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Research Articles

COCONUT AND ARECANUT BASED HIGH DENSITY MULTISPECIES CROPPING SYSTEMS*

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ABSTRACT

High density multispecies cropping models were laid out one each in coconut and arecanut plantations during 1983. Data on various aspects of the system behaviour showed that the yield of coconut and arecanut increased to the extent of 176% and 125% respectively in the two systems. The possibility of getting additional yields due to cropping system approach was evident. There was no marked yield difference of the crops in the full, two-third and one-third levels of fertilizers applied though depletion in N and Mg balance was indicated. The air space utilisation was 31% in coconut while it was 63% in the arecanut system. The biomass production of the two systems showed that there was substantial increase in coconut biomass while the biomass of other crops remained more or less the same. In general, there was build-up of P and K nutrients in the systems. Under the arecanut system N also showed increased balance. There was improved microbial activity in the systems. No serious pest and disease management problems were indicated due to the high density cropping system approach. A number of crop varieties and hybrids tolerant/resistant to the nematode pathogen could be identified. The interaction of various factors for exploiting higher levels of productivity through a system approach and the need for predicting crop choices based on data and crop performance are discussed in the paper.

INTRODUCTION

Unlike in annuals, the potential for increasing the productivity per unit area of land, time and inputs through high density cropping is considerably higher in perennial crops (Bavappa and Jacob, 1982). Studies have revealed that the roots of coconut planted 7.5 m apart effectively use only 22.3% of land area occupied by the crop (Nelliat, Bavappa and Nair, 1974) while the average air space utilisation by the canopy is about 30% (Bavappa, 1975). Thus even on simple physical considerations of soil and air space utilisation a monocrop of coconut can effectively support other plant species in the interspaces. Studies on the

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pattern of changes in the apparent coverage of ground by coconut canopy with respect to age of palms undertaken by Nelliat et al, (1974) indicated that the canopy coverage of land progressively decreased with increase in height beyond 20 years. As a result there is increase in the amount of sunlight reaching the ground. The extent of this transmission varies with age of the palm and is almost inversely related to apparent land coverage of the palm. These characteristic features of the coconut palms facilitate intensive cropping in the interspace by introducing parallel or simultaneous combinations of compatible crops (Nair, 1979). Almost a similar situation exists in arecanut plantation where the exploitation of interspaces is feasible. In India coconut and arecanut are cultivated over 1.4 million hectares and if brought under an intensive cropping programme the production and productivity of the land could substantially be increased. Two high density cropping systems were, therefore, laid out during 1983 and the results obtained are reported in this paper.

MATERIALS AND METHODS

Coconut based model

In an eighteen year old coconut plantation of 1.2 ha spaced at 8.0 × 8.0 m. 17 different crop species were planted during July 1983 in experimental farm of the Central Plantation Crops Research Institute at Kasaragod (Fig. 1). The total number of planting points in the experimental area was 14,352/ha. The coconut palms were growing under rainfed conditions until the commencement of the present experiments. The placement of the different species was done in such a way that the inter/intraspecies canopy competition is minimum. The experimental field was divided into three sub-plots of 0.4 ha receiving annually fertilizers at one-third, two-third and full dose of the recommended levels for each crop species. Perfospray irrigation was given every year during the dry period (December to May) 20 mm of water at IW/CPE ratio of 0.75 starting from 1983-84 onwards. The cultural practices recommended for each of the crops were adopted at appropriate time.

