

Influence of integrated nutrient management and high density multi-species cropping system on soil properties, plant nutrition and yield in root (wilt) affected coconut palms

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Abstract

A field experiment was conducted at Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala, India to study the effect of integrated nutrient management and high density multi-species cropping system in root (wilt) affected garden on root (wilt) index, yield of coconut palms and soil properties. The experimental results indicated that, there was improvement in soil properties like water holding capacity, organic carbon, major and micronutrient status of the soil due to adoption of integrated nutrient management practices and high density multi-species cropping system. There was improvement in the yield of the palms under different root (wilt) diseased palms coupled with reduction in root (wilt) indices due to reduction in root (wilt) symptoms especially yellowing. The increase in nut yield (five years average) was to the tune of 54.5%, 52%, 48.3% and 40.9% under apparently healthy, disease early, disease middle and disease advanced palms in comparison with pre-experimental yield.

Key words: Integrated nutrient management, cropping system, soil properties, root (wilt), nut yield.

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Introduction

Coconut (*Cocos nucifera* L.) is a versatile crop providing food, medicine, health drink, shelter, fuel, timber and fibre. In recent years many coconut farmers have suffered economic difficulties due to unstable copra prices in the world and local markets. Being a small holders' crop world over and more specifically in India, it does not provide adequate income and gainful employment to the dependent families. The productivity of coconut in Kerala state of India is as low as 6,349 nuts per hectare (For the year 2002-03) (Anonymous, 2003), mainly because of prevalence of root (wilt) disease, non-adoption of scientific agro-techniques coupled with crop being grown under rainfed condition. Coconut root (wilt) disease is a non-lethal, debilitating malady that affects the production potential of palm. The disease is caused by phytoplasma, a vascular limited pathogen. The most consistent and diagnostic symptom of the disease is the characteristic bending of the leaflets termed flaccidity, foliar yellowing and marginal necrosis of the older leaves were observed in association with the disease symptoms. The disease is prevalent in all districts of Kerala in varying severity, and the extent of incidence of the disease was highest in Alappuzha (48.03%) followed by Pathanamthitta (37.8 %), Kottayam (36.5%), Idukki (33.56%), Ernakulam (33.0 %) and Kollam (25.97%) districts. In the districts of Thrissur and Thiruvananthapuram the percentage of disease incidence was 6.19 and 2.09, respectively (Anonymous, 1996). The disease has also been noticed in districts of Tamil Nadu bordering Kerala and in Goa. There are no therapeutic control measures for the disease, however research efforts have resulted in evolving viable technologies to increase the productivity of the diseased palms.

Studies have revealed that, sole crop of adult coconut plantations spaced at 7.5 x 7.5 m apart effectively uses only 22.3 per cent of land area (Kushwah *et al.*, 1973), while the average air space utilization by the canopy is about 30 per cent and solar radiation interception is 45-50 per cent (Bavappa *et al.*, 1986). Adoption of coconut-based intercropping/mixed cropping systems is

one of the ways to utilize the natural resources effectively. The potential for increasing the productivity per unit area of land, time and inputs through high-density multi-species cropping system (HDMSCS) is considerably higher in perennial crops (Bavappa and Jacob, 1982). The advantages of HDMSCS involving compatible crops in coconut with increase in yield of coconut by 176% and additional income under red sandy loam soil in a root (wilt) disease free tract under perfo system of irrigation was clearly demonstrated (Bavappa *et al.*, 1986). The negative effects of coconut monoculture system of cultivation and impact of the application of inorganic fertilizers alone without ensuring a natural organic recycling in reducing the soil health are well known. The addition of organic matter and its positive role in managing the disease is also known. In the root wilt affected areas there is need to increase the yield as well as income which can be possible through integrated farming/cropping system.

With the above background, a study was initiated at Central Plantation Crops Research Institute (CPCRI), Regional Station, Kayangulam, Kerala, India to asses the effect of cropping system on integrated nutrient management including organic recycling, soil properties, effect on coconut, root (wilt) disease management, yield and economics of the system in root (wilt) affected area. Impact of above factors on productivity of the system and economic viability has been reported earlier (Maheswarappa *et al.*, 2003b) and influence of the above factors on the plant nutrition, nut yield, copra content, root (wilt) index of palms and soil properties are detailed in this paper.

