R.P.F.III

FINAL REPORT

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1. Institute Code No: Agr.II(443) Expt. I   2. I.C.A.R.Code No. PI - 99/ICI - F27/0311, 2710

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3. Name and address of Research Institute/Centre:

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
Kasaragod 671 124 (Kerala)

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4. Project Title: **Integrated nutrient management of palm based cropping / farming system for sustained productivity under coastal ecosystem**

Expt. I: Management of Coconut Based *Cropping System* for Sustainable Productivity under Coastal Ecosystem

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5. Name & designation of Principal investigator:

Dr C. Palaniswami, Senior Scientict(Soil Science)

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6. Name(s) and designation of Associate9s) and establishment(s) on which borne:

(a) Whole time

Dr. George V Thomas, Director,CPCRI
Dr. R. Dhanapal Senior Scientist(Agronomy)
Dr.(Mrs) K. V. Kasturi Bai Principal Scientist (Plant Physiology)
Dr. C. V. Sairam, Senior Scientist (Agrl. Economics)
Dr. H P Maheswarappa, Senior Scientist (Agronomy)
Mr. P. Subramanian, Senior Scientist (Agronomy)

(b) Part time (indicate proportion of time to be devoted and other area(s)

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7. Location of research project with complete address:(Division/Section/Sub Station)
Division of Crop Production
CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
Kasaragod 671 124 (Kerala)

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8. Date of start: 1999 9. Date of termination 2005

10. (a) Objectives (not more than 150 words)

a. Assess the biomass available through main and component crops in the system
b. To transform the available biomass into acceptable organic manures for recycling back into the system
c. To work out nutrient balance in the system
d. To study the impact of management practices on soil physico-chemical and biological environment
e. To study the microclimatic parameters and light profile in the cropping system
f. To study the sustainability of the crop yields under integrated nutrient management
g. To work out the energetics of the cropping system
h. To assess the employment generation in the system and work out the economics of the cropping system with special reference to the cost-benefit ratio

(b) Practical utility (not more than 100 words)

The main crops of the coastal region are plantation crops along with some forest trees. Amongst the plantation crops, coconut, arecanut and rubber are predominantly grown. Average annual removal of major plant nutrients (N,P,K) by coconut are 66.54 thousand tonnes of nitrogen, 28.40 thousand tonnes of phosphorus and 162.77 thousand tonnes of potash respectively while actual estimated addition through fertilizer use is 14.27 thousand tonnes of nitrogen, 9.13 thousand tonnes of phosphorus and 34.25 tonnes of potash respectively (Nair *et. al.*, 1995). This reveals a wide gulf separating the nutrient export by the crops and nutrient addition through fertilizers. In addition to the above, the nutrient use efficiency is also low due to various factors. The chemical fertilizers, now the main stay of the present agriculture are increasingly costly and in short supply. Maximization of economic returns is now the key to success of agriculture. Limited resource support and other constraints such as risk due to crop losses and fluctuating prices of commodities discourage small holders to apply fertilizers. Recycling of organic wastes viz. usufructs of crops, animal dung, urine etc. leads to considerable savings in cost of fertilizer input in the cropping/farming system, thereby, increasing cost-benefit ratio.

Coconut is a widely spaced crops wherein a number of annuals/perennial crops can be grown as inter/mixed crops. However, nutrient management in palm based cropping system is a difficult task due to varying requirements of different crops and crop communities, differential crop responses and crop residue additions. The fertilizer management according to the individual crop requirement is not the most efficient and economic way of utilizing native and applied nutrients. Such conditions call for managing the system as a whole.

11. Technical programme (Indicate briefly plan of procedure, techniques, instruments and special materials, organism, special environments etc.)

The cropping system model involves Coconut, Coffee, Pepper, Clove, Banana and Pineapple.

a. Planting and establishing coffee and pepper in the coconut based HDMSC system

b. Estimation of biomass available for recycling in all the main and component crops at different fertilizer levels.

c. Studying the response of crops to differential fertilizer treatments in terms of economic produce.

Fertiliser Treatments: Full dose, 2/3 of recommended, 1/3 of recommended, ¼ of recommended, 1/5 of recommended chemical fertiliser, and control (without chemical fertiliser). Vermicompost will be applied for all the crops depending on the extent of biomass produced per treatment.

d. To work out the changes in soil and plant nutrient status over a period of time using the standard analytical procedures (Jackson, 1973).

e. Study the changes in soil physical properties with regard to single value constants (Water holding capacity, porosity and bulk density).

f. Study the changes in soil biological properties with regard to microbial load by plate dilution technique (Pramer and Schmidt, 1964), microbial biomass (Jenkinson and Paulson, 1976) and enzyme activities.

g. The relative humidity, temperature will be recorded with the help of respective sensors connected to the datalogger of automatic weather station. Light profile in the system will be studied with the help of radiation measurement instrument.

h. Economic analysis of the system - cash flow analysis and cost-benefit ratio.

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12. Final Report on the Project:
(A summary of results not exceeding 5 typed pages precisely and concisely stating the fundamental and/or practical significance thereof.)

The experiment was initiated in 1999 in the existing Coconut Based Cropping System with clove, banana and pineapple as component crops in the research farm of Central Plantation Crops Research Institute, Kasaragod. The coconut garden has 36 years old WCT palms spaced 8 m apart and arranged in square system of planting. The experiment was laid out in 1.2 ha area. Initially, the experimental plot was divided into three treatment plots *viz.* Full, 2/3 and 1/3 of the recommended fertilizer dose and based on the results of ten years, the experiment was modified and three more treatments were introduced from 1994 onwards

In the coconut based high density multispecies cropping system, the coconut yield ranged from 128 nuts/palm/year under control treatment to 162 nuts/palm/year at 2/3rd of the recommended fertilizer dose. The productivity of the palm declined with the further reduction in the fertilizer levels. The yield of the clove tree varied with the fertilizer treatments. The clove tree did not flower below 1/4th of the recommended fertilizer treatment. Highest yield was recorded at Full recommended dose treatment (1.18 kg dried clove/tree), thereafter, the yield declined. The average wt. of pineapple fruit was highest in the full recommended dose treatment (1013.24 g) whereas lower fruit wt. was recorded in the No inorganic fertilizer treatment and 1/4th of the recommended dose treatment (466 & 405 g respectively).

Highest coconut biomass was obtained at full dose treatment (23.51 t/ha), which declined to 19 t/ha in the control treatment. The total nutrient exhaust ranged from 130.45, 18.29 and 172.64 kg of N, P and K respectively per ha in the full dose to 97.11, 13.06 and 125.45 kg of N, P and K respectively per ha in the no fertilizer treatment plot. The extent of nutrient recycling in terms of leaflets, petioles, bunches, spathe and husk was highest in full dose treatment.

The distribution of soil microbial groups was investigated in the cropping system. Crop diversity and level of fertilizer inputs influenced the microbial groups in the root zone of crops. It was seen that bacterial count was low in the root-region of pineapple and control.2/3rd dose of fertilizer recorded low number of bacteria than other treatment in coconut. The counts of fungi and actinomycetes were low in the root region of banana and coconut. Full dose of fertilizer supported very low counts of fungi and actinomycetes. Asymbiotic nitrogen fixers were more in root region of clove and pineapple. The population was maximum in 1/3rd dose of fertilizer treatment. There was an increasing trend from control to 1/3 rd dose and a decreasing trend was observed from 1/3rd to full dose. As regard to the population of P solubilizers, the population was maximum in banana among the crops and in 1/3rd dose of fertilizer. The microbial population decreased with increasing depth. The development of different microbial groups was optimum at moderate doses of mineral fertilizer input viz.; one-third and one-fourth when combined with addition of vermicompost produced by recycling of waste biomass.

The project was initiated during August 1999 in an existing arecanut + cocoa + clove cropping system. The main purpose of the project was to assess the biomass available for recycling back to the system and to work out the nutrient budgeting in the system. The system had six crops with arecanut as major crops. Other crops are cocoa, clove, pepper, banana and coffee. During the year under report, the yield of the crops was recorded and soil and plant samples were collected and part of them were analysed. The waste materials were collected and converted into vermicompost. Total wastes collected from the system were 2835 kg. The same was put for composting using earthworms and 2268 kg compost was obtained with 80% recovery. Only areca, cocoa and clove yielded, banana and pepper have just started bearing and coffee has flowered thi asins, control i.e. only OMR recorded higher mineral nitrogen and organic carbon content where as P content was higher at 2/3rd fertilizer dose and K at full dose of fertilizer, which did not vary with 2/3rd fertilizer application. Surface layer showed higher values as compared to lower depth. Under clove, organic carbon was highest with 2/3rd fertilizer dose and P was higher with OMR alone. K content was similar at 2/3rd and full dose of fertilizer and were higher compared to other treatments. Overall result indicated that 2/3rd of the recommended dose of fertilizer along with OMR was better for the cropping system.

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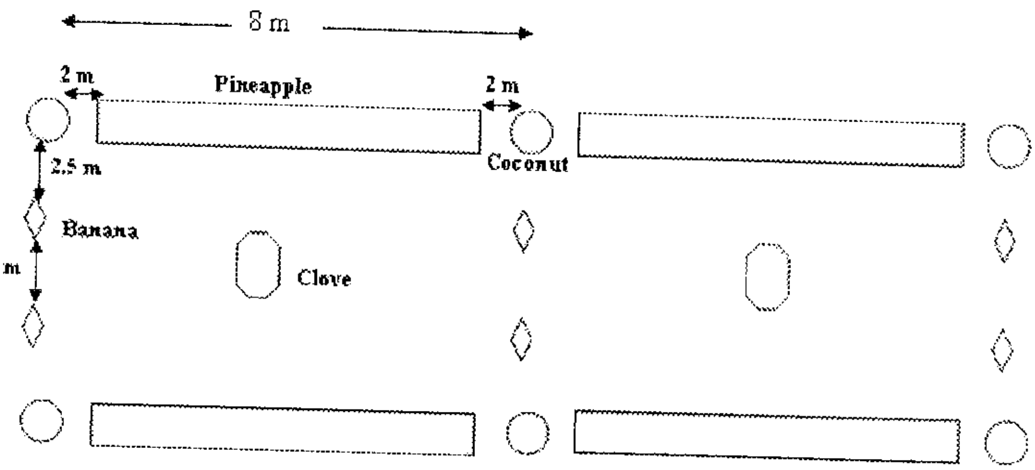
13. Progress of work in relation to the time targeted for completion of work and reasons for non achievement of targets, if any.

An INM experiment was initiated in 1999 in the existing Coconut Based Cropping System with clove, banana and pineapple as component crops in the research farm of Central Plantation Crops Research Institute, Kasaragod. The coconut garden has 36 years old WCT palms spaced 8 m apart and arranged in square system of planting. The experiment was laid out in 1.2 ha area. Initially, the experimental plot was divided into three treatment plots *viz.* Full, 2/3 and 1/3 of the recommended fertilizer dose and based on the results of ten years, the experiment was modified and three more treatments were introduced from 1994 onwards by including absolute control, 1/4 and 1/5 of the recommended fertilizer dose. The waste material collected from the garden from each treatment was separately converted into vermicompost and distributed among the crops during September in the same treatment. To increase the intensity of cropping pepper rooted cuttings (cv Panniur 1) was introduced along with existing component crops in August 1999. The pepper was trailed on coconut trunk. Pineapple was replanted in June 1999 and planted in a single row between coconut palms. Banana was replanted in June, 2000. The cropping system layout is shown in Figure 2. Fertilizers were applied in two splits for coconut i.e. $1/3^{rd}$ immediately after the onset of South - West monsoon (May-June) and remaining $2/3^{rd}$ dose and organics at the post-monsoon period (September-October). Perfo irrigation (modified form of sprinkler irrigation) was given during the dry period (December-May) at IW/CPE ratio 1.00.

PLANT NUTRIENT STATUS

The nutrient status of the plant was monitored and it was found that in general lower dose of fertilizer treatment recorded numerically higher values for coconut leaf P, Zn, Cu, Fe, Mn and Mg content due to the concentration effect. The foliar nutrient status is given in Table 2. In the case of coconut, the N content was above the critical level (1.8%) up to one-third of the fertilizer level and declined with the further reduction in the



Plant Population (per ha):
Coconut – 157; Clove – 112; Banana – 345; Pineapple – 2250
Pepper 157

Figure 2. Components of HDMSCS

fertilizer dose. Infact, at lower doses, the N content was below the critical level, suggesting that the fertilizer levels below one-third of the recommended dose are insufficient to meet the crop needs. Foliar P and K levels in coconut, though optimum in all the treatments, were higher at fertilizer levels, one-third, two-third and full, but declined thereafter with reduction in fertilizer level. In respect of component crops although, the economic and biomass yields were higher with the higher fertilizer levels, the foliar nutrient contents for P and K did not vary much among the fertilizer levels. While in tissue N content increased with the increasing fertilizer level and there is substantial yield variation in the component crops. The relation ship between coconut leaf nutrient status and nut is given in Figure 3. There was linear relationship between the coconut yield and leaf K content ($P<0.01$) indicating that the soil could respond to potassium application. Coconut leaf Mn showed second order relationship with the nut yield suggesting dilution effect of Mn in the palm at higher production level.

SOIL NUTRIENT STATUS

Soil total N, organic carbon content, available P, K, Ca, Mg and micronutrients of the surface soil recorded higher values than the subsurface soil of coconut and component crops. The soil nutrient status under various fertilizer treatments is given in Table 3. The organic matter status declined with the increased fertilizer addition. Infact, in coconut, the highest organic matter content (0.712%) was found in the No fertilizer treatment, which declined to 0.512 % in the treatment, full dose of fertilizers. The increasing fertilizer levels might have led to higher active root biomass production. The exudates so secreted by the roots might have led to the proliferation of microbes, which would have decomposed the organic matter leading to reduction in the organic matter content at higher fertilizer levels. The total N content in the soil increased appreciably with increasing fertilizer levels. At lower fertilizer levels, the organic matter content in the soil was high, still, the total N content was lower suggesting high C:N ratio of the organic matter. Similar trends were observed in all the component crops except in case of pineapple where the organic matter content was higher at higher fertilizer levels. The available P and K status of soil increased with increasing fertilizer levels in all the main

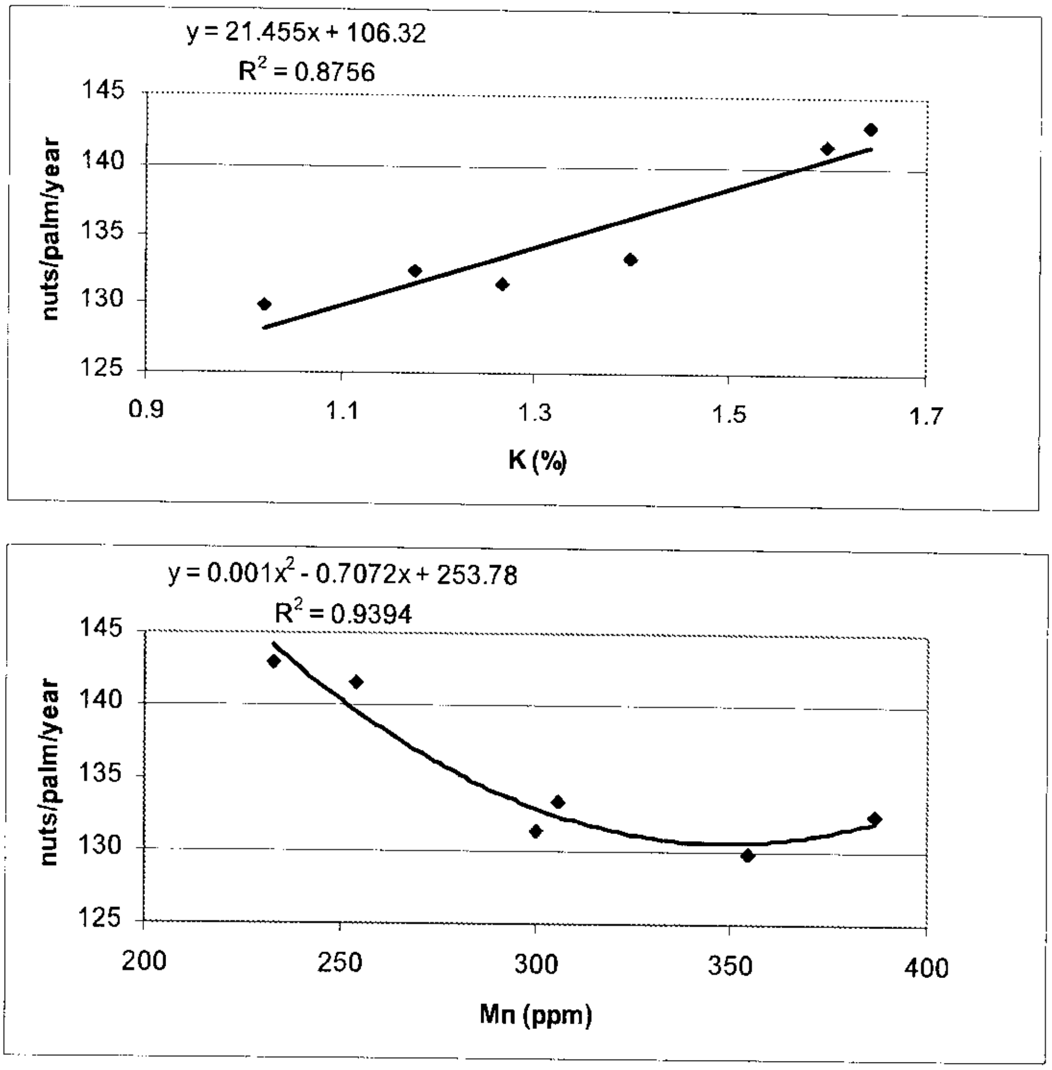


Figure 3. Relationship between coconut leaf nutrient content and nut yield

as well as component crops. Thus, P and K when applied to the soil have a tendency to get fixed, which becomes slowly available to the crop later on.

