Soil fertility status as influenced by arecanut based cropping system and nutrient management

Ravi Bhat[1] and S. Sujatha

Central Plantation Crops Research Institute,
Regional Station, Vittal – 574 243, Karnataka

(Manuscript Received: 23-11-06, Revised: 02-03-07, Accepted: 12-09-07)

Abstract

An experiment was conducted during 1999-2003 to study the impact of nutrient management through organic matter recycling on yield of component crops in arecanut based cropping system and the nutrient status at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka. The experiment was laid out in RBD with four treatments (organic matter recycling (OMR), 1/3rd of recommended NPK + OMR, 2/3rd of recommended NPK + OMR and recommended NPK + OMR). The recyclable biomass produced from the system varied between 8.72 – 10.35 t ha^{-1} $year^{-1}$. Among the component crops, only the yield of banana was significantly influenced due to nutrient management. Arecanut equivalent yield from the ABCS increased significantly from 1777 kg ha^{-1} in 1999 to 2769 kg ha^{-1} in 2002 indicating improvement in overall productivity of the system per unit area. Significant variability in nutrient status of laterite soils was observed due to ABCS and nutrient management through organic matter recycling. Organic matter recycling maintained sufficient mineral N and available P levels in soil at par with integrated nutrient management treatments. The availability of K increased significantly with integrated use of inorganic fertilizer and OMR compared to only OMR at both soil depths. Significant depletion of available K in all crop rhizospheres at both soil depths during experimental period revealed the necessity of including K in the fertilizer schedule of the system due to heavy K feeding nature of all the component crops and leaching losses. Comparatively similar yield levels and soil nutrient status noticed with OMR and integrated use of chemical fertilizers and OMR emphasizes the point that the system can be self-sustainable over a long term period.

Keywords: Arecanut, cocoa, banana, clove, vermicompost, organic matter recycling, nutrient management.

Introduction

Arecanut (*Areca catechu* L.) is predominantly grown in humid tropics of West coast of India. Small and marginal holdings of less than one hectare dominate in arecanut tract. The income generated from these holdings is insufficient to sustain the needs of farmer. Besides, the productivity of arecanut in India is stagnated at around 1200 kg dry kernel ha^{-1} (2003-04). Adoption of cropping system approach is indispensable to increase the productivity per unit area and to avoid risks due to pests, diseases and price fluctuations. Studies have revealed that arecanut utilizes only 30% of the land area and 16% of air space and permits 40% of PAR to penetrate down that can be utilized by mixed crops (Bavappa *et al.*, 1986), thus giving scope for accommodating several component crops. Several studies indicated that cocoa, black pepper, clove and banana are ideal mixed crops in arecanut plantation (Bavappa *et al.*, 1986; Ravi Bhat *et al.*, 1999).

The ultimate aim of cropping system is not only to obtain additional income but also to improve the soil fertility status in the long run. Successful cultivation of mixed crops like cocoa, black pepper, clove and banana in arecanut garden is well documented (Bhat, 1978; Bavappa *et al.*, 1986). High rates of outputs from the cropping system imply that they in the long run will deplete the soil of its nutrient store and make the system ecologically unsustainable (Nair, 1999). It was also indicated that nutrient removal rates in harvested products from these systems are so high that N deficiency would eventually limit system's productivity. Arecanut based cropping system (ABCS) involving component crops like cocoa, banana and clove have high nutrient requirement and thus places a great demand for nutrients on the soil + fertilizer system. The annual nutrient removal by arecanut is estimated at 79 kg N, 28 kg P_2O_5 and 79 kg K_2O per ha (Rethinam, 1990) and by cocoa is 43.8 kg N, 8 kg P and 64.3 kg K per ha (Ravi Bhat, 2002). Banana removes large quantities of N (320 kg), P (23 kg) and K (925 kg) to produce a yield level of 50 t ha^{-1} (Lahav and Turner, 1983).

