Technical bulletin No. 49

Integrated Nutrient Management in Coconut Based Cropping System

भाकृ अनुप
ICAR

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD - 671 124, KERALA, INDIA

CPCRI

Technical bulletin No. 49

Integrated Nutrient Management in Coconut Based Cropping System

C. Palaniswami, George V. Thomas,
R. Dhanapal, P. Subramanian,
H. P. Maheswarappa and
A. K. Upadhyay

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD - 671 124, KERALA, INDIA

Integrated Nutrient Management in Coconut Based Cropping System
Technical Bulletin No. 49
CPCRI, Kasaragod, Kerala, India, 24 p.

Published by

Dr. George V. Thomas
Director

Central Plantation Crops Research Institute
(Indian Council of Agricultural Research)

KASARAGOD - 671 124, KERALA, INDIA
Phone : 04994 – 232893, 232894, 232895 & 232996;
Fax: 04994-232322
Email: cpcri@nic.in, directorcpcri@gmail.com
Grams: 'RESEARCH' Kasaragod;
Website: http://www.cpcri.gov.in/

Compiled & Edited by

Dr. C. Palaniswami
Dr. George V. Thomas
Dr. R. Dhanapal
Dr. P. Subramanian
Dr. H.P. Maheswarappa
Dr. A.K. Upadhyay

December 2007

Photographs:
Shri K. Shymaprasad

Printed at
Niseema Printers & Publishers, Kochi - 18

CONTENT

Integrated Nutrient Management in Coconut based Cropping System

1. Introduction

Coconut (*Cocos nucifera* L.), widely known as 'Kalpavriksha' is an important perennial oil yielding crop of humid tropics. It is grown widely in the countries lying in the Indian Ocean and the Pacific Rim. India is the largest producer of the coconut and also has the largest acreage under the crop. Philippines, Indonesia, Ivory Coast, Malaysia, Thailand, Oceania, Papua New Guinea and Sri Lanka are the other leading coconut growing countries. In India, more than 90 % of the coconut acreage and production lies in the four southern states namely, Kerala, Tamil Nadu, Karnataka and Andhra Pradesh.

In general, coconut like any other plantation crops is grown on variety of soils namely lateritic and laterite, littoral 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. The major coconut growing soils are laterite, 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. The major area of the coconut being in South India suffers from prolonged spell of dry spell 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. As shown in table 1 and various studies have long established that the 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.

Table 1. General physico-chemical properties of coconut growing soils

Soil group	Mechanical composition (%)			pH*	Org. C(%)	CEC
	Clay	Silt	Sand			(C mol/kg)
Laterite	16.8 (9.2-39.2)	10.5 (2.2-20)	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 (0.03-1.81)	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 (0.23-2.91)	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)

**1:2.5 soil: water*
Figures in parentheses denote ranges
Source Pillai, (1975)

Coconut has unique feature among the plantation crops in that it flowers and fruits throughout the year. Therefore, its requirement of water and nutrients should be supplied throughout the year. Nutrient exhaust from one hectare of coconut ranged from 92 to 149 kg N, 12 to 20 kg P and 119 to 183 kg K. This clearly indicates that K and N are required in higher quantities for coconut production.

Integrated nutrient management includes the intelligent use of organic, inorganic and online biological resources (BNF) so as to sustain optimum yields, improve or maintain soil's chemical and physical properties and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Tandon, 1990). INM optimizes all aspects of nutrient cycling — supply, uptake, and loss to the environment — to improve food production. This bulletin describes interventions that may be applied to a range of agroecological zones, cropping systems, and soil types. The interventions address a few key aspects of nutrient management, including improving organic matter in the soil, increasing plant-available nutrients and supplying both organic and chemical fertilizers. These interventions have the potential to increase and sustain production levels, increase the economic potential of a production system, and counteract and minimize environmental pollution.

Growing of inter/ mixed crops in coconut garden will not only increase the utilisation of unexploited natural resources, but will also have a beneficial effect on the farm economics. High density multispecies cropping system (HDMSCS), is one of the mixed cropping systems, where a number of compatible crops are grown in a unit area to meet the diverse needs of the farmers such as food, fuel, timber, fodder and cash and are ideally suited for smaller units of land and at maximum production both temporally and spatially. This also leads to control of weeds, soil and water conservation, better microclimate and favourable microbial activity in the soil.

Nutrient management in coconut based HDMSCS would be a complex task as this will involve the interplay of various factors *viz.* nutrient recycling, fertilizer additions, differential crop responses, nutrient uptake and soil environment. Thus, there is a need to consider the system as a unit. It has been rightly summarised by Oelsligle *et al.* (1976), that 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.

It has been well established in several coconut growing countries that coconut as a monocrop is only, marginally productive and profitable. 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 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. Nevertheless, the traditional method of distribution of crops in a coconut garden is not scientific to utilize natural resources efficiently.

Nutrient management in cropping/ farming system is difficult as it involves interplay of various factors like crop requirements, differential crop responses, crop residue additions, management practices suiting crop needs, water requirement and soil environment. It is therefore imperative that whole system must be considered as one unit. Experience in coconut based cropping system suggests that it is necessary to fertilize coconut and component crops according to the nutrient requirement of individual crops to make the system more productive and competitive (Liyanage, 1985; Margate *et al.* 1994).

