

Initiatives towards improving coconut productivity

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Abstract

Coconut is a very important commercial crop associated with the livelihood of millions of the people in the country. In general the coconut productivity across the country has improved only marginally over the years despite substantial advances in production technology. Though quality of planting material is a very important component in the future productivity of the farms, the institutions that have produced improved varieties and hybrids do not have adequate infrastructure to supply the required numbers to the farmers. There is no national policy on certification and supply of quality planting material for coconut. Sample studies in Kerala indicated the adoption level to be poor for coconut hybrids? Technology for reviving neglected coconut gardens has given 75 to 150 % increase in yield. While fertilizer application is an immediate strategy for increasing productivity of coconut groves, countrywide experiments by All India Coordinated Research Project on Palms have given support to INM as a handy tool for productivity increase and its sustenance. Simple, cost effective eco-friendly techniques of basin management by growing legumes; gliricidia and vermicompost production should be popularized effectively. The good response to N application in Konkān coast and K in red lateritic soils of Kerala can be taken as guides for prescribing fertilizer schedules in these regions. Countrywide drip irrigation experiments have indicated its economic advantage in coconut cultivation. Drip irrigation to coconut groves coupled with fertilizer application can increase the yield from 30 to 110% depending upon the quantity of water applied. The coconut based high-density multispecies cropping studies at CPCRI have shown large-scale response to fertilizer application and evidence to manage the system with low inorganic inputs. Availability of biomass for recycling in the system was around 12.7 - 18.2 t per hectare under various treatments. Farming system studies involving dairy, poultry enterprises and recycling of farm wastes indicated the possibility of supplementing 74% of N, 82% of K and entire quantity of P requirement of main and component crops. A complete reorientation on production technology research is needed to evolve models for site-specific recommendations. A detailed mapping of the fertility status of the coconut groves in major coconut growing states is necessary for planning production-oriented policies. More than 90% of the 5 million coconut holdings in the country are less than one ha in size. Hence the approaches should be bottom up in scheduling development programmes and policies. A sound extension policy is needed to popularize the benefits of production technology achievements in the research front.

Key words: Coconut varieties, root (wilt) disease, resistance / tolerance

Introduction

Coconut is the most beautiful and useful of the palms known to mankind. It grows well in the tropical region between 22°N and 22° S latitude. It is essentially an oil seed crop providing all amenities for human life which include food, energetic beverage, medicine, fibre, wood and a variety of raw materials for the production of array of products of commercial importance. World area under coconut palm is 12.78 million hectares with APCC countries accounting for 11.31 million hectares. World production of copra equivalent is 10.35 million tons with 8.95 million tons (86.5%) produced by APCC countries (Chapman, 2002). In India, the crop is cultivated in 159 districts in 17 States and 3 Union

Territories accounting for 1.892 million ha with an annual production of 12822 million nuts and an average productivity of 6776 nuts/ha. The All India figures indicate that 92.43% of the area and 91.31% production in the country is concentrated in the four southern states viz., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Among these states, Kerala accounts for the largest area and production sharing 50.76% of total area and 43.66% of total production. Though the percent share of area is higher in Karnataka (18.30%) compared to Tamil Nadu (17.74%), the share of production is higher in Tamil Nadu (25.18%) than Karnataka (13.86%) (Table 1).

Area under coconut as well as production has been increasing steadily during the last five decades. Area

under coconut, which was 0.63 million hectares during 1950-51 has increased to 1.89 million hectares during 2001-02. During the same period, production increased from 3282 million nuts to 12821 million nuts. The productivity has shown a sluggish trend from 1991-92 to 2001-02. During 1990-91 it was 6592 nuts/ha, whereas during 1994-95, the country recorded the highest productivity of 7760 nuts/ha and the same was maintained around 7000 nuts/ha. However, during 2001-02 the productivity was only 6776 nuts/ha. Considering the southern states, in the traditional coconut growing state of Kerala, which has the largest area under coconut, the productivity is 6114 nuts/ha compared to average national productivity of 6776 nuts /ha. Karnataka has the lowest productivity of 4077 nuts/ha.

Table 1. All India final estimates of coconut area, production and productivity (2001-'02 revised).

States/Union Territories	Area (000' ha)	Production (million nuts)	Productivity (nuts/ha)	Share of area (%)	Share of production (%)
Kerala	925.8	5536.0	5980	50.76	43.65
Karnataka	333.8	1754.2	5255	18.30	13.85
Tamil Nadu	323.5	3192.0	9867	17.74	25.16
Andhra Pradesh	102.6	1092.7	10650	5.63	8.60
Maharashtra	16.8	244.4	14548	0.92	1.51
West Bengal	24.5	330.5	13490	1.34	2.58
A & N Islands	25.2	89.0	3532	1.38	0.68
Goa	25.0	125.1	5004	1.37	0.96
Assam	21.0	136.0	6476	1.15	1.27
Orissa	17.7	109.9	6209	0.97	1.09
Tripura	3.1	7.0	2258	0.18	0.05
Lakshadweep Is.	2.7	36.9	13667	0.14	0.41
Pondicherry	2.2	24.7	11227	0.12	0.19
All India Total	1823.9	12678.4	108163	100.00	100.00

The constraints in the productivity of coconut gardens continue to remain and shall be the major issue to be addressed in the years to come (Nampoothiri and Khan, 2002). There are several reasons for low productivity of palms viz., traditional methods of cultivation, lack of knowledge of manuring practices, senile nature of palms, lack of irrigation/facilities, moisture stress, low pH, poor fertility status of soils, prevalence of diseases like root (wilt) disease in Kerala, and parts of Tamil Nadu, Ganoderma / Thanjavur wilt in Tamil Nadu and Karnataka, pest problems especially that of eriophyid mite, red palm weevil, lack of mind set to enhance productivity, resource constraints by farmers and lastly absence of systematic replanting programme to replace senile palms and non-availability of quality planting material (Nampoothiri and Khan, 2002).

Enhancing coconut production and productivity of the coconut system and sustaining it should have a

multi pronged approach. In Kerala, 37% of the holdings are less than 0.2 ha and 59% area less than 1.0 ha. In the adjacent states of Tamil Nadu, Karnataka and Andhra Pradesh, 95%, 95.4% and 97.9% of the holdings respectively are less than one ha (Table 2).

