconut varieties and hybrids

Hybrids/ varieties	Nut yield/ palm/ year	Copra yield		Copra yield/ ha (t)	Oil content (%)	State for which recommended
		Mean/ nut (g)	Mean/ palm (kg)			
Chandrakalpa (LO)	98	195	19	1.9	72	Kerala, Tamil Nadu, Andhra-Pradesh and Maharashtra
Pratap (BGR)	151	152	23	2.3	65	Maharashtra
Chandrasankara (COD x WCT)	116	215	25	4.4	68	Kerala, Karnataka Tamil Nadu
Kerasankara (WCT x COD)	108	187	21	3.5	68	Kerala, Karnataka
Chandralaksha (LO x COD)	109	195	21	3.7	69	Kerala, Karnataka
Lakshaganga (LO x GB)	108	195	21	3.7	70	Kerala
Anandaganga (AO x GB)	95	216	21	3.6	68	Kerala
Keraganga (WCT x GB)	100	201	21	3.5	69	Kerala
VHC-1 (ECT x DG)	98	135	13	2.3	70	Tamil Nadu
VHC-2 (ECT x MYD)	107	152	16	2.9	69	Tamil Nadu
ECT x GB	140	150	21	3.7	68	Andhra Pradesh
WCT	80	176	14	2.5	68	Control

in Table-3. It could be seen that the cross-combinations between Talls and Dwarfs are not only high yielding but also precocious. The yields of hybrids in terms of nut production were much higher (95 or more nuts/palm/year) compared to around 80 nuts produced by the Tall cultivar.

The difference in copra yield is more marked in Chowghat Orange Dwarf x West Coast Tall hybrid giving as much as 25 kg per palm per year in comparison with 14 kg from West Coast Tall. However judicious selection of parental lines and cultivars within the talls and dwarfs seems necessary since combination-wise differences are noticeable.

SEED DEMAND VERSUS SUPPLY

It is of interest to examine the extent of availability of improved/released hybrids vis-a-vis its requirements. The current annual demand for coconut seedlings in the country is estimated at 15 million. The production of hybrids is to the tune of only one million and that of Talls is 2.2 million (Table 4). Thus there is a wide gap between demand and supply. This situation is being exploited by private nurseries which supply poor quality seedlings. It is, therefore necessary to increase hybrid production capability of the existing 24 seed gardens covering an area of 1,258 ha and additional seed gardens need to be established in the major coconut growing states. These seed gardens should be planted with parental materials to produce hybrids recommended for the respective states.

Coconut is mostly a crop of small farmers in India, the average size of a holdings being 0.22 ha. More than 90 per cent of the five

Table 4. Production of planting materials (in millions)

Agency	Present production (1991)			
	Talls	Dwarfs	T x D	D x T
1. Dept. of Agric., Kerala	1.26	--	0.09	0.01
2. C.S.F., Aralam	0.04	--	0.007	0.01
3. Dept. of Agric., Tamil Nadu	0.70	--	0.35	0.35
4. Dept. of Agric., Lakshadweep	0.06	--	0.05	0.05
5. C.P.C.R.I., Kerala	0.11	0.02	0.003	0.01
Total	2.17	0.02	0.50	0.43

million coconut holdings in the country are less than one ha in size (Thampan, 1988). These small holdings neither provide gainfull employment opportunities for the family labour throughout the year nor generate sufficient income to meet the family requirements. Hence the farmers traditionally raise a variety of annual and perennial crops in the interspaces of coconut gardens to meet their food, fodder, fuel-wood and timber requirements in addition to generate supplementary income. In a recent survey, Sathes Babu *et al* (1992) have reported that a farmer had raised 60 species of crops, trees and ornamental plants in 0.4 ha of homestead garden among which coconut was the predominant one. The possibilities of increasing the productivity and net returns from coconut stands by introducing compatible subsidiary crops and integrating livestock are discussed in this paper.

SCOPE FOR MULTIPLE CROPPING IN COCONUT

A spacing of 7.5 x 7.5 m is recommended for coconut (175 palm/ha) but in the homestead gardens of Kerala, the density is

much higher (200 to 250 palm/ha) where as in the *Malnad* region of Karnataka state much wider spacing are adopted with densities as low as 120 palm/ha. Experimental evidences have shown that a sole crop of coconut, at the recommended spacing of 7.5 x 7.5 m does not fully utilise the available resources.

Coconut palm like all monocots has a typical adventitious root system. Under favourable conditions, as many as 4000 to 7000 roots are found in middle-aged palms. Kushwah *et al.* (1973) reported that about 74 per cent of the roots produced by a palm under good management did not go beyond 2 m lateral distance and 82 per cent of the roots were confined to the 31 to 120 cm depth of soil. Recent studies have confirmed that more than 80 per cent of the root activity was confined to a lateral distance of 2 m from the trunk (Anil Kumar and Wahid, 1988). Thus the active root zone of coconut utilises only 25 per cent of the available land area and the remaining area could be profitably exploited by raising subsidiary crops.

The venetian structure of the

coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The apparent coverage of ground and shade cast by the canopy, and the magnitude of radiation transmitted through the canopy vary according to the age of palms as shown in Fig.1 (Nelli et al., 1974). Besides age, spacing, soil fertility, varietal characteristics and time of the day also influence the light penetration. The life span of coconut palms may be divided into three phases, namely, pre-bearing trees up to eight years (good light transmission, but decreasing with age), young palms of eight to 25 years (poor light transmission) and mature trees aged over 25 years (light transmission increasing with age) (Nair, 1979). Nair and Balakrishnan (1976) estimated that as much as 56 per cent of the sunlight was transmitted to the canopy during the peak hours (10-16 hours) in palms aged around 25 years. The diffused sunlight facilitate growing a number of shade

tolerant crops in the interspaces.

COCONUT BASED CROPPING SYSTEMS RESEARCH IN INDIA

Research on intercropping in coconut gardens was initiated during the thirties, and was intensified in the seventies with the establishment of the Central Plantation Crops Research Institute at Kasaragod. It received further impetus with the launching of the All India Coordinated Coconut and Arecanut Improvement Project in 1972 and establishment of Centres in different coconut growing states. At present, research is in progress at Kayamkulam, Pilicode, Kasaragod (all in Kerala), Goa and Ratnagiri (Maharashtra) along the West Coast, Veppankulam (Tamil Nadu) and Ambajipeta (Andhra Pradesh) in the East Coast and Arsikere (interior Karnataka) besides Sipighat in the Andaman Islands.