2. Coconut based cropping system

a) Component crops

An experiment was conducted in an existing 35 year old West Coast Tall 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, black pepper

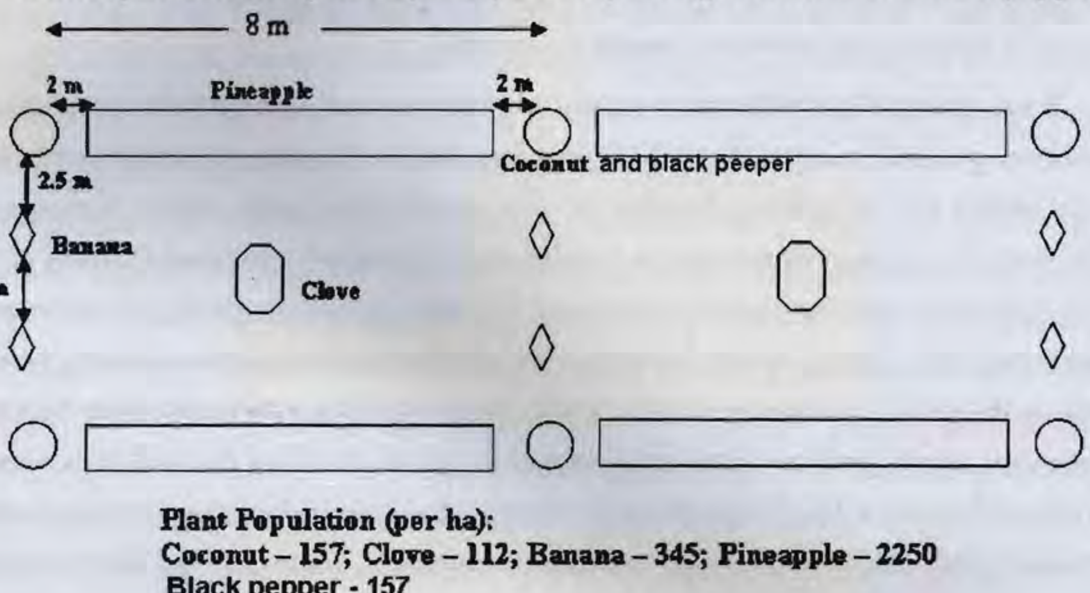


Figure 1: Planting pattern of coconut and other component crops

and pineapple were grown as intercrops (Fig. 1 & Table 2). The experiment was laid out in 1.2 ha area and the planting pattern is given in figure 1. 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 like 1/4th, 1/5th and control from the year 1994. From 1999 onwards organic recycling was practiced in the system by vermicomposting the available biomass and the lower level of fertilizer dose for component crops was kept as 1/3rd of recommended fertilizer dose. The experiment is divided into six blocks with an area of 2048 m^2 comprising of 32 coconut palms, 32 black pepper, 21 clove, 84 banana and 21 pineapple beds consisting of 2250 pineapple.

Table 2: Details of the component crops in the coconut based cropping system

Crop	Variety	Spacing	No. plants/ha
Coconut	WCT	8 x 8 m	157
Black pepper	Panniyur -1	Trailed on coconut	157
Clove	Local cultivar	8 x 8 m	112
Banana	Kadali	3 x 8 m	345
Pineapple	Kew	45 x 45 cm two rows in 4 meter bed	2250

b) Integrated nutrient management

i) Fertilizer dose

The quantity of nutrient applied for crops in the system is given in the Table 3. 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).

Table 3: Quantity of fertiliser applied for the different crops in the INM experiment (g/plant)

Crop	Nutrient	1/5th	1/4th	1/3th	2/3th	Full
Coconut	N	100	125	167	333	500
	P	64	80	107	213	320
	K	240	300	400	800	1200
Clove	N	60	75	100	200	300
	P	50	63	83	167	250
	K	150	188	250	500	750
Banana	N	40	50	67	133	200
	P	40	50	67	133	200
	K	80	100	133	267	400
Pineapple	N	2	2	3	5	8
	P	1	1	1	3	4
	K	2	2	3	5	8
Pepper	N	10	13	17	33	50
	P	10	13	17	33	50
	K	30	38	50	100	150

ii) Crop residue availability and recycling

Biomass production

The total biomass from the system was estimated on yearly basis. Highest coconut biomass was obtained in the full dose treatment (23.51 t/ha), and it was 19 t/ha in the control treatment (Table 4). Major contribution of biomass is from coconut (Fig. 2).

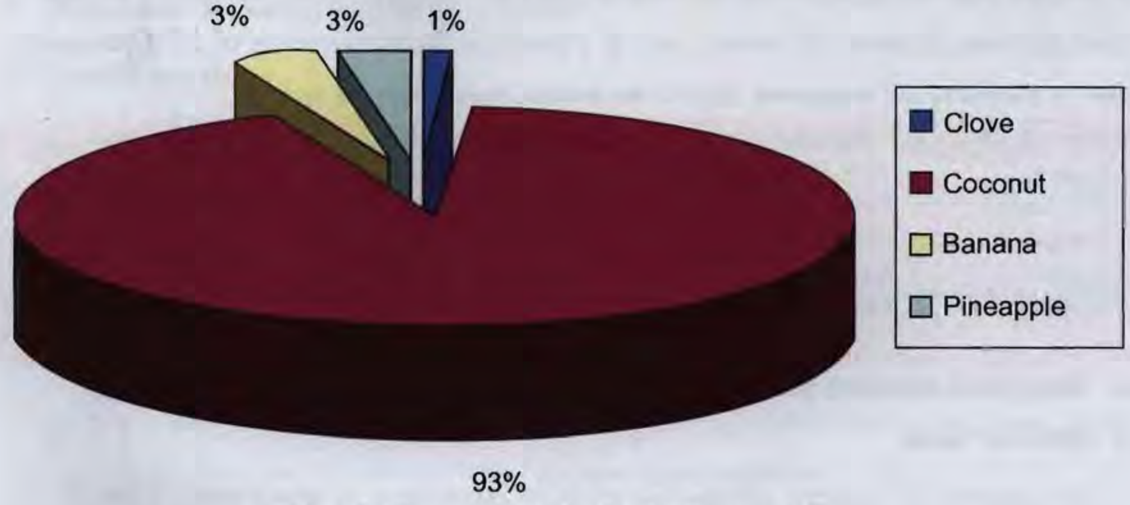


Figure 2: Biomass contribution from the component crops

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

Fertilizer treatments	Biomass (t/ha)	Nitrogen (kg/ha) Exhaust	Recycled	Phosphorus (kg/ha) Exhaust	Recycled	Potassium (kg/ha) 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

Nutrient recycling

The total nutrient exhaust in the cropping system 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 ranged from 47 to 70 kg N/ha, 5.4 to 8.5 kg P/ha and 87 to 121 kg K/ha and their per cent recyclable waste is given in Figure 3.

