Nutrient profile in an arecanut-cacao system on a laterite soil

P. Manikandan, O.P. Joshi, H. Hameed Khan, A.R. Mohapatra and C.C. Biddappa

Central Plantation Crops Research Institute, Kasaragod 670 124, Kerala, India

Received August 1985

The nutrient profile within an arecanut-cacao system on a laterite soil as attained 13 years after planting and as influenced by spacing, supply and exhaustion of nutrients was examined. 100 g of N, 40 g of P_2O_5 and 140 g of K_2O tree^{-1} year^{-1} were adequate for cacao; larger dressings gave no further benefit. A negative balance in available K in the system suggests the higher requirement/uptake of K by both crops and its consequent importance in the nutrition of the arecanut-cacao system. Inclusion of Zn in the fertilizer schedule, especially if the crops are closely planted, is also desirable. In addition, the results showed the superiority of the spacing, *viz.* arecanut (3.3 × 3.3 m) – cacao (3.3 × 3.3 m) over arecanut (2.7 × 2.7 m) – cacao (2.7 × 5.4 m).

Keywords: Arecanut-cacao mixed crop system; Laterite soil; Nutrient profile; India

That a good system of agriculture should maintain soil fertility without affecting its production potential is well known (Russell, 1973). Growing of inter-crops within plantations of perennials such as arecanut, coconut, *etc.* is likely to enrich the inter-spaces with nutrients and increase the overall production per unit area. According to Nelliat and Iyer (1977), intercropping as applied to plantation crops refers to the growing of annuals or biennials in the interspaces of the main crop and mixed cropping is used to denote the growing of perennial crops in the interspaces.

In a pure stand of arecanut (*Areca catechu* L.), some 7580 m^2 are available for growing other crops since only a 2420 m^2 area is utilised by arecanut in one hectare of land. This is based on the observation that about 80% of arecanut roots are confined to within 75 cm from the trunk (Bhat and Leela, 1969). Successful cultivation of crops such as turmeric, black pepper, cardamom (Abraham, 1956), banana (Bavappa, 1951; Bhat, 1974), yam, ginger, and pineapple (Bhat, *ibid.*) in arecanut gardens is well documented. Cacao (*Theobroma cacao* L.), a shade-loving crop, is ideally suited for growing with arecanut (Bhat and Leela, 1968; Bhat, 1978). The present Paper examines the nutrient profile within an arecanut-cacao system, as attained 13 years after planting, and as influenced by spacing, supply and exhaustion of nutrients.

Materials and methods

The fertilizer-*cum*-spacing trial of arecanut-cacao at the Central Plantation Crops Research Institute Regional Station, Vittal (Karnataka State, 12.45°N; 75.10°E) formed the basis for the present investigation. The experiment was laid out in 1970 in a confounded factorial design with six spacings, two levels of fertilizers and four replications. Arecanut ('South Kanara' cultivar) and cacao (*Forastero* variety), grown at two spacings, *viz.* arecanut (2.7 × 2.7 m) – cacao (2.7 × 5.4 m) and arecanut (3.3 × 3.3 m) – cacao (3.3 × 3.3 m), were selected for the present study. Treatment details are given in Table 1. Arecanut palms of an adjacent monocrop, considered for comparison, were planted at 2.7 × 2.7 m spacing and were supplied with the same levels of fertilizer and organic matter as the arecanut in the mixed crop.

Soil samples were collected from arecanut basins, cacao basins and the interspaces. In all cases (arecanut-cacao mixed crop and arecanut monocrop) four cacao trees and/or four arecanut palms were selected for sampling purpose. Soil samples were collected from 0–25, 25–50 and 50–100 cm depths, from arecanut basins 40 cm away from the bole and from cacao basins 50 cm away from the trunk. For arecanut, leaf samples were collected from the leaflets taken from both sides of the mid-region of leaf number 3 (from the top). The midrib, the basal and distal portions and the marginal veins were discarded. Cacao leaf samples were collected as suggested by Chapman (1975). Soil and leaf samples were collected simultaneously during May.