CROPPING SYSTEMS

Coconut based cropping systems involving annuals, perenni-

als and combinations of both annuals and perennials have been developed to suit the availability of resources like labour, rainfall and irrigation facilities, finance, soil characteristics and the farmers' needs and market demands. The crops found suitable for raising as subsidiary crops in coconut gardens include tuber crops (cassava, elephant foot yam, yams, colocasia, (Chinese potato), rhizome spices (ginger and turmeric), Cereals (upland rice), pulses (cowpea), oilseeds (groundnut and soybean), fruit crops (banana and pineapple) and vegetables (snake gourd, bottle gourd, amaranthus and brinjal) among the annuals and beverage crops (cocoa) and spices (clove, nutmeg and black pepper) among the perennials.

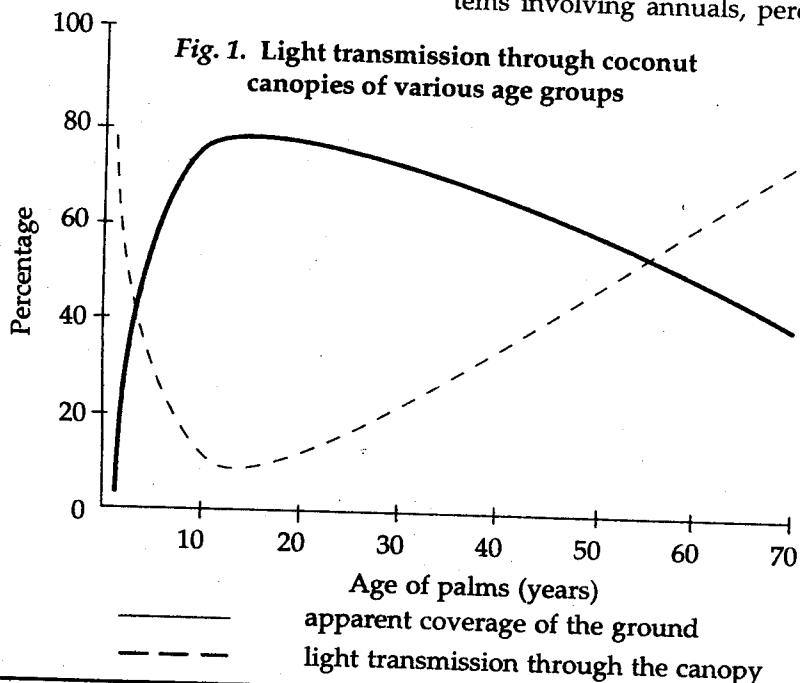
Annuals

a) Tubers and Rhizomatous Spices

Tropical tubers like cassava and elephant foot yam and rhizomatous spices like turmeric and ginger are the most popular intercrops raised in coconut gardens. The tuber crops partially meet the food requirements of a farm family and almost always find a place in the homestead gardens of Kerala. The productivity of tuber crops and rhizomatous spices raised as intercrops in coconut in different centres in Kerala is summarised in Table-5.

b) Millets and Cereals

Experiments conducted at Pilicode (Kerala) during the late thirties and early forties have shown that millets like varagu (*Paspalum scrobiculatum* Rorn) pearl millet (*Pennisetum typhoides*) and finger millet (*Eleusine coracana*) performed well as intercrops in



coconut garden, when sowing was taken up at the beginning of the south-west monsoon season. However, due to lack of demand, these crops are not grown at present (Gopalasundaram and Nelliath, 1979). Among the three varieties of upland rice (Rohini, Chennellu and Culture 12814) tried, Rohini recorded the highest yield of 1946 kg/ha at Kasaragod.

c) Pulses

Many pulses like green gram, black gram, red gram, horse gram and cowpea have been tried as intercrops at different areas and among them, cowpea performed better as a rainfed crop yielding 300 to 500 kg/ha (Gopalasundaram and Nelliath, 1979). Further studies are necessary to identify suitable varieties and standardise the agro-techniques.

d) Oilseeds

Groundnut and soybean have been reported to be compatible intercrops with coconut. At Pilicode the groundnut variety TMV-2, yielded as much as 1326 kg pods and 1448 kg haulms/ha and was highly profitable (Leela and Bhaskaran, 1978). Recent studies at Kasaragod have shown that

soybean can be successfully grown as an intercrop during the post-rainy period under irrigated conditions. The variety PK-472 had recorded the highest yield of 980 kg/ha followed by MACS-58 82 kg/ha (Hegde and Yusuf, 1992). Lourduraj *et al.*, (1992) reported that while it is uneconomical to raise soybean as an intercrop in 10 year-old coconut plantation, intercropping with soybean is profitable in 40 or 60 year old coconut palms and it gave yields of about 600 kg/ha.

e) Vegetables

Only limited work has been done on intercropping vegetable in coconut. Raising of chillies, potato and french beans was found to be a profitable practice in *maidan* areas of Karnataka (Rethinam, 1989). Recent experiments at Kasaragod have indicated vegetables like snake gourd, bottle gourd, amaranthus, coccinia, brinjal and bitter gourd as compatible crops with coconut. Intercropping with vegetables helped to generate additional employment to the tune of 215 to 365 man days/ha/year and among the different sequences tried snake gourd -

ridge gourd - amaranthus was found to be the most remunerative one (Rs.22,217/ha/annum) followed by amaranthus-bottle gourd - brinjal (Rs.20,920/ha/annum) (Hegde *et al.*, 1991).

f) Fruit Crops

Banana is a highly profitable intercrop in coconut gardens, which is very popular in areas with good irrigation facilities. Reddy *et al.* (1980) reported that in Godavari delta of Andhra Pradesh, banana was the best intercrop with complementary effect on coconut yield. At Veppankulam (Tamil Nadu), banana as an intercrop recorded a mean yield of 6 kg/bunch and gave an additional net profit of Rs.5,748/ha (Ramanathan, 1985). In Kerala, Palayamkodu, Robusta, BB Bathesa, Karpooravally and Poovan were identified as suitable varieties for intercropping (Nambiar *et al.*, 1988, Suma *et al.*, 1989) and gave mean yields ranging from 8 to 12.8 kg/bunch.