[1] Corresponding author Email: bhatravi@gmail.com

The important problems associated with laterite soils are P fixation, nutrient losses through run off due to heavy rainfall during monsoon season, leaching of basic cations Ca and K and very poor nutrient retention capacity because of low CEC of 3-15 cmol (p^+) kg^{-1} (Tandon and Ranganathan, 1988). The laterite soils of this region were found to be medium to high in available P and deficient in available K (Badrinath *et al*., 1998). In view of this, it is very important to replenish the nutrients regularly by adopting appropriate nutrient management practices to maintain the soil fertility status. Soil fertility status would help in understanding the soil nutrient depletion pattern and also be useful in formulating suitable nutrient management practices in tune with the crop needs. Previous study by Abdul Khader *et al.* (1992) indicated improvement in soil fertility status due to establishment of arecanut based high density multispecies cropping system. Manikandan *et al.* (1987) noticed a negative balance in available K in arecanut-cacao system indicating the higher requirement of potassium. Arecanut based cropping system generates considerable organic wastes, which otherwise find no use. Recycling of these wastes would improve the soil fertility status, as these wastes are rich in lignin and cellulose. Keeping these points in view, the experiment was conducted to study the impact of nutrient management through organic matter recycling on yield and soil fertility status of arecanut based cropping system.

Material and Methods

The investigation was conducted at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, India (12° 15'N latitude and 75°25'E longitude, 91 m above MSL). The average annual rainfall at this place is 3670 mm that is distributed over 120 days. Mean temperature ranges from 19 °C (minimum) to 36 °C (maximum). The rainfall during the experimental period varied between 2873 mm in 2002 to 3709 mm in 1999. The soil of the experimental site was laterite with a pH of 5.25, 1.3% organic carbon, 42.0 ppm N, 15.0 ppm and P 56.8 ppm K. The experiment was conducted during 1999-2003 in an existing arecanut garden established during 1965. The arecanut was planted at spacing of 2.7 m x 2.7 m. Cocoa and clove were planted during 1983 at a spacing of 5.4 m in two separate rows. Coffee was planted at 1.2 m spacing in every third row of arecanut. Banana was planted at 5.4 m intra-row spacing in cocoa and clove rows alternatively. Black pepper, banana and coffee were planted in 1999 as mixed crops. Black pepper was planted in arecanut basin 75 cm away from the base on northern side of the palm.

The experiment was laid out in randomized block design with four treatments and five replications. The treatments included T_1 - Organic matter recycling (OMR), T_2 - 1/3rd of recommended NPK + OMR, T_3 - 2/3rd of recommended NPK + OMR and T_4 - recommended NPK + OMR. The net plot size was 131.2 m^2. Each treatment consisted of 18 arecanut palms, 18 pepper, 3 cocoa, 3 clove, 6 banana and 11 coffee plants. Thus, one hectare of arecanut plantation accommodates 1300 pepper, 215 cocoa, 215 clove, 430 banana and 830 coffee plants. The chemical fertilizers were applied in two splits i.e., 2/3rd in September and 1/3rd in May. The recommended fertilizer dose for arecanut, black pepper and cocoa is 100 g N, 40 g P_2O_5 and 140 g K_2O per plant per year. The fertilizer recommendation for clove, banana and coffee is 300 g N, 250 g P_2O_5 and 750 g K_2O., 160 g N, 160 g P_2O_5 and 320 g K_2O and 30 g N, 20 g P_2O_5 and 30 g K_2O per plant per year, respectively. The sources of fertilizers included were urea (46 % N), rock phosphate (9 % P) and muriate of potash (50 % K). The recycled biomass included the leaves, bunch waste and husk of arecanut, pruned biomass and litter fall of cocoa, clove litter fall, suckers, leaves and pseudostem of banana and weeds. The waste material collected from each treatment was separately converted into vermicompost using African night crawler earthworm species (*Eudrilus euginae)* in three months period and recycled back to all component crops during September. The quantity of vermicompost applied to each palm/tree was 1.5 kg in T_1 treatment, 2.0 kg in T_2 and T_3, and 2.5 kg in T_4. This was based on the quantity of vermicompost prepared out of the recyclable biomass from the system.

