Research Article

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Soil fertility, system productivity and economic viability of coconut based high density multi species cropping system in Tamil Nadu, India

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Abstract

Monocropping of coconut is no longer viable in the context of price aberrations of copra, debilitating pests and dreadful diseases and intercropping turned out to be an inevitable venture. A research experiment was pursued at the AICRP (Palms) centre, Coconut Research Station, Aliyarnagar, Tamil Nadu, India during 2013-18 to assess the impact of coconut based High Density Multi Species Cropping System (HDMSCS) with cocoa (CCRP accessions), banana (var. Nendran) and pineapple (var. Kew), on soil fertility, system productivity and economic viability. The experiment was conducted in a sandy clay loam soil taxonomically classified as *Typic Haplustepts*. Four treatments *viz.,* T1: 75 per cent recommended dose of nutrients (RDN) as chemical fertilizers + 25 per cent RDN through organic recycling with vermicompost, vermiwash application, biofertilizer application and green manuring with gliricidia loppings; T2: 50 per cent RDN as chemical fertilizers with 50 per cent RDN through organic sources, T3: 100 per cent RDN through organic sources and T4: sole chemical fertilization were imposed in blocks comprising of 25 coconut palms per block. Results revealed that integration of 75 per cent recommended dose of nutrients (RDN) through chemical fertilizers and 25 per cent through organic sources (T1) resulted in increased nut yield of coconut, dry bean yield of cocoa and fruit yield of banana and pineapple. Nut yield was conspicuously lower in monocropping compared to HDMSCS. Soil organic carbon (SOC), earthworm count and microbial population were higher in the treatment, which received 100 per cent RDN through organic sources (T3). Net Returns, B: C ratio and employment generation potential were higher in HDMSCS than coconut monoculture. Partitioning of the recommended dose of nutrients through 75 per cent chemical fertilizers and 25 per cent organic manures for coconut based high density multi species cropping integrated with cocoa, banana and pineapple paved the way for enhanced soil fertility, system productivity, profitability and sustainability of coconut system in Western Zone of Tamil Nadu, India.

Keywords: Coconut; HDMSCS, INM, monoculture, soil fertility, system productivity

Introduction

Coconut is an important horticultural crop that exerts a profound influence on the rural economy of many countries where it is grown extensively. In India, its cultivation spreads over an area of 2.15 M ha with a total production of 21288.24 million nuts and productivity of 9897 nuts per ha. In Tamil Nadu, coconut is cultivated over an area of 4.36 lakh ha with an annual production of 5370.39 million nuts (CDB, 2020), thus sharing 25.22 per cent of the total production of the country. On the national front, the state stands third in position with productivity of 12291 nuts per ha, which is 24.18 per cent higher than the national productivity. Coconut is predominantly a crop of small and marginal farmers in the state. In the recent past, coconut turned out to be a sensitive victim of extreme weather events and hence monocropping of coconut is no longer viable. Also, coconut often becomes a 'hub of discussion' on the farm front due to price

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aberrations, devastating pests, dreadful diseases, and a large stock of senile palms. As the coconut growers are often exposed to economic risks and uncertainties, a unilateral increase in productivity is not the sole solution for the livelihood crisis in the coconut sector. Hence, crop diversification is the need of the hour. Thus inclusion of compatible intercrops without deteriorating the natural resources is imperative to augment system productivity to protect coconut cropping systems from getting jeopardized.

The crop geometry of coconut provides ample scope for the accommodation of intercrops in the system. Coconut palms are spaced at 7.5 m x 7.5 m and hence use only 22.3 per cent of land area effectively, while air space utilization by the canopy is 30 per cent and interception of solar radiation is 45 to 50 per cent (Nelliat, 1979). The effective root zone of an adult coconut palm is confined laterally within a radius of 2 m around the base of the palm. Over 95 per cent of the roots are found in the top 0-120 cm, of which 18.9 and 63 per cent of roots are confined to top 0 to 30 cm and 31 to 90 cm depth, respectively (Bavappa *et al.,* 1986). The underutilized natural resources of coconut monoculture can be effectively utilized by planting crops with varied stature, root architecture, and nutrient uptake to form synergistic combinations. Adopting coconut-based farming systems is one way to augment system productivity by improving soil characteristics and coconut nutrition (Maheswarappa *et al*., 1998). However, the choice of the crops depends upon the agro-climatic conditions and market potential. Hence, the present research was envisaged at Coconut Research Station, Aliyarnagar, to assess the resource flow and sustainability of coconut based high density multi species cropping system (HDMSCS) for the Western Zone of Tamil Nadu under All India Co-ordinated Research Project on Palms.