Pineapple also performs well in the partially shaded conditions of coconut gardens. At Kasaragod, a mean yield of 1.54 kg/fruit was recorded. However, pineapple requires irrigation during the dry period for its successful cultivation.

Perennials

(A number of perennials like cocoa, clove, nutmeg, pepper, jack, breadfruit, mango and timber yielding trees are often raised as mixed crops in coconut plantation (Nelliath *et al.*, 1979). However, due to improper selection of companion crops and adoption of unscientific management practices adopted, the productivity of such a system is low.

Cocoa has been identified as an ideal mixed crop with coconut.

Table 5: Productivity (t/ha) of tubers and rhizomatous spices raised as intercrops

Crop	Locations		
	Kasaragod	Kayamkulam	Pilicode
Cassava (<i>Manihot esculenta</i>)	14.8	15.9	13.8
Elephant foot yam (<i>Amorphophallus companulatus</i>)	13.5	5.4	5.2
Greater Yam (<i>Dioscorea alata</i>)	13.6	5.5	--
Lesser yam (<i>D. esculenta</i>)	9.3	--	--
Sweet potato (<i>Ipomea batatas</i>)	8.4	--	--
Colocasia (<i>Colocasia esculenta</i>)	9.2	--	--
Ginger (<i>Zingiber officinale</i>)	8.6	--	2.4
Turmeric (<i>Curcuma longa</i>)	10.9	--	4.4

Source: CPCRI unpub. data; Menon and Nair, 1978; Nambiar *et al.*, 1988

Table 6: Productivity of coconut and cocoa in the coconut cocoa mixed cropping experiment at Kasaragod

Cropping system	Coconut (nuts palm/year)		Cocoa(pods/year)	
	Pre-experimental (1966-'70)	Experimental period (1972-'87)	Per plant	Per ha
Coconut-sole crop	68.0	106.6		
Coconut + cocoa single hedge	56.7	108.3	32.3	11,270
Coconut + cocoa double hedge	39.1	88.5	19.3	12,545

Experiments conducted at Kasaragod and Pilicode since 1970 have proved beyond doubt the profitability of growing cocoa as a mixed crop in coconut. Comparison of the performance of cocoa raised in single hedge and double hedge systems in a coconut garden, planted at the recommended spacing of 7.5 x 7.5 m has shown that even though the productivity of cocoa per ha was slightly high in the double hedge system, single hedge system was more desirable. The productivity of coconut was also improved when cocoa was grown as a mixed crop (Table 6).

The experiment conducted at Pilicode in a 50-year old WCT coconut plantation spaced at 9 x 9 m from 1970 to 1983 has shown that the productivity of coconut was not affected by mixed cropping with cocoa. Under this wider spacing 9 x 9 m for coconut, the double hedge system of raising cocoa was found to be superior, yielding 378 kg dry beans/ha/year (1976 to 1983) as against 165 kg in the single hedge system (Nambiar *et al.* 1988). The net returns from cocoa were estimated to be Rs.2,542 and Rs.5,880/ha under the single and double hedge systems, respectively.

Perennial spice crops like clove, nutmeg and pepper (on coconut and on live standards) are also popular mixed crops. Potty *et al.*

(1979 b) evaluated the performance of six varieties of pepper in the multistoreyed cropping system and suggested that Karimunda and Panniyur -1 perform better under mixed cropping situations.

MULTISTOREYED CROPPING SYSTEMS

This is an intensive four crop combination which includes coconut, black pepper (trained on coconut trunk), cocoa and pineapple. The system requires irrigation during the summer months and ensures efficient foraging of soil without undue competition between component crops and intercepts solar radiation at different heights. Pineapple performs well in such a system in the initial five or six years and will have to be removed once cocoa develops its full canopy. The productivity of crops in the multistoreyed cropping system at Kasaragod is given in Table 7.

Table 7: Yield of crops in the multistoreyed cropping system

Crops	Coconut+cocoa SH*	Coconut+cocoaDH*
	+pepper +pineapple	+pepper +pineapple
Coconut (nuts/palm/year)		
(i) Pre-experimental period	45.2	38.3
(ii) Experimental period	104.5	88.8
Cocoa (pods/plant/year)	32.3	25.6
Pepper (kg/vine/year)	0.64	0.42

*SH - single hedge; DH - Double hedge

HIGH DENSITY MULTI-SPECIES CROPPING SYSTEMS

High density multi-species cropping systems, involve growing a large number of crops to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash, and are ideally suited for smaller units of land and aim at maximum production per unit area of land, time and inputs with minimum or no deterioration of land (Bawappa and Jacob, 1982). Such a system was established at Kasaragod in 1.2 ha of an 18-year old coconut plantation spaced 8 x 8 m during 1983. The system included 17 crops [mango, bread fruit, jack, nutmeg, clove, sapota, acid lime, guava, pepper, ipil-ipil, banana, papaya, coffee (San Ramon), elephant foot yam, colocasia and cassava] in addition to coconut and the population was increased to 13,030 plants/ha.

The annual crops (except banana) were withdrawn from the system in stages as the perennials grew and utilised more and more space and sunlight. Some perennials like lime, sapota, mango, guava, pepper, ipil-ipil, papaya and coffee were also withdrawn from the system as their performance was not satisfactory.

The experimental area was

divided into three plots and one-third, two-third and full dose of recommended levels of fertilisers are being applied for each crop. The mean yield of coconut and other crops during the past few years were comparable (Table 8) under different levels of manuring indicating scope for reducing the fertiliser input.