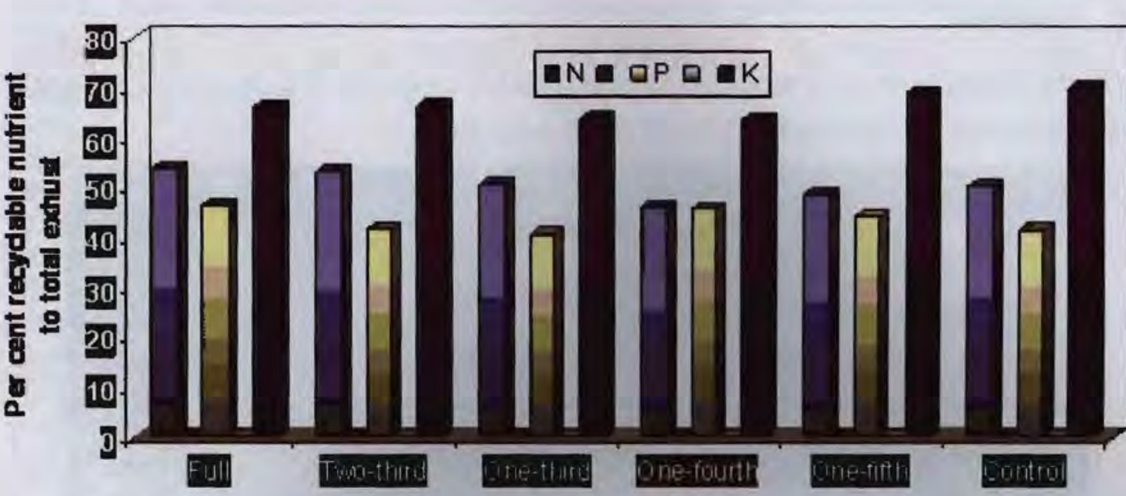


Figure 3: Per cent of recyclable nutrients to total nutrient exhust under different fertilizer levels

Vermicomposting

The weathered biomass obtained during rainy seasons may be preferred. This waste can be used without chopping, thus saving a lot of labour. These organic wastes are to be treated with cow dung at the rate of 10 per cent by weight in the form of slurry and must be allowed to undergo a preliminary decomposition for about 2 –3 weeks. The earthworms at the rate of 1000 worms per tonne of biomass are to be introduced. The compost bed should be mulched properly using any locally available plant material or gunny bags and has to be protected from direct sun light. Watering is to be done to maintain enough moisture. As full leaves are used for composting, compact mass is not formed, thus allowing free movement of air in the bed. In about 60- 75 days compost will be ready. On an average, 70 per cent recovery of vermicompost was obtained. The same technology for vermicomposting was also tested in large pits taken in the inter spaces of four coconut palms in sandy loam and coastal sandy soils and was found to work well. The average nutrient composition of the vermicompost recovered was : N % (1.8), P % (0.22), K % (0.16), Organic carbon % (17.84), and C/N (9.95). Total microbial counts and beneficial microbial population were also more in the compost compared to the base material. The C/N ratio of the organic matter ingested by the earthworm decreases and bound nutrients are converted into easily available forms.

iii) Irrigation

Perfo irrigation which is modified form of sprinkler irrigation (Fig. 4) was given during the dry period (December-May) at IW/CPE ratio 1.00.

Figure 4: Perfo irrigation in the coconut based cropping system

3. Effect of INM on crop production

a) Effect on yield

In the coconut based high density multispecies cropping system, the coconut yield (mean 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 5). 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 was highest at the 2/3rd of recommended fertilizer dose (1.55 kg/tree/year). The average weight of banana bunch (5.76 kg/bunch) and weight of pineapple fruit (890 g) was highest in the full recommended dose treatment. The black pepper yield was highest in the 2/3rd recommended fertilizer dose (1.66 kg/bush/year).

Table 5: Output from different crops under coconut based cropping system model at Kasaragod

	1999-2001	2001-03	2003-05	mean
Coconut (no. nuts/palm/year)				
Full	152	139	143	145
2/3rd	157	145	139	147
1/3rd	152	142	146	147
1/4th	138	128	147	137
1/5th	128	127	133	129
Control	121	129	131	127
Pineapple(kg/fruit)				
Full	1.01	1.15	0.51	0.89
2/3rd	0.98	0.64	0.49	0.70
1/3rd	0.75	0.60	0.36	0.57
1/4th	0.47	0.44	0.37	0.43
1/5th	0.50	0.51	0.42	0.48
Control	0.47	0.47	0.43	0.45
Clove (dry kg/tree/year)				
Full	0.83	1.58	1.91	1.44
2/3rd	0.92	1.10	2.62	1.55
1/3rd	0.87	0.99	1.89	1.25
1/4th	0.32	0.82	2.21	1.12
1/5th	0.22	0.63	2.15	1.00
Control	-	0.46	2.17	1.32
Banana (kg/ bunch)				
Full	7.10	6.67	3.51	5.76
2/3rd	6.70	6.14	3.43	5.43
1/3rd	6.70	4.14	3.27	4.70
1/4th	5.10	5.21	2.77	4.36
1/5th	4.80	4.29	2.65	3.91
Control	4.50	4.71	2.38	3.86
Black pepper (kg/bush/year)				
Full	-	0.34	1.40	0.87
2/3rd	-	0.63	2.69	1.66
1/3rd	-	0.46	1.33	0.90
1/4th	-	0.70	1.43	1.06
1/5th	-	0.34	0.50	0.42
Control	-	0.13	0.78	0.46