Soil samples were collected from basins of all component crops like arecanut, cocoa, banana, clove and coffee on all four sides and mixed to get a representative sample. Four palms in case of arecanut and two plants case of cocoa, clove and banana were selected for sampling purpose in each treatment. Soil samples were collected from 0-30 and 30-60 cm soil depth at 40-50 cm away from the base of the palm/tree during May every year before the onset of monsoon. Initial soil analysis done by Abdul Khader *et al.* (1992) before the establishment of arecanut based cropping system was used for better comparison of impact of the system. Soil nutrient analysis was done using standard procedures (Jackson, 1967). Soil mineral N ($NO3^{-2}$ + $NH4^+$) was estimated by microkjeldhal method using Deverda alloy. Available P was estimated with Bray's reagent method. The yields of different crops were recorded at regular intervals. The harvested products were sun dried to safe moisture content and expressed on per hectare basis. Black pepper started yielding after 3rd year of experimentation and thus not included in table 2. Arecanut equivalent yield was calculated using the following formula. The yield of component crops recorded per hectare of arecanut garden were considered. The prices of arecanut, cocoa, clove and banana considered for estimating arecanut equivalent yield were Rs. 70, 75, 100 and 5 per kg of the produce, respectively.

$$\text{Arecanut equivalent yield} = \text{Yield of arecanut} + \frac{\text{Yield x price of cocoa}}{\text{Price of arecanut}} + \frac{\text{Yield x price of clove}}{\text{Price of arecanut}} + \frac{\text{Yield x price of banana}}{\text{Price of arecanut}}$$

Results and Discussion

Quantification of biomass production

The recyclable biomass produced from different component crops in arecanut based cropping system varied between 8724-10354 kg ha^{-1} year^{-1} (Table 1). The arecanut crop accounted for maximum biomass production of 42 % from the cropping model followed by cocoa (24%). Weeds contributed 15 % of the total biomass. Conversion of the recyclable biomass into vermicompost resulted in 82-87 % recovery. The estimated nutrient content in vermicompost was 1.71% N, 0.21% P and 0.43% K.

Table 1. Biomass production (kg ha^{-1}) from the component crops in arecanut based cropping system

Treatments	Arecanut	Cocoa	Clove	Banana	Weeds	Total
		1999-2000				
Pre-experimental	5270	3915	763	-	-	9948
		Mean of 2001 and 2002				
Control +OMR	3656	2293	542	962	1271	8724
1/3rd NPK+OMR	3634	2499	596	1221	1648	9599
2/3rd NPK+OMR	4318	2481	462	1269	1699	10229
Full NPK+OMR	4641	2077	472	1939	1225	10354
CD (0.05)	485.5	NS	NS	378.0	NS	869.4

Yield of component crops

In ABCS, yield of arecanut, cocoa and clove did not differ significantly due to nutrient management (Table 2). However, the response of banana to nutrient management was significant. Mean data of three years revealed that recommended NPK + OMR and 1/3rd of recommended NPK+OMR increased the dry kernel yield marginally by 5.6 and 6.5 per cent, respectively over the yield levels in 1999. The results indicated that adoption of nutrient management approach with organic matter recycling has resulted in rejuvenating the old plantation besides improving the yield marginally. In cocoa, the yield improvement in 2002 with organic matter recycling,

Table 2. Yield of component crops (kg ha^{-1}) as influenced by nutrient management in arecanut based cropping system

Year	Treatment	Arecanut (Dry kernel)	Cocoa (Dry bean)	Clove (Dry flower bud)	Banana Bunch weight	Arecanut ** equivalent	Coffee (Dry berry)
1999*	Control +OMR	1460	206.4	29.0	-	1722	-
	1/3rd NPK+OMR	1420	238.6	28.8	-	1717	-
	2/3rd NPK+OMR	1530	270.9	23.9	-	1854	-
	Full NPK+OMR	1490	266.6	27.5	-	1815	-
					mean	**1777**	
	CD (0.05)	NS	NS	NS			
2000	Control +OMR	1460	436.4	29.8	1436	2069	-
	1/3rd NPK+OMR	1400	421.0	67.3	2809	2149	-
	2/3rd NPK+OMR	1480	499.0	31.7	2150	2216	-
	Full NPK+OMR	1600	410.6	35.8	4461	2412	-
					mean	**2212**	
	CD (0.05)	NS	NS	26.57	836.2		
2001	Control +OMR	1460	539.6	32.4	3185	2312	81.8
	1/3rd NPK+OMR	1428	421.4	44.0	2877	2147	86.5
	2/3rd NPK+OMR	1444	498.8	23.1	2843	2216	40.4
	Full NPK+OMR	1509	462.2	27.0	5182	2413	101.5
					mean	**2272**	-
	CD (0.05)	NS	NS	NS	1543.4		
2002	Control +OMR	1564	713.0	38.8	2660	2572	5.4
	1/3rd NPK+OMR	1709	570.5	95.8	2899	2664	18.7
	2/3rd NPK+OMR	1497	639.0	155.0	4392	2717	12.6
	Full NPK+OMR	1614	690.0	100.8	6511	2963	20.5
					mean	**2769**	-
	CD (0.05)	NS	NS	NS	2569.4		
Mean (2000-02)	Control +OMR	1495	563	33.7	2427	**2318**	
	1/3rd NPK+OMR	1512	471	69.0	2862	**2320**	
	2/3rd NPK+OMR	1474	546	69.9	3129	**2383**	
	Full NPK+OMR	1574	521	54.5	5385	**2596**	