Materials and methods

A field trial was conducted at Coconut Research Station, Aliyarnagar, in a thirty-year-old coconut garden with the palms spaced at 7.5 m x 7.5 m. The station was located near Western Ghats (10° N latitude and 77°E longitude) in the Western Zone of Coimbatore district of Tamil Nadu, at an elevation of 260 m above MSL with undulating topography. The average annual rainfall of the tract is 802 mm of which, nearly 300 mm is received during the south west monsoon, 333 mm during the north east monsoon and 169 mm during summer. Parambikulam Aliyar Canal supplemented by one open well serve as a source of irrigation. The soil type of the station is sandy clay loam (*Typic Haplustepts*). Coconut is the principal crop of the Western zone of Tamil Nadu State, India, comprising Coimbatore, Erode, parts of Karur, Namakkal, Dindigul and Theni districts, with an average annual rainfall of 715 mm. In the present experiment, coconut was integrated with cocoa, banana, and pineapple. The standard package of practices was adopted as per the Crop Production Guide of Tamil Nadu Agricultural University, Coimbatore. Pepper (Panniyur 1) variety was included in the system during 2017 and was allowed to trail over coconut. The crops and varieties integrated are presented in Table 1, and the schematic sketch of the orientation of the main crop and intercrops is illustrated in Figure 1.

The treatments were imposed in blocks comprising of twenty palms. The biomass accumulated in terms of cocoa prunings, banana pseudostem and weeds were collected and composted using *Eudrillus sp.* of earthworms in pits

Table 1. Crops integrated with geometry and fertilizer recommendation

Crop	Variety	Spacing	Plant population (ha^{-1})	Fertilizer recommendation (NPK g $plant^{-1}$ $year^{-1}$)
Coconut	Tall	7.5 m x 7.5 m	175	560:320:1200
Cocoa	CCRP accessions	3.75 m x 3.75 m	350	100:40:140
Banana	Nendran	2.0 m x 2.0 m	500	150:90:300
Pineapple	Kew	1.0 m x 1.0 m	5000	16:4:12
Pepper	Panniyur -1	Single plant per coconut basin	25	100:40:140