Coconut yield sustainability analysis

Sustainability of yield in the coconut was estimated by quantifying yield variation over the year by similar sequence matching technique. 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 control treatment compared to other fertilised treatments. 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, it was 1.39 prior to organic recycling while it was 0.87 after organic recycling (Table 6). There was decrease in amplitude after the introduction of organic recycling in the normalized sequence (Fig. 5). In the control treatment amplitude of 1.98 during pre organic recycling had reduced to 1.77 in post organic recycling . 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 6. Euclidean distance of normalized subsequence

	Full	2/3rd	1/3rd	1/4th	1/5th	Control
Pre organic recycling						
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 organic recycling						
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	-

b) Effect on foliar nutrient levels

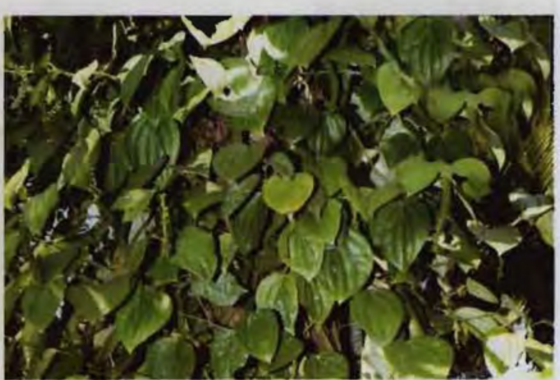
The nutrient status of the plant was monitored and it was found that in general lower dose of fertilizer treatment recorded numerically higher values for coconut leaf P, Ca, Mg, Zn, Cu, Fe and Mn content due to the concentration effect (Table 7 & 8). However, all the nutrient contents were in optimum 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 except in pineapple. In case of pineapple, application of fertilizer increased the yield and decreased the foliar N, P and K levels due to dilution effect.

Component crops in the coconut based cropping system

Coconut

Pineapple and clove

Banana



Black pepper

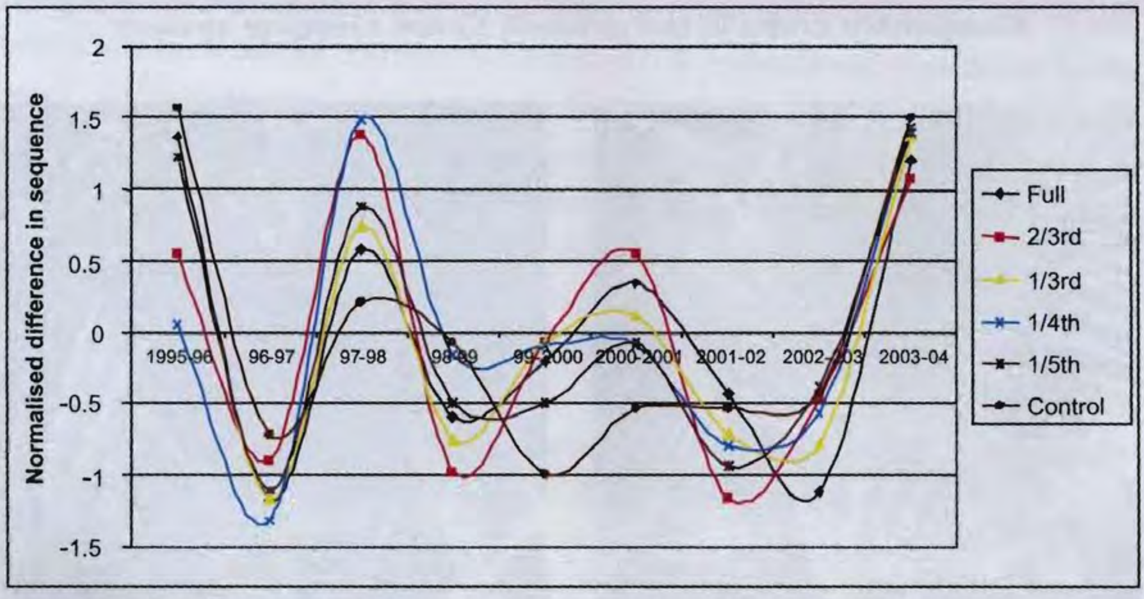


Figure 5: Normalised coconut yield difference in sequence in the coconut based cropping system model during pre and post organic recycling

Table 7: Major foliar nutrient content of coconut and component crops

Crop/ Treatment	N (%)	P (%)	K (%)
COCONUT			
Control	1.82	0.140	1.03
1/5th	1.79	0.147	0.98
1/4th	1.82	0.142	1.16
1/3rd	2.00	0.131	0.90
2/3rd	1.90	0.126	0.85
Full	1.93	0.143	1.16
CLOVE			
Control	0.980	0.138	1.026
1/5th	0.952	0.097	0.940
1/4th	1.120	0.109	0.897
1/3rd	1.288	0.099	0.898
2/3rd	1.246	0.082	1.193
Full	1.246	0.062	1.209
BANANA			
Control	1.820	0.170	2.643
1/5th	1.792	0.185	2.350
1/4th	1.830	0.177	2.322
1/3rd	1.876	0.172	2.493

2/3rd	2.058	0.143	2.218
Full	2.590	0.173	2.435
PINEAPPLE			
Control	0.770	0.261	3.028
1/5th	0.728	0.257	2.638
1/4th	0.686	0.235	2.786
1/3rd	0.784	0.215	2.436
2/3rd	0.700	0.214	2.438
Full	0.748	0.188	2.378

Table 8: Foliar nutrient content of coconut and component crops for secondary and micro nutrients

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	15.80	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

c) Effect on 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 9. 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 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.

