Green Farming Vol. **10** (3) **:** 258-265 ; May-June, 2019 **Research Paper**

Technology demonstration in coconut for higher productivity and profitability in coastal ecosystem of Maharashtra State

V.V. SHINDE[1*], S.L. GHAVALE[2], S.M. WANKHEDE[3], P.M. HALDANKAR[4] and H.P. MAHESWARAPPA[5]

AICRP on Palms, Regional Coconut Research Station, Bhatye, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli - 415 712 Ratnagiri (Maharashtra)

Received : 18 April 2019 ; Revised accepted : 20 May 2019

ABSTRACT

Integrated nutrient management involve intelligent use of organic, inorganic and biological resources so as to sustain optimum yield, improve or maintain soil chemical and physical properties and provide crop nutrition packages which are technically sound and economically attractive. In recent days, nutrient management through organic source of manures is gaining momentum for sustaining the productivity and conserving the natural resources. Hence field experiment on impact of integrated nutrient management (INM) and organics including biomass recycling in coconut based cropping system was initiated in 30 years old healthy D x T coconut plantation at Regional coconut Research Station, Bhatye, Ratnagiri (M.S) during the year 2013-14 to 2017-18. The experiment consist of four treatments *viz.,* T_1 : 75 % of recommended NPK +25 % of N through organic recycling with vermi-compost, T_2 : 50 % of RDF+ 50 % of N through organic recycling with vermi-compost + vermiwash application +bio-fertilizer application +*in situ* green manuring, T_3 : 100 % of N through organic recycling with vermi-compost +vermiwash application +bio-fertilizer application +*in situ* green manuring and green leaf manuring (glyricidia leaves) + composted coir pith, husk incorporation and mulching with coconut leaves and T_4 : control: mono-crop of coconut with recommended NPK and organic manure were imposed. The component crops were nutmeg, cinnamon, banana and pineapple. Annual leaf production did not differ among the treatments; however, integrated treatments resulted in higher number of leaves (11.79 Nos.). Five years mean data on nut yield indicated that, application of organic manures in combination with inorganic fertilizer either in 75 % of recommended NPK +25 % of N through organic recycling with vermi-compost (142.47 nuts/palm/year) or 50 % of RDF+50 % of N through organic recycling with vermi-compost +vermiwash application +bio-fertilizer application +*in situ* green manuring (128.96 nuts/palm/year) resulted the higher nut yield. There was improvement in the nutrient status of coconut leaves with INM practices compared to inorganic or organic manure alone application. The soil organic carbon was higher in the treatment T_1. Microbial population of fungi were more in treatments T_3 whereas the bacteria and actinomycetes present in top soil were higher in treatment T_1 and T_2 respectively. Earthworm population were highest in the treatment T_3 followed by the treatment T_1 and T_2. The highest (2.57) benefit: cost ratio was recorded in T_1 followed by T_2 (2.25) as compared to the other treatments.

Key words : *Coconut, INM, Microbial population, Nutrient status, Nut yield, Organic recycling.*

INTRODUCTION

Coconut (*Cocus nucifera*) is widely grown in coastal sandy soils which occur all along the coastal tract of West and East coast of Peninsular India. However, coconut productivity is very low in the coastal sandy soils due to an array of facts like poor water holding capacity, excessive infiltration, rapid leaching loss of nutrients resulting in low nutrient retentive capacity and low availability of major and micro nutrients, small specific surface area on account of low clay and organic matter content, low CEC and low organic carbon content (Ollangnier and Ochs, 1978). Moreover, the sole crop of coconut planted at a wider spacing of 7.5 m x 7.5 m is not able to fully utilize the available basic resources of crop production, *viz*., soil, solar energy, water and nutrients. Introduction of component crops, especially, adoption of multi-storeyed cropping system with compatible crops favours better utilization of resources for

[1]Agronomist *(agronomistbhatye17@gmail.com), [2]Research Officer, [3]Jr. Entomologist, [4]Director of Research, [5]Project Coordinator (Palms)

augmenting returns besides alleviating inherent soil limitations. Adoption of such systems can provide food security through food sufficiency, nutritional foods rich in vitamins and minerals, employment generation through farm diversification and ecological stability (Ramadasan and Lal, 1966). There is a need to consider the system as a unit especially with respect to supply of inputs like organic manures, fertilizers, herbicides, water and plant protection chemicals (Nampoothiri, 2001). The fertilizer doze for coconut is 2.25:3.0:2.0 kg urea, single super phosphate and muriate of potash per palm per year and continuous application of large quantities of fertilizers over a considerable period of time will definitely affect the physico-chemical and biological properties of soils turning the system unsustainable in all aspects. In this context, an investigation entitled "Systems approach in coconut for higher productivity and profitability in coastal ecosystem of Maharashtra State" was carried out to develop appropriate cost effective practices for enhancing nutrient use efficiency, productivity and profitability of coconut based INM systems.