Table 2. Distribution of coconut holdings in major coconut growing states

Holding size (ha)	Kerala	Karnataka	Tamil Nadu	Andhra Pradesh
<0.2	37.10	52.5	69.1	56.5
>0.2 to <1.0	52.80	42.9	26.1	41.4
>1.0 to <2.0	7.90	3.6	3.2	1.8
2.0 and above	2.20	1.0	1.7	—

Thampan (1988) reported that more than 90% of the 5 million coconut holdings in the country are less than one ha in size. These small holdings neither provide gainful employment opportunities for the family labour through out the year, nor generate adequate income to meet the family requirements.

Why coconut productivity should be increased

- Around 30% of the palms in the premier coconut growing states are senile and showing declining trend in productivity.
- Of the 13,000 million nuts produced in the country, 52 % is utilized for domestic consumption, 10 % as tender coconut, 40 % for production of edible oil, leaving a marginal amount for other value added products and export.
- More production and change in supply of coconuts will bring changes in processing and marketing sector and pressure to innovate.
- The technology to produce virgin coconut oil by a three-step wet and cold process is being perfected (Beensch *et al.*, 2004) in CRI, Sri Lanka in collaboration with *gtz* (Society for Technical Cooperation), Germany, and ADB. The potential health benefits of coconut oil and diet-coconut-fibre is being realized through out the world. This is going to increase the demand for coconut oil more in the western countries in the coming years.
- Experts and trade analyst are one in saying that the demand for lauric oils (63% of which is shared by coconut oil) is bound to increase by 2-3% a year (Boceta, 2000).
- Inability of the industry to meet the demand for coconut oil, thereby increasing its price in domestic market.
- Coconut farming will continue to be a major profession and hence its productivity has to be

increased to improve the standard of living of the coconut farmers.

- (h) Manju Madhusudanan *et al.*, (2000) working on the relationship between age of the coconut plantation and the net returns realized in the Kottayam district of Kerala, suggested that the annuity values estimated for net returns at 14 % discounted rate was highest during 65th year and it would be ideal to replace coconut palms after 65 years. They also observed that maximum net returns were obtained during the 35th year.

Considering the above and the fragmental nature of coconut holdings, the efforts should be bottom up in scheduling programme and policies to increase production and productivity of coconuts.

Production and productivity initiatives in coconut

Collection, conservation, evaluation and crop improvement initiatives are necessary as the variability is being depleted by large scale felling and replanting in different states. Preserving the gene pool is necessary for subsequent evaluation and utilization in various aspects of crop improvement programme. In this context *in-situ* conservation of germplasm in the country is also necessary.

In traditional coconut growing areas especially in Kerala, the productivity can be increased and sustained by supplying quality planting material, resorting to systematic scientific cultivation, adoption of coconut based cropping/farming system etc.

In our country the average productivity of copra is 1.1 t /ha under the present system of management. However, the released varieties for commercial cultivation in different states are capable of producing 18000 to 20,000 nuts/ha depending upon the soil conditions and input management equivalent to 3.0-4.5 tons copra/ha (AICRPP, 2001). The present productivity of 6776 nuts/ha could be increased substantially by cultivating improved varieties and scientific input management.

The annual requirement of coconut seedlings for the country is estimated to be 20 million. These seedlings are needed for regular under planting in traditional areas, new planting both in traditional and non-traditional areas, rehabilitation of gardens affected by root (wilt) disease (under planting and new planting) in Kerala. To meet the demand of coconut in the next decade it is necessary to take up new planting at the rate of 30,000 ha/year as against the present plan of 13,500 ha/year. In the premier coconut state of Kerala,

rehabilitation management and regular under planting with superior planting material are possible means of increasing the productivity especially in the root (wilt) affected areas. For regular under planting in Kerala alone, 6 million seedlings are needed annually (Nampoothiri and Khan, 2000).

Variety release through selection

Research efforts by CPCRI and AICRP (Palms) have led to release of high yielding varieties for different regions of the country (Table 3).

Table 3. Coconut varieties released through selection

Variety	Mean yield (nuts/palm)	Increase over WCT (%)	Copra per nut (g)	Copra per palm (kg)	Increase in copra over WCT (%)
Lakshadweep Ordinary	97	21.2	195	18.9	92.3
Pratap (Banawali Green Round)	151	88.8	152	22.7	57.6
Philippines Ordinary	110	37.5	198	21.8	55.7
Assam Green Tall	101	26.25	150	16.0	54.3
Arasampatty Tall	176	120	—	—	—
WCT (check)	80	—	180	14.4	—

Variety release through hybridization

Since the finding of hybrid vigour in coconut (COD x WCT) by J.S. Patel in 1937, 95 hybrid combinations were evaluated and 11 hybrids were released for commercial cultivation in different regions of the country (Table 4).

Though eight hybrids were released over years for cultivation in Kerala, the proportion of hybrids occupying the land is only 6.09% compared to 93% by the traditional WCT palms as reported in a sample survey conducted during 1998 covering 31249 palms (Thampan, 2002).

In their review of farmers perception of high yielding coconut varieties in APCC countries, Rethinam *et al.* (2002) observed that as long as the new varieties are not amenable to low external input farming, the farmers may not opt for them either for new planting or old planting. According to them, the farmers' non-participating trials conducted in India in the research stations will not infuse confidence in the minds of farmers about the economic benefits of cultivating hybrids.

Since 60% of the area under coconut in Kerala is infected by the root (wilt) disease and the released varieties are susceptible to the disease, CPCRI has a very ambitious programme to identify and develop root (wilt) resistant / tolerant varieties to improve productivity of the palms in the state.