Materials and methods

Experimental site

The experiment was carried out at Central Plantation Crops Research Institute, Regional Station, Kayamkulam, Kerala, India which is situated at 9° 8' N latitude and 76°31' E longitude at an elevation of 3.05 m above mean sea level. The experimental area receives an

annual rainfall of 2,580 mm, with the mean maximum temperature ranges between 29°C to 32.9°C and mean minimum temperature of 20.6°C to 24.9°C. The soil of the experimental field is loamy sand with low fertility and acidic in nature (pH 5.5). The mechanical composition of the soil is 69% fine sand, 18.9% coarse sand, 8.9% clay and 3.2% silt.

Experimental details

a. Integrated management practices for coconut in root (wilt) affected garden adopted from 1998 onwards:

- ❖ Growing cowpea as green manure crop in the coconut basin during April-May months and incorporating in the basin when it attains maximum growth during September-October.
- ❖ Application of 50 kg composted coir pith during September-October.
- ❖ Application of inorganic fertilizer: N:P:K-@ 500:300:1,000 g/palm/annum applied in 2 splits in the form of urea, rajphos, and muriate of potash (1/3rd during May-June and 2/3rd during September-October) along with MgSO₄-1.0 kg/palm/annum.
- ❖ Need based plant protection measures particularly for leaf rot control were carried out as per the recommendation. Leaf rot affected portions of the spindle leaf only was cut and removed. 300 ml of fungicidal solution containing 2 ml of Contaf 5% EC or 3 g Dithane M-45 was poured around the spindle leaf during April-May and October-November.
- ❖ Mulching with coconut leaves was done during November to May months.
- ❖ Irrigation was provided with hose irrigation during initial years and later perfo irrigation adopted and water to a depth of 20 mm was provided at the IW/CPE ratio of 1.0.

b. High density multi-species cropping system

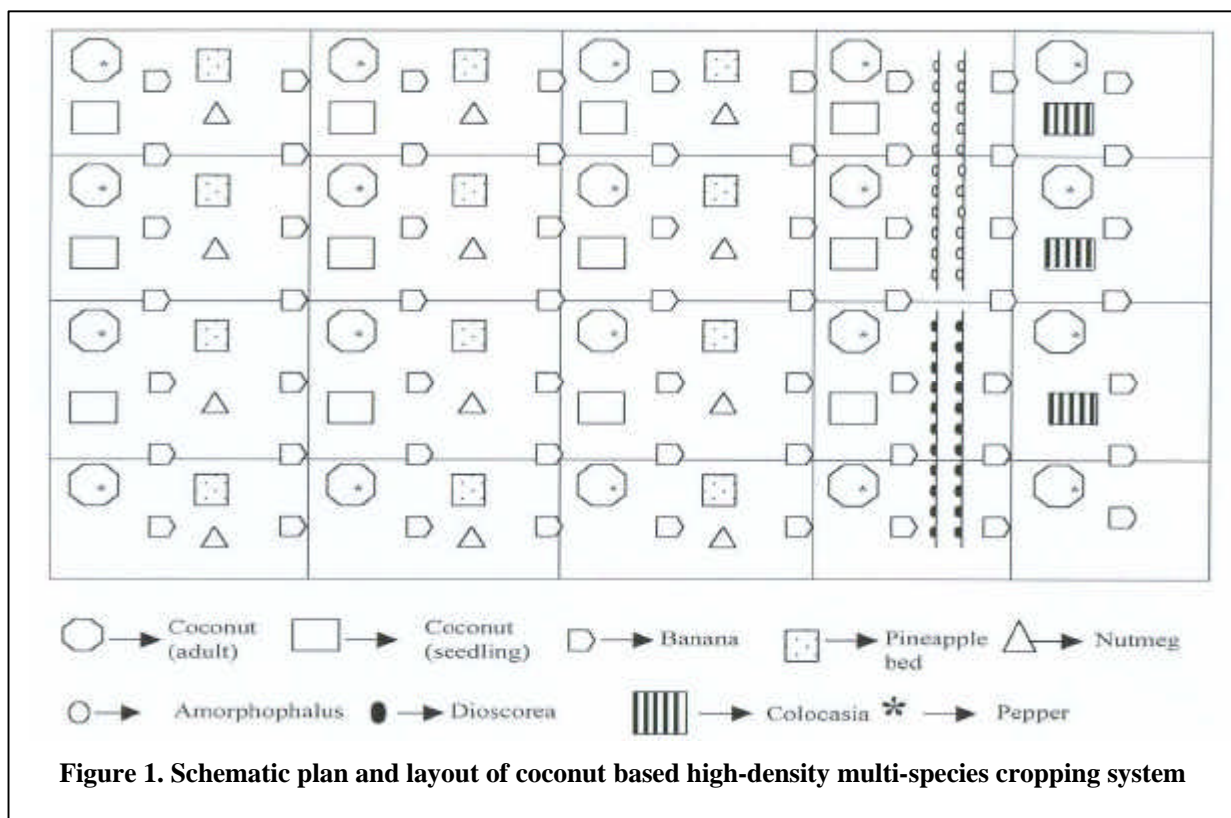
High-density multi-species model with different crops was initiated in an area of 1.0 ha of coconut root (wilt) affected garden during 1993-94 in the existing coconut garden planted