Note: * - Pre-experimental ** - CD (0.05) for years - 249.5; for treatments - NS

1/3rd NPK + OMR, 2/3rd NPK + OMR and recommended NPK + OMR was 507, 332, 368 and 423 kg ha^{-1} over their respective yield levels in 1999. This shows that cocoa did not respond to fertilizer application in the system due to highly shaded conditions existing in the system. Mean of three year data indicated a yield increase of 95-172 % with nutrient management. With nutrient management, the yield of clove improved considerably over the years and the increase was maximum with 2/3rd NPK + OMR (131.1 kg ha^{-1}) in 2002 over pre experimental yield level. From mean data (2000-02), it was noticed that there was substantial yield increase of 98 -193% with conjunctive use of inorganic fertilizers and biomass recycling compared to pre-experimental yield. The yield increase, though not significant among treatments, appeared to be by and large due to OMR and better soil fertility status in pre-experimental stage.

Recommended NPK + OMR significantly increased the cumulative yield of banana (16154 kg ha^{-1}) by 72-122 % over other nutrient management treatments. Both main and ratoon crops of banana responded significantly to integrated use of recommended NPK + OMR. Adoption of only OMR reduced the yield of second ratoon crop, while integrated use of 2/3rd or recommended NPK + OMR improved the yields of ratoon crop considerably. Combined use of 1/3rd NPK + OMR sustained the yield levels of ratoon crop. The results show the importance of combined use of recommend chemical fertilizers and OMR to sustain and improve the yield of main and ratoon crop of banana due to its heavy feeding nature.

Arecanut equivalent yield was calculated to know the overall productivity of the system per unit area. The equivalent yield from the ABCS increased significantly from 1777 kg ha^{-1} in 1999 to 2769 kg ha^{-1} in 2002 (Table 1). Though nut equivalent yields did not vary significantly due to nutrient management, the improvement in yield over the years clearly indicates the impact of nutrient management approach on rejuvenation of old plantation.

pH

The soil was examined in different crop rhizospheres in ABCS during 2002 and the data are presented in Table 3 along with the earlier reported pH values. Soil pH was significantly influenced due to different crops, while it was at par among nutrient treatments. Cocoa crop rhizosphere registered significantly lower soil pH (5.00) than other crop rhizospheres. It might be due to continuous litter fall and slow decomposition of organic residues and release of organic acids in cocoa basin. Overall, positive impact of ABCS was noticed with increase in soil pH to 5.22 and 4.95 at 0-30 and 30-60 cm soil depth, respectively in 2003 compared to the reported value of 4.70 and 4.45 in 1988.

Table 3. Influence of crop rhizospheres and nutrient management on pH at different soil depths in ABCS in 2003

Crop/	0-30 cm					30-60 cm				
Treatment	Control +OMR	1/3rd NPK+ OMR	2/3rd NPK+ OMR	Full NPK+ OMR	Mean	Control + OMR	1/3rd NPK+ OMR	2/3rd NPK+ OMR	Full NPK+ OMR	Mean
Areca+ Pepper	5.14	5.06	5.24	5.12	5.14	4.92	4.82	4.85	4.74	4.83
Cocoa	5.07	5.27	4.82	4.85	5.00	4.60	5.02	4.86	4.67	4.79
Clove	4.93	5.53	5.33	5.87	5.41	4.83	4.94	4.67	4.71	4.79
Banana	5.47	5.27	5.47	5.30	5.38	5.34	5.24	5.30	5.14	5.25
Coffee	5.28	5.08	5.11	5.17	5.16	5.10	4.97	5.04	5.15	5.07
Mean	5.18	5.24	5.19	5.26	5.22	4.96	5.00	4.94	4.88	4.95
Crop(C)	CD (0.05)			0.127				0.096		
Treat(T)	CD (0.05)			NS				NS		
C x T	CD (0.05)			0.254				0.192		