Table 4. Performance of released hybrids of coconut under experimental conditions

Hybrids/Varieties	Nut yield/ palm/ year	Copra yield		Copra yield ha (t)	Oil content %	State for which recommended
		Grams / Nut	Kg /Palm			
Chandra Sankara(COD x WCT)	116	215	25	4.4	68	Kerala, Karnataka, Tamil Nadu
Kera Sankara(WCT x COD)	108	187	21	3.5	68	Kerala, Karnataka
Chandra Laksha(LCT x COD)	109	195	21	3.7	69	Kerala, Karnataka
Laksha Ganga (LCT x GBGD)	108	195	21	3.7	70	Kerala
Ananda Ganga(ADOT x GBGD)	05	216	21	3.6	68	Kerala
Kera Ganga(WCT x GBGD)	100	201	21	3.5	69	Kerala
Kera Sree(WCT x MYD)	112	216	24	4.2	66	Kerala
Kera Sowbagya(WCT x SS Apricot)	130	195	25	4.3	65	Kerala
VHC-1(ECT x CGD)	98	135	13	2.3	70	Tamil Nadu
VHC-2(ECT x MYD)	107	152	16	2.9	69	Tamil Nadu

(Source: Annual Report, AICRP Palms 2001)

The Coconut Development Board has established a network of demonstrations-cum-seed production farms viz., two in Kerala (Neriamangalam and Vellanikkara), one each in Karnataka (Mandya), Andhra Pradesh (Vegivadi), Chattisgarh (Kondagaon), Bihar (Madhepura), Tripura (Belbari), Assam (Abhayapuri) and Orissa (Pitapalli). The CDB is also providing funds for establishment of regional coconut nurseries by State Governments, private sector seed gardens, and nurseries. The State Governments of Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh play a major role in producing quality planting material.

Tamil Nadu, semi-arid *maidan* tract of Karnataka and northern Kerala experience dry spells for 5-7 months which influences substantially the productivity and warrants planting drought tolerant material.

Nevertheless, to strengthen coconut seedling production programme in the country a close watch is needed in the areas of selection of mother palms, seed nuts, nursery inspection etc. to prevent exploitation by private agencies. In this context a seed/ nursery certification policy/programme is necessary for coconut to prevent the unscrupulous seedling production programme going on unabated in the southern states by private entrepreneurs.

Achievements in productivity of coconut groves

Coconut has the unique feature among the plantation crops in that it flowers and fruits through out the year, its performance depends upon the right variety for the area, management of nutrient input and irrigation.

The present yield of coconut in the premier coconut growing states of Kerala, Karnataka and parts of Tamil Nadu is a standing testimony towards low inorganic input and poor management. Tradition, cost-factors, fluctuating market for the produce, time taken

for realizing benefits on the investments are some of the reasons for the farmers towards increasing productivity of their gardens.

By nature of its growth, coconut palm demands continuous supply of nutrients from the soil. Such removal of nutrients from a restricted zone depletes the soil nutrient reserves. An assessment of the nutrient export usually provides guidelines for approximating the quantity of nutrients and the proportion in which they are to be supplied. As nutrient replacement needs increase at a faster rate than uptake and removal due to limited root area for absorption, it is important to maintain nutrient supplies at a level of slight luxury consumption (Khan, 1993). The nutrient removal values reported by various workers vary (Pillai, 1919; Pillai and Davis, 1963; Ouverier and Ochs, 1978) was found to be in the ratio of 1.0: 0.13: 1.43 for N: P: K respectively. An adult WCT palm producing 40 nuts and producing 12-13 fronds/year absorbed 321 g N, 69 g P, 406 g K 196 g Ca and 72 g Mg (Pillai and Davis (1963). A comparison of the estimates of nutrient exports reported from India and Ivory Coast has shown the dominant requirement to be potassium and probably chlorine (Table5).

Table 5. Proportion of nutrients removed in nuts and in stem and leaves of two cultivars of coconut

Cultivars	Parts of palm	Nutrients							
		N	P	K	S	Ca	Mg	Na	Cl
West Coast Tall	Stem + leaves	49	50	22	-	77	59	-	-
	Yield of nuts	51	50	78	-	23	41	-	-
PB121, MAWA hybrid	Stem + leaves	38	25	22	70	87	62	63	50
	Yield of nuts	62	75	78	30	13	38	37	50

Source : Pillai and Davis (1963), Ouverier and Ochs (1978)

From the above table the following observations can be made:

- Hybrid palm require more N and P compared to tall and utilize higher proportion of absorbed N

and P for production of more nuts. In tall, these nutrients are utilized more or less equally in the production of nuts and growth.

- For both cultivars, the K removal through bunches is 78% of K uptake.
- Ca is utilized more for the production of leaves and stem and least for the nuts.
- About 60% of Mg removed is utilized for the growth of stem and leaves to meet the photosynthetic needs.
- Importance of chlorine is next to K and hence Chlorine bearing fertilizers assume significance in coconut nutrition (Oguis et al., 1979).
- Na and S are more utilized for the growth of stem and leaves than for development of nuts.
- Regular fertilizer application is necessary to supply optimum level of nutrients for sustained productivity.

Fertilizer management trials

CPCRI has demonstrated in the farmer's field, the potential benefit of the technology of reviving neglected gardens in Kerala (Nelliath *et al.*, 1988). The yield increase ranged from 75% to 175% in the various treatments. Of all the treatments, recommended dose of fertilizer application gave 155% increase compared to the farmers yield level of 20 nuts /palm (Table 6).

Table 6. Improving the productivity of neglected coconut garden – laterite soil.

Treatment	Cumulative yield (5 years)	Average yield (nuts/palm)	Copra production (g/nut)
Farmers practice	101	20(—)	130
33% Recommended Dose (RD) 1 st year	179	35 (75%)	143
66% RD 2 nd year	231	46 (130%)	160
50% RD 1 st year – full dose subsequently	221	45 (125%)	165
Recommended dose	265	51 (155%)	146
Double RD 1 st year – RD subsequently	259	52 (160%)	198

Recommended dose (500:320:1200 g N, P₂O₅, K₂O/palm/year)

Management of coconut groves through cultural practices alone, like cultivation of interspaces twice a year and weed control using herbicides only produced yields ranging from 10.7 to 32.3 nuts/palm as compared to fertilizer treatments coupled with cultural practices which produced

yields ranging from 83-108 nuts/palm/year indicating that cultural practices alone could not sustain higher productivity. However, long-term studies indicated that cultural practices alone are superior to no cultivation and no manuring which are akin to neglected conditions (Khan *et al.*, 1996). The yield data also reflects the poor inherent fertility status of soil, which could support only low yields of palms (Table 7). This study brought out the fact that fertilizer application or INM practices are a must for increasing and sustaining productivity of coconut groves.