during 1965. The crop with their population and planting period is presented in Table 1 and schematic planting layout is given in Figure 1. The coconut palms were of different age group; 10-20 years: 46 palms, >20 years: 79 palms constituted the experimental area. Coconut palms were indexed for root (wilt) disease as per the procedure given by Nambiar and Pillai (1985) during June 1998 and after four years during July 2002. During 1998, of the total adult palms, 11% were apparently healthy, 29% were Disease Early, 53% were Disease Middle and 7% were Disease Advanced palms. The disease-advanced palms yielding less than 10 nuts per palm per year were removed. Under planting with seedlings was carried out in between the palms within the row during 1995-96. Component crops were managed with the package of practices recommended as per the Kerala Agricultural University recommendations (KAU, 1996). Coconut monocrop plot adjacent to HDMSCS plot was selected for taking the soil samples for soil properties study and coconut leaf samples for comparative study with HDMSCS plot. The coconut monocrop was aged 33 years and managed with application of recommended inorganic fertilizer only and under rainfed condition.

Soil samples were taken from two opposite sides of the palm, from the circular basin at 1.0 m distance away from the bole, at three depths viz. 0-25 cm and 25-50 cm and 50-100 cm using a tube augur from 8 palms each under apparently healthy and disease middle category palms in HDMSCS plot and monocrop plot. From the component crops soil samples were taken from two opposite sides of banana from 36 plants, nutmeg from 24 plants at two depths viz. 0-25 and 25-50 cm depth. From amorphophallus and dioscorea crops soil samples were collected from 12 spots each in between the plants at two depths viz. 0-25 and 25-50 cm depth and from pineapple crop (from 12 beds) the soil samples were collected from 0-25 cm depth in HDMSCS plot. The soil samples were air dried in shade, ground to pass through 2 mm sieve and analysed for total

Table 1. Crops with their population and planting year in HDMSCS plot in root (wilt) affected coconut garden

Crops	Population	Year of planting
Coconut: Adults	125 Nos. (1995-1998) 112 Nos.(1998-2002)	1965
Seedlings (Underplanted)	152 No.	1995-96
Nutmeg (local):	45 Nos.	1993-94
Pepper (karimunda)	30 Nos.	1993-94
Banana: (Poovan, Njalipoovan, Robusta, Nendran, Palayankodan Karpooravalli):	500 Nos.	193-94 and replanted once in 3 years
Pineapple (Kew):	3600 Nos.	1993-94 and replanted once in 3 years
Tuber crops: Amorphophallus (Local): Colocasia (Local): Dioscorea (Local):	100 Nos 100 Nos. 100 Nos.	Annual crops planted during pre-monsoon period of every year



nitrogen, phosphorus, potassium, secondary and micro nutrient status. Water holding capacity of the soil for 0-25 cm depth was estimated by following Keen Reczkowski box measurement method (Keen and Reczkowski, 1921). Organic carbon content of the soil was analysed by Walkley and Black's wet oxidation method and pH (1:2.5 soil water suspension) by Beckman's pH meter method (Jackson, 1973). Soil samples were analysed for total nitrogen by alkaline permanganate method, the available phosphorus was estimated (Bray-1) following the procedure outlined by Jackson (1973) and available potassium was determined in the 1N NH₄OAC flame photometrically. Micronutrient analysis was carried out as per the procedure given by Lindsay and Norvell (1978).

The leaf samples were collected from index leaf (14th leaf) of the palm by using a specially designed knife, by cutting 4-5 leaflets from the middle of the frond on both the sides. The leaves were collected from 8 palms each under category of apparently healthy and disease middle symptoms in HDMSCS plot and monocrop plot. The leaf samples were washed with distilled water, oven dried at 65°C for 72 hrs and powdered using a Tecator Cyclotec sample mill. The powdered fraction (0.5 mm) of leaf sample was digested in HNO₃:HClO₄ (2:1) and analysed for phosphorus by vanado molybdate colorimetry method and potassium content by flame photometry method (Jackson, 1973). The nitrogen content in plant sample was estimated according to micro Kjeldahl procedure as described by Jackson (1973). Calcium, magnesium and micronutrients were analysed using Atomic Absorption Spectrophotometer-Model Varian SpectrAA 55 (Lindsay and Norvell, 1978).