There was quadratic relationship between the available K and coconut yield and leaf K content (P <01, Figure 4).

Table 2. Foliar nutrient content of coconut and component crops

Crop/ Treatment	N (%)	P (%)	K (%)
COCONUT			
Control	1.820	0.1400	1.0263
1/5th	1.792	0.1474	0.9823
1/4th	1.820	0.1422	1.1607
1/3rd	2.002	0.1313	0.8967
2/3rd	1.904	0.1255	0.8480
Full	1.932	0.1427	1.1607
CLOVE			
Control	0.980	0.1381	1.0263
1/5th	0.952	0.0971	0.9407
1/4th	1.120	0.1093	0.8972
1/3rd	1.288	0.0990	0.8981
2/3rd	1.246	0.0821	1.1932
Full	1.246	0.0620	1.2094
BANANA			
Control	1.820	0.1700	2.6435
1/5th	1.792	0.1858	2.3509
1/4th	1.830	0.1776	2.3226
1/3rd	1.876	0.1725	2.4932
2/3rd	2.058	0.1432	2.2186
Full	2.590	0.1733	2.4355
PINEAPPLE			
Control	0.770	0.2614	3.0288
1/5th	0.728	0.2575	2.6385
1/4th	0.686	0.2350	2.7860
1/3rd	0.784	0.2157	2.4360
2/3rd	0.700	0.2141	2.4384
Full	0.748	0.1882	2.3788

Table 2. Foliar nutrient content of coconut and component crops (continued..)

Crop/ Treatment	Ca(%)	Mg(%)	Zn(ppm)	Cu(ppm)	Mn(ppm)	Fe(ppm)
COCONUT						
Control	0.40	0.22	24.50	5.95	354.50	233.15
1/5th	0.34	0.19	29.15	6.05	386.75	265.30
1/4th	0.35	0.21	27.05	7.25	300.25	145.50
1/3rd	0.48	0.23	21.80	7.50	253.75	175.05
2/3rd	0.53	0.20	18.40	6.30	232.50	122.70
Full	0.53	0.19	16.40	6.65	306.00	125.00
CLOVE						
Control	0.74	0.18	11.50	12.40	1122.25	217.65
1/5th	0.83	0.18	85.80	20.60	1017.50	182.40
1/4th	0.83	0.21	13.30	10.65	857.25	253.65
1/3rd	0.72	0.18	10.50	4.90	913.25	230.00
2/3rd	0.66	0.21	11.85	4.45	1121.25	225.80
Full	0.57	0.18	8.50	5.20	852.50	204.15
BANANA						
Control	0.49	0.26	21.40	10.10	819.75	204.95
1/5th	0.59	0.31	26.35	13.15	907.50	737.70
1/4th	0.46	0.29	16.20	10.95	679.25	327.35
1/3rd	0.50	0.30	18.45	12.50	785.50	200.20
2/3rd	0.45	0.32	16.30	10.45	919.75	275.90
Full	0.43	0.31	15.60	7.60	405.50	173.00
PINEAPPLE						
Control	0.38	0.26	11.65	7.85	142.00	152.50
1/5th	0.35	0.31	12.00	7.85	159.25	168.15
1/4th	0.38	0.25	9.45	7.40	226.25	146.95
1/3rd	0.34	0.30	9.40	12.25	205.00	191.05
2/3rd	0.37	0.23	5.70	7.80	171.75	189.90
Full	0.31	0.25	4.90	10.10	166.00	146.30

Table 3. Soil nutrient status of the coconut based cropping system

Treatments	Org. Matter (%)	Total N (ppm)	Available P (ppm)	Available K (ppm)
Coconut (Average of three depths)				
No fertilizer	0.712	265	98.71	76.71
One -fifth	0.700	365	161.73	96.80
One-fourth	0.702	755	165.67	117.24
One-third	0.519	1435	220.44	112.36
Two-third	0.523	1410	285.57	161.21
Full	0.512	1460	342.65	229.60
Clove (Average of two depths)				
No fertilizer	0.736	175	48.13	62.71
One -fifth	0.706	300	49.93	74.88
One-fourth	0.699	345	57.29	88.99
One-third	0.621	1360	59.07	124.57
Two-third	0.632	1195	76.25	168.54
Full	0.615	1280	93.78	161.21
Banana (Average of two depths)				
No fertilizer	0.741	290	28.86	42.01
One -fifth	0.723	230	29.81	75.49
One-fourth	0.714	515	25.54	97.59
One-third	0.563	1050	29.15	109.79
Two-third	0.598	1215	29.55	162.43
Full	0.576	1250	32.81	236.92
Pineapple				
No fertilizer	0.623	340	27.34	29.92
One -fifth	0.617	280	21.03	42.61
One-fourth	0.599	410	41.84	63.31
One-third	0.589	530	42.33	65.75
Two-third	0.732	600	47.29	77.92
Full	0.741	620	50.27	121.75

Table 3. Soil nutrient status of the coconut based cropping system (continued...)

	Ca (ppm)	Mg (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Coconut (Average of three depths)						
Control	93.99	23.72	86.99	0.67	1.46	33.71
1/5th	91.76	17.32	78.13	0.35	1.00	35.49
1/4th	99.07	15.86	113.10	0.91	2.04	53.69
1/3rd	68.75	16.61	87.21	0.55	1.41	57.98
2/3rd	76.44	13.35	78.29	0.65	1.13	49.61
Full	71.68	12.96	97.71	0.78	1.16	51.29
Clove(Average of two depths)						
Control	107.16	15.09	90.19	0.91	1.48	54.31
1/5th	94.78	8.35	108.22	1.28	1.72	55.25
1/4th	90.58	17.14	115.18	0.87	2.18	61.22
1/3rd	103.51	25.43	81.36	1.16	2.44	66.15
2/3rd	117.61	28.43	91.20	0.83	1.59	46.02
Full	75.32	25.98	103.86	1.07	1.53	44.15
Banana (Average of three depths)						
Control	81.51	17.59	76.80	0.87	1.28	33.74
1/5th	65.20	15.17	93.83	0.95	1.21	56.65
1/4th	88.75	27.62	97.90	1.11	1.56	40.01
1/3rd	96.17	31.39	81.89	0.74	1.35	68.79
2/3rd	100.54	40.34	103.45	0.81	1.73	80.53
Full	101.30	33.36	73.97	1.03	2.31	47.62
Pineapple						
Control	168.87	32.41	98.88	1.58	2.57	29.21
1/5th	105.25	31.56	91.42	1.12	2.22	52.86
1/4th	121.94	50.37	60.45	0.95	2.39	59.27
1/3rd	165.34	48.13	66.24	1.36	2.74	58.25
2/3rd	136.91	34.65	99.82	1.05	2.43	41.97
Full	131.92	29.05	101.30	1.12	2.18	39.46

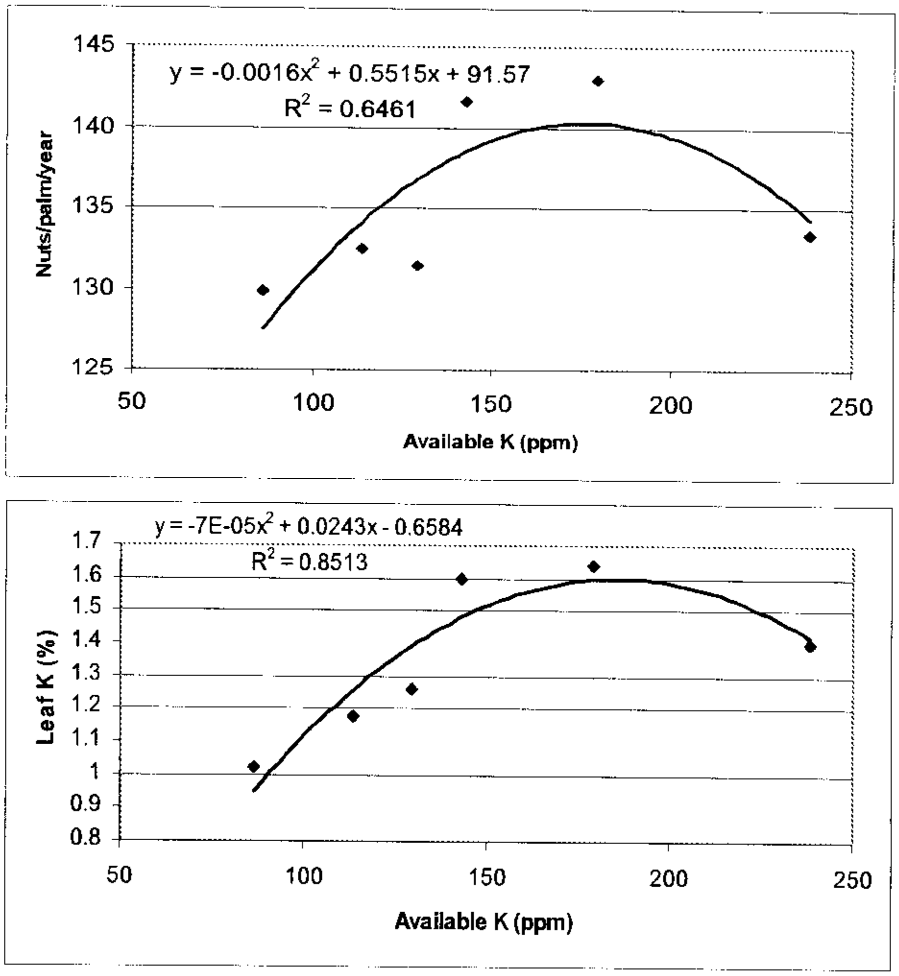


Figure 4. Relationship of available K with coconut yield and leaf K content.

BIOMASS PRODUCTION & NUTRIENT RECYCLING

The nutrient cycle comprises the supply, uptake, and the loss of nutrients to the environment. Nutrient recycling returns nutrients to the agroecosystems that would otherwise be lost to the environment. Intercropping and application of crop residues and farmyard manure are nutrient recycling techniques.

Highest coconut biomass was obtained at full dose treatment (23.51 t/ha), which declined to 19 t/ha in the control treatment (Table 4). The total nutrient exhaust ranged from 130.45, 18.29 and 172.64 kg of N, P and K respectively per ha in the full dose to 97.11, 13.06 and 125.45 kg of N, P and K respectively per ha in the no fertilizer treatment plot. The extent of nutrient recycling in terms of leaflets, petioles, bunches, spathe and husk was highest in full dose treatment (Figure 5).

Table 4: Biomass production and nutrient export in coconut from the system (on dry wt. basis)

Fertilizer treatments	Biomass (t/ha)	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
		Exhaust	Recycled	Exhaust	Recycled	Exhaust	Recycled
Full*	23.51	130.43	70.58	18.29	8.55	172.64	114.26
Two-third	22.71	130.29	69.58	18.09	7.54	182.35	121.11
One-third	22.29	121.29	61.71	16.81	6.86	176.74	113.09
One-fourth	20.72	103.21	47.87	17.86	8.19	142.49	90.97
One-fifth	20.24	98.03	47.78	15.38	6.82	134.03	92.31
Control	19.05	97.11	48.92	13.06	5.44	125.45	87.84

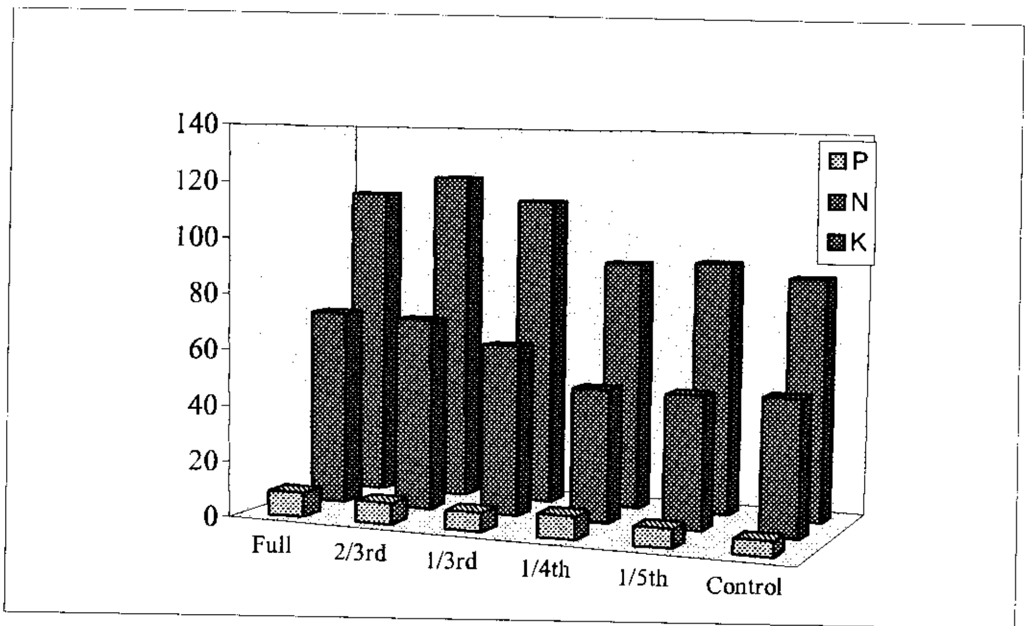


Figure 5: Extent of nutrient recycling (kg/ha) under different fertilizer levels

MICROBIAL PARAMETERS

The distribution of soil microbial groups was investigated in the cropping system (Table 5). Crop diversity and level of fertilizer inputs influenced the microbial groups in the root zone of crops. It was seen that bacterial count was low in the root-region of pineapple and control.2/3rd dose of fertilizer recorded low number of bacteria than other treatment in coconut. The counts of fungi and actinomycetes were low in the root region of banana and coconut. Full dose of fertilizer supported very low counts of fungi and actinomycetes. Asymbiotic nitrogen fixers were more in root region of clove and pineapple. The population was maximum in 1/3rd dose of fertilizer treatment. There was an increasing trend from control to 1/3 rd dose and a decreasing trend was observed from 1/3rd to full dose. As regard to the population of P solubilizers, the population was maximum in banana among the crops and in 1/3rd dose of fertilizer. The microbial population decreased with increasing depth. The development of different microbial groups was optimum at moderate doses of mineral fertilizer input viz.; one-third and one-fourth when combined with addition of vermicompost produced by recycling of waste biomass.