Table 7. Effect of management practices on yield of coconut palms

Treatments	Yield (nuts/palm/year)	
	1991-92	1987-88 to 1990-91
Cultivation + organic + inorganic fertilizers	88.3	107.9
Cultivation + inorganic fertilizers	78.1	91.2
Inorganic fertilizer + forking	70.1	83.0
Cultivation alone	36.4	32.3
Weed control with herbicides	20.5	10.7
No cultivation and no manuring (neglect)	2.7	0.4

Fertilizer trial for adult coconut palms (WCT) in laterite soils under rain-fed condition in the cultivator's fields has revealed that application of NPK @ 0.50,0.32 and 1.20 kg/palm/year along with 25 kg green leaf and 10 kg FYM increased the yield up to 67%. The application of fertilizers at the above level was most economical leading to a Cost Benefit ratio of 3.96 as against 1.45 in the case of cultivators practice alone (Balakrishnan and Neema, 2000).

Continuous absorption of nutrients by coconut roots from a limited area of the soil depletes potassium and other minerals and the K pool cannot restore much K needed by the coconut roots (Menon and Pandalai, 1958). Extensive fertilizer demonstration studies involving 24,000 palms in the west coast of India indicated that application of additional dose of K and higher doses of NPK increased yield whereas standard dose failed to elicit adequate response in farmers field. Application of 340g N, 350 g P₂O₅ and 680 g K₂O/palm/year improved nut yield by 35% and copra out turn by 44% where the palms were hitherto un-manured. Where response to fertilizer application was not observed, a further significant increase in yield was obtained when K levels were raised to 900 g K₂O/palm/year (John and Jacob, 1959).

The palms, which received adequate nutrition from the beginning, produced more yield (Table 8) than those supplied with nutrient after maturity (Fremont and Ouvrier, 1971).

Table 8. Timing effect of first potash fertilizer application on the performance of young coconut palms.

Year	Characteristics observed	Time of K application	
		From field planting	From bearing age only
1956	No. of fronds	8.89	7.69
1958	Length of frond (cm)	256	233
1959	Girth (cm)	124.1	105.4
1960	Frond production/year	11.7	10.7
1962	Kg copra/ha	2560	272
1966	Kg copra/ha	2480	2272
1970	Kg copra/ha	—	2096
1961-70	Cumulative yield (kg/ha)	17,344	12,704

There is some typically potash and nitrogen deficient soils which give appreciable response to nutrient application. Wahid *et al.*, (1988) in a long-term fertilizer application experiment at Balaramapuram (Kerala) observed that in the 21st year of planting the yield obtained was 7, 68 and 77 nuts/palm/year respectively, in no fertilizer, 450g K₂O and 900 g K₂O treatments where response to P and N application was not observed.

In coastal sandy soils of Konkan region of Maharashtra, importance N on coconut yield (Table 9) and other biometric characters were well established from a long-term fertilizer experiment (AICRPP, 1983). Yield data revealed a higher order interaction between N and K for nut production as cited by Khan (1993).

Table 9. Effect of fertilizers on yield of coconut in a long-term experiment at Ratnagiri (1958-'62)

Treatment N g/palm	P ₂ O ₅ g/palm/year				K ₂ O g/palm/year			
	0	225	450	Mean	0	450	900	Mean
0	33	25	28	28.7	37	19	30	28.6
375	78	87	86	83.7	91	76	85	84
750	90	89	90	89.7	76	95	97	89
Mean	67	67	68	—	68	63	71	—

Source: AICRPP Annual Report (1995)

Boron deficiency in coconut is often reported from different parts of the country. The disorder has been noticed in about 11% palms in Assam leading to an annual economic loss of 6.38 million nuts. (Baranwal *et al.*, 1989). In Kerala about 12% of the palms are affected (Pillai *et al.*, 1983). Detailed symptomatology of the deficiency in young palms which is also referred to as crown chocking disease / frond choke etc., has been described by Baranwal *et al.*, 1989. Kamalakshamma and Anitakumari (1999) has presented a detailed photographic evidence of various symptoms associated with boron deficiency in coconut in Kerala. Some guidelines available in this regard for young palms are provided below (Table 10).

Table 10. Recommendation for Boron deficiency in different states

Area	Treatment
West Bengal	Borax-decahydrate (11.3% B) 20g/palm
Kerala	Borax-decahydrate 200-500 g/palm followed by irrigation
Assam	Borax-50 g /palm. Repeat twice in severe cases at an interval of 3-4 months
Ivory Coast, West Africa	Borax-pentahydrate (14.8% B) 15g/palm once in six months

Source : Hameed Khan (1993)

Fertilizers had a significant effect on yield of high yielding WCT, COD x WCT and WCT x COD hybrids under rain fed conditions (Khan *et al.*, 1986). The study also indicated that superiority of COD x WCT manifests itself with out fertilizer but is more pronounced at M₁ level. The data suggested that while the variety WCT continues to respond to fertilizers beyond M₁ rates, this is not the case with hybrid palms (Table 11). Further extending the study, Reddy *et al.*, (2002) observed that over the years there was a general increase in yield of palms than what was recorded by Khan *et al.*, (1996). The cost benefit ratio was favorable under M₁ fertilizer treatment. For every Rupee invested on manuring, the total net return was Rs.2.80 under M₁ and Rs. 2.85 under M₂ level of fertilizers.

Table 11. Yield of coconut genotypes under different fertilizer trials

Genotype	Yield of nuts/ palm/year			Cumulative yield (1972-1983)		
	July 1988 – June 1983					
Fertilizer levels	M ₀	M ₁	M ₂	M ₀	M ₁	M ₂
WCT	33.7	66.9	84.4	131	435	578
COD x WCT	45.9	92.2	94.7	293	936	737
WCT x COD	26.4	79.2	80.4	87	473	503

(M₀ – Control; M₁ – 500 g N, 220g P, 830g K; M₂ – 1000 g N, 440g P, 1660g K/palm/year)

The general recommendation of chemical fertilizers for adult coconut palms was 500:320:1200 g, N: P₂O₅: K₂O respectively. However multi-location trials conducted under the aegis of All India Coordinated Research project on Palms has brought out the following N: P₂O₅: K₂O recommendations for different states for optimum productivity.