Nut yield of adult palms was recorded palm wise and mean was worked out. Among under planted coconut, only 10 per cent of the palms started yielding during 2001. Copra content of adult palms from the different indexed palms was studied during 2001-2002 (July, October, January and April months' harvest) under HDMSCS plot by collecting 4 nuts per palm from single harvest and mean was worked out.

Results and discussion

Soil properties

The water holding capacity of the top 0-25 cm soil from the root region of coconut and different crops in HDMSCS plot was higher (37.4% to 38.5%) compared to coconut monocrop plot (35.3 to 35.8%). This clearly depicts positive effect of integrated nutrient management practices on water holding capacity of the soil particularly application of composted coir pith in increasing water holding capacity of the soil. The soil chemical properties data is presented in Table 2 and it indicated that the organic carbon, pH, total N, available P and K status of the soil under HDMSCS found to be higher compared to monocrop plot. Increase in available P with application of organic manure, incorporation of green manure crop might be attributed to P solubilising capacity of the organic manure. Higher K availability in soil is due to their easy decomposition of mineral constituents and their effect in dislodging the exchangeable K into the soil solution. Increase in pH of the soil under HDMSCS plots compared to monocropping may be due to the impact of addition of organic manure which has influenced in rise in pH of the soil as pointed out earlier by Liyanage *et al.* (1989), Bopaiah (1988) and Khader *et al.* (1992). Addition of organic manure and *in situ* growing and incorporation of cowpea as green manure crop in the coconut basin had increase in status of major nutrients. Growing green manure crop, cowpea in the basins of coconut added 24 to 25 kg of green biomass and incorporation of the same resulted in addition of major nutrients as reported by Maheswarappa *et al.* (2003a) in coconut basins. Bopaiah (1988) also reported increase in organic carbon content, available P and K status in coconut based mixed cropping with pepper, cocoa in red sandy loam soil of Kasaragod. Available "P" increase was mainly attributed to release of fixed "P" by increase in activity of "P" solubilising enzymes as reported by Bopaiah and Shetty (1991). Nambiar *et al.* (1989) also reported increase in all the 'P' fractions and all the 'K' fractions under coconut based high density multi-species cropping

system over a period of three years in red sandy loam soil condition of Kasaragod, India. The beneficial interactions of mixed cropping of coconut with cocoa, coffee, pepper, clove, banana, cinnamon in terms of improvement in soil physical and chemical characters like organic carbon, nutrient status has been reported by Liyanage and Dassanayake (1993). Improvement in soil chemical characters like build up of NPK status and increase in organic carbon content has been reported in high density multi-species cropping system in arecanut at CPCRI (RS), Vittal, Karnataka grown in laterite soil (Khader *et al.*, 1992). There was not much variation in the status of Ca and Mg in HDMSCS and monocrop situation.

It is clearly evident from the Table 2 that, soil micronutrients status like Fe, Cu and Zn was higher in the coconut based HDMSCS plot compared to monocrop plot of coconut. This increase in the status might be attributed to adoption of integrated nutrient management practices with organic recycling and HDMSCS in the garden. In general the coconut soils of Kerala are sufficient in exchangeable Fe, Cu and Al as reported by Pillai *et al.* (1975). Addition of organic manure and incorporation of green manure crop residue might have resulted in release of Fe and Cu in the soil. In arecanut + cocoa cropping system also, Manikandan *et al.* (1985) reported the increase in available Fe and Cu status compared to monocrop of arecanut.

Coconut leaf nutrient status

Leaf nutrient status of coconut leaf presented in the Table 3, indicated that, there was not much variation in composition of N, P, K, Ca and Mg nutrients in the leaf tissues of coconut grown in HDMSCS and palms grown with inorganic fertilizer alone under monocrop plot. The composition of micronutrients like Zn, Fe and Cu was higher in palms grown in HDMSCS plot compared to palms grown with inorganic fertilizer alone under monocrop plot. This clearly indicates additional benefit of *in situ* growing and incorporation of green manure crop, addition of composted coir pith in enhancing micronutrient status. Palms grown under integrated management practices have absorbed the