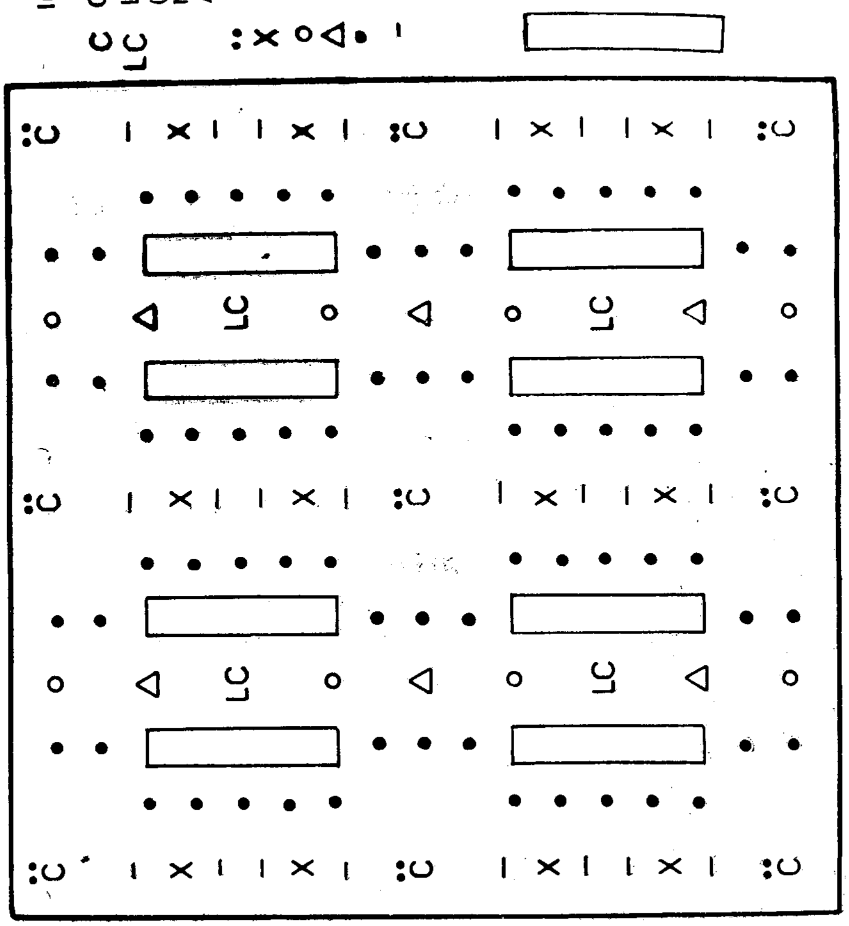
Arecanut based model

This was laid out during August–September 1983 in the experimental farm of the Central Plantation Crops Research Institute, Regional Station at Vittal with six different crops (Fig. 2) in one hectare of 17 year old irrigated arecanut plantation having 1300 arecanut palms spaced at 2.7 × 2.7m. After the planting of the different crops, irrigation was continued during the dry period (November–May) through sprinklers of 30 mm of water at IW/CPE ratio of 1.0. All the crops in the model were manured individually at the recommended levels.

Inputs and outputs

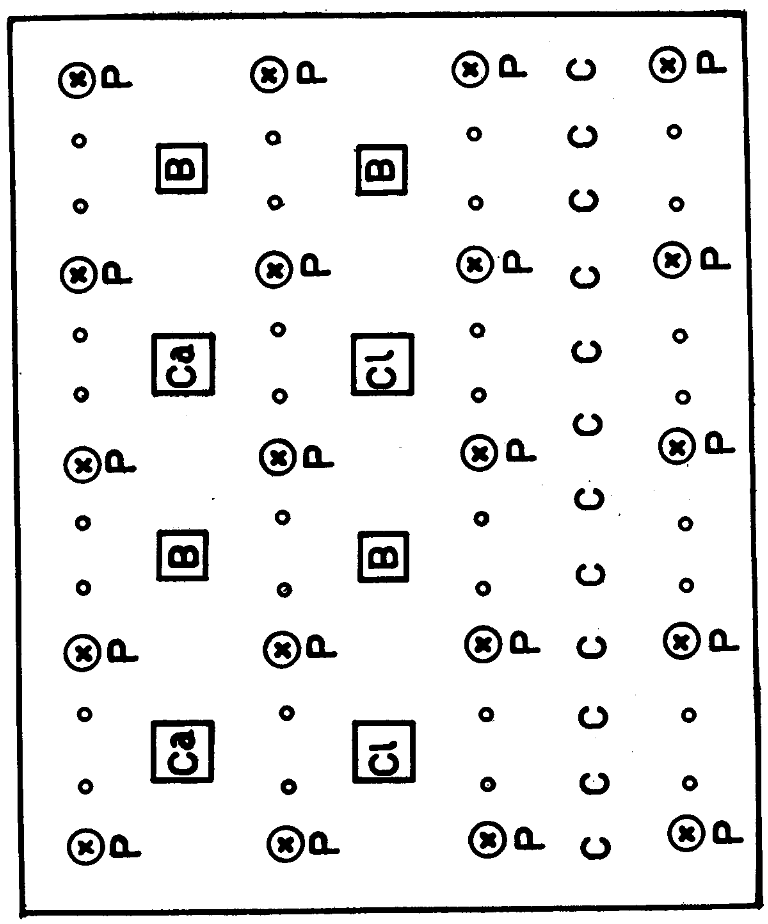
A record of the quantities of the inputs such as planting materials, manures and fertilizers, plant protection chemicals, energy for pumping irrigation water and labour used for establishing and sustaining the crop models was maintained. Harvesting of the economic produce was done at appropriate stages