Soil samples (2 mm fraction) were analysed for organic C, available P and K, and pH by standard procedures (Jackson, 1967). Available Cu, Zn, Mn and Fe were extracted by the DTPA procedure of Lindsay and Norvel (1969). Leaf samples were washed with 0.1% Teepol followed by tap water and distilled water, dried in an air-draught oven at 65 ± 5°C and powdered in a Wiley mill with steel blades. Total N in the leaf samples (0.5 mm fraction) was estimated by micro-Kjeldahl method (Jackson, *ibid.*). The powdered leaf samples were digested in a 1:2 perchloric-nitric acid mixture. P (vanado-molybdate) and K (flame photometry) were estimated following Piper (1966). Cu, Zn, Fe and Mn in soil extracts and leaf digests were estimated using a Varian Techtron atomic absorption spectrophotometer. Bulk density of the soil samples was estimated (Black, 1965) and was used to calculate the nutrient contents of the soil on a volume basis.

Results and discussion

Results of soil pH and the available nutrients (0–100

Contribution No. 476, Central Plantation Crops Research Institute, Kasaragod

0041-3216/87/010013-04 $03.00
© 1987 Trop. Agric. (Trinidad)

Table 1 Spacing and manurial schedule of the arecanut-cacao treatments

Treatment	Crop	Spacing (m)	Manurial schedule[a] g $palm^{-1}$ yr^{-1}		
			N	P_2O_5	K_2O
T_1	Arecanut[b]	2.7 × 2.7	100	40	140
	Cacao	2.7 × 5.4	100	40	140
T_2	Arecanut[b]	2.7 × 2.7	100	40	140
	Cacao	2.7 × 5.4	200	80	280
T_3	Arecanut[b]	3.3 × 3.3	100	40	140
	Cacao	3.3 × 3.3	100	40	140
T_4	Arecanut[b]	3.3 × 3.3	100	40	140
	Cacao	3.3 × 3.3	200	80	280

[a] N as urea, P_2O_5 as single superphosphate and K_2O as muriate of potash
[b] In addition, 12 kg green leaf and 12 kg cattle manure are added to the basin of every arecanut palm, each year in September. Fertilizers are applied in two doses, half during February and half during September

cm), calculated on a volume basis, under different treatments are given in Table 2. Soils were moderately acidic with arecanut basins of the monocrop recording significantly higher pH than the other basins and the interspaces; the higher pH recorded in the arecanut basins might be due to the application of cattle manure. Cacao leaf-fall is not confined to cacao basins but is fairly uniformly spread over the entire area (Bhat, S.K., personal communication). Cacao leaf fall and its subsequent mineralisation must therefore have reduced the pH of the arecanut basins in the mixed crop compared with that of the monocrop. Cacao basins recorded lower pH values due to the addition of inorganic fertilizers alone. Doubling the dose of fertilizers applied to cacao basins reduced the pH more than did the single dose. Interspaces recorded generally a higher pH than the cacao basins.

Basins of arecanut and cacao plants were found to be rich in organic matter compared with the interspaces. The cacao leaf-fall seems to have influenced the organic matter status of the basins as well as of the interspace, especially in T_2 and T_4 (Table 2). This is due to the higher fertilizer application to cacao in these treatments which probably resulted in higher biomass which, in turn, led to larger quantities of leaf litter being added to the soil.

The available P status of both cacao and arecanut basins was high, those of arecanut generally recording higher values. The interspaces were generally low in their available P status and the fertilization to basins seems not to influence the interspace P fertility, whereas the mixed cropping with cacao had resulted in a general increase in available P of the interspaces compared with the monocrop.