available nutrients from the soil and resulted in higher concentration of nutrients in the palms. Increase in uptake of nutrients may be due to the fact that irrigation favours the uptake and/or utilization of nutrients. The efficacy of irrigation could be noticed by way of improved water uptake through the newly regenerated roots and lesser transpiration rate as reported by Rajagopal *et al.* (1986 a and b). A comprehensive study on the nutritional factors of the disease by Pillai *et al.* (1975) indicated that the palms in the disease affected areas, whether apparently healthy or visibly diseased, were in a state of imbalanced nutrition, possibly the result of a relatively higher content of N, P and K on the one hand and lower content of Ca, Mg and S on the other. Hameed Khan *et al.* (1985) also reported higher Fe, Cu and Mn content in the crowns of root (wilt) affected palms and the correlations between elemental concentrations in question in different leaves in the crown and the disease index revealed no relationship. Nambiar *et al.* (1983) also reported increase in Fe and Mn content in diagnostic leaves of coconut due to application of coir dust and cattle manure in littoral sandy soil of Kasaragod in disease free area.

Root (wilt) index

Indexing of palms for root (wilt) disease intensity during June 1998 and during July 2002 is presented in Table 4. It is clearly evident from the Table that, there was reduction in the root (wilt) index after four years to the tune of 2.9 in disease early, 5.6 in disease middle and 6.4 in disease advanced palms. Decrease in root (wilt) index was mainly attributed to decrease in the root (wilt) symptoms like flaccidity (56% reduction), yellowing (69% reduction) and necrosis (40% reduction) in HDMSCS plot. Application of MgSO₄ might have contributed to decrease in yellowing symptoms, which is in conformity with the results of earlier workers also (Pillai *et al.*, 1975; Cecil *et al.*, 1978 and Sahasranaman *et al.*, 1983). Integrated nutrient

Table 2. Soil nutrient status in coconut based HDMSCS as influenced by integrated management practices and in comparison with monocrop

Location	Depth (cm)	Total N (ppm)	Avail. P (ppm)	Avail. K (ppm)	Avail. Ca (ppm)	Avail. Mg (ppm)	Avail. Fe (ppm)	Avail. Mn (ppm)	Avail. Cu (ppm)	Avail. Zn (ppm)	OC (%)	pH
Under HDMSCS:												
Coconut basin: Apparently healthy	0-25	447	96	124	94	45	36.26	2.74	2.96	13.41	0.32	6.3
	25-50	330	78	114	87	37	35.17	2.78	2.82	12.33	0.22	5.8
	50-100	280	61	107	82	34	31.40	2.12	2.08	12.88	0.20	5.3
Disease middle	0-25	419	90	129	91	43	38.22	3.24	2.68	12.91	0.31	6.4
	25-50	320	81	104	93	42	29.13	2.76	2.47	12.81	0.20	5.5
	50-100	240	60	101	87	40	25.42	2.02	2.30	13.02	0.16	5.0
Under Monocrop:												
Apparently healthy	0-25	401	88	109	96	49	21.00	2.83	1.24	8.90	0.14	6.0
	25-50	340	75	103	85	33	25.77	2.77	1.40	7.31	0.13	5.7
	50-100	220	52	98	70	39	24.38	2.54	1.83	7.01	0.13	5.6
Disease middle	0-25	360	89	110	93	44	23.46	2.68	1.77	7.61	0.12	6.0
	25-50	308	72	99	82	34	20.81	2.20	1.54	7.41	0.11	5.4
	50-100	290	59	98	71	42	20.34	2.12	1.63	6.80	0.13	5.3
Interspace (without crops)	0-25	390	45	104	53	45	12.18	2.67	1.64	9.30	0.18	5.8
	25-50	280	57	109	88	36	13.57	2.50	1.73	8.69	0.19	5.4
Under HDMSCS:												
Nutmeg	0-25	410	83	114	104	39	17.38	2.81	3.15	13.20	0.29	6.3
	25-50	300	75	128	89	36	22.37	1.96	2.60	13.00	0.18	5.8
Banana	0-25	337	85	137	95	36	19.36	2.90	2.44	13.21	0.30	6.2
	25-50	280	76	129	88	40	28.54	3.01	2.37	12.80	0.23	5.7
Amorphophallus	0-25	390	56	71	83	38	14.98	1.51	1.49	13.25	0.29	6.1
	25-50	280	31	104	82	27	16.93	2.48	1.65	13.10	0.18	5.6
Dioscorea	0-25	340	39	99	98	42	18.47	2.09	1.18	12.81	0.31	6.3
	25-50	220	29	95	101	36	16.38	2.52	1.84	12.61	0.19	5.8
Pineapple	0-25	270	118	97	83	41	17.38	2.63	2.62	13.02	0.29	6.3

Table 3. Coconut leaf nutrient status as influenced by integrated management practices in HDMSCS plot in comparison with monocrop