Fig. 1. Coconut based high density cropping model



Symbol	Index to crops	Density/ha
C	Coconut	156
LC	Large canopy crops (Mango, Bread fruit, Jack, Nutmeg, Clove, Sapota, Acid Lime & Guava)	156
:	Pepper	156
X	Subabul	312
o	Banana	234
△	Papaya	234
•	San Ramon Coffee	3120
I	Tuber Crops (Elephant foot yam, Colocasia & Tapioca)	624
▭	Pineapple	9984
	Total	14,976

Fig. 2. Arecanut based high density cropping model



Index to crops		Density/ha
⊗	Arecanut	1300
P	Pepper	1300
Ca	Cocoa	210
CL	Clove	180
B	Banana	390
o	Pineapple	2400
C	Coffee (Sanramon)	780
	Total	6560

and the yields recorded. Since the aim of the experiment was to maximise the use of air and soil space, the yield of all the crops other than the main crop was converted and expressed on per hectare basis wherever necessary.

Canopy measurements

The canopy shape of individual crops was assumed to be in a certain geometric shape and observations like plant height, canopy height and diameter (at widest point, top and bottom) were recorded during September every year. Making use of these observations, canopy volume and surface area of the canopy were computed employing the appropriate geometrical formulae depending upon the canopy shape of the individual crops (Jamaluddeen and Jacob, 1983).

Biomass production

The biomass stand of the crops was estimated in September every year by adopting a partial destructive method. The twigs and leaves from a known volume of canopy were collected, dried, dry weight estimated and using this data the biomass of the total canopy was calculated. The dry weight of the harvested produce of different crops was estimated on sample basis and the biomass of the produce removed was computed. The data were pooled and expressed on per hectare basis for the period of 12 months from July to next June.

Nutrient budget

The annual nutrient enrichment was computed by determining the nutrients added through biomass recycling, microbial biomass, canopy flushing by rainfall, fertilizers and native soil nutrients for the period July to next June. The annual efflux of nutrients from the system through run off, leaching and produce utilization was also computed for the same period. The run off losses of soil, water and nutrients was studied by installing mini surface run off lysimetry in the plot. The leaching losses of nutrients was studied by simulating the field conditions in the laboratory. The produce utilization losses of nutrients were estimated by analysing representative samples of the produce harvested from time to time. From the data on nutrient addition and depletion, the net balance of nutrient in the system was calculated for a period of three years.

Microbiological studies

Soil samples were collected in the month of October 1986 from the root region and interspaces of the high density and monocropping systems. The microflora were enumerated by soil dilution and plate count method (Allen, 1957). The asymbiotic nitrogen fixers were enumerated using Jensen's medium (Jensen, 1942) and phosphate solubilizers using Pikovsyako's medium modified by Sundara Rao and Sinha (1963). Soil microbial biomass was estimated following method of Jenkinson and Powlson (1976).

Pests and diseases

The incidence of pests and diseases were systematically monitored and control measures undertaken whenever necessary. Since crops like pepper and banana are already known to be attacked by nematodes, critical observations on the nematode population were recorded. The crops were screened in the green house as well as in the field against burrowing *(Radopholus similis)* and root knot *(Meloidogyne incognita)* nematodes. In order to keep the nematode population below the threshold level phorate/carbofuran @ 3g a. i./ plant was applied in June and September to the susceptible crops.

RESULTS

The yearwise yield of coconuts, pineapple, banana etc. under the three different levels of fertilizers are given in Table I. During the first two years, in all the three fertilizer levels, the yield of nuts was around 10,000/ha/year which by third year went up to around 27,000/ha. The yield of coconut and other crops was more or less same under the three levels of fertilizers. However, the mixed crops in general given only 25–70% of the yields realisable under open conditions. Among the different crop species tried, pineapple gave the maximum total yield followed by banana. The yield of papaya and all the tubers was rather poor. The yield of arecanut and other crops during the first three years (Table II) show that there is a gradual increase in the yield of arecanut from the first year to the third year. Among the mix planted species banana and pineapple yielded in the second and third years and the performance of banana was excellent. Pepper, cocoa and coffee started bearing in the third year and their performance requires further study.