Table 9: 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

	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

d) Effect on microbial parameters

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 (Table 10) whereas 2/3rd dose of fertilizer recorded lower number of bacteria than other treatments 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 1/3rd dose and a decreasing trend was observed from 1/3rd to full dose. Regarding 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 10: Microbial population 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	16.0
One-fifth	19.9	35.0	61.3	35.0	21.4
One-fourth	22.6	45.0	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	53.0	25.0	12.5

Higher content of microbial biomass was recorded in root region soils of coconut and component crops at medium levels of fertilizer inputs than full-recommended fertilizer dose or at very low and low fertilizer treatments (Table 11). The quantity of carbon mineralised, phosphatase and dehydrogenase activities of soil also varied under different fertilizer treatments and a decreasing trend was observed with increasing soil depth. Medium level of fertilizer inputs along with recycling of waste biomass resulted in the development of congenial conditions for higher level of microbial activity in the cropping system.

Table 11: Microbiological parameters recorded in the coconut based cropping system

Crop	Treatment	Microbial biomass (µg/ g soil)	C mineralisation (µg C / g soil)	Phosphatase activity (µg p-nitrophenol / g soil / h)	Dehydrogenase (µg formazan / g soil / h)
Coconut	Control	363.55	38.25	32.68	12.90
	1/5th	290.35	37.78	40.81	14.87
	1/4th	447.87	39.04	39.54	18.93
	1/3rd	393.53	38.31	40.74	14.85
	2/3rd	411.34	36.71	35.85	14.71
	Full	421.91	29.41	45.82	12.80
Pineapple	Control	64.12	22.76	31.16	12.61
	1/5th	68.78	26.08	37.98	17.25
	1/4th	86.08	25.12	43.31	17.80
	1/3rd	51.48	20.45	39.10	16.10
	2/3rd	76.32	19.94	34.42	12.44
	Full	67.21	20.10	45.95	12.02
Clove	Control	306.41	41.75	24.25	13.06
	1/5th	320.54	38.61	46.37	15.12
	1/4th	458.63	45.63	50.06	19.60
	1/3rd	306.80	35.26	38.82	14.36
	2/3rd	342.65	41.68	44.82	14.22
	Full	330.78	42.09	46.07	12.61
Banana	Control	231.32	32.47	35.98	15.14
	1/5th	268.36	27.79	39.93	19.38
	1/4th	370.36	37.60	41.46	19.48
	1/3rd	310.07	32.06	49.13	18.86
	2/3rd	333.67	30.36	39.75	17.54
	Full	273.96	30.11	47.65	14.89

e) Rainfall Partitioning

For measuring throughfall 7 raingauges were equally distributed under the canopy of coconut and for clove throughfall measurement, 3 raingauges were kept under the canopy. These raingauges were made up of 7.5 cm diameter funnel and a 2.5 dm^3 plastic/ glass container. The gross rainfall measurements were taken from the Institute weather station. Throughfall gauges were randomly relocated at weekly interval. Steep angle funnels were used to minimise any splash out from the gauges during rainstorms and, with the funnel of each gauge about 0.5 m above the ground, there was little opportunity for water to splash in after hitting the floor. Observation of the height to which soil particles had been deposited on the sides of a standing board showed a maximum splash height of about 0.3 m.

Stemflow from 4 coconut and two clove trees was measured by halved polyvinyl sheet tubing (5 cm wide) which was stapled and sealed with caulking around the circumference of each tree with the ending in a collection container (Fig. 6). The equivalent depth of stemflow was derived by employing the following area per tree equation:

Figure 6: Throughfall and Stemflow studies in HDMSCS in the clove

SF = SFVol/A

where SF is the estimated stemflow (mm) for a given canopy cover area (A) in m^2 and SFVol is the stemflow volume of the representative trees (litres).

The canopy storage capacity was determined by a plot of throughfall versus gross rainfall for day with a depth great enough to saturate the canopy (assumed to be > 3 mm). Canopy storage capacity of coconut was 1.8 mm and throughfall was 85 to 90 % of the gross rainfall. Canopy storage capacity of clove was 2.8 mm and throughfall was 34 to 62 % of the gross rainfall (Fig 7).