Reported pH values (1988)

Soil Depth (cm)	Arecanut + pepper	Cocoa	Clove	Coffee
0-25	4.6	4.5	4.9	5.1
25-50	4.3	4.5	4.7	5.2
50-75	4.7	5.2	4.6	5.5

Source (Abdul Khader *et al.*, 1992)

Organic carbon

The organic carbon was significantly influenced due to crop rhizospheres and nutrient management at 0-30 cm depth and only crop rhizospheres at 30-60 cm depth (Table 4). There was no significant variation in organic carbon content in different years at 0-30 cm depth while significant variation was observed at 30-60 cm depth. This might be due to faster decomposition of organic matter in tropical climate due to fairly equable temperatures (19-36 °C) throughout the year at this location and recycling of organic wastes back to the system in the form of vermicompost after initiation of the experiment. Organic carbon content was significantly higher in arecanut + pepper rhizospheres (1.87%) than in cocoa (1.62%) and clove (1.66%). Organic carbon content improved slightly in arecanut basins at 0-30 cm soil depth over 2-year period. Overall in the system, OMR maintained significantly higher organic carbon content (1.83 %) followed by 2/3rd NPK + OMR (1.75%). The

Table 4. Influence of crop rhizospheres and nutrient management on organic carbon content (%) in ABCS over the years

Treatment	Arecanut + pepper				Cocoa				Clove			
	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002	Mean
						0-30 cm						
OMR	1.89	2.00	2.05	1.98	1.91	1.59	1.66	1.75	1.74	1.65	1.89	1.76
1/3 NPK + OMR	1.75	1.88	1.93	1.86	1.56	1.67	1.30	1.51	1.74	1.49	1.60	1.61
2/3 NPK + OMR	1.92	1.92	1.93	1.92	1.74	1.59	1.40	1.58	1.81	1.82	1.58	1.74
Full NPK + OMR	1.61	1.94	1.57	1.71	1.52	2.02	1.47	1.67	1.75	1.35	1.51	1.54
Mean	1.79	1.94	1.87	1.87	1.68	1.72	1.46	1.62	1.76	1.58	1.65	1.66
						30-60 cm						
OMR	1.20	1.39	1.22	1.27	1.58	1.07	1.05	1.23	1.27	1.07	1.21	1.18
1/3 NPK + OMR	1.12	1.31	1.33	1.25	1.37	1.06	1.03	1.26	1.20	1.03	1.32	1.18
2/3 NPK + OMR	1.49	1.33	1.41	1.41	1.31	1.14	1.14	1.20	1.36	1.12	1.19	1.22
Full NPK + OMR	1.50	1.23	1.40	1.38	1.25	1.14	1.11	1.17	1.25	0.97	1.05	1.09
Mean	1.33	1.31	1.34	1.33	1.38	1.10	1.16	1.22	1.27	1.05	1.19	1.17

	0-30 cm CD (0.05)	30-60 cm CD (0.05)
Year (Y)	NS	0.073
Crop rhizosphere (C)	0.101	0.097
Treatment (T)	0.116	NS
C x T	NS	NS
Y x C x T	0.285	NS

application of chemical fertilizers might have enhanced the rate of organic matter decomposition and thus resulting in less organic carbon content in NPK+OMR treatments. The organic carbon content under banana (1.58-1.78%) and coffee (1.51-1.77%) was improved over initial status (1.4%) in the interspace of the cropping system. The organic carbon content before establishment of the system in 1983 varied between 0.60 to 1.05% at different soil depth as reported by Abdul Khader *et al.* (1992). Overall, the combination of cropping system approach and nutrient management resulted in enrichment of organic carbon (1.24 -1.72 %), an increase of 64 – 107 % in 2002 when compared to the organic carbon status in 1983. *In situ* addition of organic matter through dead and decayed roots would have been resulted in organic carbon enrichment in system. Armson (1997) reported that 20-30% of the total living biomass of trees is in roots and there is a constant addition of organic matter and nutrients through dead and decayed roots.