The data on the air space utilization by different crops (Table III) show that air space occupied by coconut and arecanut reduced marginally due to the increase in the total air space availability. The percentage utilization by other crops remained more or less the same in different years in the coconut based model and accounted for about 25% of the space occupied by coconut. In the arecanut based model, the space occupied by other crops was higher than that occupied by arecanut and showed substantial increase over years primarily contributed by pepper.

The standing biomass, biomass removed and economic biomass for the three years of experimentation are given in Table IV in respect of both coconut based and arecanut based models. There was substantial increase in coconut biomass during the third year.

The budget and balance of N, P, K and Mg of the coconut based model are given in Table V. The data indicate that the N balance in the system is gradually depleting irrespective of the fertilizer levels, the depletion being more pronounced in one-third dose of fertilizer levels. In the case of P and K there is build up in all the three levels of fertilizers. With regard to Mg, there is net depletion over the years in all the three levels. In arecanut based model the nutrient balance studies were done only during the third year (1985–86) of experimentation (Table VI). There is a net gain of all the three nutrients in the system. The amount of N, P, K recycled through various processes annually was substantial, almost one-half in case of N and equal in the case of K.

Table I. *Output from the crops (Kg/ha) – coconut based model*

Crops	Produce	1983–84			1984–85			1985–86		
		F	2/3	1/3	F	2/3	1/3	F	2/3	1/3
Coconut	Nuts*	9,719	11,029	10,374	9,344	11,778	8,908	27,097	25,912	29,141
Subabul	Prunings	–	–	–	1,314	896	902	1,748	1,381	1,056
Banana	Fruits	–	–	–	1,271	1,058	1,276	821	757	1,077
Papaya	Fruits	61	61	23	292	358	301	–	–	–
Elephant foot yam	Tubers	Not harvested in the first year			308	407	316	–	–	–
Colocasia	Tubers		-do-		224	291	226	–	–	–
Tapioca	Tubers	73	120	30	–	–	–	–	–	–
Pineapple	Fruits	–	–	–	5,900	4,602	5,332	4,603	4,173	4,320

F – Full dose of fertilizers 2/3 – Two-third of full dose 1/3 – One-third of full dose * – Quantity in numbers/ha

Table II. *Output from the crops (Kg/ha)-arecanut based model*

Crops	Produce	1983–84	1984–85	1985–86
Arecanut	Chali	1582	2490	4130
Banana	Fruits	–	2656	2146
Pineapple	Fruits	–	1263	419
Pepper	Dry pepper	–	–	45
Cocoa	Pods	–	–	71
Coffee	Dry beans	–	–	10

Table III. *Air space utilization*

Particulars	1984	1985	1986
Coconut based model			
Total air space (000m³/ha)	139	145	149
Percentage occupied by coconut	25.9	24.8	24.2
Percentage occupied by other crops	6.5	6.2	6.7
Arecanut based model			
Total air space (000m³/ha)	120	127	135
Percentage occupied by arecanut	17.5	17.3	16.3
Percentage occupied by other crops	23.3	29.9	46.7

In Table VII the data on total microbial population, population of beneficial micro-organisms and soil microbial biomass under the coconut based system are furnished with that under coconut monocropping. There is considerable increase in the total and beneficial microbial population and soil microbial biomass in the coconut basins as well as in the coconut interspace. In arecanut based system (Table VIII) there is considerable increase in the total microbial population in the arecanut interspace alone while in the basins the increase has been marginal.

Table IV. *Biomass production (t/ha)*

Particulars	Coconut based model				Arecanut based model			
	Crops	1983–84	1984–85	1985–86	Crops	1983–84	1984–85	1985–86
Total standing biomass	Coconut	35.1	37.9	50.1	Arecanut	20.8	21.5	22.3
(Estimated in September every year)	Other crops	7.0	7.0	7.4	Other crops	–	4.0	6.1
Total biomass removed	Coconut	6.6	6.4	17.4	Arecanut	8.7	9.2	10.5
	Other crops	1.4	4.8	3.8	Other crops	–	3.3	5.5
Total economic yield	Coconut	6.5	6.2	17.1	Arecanut	1.6	2.5	4.1
	Other crops	–	4.7	3.6	Other crops	–	1.2	0.8

The occurrence and population status of *R. similis*, *M. incognita* and *Pratylenchus coffeae* are given in Table IX. There has been substantial reduction in the nematode population excepting in the case of *R. similis* in banana.