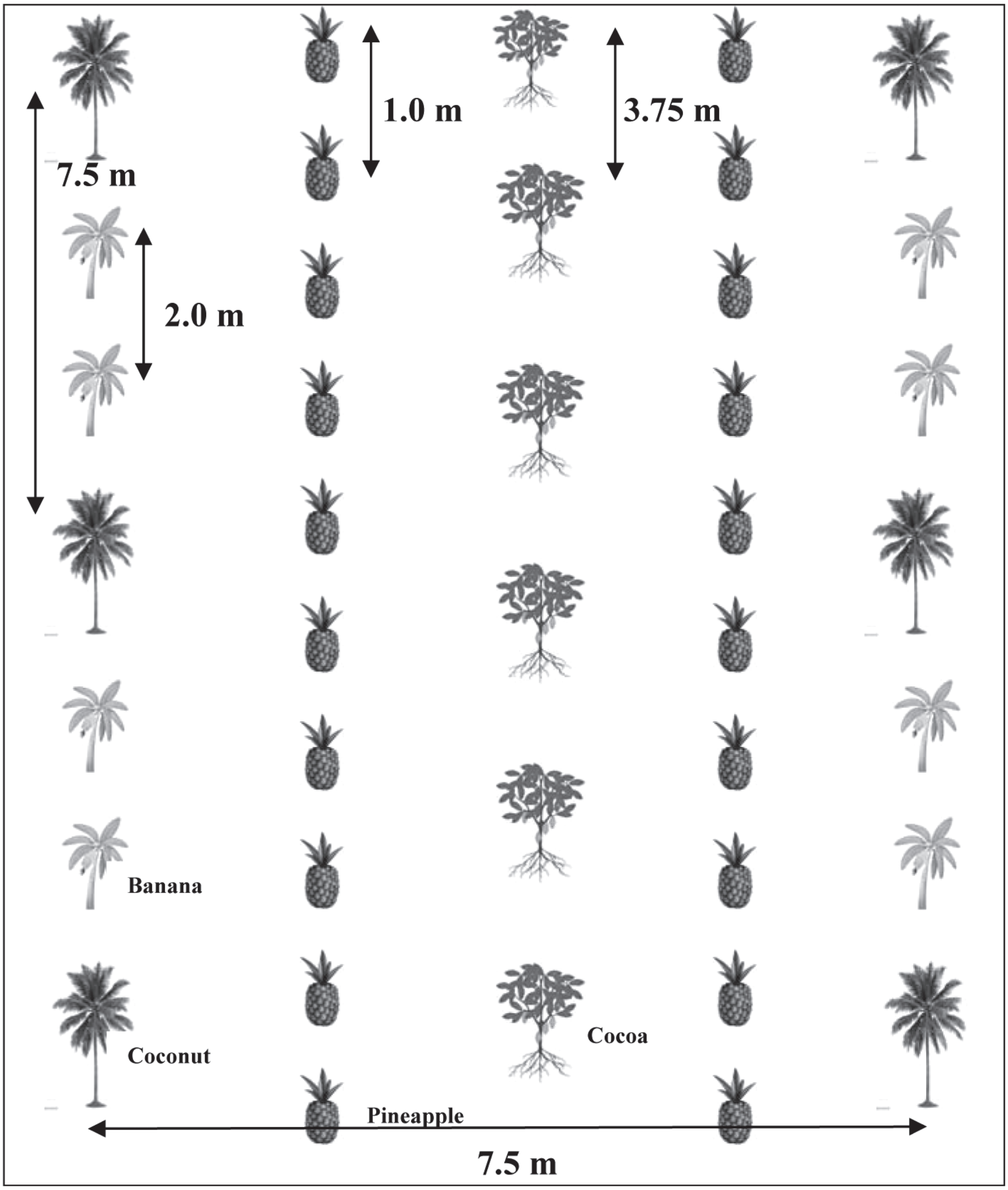

Fig. 1. Orientation of crops in HDMSCS

The experiment comprised of three treatments *viz.,*

T1: 75 per cent recommended dose of nutrients (RDN) as chemical fertilizers + 25 per cent RDN through organic recycling with vermicompost, vermiwash application, biofertilizer application and green manuring with gliricidia loppings.

T2: 50 per cent RDN as chemical fertilizers + 50 per cent organic recycling with vermicompost, vermiwash application, biofertilizer application and green manuring with gliricidia loppings.

T3: Fully organic (100 per cent RDN through organic recycling with vermicompost, vermiwash application, bio-fertilizer application, green manuring, green leaf manuring with gliricidia loppings),

T4: 100 per cent RDN as chemical fertilizers only.

Table 2. Nutrient phasing across different treatments

Crop	100 % RDN			75 % RDN			50 % RDN		
Nutrient	N	P	K	N	P	K	N	P	K
	(g plant^{-1} year^{-1})								
Coconut	560	320	1200	420	240	900	280	160	600
Banana	150	90	300	110	65	225	75	45	150
Cocoa	100	40	140	75	30	105	50	20	70
Pineapple	16	4	12	12	3	9	8	2	6

excavated for the purpose. Excess water drained out from the vermicompost pits was collected and applied to the crops. Nutrient phasing across different treatments is furnished in Table 2.

Initial and final soil samples were collected and parameters, *viz*., pH (Jackson, 1973), available nitrogen (N) by alkaline permanganometry (Subbiah and Asija, 1956), available phosphorus (P) by Olsen *et al*. (1954), available potassium (K) by Stanford and English (1976) and organic carbon (OC) by Walkley and Black (1934) were analyzed and estimated. Enumeration of microbial population, *viz*. bacteria, fungi and actinomycetes, was done by dilution, plating and culturing (Alef and Nannipieri, 1995). Observations pertinent to growth and yield parameters of coconut and component crops were recorded, the mean values were computed, and statistical analysis was done for comparing the yield of coconut across various treatments in HDMSCS. Coconut equivalent yield was worked out based on the yield of the intercrops and the market price of the economic produce. Earthworm population was enumerated in the basins at a depth of 0 to 15 cm across various treatments. The economic assessment was carried out considering the cost of inputs and the market price of the produce during the period of experimentation.