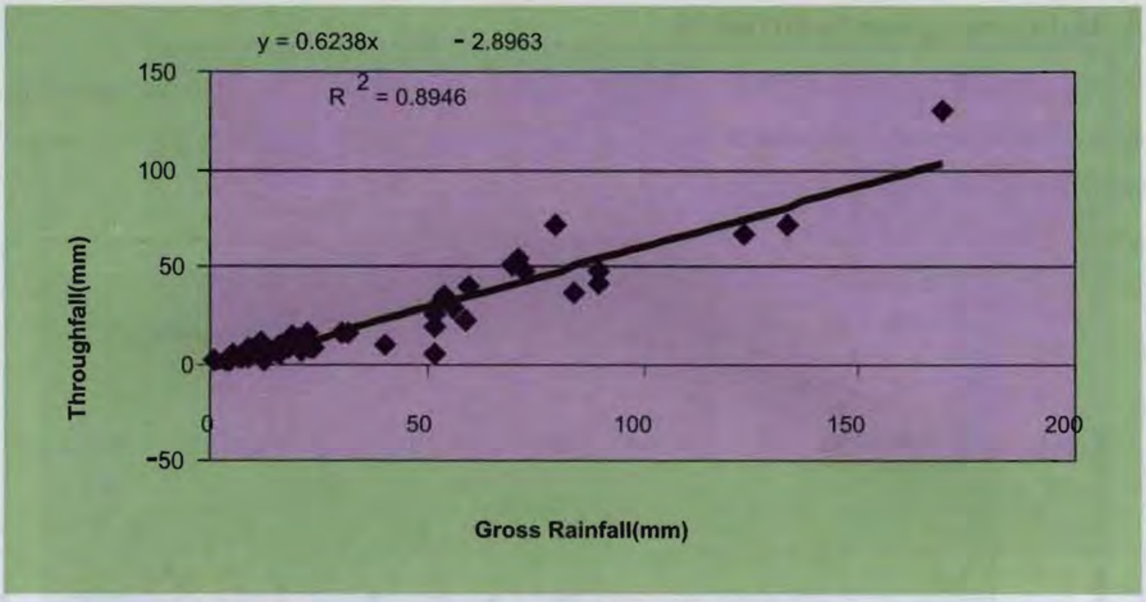


Figure 7: Canopy storage capacity

The trunk storage capacity was determined by a plot of stemflow versus gross rainfall. Trunk storage capacity of coconut was 3.5 mm and stemflow was 57 % of the gross rainfall. Trunk storage capacity of clove was 0.11 mm and stemflow was 11 % of the gross rainfall (Fig. 8).

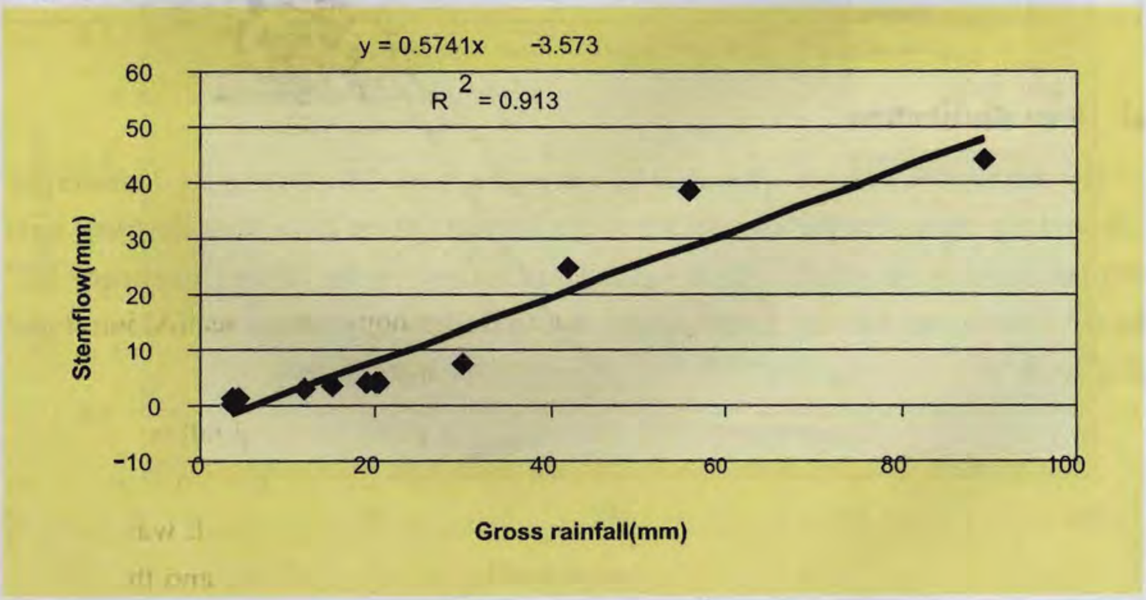


Figure 8: Coconut trunk storage capacity

f) Light interception in HDMSCS

The per cent light transmitted by the different canopies of the coconut based cropping system experiment showed that 26.7 % of the incident light is available for the under story intercrop (Fig. 9).

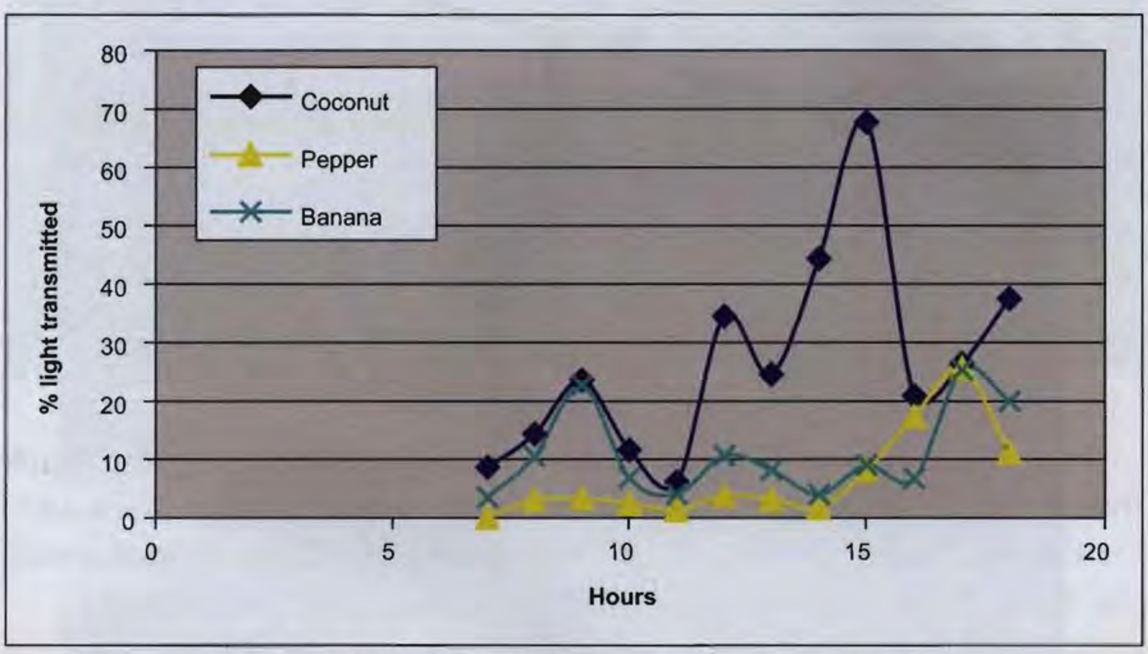


Figure 9: Light interception in coconut based cropping system

g) Root distribution

The distribution of roots quantified by sampling with 7.5 cm (internal diameter) by 125 cm long cores. For each tree in 50 cm, 100 cm and 150 cm away from the trunk upto 100 cm depth were taken. Root weight was highest in the control treatment 5.27 kg m^{-3}. The higher root dry matter weight was in the 25 -50 layer and in the control plot (Fig 10. & 11).