The extent of susceptibility of the different crops to the attack by the above nematodes is given in Table X. It will be observed that of the different crops cultivated, coconut, arecanut, banana and pepper are highly susceptible to the attack by *R. similis*. Pepper is also seriously damaged by *M. incognita*. Subabul is the other species that is susceptible to the attack of this nematode. Tuber crops are generally free from the attack of *R. similis*. However, elephant foot yam is seriously damaged by root-knot nematode. A list of resistant/tolerant varieties/hybrids to the *R. similis* and *M. incognita* is given in Table XI. There are a number of varieties and hybrids in coconut, arecanut, pepper, subabul and banana that are either tolerant or resistant to the root-knot and burrowing nematodes.

DISCUSSION

The response of coconut to any given management practice is reflected in yield generally from the third year of imposing of such treatment (Muliyar and Nelliat, 1971). The result obtained in the present study (Table I) is also in conformity with this. The yield increase of coconut due to the total package of treatment has been 156% compared to the pre-treatment yield of the plot. Under the recommended levels of N, P_2O_5 and K_2O (500, 320 and 1200g/plant/year respectively) the mean yield of nuts/palm was 58 and when coupled with irrigation the yield increased to 95 nuts (Bavappa, 1986). In the present study the average pre-experimental yield level of the palms receiving the recommended fertilizer dose was 63 nuts which increased to 174 nuts as against the normal response of 95 nuts obtained under manured and irrigated conditions. A more or less similar additional advantage was observed under the coconut and cocoa cropping system (Nair et al, 1975). This

Table V. *N, P, K and Mg budget and balance (Kg/ha) – coconut based model*

Fertilizer level	N 1983–84 Budget	N 1983–84 Removed	N 1983–84 Balance	N 1985–86 Budget	N 1985–86 Removed	N 1985–86 Balance	P 1983–84 Budget	P 1983–84 Removed	P 1983–84 Balance	P 1985–86 Budget	P 1985–86 Removed	P 1985–86 Balance
F	733	413	320	743	538	205	198	8	190	395	20	375
2/3 F	665	383	282	683	490	193	170	8	162	315	18	297
1/3 F	555	325	230	475	403	72	148	8	140	243	20	223

Fertilizer level	K 1983–84 Budget	K 1983–84 Removed	K 1983–84 Balance	K 1985–86 Budget	K 1985–86 Removed	K 1985–86 Balance	Mg 1983–84 Budget	Mg 1983–84 Removed	Mg 1983–84 Balance	Mg 1985–86 Budget	Mg 1985–86 Removed	Mg 1985–86 Balance
F	610	110	500	1403	488	915	95	10	85	73	28	45
2/3 F	455	100	355	1025	335	690	93	10	83	75	28	47
1/3 F	300	80	220	740	428	312	93	10	83	78	30	48

Table VI. *N P K budget and balance during 1985 – 86 (Kg/ha)– arecanut based model*

Budget components	N	P	K
Nutrients added through fertilizers	437	104	589
Nutrients added through organic recycle	220	17	480
Total budget for 1985–86	657	121	1069
Nutrients harvested through crop produce	57	3	31
Nutrients lost by other means	459	–	118
Nutrient balance at the end of 1985–86	141	118	920

advantage has been attributed to the favourable microbial activity existing under the coconut–cocoa system (Nair and Rao, 1976). A similar increase in the microbial activity is also seen in the system under discussion (Table VII). There has been an overall increase in the total microbial population specially asymbiotic N fixers, P solubilizers and soil microbial biomass.