Table 5. Influence of crop rhizospheres and nutrient management on mineral N content (ppm) in ABCS over the years

Treatment	Arecanut + pepper				Cocoa				Clove		
	2000	2001	2002	Mean	2000	2001	2002	Mean	2001	2002	Mean
					0-30 cm						
OMR	95.7	87.8	94.5	92.7	98.0	69.8	72.6	80.1	77.7	76.1	76.9
1/3 NPK + OMR	99.2	85.5	79.5	88.1	70.0	75.4	71.5	72.3	70.9	80.7	75.8
2/3 NPK + OMR	100.7	83.3	84.1	89.4	42.0	73.2	70.3	61.8	78.8	85.4	82.1
Full NPK + OMR	99.3	87.8	87.6	91.6	28.0	76.5	72.6	59.1	82.2	78.4	80.3
Mean	98.7	86.1	86.4	90.4	59.5	73.7	71.8	68.3	77.4	80.1	78.8
					30-60 cm						
OMR	88.7	75.4	62.2	75.4	84.0	58.5	64.5	69.0	58.5	65.7	62.1
1/3 NPK + OMR	99.2	83.3	57.6	80.0	77.0	63.0	69.2	69.7	61.9	71.5	66.7
2/3 NPK + OMR	107.6	68.7	61.1	79.1	56.0	49.5	65.7	57.1	67.5	71.5	69.5
Full NPK + OMR	95.7	68.7	63.4	75.9	56.0	67.5	63.4	62.3	86.7	71.5	79.1
Mean	97.8	74.0	61.1	77.6	68.3	59.7	65.7	64.5	68.7	70.0	69.3

	0-30 cm CD (0.05)	30-60 cm CD (0.05)
Year (Y)	NS	0.073
Crop rhizosphere (C)	0.101	0.097
Treatment (T)	0.116	NS
C x T	NS	NS
Y x C x T	NS	NS

Mineral nitrogen ($NO_3^- + NH_4^+$)

Mineral N content was significant in different crop rhizospheres due to nutrient management in ABCS at 0-30 cm soil depth, while no significant variation was observed among nutrient management treatments at 30-60 cm soil depth (Table 5). Mineral N (ppm) was significantly higher in arecanut + pepper rhizospheres (90.4) at 0-30 cm depth than in cocoa (68.3) and clove (78.8). OMR maintained significantly higher mineral N in arecanut + pepper and cocoa rhizosphere than in clove basin. Depletion of mineral N in arecanut + pepper and cocoa rhizospheres with application of chemical fertilizers compared to OMR implies higher N uptake by crops or possible losses due to leaching, volatilization etc. Thus, ABCS can be self sustainable with respect to the availability of mineral N.

Available phosphorus

At both soil depths the available P content varied significantly in different crop rhizospheres and years, while variation was not observed due to nutrient management (Table 6). Available P content was significantly higher in arecanut + pepper rhizosphere (64.5 ppm at 0-30 cm and 18.6 ppm at 30-60 cm depth). The available P content was drastically reduced in cocoa (26.2 ppm) and clove (37.6 ppm) rhizospheres at 0-30 cm depth compared to arecanut + pepper rhizosphere. The more or less similar nutrient status in 2000 irrespective of treatments might be due to maintenance of the system previously with recommended practices. Unlike in arecanut, the initial available P content was in medium range in cocoa basins. Generally, phosphorus availability in acid soils is low (Perur, 1996). With

Table 6. Influence of crop rhizospheres and nutrient management on available P content (ppm) in ABCS over the years

Treatment	Arecanut + pepper				Cocoa				Clove			
	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002	Mean
					0-30 cm							
Mean	14.6	7.5	33.7	18.6	4.6	2.9	18.5	8.7	4.8	3.1	12.2	6.7
OMR	58.2	36.9	98.8	64.6	16.2	15.8	32.6	21.5	65.3	31.5	37.8	44.9
1/3 NPK + OMR	62.2	73.9	81.2	72.4	21.4	14.8	46.1	27.4	38.6	24.0	37.6	33.4
2/3 NPK + OMR	74.9	33.0	70.7	59.5	35.6	19.4	39.0	31.3	38.4	28.3	46.9	37.9
Full NPK + OMR	68.9	42.1	72.9	61.3	17.1	23.2	33.5	24.6	30.3	29.9	42.5	34.3
Mean	66.1	46.5	80.9	64.5	22.6	18.3	37.8	26.2	43.1	28.4	41.2	37.6
					30-60 cm							
OMR	8.0	6.9	32.8	15.9	1.7	3.6	16.3	7.2	8.1	3.7	11.7	7.8
1/3 NPK + OMR	7.3	8.8	42.4	19.5	5.3	3.2	22.5	10.3	3.0	2.4	11.0	5.5
2/3 NPK + OMR	20.7	6.8	29.1	18.9	9.4	2.4	17.1	9.6	3.9	3.3	13.2	6.8
Full NPK + OMR	22.5	7.7	30.3	20.2	1.9	2.6	18.1	7.5	4.0	3.2	12.7	6.6
Mean	14.6	7.5	33.7	18.6	4.6	2.9	18.5	8.7	4.8	3.1	12.2	6.7
	0-30 cm	30-60 cm										
	CD (0.05)	CD (0.05)										
Year (Y)	6.59	2.79										
Crop rhizosphere (C)	7.76	2.72										
Treatment (T)	NS	NS										
C x T	NS	NS										
Y x C x T	22.85	NS										