COCONUT BASED MIXED FARMING SYSTEMS

Coconut offers considerable scope for raising shade tolerant forage crops in the interspaces and integrating animal enterprises. Fodder grasses like hybrid napier (Pusa Giant and NB 21), Guinea grass and Guatemala grass yield about 50 to 60 t green fodder/ha/year under coconut shade (Jacob Mathew and Shafee, 1977), which is sufficient to maintain five cross-bred milch cows. Among the legumes, Brazilian lucerne and cowpea perform well yielding about 30 t/ha (Sahasranaman and Pillai, 1976).

A family model mixed farming unit was maintained at CPCRI, Kasaragod from 1972 to 1988. Fodder crops were raised in 1.04 ha of a 60-year old coconut garden, pepper was trained on coconut trunk and intercrops like banana, cassava and vegetables were raised along the borders and field bunds. Five cross-bred Jersey cows were given to the family and a biogas plant was also erected. The cow dung slurry from the gas plant

and urine were recycled within the experimental area. The output from one ha of the model is furnished in Table 9. This system generated maximum employment opportunities.

Table 9: Mean annual output from one ha of mixed farming unit

Items	Output
Coconut	11,270 nos
Milk	7,089 ltr
Pepper	80 ha
Banana	250 kg
Beef (estimated)	350 kg
Biogas	2.8-3.5 m ³ /day
* Dung	14.6 t
* Urine	3600 ltr

* recycled within the system

Salam *et al.* (1991), using the linear programming technique have developed a coconut based mixed farming model integrating crop and livestock systems suitable for coastal uplands of south Kerala under rainfed conditions. The homestead model in 0.20 ha includes coconut + pepper (35 nos), banana (95), tapioca (50), mango (2), arecanut (1), jack + pepper (1), bread fruit (1), tamarind (1), guinea grass (800 m²), kitchen garden (160), cow (one crossbred and its calf), goats (two female goats and their kids) and (ten birds under backyard system of rearing). This

system generates a net return of Rs 12,628 from 0.20 ha of land with a benefit-cost ratio of 1.64.

COCONUT BASED SERICULTURE

In *maidan* areas of Karnataka state, where coconuts are generally grown at a wider spacing of 9 x 9 m or more, growing of mulberry as a mixed crop and silk worm rearing is very popular. Shanthamallaiah *et al.* (1985) reported that sericulture yielded about 420 kg of silk worm cocoons/ha of coconut garden/year. In addition, the yield of coconut palms was also increased to 85 nuts/palm/year from 76 nuts in the sole crop of coconut. The net income was more than trebled and employment potential doubled.

COMPLEMENTARY INTERACTIONS IN COCONUT BASED CROPPING SYSTEMS

Experiments conducted during the last two decades have indicated many complementary interactions between component crops in the system. The beneficial effects include improvement in soil fertility status, enhanced microbial activity, higher interception of light, better micro-climate and reduced weed growth which helped to achieve higher productivity.

Cocoa raised as mixed crop in coconut adds considerable quantity of organic matter to the soil through shed leaves and prunings, estimated to be 818 and 1985 kg (oven dry weight) /ha/year, respectively in single and double hedge system. This helps in recycling considerable quantities of plant nutrients, besides improving soil organic carbon status (Varghese *et al.*, 1978 b). Nair and Rao (1977a) reported that activity

Table 8: Mean yield of crops in coconut based high density multi-species cropping system at Kasaragod (1985-86 to 1989-90)

Crops	Produce and units	Fertiliser levels		
		One third	Two third	Full
Coconut	nuts/ha/year	23634	23166	23010
Pineapple	fruits (kg/ha/year)	2676	2509	2765
Banana	bunches (kg/ha/year)	1194	1425	1465

of nitrogen fixers like *Beijerinckia*, phosphate solubilisers like *Pseudomonas* sp. and *Aspergillus niger*, and *Escherichia* sp., *A. flavus* and *A. fumigatus* which produce growth promoting substances was much higher in coconut-cocoa mixed stands compared to coconut monocrop stands. The available phosphorus content of rhizosphere soil was found to be 65 ppm in coconut + cocoa double hedge, 41 ppm when cocoa was grown in single hedge, compared to 20 ppm in coconut sole crop (Nair and Rao, 1977 b). Leela and Bhaskaran (1978) also observed improvement in soil available N, P, K and Ca status of coconut intercropped with groundnut.

The micro-climate inside a mixed crop system was characterised by lower maximum temperature, smaller diurnal variation and less evaporative demand compared to pure crop stands (Nair and Balakrishnan, 1977). Raising groundnut as an intercrop, suppressed weed growth in coconut plantations and maintained good tilth for the major part of the year (Sahasranaman, 1964; Leela and Bhaskaran, 1978).

MANAGEMENT OF THE SYSTEMS

The success or failure of a coconut based system is often decided by the choice of the system components, based on the availability of light, age of coconut palms and their spacing, soil type, climatic conditions, moisture availability, irrigation facilities, canopy architecture and light requirements of subsidiary crops and market demand. Lalitha Bai and Nair (1982) studied the shade response of different intercrops and classified sweet potato as shade sensitive, coleus and colocasia as shade tol-

erant and ginger and turmeric as shade loving. Attempts have also been made to identify varieties suitable for multiple cropping situations in crops like banana, citrus, pepper and turmeric (Valsamma *et al.*, 1987; Potty *et al.*, 1979 a; Suma *et al.*, 1989). Varghese *et al.* (1978 a) indicated the need for crop rotation among the annual intercrops and application of adequate fertilizers for both the main crop of coconut and the intercrops to maintain the population of companion crops at optimum levels by proper placement of the subsidiary crops, especially perennials besides canopy management by pruning etc.

ECONOMICS

Adoption of any system by the farming community will ultimately be decided by its economic advantages. The monocrop of coconut provides employment opportunities for only around 150 mandays/ha/year and gives a net income of Rs.10,400/ha. The various systems that have been developed and discussed in this paper generate additional employment to the tune

of 130 to 606 mandays/ha/year and the estimated net returns range from Rs.18,670 in the case of coconut + cassava system to Rs.50,000/ha in coconut based mixed farming (Table 10).

SOIL CONDITIONS OF COCONUT GROWING AREAS

Major area under coconut is restricted to east and west coast of the peninsular India where it is grown in highly heterogeneous soil conditions from littoral sands to heavy clayey soils and highly calcareous coral soils, in lowlying swampy and marshy soils with pH varying from 3.5 to 9.00. Consequently there is considerable variation in the production and productivity of palms in the country. Climatic conditions, irrigation, soil types, adoption cultural practices further bring in variations in productivity.