In general, the available K levels were found to be high in basins and interspaces, though the basins recorded higher values; arecanut basins of the monocrop recorded the highest value. The heavy K-feeding nature of both cacao and arecanut (Nelliat, 1978), probable luxury consumption and the consequent immobilisation of considerable quantities of K in the plants (von Uexkull, 1978), and root competition in the mixed cropping could have resulted in a lower available K status in the mixed cropping compared with monocropping. The results obtained are in conformity with the reports of von Uexkull (*ibid.*) that a good crop of cacao would remove over 170 kg K ha^{-1}; even good soils will not

Table 2 pH and available nutrient content (0–100 cm) in soil under different treatments

Treatment		pH	Org. C ($kg\ m^{-3}$)	Available nutrients ($g\ m^{-3}$)					
				P	K	Cu	Zn	Fe	Mn
Monocrop	areca basin	6.3	8.4	22.2	352.7	10.3	11.2	34.3	105.6
	interspace	5.7	6.5	1.5	153.0	7.9	1.6	32.0	60.6
T_1	areca basin	6.1	9.1	47.6	200.2	14.2	5.3	78.8	107.4
	cacao basin	5.5	6.2	9.3	154.7	11.2	6.6	44.8	108.5
	interspace	5.7	5.9	5.5	170.4	5.4	0.8	30.9	65.4
T_2	areca basin	5.5	11.0	72.5	151.9	18.5	2.8	62.4	88.2
	cacao basin	4.9	8.9	97.9	293.0	15.0	2.9	88.8	113.4
	interspace	5.5	7.7	3.3	132.3	9.1	1.0	46.0	61.9
T_3	areca basin	5.9	8.4	23.4	129.6	16.3	14.5	42.3	114.4
	cacao basin	5.4	7.3	17.2	88.8	14.3	8.5	59.4	143.6
	interspace	5.5	6.1	1.6	98.4	11.4	1.8	37.7	94.8
T_4	areca basin	5.9	15.3	81.3	259.1	32.5	30.9	121.1	229.9
	cacao basin	5.2	8.9	55.0	179.6	21.7	9.8	81.6	152.9
	interspace	5.7	7.8	5.5	120.2	13.7	3.5	49.8	77.5
LSD, $P = 0.05$	areca basin	0.11	2.99	NS	58.3	10.1	12.3	26.8	78.2
	cacao basin	0.17	1.29	24.9	78.9	6.1	4.7	13.7	NS
	interspace	0.09	1.08	2.2	39.2	3.3	1.1	5.1	8.5

NS, Not significant

be able to supply K at such rates (*plus* the K immobilised in the living tree) for long. Doubling the fertilizer dose to cacao nearly doubled the available K status of the cacao basins.

The available micronutrients in arecanut and cacao basins were quite adequate, though the interspaces had low available contents. Mixed cropping of cacao and arecanut had increased the available Cu, Fe and Mn contents of the interspaces as well as the arecanut basins, compared with monocropping; the cacao leaf-fall and its subsequent mineralisation must have enriched the interspaces with these nutrients. Interestingly, the available Zn in the interspaces in general and in the arecanut basins of T_1 and T_2 was low in comparison with the monocrop. Though cacao leaf-fall would have enriched the soil available Zn, the susceptibility of this nutrient to leaching (Aubert and Pinta, 1977), especially in this region where annual rainfall is ≈ 3200 mm, could have led to depletion of the available Zn in the soil. Leaching studies carried out with the soil of this region (Anonymous, 1985) also indicated a heavy leaching of Zn, followed by that of Mn and Cu, due to NPK fertilization. However, Fe was not leached at all. A decrease in the pH of the system from mixed cropping would have resulted in a further loss of Zn from leaching in comparison with the monocrop. Closer planting of arecanut and cacao, as in T_1 and T_2, would have further accentuated the loss of soil Zn due to intensive mining and exhaustion in addition to leaching losses.

Table 3 shows the leaf nutrient concentration of arecanut and cacao in different treatments. The monocrop of arecanut recorded the highest leaf nutrient concentrations of N, P and K, and mixed cropping cacao in arecanut lowered the leaf nutrient concentration. The fact that the leaf nutrient concentration of cacao was not significantly increased by doubling the fertilizers level to cacao suggests that cacao does not benefit from such excessive fertilization. This corroborates the observations (Anonymous, 1983) that the application of a double dose of fertilizers did not increase the cacao yield significantly. It is interesting to note that none of the treatments/fertilizer levels raised the leaf N, P, K concentrations of cacao above suggested critical levels (Haque and Aggrey, 1980). This indicates the need for establishing the critical levels for foliar N, P and K to suit Indian conditions. It is seen from the Table that mixed cropping significantly affected the leaf nutrient concentration of arecanut in comparison with the monocrop only for P and Cu. Excepting Zn, the concentration of no other leaf nutrient in cacao is affected significantly by the treatments.