Maidan tract of Karnataka	: 650: 450: 900
Konkan coast of Maharashtra	: 750: 225 : 900
Tamil Nadu alluvial tract	: 560 : 320:1200
Andhra Pradesh	: 650 : 450: 1200

Coconut palms receive fertilizers in a restricted area over years. As phosphorus is an immobile nutrient it accumulates in the soil in the fertilized zone around

the bole. Monitoring the plant phosphorus leaves and that of soil over 14 years Khan *et al.*, (1992) suggested 10-12 ppm of available P (Bray and Kurtz-P.) was sufficient for maintaining optimum nutrition for coconut. They further indicated that for soils less than 10 ppm available P, 320g P₂O₅/palm/year can be applied and soils testing 10-20 ppm a maintenance dose of 160g P₂O₅/palm/year will suffice. If soil test value is more than 20 ppm P, application of phosphate fertilizers can be skipped and restarted when the value falls below 20. The studies indicated that soil testing based fertilizer application could increase productivity of coconut with further savings on fertilizer bill.

Integrated Nutrient Management of coconut groves

Of late, it has been recognized country wide that continuous application of chemical fertilizers has deleterious effect on soil biodiversity and on some physio-chemical properties and there by affecting productivity of the crops. This is particularly important for coconut, which has a restricted zone around the bole from which it mainly derives its nutrition and the zone into which the manures and fertilizers are applied.

Residues from coconut plantations constitute a potent source of carbon and plant nutrients, two inputs essentially required for sustainable productivity of soils. In fact conversion of residue in an acceptable manner and recycling is not much rooted in the coconut system where more or less a clean farming is practiced in the southern states.

Estimates from the hectareage of coconut gardens in the country indicated that around 11.2 million tons of recyclable biomass and 7.5 million tons of coir pith are likely to be generated (Biddappa *et al.*, 1996). Nair *et al.*, (1996) estimated it to be equivalent to 0.79, 0.076 and 0.49 million tons of N, P₂O₅ and K₂O respectively. This can be advantageously recycled in coconut gardens with appropriate methods of composting.

Recent estimates of coconut biomass in the form of dried leaves, inflorescence waste, husk, copra and shell ranged from 45.95 to 81.88; 5.36 to 10.63 and 79.39 to 127.34 kg/ha N, P and K, respectively. Prabhu *et al.*, (1998) in CPCRI perfected the technology of producing vermicompost for converting coconut wastes to eco-friendly organic manure with 70% recovery and having a C:N ratio of 9.95.

Thomas and Shantharam (1984) advocated a low cost technology of improving the organic matter and nutrient status of fertilizer basins of coconut to grow leguminous creepers such as *Calapagonium*

muscunoides, *Pureria phaseoloides* and *Mimosa invisa*. This practice done during June to October (140-150 days) can yield 18-24 kg organic matter in a circular area of 10 m² around the bole, contributing to substitution of 50% of fertilizer N requirement of a coconut palm. They also indicated that nodulation can be improved by inoculation with bio-fertilizers.

To evolve appropriate technology of Integrated Nutrient Management to improve and sustain productivity of coconut groves, countrywide experiments were started under the aegis of All India Coordinated Research Project on Palms during 1996. Interim results of those experiments presented are to be viewed for individual centres and are not for comparison in particular (Table 12).

Table 12. Yield of coconut palms under INM in different parts of India

Treatments	Yield- Nuts/palm 2000-01			
	Aliyarnagar Tamil Nadu	Arsikere Karnataka	Veppankulam Tamil Nadu	Ratnagiri Maharashtra
Farmers practice	171	60	89	70
Recommended chemical fertilizers(CF)	103	81	113	91
Composted Coir Pith (CCP)	178	101	*	71**
50% CCP + 50% CF	174	99	*	88**
Neem cake + bone meal + ash	159	93	99	88
50 kg CCP	*	*	96	*
25 kg CCP + 50% CF	*	*	*	*
50 kg FYM + 100 kg CCP	*	*	130	*
CD	NS	24.4	21.76	*6.99
CV	13.8	18.7	—	

*Treatments not imposed: ** coconut palm wastes cut and spread instead of CCP
Aliyarnagar: Red sandy loam; Arsikere: Red sandy loam (semi arid);
Veppankulam: Alluvial soil; Ratnagiri: Coastal alluvium (sandy loam).

Liyanage and Jayasundara (1988) in Srilanka reported that *gliricidia* lopping @ 30 kg/palm meets total requirement of N and part of P and K, thus reducing the cost of inorganic inputs by about 40 % and improved fertility status of degraded ultisols. Extending this study to coastal sandy soils Subramaniam *et al.*, (2000) at CPCRI demonstrated that *gliricidia* could yield 2.3 t/ha of green matter, which can meet 80% N, 23 % P and 15 % K requirement of palms. In this experiment *gliricidia* was grown in three rows in the interspaces of palms spaced at 7.5 x 7.5 m.

Irrigation and coconut productivity

Irrigation plays a major role in coconut productivity in the southern states of Tamil Nadu, Andhra Pradesh, where coconut is grown under irrigation. In Kerala, Karnataka, Goa and Maharashtra summer irrigation is 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 large extent.

Irrigation and fertilizer interactive studies are limited in coconut, though the beneficial interactive effects are well recognized. The average contribution of irrigation and fertilizer was:

Yield with irrigation (no fertilizer)	: 52 nuts/palm
Yield with fertilizer (no irrigation)	: 41 nuts/palm
Yield with irrigation and fertilizer	: 72 nuts/palm

Countrywide experiments were laid out under the AICRPP network to assess the requirements for a rational use of water. The economic benefits have been well established. An example of how the technology of drip irrigation influenced the productivity parameters is presented below (Table 13) (Venkitaswamy and Hameed Khan, 2004). The BC ratio for irrigation treatments of 100 Eo was 2.11. The investment cost on drip system can be realized in 4.3 years under 100% Eo.