Kerala is the premier coconut growing state in the country with vast acreage under laterite soils followed by coastal sandy soils, red sandy loams, alluvial soils, kari soils (reclaimed marshy soils) and

Table 10: Economics and employment potential of coconut based farming systems

Systems	Net returns (Rs/ha/year)	additional employment (mandays/ha/year)
Coconut - sole crop	10,400	--
Coconut + cassava	18,670	130
Coconut + elephant foot yam	20,940	131
Coconut + ginger	36,590	500
Coconut + banana*	25,675	NA
Coconut + cocoa*	24,600	NA
Coconut + clove*	38,500	NA
Multistoreyed cropping system*	30,300	191
Coconut based mixed farming*	50,000	600

NA = Not available

* = under irrigated conditions

valley soils. The major coconut growing areas in Karnataka are the coastal alluviums and laterite soils of the maidan area. In Lakshadweep Islands, coral soils harbour large areas under coconut. These soils are excessively drained, poor in organic carbon, rich in phosphorus and are highly calcareous.

In the east coast, Tamil Nadu and Andhra Pradesh are the dominant coconut growing states, besides Orissa, West Bengal, Assam and Pondicherry. The climatic conditions and soil characteristics are in contrast compared to west coast which is blessed with abundant rainfall and luxuriant growth of forest vegetation. Major soils of east coast are alluvial soils of the deltaic regions and coastal sandy soils. In Tamil Nadu large areas are seen under red and black soils.

As such wide variations in soil characteristics exist and crop performance depends upon the soil fertility and undesirable soil characteristics. Generally coconut palms need good soil physical conditions especially depth of soil, regular and optimum supply of nutrients and water. However palms are observed to adapt themselves to low fertility conditions such as the highly exhausted/im-poverished laterite soils which occupy larger areas in Kerala and coastal sandy soils. Experimental evidences have shown that palms growing in these soils respond well to manuring and produce excellent yields.

The productivity of coconut is low due to various causes, the main cause being the poor attention the palms receive at the hands of the growers. The national average yield from 1950-51 to 1990-91 fluctuated from 28-34 nuts/palm

which is far below the yields realised in well managed gardens and research stations, thus indicating the role of management and fertilizer inputs in yield increase of the existing gardens.

MINERAL NUTRIENT EXPORT

Formulating a fertilizer schedule for any crop should take into consideration the nutrient removal by the above ground parts especially in perennials like coconut which exploit a limited volume of soil for mining nutrients for its growth. A number of workers have estimated the nutrient export by coconut palms (Pillai and Davis 1963, Ramadasan and Lal, 1966 and Ouverier and Ochs, 1978). Though values reported vary, there appears to be general agreement on the ratio of nitrogen and pottassium exported by the coconut palms.

A moderate estimate for adult West Coast Tall palms producing 40 nuts per annum and 12-13 leaves and considering the nutrients re-

tained in the other above ground parts including stem was worked out by Pillai and Davis 1963. They found the nutrient export to be maximum for pottassium, followed by nitrogen, calcium, magnesium and phosphorous in that order (Fig.2). IRHO workers added chlorine to the list (Ouverier and Ochs, 1978). A more detailed analysis of the figures suggest that K is the most required nutrient and is removed from the system through the harvest of the nuts while calcium and magnesium through the leaves.

Interesting comparison was made between tall (WCT - India) cultivars and PB 121 (Hybrid - IRHO) on the mineral nutrient exports (Ochs *et al.* 1993) (Table11).

It can be seen that mineral exports by hybrids are considerable, commensurate with their high productivity. However, the nutrients exported for production of one ton of copra is considered they appear

Fig. 2. Quantity of nutrients removed (grams) by a single WCT palm

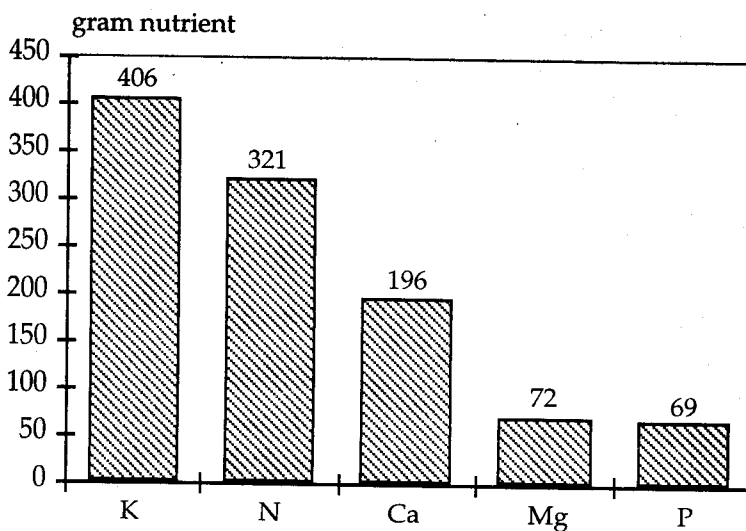


Table 11. Mineral nutrient exports by PB-121 hybrid coconuts in Ivory Coast and by tall coconuts (WCT - India) - (excluding stems and leaves).

Element	PB-121 (6700 kg copra/ha)	WCT (India) (1500 kg copra/ha)
<i>(a) In kg/ha/yr</i>		
N	108	28.4
P	15	5.9
K	193	54.6
Ca	9	7.8
Mg	15	1.6
Na	20	--
Cl	125	--
S	9	--
<i>(b) In kg/ ton of copra</i>		
N	16.1	18.9
P	2.2	3.9
K	28.8	36.4
Ca	1.3	5.2
Mg	2.2	1.1

Source : Ochs *et al.* 1993

to be same but hybrids require less nutrients than tall for producing a ton of copra indicating their exceptional heterosis vigour in converting less nutrients efficiency.