	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Mn(ppm)	Zn(ppm)	Fe(ppm)	Cu(ppm)
Under HDMSCS:									
Apparently healthy	1.90	0.12	1.25	0.45	0.25	88.1	27.5	207.7	3.52
Disease middle	1.93	0.12	1.25	0.39	0.23	75.7	23.8	218.9	3.06
Under monocropping:									
Apparently healthy	1.86	0.10	1.26	0.42	0.26	87.2	24.2	141.2	2.71
Disease middle	1.92	0.11	1.24	0.42	0.24	74.9	20.0	142.0	2.80

Table 4. Root (wilt) disease index of coconut palms as influenced by integrated nutrient management practices in HDMSCS plot

Disease index	During June 1998	During July 2002	Increase (+) /Decrease (-)
Disease early (<20) (33 palms)	15.1	12.2	-2.9
Disease middle (20-50) (59 palms)	41.4	35.8	-5.6
Disease advanced (>50) (8 palms)	60.8	54.4	-6.4

Table 5. Coconut nut yield and copra yield as influenced by integrated management practices In HDMSCS plot

Disease index	Average nut yield (Nuts per palm per year of adult palms)							Copra content (g/nut) (2001-2002)	Copra outturn per palm (kg) (2001-2002)
	Pre-exptl. (1991-'93)	1997-98	1998-99	1999-00	2000-01	2001-02	Average of 1997-2002		
Apparently healthy (12 palms)	44	48	53	64	88	87	68.0	179.3	15.6
Disease early (33 palms)	40	45	42	59	84	74	60.8	182.4	13.5
Disease middle (59 palms)	36	42	41	55	74	55	53.4	181.7	10.0
Disease advanced (8 palms)	21	29	28	30	35	26	29.6	180.6	4.7

increase in availability of nutrients and uptake by palms and improvement in growth, but these factors were not related with the incidence or control of root (wilt) disease. Adoption of leaf rot control measure improved the photosynthetic area of the palms which has direct effect on the productivity of the palms. Rajagopal *et al.* (1987a) also reported reduction in flaccidity, yellowing and necrosis and increase in the overall photosynthetic area (about 55% improvement) due to summer irrigation and application of recommended fertilizer for coconut in root (wilt) affected garden.

Nut yield and copra content

Nut yield for five years under different root (wilt) indexed palms in the HDMSCS plot (Table 5) revealed that, there was increase in nut yield to the tune of 54.5%, 52%, 48.3% and 40.9% under apparently healthy, disease early, disease middle and disease advance indexed palms, respectively compared to pre-experimental yield. Improvement in yield has been noticed from third year onwards after imposing the integrated nutrient management practices. Increase in yield might be due to improvement in soil characters, and better growth of coconut as reflected by reduction in yellowing, necrosis and increase in photosynthetic area of palms due to integrated management practices. Apparently healthy palms recorded the highest yield followed by disease early and disease middle palms. Application of balanced dose of fertilizer along with organic manure application and irrigation has favoured the growth and development of the palms and reduced intensity of root (wilt) symptoms. Rajagopal *et al.* (1986a and 1987b) have reported that, leaves of diseased palms had lower stomatal resistance (with relatively high transpiration rates) and leaf water potentials than apparently healthy palms. Diseased palms also indicated that dysfunction of stomatal regulation and there was abnormally wide stomatal opening. Rajagopal *et al.* (1987a) while studying the influence of summer irrigation, application of recommended chemical fertilizer and plant protection measures in root (wilt) affected garden under farmers' plot have reported that there was overall improvement of the conditions of the palms with increased nut

yield ranging from 64% to 200%. Increase in yield was mainly attributed to increase in the photosynthetic area of the palms and reduction in yellowing and necrosis symptoms, which has direct influence on the female flower production, fruit set and nut yield. Muralidharan *et al.* (1986) reported increase in yield to the tune of 59.3% under rainfed situation and 36% under irrigated condition due to the practice of integrated management practices in farmer's field in root (wilt) area. In a large scale demonstration in mildly affected areas there was increase in nut yield to the tune of 29.2 nuts/palm/year due the adoption of integrated management practices (Anonymous, 1986). Rethinam *et al.* (1991) also have reported that integrated management increased the nut yield from 28 to 51 nuts per palm per year within 3 years in mildly affected area and 23.4 nuts per palm per year on an average in disease affected area. Intercropping with tuber crops in root (wilt) affected garden resulted in overall increase in nut yield and decrease in disease intensity (Menon and Nayar, 1978 and Antony, 1983). Mixed cropping with cocoa under single and double hedge systems increased the yield of coconut by 27.1% and 35% respectively without any deterioration in the disease intensity of the palms under rainfed conditions (Nair *et al.*, 1975). Increase in nut yield to the tune of 28% due to application of organic manure or recycling organic manure when mixed farming was followed in root (wilt) affected coconut garden has been reported by Sahasranaman *et al.* (1983). Thomas *et al.* (1993) also reported increase in yield of disease affected palms due to *in situ* incorporation of green manures and inorganic nutrients without deterioration in the root (wilt) disease condition.