Table 13. Summary of yield parameters influenced by different levels of Irrigation to coconut – VHC-2 hybrid (Aliyarnagar, 2001)

Treatment/ water applied / palm	Mean values for four years – VHC-2 hybrid					
	Leaf Prod- uction	Funcio- nal leaves	Bunch produ- ction	Female flower	Nuts / palm	%
No irrigation	13.38	32.48	8.63	174	68	—
Drip 33% Eo 4485 L*	13.68	33.52	9.83	196	89 (+21)	31
Drip 60% Eo 8790 L	14.33	36.55	11.50	253	122 (+54)	79
Drip 100% Eo 11359 L	15.08	38.25	12.78	306	147 (+79)	116
Basin irrigation 13533 L	15.11	37.23	13.03	315	146 (+78)	114

* Exclusive of rain fall contribution of 5848 liters: Source: Venkitaswamy and: Khan (2004)

In an interesting experiment by CPCRI, it was demonstrated that palms with different yield level showed differential response to drip irrigation (Table 14). Low yielder (<20 nuts/palm/year) show remarkable response (24%) compared to high yielder (61-80 nuts/palm/year) (33.8%). The trial has clearly demonstrated that irrigation

is a very important productivity component in the coconut system.

Table 14. Response of different yield groups in coconut to summer irrigation

Particulars	Yield of nuts/palm under different yield categories				
	Poor< 20 nuts	Low (20-40)	Medium (45-60)	High (61-80)	Mean
Pre irrigation	13.4	30.2	54.3	70.9	42.2
Post irrigation	42.2	69.5	85.2	94.8	73.5
Increase: - Nuts	28.8	39.3	31.0	29.4	31.9
- Percent	(214.0)	(130.1)	(67.4)	(33.8)	(74.2)

(Dhanapal personal communication)

CPCRI has come out with excellent technology of managing drought situations based on the results of a network of experiments in Kasaragod (Kerala), Kidu and Arsikere (Karnataka), Ambajipeta (Andhra Pradesh), Ratnagiri (Maharashtra) and Veppankulam (Tamil Nadu) (Naresh Kumar *et al.*, 2002) and improve the productivity of palms. Later, Venkitaswamy *et al.*, (2002) brought out the salient features of drought management with usufructs of coconut and economizing irrigation water and increasing productivity in northern districts of Tamil Nadu.

Coconut based cropping / farming systems towards enhancement of coconut productivity

It has been well established that coconut as a mono-crop is only, marginally productive and profitable. Despite the efforts made to demonstrate the advantages of the technology, the productivity of coconut groves remained stagnant or show a marginal increase. The reasons are many.

The interplay of various factors viz. limited size of holdings, number and age of trees, unscientific methods of planting, home needs, labour requirement for crop, fluctuating returns to farm families, poor employment opportunities, and easiness of marketing are some of the considerations for the grower to diversify his farm operations for higher returns by adopting intercropping, mixed cropping or introducing other enterprises like dairy, poultry etc. in the system (Khan and Upadhyay, 2001). It has also been well understood that under coconut based cropping system, the same land can be put to use to produce other crops so that the productivity of the land is increased.

The coconut farmers in India (especially in Kerala) are accustomed to growing a variety of annual and perennial crops in the interspaces of coconut palm to meet their food, fodder, fuel wood and timber requirements, in addition to generating supplementary income. Not all the coconut groves are amenable for

multiple cropping. The sustenance of a land for higher productivity is governed by the inherent soil fertility, other soil physico-chemical characteristics and management practices followed. The soil resource base being poor, there is a need to improve the crop growing environment to ensure adequate availability of nutrients to the crop. Nutrient management assumes significance due to the fact that coconut and component crops in the system requires continuous supply of nutrients throughout their life period for higher productivity.

According to Magat (1990), the potential (maximum) annual biological productivity of a cropping system under optimum conditions (Loomis and Williams, 1973) is of the order of 280.5 t/ha of dry matter (770 kg/ha/day) for coconuts even at high nut yield of 100 nuts/palm and 200 nuts/palm, whereas the annual productivity is only 18.7 t/ha and 35.5 t/ha of dry matter (or 6.6 and 12.6 % respectively of potential biological activity).

The canopy of coconut is known to intercept only 44 per cent of incident solar radiation due to its poor light use efficiency of 1.4 g dry matter / MJ (Liyanage, 1994). Light transmitted through the canopy was also found to vary with age. A 10 – 20 year old coconut plantation was found to intercept only 20%, and plantations of 40 years and above 50 % and more of solar radiation. During the peak hours (10-16 hrs) a plantation of 25 years old palms could transmit 56 % of the incident sunlight.

In this context, Magat and Margate (1998) in Philippines advocated coconut leaf pruning (CLP) below leaf rank 19 for facilitating more penetration of light in the system under various situations. Even though some farmers may follow this practice in India, systematic studies in this aspect have not been conducted in India to advocate the technology of growing inter and mixed crops in crowded coconut gardens.

Reddy and Biddappa (2000) have presented a review of coconut based cropping/farming systems in India and Khan and Upadhyay (2001) on the integrated nutrient management in coconut based cropping/farming system for sustained productivity. Literature is replete with information on the feasibility of growing cereals, pulses, oilseeds, root crops, pasture legumes grasses, vegetables, tuber crops, an array of fruit crops, flowers, beverage crops like cacao and tree spices as inter- and mixed crops in Kerala. Recently the economic feasibility of growing medicinal and aromatic plants has also been indicated. According to Hegde and Yusuf (1993) even certain varieties of soybean like PK 472, MACS 13 and MACS 48 were found to be highly suitable as intercrops

(870 to 980 kg/ha) in the post rainy season in the coconut groves of Kerala.

Banana was found to be the most common, profitable and compatible mixed crop in coconut gardens in southern states where ever irrigation facilities were available. In Andhra Pradesh, 1200-1300 banana bunches/ha were harvested when grown as an inter crop in the coconut garden.

In Tamil Nadu, Coconut + Banana + yam, Coconut + Banana + Curry leaf, Coconut + Banana + Bhendi + *Sirukizhangu* fetched a net Profit of Rs. 40650 to Rs.46840/ha compared to coconut alone which fetched Rs. 31,000/ha. This model has also generated an additional employment for 138 man-days.