Table 5. Microbial colony in coconut based cropping system

Fertilizer level	Actinomycetes (10^3 cfu/g soil)	Fungi (10^4 cfu/g soil)	Bacteria (10^5 cfu/g soil)	N – fixers (10^3 cfu/g soil)	P solubilizers (10^4 cfu/g soil)
Control	14.3	29.8	37.8	28.3	16
One-fifth	19.9	35	61.3	35.0	21.4
One-fourth	22.6	45	77.5	55.2	24.1
One-third	31.3	55.6	113.2	69.0	31.7
Two-third	14.3	28.2	63.5	36.5	15.8
Full	9.9	25.8	53	25.0	12.5

Yield

In the coconut based high density multispecies cropping system, the coconut yield 9mean of six years) ranged from 127 nuts/palm/year under no fertilizer control treatment to 147 nuts/palm/year at two third and one third of the recommended fertilizer dose(Table 6). The productivity of the palm declined with the reduction in the fertilizer levels beyond 1/3rd of the recommended fertilizer treatment. The yield of the clove tree varied with the fertilizer treatments. The clove yield ranged from 0.246 kg/tree/year under no fertilizer control treatment to 1.44 kg/tree/year at full dose of the recommended fertilizer dose. The average weight of banana bunch was highest in the full recommended dose treatment (6.20 kg/bunch). The average weight of pineapple fruit was highest in the full recommended fertilizer dose treatment (528 g).

Table 6. Output from 1.2 ha coconut based cropping system model at Kasaragod (mean of six years)

Treatment	Coconut	Pineapple (kg/fruit)	Clove (dry kg/tree)	Banana (kg / bunch)	Black pepper (kg / bush)
Full dose	146	0.53	1.44	6.21	0.34
2/3rd rec. dose	147	0.52	0.72	5.49	0.63
1/3rd rec. dose	147	0.50	0.52	4.01	0.46
1/4th rec. dose	139	0.43	0.51	4.55	0.70
1/5th rec. dose	128	0.49	0.49	3.43	0.34
No fert.- Control	127	0.41	0.25	4.21	0.13

FERTILISER RESPONSE FUNCTION OF COCONUT

In the experiment, there is no factorial combination of the fertilizer treatment the NPK recommended dose is taken as one and other treatments were also transformed accordingly. The quadratic response fitted showed significant correlation coefficient (Figure 6). The optimum fertilizer requirement worked out to be 359 g N, 229 g P_2O_5 and 860 g K_2O per palm per year, which gave the nut yield of 151.77 nuts/year.

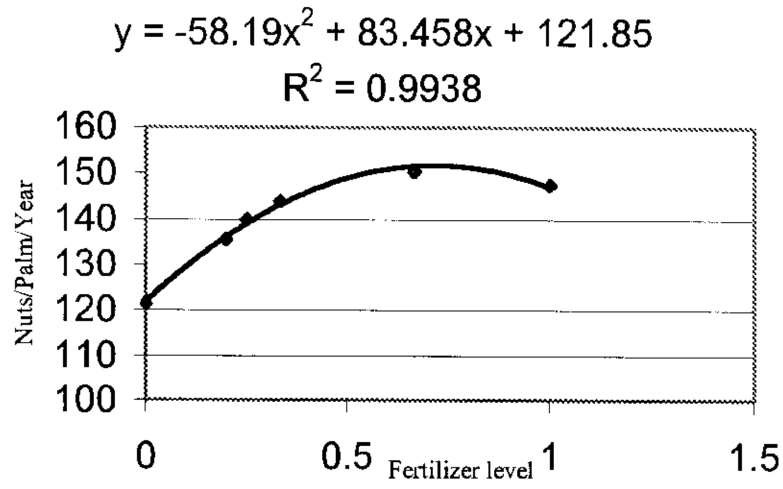


Figure 6 Fertilizer response function for coconut

ENERGY BALANCE IN THE CROPPING SYSTEM

Although the energy of sunlight is a fundamental input to agriculture, the energy balance of agricultural systems depends on the additional energy supplied from non-renewable sources. Sustainable agriculture practices can improve the energy balance and ensure that it remains positive - there is more energy coming out than going in. Agricultural productivity is closely linked with the energy inputs. The measure of energy flow in crop production systems provides a good indicator of the technological aspects of crop production system in agriculture. For sustainability in energy management the efforts have to be double pronged, firstly efficient use of commercial energies, and secondly harnessing renewable energy sources as supplementary and substituting commercial energy sources.

Balance : Total energy input/total energy output, including transport where relevant

Ratio : Renewable over non-renewable energy inputs

Energy balancing in agriculture requires consideration of the energy consumption, on-farm energy fluxes and energy output (Kalk et al. 1996). According to Heyland &

Solansky (1979) energy inputs can be differentiated for direct (e.g. crude oil, diesel) and indirect (e.g. machinery, fertilizer and plant protection agents) types.

The non renewable energy input in to the system ranges from 29633 to 39694 MJ/ha. The energy values from the economic output are between 7824 to 15064 MJ/ha (Table 7). The use efficiency is highest in the treatments receiving full dose of fertilizers (0.38).

Table 7. Energy balance in HDMSCS

Treatments	Fert. Pest. MJ/ha	Irrigation MJ/ha	Total input MJ/ha	Economic out put MJ/ha	Energy efficiency
Control	2562	27070	29633	7824	0.264
One-fifth	3549	27070	30620	7875	0.257
One-fourth	3796	27070	30867	8939	0.289
One-third	4207	27070	31278	8637	0.276
Two-third	8415	27070	35486	11306	0.318
Full	12623	27070	39694	15064	0.379

N-MINERALISATION

Nitrogen (N) is mineralized when microorganisms convert N in soil organic matter to ammonia, nitrate, and nitrite. *In situ* N-mineralisation was determined as the difference between extractable N in incubated and initial soil samples. Soil samples were taken from two 20 cm PVC tubes with a diameter of 5 cm that were inserted vertically into the topsoil (10 cm). In general rate of N- mineralisation was higher in coconut basin area (2.2 ppm –N per day) upto one third of recommended fertiliser dose(Figure 7.). However, in lower dose of fertiliser clove soil had higher N- mineralisation rate (3.43 ppm –N per day).

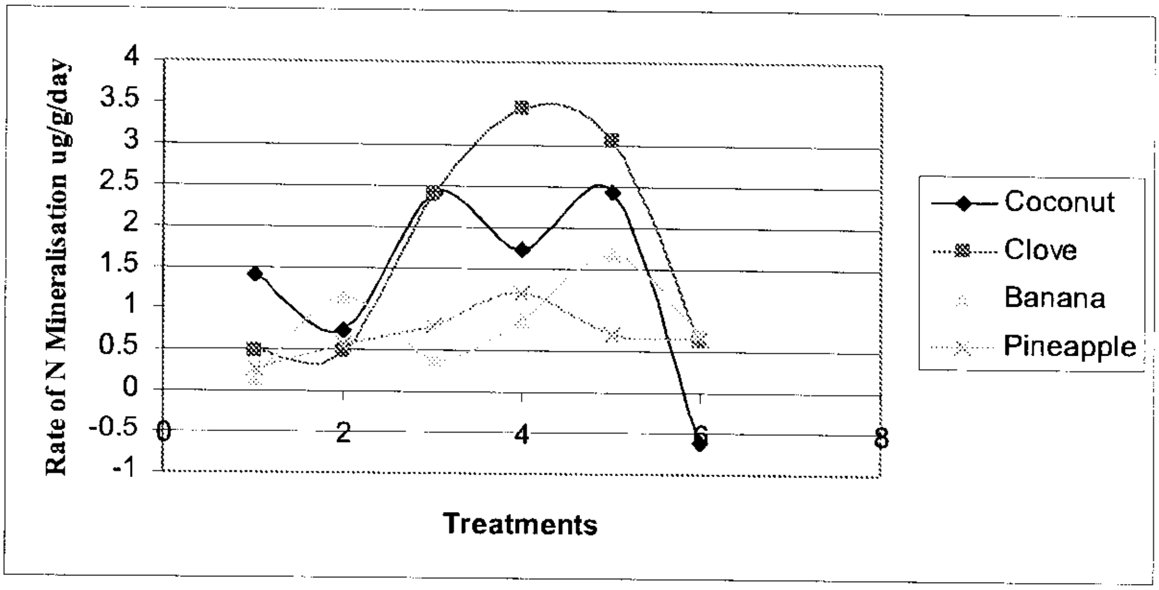


Figure 7. ***In situ* N- mineralisation in different root zone soils of coconut based cropping system**

SOIL ORGANIC CARBON SEQUESTRATION

There is a critical need for best management practices that enhance SOC sequestration. At the local and regional levels, increased SOC contributes positively to soil tilth, fertility, and water-holding capacity, and thereby increases crop production, promotes sustainability, and enhances land value for producers (Lal et al., 1997). At the global level, increased sequestration of C in agricultural soils has the potential to mitigate. In the integrated nutrient experiment, after organic recycling there was soil carbon buildup in coconut basin while in area of pineapple soil carbon store was depleted(Figure 8.).

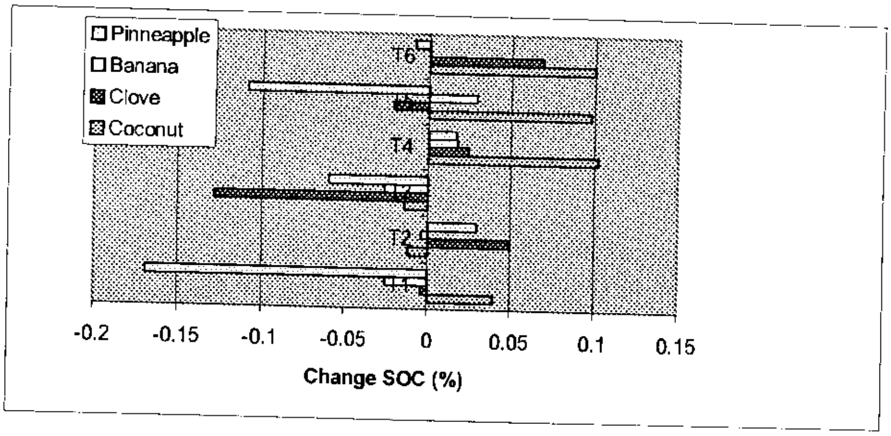


Figure 8. Change in SOC in the coconut based cropping system

YIELD SUSTAINABILITY

Sustainability of yield in the coconut can be estimated by quantifying yield variation over the year. This can be done by similar sequence matching technique. Similar sequence matching algorithms are classified into whole matching and subsequence matching (Faloutsos et al., 1994). Whole matching finds data sequences that are similar to a query sequence, where the lengths of data sequences and the query sequence are all identical. Subsequence matching finds subsequences, contained in data sequences, that are similar to a query sequence of an arbitrary length.

The proposed algorithm enables finding a data sequence that has a fluctuation pattern similar to the query sequence even though they are not close to each other before the normalization transform. By this we can compare the yield fluctuation pattern between the treatments in coconut over the years.

Given a sequence $\vec{X} = (x_i)$ $(0 \le i < n)$ of the length $n(\ge 1)$, the *normalized sequence* $v(\vec{X}) = (\tilde{x}_i)$ is defined as follows (Goldin and Kanellakis, 1995; Rafiei and Mendelzon, 1997):

$$\tilde{x}_i = \frac{x_i - \mu(\bar{X})}{\sigma(\bar{X})}$$

where $\mu(\vec{X})$ and $\sigma(\vec{X})$ are the mean and standard deviation of the sequence $\vec{X}$, respectively.

Summery of notations

Notation	Definition
$\vec{S}=(s_i)$	Yield data over the years $\vec{S}=(s_0,...,s_{N-1})(0 \le i \le N)$
$\vec{X}=(x_i)$	A subsequence contained in the data sequence $\vec{S}$ $\vec{X}=(x_0,...,x_{n-1})(0 \le i < n \le N)$
$\vec{T}=(t_i)$	The sequence to be compared $\vec{T}=(t_0,...,t_{n-1})(0 \le i < n)$
$d(\vec{X},\vec{T})$	Euclidean distance between two sequences $\vec{X}$ and $\vec{T}$ $d(\vec{X},\vec{T})=\left\{\sum(x_i-t_i)^2\right\}^{1/2} \quad \left(Len(\vec{X})=Len(\vec{T})\right)$
Amplitude($\vec{X}$)	$w=\max(\vec{X})-\min(\vec{X})$

It was observed that the control treatment came closer to other treatments after organic recycling. Without application of recycled organics there was higher year to year yield variation in the in the control treatment compared to other fertilised treatment. After recycling of the organics, year to year yield variation of control treatment was similar to other treatments. As indicated by the mean euclidean distance of control with other treatments was 1.39 prior to organic recycling while it was 0.87 after organic recycling(Table). There was decrease in amplitude after the introduction of organic recycling in the normalized sequence(Figure 9). In the control pre experiment amplitude of 1.98 had reduced to 1.77 post experiment. This clearly indicates that the decrease in the year to year yield variation. However, the amplitude decrease was more perceptible in control treatment compared to other treatments.

Table 8. Euclidean distance of normalized subsequence

Pre exp	Full	2/3rd	1/3rd	1/4th	1/5th	Control
Full	-	0.9415	0.2647	1.0225	0.4370	1.1245
2/3rd	0.9415	-	0.7244	0.9311	0.8487	1.7641
1/3rd	0.2647	0.7244	-	0.9681	0.5194	1.3481
1/4th	1.0225	0.9311	0.9681	-	0.8482	1.6880
1/5th	0.4370	0.8487	0.5194	0.8482	-	1.0147
Control	1.1245	1.7641	1.3481	1.6880	1.0147	-
Post exp.						
Full	-	1.0020	0.5122	0.8162	1.0047	1.1507
2/3rd	1.0020	-	0.7617	0.8161	0.7414	1.3105
1/3rd	0.5122	0.7617	-	0.3152	0.5050	0.7629
1/4th	0.8162	0.8161	0.3152	-	0.2357	0.5335
1/5th	1.0047	0.7414	0.5050	0.2357	-	0.6137
Control	1.1507	1.3105	0.7629	0.5335	0.6137	-

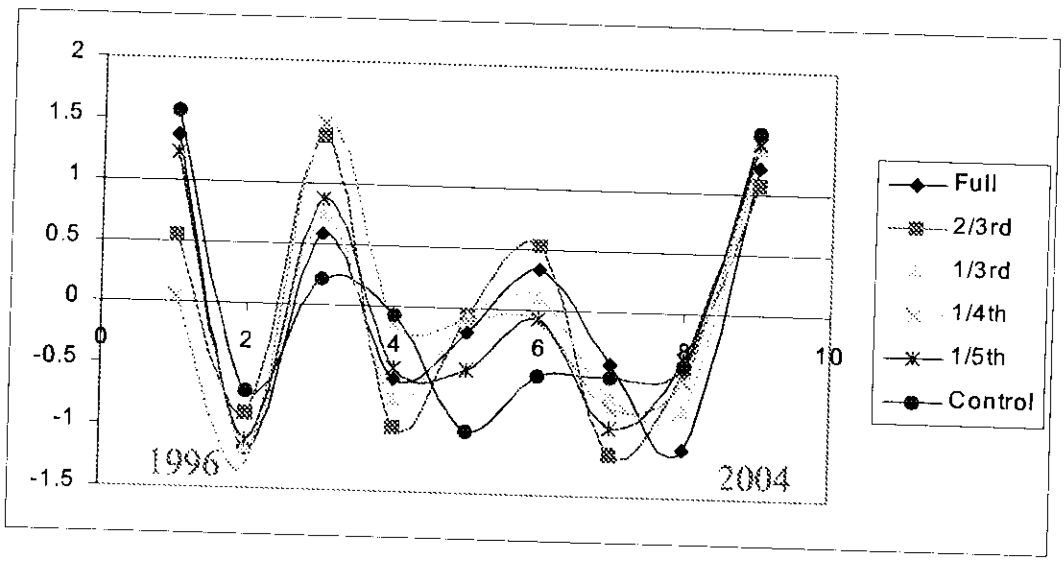


Figure 9. Pre and post organic recycling normalised yield difference in sequence

Conclusion

Integrated nutrient management by using 2/3 recommended fertiliser dose along with recycling of biomass by vermicomposting gives the best economic benefit in a sustainable manner. INM on coconut based cropping system demonstrated demostarted model to the farmer for integrate nutrient management in a cropping system. The system is more sustainable and production and productivity will increase without affecting the ecosystem. There is a positive impact through improvement of soil health by recycling of waste products in the system as organic manures. Further it will be eco-friendly with nature which will enable to increase the production and productivity of the system.