A similar comparison (Table 12) between PB-121 hybrid and WCT on the percentage removal of nutrients for development of bunches with nuts and stem and leaves indicate that hybrids require more N and P compared to tall and a higher proportion of absorbed N (62%) and P (75%) are utilized for production of more nuts whereas tall utilize 51% of absorbed N and 50% of absorbed P for production of nuts. Most interestingly tall and hybrids utilized 78 per cent of absorbed K for yield of nuts. The data suggested that increased pro-

Table 12. Percentage of removal of nutrients for the yield of nuts and for the growth and development of stem and leaves by WCT and hybrid PB-121.

Cultivar	Part of palm	Nutrients				
		N	P	K	Ca	Mg
WCT	Stem + leaves	49	50	22	77	59
	Yield of nuts	51	50	78	23	41
PB-121 hybrid	Stem + leaves	38	25	22	87	62
	Yield of nuts	62	75	78	13	38

ductivity is eventually accompanied by a proportional increase in the uptake of nutrients especially K for tall and K and more N and P for hybrids.

In the present context of increased cost of fertilizers especially those of potash recycling of usefructs of coconuts assume importance. Ochs *et al.* (1993) reported that the husk is responsible for greatest proportion of exports:- 67 per cent of potassium and 85 per cent chlorides which are removed from the system if husks are either sold or used as fuel. Moreover recycling of husks in the field depends upon many other economic considerations. The use of coir pith also assumes importance and CPCRI is initiating studies on the use of composed coir pith using *Peurotus* sp.

NUTRITIONAL REQUIREMENT OF SEEDLINGS AT NURSERY STAGE

Studies on manuring seedlings at nursery stage is very limited in the country. Experimental evidences (Foale, 1968; Fremond *et al.* 1966; Magat, 1993) show that application of NPK, Ca and Mg (Ziller and Fremond, 1961) are necessary to produce healthy seedlings, for better establishment, faster growth and early bearing in the main field. Nelliatt (1972) is of opinion that young seedlings are in short supply of nutrients for a major part of

their one year growth in the nursery, and recommended the application of NPK fertilisers in the month of December, February and April to supply 40 kg N, 20 kg P₂O₅ and 40 kg K₂O per application per ha in nurseries where seed-nuts are planted in the month of May-June.

NUTRITIONAL REQUIREMENT OF PALMS AT PRE-BEARING AGE

When young seedlings are transplanted they need adequate care for better establishment. Systematic fertilizer application is necessary for faster and vigorous growth and also for reducing the pre-bearing age.

Absorption of nutrients by young seedlings was evidenced by the systematic studies of Charles (1968). For successful cultivation of palms it is essential that the vegetative phase be overcome early with balanced fertilization. Countrywide systematic fertilizer experiments in divergent soil types with Cv. West Coast Tall (AICCAIP, 1983) and hybrids (AICRPP, 1991) indicated the significant influence of fertilizer inputs like N,P,K (and their interactions) on higher frond production, precocity in flowering, palm height etc. (Table 13).

At Veppankulam, Tamil Nadu, application of N, P and K at adult

Table 13. Effect of fertilizers of three year old WCT young palms at CPCRI, Kasaragod

Growth characters	Treatments				
	Control	N ₁	N ₂	N ₁ P ₁ K ₁	N ₂ P ₂ K ₂
Height (cm)	251	261	264	306	323
Girth (cm)	42	41	43	56	56
Leaves	22	22	23	24	24

N₁ - 0.5 Kg N; N₂ - 1.0 kg N; P₁ - 0.25 kg; P₂ - 0.5 kg P₂O₅
 K₁ - 0.75 kg K₂O; K₂ - 1.5 kg K₂O/palm/yr.

palm dosage of 340 g N, 230 g P₂O₅ and 450 g K₂O year influenced the palms to flower one year ahead of control (no fertilizer) palms. When double the above dosage was applied, the pre-bearing age was further reduced by four months (Varisai Mohammed *et al.*, 1969).

Application of NPK fertilizers to young palms of COD x WCT and WCT x COD hybrids and high yielding WCT had significantly influenced the nutritional status of young palms (Table 14) and also the growth characters.

Considering the response of young palms at the pre-bearing stage Nelliatt (1972) opined that palms in general and WCT in particular may receive adult palm dosage from the third year onwards since response in terms of

yield is obtained only two years after fertilizer application.

Thus it is appropriate that one-tenth of adult palm dosage is given at three months after planting, one-third dose at second year and two-thirds dosage from third year onwards. From fourth year the palms will receive full adult palm dosage.

MANURING OF ADULT COCONUT PALMS

Manuring of adult coconut palms has not been a regular practice in most of the coconut growing states. However, remarkable increases in yield due to NPK fertilizer application have been obtained in most of the coconut growing countries. In the west coast of India, Mathew, (1976) observed that about 1 per cent of coconut plots receive inorganic fertilizers

though around 50 per cent of plots meagre quantity or organics in the form of farm-yard manure and green leaves. An improvement in this situation is possible due to efforts of agricultural extension agencies. Nevertheless, the situation remains same as seen from the average yield of 28 nuts/palm/year in Kerala.

In large scale fertilizer demonstration trials, on the west coast of India a yield increase of 35 per cent in nut production and 44 per cent in copra was obtained with 0.34 kg N, 0.34 kg P₂O₅ and 0.68 kg K₂O/palm/year (John and Jacob, 1969). Potassium deficiency was acute and in such situations higher doses of K at 0.90 kg/palm/year produced better yields. In general palms in the west coast responded well to higher doses of N, P₂O₅ and K₂O.

In long term fertilizer experiments (1953-1969) in red sandy loam soil at Kasaragod, response to N was obtained from third year, P from ninth year and K from fifth year of commencement of treatment. These experiments suggested the existence of multiple nutrient deficiencies and the need to tackle them to increase productivity.

Nelliatt *et al.* (1984) demonstrated that palms growing without fertilizer inputs and under total neglect in laterite soil conditions can be revived by applying double the recommended dose in the first two years followed by recommended dose of 0.5, 0.32 and 1200 g N, P₂O₅ and K₂O/palm/year respectively with a cost-benefit ratio of 1:2.53. The return of investment for every Rupee varied from Rs.1.48 to 2.32 in other treatments (Table 15).