MATERIALS AND METHODS

The field experiment on impact of INM and organics including biomass recycling in coconut based INM system was initiated at Regional Coconut Research Station, Bhatye, Ratnagiri, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (M.S) during the year 2013-14 to 2017-18. The climate of the experimental site is warm and humid tropical with mean annual rainfall of 3,500 mm and 120 rainy days. The mean temperature ranges from 21°C (mini.) to 36°C (maximum). The average relative humidity varies between 60 and 95%. The soil of the experimental plot was sandy loam in texture, well drained with medium fertility status. The experiment was laid out in 30-year-old coconut garden (cv. D x T – 'COD x West Coast Tall') which was planted at a distance of 7.5 m × 7.5 m in a square system. The experiment consist of four treatments *viz.,*

- T_1 : 75 % of recommended NPK +25 % of N through organic recycling with vermicompost,
- T_2 : 50 % of RDF+50 % of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring,
- T_3 : Fully organic : 100 % of N through organic recycling with vermicompost + vermiwash application +bio-fertilizer application + *in situ* green manuring and green leaf manuring (glyricidia leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves and
- T_4 : Control: mono-crop of coconut with recommended NPK and organic manure were imposed.

Each treatment consisted of 4 palms/block. The coconut palms along with component crops like nutmeg, cinnamon, banana and pineapple as a farming model. The experiment was conducted on 0.40 ha coconut garden that where inter planted with released varieties of the Maharashtra State (**Table 1**) as depicted in **Fig. 1 and 2**. The statistical design was non-replicated.

Table 1. Plant population in coconut based integrated nutrient management system

Sr. No.	Name of the crop	Varieties/ Hybrids	Number of plant/block	Number of plant/acre
1.	Coconut	D x T	20	70
2.	Nutmeg	Konkan Swad	12	54
3.	Cinnamon	Konkan Tej	62	246
4.	Banana	Konkan SafedVelchi	72	246
5.	Pineapple	Kew	960	4320

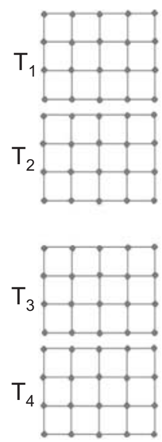

Fig. 1. Layout of the experimental field

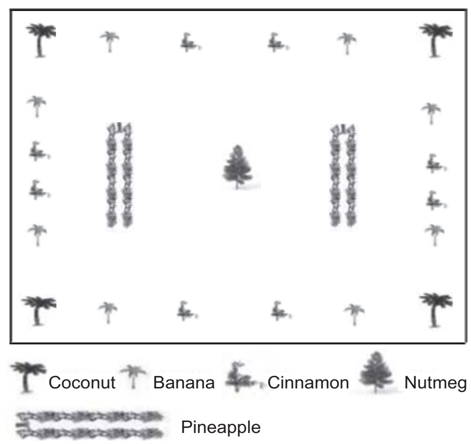

Fig. 2. Layout of single plot

The quantity of NPK and vermicompost applied under different treatments has been described by Maheswarappa *et al.* (2011). As per the treatments, vermicompost was applied during September–October and inorganic fertilizers in the form of urea, SSP and muriate of potash were applied in 2 equal splits during June-July and September–October. Vermicompost was obtained by decomposing coconut leaves as per the procedure explained by Prabhu *et al.* (1998). The biomass was recycled back into the system after making vermicompost and recommended dose of fertilizer was applied both for coconut and component crops as per treatment details and farm waste utilization was done effectively to meet nutrient requirement. The vermicompost was prepared and applied to meet the requirement of nutrients. The vermiwash collected was drenched in the basin of each crop by diluting it in the ratio of 1:10 with water and applied twice in the year for coconut @5 lit./basin, nutmeg@3 lit./tree, banana @2 lit./plant, pineapple 4 lit. in a bed of 40 plants and cinnamon @ 2 lit./plant. In addition to this glyricidia plants were grown as green manuring crop at a border of plot and green leaf manuring was done for coconut and intercrops in the month of June, while application of fertilizer. The coconut palms were irrigated with drip system while the sprinkler irrigation was followed for irrigating different crops in the system. During December to January, 27 lit. water and 32 lit. water during February to May per palm/day was applied. Husk burial was followed before planting perennial crops and husk burial in the trenches was followed in each set of four coconut palms (once in 3 year). Dried coconut leaves were used for mulching in summer months (February-May) in order to reduce the evaporation of moisture from the soil.