HDMSCS-demonstration plot Hill block

In the HDMSCS experiment at Hill bock the inter crop yields were as follows: banana 2.66 kg/bunch, black pepper 1.25 kg/stand and pineapple 1.03 kg/fruit. The estimated total income ranged from Rs 1,52,531/ha in coconut-black pepper-pineapple to Rs 1,57,910/ha in coconut-black pepper-banana. The maximum net return of Rs. 1,12,310 in coconut-black pepper-banana with BCR of 3.46.

14. Publications:

(a) Research papers

Subramanian, P., Srinivasa Reddy, D.V., **Palaniswami, C.**, Gopalasundram, P. and Upadhyay, A. K. 2005. Studies on nutrient export and extent of nutrient recycling in coconut based high density multispecies cropping system. Cord, 21(1) 20-27.

George V. Thomas and **Palaniswami, C.** 2005. Effect of different components of farming system and on farm organic recycling on coconut crop and soil fertility. In: Proceedings of Nation Seminar on More remunerative coconut based farming system 12th December 2005, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharastra , pp 49-61

Upadhyay, A. K., **Palaniswami, C.** Hameed Khan, H. and Balamurugan, J. 2005. Influence of fertilizer regime on potassium dynamics in a red sandy loam soil. Journal of Plantation Crops, 33(2):95-98

Khan,H.H.,**Palaniswami, C.** and Upadhyay, A. K. 2002. Potassium Dynamics in Coconut and Coconut based Cropping Systems. In: Use of Potassium in Kerala Agriculture Eds: T. Nagendra Rao and K,. N Tiwari, Kerala Agriculture University and Potash & Phosphate Institute of Canada- India Programme. pp 17-29

(b) Popular articles
(c) Reports

} Two copies **each** to be Supplied with this proforma

15. Details (Nos. etc.) of Field/laboratory Note Books and their final location.

Field books and other records available in the Soil Science section, Crop Production Division, CPCRI, Kasaragod

16. Signature of Principal Investigator

17. Signature of Head of Division/~~Station/section~~

18.Signature of Director

Studies on nutrient export and extent of nutrient recycling in coconut based high density multispecies cropping system

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Abstract

Investigations were carried out to assess the biomass available for recycling from coconut based high density multispecies cropping system (coconut, clove, banana and pineapple) under graded levels of fertilizers (full, two-third, one-third, one-fourth and one-fifth of the recommended level of fertilizer for each of the component crops and control). The total biomass removed from the system ranged from 19.1 to 27.6 t ha^{-1} $year^{-1}$. The highest biomass production was recorded from two-third level of fertilizer dose (27.6 t ha^{-1} $year^{-1}$). Out of the total biomass obtained, the quantity available for recycling ranged from 12.7 to 18.5 t ha^{-1} $year^{-1}$, which can contribute 56 to 110 kg N, 6.7 to 13.5 kg P and 108 to 225 kg K per hectare.

Key words: Nutrient recycling, high density multispecies, graded levels of fertilizers cropping system, coconut, clove, banana, pineapple.

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Introduction

High density multispecies cropping systems (HDMSCS) involve growing of a large number of crops per unit area to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. They are ideally suited for small land holdings and aim at maximum utilization of natural resources in unit time without degrading the quality of environment. But, with many component crops, the chemical input load in the form of fertilizers on the soil to meet the crop needs is high. Fertilizers are becoming prohibitively costly because of the increase in the cost of raw materials and power used in the manufacturing process. In addition, the raw materials needed for their manufacture are either fossil fuels or mineral ores, which are getting depleted at a faster rate. Now a days there is greater awareness regarding soil health and organic farming. Under these situations sustaining the productivity to meet the ever-growing demand of the population while, protecting the quality of environment is the need of the hour. This can be achieved through judicious utilization of chemical fertilizers and organic manures. However, availability and cost of organic manure is the main constraint. Hence there is an urgent need to recycle the organic residues generated in high intensity cropping systems in an effective manner. The importance of intensive cropping lies in the nutrient economy, as the extensive cover in the plantation floor increases the plant cycling fraction of nutrients (Khanan and Nair, 1977). Coconut is being grown as a monocrop or in homestead gardens or in high density multispecies cropping systems. Coconut based homestead farming is capable of maintaining soil health and ensuring environmental safety and it is economically efficient, ecologically sound and biologically sustainable (Salam *et al.*, 1991). Biomass productivity of coconut pineapple - intercropping system was 4.3 times that of pure coconut stands and this combination is considered to be one of the optimum cultivation patterns in tropical areas (Peng-FangRen *et al.*, 1996).

Cocoa, as a component of multiple cropping system adds substantial quantity of organic matter to the soil, thus leading to internal recycling of nutrients in the system. It has been observed that 8.2 and 19.8 t/ha/year (oven dry basis) of cocoa litter fall were obtained from single and double hedge systems of planting, respectively (Varghese *et al.*, 1978). Taking nutrient concentration of cocoa leaves to be 2.84% N, 0.26% P and 1.73% K on dry weight basis, it could be assumed that about 50 kg N, 11 kg P_2O_5 and 35 kg K_2O could be returned to the soil every year through leaf fall of cocoa under double hedge system of mixed cropping.

The practice of growing large number of crops in the interspaces of coconut would add lot of biomass to the soil and indirect addition of nutrients. This makes it necessary to rationalise the fertilizers to the crops in the system. The results of HDMSCS model studied under different levels of recommended fertilizers for ten years at Kasaragod indicated that there was no marked yield difference of crops in the full and two-third levels of fertilizers. This indicates the scope for scaling down of the recommended fertilizer dose of different crops in the system (Anonymous, 1995). Coconut based high-density multispecies cropping system generates large amount of biomass which if effectively recycled can meet major nutrient needs of the crop. The present investigation was therefore undertaken to study the annual biomass production of coconut and component crops and biomass available for recycling under various fertilizer levels in a coconut based high density multispecies cropping system.

Materials and methods

The present study was conducted over a period of two consecutive years (1998 and 1999) in an existing coconut based high density multispecies cropping system which was started in the year 1983 in the research farm of Central Plantation Crops Research Institute, Kāsaragod, in an 18 years old WCT coconut garden. The coconut palms were spaced 8 m apart and arranged in square system of planting. Clove (132 nos.), banana (343 nos.) and pineapple (3456 nos.) were grown as intercrops. The experiment was laid out in 1.2 ha area. Initially, the experimental plot had three treatments *i.e.* full, two-third and one-third of the recommended fertilizer dose for each component crop. Later, based on the results of ten years, the experiment was modified in 1994 with three more additional treatments. The treatment details are given in Table 1. Fertilizers were applied in two splits i.e., one-third immediately after the onset of southwest monsoon (May-June) and remaining two-third dose at the post-monsoon period (September-October). Perfo irrigation was provided at Irrigation Water/Cumulative Pan Evaporation ratio - 0.75 (irrigation water 20mm) from December-May.

Table 1. Treatment details

Plot	Treatment	Plot size (ha)
I	Full level of recommended dose	0.2
II	2/3rd level of recommended dose	0.2
III	1/3rd level of recommended dose	0.2
IV	1/4th level of recommended dose	0.2
V	1/5th level of recommended dose	0.2
VI	No fertilizer	0.2

Note: The recommended dose of coconut, clove, banana and pineapple is 500: 320: 1200, 300: 250: 750, 200:200:400 and 8: 4: 8 g N, P_2O_5, K_2O/plant/year, respectively.

Method of sampling

a) Coconut

Dry leaves: Total leaves in the crown were counted and the first fully opened leaf was marked in six palms/treatment (totally thirty six palms). Each year, the number of dried leaves fallen on the ground were counted from January to December. The samples were collected every quarter (February, May, August and November). The fallen leaves were separated in to petiole and leaflets and were weighed. Sub samples of each of these were oven dried and dry weight was estimated. The nutrient content of powdered dry samples was determined.

Inflorescence: Dry weight of spathe and bunch waste was estimated in a similar manner as mentioned above.

Nut components: Twelve nuts/tree were collected for nut component analysis during different periods starting from January to December. Nuts were stored under shade for one month and the weight of husk, copra and shell recorded. Sub samples were taken and oven dried for dry matter estimation and nutrient analysis.

b) Banana

Samples were collected at the time of harvest. Six plants per treatment (totally thirty six plants) were removed at the ground level at the time of harvest and aboveground biomass was estimated. The plants were dissected into leaves, pseudostem, peduncle and fruits. Each part was weighed separately and sub samples were taken. The various sub samples were oven dried and the percentage of oven dry matter and total dry weight of the whole plant was estimated. After milling, the samples were analysed separately for N, P and K as per the standard procedures.

c) Clove

Totally thirty-six plants (six trees/treatment) were marked for biomass estimation. The fallen leaves and flower buds were accounted for the study. The fallen leaves were collected at fortnightly interval and flower buds once in a year for dry matter estimation and nutrient analysis.

d) Pineapple

One hundred and forty four plants at the rate of twenty four plants/treatment were collected at the time of harvest. Each plant was divided into root, stem, leaves, fruit and crown and weighed. From this, sub samples were taken. The various sub samples were weighed and dried in the oven at 70° C, reweighed and the percentage of oven dry matter and total dry weight of the whole plant calculated. After powdering, they were analysed separately for N, P and K as per the standard procedures.

Results and discussion

Annual biomass removed from the system and amount available for recycling

The data clearly revealed that the two- third and full dose of recommended level of fertilizer recorded higher amount of biomass and the lowest biomass was recorded in the unfertilized plots (Fig.1). The biomass produced in the system from main and different component crops was in the order of coconut, banana, clove and pineapple. Each crop is discussed below.

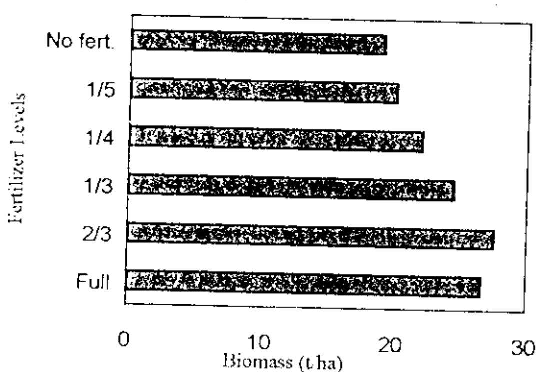

Fig. 1. Total removable biomass from the system

Coconut

The biomass removed from coconut was in the form of leaves, inflorescence waste and nuts. The annual biomass removed from the system ranged from 17.7 to 24.8 t/ha/year. The treatment two-third level recorded the highest biomass of 24.8 t/ha/year, which was comparable to full dose of fertilizer (23.6 t/ha/year). The lowest biomass was recorded in the control plot (17.7 t/ha/yr). Ouvrier and Ochs (1980) estimated that dry matter production of Dwarf x West African Tall in the Ivory Coast was just over 30 t/ha/year with the copra yield of 6,700 kg/ha. The results clearly illustrate that when the fertilizer dose was reduced to two-third of the recommended level, the biomass production and yield of coconut palms could be sustained at very high levels, probably as a result of compensation from biomass recycling. The biomass available for recycling is presented in the Table 3. Leaves, inflorescence waste and husks were available for recycling. Like biomass production, more biomass available for recycling was recorded under two- third and full dose of fertilizer levels.

Clove

Total biomass removed from the system is presented in the Table 2. The biomass was removed in the form of leaves and flower buds. The highest biomass was produced when two-third dose of fertilizer was applied to the clove trees and the same declined gradually with the reduction in fertilizer level. The same trend was observed in the economic product also i.e. flower buds. This clearly indicated that when clove was grown as a component crop in the coconut based cropping system, two-third of the recommended level of fertilizer was required to realize higher biomass production. Out of total biomass removed from the system, only fallen leaves of clove will be available for recycling and total weight of fallen leaves per year is calculated and presented in Table 3. The highest amount of biomass available for recycling was recorded under two-third level of recommended dose of fertilizer (800 kg) and it gradually declined with the lowering of fertilzer dose. Nazeem *et al.* (1996) found that 3.8 kg of dry matter/tree was produced when clove was grown as monocrop under full fertilizer level.

Banana

The annual biomass removed from the banana in HDMSCS model including economic part ranged from 716 to 1767 kg/ha (Table 2). The highest biomass production was from full dose of fertilizer and gradually decreased with reduction in the level of fertilizer application. Banana is a heavy feeder and the required fertilizer is supplied with in a shorter period of six to eight months. Therefore, the biomass recycling and the nutrient supply would not be affected to the same extent as that of perennial crops like coconut and clove. The part of banana available for recycling is pseudo stem and leaves. The highest level of recyclable biomass was recorded under full dose of the recommended level of fertilizer and followed the same trend as that of total biomass production under different fertilizer levels. The amount of biomass available for recycling ranged from 503 to 1295 kg /ha (Table 3).

Pineapple

Like banana, more amount of biomass was produced in the full dose of fertilizer and it gradually declined with the reduction in fertilizer dose. It clearly revealed that for higher biomass production, full dose of fertilizer is necessary when pineapple is grown as component crop (Table 2). The same trend was observed in biomass available for recycling also and it ranged from 263 to 435 kg/ha. Roots, peduncle, leaves and crown of pineapple were available for recycling (Table 3).

Annual nutrient export and extent of nutrient recycling in the coconut system

Irrespective of the level of fertilizer applied, potassium dominates in nutrient export, and ranged from 119.1 to 183.6 kg/ha followed by nitrogen (92.4 to 149.3 kg/ha) and phosphorous (12.9 to 20.8 kg/ha) (Table 4). This clearly indicated that potassium and nitrogen are required in higher quantities for the mineral nutrition of coconut. Ochs and Ollaagnier (1977) concurred that potassium is the dominant element in fertilizer requirement of coconut. Manciot *et al.* (1979) estimated the annual total nutrient uptake for the whole palm (hybrids yielding 6.7 t of copra/ha) as 174, 20 and 245 kg of N,P and K per ha, respectively. The extent of nutrient recycling through the biomass available is presented in the Table 5. It clearly reveals that there is a possibility of recycling nitrogen to the tune of 46.0 to 81.9 kg/ha and phosphorous to the tune of 5.4 to 10.6 kg/ha and potassium to the tune of 79.4 to 127.3 kg/ha. This also clearly indicates the vast scope for considerable reduction in fertilizer requirement, which can be achieved by effectively recycling the biomass available in the coconut garden. Ouvrier and de Taffin (1985) observed that leaving the husk in the field, where it was quickly broken down, released the locked up nutrients thereby reducing the inorganic fertilizer requirement of coconut.