However, in arecanut cropping model, the response to the package was observed from second year of the commencement of the treatment. Bavappa and Annaji Rao (1970) have recorded that floral initiation in arecanut takes place 20 months in advance of the inflorescence opening. The higher yield observed in the second year can thus be expected. Since arecanut was already under regular manuring and irrigation, the yield increase of 36% and 125% during the second and third year respectively (Table II) appeared to be by and large due to the cropping system adopted and the organic matter recycling contributing 50% of N and equal amount in K

Table VII. *Total microbial population, population of beneficial micro organisms and soil microbial biomass in 0–25 cm soil layer in the coconut based model.*

Cropping system	Location from where soil samples were drawn	Total microbial population /g of soil (× 10^3)	Population of beneficial micro organisms/g of soil		Soil microbial biomass (μgC/g of soil)
			Asymbiotic N_2 fixers (× 10^3)	P Solubi-lizers (× 10^3)	
Coconut monocropping	Coconut basin	516	39	572	353
Coconut monocropping	Coconut interspace	285	10	231	190
Coconut based HDMSC model	Coconut basin	769	53	975	489
Coconut based HDMSC model	Coconut interspace	323	25	282	380

Table VIII. *Total microbial population and soil biomass in 0–25 cm soil layer in the arecanut based model.*

Cropping system	Location from where soil samples were drawn	Total microbial population/g of soil × (10^3)	Soil microbial biomass (μg C/g of soil)
Arecanut monocropping	Arecanut basin	768	763
Arecanut monocropping	Arecanut interspace	126	616
Arecanut based HDMSC model	Arecanut basin	819	788
Arecanut based HDMSC model	Arecanut interspace	530	676

Table IX. *Occurrence and population build up of* R. similis, P. coffeae *in coconut based system.*

Crop	Nematode species	Nematode population in 1g of root	
		1981	1986
Coconut	*Radopholus similis*	20–145	10–65
Pepper*	*R. similis*	45–210	5–75
	M. incognita	27–280	12–85
Banana*	*R. similis*	7345	7160
	M. incognita	25–80	0–25
Subabul	*M. incognita*	0	45-125
Pineapple	*M. incognita*	10	5
Clove	*R. similis*	0	0
Acid lime	*M. incognita*	0	0
Coffee	*Pratylenchus coffeae*	2–10	25–40

* Treated with nematicide

(Table VI). Microbial studies showed marginal increase in the population load and soil microbial biomass. As such it is necessary to continue the studies on soil microbiological changes and nutrient balance for getting a better insight into the yield behaviour of the arecanut.

The yield of the main crop of coconut as well as that of others did not show much variation when three levels of fertilizers were applied (Table I). One of the objectives of a system approach is to achieve a higher efficiency in production. The mean annual dose of N, P_2O_5 and K_2O for the different crops worked out to 257, 188 and 482 kg/ha respectively. A reduction to one-third of this dose is a substantial saving in the inputs. However, depletion of N has been observed due to the reduction in the fertilizer levels. (Table V). Root studies undertaken in mixed stand of tea and clove showed increase in weight, number and length of roots in clove compared to the monocrop (Mathavan, Bavappa and Gunasena, 1984). In the cropping systems under discussion similar to that observed in clove, root production and matting appear to have helped higher foraging of the soil mass and absorption of the applied nutrients. It is necessary to undertake root studies for drawing final conclusions.

Cropping system approach envisages better utilisation of the air space by the component crops. While the monocrop of coconut utilises about 25% of the available air space, other crops have been able to use only about 6% (Table III). The low utilisation of space by component crops is primarily due to the fact that the crops included (three annuals, three semi-perennials and eleven perennials) are in their early stages of establishment. As against this, in the arecanut based model the air space used by arecanut and other crops in the third year of planting is 16.3% and 46.7% respectively. The arecanut based system which had no annuals appeared to be more efficient in air space use due to the better growth of all the component crops particularly pepper. In high density planting programmes it may not be advantageous to include annual tuber crops and papaya as also evident from the low yields obtained from these crops.

In enhancing the unit area productivity, biomass pathway is important for meeting the diverse needs of the farmers. In the coconut based system there has been substantial increase in the biomass (Table IV) by third year. Coconut produced 50 t/ha of biomass which is in conformity with the estimates made by Corley (1983). He also reported an economic yield of 13 tonnes. This was observed to get increased to about 17 t/ha due to better yield of coconut. The biomass production by arecanut was 22 t/ha. Since the biomass production by other crops is more or less the same (6-7 t/ha) in terms of total biomass production, coconut based system produces double that of the other.

The NPK and Mg budget and balance of the coconut based system (Table V) present interesting discussion.