The soil and leaf samples were collected from 3 palms in each plot. Soil samples were collected from 0–25 cm, 25-50 cm and 50-100 cm depth, 1 m away from the bole of the coconut using augur and soil properties were determined by adopting standard procedures. The leaf samples were collected from index leaf (4th 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 leaf samples were washed with distilled water, oven-dried at 65°C for 72 hr and powdered using a Tecator Cyclotec sample mill. The powdered fraction (0.5 mm) of leaf sample was digested in di-acid mixture of HNO_3 : $HClO_4$ (3:1) and analysed for phosphorus and potassium content. The nitrogen content in plant sample was estimated according to modified Kjeldahl procedure using Tecator Kjeltec Auto Analyser. The content of K was estimated in atomic absorption spectrophotometer.

Soil samples drawn from the circular basins at 1.0 m away from the bole, at 0–25 cm using a tube augur were used for microbial enumeration. The population of bacteria, fungi and actinomycetes were determined in the collected soils. The results of the microbial analyses were given as CFU/g of dry soil. Each CFU value was the average of 4 × 3 sample replicates. Annual leaf production was recorded from the selected palms by marking a newly emerged leaf and later counting the number of leaves emerged above the marked leaves as leaf production per palm per year in each year. Numbers of spadices and buttons were timely recorded. Nuts were harvested at maturity stage palm-wise and average for the year was worked out. Copra and oil yield were also calculated. Growth and yield characters of component crops were timely recorded. Earthworm population (Nos./m^2), biomass generation (kg) and light interception (%) were recorded and economics of coconut based integrated nutrient management system was worked out.

RESULTS AND DISCUSSION

Number of leaves on crown

The mean data regarding to the number of functional leaves on crown shown (**Table 2**) that the highest number of functional leaves (30.96 Nos.) were in the treatment T_1 whereas lowest (29.29 Nos.) in the treatment T_4. Nath *et al*. (2012) reported increase in number of leaves due to INM in coconut. The results are in tune with the observations of Maheswarappa *et al*. (2014) wherein application of different sources of organics and inorganics did not reduce or increase the number of leaves on crown. The number of leaves present on the crown also did not differ among the treatments. Being a perennial crop, effect of different treatments might not have any influenced on the growth and development of the palms.

Rate of leaf production

Number of leaves produced per palm per year did not differ among the treatments (Table 2). However, it was found that the leaf production was higher (11.79 Nos.) in the INM treatments T_2 compared to other treatments. Nath *et al*. (2012) reported increase in leaf production owing to integrated nutrient management in coconut. Being a perennial crop, effect of different treatments might not have significantly influenced the growth and development of the palms.

Number of spadices

Number of spadices produced per palm per year did not differ among the treatments (**Table 3**). However, it was found that the mean of spadices production were higher (11.45 Nos.) in the INM treatments T_1 followed by treatment T_2 (11.34 Nos.) and T_3 (11.29 Nos.) whereas lower mean of spadices production were in treatment T_4 (11.19 Nos.). Kalpana *et al*. (2008) reported increase in spadices production owing to INM in coconut and recorded maximum mean spadices per palm per year in the application of 100% CCP and 50% CCP + 50% RDF.

Number of buttons

Number of buttons (female flowers) produced per palm per year did differ among the treatments (Table 3). However, it was found that the mean of buttons production was higher (326.04 Nos.) in the INM treatments T_1 followed by treatment T_2 and T_3

Table 2. Effect of integrated nutrient management system on growth characters of coconut

Treatment	Number of leaves on crown (Nos./palm)						Rate of leaf production (Nos./palm/year)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	30.93	31.38	31.38	31.47	29.65	30.96	11.68	12.00	11.73	11.75	11.75	11.78
T_2	30.35	30.05	30.03	30.80	28.45	29.94	11.70	12.65	11.40	11.65	11.55	11.79
T_3	30.52	30.22	29.43	30.22	29.16	29.91	11.90	11.65	11.55	11.97	11.83	11.78
T_4	29.73	29.48	28.97	29.92	28.33	29.29	11.53	11.58	11.47	11.95	11.71	11.65