Clove

The annul export of nutrients through leaf and flower buds ranged from 5.9 to 11.9, 0.31 to 0.58 and 7.6 to 15.7 kg/ha for nitrogen, phosphorous and potassium respectively, under different levels of fertilizers (Table 4). The contribution from leaves could be recycled in the system was 5.5 to 10.8, 0.28 to 0.47 and 6.6 to 12.2 kg/ha of N,P and K, respectively (Table 5).

Banana

Nutrient export from banana ranged from 3.6 to 16.1, 0.6 to 1.9 and 19.0 to 85.7 kg/ha of N, P and K, respectively (Table 4). Out of this, the parts like pseudostem and leaves could be recycled. From this 2.9 to 13.2 kg N, 0.4 to 1.5 kg P and 14.9 to 73.7 kg K per hectare could possibly be ploughed back in to the system. (Table 5)

Pineapple

Nutrient export from root, peduncle, leaves, fruit and crown were calculated and it ranged from 2.6 to 5.5, 0.7 to 1.1 and 9.7 to 19.7 kg/ha of N, P and K, respectively (Table 4). Except the fruit portion, all other parts could be recycled in to the system through which 1.9 to 4.4, 0.6 to 0.9 and 7.2 to 15.3 kg /ha of N, P and K could be returned back to the soil (Table 5). observed in the no fertilizer treatment (Table 6). Among the nutrients exported by the crops, potassium export was the highest as potassium requirement for all the crops were very high. However, all the quantity of nutrients exported cannot be recycled back to the system as

Table 2. Total annual biomass removal of coconut and component crops in the coconut based high-density multispecies cropping system under different fertilizer levels (t/ha)

Amount of Biomass removal/crops	Coconut	Clove	Banana	Pineapple	Total
Full	23.55	0.762	1.767	0.585	26.664
Two-third	24.80	0.800	1.407	0.541	27.548
One-third	21.98	0.710	1.329	0.524	24.543
One-fourth	19.94	0.581	1.124	0.485	22.130
One-fifth	18.49	0.445	0.851	0.321	20.107
Control	17.72	0.349	0.716	0.315	19.100

Table 3. Total annual biomass available for recycling from 1 ha of coconut based multispecies cropping system under different fertilizer levels(t/ha)

Amount of biomass removal/crops	Coconut	Clove	Banana	Pineapple	Total
Full	15.80	0.666	1.295	0.435	18.196
Two-third	16.46	0.676	0.962	0.399	18.497
One-third	14.11	0.619	0.927	0.387	16.043
One-fourth	12.50	0.524	0.738	0.351	14.133
One-fifth	11.65	0.3[illegible]2	0.575	0.263	12.832
Control	11.60	.349	0.503	0.215	12.667

Table 4. Annual nutrient export of coconut and component crops from 1 ha of coconut based multispecies cropping system under different fertilizer levels (kg/ha)

Amount of biomass removal/crops	Coconut			Clove			Banana			Pineapple		
	N	P	K	N	P	K	N	P	K	N	P	K
Full	149.3	20.8	179.3	11.9	0.58	13.0	16.1	1.9	85.7	5.5	1.1	19.7
Two-third	139.4	18.4	183.6	11.9	0.59	15.7	10.6	1.7	69.0	5.2	1.0	19.3
One-third	125.2	16.5	164.2	10.8	0.52	12.8	8.3	1.4	63.8	4.5	1.1	15.5
One-fourth	106.3	16.8	135.1	7.4	0.47	10.6	6.7	1.2	37.1	4.2	1.0	13.9
One-fifth	92.6	13.2	127.3	6.0	0.40	9.3	4.3	0.6	24.9	2.8	0.7	10.0
Control	92.4	12.9	119.1	5.9	0.31	7.6	3.6	0.6	19.0	2.6	0.7	9.7

Table 5. Annual possible nutrient recycling from 1 ha of coconut based multispecies cropping system under different fertilizer levels (kg/ha)

Crops/ nutrients	Coconut			Clove			Banana			Pineapple		
	N	P	K	N	P	K	N	P	K	N	P	K
Full	81.9	10.6	125.4	10.8	0.47	10.7	13.2	1.5	73.7	4.4	0.89	15.3
Two-third	81.0	8.3	127.3	10.5	0.44	12.2	8.6	1.3	59.0	4.0	0.79	15.0
One-third	67.0	7.2	110.4	9.8	0.42	10.5	6.6	0.9	54.3	3.7	0.92	12.3
One-fourth	52.7	8.1	85.3	6.8	0.41	9.0	5.2	0.8	29.0	3.4	0.90	10.9
One-fifth	47.6	5.7	83.9	5.5	0.34	7.9	3.4	0.4	19.6	2.0	0.60	8.5
Control	46.0	5.4	79.4	5.6	0.28	6.6	2.9	0.4	14.9	1.9	0.64	7.2

Table 6. Total nutrient export and recycling in the system (kg/ha)

Crops/ nutrients	Total nutrient export			Total nutrient recycling			Total amount of fertilizer applied		
	N	P	K	N	P	K	N	P_2O_5	K_2O
Full	182.9	24.4	297.7	110.3	13.5	225.1	48	8	50
Two-third	167.1	21.6	287.7	104.1	10.7	213.5	61	8	59
One-third	148.8	19.3	256.3	87.1	9.4	187.6	68	9	69
One-fourth	124.6	19.5	196.6	67.9	10.2	134.2	79	11	75
One-fifth	105.7	14.9	171.4	58.4	7.0	119.8	135	21	133
Control	104.5	14.5	155.4	56.4	6.7	108.1	-	-	-

some of the components of biomass are of economic importance. However, the biomass, which could be recycled, is also in the same order of export as that in the biomass as far as treatments is concerned. It is interesting to note that the recyclable biomass obtained from two third level of fertilizer application was slightly more than full dose. The results are clearly indicated that if the recyclable biomass is composted properly and ploughed backed in to the system, there is further possibility of scaling down the dependence on chemical fertilizer and sustain the system.

From the above discussion, it may be concluded that in coconut and clove the yield and dry matter production was reduced considerably when the fertilizer dose was reduced below two-third level of recommended dose. In case of banana and pineapple, higher dry matter production and economic yield is reported under full dose of recommended level and thereafter it was reduced gradually. It indicates that in order to realize their full potential banana and pineapple, should be fertilized with full dose of fertilizer and two-third level for coconut and clove is adequate under present situations.

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EFFECT OF DIFFERENT COMPONENTS OF FARMING SYSTEM AND ON FARM ORGANIC RECYCLING ON COCONUT CROP AND SOIL FERTILITY

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Humid tropical regions of Asia and Pacific are more conducive to coconut cultivation. In the world, coconut is cultivated in 12.78 million hectare with a total production of 54802 million nuts (Anon. 2000). The crop is mainly concentrated in the small sector (> 90 %) in major coconut producing countries, thus, making its production as one of the most important activity at the farm level. The amount of land that qualifies a farmer to be called as smallholder varies from < 1 hectare to 5 hectare. In South East Asia, it is 1-2 hectare. It has been well established in several coconut growing countries that coconut as a monocrop is only, marginally productive and profitable. In India coconut is cultivated in 18.9 lakh ha with a total production of 12.7 billion nuts. The interplay of various factors viz. limited size of holdings, number of trees, needs of the family, labour requirement for crop, fluctuating returns to farm families 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. Moreover, under coconut based cropping / farming system, the same land can be put to use to produce other crops so that the productivity of the land is increased. This wisdom has led the farmers to evolve through their innovative efforts very successful models, which have come to stay in different countries. From a recent survey report, it is noted that a farmer had raised 60 species of crops, viz. trees and ornamental plants in 0.4 hectare of homestead gardens in the premier coconut growing state of Kerala.

Coconut – poor resource user

When coconut is grown as monoculture, as little as 25 % of land may be effectively used for its growth and productivity (Ontolan, 1988; Darwis and Tarigans, 1990; Magat, 1990). According to Magat (1990), whereas 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, 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). Clearly, coconut monocropping has a very low utilization efficiency of agricultural land and even when improved varieties are cultivated, is likely to remain so.

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). The amount of light transmitted ranges from 20 % under 10 – 20 year old palm, to 50 % in a plantation of 40 years and over (Opio, 1999). At CPCRI it is estimated that on an average 56 % of the sunlight was transmitted through the canopy during the peak hours in palms aged around 25 years (Nair and Balakrishnan, 1976). However, Bavappa (1990) opined that measurement with lux meter (Nair, 1979) and lambda quantum sensors (Reynolds. 1988) reported earlier do not present PAR in quantitative terms. Recently, Eroy and Dauzat (1997) observed that on a bright sunny day the PAR at PCA-DRC, Davov city was 6500-7500 ft candles, while under 19 year old palms with triangular planting it was 1850 ft candles. Magat and Margate (1998) advocated coconut leaf pruning (CLP) below leaf rank 19 for facilitating more penetration of light in the system under various situations. Chipungahelo *et. al.* (1998) measured PAR using silicon cell light sensors at Mkuranga Experimental Station, Dar-es Salam in different months. Under 72 palms /ac the density of the transmission ranged from 54-62 %. Lower light transmission was recorded under 95 palms/ac (47-54%). Nethsinghe (1966), Kushwah *et. al.* (1973) and Anil Kumar and Wahid (1998) have studied the active coconut root zone for an understanding of the foraging potential and guiding fertilizer application.

Coconut Based Cropping System

Yield

In the coconut based high density multispecies cropping system, the coconut yield 9mean of six years) ranged from 127 nuts/palm/year under no fertilizer control treatment to 147 nuts palm/year at two third and one third of the recommended fertilizer dose(Table 1). The productivity of the palm declined with the reduction in the fertilizer levels beyond 1/3rd of the recommended fertilizer treatment. The yield of the clove tree varied with the fertilizer treatments. The clove yield ranged from 0.246 kg/tree/year under no fertilizer control treatment to 1.44 kg/tree/year at full dose of the recommended fertilizer dose. The average weight of banana bunch was highest in the full recommended dose treatment (6.20 kg/bunch). The average weight of pineapple fruit was highest in the full recommended fertilizer dose treatment (528 g).

Table 1 Output from 1.2 ha coconut based cropping system model at Kasaragod (mean of six years)

Treatment	Coconut	Pineapple (kg/fruit)	Clove (dry kg/tree)	Banana (kg / bunch)	Black pepper (kg / bush)
Full dose	146	0.53	1.44	6.21	0.34
2/3rd rec. dose	147	0.52	0.72	5.49	0.63
1/3rd rec. dose	147	0.50	0.52	4.01	0.46
1/4th rec. dose	139	0.43	0.51	4.55	0.70
1/5th rec. dose	128	0.49	0.49	3.43	0.34
No fert.- Control	127	0.41	0.25	4.21	0.13

Response function of coconut

In the experiment, there is no factorial combination of the fertilizer treatment the NPK recommended dose is taken as one and other treatments were also transformed accordingly. The quadratic response fitted showed significant correlation coefficient (Fig 1). The optimum fertilizer requirement worked out to be 359 g N, 229 g P_2O_5 and 860 g K_2O per palm per year, which gave the nut yield of 151.77 nuts/year.

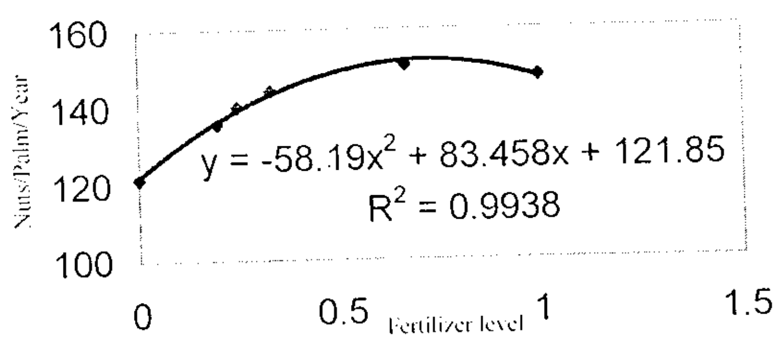

Fig. 1 Fertilizer response function for coconut

Soil and plant nutrient status

The foliar nutrient status is given in Table 2. In the case of coconut, the N content was above the critical level (1.8%) up to one-third of the fertilizer level and declined with the further reduction in the fertilizer dose. In fact, at lower doses, the N content was below the critical level, suggesting that the fertilizer levels below one-third of the recommended dose are insufficient to meet the crop needs. In the case of the component crops, the foliar nitrogen level did not vary much among the fertilizer doses, however, substantial yield difference suggests dilution effect at higher fertilizer levels. Foliar P and K levels in coconut, though optimum in all the treatments, were higher at fertilizer levels, one-third, two-third and full, but declined thereafter with reduction in fertilizer level. In respect of component crops although, the economic biomass yields were higher with the fertilizer levels, the foliar nutrient contents for P and K did not vary much among the fertilizer levels. This was mainly due to dilution effect with increased biomass production.

The soil nutrient status under various fertilizer treatments is given in Table 3. The organic matter status declined with the increased fertilizer addition. In fact, in coconut, the highest organic matter content (0.712%) was found in the no fertilizer treatment, which declined to 0.512 % in the treatment, full dose of fertilizers. The increasing fertilizer levels might have led to higher active root biomass production. The exudates so secreted by the roots might have led to the proliferation of microbes, which would have decomposed the organic matter leading to reduction in the organic matter content at higher fertilizer levels. The total N content in the soil increased appreciably with increasing fertilizer levels. At lower fertilizer levels, the organic matter content in the soil was high, still, the total N content was lower suggesting high C:N ratio of the organic matter. Similar trends were observed in all the component crops except in case of pineapple where the organic matter content was higher at higher fertilizer levels. The available P and K status of soil increased with increasing fertilizer levels in all the main as well as component crops. Thus, P and K when applied to the soil have a tendency to get fixed, which becomes slowly available to the crop later on. In the case of coconut, 20 ppm of available P is sufficient to maintain the P nutrition of coconut (Khan *et al.*, 1992). Thus, the foliar P content was optimum at the lower fertilizer levels also.

Table 2: Yield and foliar nutrient level of the coconut based cropping system

Treatments	Mean yield (1996-97 to 1997-98)	Nutrient content (%)		
		N	P	K
Coconut*				
No fertilizer	122	1.48	0.109	1.37
One -fifth	124	1.64	0.109	1.44
One-fourth	134	1.65	0.110	1.34
One-third	144	1.82	0.123	1.44
Two-third	155	1.82	0.122	1.51
Full	148	1.80	0.123	1.61

Table 3: Soil nutrient status of the coconut based cropping system

Treatments	Org. Matter (%)	Total N (ppm)	av. P (ppm)	av. K (ppm)
Coconut (Average of two depths)				
No fertilizer	0.712	265	98.71	76.71
One -fifth	0.700	365	161.73	96.80
One-fourth	0.702	755	165.67	117.24
One-third	0.519	1435	220.44	112.36
Two-third	0.523	1410	285.57	161.21
Full	0.512	1460	342.65	229.60

Integrated nutrient management infact is an integral part of coconut based cropping system. While the main and component crops receive inorganic nutrients based on individual crop requirements, the organic addition brought through leaf litter recycling, stem flow, through fall etc., complementary interactions and biological activity brings in all benefits of integrated nutrient management on productivity.

A number of studies on response of coconut palms to fertilizer applications have shown poor bearers exhibiting greater response and the palms with nut yields exceeding 60 nuts per year showing least/no response. The increase in the yield of nuts in control (coconut alone) plot reflected the influence of better management practices like irrigation and probably, its interaction with higher dose of fertilizers. Even after accounting for that, there seems to be some beneficial interactive effect of the crop combination of coconut and cocoa. This synergistic effect of increase in the yield of palms is an excellent example of non-monetary input in crop production (Nair, 1979). 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.

Experiments carried out at Kasaragod have indicated vegetables like snake gourd, bottle gourd, amaranthus, coccinia, brinjal and bitter gourd as compatable crops with coconut. Intercropping with vegetables helped to generate additional employment to the tune of 215 to 365 mandays/ha/year.