In order to understand the extent to which the interspace in arecanut is exploited/enriched due to mixed cropping with cacao, the available nutrient contents were calculated for one hectare-metre separately for each of arecanut basin, cacao basin and interspace. This calculation is based on the observation that arecanut roots are confined mainly within a circle of 75 cm radius from its trunk (Bhat and Leela, 1969) and those of cacao within 100 cm radius from its trunk (Bhat and Bavappa, 1972). Subsequently, the net gain/loss in the available nutrient contents of the system over monocrop was worked out (Table 4), taking into account the existing nutrient status of different treatments, the actual nutrient input in all the treatments including monocrop during a year, but excluding the nutrient contribution from the fallen leaves and the added organic matter. This gives an idea of the relative nutrient status of the system as influenced by different treatments and their effects. It is seen that the mixed cropping resulted in the gain of nutrients such as P, Cu, Fe and Mn. A negative balance in available K in all treatments indicates the higher requirement/uptake of K by both crops and its consequent importance in the arecanut-cacao system. While there is a loss of Zn in the system in T_1 and T_2, there is a net gain in treatments T_3 and T_4. This might be due to the larger number of plants in T_1 and T_2 (2056 plants ha^{-1}) compared with T_3 and T_4 (1836 plants ha^{-1}) and the consequent increased uptake by the crops. The highly leached acidic nature of the soils, which are deficient in Zn (Aubert and Pinta, 1977; Anonymous, 1985), coupled with the exhaustion of Zn by the system components, probably indicates the necessity of including Zn in the fertilizer schedule of such a mixed cropping system, especially when the crops are closely planted as in T_1 and T_2. From Table 4, it is seen that treatments T_3 and T_4 showed a net gain for most of the nutrients compared with T_1 and T_2. This indicates the superiority of the spacing, arecanut (3.3 × 3.3 m) – cacao (3.3 × 3.3 m) over arecanut (2.7 × 2.7 m) – cacao (2.7 × 5.4 m) and corroborates reports that the combined yield of arecanut and cacao was maximal when both crops were spaced at 3.3 × 3.3 m (Sannamarappa and Muralidharan, 1982). Balasimha and Subramonian

Table 3 Leaf nutrient concentration of arecanut and cacao in different treatments

Treatment		N	P	K	Fe	Zn	Mn	Cu
			%			ppm		
Arecanut	(monocrop)	2.25	0.20	1.59	170.7	32.8	85.5	11.3
Arecanut	T_1	2.14	0.18	1.43	216.4	32.1	98.6	21.3
Arecanut	T_2	2.26	0.18	1.40	163.3	25.2	110.6	16.1
Arecanut	T_3	2.01	0.17	1.28	205.7	33.1	122.9	27.7
Arecanut	T_4	2.16	0.18	1.41	166.7	31.3	89.5	32.5
LSD, $P = 0.05$		NS	0.011	NS	NS	NS	NS	11.41
Cacao	T_1	1.30	0.12	1.63	134.7	143.0	881.5	19.6
Cacao	T_2	1.46	0.10	1.53	120.8	72.1	542.5	28.0
Cacao	T_3	1.36	0.10	1.40	152.1	88.6	595.5	18.3
Cacao	T_4	1.42	0.13	1.20	109.7	96.3	619.1	19.3
LSD, $P = 0.05$		NS	NS	NS	NS	47.5	NS	NS

NS, Not significant

Table 4 Net gain (+) or loss (−) in the system over monocropping in 1 ha, 1 m depth of arecanut due to mixed cropping with cacao

Treatment	Available nutrients (kg ha^{-1} m^{-1})						
	Organic C	P	K	Cu	Zn	Fe	Mn
T_1	−1715	+72.7	−367.0	+1.4	−7.9	+129.3	+133.5
T_2	+17819	+284.2	−488.8	+40.1	−20.7	+266.3	+78.4
T_3	+5055	+12.8	−1071.4	+43.8	+18.6	+121.5	+405.5
T_4	+30169	+200.3	−608.4	+104.2	+58.4	+379.8	+523.6

(1984) reported that the mid-day light profile revealed a maximum PAR in the system where both arecanut and cacao were spaced at 3.3 × 3.3 m. They attributed this observed higher PAR and NR activity partially to explain the higher yields obtained in this system.