Table 3. Effect of coconut based integrated nutrient management system on yield and yield attributing characters of coconut

Treat-ment	Number of spadices (Nos./palm)						Number of buttons (female flowers) (Nos./palm)						Nut yield (Nos./palm)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	10.35	11.95	11.50	11.65	11.80	11.45	311.15	323.96	330.08	334.72	330.30	326.04	131.63	126.03	178.25	129.53	146.90	142.47
T_2	11.20	11.50	10.95	11.50	11.55	11.34	330.75	314.05	312.00	319.95	326.45	320.64	127.28	120.43	146.92	110.50	139.65	128.96
T_3	10.72	11.28	11.27	11.37	11.83	11.29	324.43	314.53	316.08	319.77	327.59	320.48	112.85	98.60	125.40	124.85	137.05	119.75
T_4	10.60	11.20	10.78	11.68	11.71	11.19	309.40	308.67	302.67	311.67	329.55	312.39	100.00	102.40	87.45	123.80	134.30	109.59

whereas lowest mean of buttons production was in the treatment T_4. Kalpana *et al.* (2008) reported increase in buttons production due to INM in coconut and recorded maximum mean of female flowers per palm per year in the application of 100% CCP and 50% CCP + 50% RDF and Nath *et al.* (2012) reported increase in buttons production owing to INM in coconut.

Coconut nut yield

The coconut nut yield recorded among the treatments over the years and the mean data are presented in Table 3. In general, there was an increase in the yield of coconut and the yield obtained in different treatments was higher over the years than the pre-treatment yields, which was mainly owing to the effect of treatments and irrigation provided to coconut palms.

During 2014-2017, T_1 treatment recorded higher nut yield and was at par with T_2 treatment and was differed compared to the other treatments. The yield obtained under T_1 treatment and T_2 treatment was at par and ranged from 98.60 to 126.03 nuts/palm/year. The mean data on nut yield for 5 years (2013-14 to 2017-18) indicated the differences among the treatments (Table 3). Application T_1 treatment recorded higher nut yield and differed with the other treatments. Increase in yield under these treatments might be owing to better availability of required nutrients which resulted in improvement in yield. Srinivasa Reddy and Upadhyay (2002), Talashilkar *et al.* (2008) and Nath *et al.* (2012) reported increase in yield of coconut with the application of inorganic fertilizer (50%) and 50% through vermicompost and the positive effect of integration of organic and inorganic fertilizer combination on coconut yield in different soil types also. Nut yield recorded under T_1, T_2 and T_3 treatments were at par with each other and ranged from 119.75 to 142.47 nuts/palm/year. An increase in annual productivity in coconut by following mix cropping has been reported by Nelliat *et al.* (1974). Additional increased in yield of coconut with farming system component could be due to synergistic effect of crop combination and nutrient status maintained in the system. Application of vermicompost alone could not result in increase in yield of coconut, as it could not provide the required P and K and application of inorganic fertilizer alone could not provide the suitable soil environment for the growth and development of coconut.

Copra and oil yield

The coconut copra and oil yield recorded among the treatments over the years and the mean data are presented in **Table 4**. In general, there was an increase in the copra and oil yield of coconut and the yield obtained in different treatments was higher over the years than the pre-treatment yields, which was mainly owing to the effect of treatments and irrigation provided to coconut palms. During 2014-2017, T_1 treatment recorded higher copra and oil yield and was at par with T_2 treatment and was differed compared to the other treatments. The mean copra and oil yield obtained under T_1 treatment and T_2 treatment was at par and ranged from 23.06 to 25.73 kg/palm/year and 15.72 to 17.11 kg/palm/year respectively. Also the oil yield (tonnes/ha) obtained under T_1 treatment and T_2 treatment was at par and ranged from 16.25 to 15.71 tonnes/hectare.