On farm waste recycling in cropping system

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 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 (Fig.2). In this the contribution from coconut alone was approximately 85 % (Fig.3).

However, availability of biomass for recycling in the system was around 12.7 t to 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 (Fig. 4). Studies are in progress at CPCRI, Kasaragod.

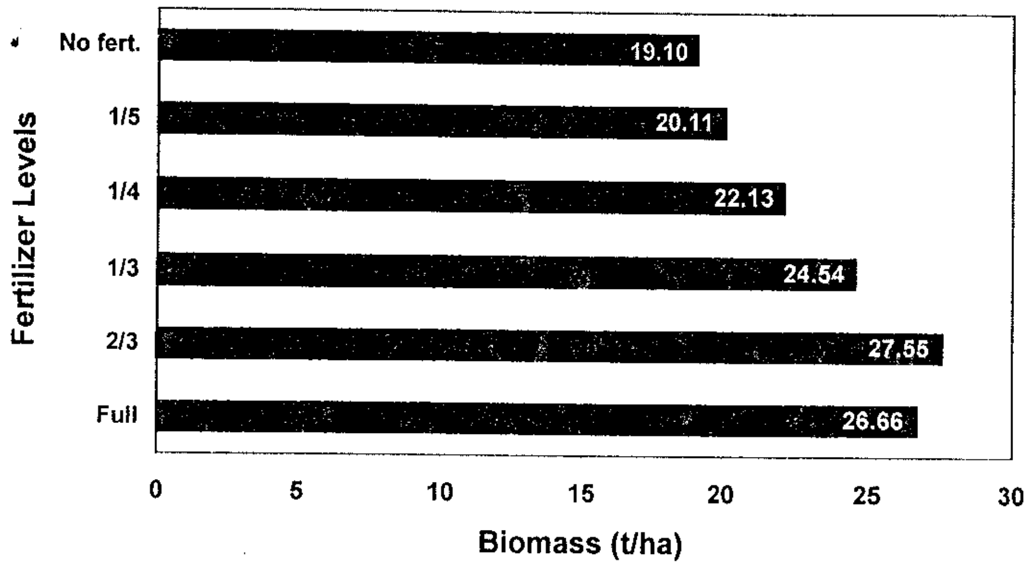

Fig. 2: Total removable biomass from the system

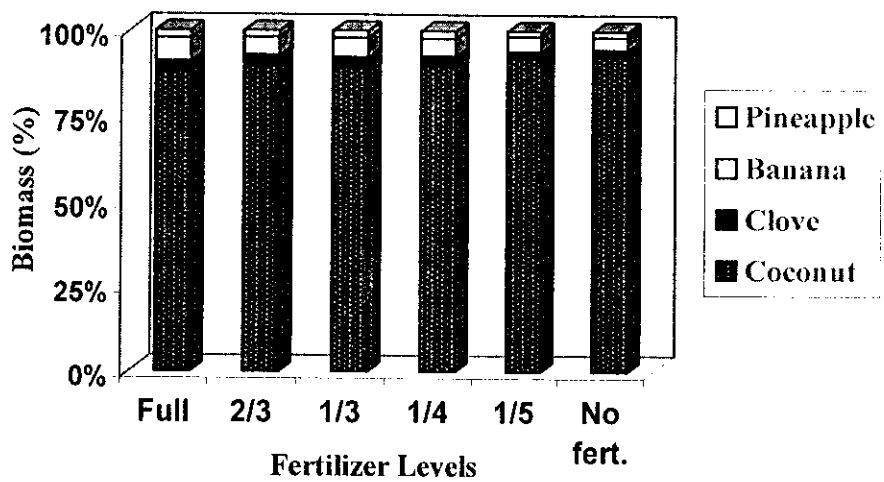

Fig. 3: Per cent contribution of crops to removable biomass

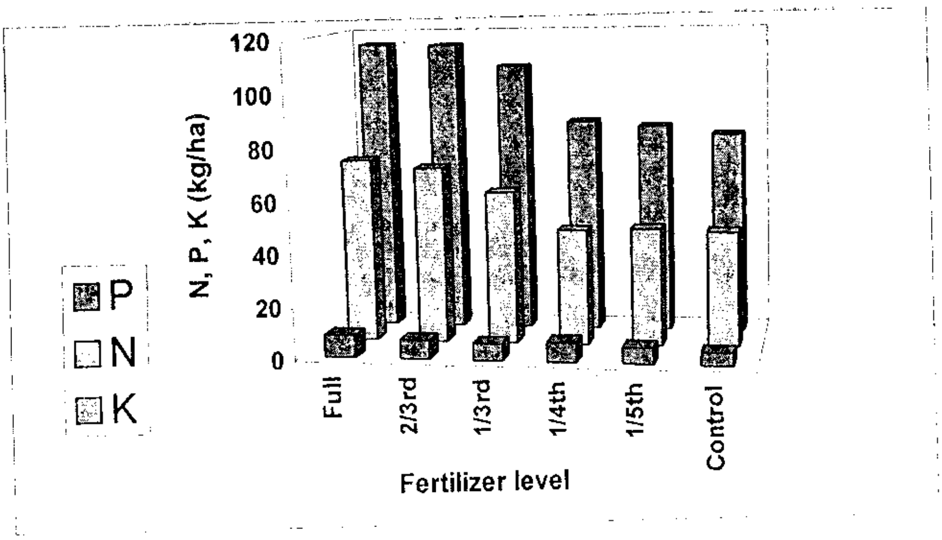

Fig. 4: Extent of nutrient recycling under different levels of fertilizer input- Coconut

The biomass generated in a coconut based cropping system is a mixture of lignocelluloses material with a wide C:N ratio. Prabhu *et. al.* (1998) demonstrated that the technology to convert the biomass into vermicompost. The vermicompost thus, obtained has a C: N ratio of 9.9 and a nutrient content of 1.8% N, 0.21% P and 0.20% K.

Bioconversion of wastes using vermicompost technology and coir pith compost preparation using *Pleurotus sajor caju* / *P. platypus* has been standardised

With coir pith using *Pleurotus sajor caju* / *P. platypus* a good compost with a C:N ratio of 20:1 is obtained in about 40-45 days (Savithri and Khan, 1994). Bioconversion of coir pith to compost was also found feasible by mixing coir pith with coffee husk 1:3 and using a mixture of *Pleurotus florida* and *Trichoderma* sp. as microbial inoculants. Highest recovery of 86.5% was obtained.

Microbial parameters:

The distribution of soil microbial groups was investigated in the cropping system (Table 4). Crop diversity and level of fertilizer inputs influenced the microbial groups in the root zone of crops. It was seen that bacterial count was low in the root -region of pineapple and control.2/3rd dose of fertilizer recorded low number of bacteria than other treatment in coconut. The counts of fungi and actinomycetes were low in the root region of banana and coconut. Full dose of fertilizer supported very low counts of fungi and actinomycetes. Asymbiotic nitrogen fixers were more in root region of clove and pineapple.

The population was maximum in 1/3rd dose of fertilizer treatment. There was an increasing trend from control to 1/3 rd dose and a decreasing trend was observed from 1/3rd to full dose. As regard to the population of P solubilizers, the population was maximum in banana among the crops and in 1/3rd dose of fertilizer. The microbial population decreased with increasing depth. The development of different microbial groups was optimum at moderate doses of mineral fertilizer input viz.; one-third and one-fourth when combined with addition of vermicompost produced by recycling of waste biomass.

Table 4: Microbial colony in coconut based cropping system

Fertilizer level	Actinomycetes (10^3 cfu/g soil)	Fungi (10^4 cfu/g soil)	Bacteria (10^5 cfu/g soil)	N – fixers (10^3 cfu/g soil)	P solubilizers (10^4 cfu/g soil)
Control	14.3	29.8	37.8	28.3	16
One-fifth	19.9	35	61.3	35.0	21.4
One-fourth	22.6	45	77.5	55.2	24.1
One-third	31.3	55.6	113.2	69.0	31.7
Two-third	14.3	28.2	63.5	36.5	15.8
Full	9.9	25.8	53	25.0	12.5

Coconut based mixed farming system

The sustainability and profitability of coconut based farming system comprising coconut, pepper, banana, fodder grass, dairy unit (6 cows HF cross), silk worm rearing, poultry and pisciculture are assessed in a farming system model at CPCRI, Kasaragod. The soil is *Arenic paleustult.* The coconuts-fodder grass-mulberry receive in organic fertilizers and organic manures obtained as waste such as cow dung (60 tons) and dairy shed washings, poultry and quail bird droppings (457 kg), waste from rearing of silk worms (48 kg) etc. Recently the dry coconut leaves and other plant wastes (approx, 8 tons per ha) are converted into vermi-compost employing the earthworm *Eudrilus* sp. and applied to the system. The vermi-compost has a nutrient content of 1.8% N, 0.3% P and 0.6% K. Fodder grass (26.5 tons) is fed to the cows. With the recycling of organics there are indications for soil and leaf analysis data that the inorganic fertilizer input in the system can be scaled down and over years the system can be self-sustaining. From this enterprise, 21280 coconuts, 10301 litre cow milk, 1044 kg broiler chicken, 2479 numbers of quail bird eggs, 18 kg quail birds were obtained. Around 98 per cent of the revenue was derived from coconut, dairy and poultry components.

Nutrient and Microbiological investigation

An evaluation of the soil under monocrop of coconut has shown increase in the nutritional status of soil in respect of available N and substantial increase in available K content in the manuring circles of the palm (Table 5). However, the change in the available P content was not remarkable. The nutrient status of the soil decreased with depth. Incidentally, the potash content of soil in the coconut basins where grass is grown is less. On comparing the nutrient status of interspaces of the monocrop and the grass plots, no marked differences were observed for available N, P and K in spite of the fact that the grass plots received basal dressings of P and K fertilizers and side dressings of nitrogen periodically. The plant nutrient status indicated improved NPK due to beneficial interaction of palms with improved soil fertility status.

Microbial biomass and activities of soil enzymes (phosphatase and dehydrogenase) indicated that the soil biological activity were more in the farming system when compared to the monocrop of coconut (Table 6). Microbial biomass was high in the system where organic recycling is practiced. This microbial biomass is considered among the most labile pools of organic matter and thus, serves as the reservoir of organic matter. Phosphatase activity related to hydrolyzing P compounds and liberates inorganic P for absorption by plants. The dehydrogenase activity is remarkably high compared to monocropped basins indicating microbial oxidative activity.

Table 5: Impact of fertilizer application on the available nutrient content in soil

System	Depth (cm)	Available nutrients (kg/ha)			Org. C (%)
		N	P	K	
Monocrop	0-25	271.49	223.14	422.35	0.43
	25-50	189.88	89.28	293.82	0.28
	50-100	159.78	26.26	426.96	0.25
Coconut basin (Grass plot)	0-25	229.88	189.64	197.40	0.41
	25-50	181.80	108.98	192.96	0.27
	50-100	178.16	52.08	211.18	0.27
Monocrop - Interspace	0-25	189.48	118.15	146.91	0.29
	25-50	201.39	74.83	156.09	0.24
Grass plot - Interspace	0-25	249.20	80.17	148.43	0.37
	25-50	184.83	72.44	142.33	0.27

Table 6: Microbial activity in coconut – grass system

Treatments	Coconut		Grass	
Depth	0-25(cm)	25-50(cm)	0-25(cm)	25-50(cm)
Microbial biomass(µg C / g soil)				
Monocrop*	151.06	89.36	187.5	113.33
Mixed farming	181.98	114.80	219.59	142.77
Phosphatase (µg p-nitrophenol /g soil /h)				
Monocrop*	31.16	15.43	39.16	15.67
Mixed farming	41.23	27.15	47.29	21.94
Dehydrogenase (µg formazan / g soil / h)				
Monocrop*	5.02	2.66	7.14	4.18
Mixed farming	9.36	6.51	14.46	10.03

- In the monocrop – instead of grass it may be read as interspaces

Nutrient flow

The maintenance of the system viz. dairy, poultry and silk worm rearing contribute to sizable quantities of biomass viz. 14 tonnes of cow dung, 295 kg of poultry bedding materials and droppings, 12 kg of silk worm waste (all on dry weight basis) and 50000 litres of cowshed washings. This waste biomass on recycling will meet 74 % N, entire quantity of P, and 82 % of K requirement of both coconut and grass.

Conclusion

Coconut will continue to be an important crop associated with the livelihood of millions in Asia and Pacific regions. The opportunity cost of coconut is relatively high, considering further that coconut occupies prime land and does so for a long time. Farmers in many coconut growing countries are increasingly aware of the economic benefits of coconut based cropping systems. Efforts by respective government agencies to popularize the system have not met with adequate success. The reasons are many fold.

Traditional wisdom of farmers and innovations are considered and followed in our research, more or less restricted to re-structuring the farming systems in the farm-stead/home-stead. Important considerations that could guide coconut farmers when they venture into CBFS as suitability of farms for inter cropping, favourable climate conditions, suitable soil conditions, availability of good quality planting material, farmers resources and attitude, tenurial and working arrangements and available market. Though the above are quoted for conditions of Philippines, it may hold good to a certain extent for other countries as well.

The determinants and deterrents related to adoption of cropping/farming system has to be properly understood in every coconut growing country. The farmers' socioeconomic status is heterogeneous and income from coconut is not stable. It is more influenced by the biophysical environment in terms of soil and climate. In each state or province an inventory of coconut farms/farmers may have to be developed. Based on the strength of the inventory, with reference to land suitability, irrigation, personnel, and economic conditions; cropping systems suitable to the needs are to be developed. Wherever possible soft loans can be extended through agricultural banks. In each state/province prescription profiles may be developed based on the above considerations.

Difficulties for smallholder are, to access innovative technologies. 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, deter the farmers from adopting technologies. Poor knowledge base of the farmers can be related to ineffective and limited extension services. Uncommitted attitude of the farmers brought about by their low educational attainment.

Each coconut growing state should create a knowledge base needed for developing a strategy to propagate cropping system research, resource generation, improve employment opportunities and profit maximization. Specific development scheme for CBCS / CBBFS are to be formulated and effectively implemented in various zones. Improvement in the existing cropping system is more rational than complete intervention

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Influence of fertilizer regime on potassium dynamics in a red sandy loam soil

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Abstract

Potassium adsorption studies were carried out in a red sandy loam soil (*Arenic Paleustult*) under various fertilizer regimes in coconut under coconut based cropping system at Kasaragod. The soil samples were collected from the basin of the coconut palms. Adsorption studies are carried out using batch technique with five K levels viz. 0, 250, 500, 750 and 1000 ppm K. In the treatments, no fertilizer, one-fifth and one-fourth of the recommended dose, the adsorbed K increased up to 750 ppm K level, and there upon it showed a decline at 1000 ppm K level. However, in case of other three fertilizer regimes, the adsorption of K increased to 500 ppm K level, beyond which there was decline in K adsorption. Within the K levels, K adsorption declined from no fertilizer upto one-fourth of the recommended dose and after which the K adsorption increased with increasing fertilizer levels. The optimum K application to maximize the soil solution K for optimum plant nutrition at each treatment level ranged from 662 ppm (full dose) to 692 ppm (No fertilizer). The quantity of K fertilizer required to optimize the soil solution K concentration in red sandy loam soil is 1150g K_2O palm^{-1}year^{-1}, which very well matches with the general K recommendation (1200g K_2O palm^{-1}year^{-1}) for the crop in India.