Acknowledgements

The authors are grateful to Dr K.V. Ahamed Bavappa, Director, CPCRI, Kasaragod, and Shri K. Shama Bhat, Joint Director, CPCRI Regional Station, Vittal, for their help, suggestions and facilities rendered during the course of this investigation.

References

Abraham, P. (1956) Spices as intercrops in coconut and arecanut gardens, *Arecanut J.* **7** 56–58

Anonymous (1983) *Annual Report for 1983* Central Plantation Crops Research Institute, Kasaragod, India, 249 pp

Anonymous (1985) *Annual Report for 1984*, Central Plantation Crops Research Institute, Kasaragod, India, 211

Aubert, H. and Pinta, M. (1977) *Trace Elements in Soils*, Amsterdam, Elsevier Scientific Publishing Company

Balasimha, D. and Subramonian, N. (1984) Nitrate reductase and specific leaf weight of cocoa and light profiles in arecanut-cacao multiple cropping, *Proceedings of PLACROSYM VI* (in press)

Bavappa, K.V.A. (1951) Some common intercrops in arecanut garden, *ICAC Monthly Bulletin* **2** 16–17

Bhat, K.S. (1974) Intensified intermixed cropping in areca garden – the need of the day, *Arecanut and Spices Bulletin* **5** 67–69

Bhat, K.S. (1978) Agronomic research in arecanut – a review, *J. Plant. Crops* **6** 67–80

Bhat, K.S. and Bavappa, K.V.A. (1972) Cocoa under palms, in: *Cocoa and Coconuts in Malaysia*, (Eds. Wastie, R.L. and Earp, D.A.) Kuala Lumpur, Malaysia, The Incorporated Society of Planters, 116–121

Bhat, K.S. and Leela, M. (1968) Cultural requirements of arecanut, *Indian Farming* **18** 8–9

Bhat, K.S. and Leela, M. (1969) The effect of density of planting on the distribution of arecanut roots, *Trop. Agric. (Trinidad)* **46** 55–61

Black, C.A. (1965) *Methods of Soil Analysis, Part I*, Madison, Wisconsin, USA, American Society of Agronomy Inc.

Chapman, H.D. (1975) *Diagnostic Criteria for Plants and Soils*, New Delhi, Eurasia Publishing House (P) Ltd

Haque, I. and Aggrey, W.G.S. (1980) Nutritional survey of coffee and cocoa groves in Sierra Leone, *Commun. Soil Sci. Plant Anal.* **11** 485–505

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

Lindsay, W.L. and Norvell, W.A. (1969) Development of a DTPA micronutrient soil test, *Agron. Abstr.* **69** 84

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, 367–378

Nelliat, E.V. and Iyer, R.D. (1977) Diamond jubilee celebrations of coconut research in India, a report, *J. Plant. Crops* **5** 45–46

Piper, C.S. (1966) *Soil and Plant Analysis*, New York, Interscience Publishers

Russell, E.W. (1973) *Soil Condition and Plant Growth*, London, English Language Book Soc. and Longman

Sannamarappa, M. and Muralidharan, A. (1982) Multiple cropping, in: *The Arecanut Palm*, (Eds Bavappa, K.V.A., Nair, M.K. and Premkumar, T.) Kasaragod, Central Plantation Crops Research Institute, 133–149

von Uexkull, H.R. (1978) Potassium requirements of some tropical tree crops (oil palm, coconut palm, rubber, coffee, cocoa), in: *Potassium Research – Review and Trends*, Bern, Proc. 11th Congr., Int. Potash Inst. 291–324