Results and discussion

Yield of coconut and intercrops

The yield of the main crop (coconut) and the accommodated intercrops are furnished in Table 3 and illustrated in Figure 2. Differential nutrient management options registered a spectacular impact on the nut yield of coconut during the experimental period (2013-18). Application of 75 per cent recommended dose of nutrients as chemical fertilizers and 25 per cent organic sources registered a conspicuous increase in nut yield over the pre-experimental period and the other treatments. Contrarily, a sharp decline in nut yield in the treatments T2 and T4 and a mild decline in T3 was witnessed during 2014-15 over the pre-experimental period. The trend reversed with a gradual increase in productivity in the years that followed; however, it did not surpass that recorded during the pre-experimental period. An array of evidences have underlined the significance of Integrated Nutrient Management (INM) in enhancing the nut yield of coconut (Bavappa *et al*., 1986, Maheswarappa *et al*., 2013 and Padma *et al*., 2016), which may be due to the readily available forms of nutrients in chemical fertilizers together with the regulated release of nutrients through organic manures. Sole chemical fertilization devoid of organic manures paves the way for leaching, volatilization and fixation losses of nutrients in the clay matrices, thus impairing nutrient mobility in the rhizosphere region, pulling down the productivity. The results also emphasize that a complete organic package could not sustain the nutrient demands of coconut over a long period, thus resulting in depression in nut yield over the INM packages T1 and T2. Maheswarappa *et al.* (2005) contemplated the increased productivity of palms in HDMSCS to the favourable microclimate offered by the intercrops, resulting in soil moisture retention and soil organic carbon build-up, leading to enhanced nutrient uptake by the main crop.

The dry bean yield of cocoa registered a gradual increase across years in all the treatments, and the effect was highly visible in T1 compared to T2 and T3. In banana, a decline in fruit productivity was observed compared to that recorded in the pre-experimental period. In pineapple, an inconsistent trend was observed across years in fruit yield due to the differential impact of treatments. However, the pooled data across five years (Table 4) revealed that the mean coconut productivity was higher in T1 (75 per cent RDN as chemical fertilizers + 25 per cent organic) followed by T2, and the lowest productivity was recorded in sole chemical fertilization. The yield of intercrops, *viz.,* cocoa, banana and pineapple, also followed a similar trend. Under HDMSCS at Kasaragod, the yield of banana and pineapple were observed to be highest in the treatment, which received 100 per cent NPK and organic manure recycling (Palaniswami *et al.,* 2007).

Coconut equivalent yield was higher in T1 with 113642 nuts per ha, followed by 110604 nuts per ha in T2 and 107092 nuts per ha in T3 (Table 5). An increase in coconut yield due to the combined application of inorganic fertilizers and organic manures has been reported by a line of workers (Palaniswami *et al*., 2007; Upadhyay *et al*., 2009; Krishna Kumar and Maheswarappa, 2010; Maheswarappa *et al*., 2011; 2013). Compared to monoculture, the yield of coconut in HDMSCS is high, which underlines the significance of favourable microclimate offered by the intercrops in realizing increased nut yields.

Soil quality

Soil quality was assessed based on the estimation of soil fertility (Table 6) and biological parameters (Tables 7, 8) across various treatments. The pH of the soil samples registered a decline in the treatments T1, T2 and T3 during 2018 compared to the pre-experimental values. This may be attributed to the contribution of organic acids from organic manures pulling down the pH values. Electrical conductivity registered an increase during 2018 compared to that recorded in 2013, which may be ascribed to the mobility of ions in the rhizosphere. Irrespective of the treatments imposed, $KMnO_4$ - N registered an increase during 2018 compared to the pre-experimental values. The quantum of increase was conspicuous in T1 compared to the rest of the treatments. The content of Olsen - P and 1N NH_4OAc-K also followed a similar trend due to the balanced application of nutrients in T1. Soil organic carbon (SOC) content showed a build-up in T1, T2 and T3 whilst depletion was encountered in T4, which is a natural corollary because of the short supply of organic manures.