Key words: Potassium adsorption, red sandy loam, soil solution K level, coconut, potassium requirement

Introduction

The role of potassium in the soil and thereby in the crop nutrition is very important and complex. In the Indian agriculture, potassium is second or comparable to nitrogen in its importance. It is one of the three major nutrients removed in appreciable amounts from the soil and has to be replenished quickly to the soil nutrient pool to offset any yield decline. The major area of the coconut being in South India suffers from prolonged spell of high temperature and high rainfall leading mainly to leaching losses of silica and bases from parent material with concurrent accumulation of oxides of Fe and Al. Based on the ratings of Muhr *et al.* (1963), Pillai (1975) has reported that all the soil groups of Kerala under coconut are generally deficient in available K and no soil group come under high ratings. Nevertheless, potash requirement of coconut is also very high as indicated by the amount of nutrients removed annually by the palm. The nutrient removal ratio of N: K of 1: 1.2 – 1.75 themselves is indicative of its influence being exerted on the crop (Khan *et. al.*, 2000).

Critical studies on soil potassium in relation to coconut nutrition are lacking except for some manurial experiments with potassium as one of the factorial component (Biddappa *et al.*, 1993). Khan *et al.* (1982) found that K adsorption was comparatively more and uniform in laterite soils than in red sandy loam, river alluvium and coastal sands cultivated to coconut. As K is likely to get depleted more easily from the feeding zone and the K pool also cannot restore much K needed by the coconut palm, which has a heavy demand for potassium, there is a need for evolving a more suitable way of K management.

In light of above, objectives of the study were: to study the impact of fertilizer regime on the K adsorption behaviour in the soil of coconut basin and extent of K required to maximize the soil solution K for optimum plant nutrition.

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Materials and Methods

Location of the experiment: The present study was conducted in an existing 35 year old coconut garden intercropped with clove, banana and pineapple in the research farm of Central Plantation Crops Research Institute, Kasaragod, Kerala, India. The coconut palms are spaced 8 m apart and arranged in square system of planting. Clove, banana and pineapple were grown as intercrops. The experiment was laid out in 1.2 ha area. The soil is red sandy loam (*Arenic Paleustult*). The soil had pH 5.3, clay 22 %, 0.48 % organic carbon and CEC 4.7 cmol kg^{-1} soil. Initially (1983), the experimental plot had three treatments *i.e.* full, two-third and one-third of the recommended fertilizer dose. Later, based on the results of ten years wherein one-third was found sufficient for maintaining the optimum crop nutrition, the experiment was modified by including three more additional treatments from the year 1994. The treatment details are given in Table 1. The experiment is divided into six blocks and not replicated. The N, P and K were applied in the form of urea, Mussoorie-phos and muriate of potash respectively, in two splits *viz.* one-third (33 %) in May-June (beginning of monsoon) and two-third (66 %) in September- October (receding monsoon). Fertilizers were applied as broadcast in circular basins of 1.8 m around the palm. In the irrigation treatment, palms were irrigated at 100 % open pan evaporation (Eo) through perfo-irrigation system.

Table 1. Details of treatment

Plot	Treatment	Plot size (ha)
I	Full recommended dose	0.2
II	$2/3^{rd}$ of recommended dose	0.2
III	$1/3^{rd}$ of recommended dose	0.2
IV	$1/4^{th}$ of recommended dose	0.2
V	$1/5^{th}$ of recommended dose	0.2
VI	No fertilizer	0.2

Note: Recommended fertilizer dose for coconut, clove, banana and pineapple is 500: 320: 1200, 300: 250: 750, 200:200:400 and 8: 4: 8 g N, P_2O_5, and K_2O plant^{-1} year^{-1} respectively

Methodology

The soil samples were collected up to 30 cm depth from the coconut basin 1m away from the bole. From each treatment, samples were collected from the basin of four palms each and pooled together for this experiment. The soil samples were air dried in shade, ground to pass through 2 mm sieve and analysed for available potassium status. The available potassium was determined in the 1N NH_4OAc (Hanway and Heidel, 1952) flame photometrically. In a sample vial, 2.5 gm soil was weighed and incubated for 24 hours with 25 ml K solution containing various amounts of K (0, 250ppm, 500ppm, 750ppm and 1000ppm K added as a solution of KCl). The experiment was conducted in three replications. After the incubation period, the sample vials were shaken for 1 hour and the suspension was allowed to equilibrate for the same time at the room temperature. The supernatant was filtered through Whatman filter paper no. 1 and the K content in the solution was determined flame photometrically. The adsorption or desorption of K was determined by taking the difference in the concentration of K in the initial and final reading. Adsorption data was fitted with different models (Freundlich, Langmuir and different polynomial model) and the best fit was used for calculation of adsorption maxima and global minimum.

Results and Discussion

The potassium adsorption varied with the fertilizer regimes (Table 2). The adsorption of K declined with increasing fertilizer levels. The adsorption was more in the fertilizer treatment, No Fertilizer at 250 ppm of applied K (221.05 ppm) and this declined appreciably to 51.63 ppm at Full dose of recommended fertilizer levels. At 500 and 750 ppm K level, K adsorption was high at No fertilizer and One-fifth of the recommended dose but declined at one-fourth of the recommended dose, which increased at further increase in fertilizer regimes. But at 1000 ppm K level, no particular trend was observed. The fertilizer treatment, One-fourth of the recommended dose showed lower adsorbed K values in the treatments 500, 750 and 1000 ppm K level compared to the other treatments. In the case of treatments, No fertilizer, One-fifth and One-fourth of the recommended dose, the adsorbed K increased up to 750 ppm K level, and there upon it showed a decline at 1000 ppm K level. In the case of other three higher fertilizer regimes, the adsorption of K increased to 500 ppm K level, beyond which there was decline in K adsorption. Within the K levels, the potassium adsorption declined with increasing fertilizer level upto one- fourth of the recommended dose. However, beyond one-fourth level, the K adsorption increased with the increasing fertilizer level.

Table 2. Adsorption of potassium (ppm) in soil under different fertilizer regimes

Fertilizer regime	Levels of K added (ppm)				
	0	250	500	750	1000
No Fertilizer	0	221.05	1259.47	1298.89	861.28
$1/5^{th}$ Recommended dose	0	136.81	1259.47	1359.11	649.13
$1/4^{th}$ Recommended dose	0	94.45	1110.78	1118.25	578.11
$1/3^{rd}$ of recommended dose	0	93.98	1211.00	1178.46	791.18
$2/3^{rd}$ of recommended dose	0	94.45	1260.41	1218.26	791.18
Full Recommended dose	0	51.63	1260.41	1238.21	575.29

The perusal of Table 2 revealed that adsorption of K was more in the lower fertilizer regimes (No fertilizer, 1/5 and 1/ 4 of the recommended dose), which may be on account of lower K application rates. Variation was also observed in K adsorption between fertilizer regimes *vis a vis* K treatments, which could be attributed to the variation in saturation of exchange complex with K. Interestingly, within the K levels, the potassium adsorption declined with increasing fertilizer level upto one- fourth of the recommended dose. However, beyond one-fourth level, the K adsorption increased with the increasing fertilizer level. In the case of higher fertilizer regimes, the increased adsorption may be attributed to added phosphatic fertilizers, which contributes phosphate ions, which is capable of neutralizing positive charges of Fe hydroxides in the clay fraction generating electronegative sites that can be occupied by K^+ ions (Mekaru and Uehara, 1972; Uehara and Gilman, 1981). With the application of phosphatic fertilizer, there is buildup of available P in the soil. The P tends to accumulate, as the crop requirement for P is less. Infact, it has already been established that soil test values of 20 ppm of air dry soil available P is sufficient to maintain the P nutrition of coconut Khan *et al.* (1992). The available P status of the soil ranged between 98 ppm (No fertilizer level) and 343 ppm (Full dose of recommended fertilizer).

On fitting the adsorption versus equilibrium concentration values, quadratic function gave the best fit compared to Langmuir and Freundlich equations. Adsorption maxima were calculated from the quadratic function. Adsorption maxima varied with the fertilizer regime (Table 3). The adsorption maxima increased up to one-fifth of the recommended dose and there upon, it declined at one-fourth of the recommended dose, further, which it increased with the increasing fertilizer regimes. This variation can be attributed to the increased phosphorus application as stated above that contributes phosphate ions, which is capable of neutralizing positive charges of Fe hydroxides in the clay fraction generating electronegative sites that can be occupied by K^+ ions. The soil solution K level required for optimum K

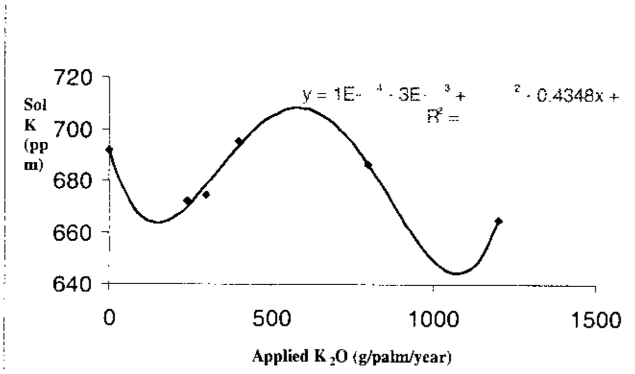

Fig. 1. Minimum soil solution K level as effected by fertilizer regime

nutrition of the coconut ranged between 651 to 697 ppm under various fertilizer regimes. This suggests that a minimum soil solution K level in the vicinity of 650ppm or above is required to meet the K demands of the crop. On plotting the fertilizer regime against soil solution K level, 4th degree polynomial curve gave the best fit (Fig. 1). The global minimum was calculated using the procedure given by Press *et. al.* (1992). To supply / maintain the required soil solution K level of 650 ppm, the required fertilizer K was found to be 1150 g K_2O/ palm/year which matches the K recommendation of 1200g K_2O/palm/year for coconut.

Table 3. Effect of fertilizer regime on adsorption K maxima and soil solution K level

Fertilizer regime	Adsorption K maxima (ppm)	Optimum soil solution K (ppm)
No Fertilizer	1399.50	691.65
1/5th of recommended dose	1452.20	665.71
1/4th of recommended dose	1237.17	687.86
1/3rd of recommended dose	1325.20	697.97
2/3rd of recommended dose	1352.01	686.27
Full recommended dose	1373.28	651.57

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Potassium Dynamics in Coconut and Coconut Based Cropping Systems

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Abstract

Potassium is a vital major nutrient for coconut as it's requirement is high. Coconut growing soils of Kerala are generally low in available potassium. Estimates indicate potassium use in the state is less than half compared to fertilizer removal in coconut growing areas there by causing depletion of soils' nutrient reserves. Systematic studies on soil K – crop relationships in coconut and coconut based cropping systems are lacking in Kerala.

Potassium plays an important role in nutrition of coconut. It helps in maintaining ionic balance in the cell, water relations and helps in root development. It is necessary for the formation of sugar, fat and fibrous materials. Potassium is also known to favour early bearing in coconut. K-deficiency leads to chlorosis, leaf scorch and the development of poor crown with short fronds (Manciot *et al.*, 1979). Coconut has unique feature among the plantation crops as it flowers and fruits through out the year. Hence, adequate water and nutrients should be maintained during the entire period. Proper nutrition during early stages has a profound influence on yields during the productive lifetime of the species.

Coconut growing soils and their potassium status

In general, coconut like any other plantation crops is grown on variety of soils namely laterite, [illegible] coastal sand, red sandy loams, alluviums, coral, peaty and black soils. The ideal coconut growing soils are well drained and aerated with a minimum depth of 80 to 100 cm, pH range between 5 to near neutral, adequate nutrient availability and water holding capacity (Fremond, [illegible]). The major coconut growing soils are lateritic, coastal sand and alluvial. Except for alluvials, all the other soils have low native fertility and poor physical properties. Some of the characteristics of coconut growing soils are shown in **Table 1**.

Table 1. General physico-chemical properties of the soils

Soil group	Mechanical composition (%)			pH (1:2.5 soil-water)	Organic Carbon (%)	CEC (m.e./100g)
	Clay	Silt	Sand			
Laterite	16.8 (9.2-39.2)	10.5 (2.2-20.0)	64.4 (49.2-86.8)	5.72 (4.0-6.8)	0.55 (0.06 -1.8)	5.1 (1.0-14.4)
Alluvial	17.9 (9.2-31.6)	6.9 (1.0-18.0)	75.1 (50.4-89.2)	5.79 (4.2-7.1)	0.69 (0.03-1.8)	4.4 (0.7-11.3)
Reclaimed marshy	15.0 (9.0-26.4)	3.9 (0.0-13.6)	78.7 (64.0-91.0)	4.76 (3.7-6.5)	0.68 (0.23-2.9)	4.1 (0.6-24.3)
Coastal sandy	6.8 (3.6-10.8)	0.8 (0.07-7.8)	92.4 (87.2-95.4)	6.67 (5.2-8.3)	0.13 (0.00-0.46)	0.5 (0.4-5.4)
Sandy loam	17.0 (8.8-30.2)	3.8 (10.6-14.0)	79.4 (69.4-90.2)	5.81 (4.8-8.6)	0.31 (0.06 1.44)	3.7 (1.0 11.7)

Source: Pillai, 1975. (*Figures in parentheses denote ranges*)

The major area of the coconut being in South India suffers from prolonged spell of high temperature and high rainfall leading mainly to leaching losses of silica and bases from parent material with concurrent accumulation of oxides of Fe and Al. This leads to the formation of laterites, a dominant soil group under plantation crops. Various studies have long established that these soils are acidic in reaction with poor native fertility, low CEC, a characteristic of Kaolinite as dominant clay minerals and have high presence of sesquioxides. Based on the ratings of Muhr *et al.* (1963), Pillai (1975) has reported that all the soil groups of Kerala under coconut are generally deficient in available K and no soil group following under high ratings. The mean values for coastal sandy soil in the 0-50 cm and 50-100 cm layers were 12.2 and 10.9 ppm K and corresponding values for sandy loam soils were 28.4 and 28 ppm K, respectively. Robert Cecil (1981) reported similar values for the sandy loam soil of Kayamkulam. Surveying the soils of Badagara taluk, a premier coconut-growing tract, Ramanandam (1977) reported that the soils were poor in K. Krishnakumar and Koshy (1985) held similar opinion for 'Poonthalpadam' area in Kerala where the exchangeable K varied from 0.07 to 0.24 m.e./100 g. Bastin and Venugopal (1986) indicated that the Alfisols, which are intensively cultivated for coconut, are generally low to medium in potash status (**Table 2**).

Table 2. Available K status in different red soil series (Alfisols) of Kerala

Soil series/Location	Available potassium status (ppm)		
	Mean	Range	Rating
Vellayani (Trivandrum)	23.7	12.1 - 36.6	Low
Cheriyoor (Quilon)	34.2	12.3 - 68.1	Low - Medium
Bhavanikkavu (Quilon)	44.4	20.2 - 75.1	Low - Medium
Beypore (Calicut)	36.8	6.0 - 112.7	Low - Medium
Chirakkal (Cannore)	40.8	12.1 - 113.6	Low - Medium
Kunhimangalam (Kasaragod)	19.6	4.5 - 34.3	Low

Potassium dynamics in soil

Critical studies on soil potassium in relation to coconut nutrition are lacking except for some manurial experiments with potassium as one of the factorial component (Biddappa *et al.*, 1993). Hameed Khan *et al.* (1982) found that K adsorption was comparatively more and uniform in laterite soils than in red sandy loam, river alluvium and coastal sands cultivated to coconut. The magnitude of the constants K and 1/n and the difference in the values of Freundlich adsorption isotherm was attributed to the contents and nature of clay minerals in these soils. The influence of clay minerals in K supply to the nutrient pool was also indicated by Ramanathan and Krishnamoorthy (1976).

Hameed Khan *et al.* (1982) further observed that desorption of applied K showed a constant release after third and fourth extraction, irrespective of soil groups. Even after the 8^{th} extraction, a constant release of 1.5 to 2.5 ppm K was observed in two extractions. The soils under the study were dominated by kaolinite clay minerals, which have no interlattice binding sites for K, and hence cannot hold any non-exchangeable K (Patil *et al.*, 1976). As K is likely to get depleted more easily from the feeding zone and the K pool also cannot restore much K needed by the coconut palm, which has a heavy demand for potassium, there is a need for evolving a more suitable way of K management. Report of John and Jacob (1959) on extensive fertilizer demonstration studies involving 24,000 coconut trees in the west coast of India lends support to the above contention. They indicated that application of additional dose of potash and higher doses of NPK resulted in increased yield where standard dose failed to elicit adequate response in farmer's field.