recycling of organic residues, organic P availability will be more, as organic phosphates are less readily fixed than inorganic P. This would have resulted in higher availability of P and similar nutrient status in all treatments and crop basins. In general the P content was higher at surface level (0-30 cm) and drastically reduced at 30-60 cm. This denotes the less mobility of phosphorus in soil. It might be due to strong P adsorption in acid laterite soils. Further, the available status of N and P in ABCS reveals that there is greater scope for internal recycling of N and P due to increased biomass production and utilization through vermicomposting.

Available potassium

Availability of K varied significantly in different years, crops and treatments at both soil depths (Table 7). Significant increase in available K content was noticed with integration of OMR and chemical fertilizers over only OMR at both soil depths in all crop rhizospheres. This implies that OMR is not sufficient to maintain available K in soil and application of chemical fertilizers is essential in laterite soils due to leaching of K and lesser K content in organic residues. In general, available K content reduced in cocoa

Table 7. Influence of crop rhizospheres and nutrient management on available K content (ppm) in ABCS over the years

Treatment	Arecanut + pepper				Cocoa				Clove			
	2000	2001	2002	Mean	2000	2001	2002	Mean	2000	2001	2002	Mean
					0-30 cm							
OMR	43.9	41.0	62.6	49.2	82.1	94.5	59.6	78.7	65.4	33.9	67.3	55.5
1/3 NPK + OMR	53.9	73.4	61.1	62.8	129.9	102.8	81.4	104.7	70.9	66.6	79.1	72.2
2/3 NPK + OMR	62.8	59.4	73.1	65.1	143.1	102.8	70.8	105.6	82.3	73.5	90.3	82.0
Full NPK + OMR	61.0	72.0	77.6	70.2	146.0	112.3	80.8	113.0	82.5	142.5	91.4	105.5
Mean	55.4	61.5	68.6	61.8	125.3	103.1	73.2	100.5	75.3	79.1	82.0	78.8
					30-60 cm							
OMR	30.2	42.0	48.4	40.2	64.4	78.0	55.5	66.0	70.8	33.3	60.9	55.0
1/3 NPK + OMR	47.4	57.3	62.4	55.7	90.0	64.3	63.7	72.7	172.5	70.1	72.0	104.9
2/3 NPK + OMR	49.6	42.3	74.5	55.5	94.8	75.2	53.1	74.4	241.7	109.7	91.1	147.5
Full NPK + OMR	44.7	58.1	80.3	61.0	94.8	90.0	72.2	85.7	237.7	167.6	88.3	164.5
Mean	43.0	49.9	51.4	53.1	86.0	76.9	61.1	74.7	180.7	95.2	78.1	118.0
		0-30 cm			30-60 cm							
		CD (0.05)			CD (0.05)							
Year (Y)		7.64			7.41							
Crop rhizosphere (C)		9.18			7.70							
Treatment (T)		10.60			8.89							
C x T		NS			NS							
Y x C x T		26.46			25.66							

rhizosphere over the years, while it was maintained in clove rhizosphere in all the years despite high recommended rate of K i.e., 750 g K_2O per tree per year. The available K content in cocoa rhizosphere reduced drastically from 125.3 ppm in 2000 to 73.2 ppm in 2002 at 0-30 cm soil depth. Similar trend was noticed in 30-60 cm soil depth. Manikandan *et al.* (1987) noticed a negative balance in available K in arecanut-cacao system indicating the higher requirement of potassium. In arecanut + pepper rhizosphere the reduction was marginal, whereas in clove rhizosphere a marginal increase in available K content was noticed over the years. The reduction in availability of K indicates the heavy K feeding nature of cocoa (Nelliat, 1978) and probable luxury consumption.