Copra content under different indexed palms studied in the HDMSCS plot (Table 5) indicated that, there was not much difference in the copra content per nut, among the different category of root (wilt) indexed palms. Adoption of integrated nutrient management practices resulted in copra development to the optimum potential of the coconut. The out turn of copra per palm was less under disease advanced palms

due to the production of less number of nuts per palm.

Conclusion

Integrated nutrient management practices coupled with adopting high density multi-species cropping system under root (wilt) affected garden resulted in improvement in growth of palms with reduction in the root (wilt) symptoms. The increase in nut yield (five years' average) was to the tune of 54.5%, 52%, 48.3 % and 40.9% under apparently healthy, disease early, disease middle and disease advanced palms compared to pre-experimental yield. There was improvement in soil properties like water holding capacity, organic carbon, major and micronutrient status of the soil due to adoption of integrated nutrient management practices and high density multi-species cropping system.

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References

- Anonymous, 1986. Coconut root (wilt) disease-present status of research and management. Technical Bulletin No. 14. Central Plantation Crops Research Institute, Kasaragod, Kerala, India.
- Anonymous, 1996. Coconut root (wilt) Survey, 18-19. Department of Agriculture, Government of Kerala, India.
- Anonymous, 2003. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.
- Antony, J. 1983. Microbiological activities in the root region of coconut under intercropping with tuber crops. Ph.D. Thesis, University of Kerala, Trivandrum.
- Bavappa, K.V.A. and Jacob, V.J. 1982. High density multispecies cropping-A new approach to small scale farming in the tropics. *World Crops* **34**(2):47-50.
- 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 Shama Bhat, K. 1986. Coconut and arecanut based high-density multispecies cropping system. *J. Plant. Crops* **14**(2): 74-87.
- Bopaiah, B.M. 1988. Microbiological studies in relation to high density multi-species cropping system in coconut. Ph.D. Thesis. University of Mysore, India.
- Bopaiah, B.M. and Shetty, H.S. 1991. Soil microflora and biological activities in rhizospheres and root regions of coconut based multistoried cropping and coconut monocropping systems. *Soil Biol. Biochem.* **23**(1): 89-94.
- Cecil, R.S., Pillai, N.G., Mathew, A.S and Kamalakshi Amma, P.G. 1978. Effect of application of N,P,K, Ca and Mg on young west coast tall palms in the root (wilt) affected area, pp. 101-113. *In: Proceedings of 1st Plantation Crops Symposium (PLACROSYM I)*. Indian Society for Plantation Crops, Kasaragod, India.
- Hameed Khan, H., Biddappa, C.C., Joshi, O.P. and Cecil, S.R. 1985. Micronutrient distribution in the crowns of healthy and root (wilt) diseased palms. *J. Plant. Corps* **13**: 66-68.
- Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.
- KAU, 1996. Package of practices recommendations-Crops 1996.