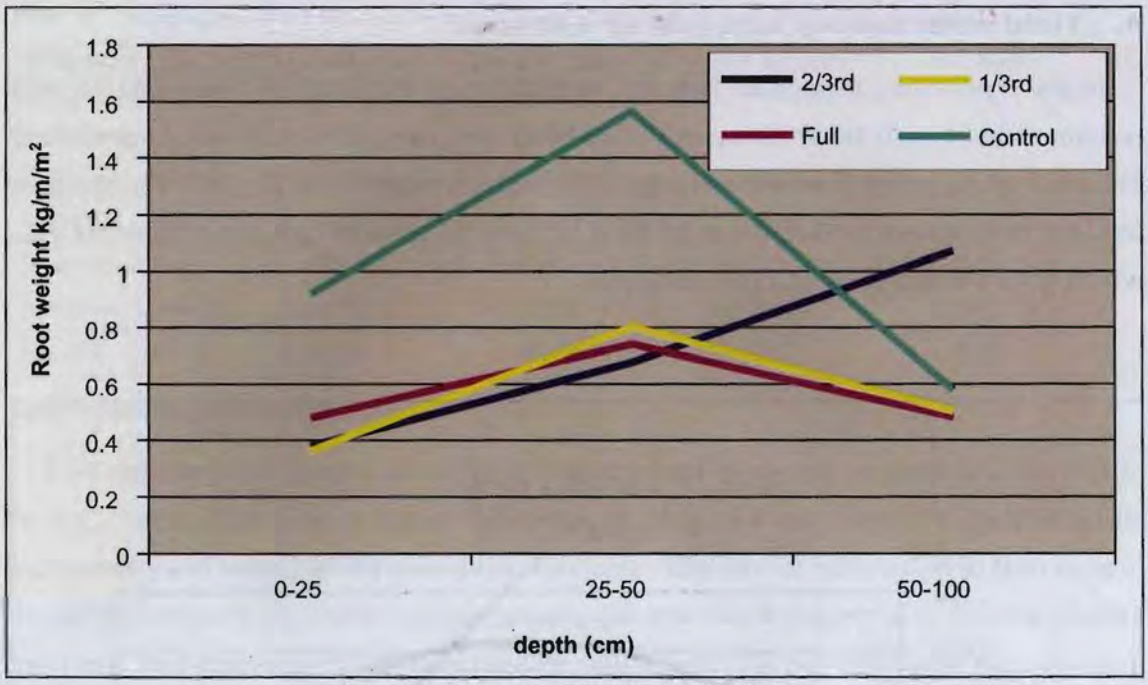


Figure 10: Coconut root distribution in soil layers

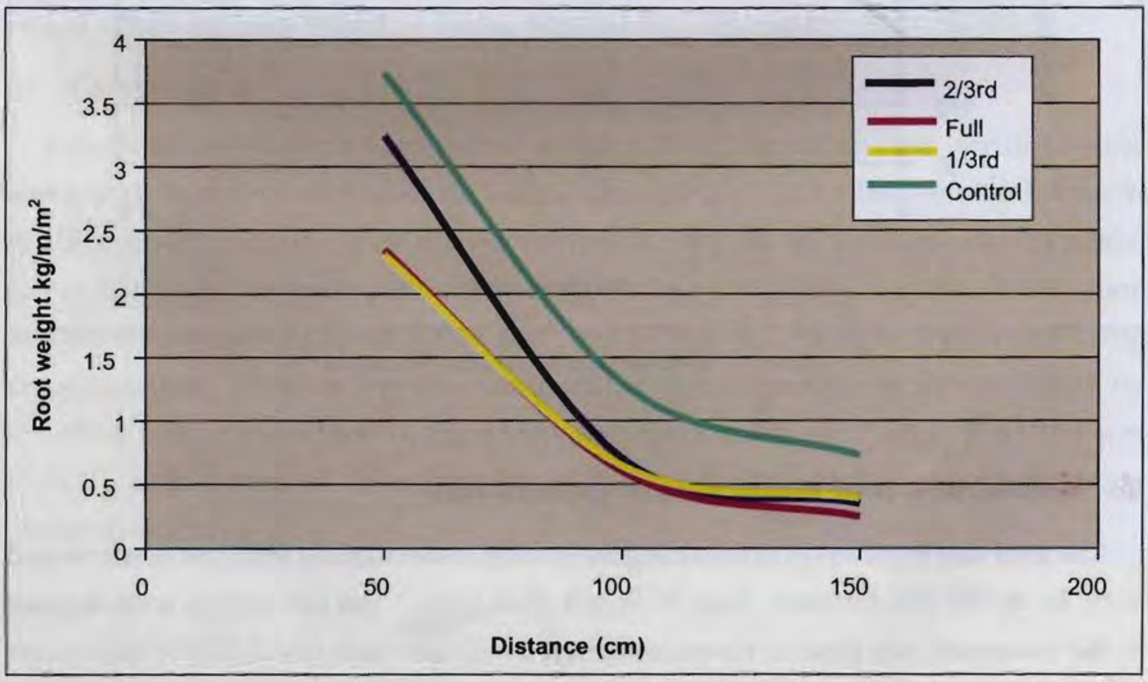


Figure 11: Coconut root distribution away from tree base

4. Yield relationship 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. 12). 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 151.7 nuts/year.