The overall results of adoption of ABCS with nutrient management approach revealed that the system can be self-sustainable over the years as similar yield levels and soil nutrient status were noticed with OMR and integrated use of chemical fertilizers and OMR. Further, the study indicated that application of N and P through inorganic fertilizers could be reduced or skipped, while the system proved exhaustive with regard to the availability of K. The exhaustion of K probably indicates the necessity of including K in the fertilizer schedule of the system, as organic matter cannot supplement K requirement of crops as all the component crops are heavy feeders of this major nutrient.

Acknowledgements

The authors would like to thank the Director, Central Plantation Crops Research Institute, Kasargod, India for full cooperation and World Bank sponsored National Agricultural Technology Project (NATP) for funding this project.

References

Abdul Khader, K.B., Balasimha, D. and Bhat, N.T.1992. Resource use in arecanut based high density multispecies cropping system *J. Plantation Crops* **20** (Supplement): 19-24.

Armson, K. A. 1997. Forest Soils: Properties and processes. University of Toranto Press, Toranto, Canada.

Badrinath, Gajendragad, M. R. and Balakrishna Rao, K. 1998. Distribution of micronutrients in laterite soils of Puttur in relation to some soil properties. In: *Red and Lateritic soils* (Eds) (Sehgal J, Blum W.E. and Gajbhiye, K S.) Volume 1. 271- 274.

Bavappa, K.V.A., Kailasam, C., Khader, K.B.A., Biddappa, C.C., Khan, H.H., Kasturi Bai, K.V., Ramadasan, A., Sundararaju, P., Bopaiah, B.M., George V. Thomas., Misra, L.P., Balasimha, D., Bhat, N. T. and Bhat, K.S. 1986. Coconut and arecanut based high density multispecies cropping systems. *J. Plantation Crops* **14**: 74-87.

Bhat, K. S. 1978. Agronomic research in arecanut – a review. *J. Plantation Crops* **6**: 67-80.

Jackson, M L 1967. *Soil Chemical Analysis.* Prentice Hall of India Pvt Ltd., New Delhi.

Lahov, E. and Turner, D.W. 1983. *Banana nutrition*. Plant Bulletin No. 7. International Potash Institute, Berne, Switzerland.

Manikandan, P., Joshi, O.P. Khan, H.H., Mohapatra, A.R. and Biddappa, C.C. 1987. Nutrient profile in an arecanut-cacao system on a laterite soil. *Tropical Agriculture* **64**(1):13-16.

Nair, P. K. R. 1999. Agroforestry research at a crossroads. *Annals of Arid Zone* **38** (3 & 4): 415-430.

Nelliat, E. V. 1978. K nutrition of plantation crops- a review of work done in India. In: *Potassium in Soils and Crops*, New Delhi, Potash Research Institute of India. 367-377.

Perur, N. G. 1996. Acid soils of Karnataka. In: *Acid Soils of India* (Eds. Mahapatra, I.C., S. C. Mandal, C. Misra, G. N. Mitra and N. Panda), Indian Council of Agricultural Research, New Delhi pp. 165-173.

Ravi Bhat, Reddy, V.M. and Khader, K.B.A. 1999. Areca based high density multispecies cropping system in coastal Karnataka. *J. Plantation Crops* **27**(1): 22-26.

Ravi Bhat. 2002. Climate, soil and agronomy. In *Cocoa* (Ed. D. Balasimha), Central Plantation Crops Research Institute, Kasargod, Kerala, India.

Rethinam, P. 1990. Potassium nutrition in plantation crops. In *Proceedings of Seminar on potassium for plantation crops*. Nov. 6-8, 1990 pp 7-15.

Tandon, H.L.S. and Ranganathan, V. 1988. Fertilizers and their management in plantation crops. In: *Fertilizer management in plantation crops – A guide book*., (Ed. Tandon, H.L.S.) Fertilizer Development and Consultation Organization, New Delhi. pp 26-80.

Young, A. 1997. *Agroforestry for Soil Management*. CAB International, U.K pp 98-110.