The selective distribution of potassium in representative soils (Hameed Khan *et al.*, 1982) revealed that the major part of applied K was extracted with boiling HNO_3 followed by 1 N NH_4OAc and more or less uniform extraction of K in 0.01 M $CaCl_2$. Variation in water soluble K among soil groups was attributed to initial available K in soils, prior to saturation with K for the study. There was evidence to show that applied K was converted into difficult exchangeable forms and the equilibrium between exchangeable and labile-K is maintained relatively faster in these soils. Further, in the incubation experiments with different coconut growing soils, highest watersoluble K fraction was obtained in sandy soil followed by laterite, red sandy loam and alluvial soils. The exchangeable K fraction was highest in red sandy loam followed by laterite, alluvial and sandy soil. This variation in the fractional distribution of K is on account of the variation in the mineralogical constituent of the soil and the initial soil K status.

Soil profiles from three soil series of Kannur district were analysed for different K fractions. In Dharmadham series, the water soluble K ranged from 4 to 39 ppm, Exch. K from 1 to 69 ppm and non-exch. K from 11 to 98 ppm whereas the water soluble K ranged from 4 to 18 ppm, Exch. K from 2 to 53 ppm and non-exch. K from 37 to 71 ppm in Kunhimangalam series. In Pilathara series, the water soluble K ranged from 4 to 8 ppm, Exch. K from 10 to 36 ppm and non-exch. K from 44 to 125 ppm. In general, the soils are poor in K status, and will need investment in the form of K currency for high yields.

Nutrient exhaust

According to Von Uexkull (1985) potassium is usually the least needed major nutrient in low yield agriculture but climbs into dominant position when yields are maximized. Kanwar (1993) stated that low yield level of 40 nuts/palm/year can be sustained without replenishing the K to the soil, however, at yield levels of 150 nuts, all the K removed must be replenished, and for still higher yields, the application of K from fertilizer sources far exceeds the nutrient removal.

Nevertheless, potash requirement of coconut is very high as indicated by the amount of nutrients removed annually by the palm (**Table 3**). The nutrient ratio of N: K of 1: 1.2 – 1.4 themselves is indicative of its influence being exerted on the crop. The nutrient exhaust studies conducted in India show that the proportionate requirement of NPK of the palms in terms of N: P_2O_5: K_2O is 2:1:3 and the quantitative order of requirement of major nutrients for adult bearing palm is K>N> Ca> Mg> P which suggests that K is the dominant nutrient required by palm while P requirement is the least. It has been estimated that in India, total potassium removal by the coconut crop is 336 thousand tonnes and the estimated fertilizer K consumption is 150 thousand tonnes (Nair *et al.*, 1996). This shows a huge gap in K nutrient supply to the crop.

Table 3. Annual nutrient removal by coconut palm

Location	Basis	Nutrient Removal						References
		kg			Ratio			
		N	P	K	N	P	K	
India	70 palms/acre yielding 40 nuts/palm	22.5	5.2	28.4	1	0.23	1.26	Pillai and Davis (1963)
India	175 palms/ha	97.3	21.0	121.1	1	0.22	1.24	Ramadasan and Lal (1966)
Ivory Coast (IRHO)	Hybrid palms (PB 121) 6-7 tons copra/ha	174.0	20.0	249.0	1	0.12	1.43	Ouvrier and Ochs (1978)

Response to K application

Foale (1968) reported that nutrient contribution by endosperm to the growing seedling decreased from 4th month after germination, suggesting that the young seedlings are actually in short supply of nutrients for major part of their one year growth in the nursery when seedbed is not adequately supplied with nutrient. Though, food reserves where adequate as far as carbon compounds and nitrogen were concerned (Harris, 1970), potassium uptake was more and the experiments indicated the advisability of applying potassium. Application of balanced fertilizers consisting of N, P, K, Ca and Mg to the nursery seedlings improved the vigour and quality of seedlings (Nelliat *et al.,* 1976). The seedlings obtained from seed nuts collected from palms manured with K displayed better vigour and growth than those obtained from unmanured plots (Nelliat, 1973).

Influence of potassium on young palms: On an average one leaf is produced every month and this leaf remains on the palm for at least 3 years. In young immature trees, lack of K results in shortening of the lifespan of leaves, decreased leaf size and reduced rate of leaf production. This extends the immature phase and the trees grown under such conditions will not commence before 10 -12 years of age, whereas palms receiving adequate nutrition will start bearing from 3-4 years from field planting itself. Thus, the importance of K is not only for the faster development and vigorous growth, but also for reducing the prebearing period (Smith, 1968). The palms, which received adequate nutrition from the beginning, produced more yield than those supplied after maturity. In coconut experiments in the Ivory Coast (Fremond and Ouvrier, 1971), the effect of applying K and the time of field planting was compared to withholding K applications until the age of bearing (**Table 4**). The later practice was decidedly inferior for all palms. In a sandy loam soil at Kasaragod, palms which received 1.0 kg N and 1.5 kg K_2O flowered first (Nelliat, 1978).

Table 4. Timing effects 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	9	8
1958	Length of frond (cm)	256	233
1959	Girth (cm)	124	105
1960	No. of fronds (one yr)	12	11
1962	Copra (kg/ha)	2560	272
1966	Copra (kg/ha)	2480	2272
1970	Copra (kg/ha)	-	2096
1961-1970	Cumulative yield (kg/ha)	17344	12704

Influence of potassium on adult palms: Coconut continuously mines nutrients from the soil nutrient bank to produce higher yields. The potassium levels influence the yield and yield attributing characters in coconut. Menon and Pandalai (1958) on reviewing the work has summarised that coconut responded positively to potassium application and K had beneficial effect on copra production compared to nitrogen which had an adverse effect. This further reflects the importance attached to potassium in coconut nutrition.

Application of 340 g N, 340 g P_2O_5 and 680 g K_2O/palm/ year improved the nut yield by 35 percent and copra out turn by 44 percent in the cultivators gardens where the palms were hitherto unmanured. Further, where response to fertilizer application was not observed, significant increase was obtained when K level was raised to 900 g K_2O/palm/year (John and Jacob, 1959). Muliyar and Nelliat (1971) reported that potassium improved all the nut characters studied *viz.* weight of whole nut, weight of husked nut, volume of husked nut and copra weight per nut, whereas nitrogen had an adverse effect. In a long-term fertilizer experiment in red loam soil, Wahid *et al.* (1988) recorded significantly higher nut yield with potassium application. Besides early bearing was also achieved with increased levels of K application. The yield was 7, 68 and 77 nuts/palm/year in the 21st year after planting under no fertilizer, 450 g K_2O and 900 g K_2O/ palm/year respectively.

Long-term impact of fertilization on nutrient status

Hameed Khan *et al.* (1986) reported that after 18 years of coconut growth, the control (M_0) plot analyzed 19 ppm available K where as it was 55 and 70 ppm in M_1 and M_2 treatments, respectively. K levels in the control and treated plots decreased with depth. Further, Reddy *et al.* (2000) after 32 years of fertilization observed that the available soil potassium content was 66 ppm in M_0 plot under rainfed condition, which increased, to 212 ppm and 318 ppm with M_1 and M_2 levels of fertilizer application at 0-25 cm soil depth. Under irrigation, a reduction in soil available K was observed in M_1 and M_2 plots (**Table 5**). Application of potassic fertilizers also raised the leaf K levels to 1.14 percent (M_1) and 1.25 percent (M_2) compared to 1.07 percent in M_0 under rainfed condition. Under irrigation, leaf K content was 1.07 percent under M_1 and 1.20 percent under M_2 compared to 0.90 percent under M_0. Application of K fertilizer at M_1 level was found to maintain K content of leaves above critical level (0.8 to 1.0 percent). This suggests that doubling the K levels had little effect indicating that rates beyond 830 g K (1000g K_2O) per years are probably not needed. Thus a soil available K (1N NH_4Oac) content of 50-60 ppm (0.128 to 0.153 m.e./100g) is adequate for maintaining sufficiency levels in coconut. Manicot *et al.* (1979) reported that 0.015 to 0.20 m.e./100g (59-78 ppm) and Loganathan and Balakrishnamoorthy (1980) suggested that 0.13 m.e./100g (51 ppm) of exchangeable K is sufficient for satisfactory growth of coconut palm.

Table 5. Long term effect of fertilization on available potassium status of red sandy loam soils (Arenic Paleustult) at different soil depths (cm)

Fertilizer level	Available K (ppm)			
	Irrigated condition		Rainfed condition	
	0-25 cm	25-50 cm	0-25 cm	25-50 cm
M_{-1} (No fertilizer)	79	38	66	66
M_1 (500g N: 218g P: 833g K /palm/year)	110	69	202	153
M_2 (1000g N: 437g P: 1667g K/palm/year)	212	129	318	235

Source: Reddy *et al.* (2000)

In another long term studies in littoral sandy soil at Kasaragod, the available potassium status of the soil (0-100 cm depth) increased from 50 ppm at K_1 level (750g K_2O/palm/year) to 96 ppm at K_2 level (1250g K_2O/palm/year) to 106 ppm at K_3 level (1750g K_2O/palm/year) (Reddy *et al.*, 1999). This shows a near sufficiency level for available K in the soil. Thus, the statement of Biddappa *et al.* (1993) - soil available K content of 50–60 ppm is adequate for maintaining the sufficiency levels in coconut appears to be true.

Anil Kumar and Wahid (1989) found that application of muriate of potash increased available K and organic carbon status of soil. The effect of soil K was N-dependent as revealed from the significant N x K interaction. Higher rates of ammonium sulphate lead to reduction in exchangeable K. They observed accumulation of K in lower depths in contrast to the observations recorded by Hameed Khan *et al.* (1986) in red sandy loam. Further, Joseph and Wahid (1997) has observed that the application of muriate of potash resulted in a large increase in K reserves in soil to depth of 100 cm. The increase in K content was nearly 200 ppm within this depth. Relatively less accumulation of K was noticed in the 0-50 cm root zone than below it.

A desorption equilibrium model was prepared for laterite and red sandy loam soils for computation of the amount of K_2O/palm needed to raise the available potassium content of soil to a desired level. Though Hameed Khan *et al.* (1986) have indicated 50-60 ppm of available K as a desired level (based on its reflect on plant K and yield), however, in the present study, 80 ppm available K (1 N NH_4OAc) was assumed as the base value in the coconut basin to maintain a plant content of 0.8-1.0% (Annual report, 1985). To regulate satisfactory release of K for coconut, a ready reckoner table was prepared to guide the level of K_2O to be applied per palm (**Table 6**). It was observed that the potential buffering capacity (PBC^{k}) of laterite and red sandy loam soil with reference to potassium was different and hence the amount of K to be applied is less for laterite soil compared to red sandy loam to sustain available K content at 80 ppm.

Table 6. Dosages of K required for laterite and red sandy loam soils to raise the soil test value of K to any predetermined level (g K_2O/palm/year)

Soil test value (kg/ha)	80	70	60	50	40	30	20	10
Laterite Soil								
0	1514	1238	1062	885	708	531	354	177
10	1238	1062	885	708	531	354	177	0
20	1062	885	708	531	354	177	0	
30	885	708	531	354	177	0		
40	708	531	354	177	0			
50	531	354	177	0				
60	354	177	0					
70	177	0						
80	0							
Red sandy loam soil								
0	2087	1826	1565	1305	1043	782	522	260
10	1826	1565	1305	1043	782	522	260	0
20	1565	1305	1043	782	522	260	0	
30	1305	1043	782	522	260	0		
40	1043	782	522	260	0			
50	782	522	260	0				
60	522	260	0					
70	260	0						
80	0							

Nutrient interaction

The interaction of potassium with level of other nutrient is more important than that of with the qualitative factors like form of fertilizer, method and date of application, crop variety *etc.* Several studies have revealed strong interactions of potassium with other nutrient elements like Ca, Mg, Na and N.

Manciot *et al.* (1979) reported that there exist strong antagonisms between K-Ca, K-Mg and K-Na. Often, Mg level in the tissue decreased consequent upon high fertilization. Application of potassium lead to a significant drop in the content of Ca, Mg and Na in the leaf (**Table 7**). Wahid *et al.* (1988) also indicated the antagonistic effect of combined level of Na, Ca and Mg on K in the palms judged through foliar analysis.

Table 7. Effect of KCl application on the nutrient concentrations in the leaf

KCl application (kg/palm/year)	Nutrient content (%)					
	N	P	K	Ca	Mg	Na
Control	1.80	0.091	0.20	0.495	0.567	0.166
5	1.75	0.097	0.98	0.507	0.188	0.294
10	1.74	0.094	1.38	0.401	0.159	0.234
15	1.74	0.097	1.55	0.392	0.125	0.181

The results of the experiments conducted at CPCRI, Kasaragod in red sandy loam and lateritic soils have shown that application of NPK fertilizer without Mg showed significant reduction in leaf Mg content.

Coconut based cropping system

Nutrient management in the cropping system is the interplay of various factors *viz*, crop's nutrient requirement, differential responses in different soils, crop residue additions, climatic variations *etc.* It is therefore necessary to study the system as a single unit. In intensive cropping system with tree crops, the application of fertilizers according to the estimated requirement for each crop is certainly not the most efficient and economic way of utilizing the native and applied nutrients. Bench mark data on total nutrient demand, nutrient removal in harvested and non harvested products and the rate of nutrient accumulation during ontogeny are needed for each species in a multicropped system to arrive at answers on rate, time, source and placement of various nutrients (Nair, 1979).

In case of coconut-cocoa system, cocoa, as a component of multiple cropping system adds substantial quantity of organic matter to the soil, thus leading to annual internal recycling of nutrients in the system. It has been observed that 8.2 and 19.8 t/ha/year (oven dry basis) of cocoa litterfall was obtained from single and double hedge systems of planting respectively (Varghese *et al.*, 1978). Taking nutrient concentration of cocoa leaves to be 2.84 percent N, 0.26 percent P and 1.73 percent K on dry weight basis (Fernstman, 1968), it could be assumed that about 50 kg N, 11 kg P_2O_5 and 35 kg K_2O could be returned to the soil every year through leaf fall of cocoa under double hedge system of mixed cropping.

Conclusions

The reserves of potassium in soils growing coconut are lower on account of low CEC and high amounts of 1:1 clay type, mainly Kaolinite. Since, K is required in many physiological functions but does not form part of plant structure, K supply through external sources could be necessary so as to meet the crop's K requirement. Secondly, it can be considered a mobile capital investment highly capable of being recycled but also highly susceptible to loss in tropical soils. The ability of K to be reused in this sense is unmatched by any other macronutrient. Accomplishing efficient recycling requires a thorough understanding and management of K dynamics.

Coconut based cropping system can solve some of these problems. In the cropping system, there is more mining of the nutrients from different layers and the K reaches the above ground layer. When the older leaves begin to senesce, the K that is not translocated to economic produce is water-soluble and subject to elution by rainfall and this is deposited on the soil surface and can be effectively taken up by the crop.

Further, crop residues contain the remnants of nutrients after the plant has transferred its absorbed nutrients to its economic produce (about 75 percent of absorbed N and P, 50 percent of S and 25 percent of absorbed K) (Tandon, 1991). Thus, crop residues are more important sources of potash as compared to nitrogen and phosphorus.

Climatic factors influence the yield potential and yield of the crop. Even small differences in management levels right from the time of field planting will have tremendous influence on crop yield and fertilizer response. Because of the complexity of the factors, the many interactions between K nutrition, soil management, and climate are poorly understood and needs further studies on this.

Another field of research needed is the possible effect of K and Cl on leaf temperatures.

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