- Directorate of Extension, Mannuthy, Thrissur, Kerala, India.
- Keen, B.A. and Reczkowski, H. 1921. The relation between the clay content and certain physical properties of a soil. *J. Agric. Sci.* **11**: 441-449.
- Khader, K.B.A., Balasimha, D. and Bhat, N.T. 1992. Resources use in arecanut based high density multispecies cropping system. *J. Plant. Crops* **20** (Supplement): 19-24.
- Kushwah, B.L., Nelliath, E.V., Markose, V.T. and Sunny, A.F. 1973. Rooting pattern of coconut. *Indian J. Agron.* **18**: 71-74.
- Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for Zinc, Iron, Manganese and copper. *Soil Sci. Soc. Amer. J.* **42**:421-428.
- Liyanage, L.V.K., Jayasundera, H.P.S., Mathes, D.T. and Fernando, D.N.S. 1989. Integration of pasture, fodder and cattle in coconut small holdings. *Cord* **5**(2): 53-67.
- Liyanage, M.S. de and Dassanayake, K.B. 1993. Experience on coconut based farming system in Sri Lanka. pp. 357-368. In: *Advances in Coconut Research and Development*, M.K. Nair, H.H. Khan, P. Gopalasundaram and E.V.V. Bhaskara Rao (Eds.). Oxford and IBH Publishing Co. Ltd., New Delhi.
- Maheswarappa, H.P., Anitha Kumari, P. and Sairam, C.V. 2003b. High density multi species cropping system for root (wilt) affected coconut gardens – Its impact on productivity and economic viability. *J. Plant. Crops* **31**(1): 23-27.
- Maheswarappa, H.P., Anitha Kumari, P., Kamalakshamma, P.G. and Shanavas, M. 2003a. Cowpea (*Vigna unguiculata*) as a low cost input green manure crop for basin management under coconut root (wilt) garden. *Indian Cocon. J.* **34**(5): 11-13.
- Manikandan, P., Joshi, O.P., Hameed Khan, H., Mohapatra, A.R. and Biddappa, C.C. 1985. Nutrient profile in an arecanut-cacao system on a laterite soil. *Trop. Agric., Trinidad* **64**(1): 13-16.
- Menon, K.S. and Nayar, T.V.S. 1978. Effect of intercropping with tuber crops in root (wilt) affected coconut gardens, pp. 416-424. In: *Proceedings of PLASCROSYM I*, Indian Society for Plantation Crops, Kasaragod, Kerala.
- Muralidharan, A., Nair, M.G. and Jayashankar, N.P. 1986. Response of coconut root (wilt) disease to management practices. *Indian Cocon. J.* **17**(1): 3-6.
- Nair, P.K.R., Verma, R., Nelliath, E.V. and Bavappa, K.V.A. 1975. Beneficial effect of crop combination of coconut and cocoa. *Indian J. Agric. Sci.* **45**: 165-171.
- Nambiar C.K.B., Biddappa, C.C., Bopaiah, M.G., and Kailasam, C. 1989. Influence of high density multispecies cropping on the P and K forms in the soil. *J. Plant. Corps* **17**(1): 36-43.
- Nambiar, C.K.B., Hameed Khan, H., Joshi, O.P. and Pillai, N.G. 1983. A rational approach to the management of coastal sands for establishment and production of coconuts. *J. Plant. Crops* **11**(1): 24-32.
- Nambiar, P.T.N. and Pillai, N.G. 1985. A simplified method of indexing root (wilt) affected coconut palms. *J. Plant. Crops* **13**(1): 35-37.
- Pillai, N.G., Wahid, P.A., Kamala Devi, C.B., Ramanandan, P.L., Robert Cecil, S., Kamalakshi Amma, P.G., Mathew, A.S. and Nambiar, C.K.B. 1975. Mineral nutrition of root (wilt) affected coconut palm. Fourth session of FAO Technical Working Party on coconut production, protection and processing, Kingston, Jamaica.
- Rajagopal, V. Sumathikuttyamma, B. and Patil, K.D. 1987b. Water relations of coconut palms affected with root (wilt) disease. *New Phytology* **105**: 289-293.

- Rajagopal, V., Mathew, C., Patil, K.D., and Abraham, A.J. 1986b. Studies on water uptake by root (wilt) diseased coconut palms. *J. Plant. Crops* **14**: 19-24.
- Rajagopal, V., Patil, K.D. and Sumathikuttyamma, B. 1986a. Abnormal stomatal opening in coconut palms affected with root (wilt) disease. *J. Experim. Bot.* **37**: 1398-1405.
- Rajagopal, V., Patil, K.D., Mathew, C. and Sumathikuttyamma, B. 1987a. Physiological studies on root (wilt) diseased coconut palms under different management practices. *J. Plant. Crops* **16** (Suppl.): 47-53.
- Rethinam, P., Antony, K.J. and Muralidharan, A. 1991. Management of coconut root (wilt) disease. p. 60. *Second International Symposium of Coconut Research and Development*. Abstract of paper CPCRI, Kasaragod, India.
- Sahasranaman, K.N., Pillai, N.G., Jayashankar, N.P., Varkey, T., Kamalakshi Amma, P.G. and Radha, K. 1983. Mixed farming in coconut garden - Economics and its effect on root (wilt) disease, pp. 160-165. In: *Coconut Research and Development* (Ed.) N.M. Nayar, Wiley Eastern Ltd., New Delhi.
- Thomas, George, V., George, Mathew and Shantaram, M.V. 1993. Effect of growing green manure legumes in the basins of root (wilt) affected coconut palms, pp. 421-422. In: *Advances in Coconut Research and development*, M.K. Nair, H.H. Khan, P. Gopaldasundaram and E.V.V.B. Rao (Eds.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.