The population of earthworms is a potential indicator of soil health and is important for maintaining soil fertility, soil structure and aggregate stability (Edwards and Lofty, 1977; Clements *et al.,* 1991). In the coconut basin, the population of earthworms was higher in T3 (Fully organic), followed by 50 per cent organic and 25 per cent organic treatments. The earthworm population was very meagre in 100 per cent RDN as well as sole chemical fertilization. In cocoa and banana basins, the population of earthworms in T4 was on par with T1, whilst the count was higher in T3. Similar results

Table 3. Effect of nutrient management options on the yield of main crop and intercrops in HDMSCS

Treatments		2013-14	2014-15	2015-16	2016-17	2017-18
T1	Coconut (nuts ha^{-1})	16450	18893	18478	17988	18600
	Cocoa beans (kg ha^{-1})	222	268	310	300	312
	Banana (kg ha^{-1})	23150	23100	15400	15250	15400
	Pineapple (kg ha^{-1})	2560	2700	2500	2390	2450
T2	Coconut (nuts ha^{-1})	20650	14678	15195	16250	17100
	Cocoa beans (kg ha^{-1})	259	259	277	292	298
	Banana (kg ha^{-1})	23000	23100	15000	15100	15190
	Pineapple (kg ha^{-1})	2350	2250	2400	2300	2300
T3	Coconut (nuts ha^{-1})	16100	15769	16820	15880	15820
	Cocoa beans (kg ha^{-1})	268	222	298	280	280
	Banana (kg ha^{-1})	22600	22750	15000	15000	15000
	Pineapple (kg ha^{-1})	2220	2200	2400	2260	2300
T4	Coconut (nuts ha^{-1})	18200	13125	12900	13712	12900

Table 4. The pooled mean of the yield of the main crop and intercrop (2013-18)

Treatment	Coconut (Nuts ha^{-1})	Dry beans of cocoa	Banana	Pineapple
			kg ha^{-1}	
T1: 75% RDN as chemical fertilizers + 25% organic	18082	282	18460	2520
T2: 50% RDN as chemical fertilizers + 50% organic	16775	277	18278	2320
T3: Fully organic	16078	270	18070	2276
T4: 100% RDN as chemical fertilizers	14005	-	-	-
Mean	16235	276	18269	2372
CD (P= 0.05)	333.1	10.4	140	126

Table 5. Effect of nutrient management options on coconut equivalent yield in HDMSCS

Treatment	Coconut (nuts ha^{-1})	Cocoa beans	Banana	Pineapple	Coconut equivalent yield (nuts ha^{-1})
		Coconut equivalent yield (nuts ha^{-1})			
T1: 75% RDN as chemical fertilizers + 25% organic	18082	3995	107667	1980	113642
T2: 50% RDN as chemical fertilizers + 50% organic	16775	4038	104633	1933	110604
T3: Fully organic	16078	3825	101167	2100	107092
T4: 100% RDN as chemical fertilizers	16005	-		-	-
Mean	16735	3953	104489	2004	110446

were earlier reported by Mader *et al*. (2002) and Padma *et al*. (2016), wherein the earthworm population was higher in the treatment that received a strict organic manure application. Similarly, the population of bacteria, fungi, and actinomycetes was higher in T3, followed by T2 and T1, which can be ascribed to the higher organic carbon content in the treatments serving as microflora. Rao and Patra (2009) postulated that soil microbes are vital to soil functionality and that in high-input agriculture, particularly in tilled agro-ecosystems, there is a decrease in species richness and the management practices that maintain soil cover and return organic matter to the soil along with chemical fertilizers, *i.e.*, integrated soil fertility management (IFSM) are the best options for ensuring long term soil

Table 6. Effect of nutrient management options on soil fertility status in HDMSCS

Treatment	pH		Electrical conductivity (dSm^{-1})		$KMnO_4$ N (kg ha^{-1})		Olsen P (kg ha^{-1})		1N NH_4OAc-K (kg ha^{-1})		Organic C (g kg^{-1})	
	2013	2018	2013	2018	2013	2018	2013	2018	2013	2018	2013	2018
T1	7.50	7.48	0.14	0.16	213	250	11.5	12.5	137	151	4.6	5.1
T2	7.38	7.24	0.16	0.18	241	252	12.2	12.6	154	165	4.1	5.1
T3	7.64	7.40	0.14	0.16	229	249	11.9	12.1	148	158	4.6	5.8
T4	7.71	7.73	0.19	0.20	238	251	11.1	11.9	161	168	4.6	3.4