Cocoa as a mixed crop in coconut garden added to the soil 818 and 1985 kg (oven dry wt.) of biomass/hectare/year through shed leaves and pruning under single and double hedge systems respectively. As much as 50 kg N, 4.85 kg P and 29.1 kg K per hectare could be returned to the soil every year under the double hedge cocoa system (Varghese *et al.*, 1978). The addition of large amount of organic refuses by the cocoa was found to improve the soil physico-chemical characteristics and there by positively influence the yield of coconut (Table 15). In the 15-year experimental period, the mean yield of coconut has increased from 89-128 % in the cocoa system compared to only 57 % in the monocrop of coconut.

Table 15. Influence of mixed cropping of coconut with cocoa on productivity of palms

Cropping system	Coconut yield (nuts/palm/year)	
	Pre-experimental period (1966-70)	Experimental period (1972-87)
Coconut sole crop	68	107 (157)*
Coconut + cacao (single hedge)	57	108 (189)
Coconut + cacao (double hedge)	39	89 (228)

* Fig. in parenthesis indicate % increase in yield

A number of studies on response of coconut palms to fertilizer applications have shown that palms with yields exceeding 60 nuts per year showing least/no response and poor bearers exhibiting greater response. However, the response of palms in a coconut-cocoa system has revealed interesting results (Table 16). The increase in the yield of nuts in control (coconut alone) plot reflected the synergistic effect and non-monetary input in crop production (Nair, 1979). Minimizing stress with irrigation and fertilizer application has increased the conversion efficiency and harvest index. The system functions as a self-reliant system based on the regenerative capacity of a biologically active soil and

beneficial interactions of the different components involved.

Table 16. Yield of coconut palms of different groups before and after planting cocoa as a mixed crop

Yield group (nuts/palm/ year)	Average annual yield of nuts per palm								
	Coconut alone			Coconut + cocoa (SH)			Coconut + cocoa (DH)		
	PEY	EY	Increase	PEY	EY	Increase	PEY	EY	Increase
< 30	19	57	38	22	74	52	15	85	70
30-60	50	125	75	42	141	95	53	118	65
> 60	88	178	90	83	170	87	78	190	112
Mean	73	120	47	67	112	45	50	109	59

SH - Single Hedge; DH - Double Hedge; PEY - Pre Experimental Yield (average of 2 years); EY - Experimental Yield (after planting cocoa, 1972-73 to 1974-75) (Cocoa maintained under irrigation 200 to 300 litres of water/week. Nampootheri et al., 2000)

It has been estimated that in Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa, and West Bengal around 3.0 lakh hectares of coconut gardens have the potential to accommodate cocoa as a mixed crop. Against a projected demand of 30,000 mt of dry beans in 2005 AD, the present productivity is only 7000 to 8000 mt. leaving a huge gap to be bridged. This can be exploited both to the advantage of increasing coconut productivity and production of cocoa.

In a coconut based tree spices mixed cropping system started during the year 1982 in the coastal sandy soils of Ratnagiri, Maharashtra, the coconut yield increased gradually over the years after introduction of the tree spices viz. allspice, pepper, garcinia, cinnamon and clove and management practices followed for component crops (Anon. 2000).

Progressive increase in coconut yield was recorded by 93.44 % in clove plot, 82.99 % in allspice plot, 71.61 % in cinnamon plot and 70.61% in nutmeg block after 24 years of mixed cropping (Table 17). The coconut palms and tree spices received inorganic fertilizers as per standard schedule. The leaf falls except that of coconut was not removed from the system. Recently, competition between tree spices and coconut for the resources has been observed leading to slight decline in coconut yield. Experiences suggest the necessity to systematically remove the spice crop adjacent to the coconut palms to avoid possible root competition.

Table 17. Average yield of coconut per palm grown in different blocks of spice crop for the year 2001-2002

Block/Particulars	Nutmeg	Cinn-amon	Clove	Garcinia	Black pepper	Allspice	Control
Average yield before planting spices	70.56	69.25	47.08	63.67	82.87	49.15	76.78(Average yield of 24 years)
Average yield after planting spices 1982-2000	119.71	118.84	91.07	95.28	102.01	89.94	
Percent increase	69.66	71.61	93.44	49.65	23.10	82.99	

In the recently introduced cropping system research in West Bengal (India), intercropping with turmeric, ginger, elephant foot yam and colocasia has given a net return of Rs 31620/- to Rs 58420/- depending upon the intercrop raised (Hore et al., 2001). However, the net return from the coconut mono-crop was only Rs 18170 per hectare (Table 18).

Table 18. Economics of coconut based intercropping system in West Bengal

Crop combination	Cost of cultivation (Rs)	Gross Return (Rs)	Net return (Rs)	Profit from intercrop (Rs)
Coconut monocrop	19000	37170	18170	-
Coconut + Turmeric	47000	88620	41620	23450
Coconut + Ginger	73950	132370	58420	40250
Coconut + EF yam	76750	121170	44420	26250
Coconut + Colocasia	36900	68670	31680	13510

Note: Coconut - Rs3.50/nut; Turmeric - Rs 3.50/kg; Ginger - Rs 8.00/kg; EF yam - Rs4.00/kg; Colocasia - Rs 3.00/kg

The Central Plantation Crops Research Institute, Kasaragod has demonstrated the technology of high-density multi-species cropping system for getting high sustainable yields of coconut at lower level of fertilizer input. The total removable biomass (in terms of fronds, bunch waste, nuts in case of coconut, fallen leaves and flower buds in clove, above ground biomass for banana

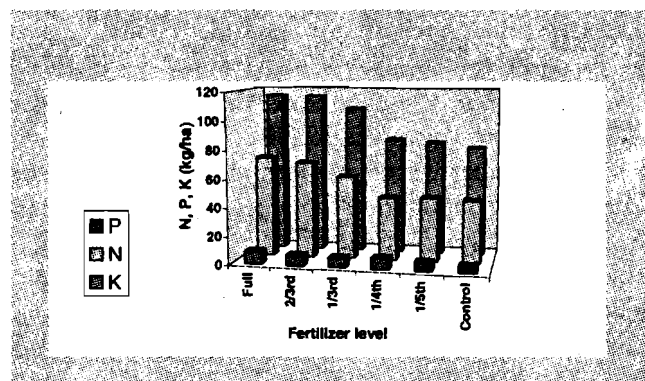


Fig. 1. Extent of nutrient recycling under different levels of fertilizer input - coconut and fruits, crown and leaves in case of pineapple) from the system was 19.1 t/ha in the control plot and ranged between 20.11 and 27.55 t/ha under graded levels of

fertilizer. In this the contribution from coconut alone was approximately 85 %. However, availability of biomass for recycling in the system was around 12.7 - 18.2 t per hectare under various treatments. This biomass if recycled can enhance the productivity and sustenance of the system in terms of nutrient need besides economic benefits (Table 19). Further studies are in progress.