Table 14. Influence of NPK nutrition on the leaf nutrient contents of coconut varieties and hybrids.

Fertilizer level/palm/Yr	Nutrient status (%) Frond, 9				
	N	P	K	Ca	Mg
N ₀ P ₀ K ₀	1.40	0.12	0.46	0.30	0.18
N ₁ P ₁ K ₁	1.50	0.13	0.82	0.29	0.19
N ₂ P ₂ K ₂	1.55	0.12	0.92	0.30	0.16
CD 5%	0.095	NS	0.075	NS	0.03

N₁P₁K₁ = 500 gN; 500 g P₂O₅, 1000 g K₂O

N₂P₂K₂ = 1000 g N, 1000 g P₂O₅ and 2000 g K₂O

(Source: Kamaladevi *et al.* 1972)

Table 15. Response of WCT palms grown under neglect in laterite soil

Treatment	Cumulative yield (5 years)
T ₁ Farmers' practice	101
T ₂ 1/3 dose - I year and 2/3 dose subsequently	179
T ₃ 50% recommended dose - I year and full dose subsequently.	231
T ₄ Recommended dose	221
T ₅ Double the recommended dose in the first year and recommended dose subsequently	265
T ₆ Double the recommended dose	259

Recommended dose : 500 g N, 320 g P₂O₅, 1200 g K₂O/palm/Yr.

Under Kerala conditions, large scale yield responses were obtained by application of NPK fertilizers to high yielding West Coast Tall and COD x WCT and WCT x COD hybrids. The M₁ treatment viz., 500 g N, 500 g P₂O₅ and 1000g K₂O doubled the yields of WCT and COD x WCT palms, and raised the nut yield of WCT x COD types by three times (Table 16). Doubling the M₁ rates had only effect with WCT palms indicating that COD x WCT and WCT x COD hybrids do not require higher fertilizers than those recommended for tall palms (Hameed Khan *et al.* 1986).

As to genetic differences between palms, it is clear that the COD x WCT hybrids greatly out-yielded WCT variety and its reciprocal cross. The superiority of the COD x WCT palms manifests itself already without fertilizer use,

Table 16. Yield of coconut cultivars under different fertilizer levels.

Cultivar	Yield-nuts/ palm/yr (July 1981 - June 1983)			Cumulative yield (1972 upto 1983)		
	M ₀	M ₁	M ₂	M ₀	M ₁	M ₂
WCT	34	67	84	131	435	578
COD x WCT	46	92	95	293	936	737
WCT x COD	26	79	80	87	473	503

but it becomes far more pronounced with improved nutrition from M₁ level of treatment (Table 16).

Specific instances of mineral nutrient deficiencies and large response to applied nutrients was recorded at Konkan coast (nitrogen) (AICCAIP, 1983) (Table-17) and Balaramapuram (potassium) (Wahid *et al.* 1988)

In this region N deficiency was more and spectacular response to N doses of fertilizer was observed. A higher order of interaction involving N and K produced maximum number of nuts.

Wahid *et al.* (1988) have concluded from a 3³, NPK factorial experiment the need to apply N and K in augmenting coconut yield particularly K at increased rates. They observed that the main effect of P was marginal.

These studies indicated in iden-

tifying mineral nutrient deficiencies of the area to get maximum response to added inputs.

Soil testing and plant analysis play a major role in reducing the cost of fertilizer inputs. Monitoring the residual effect of long term phosphorus application through soil and plant analysis Khan *et al.* (1990) observed that soil test values of less than 10 ppm of available P warrants full dose (320 g P₂O₅) fertilizer application and soils testing 10-20 ppm need only 50 per cent of recommended dose. For soils testing more than 20 ppm, application of phosphorus can be withheld for certain years.

Interestingly VA mycorrhizal association was more in the root zone of palm where P application was withheld compared to palms receiving 50 per cent recommended dose and full dose (Table 18), the micorrhizal fungi regulating P supply to palms.

Table 17. Influence of NPK fertilizers and their interactions on yield of coconut in Ratnagiri (Konkan coast)

Treatment (per palm/ Year	P ₂ O ₅ /palm/year			Mean nuts/ palm/year	K ₂ O/palm/year			
	0	225	450		0	450	900	
0	33	25	28	28.6	37	19	30	28.6
375 g N	78	87	86	83.6	91	76	85	84.0
750 g N	90	89	90	89.6	76	95	97	89.3

SE ± for main effect 1

CD 5% for main effect 11.9

SE for interaction of NP and NK 7.1

Table 18. VA mycorrhizal association in different P treatments

Treatment	Per-cent colonizn.	Inten-sity of infection (%)	Spore count g ₁₀ soil
P ₀	79.3	38.1	128.9
P ₁	52.1	20.1	94.0
P ₂	47.9	17.4	81.9
SE/plot	16.0	8.8	39.7
CD 5%	18.67	10.28	--

Khan *et al.* (1985) while evaluating the comparative efficiency of four P carriers viz., super phosphate, ammonium phosphate, nitrophosphate and rock phosphate over a period of six years recommended rock phosphate as the ideal and cheap carrier of P for coconut for acidic laterite soils.

SODIUM CHLORIDE NUTRITION

Beneficial effects of common salt application has been fully realised in many coconut growing countries like India, Indonesia, Philippines, Ivory Coast and Sri Lanka. Common salt is applied as a source of chlorine to realise increased yields, to increase drought resistance, resistance to fungal diseases, produce more vigorous and healthy seedlings, and to soften the hard laterite pan to aid penetration of roots.

Studies at Agricultural Research Station, Pilicode indicated that applying equal quantities of sodium chloride and muriate of potash (500 g each) produced same result as that of treating the palms with 1000 g K₂O/palm. Wahid *et al.* 1988 recorded that early flowering index of NaCl treated palms was higher than KCl treated palms.