While there has been no build up of N and Mg, the levels of P and K doubled by the third year. Consequently, there was a depletion in the N and Mg balance. Application of higher doses of fertilizers appears to reduce the rate of N depletion. The depletion of Mg is uniform irrespective of the levels of fertilizer used. In acid soils the displacement of Mg from its exchange sites occurred due to heavy input of K^+ and NH_4^+ fertilizers resulting in leaching losses of Mg (Ochs and Ollagnier, 1977). It thus appears that from the point of view of Mg management that even one-third dose of N-K fertilizer is high. It is worthwhile to bear in mind that the present experiment is in its initial stage and the organic matter recycling capability of the system through leaf fall and root degeneration is still to develop. In the meanwhile if the N depletion trend continues affecting yields and biomass production, necessary corrective measures will have to be undertaken in respect of this nutrient. On the other hand, the P and K build-up in the system strongly suggests the adequacy of one-third dose for maximum system productivity.

There was no excessive incidence of any pest or disease in the systems. It also appeared that through adoption of appropriate control measures pathogens like nematodes could be kept under check (Table IX) in spite of the high susceptibility of coconut, arecanut, banana, pepper and subabul to nematodes (Table X). The finding that a number of varieties and hybrids of different crop species are tolerant/resistant to the burrowing and root-knot nematodes (Sosamma, Koshy, Bhaskara Rao, 1980 and 1986; Ramana and Mohandas, 1986) enables the management of this pathogen by appropriately choosing the varieties while planting the system. In particular, the resistance of the recently released coconut hybrid CDO × WCT (Chandrasankara) arecanut varieties VTL-11 (Sumangala) and VTL-17 (Sreemangala) make them ideally suited for mixed cropping situations.

Table X. *Susceptibility of different crops to nematode infestation.*

Crops	*R. similis*	*M. incognita*	*P. coffeae*
Coconut	+++	−	+
Arecanut	+++	+	+
Banana	+++	++	+
Pepper	+++	+++	−
Cocoa	−	+	−
Nutmeg	+	+	−
Cinnamon	−	−	−
Pineapple	−	+	−
Clove	+	+	−
Coffee	+	+	+++
Lemon	−	−	−
Subabul	−	+++	−
Tapioca	−	+	−
Elephant foot yam	−	+++	−
Colocasia	−	+	−

+++ = Highly susceptible
++ = Moderately susceptible
+ = Less susceptible
− = Negative (Non-host)

In tree crops agriculture involving different species, experimentation to evolve compatible crop combinations is beset with a variety of problems such as large field areas required for the trial, limitations in the choice of crops for developing the crop communities, management practices that are to be given and above all the density at which plantings are to be undertaken. Since

Table XI. *Varieties less susceptible to nematode infestation.*

Crops	Cultivars	Hybrids
Coconut	Kenthali Klappawangi	Tall × Gangabondam CDO × WCT* MDY × Java Giant* San Ramon × Gangabondam
Arecanut	Hirehalli VTL-11*, VTL-17* VTL-18 c	VTL-11 × VTL-12 VTL-11 × VTL-17* Thirthahalli × VTL-12
Pepper	P. 812* Neyyatinkaramundi Jeerakamundi Karimunda Kudirugunda Arakkulam Munda Aimperian	
Subabul	K-500*, K-72* K-341* K-67	
Banana	Palayamthodan Robusta	

* Tolerant/resistant

testing these varieties in varied combinations to arrive at a meaningful conclusion is rather impracticable, a high density planting approach was made so that on the basis of crop performance and ancillary data generated, appropriate crops may be chosen for developing the cropping model. The prediction model already planned for nutrient budget and balance in cropping system (Biddappa et al, 1984) may have to be adequately expanded to cover all aspects of investigation so that the interaction effects are brought out and predictions made more meaningful.

The data presented in this paper relate to the initial three years of the trial which indeed is rather short for drawing final conclusions. All the same this excercise has been undertaken to ensure that the research efforts going on in diverse disciplines covering the programme are complimentary and adequate to understand the dynamics of the system. To this extent certain leads have been indicated. Corrective measures have to be undertaken so that over a period of time efficiency of the system is increased. Since the input and output data are inadequate no attempt has been made to make an economic analysis of the systems at this stage. It is however most important that data generation in all areas of the system are continued on an inter-disciplinary basis and manipulation of various inputs done at appropriate time to make the system a balanced and self-generating one with minimum inputs.

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