Table 7. Effect of nutrient management options on earthworm population in HDMSCS

Treatment	Coconut basin	Cocoa basin	Banana basin
	(Nos m^{-2} at 0 -15 cm depth)		
T1: 75% RDN as chemical fertilizers + 25% organic	7	10	4
T2: 50% RDN as chemical fertilizers + 50% organic	12	11	7
T3: Fully organic	13	12	9
T4: 100% RDN as chemical fertilizers	2	10	4

Table 8. Effect of nutrient management options on soil microbial population in HDMSCS

Treatment	Bacteria (x10^4)	Fungi (x10^3)	Actinomycetes (x10^5)
		(cfu g^{-1} soil)	
T1: 75% RDN as chemical fertilizers + 25% organic	74.4	15.4	14.6
T2: 50% RDN as chemical fertilizers + 50% organic	85.2	17.8	15.6
T3: Fully organic	96.6	18.4	17.3
T4: 100% RDN as chemical fertilizers	62.4	12.4	12.0

Table 9. Effect of nutrient management options on recyclable biomass yield and vermicompost production in HDMSCS

Treatment	Cocoa (t ha^{-1})	Coconut (t ha^{-1})	Banana (t ha^{-1})	Weeds (t ha^{-1})	Total biomass (t ha^{-1})	Vermi compost production production (t ha^{-1})
T1: 75% RDN as chemical fertilizers + 25% organic	0.62	6.8	62.0	1.47	70.89	42.0
T2: 50% RDN as chemical fertilizers + 50% organic	0.59	7.7	70.0	1.48	79.77	47.0
T3: Fully organic	0.72	6.9	64.0	1.48	73.10	43.0
T4: 100% RDN as chemical fertilizers	-	7.2	-	1.56	8.76	3.60

sustainability, which is highly warranted for perennial ecosystems like coconut.

Recyclable biomass and vermicompost production

Under HDMSCS, there is ample scope for recycling of biomass through vermicompost technology. An elevated quantity of cocoa prunings was generated in fully organic treatment (T3), whilst the residues of coconut were higher in T2 followed by T4. The total biomass generated was higher in the treatment, which received an equal proportion of chemical fertilizers and organic manures (T2) due to profuse vegetative growth and was the lowest in T4. Quantity of vermicompost produced employing *Eudrillus sp*. of earthworms was higher in T2 (47 t ha^{-1}) followed by T3 and T1 (Table 9). Thus coconut based HDMSCS offers ample scope for vermicompost production from the recyclable biomass.

Employment generation and cost economics

Employment generation was remarkably higher in T3 because of the high labour force involved to meet the entire nutrient demands of the crop through organic manures. Employment generation was the lowest in coconut monoculture (T4). The economics of coconut based HDMSCS was calculated based on the prevailing market price of the economic produce and is furnished in Table 10. The cost of cultivation was highest in T3 because of the high cost of organic sources of nutrients to supply an equal proportion of nutrients as chemical

Table 10. Effect of nutrient management options on cost economics in HDMSCS

Treatment	Employment generation (man days year^{-1})	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
T1: 75% RDN as chemical fertilizers + 25% organic	188	189814	546058	334064	2.88
T2: 50% RDN as chemical fertilizers + 50% organic	205	196739	506264	311015	2.57
T3: Fully organic	225	211994	499138	309323	2.35
T4: 100% RDN as chemical fertilizers	132	123340	230460	107120	1.87

fertilizers. The highest gross returns was accrued in T1, and the lowest was obtained in coconut monoculture (T4). The net returns and the benefit-cost ratio were higher in T1, followed by T2, and lowest in T4. The systems approach in coconut paves the way for increased productivity and additional income, as reported by earlier workers Maheswarappa *et al*. (2003) and Palaniswami *et al.* (2007).

Conclusion

The present research emphasizes the significance of the systems approach in coconut towards realizing higher system productivity, enhanced soil quality, gainful employment and the highest benefit-cost ratio. Thus for the Western Zone of Tamil Nadu, integration of coconut with cocoa, banana and pineapple and application of 75 per cent of the recommended dose of nutrients as chemical fertilizers and 25 per cent substitution through organic sources is highly remunerative than the presently practised coconut monoculture and 100 per cent sole chemical fertilization.

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