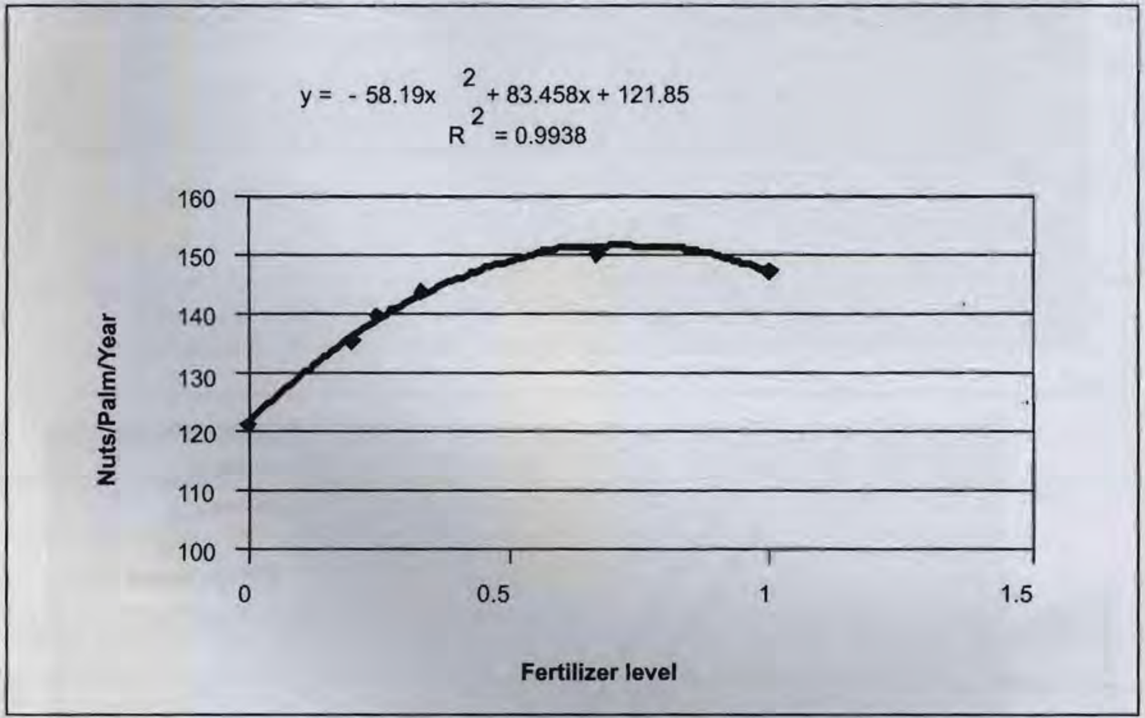


Figure 12: Fertiliser response function for coconut

5. Economics and employment generation

The total cost involved in maintaining the system under various fertilizer doses ranged from Rs 48,983 (No fertilizer dose) to 56,973 (Full dose). The net returns were highest in the treatment, two third of the recommended fertilizer dose (Rs 63,579/-) with a cost benefit ratio of 1: 2.18 (Table 12).

Table 12: Economics of the INM in coconut based cropping system (Mean of six years)

Treatment	Cost cultivation (Rs./ha)	Gross Returns (Rs./ha)	Net Returns (Rs./ha)	B:C Ratio
Full dose	56973	117204	60230	2.05
2/3rd rec. dose	53649	117228	63579	2.18
1/3rd rec. dose	50324	109119	58795	2.16
1/4th rec. dose	49989	106832	56843	2.13
1/5th rec. dose	49787	100351	50563	2.01
No fert.- Control	48983	93015	44032	1.89

Employment generation

The employment potential of the coconut based cropping system is observed to be very high. The labour input utilization of irrigated monocrop of coconut(at its stabilized yield stage) is 144 man days/ha/year. The labour utilization in the coconut cropping system with clove, banana, pineapple and black pepper was 332 man days/ ha/year. In percentage term the increase was about 130 per cent over the sole crop system. Since it is expected that the bulk of the labour force is available from the family source of the farmer, family labour income could therefore be considerably raised when coconut based cropping system was adopted.

6. Conclusion

Integrated nutrient management by using 2/3rd recommended fertilizer dose along with recycling of biomass by vermicomposting gives the best economic benefit in a sustainable manner. INM on coconut based cropping system demostarted model to the farmer to 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.

References

Liyanage, L.V.K. 1985. Rationale for intercropping. *Coconut Bulletin*, **2**: 31-34.

Margate, R.Z., Maravilla, J.N., Ebuna, R.M. and Eroy, M. N. 1994. Response of coconut and coffee to fertilizers applied either or both crops in an intercropping system. *CORD* **X**(2): 41-61.

Oelsligle, D.D., McCollum, R.E. and Kang, B.T. 1976. Soil fertility management in tropical multiple cropping. *In: Multiple Cropping*. Papendick, R.I., Sanchez, P.A. and Triplett, G.B. (Eds.) American Society of Agronomy, Special Publication 27:275-292.

Pillai, N.G. 1975. Studies on mineral nutrition of coconut palm with special reference to the root (wilt) disease. Ph.D. Thesis. University of Keral, Trivandrum.

Tandon, H. L. S. 1990. Integrated nutrient management for sustainable agriculture. *In: Proceedings of the International Symposium on Natural Resources Management for a Sustainable Agriculture* (R.P. Singh, Ed.) Vol. I, 6th-10th February, 1990, New Delhi, pp 203-222.