Table 19. Biomass and nitrogen yield of some green manure legumes in coconut basins

Legume species	Laterite soil		Sandy soil	
	Green matter yield (kg/basin)*	N yield g/basin	Green matter yield (kg/basin)*	N yield g/basin
<i>Calapagonium muconoides</i>	27.2	186.5	14.7	102.6
<i>Mimosa invisa</i>	25.00	197.6	17.00	153.2
<i>Puereria phaseoloides</i>	28.5	196.2	19.4	121.3

*Manuring circle of 1.8 m radius

Source : Thomas and Shantharam, 1984

GREEN MANURING AND GREEN LEAF MANURING

Studies on limited organic farming with leguminous green manure crops within the coconut basin during rainy season (4-5 months) showed that *Puereria phasioloides*, *Mimosa invisa*, *Calapagonium muconoides* produced sufficient green matter which on incorporation not only enriched soil nitrogen but also increased the microbial population considerably (Table 19). This practice not only improves the soil health, but also reduces the dependence on inorganic fertilizers to a certain extent.

MICRONUTRIENTS

Use of micronutrients in coconut nutrition has received less at-

tention probably due to absence of any serious deficiency symptoms. Nevertheless, many micronutrient mixtures are manufactured and advocated for coconut in the east coast of India and, to a certain extent in the southern districts of Kerala. In the Kasaragod district coastal sandy soils were found to have higher deficiencies of Cu, Zn and Mn as compared to laterite soils (Manikandan *et al.* 1986).

Boron deficiency, often referred as crown chocking disease/front choke, etc. has been noticed in about 11 per cent of palms in Assam leading to an annual loss of 6.38 million nuts. The disorder can be cured by the application of borax. Some guidelines are presented in Table 20.

Table 20. Guidelines on treatment of Crown chocking disorder

Area	Treatment	Reference
Assam, India	Borax -50g/palm (repeat twice in severe cases at an interval of 3-4 months)	Baranwal <i>et al</i> , 1989
West Bengal, India	Borax - decahydrate (11.3% B) 20 g/palm	Chakraborty <i>et al</i> , 1970
Kerala, India	Borax - decahydrate 200-500g/palm followed by irrigation	Cecil and Pillai, 1978
Ivory Coast, W.Africa	Borax - pentahydrate (14.8% B) 15 g/palm once in six months	Brunin and Coomans, 1973

Pencil point or stem tapering disease has been reported to be due to multiple nutrient deficiencies (Bhaskaran *et al.* 1978). In addition to normal NPK application, treating the palms with a micronutrient cocktail mixture of 227 g each of borax, and Cu, Fe, Mn, Zn in sulphate forms plus 10 g of ammonium molybdate. The salts were dissolved in 40 litres of water and applied as soil drench. Younger palms also received a foliar spray of 15 litres in which 30 g each of the above micronutrient salts were dissolved in water along with 2 g ammonium molybdate.

INTEGRATED NUTRIENT - WATER MANAGEMENT

Response to irrigation was seen from third year at Kasaragod (Thampan, 1987) and Chalakudy (Nair, 1989). Significant yield improvement was also seen by drip irrigation (30 ltr/palm/day) in all districts of Kerala from third year onwards (CWRDM, 1988).

Bhaskaran and Leela (1977) observed a general increase in yield in the post treatment period varying from 34 to 215 per cent depending upon the yield category of palms. They observed that low yielders (<20 nuts/palm/yr) responded more to irrigation (800 ltr/week) by higher yield increase (Table 21).

Since coconut palms are known to with-stand high salt concentration ranging from 0.6 - 1.0 per cent, irrigation with sea water at 90 ltr/palm in basins of 1.5 m radius twice a week was found to be as good as irrigation with fresh water and increased yield by 41 per cent over rainfed palms in sandy soils. In sandy loam soils mixing sea water with fresh water in a ratio of 1:2 recorded better yields (Table 22) (Mohd. Yusuf and Varadan, 1993).

Table 21. Response of palms to irrigation at Nileshwar

Particulars	Mean yield averaged/over yield category (nuts/palm/yr)	
	1. Pre-irrigation yield	42.2
2. Transit period (3 yrs) yield	62.6	(33.6 - 82.9)
% increase over 1	48.3	(150.4 - 16.9)
3. Post-irrigation yield	73.5	(42.4 - 94.8)
% increase over 1	74.2	(214.9 - 33.8)
4. Cost Benefit ratio	1:3.1	--

(Figures in parenthesis indicate the range in yield/yield increase in poor (<20 nuts), low, medium and high (61-80 nuts).

Table 22. Effect of sea water and fresh water on the yield of coconut (1967-68)

Treatment	Mean yield (nuts/palm/yr)
1. <i>Sandy soil</i>	
i) Irrigation with sea water	42.2
(ii) Irrigation with fresh water	43.0
(iii) Unirrigated	30.0
2. <i>Sandy loam soil</i>	
(i) Unirrigated	52.6
(ii) Sea water + fresh water (2:1)	60.8
(iii) Sea water + fresh water (1:2)	80.5
(iv) Sea water alone	67.1
(v) Fresh water alone	53.6

Different methods of irrigation to coconut were tested (1985-87) at CWRDM, Calicut and it was concluded that for a wide spaced crop like coconut drip irrigation is ideally suited and its influence on yield is comparable to basin irrigation with 600 ltr/palm/week (Table 23).

Irrigation and fertilizer interaction studies are limited in coconut, though the beneficial interactive effect is well recognised.

Yield of palms receiving only irrigation- 52 nuts/palm/yr

Yield of palms fertilized without irrigation - 41 nuts/palm/yr

Yield of palms fertilized and irrigated - 75 nuts/palm/yr

Table 23. Mean yield of coconut under different irrigation methods

Treatment	yield of nuts/palm/yr			
	1985	1986	1987	Mean
1. Basin irrigation @ 600 ltr/palm/week	59	58	72	63
2. Ring method of irrigation @ 300 ltr/palm/day	51	50	47	49
3. Sprinkler irrigation @ 60 ltr/palm/day	49	56	61	55
4. Drip irrigation @ 30 ltr/palm/day	59	68	51	59
5. No irrigation	52	68	37	52

These studies assume importance especially in Kerala, parts of Karnataka and Goa where of late summer irrigation is found to be necessary, despite heavy rainfall which is received during June to September. As fertilizer application is done after monsoon and a dry period follows thereafter, supplemental irrigation can improve productivity as also fertilizer use efficiency to a larger extent (Hameed Khan, 1993).

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