Potash is the major nutrient recycled through the biomass generated followed by nitrogen and phosphorus.

At Kasaragod (India) in a mixed farming unit (1.2 hectare) comprising coconut, pepper, fodder grass, mulberry, dairy, poultry and pisciculture, the total variable cost involved in maintaining the above system was Rs 1,56,617. The net return obtained from the system was Rs 85,824 per annum. The system generates huge quantity of waste biomass, which will meet 74 % N, entire quantity of P, and 82 % of K requirement of both coconut and grass (Table 20). The yield of the palms in the system increased from 59 nuts to 97 nuts /palm/year.

Table 19. Yield of main and component crops under the high density multispecies cropping system

Treatment	Coconut Nuts/palm	Pine apple Kg/fruit	Clove Kg/tree	Banana Kg/bunch
Full Rec.dose	144	0.75	0.53	7.1
1/3 Rec.dose	130	0.54	0.40	6.8
2/3 Rec.dose	143	0.64	0.27	4.3
1/4 Rec.dose*	125	0.44	0.97	5.9
1/5 Rec.dose*	122	0.56	0.68	5.2
No fertil.control*	128	0.61	0.76	5.2

Intercropping, mixed cropping, and mixed farming systems enhance the productivity of the land, ensure income and employment opportunities besides beneficial influence on the physical, chemical and biological properties of the soil creating a base for sustainable productivity.

Table 20. Nutrient flow in the coconut based farming system at Kasaragod.

Items	Quantity	N (kg)	P (kg)	K (kg)
A) Nutrient contribution by the components of the system				
Cow dung	14 tonnes	98.00	70.00	105.00
Poultry	295 kg	1.92	2.36	2.08
Silk worm	12 kg	0.11	0.05	0.09
Cows urine and cowshed washings	50,000 litres	30.00	-	28.00
Total	-	130.03	72.41	135.17
B) Nutrient substitution through recycling of the coconut fronds (minus petiole)				
Coconut Leaves (in terms of vermicompost)				
	1.45 tonnes	26.14	4.36	6.94
Total (A+B)	-	156.17	76.77	142.11

C) Inorganic addition to the system				
i) Coconut palms	500: 320: 1200g N, P ₂ O ₅ , K ₂ O (per palm basis)	79.00	22.12	157.37
ii) Grass*	160: 20: 20	131.2	16.4	16.4
Total (i + ii)	-	210.2	38.52	173.77
Percent supplementation of inorganic through on-farm waste recycling				
Percent supplementation	-	74.29	Entire	81.78

*Full P (80 kg) & K (80 kg) dose is applied at the time of planting. Fresh grass is planted every four years. So shown as split for each year. Soil type - Red sandy loam: (Arenic Paleustults)I

Future outlook

Coconut will continue to be an important crop associated with the livelihood of millions in the country.

In general the coconut productivity across the country has improved only marginally over the years despite substantial advances in production technology. The higher productivity reported in certain states like Maharashtra, Andhra Pradesh and West Bengal, Pondicherry and Lakshadweep is mainly associated with the fertile soil conditions, irrigation and population of palms in an unit area than more with the adoption of technology. Nevertheless, these states hold a very good potential for extension agencies to popularize modern production technology as they share around 38 % of the production in the country.

Good technical information on production technology, processing, and value addition is available, but is not reaching the farmer in a form they can use due to poor extension base in the coconut growing states.

Poor resource allocation to the institutions and resource limitations of the farmers are the key causes for poor technology delivery and its adoption.

Coconut farmers should be encouraged to adopt organic recycling in the groves using usufructs of coconut and component crops, producing vermicompost, basin management with short duration legumes to improve organic base for building soil fertility and productivity, which in turn will reflect on sustaining coconut yields.

A complete reorientation on production technology research is needed to evolve models for site-specific recommendations based on soil suitability classes, climate, irrigation facilities and topography of the land and farmers resource conditions. Instead of universal approach for east coast, west coast and inland coconut growing conditions, there is a need for site-specific approach for which reorientation of research programme is needed.

A detailed mapping of the fertility status of the coconut groves is necessary for the major coconut growing states. The farms can be characterized based on soil and leaf analysis for major (NPK), secondary (Cs, Mg, S) and micronutrients (Fe, Mn, Cu, Zn, B, Cl). This is necessary for planning production-oriented policies.

The national institute has the responsibility to conduct explorative surveys to identify potential areas for adopting coconut based farming system on scientific basis in different states. The state agricultural universities and department of agriculture also have a commitment in this. Unless marketable surplus is available, the status of the industry and living conditions of the farmers cannot be improved. This is possible only by increasing on farm productivity and employment opportunities.

The country should create a knowledge base in the coconut growing states for developing a strategy to propagate innovative production technologies, cropping system research, resource generation, improve employment opportunities and profit maximization. The existing programmes have their own limitations.

In this era of contract farming, technology efficient villages are to be developed to facilitate farmers to get counseling on innovative technologies, cropping system, quality planting material, farm finance and market linkage with better economic returns.

Poor knowledge base of the farmers can be related to ineffective and limited extension services. Why there is an uncommitted attitude of the farmers towards technology adoption? Small holders do not get adequate finances to be invested in farming of high inputs and innovative techniques for increasing production. Limited technical know-how on alternate production activities such as organic farming, integrated nutrient management, drip irrigation etc, deter the farmers from adopting technologies

On the research front, efforts should continue to evolve scientific innovations to bring down cost of production.

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