Table 4. Effect of coconut based integrated nutrient management system on copra and oil yield of coconut

Treat-ment	Copra yield (kg/palm)						Oil yield (kg/palm)						Oil yield (tonnes/ha)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	21.45	21.44	30.30	28.87	26.59	25.73	14.53	14.57	20.61	18.51	17.34	17.11	2.81	2.55	3.61	4.07	3.21	3.25
T_2	21.64	20.40	24.98	25.05	23.21	23.06	14.69	13.87	16.98	16.82	16.25	15.72	3.99	2.42	2.97	3.51	2.82	3.14
T_3	18.86	16.76	21.32	23.58	21.32	20.37	12.85	11.39	14.50	14.71	14.57	13.60	2.24	1.99	2.54	3.25	2.45	2.49
T_4	17.02	17.38	14.87	17.14	17.50	16.78	11.57	11.82	10.11	11.85	11.66	11.40	2.02	2.07	1.77	2.35	1.75	1.99

Increase in copra and oil yield under these treatments might be owing to better availability of required nutrients which resulted in improvement in yield. Application of any single manure could not result in increase in copra and oil yield of coconut, as it could not provide the required P and K and application of inorganic fertilizer alone could not provide the suitable soil environment for the growth and development of coconut. Results analogous to these finding were recorded by Kalpana *et al*. (2008) in the coconut based INM on nut yield and quality of coconut under coastal ecosystem.

Growth and yield of components crops

The growth of component crops as influenced by coconut based INM system in coconut is presented in **Table 5**. It was observed that the height of nutmeg plants increases after the 4^{th} year of treatment initiation and the maximum mean height of nutmeg plants was 154 cm in T_3 whereas the minimum was in treatment T_2 (79 cm).

The mean maximum number of nutmeg branches was in treatment T_3 (10.3 Nos.) whereas minimum in treatment T_2 (5.8 Nos.). The mean maximum height of cinnamon plants was (228.9 cm) in T_1 whereas the minimum was in treatment T_2 (206.4 cm). The mean maximum number of cinnamon branches was in treatment T_3 (15.33 Nos.) whereas minimum in treatment T_2 (7.77 Nos.). The yield of component crops as influenced by coconut based INM system in coconut is presented in **Table 6**. The highest mean yield of component crops namely pineapple and banana were in the treatment T_3

Table 5. Effect of coconut based integrated nutrient management system on growth characters of component crops as an intercrops in coconut orchard

Treatment	Height of nutmeg plant (cm)						No. of branches in nutmeg					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	29.5	84.0	95.0	107.4	120	87.2	3.0	5.0	7.0	8.4	9.4	6.6
T_2	39.4	76.4	84.4	92.8	102	79.0	2.4	3.4	6.8	7.6	9.0	5.8
T_3	111.8	118.2	150.4	163.4	226	154.0	8.0	7.6	11.2	12.8	12.0	10.3
T_4	-	-	-	-	-	-	-	-	-	-	-	-

Contd.... Table 5.

Treatment	Height of cinnamon plant (cm)						No. of branches in cinnamon					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	93.00	178.60	206.45	250.75	415.5	228.9	10.00	11.45	15.50	17.15	2.65	11.35
T_2	54.95	156.85	189.50	231.50	399.0	206.4	5.90	4.80	12.30	13.55	2.30	7.77
T_3	87.25	186.75	219.65	241.50	373.0	221.6	10.70	20.25	21.15	22.80	1.75	15.33
T_4	-	-	-	-	-	-	-	-	-	-	-	-

Table 6. Effect of coconut based integrated nutrient management system on yield of component crops as an intercrops in coconut orchard

Treatment	Yield of component crops/block											
	Pineapple (kg)						Banana (kg)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	45.0	50	60	65	35	51.0	179.5	450	420	470	490	401.9
T_2	55.0	45	50	57	30	47.4	187.0	400	360	400	430	355.4
T_3	37.5	40	70	76	40	52.7	96.0	350	480	550	580	411.2
T_4	-	-	-	-	-	-	-	-	-	-	-	-

Contd.... Table 6.

Treatment	Yield of component crops/block											
	Cinnamon bark (kg)						Cinnamon leaves (kg)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	4	8.4	17.0	19.0	21	13.88	40	42	60	65	67	54.8
T_2	5	8.0	8.0	9.5	10	8.10	50	40	40	42	45	43.4
T_3	3	9.0	8.4	8.5	9	7.58	30	45	42	45	48	42.0
T_4	-	-	-	-	-	-	-	-	-	-	-	-

such as 52.7 kg/block and 411.0 kg/block respectively whereas highest mean yield of component crops cinnamon bark and cinnamon leaves were in the treatment T_1 such as 21 kg/block and 54.8 kg/block respectively. Similar results were also reported by Bavappa and Jacob (1982) in coconut farming system.

Biomass generation, vermi-compost production and light interception

The biomass generation was highest in the treatment T_3 (5700 kg/ha/year) followed by the treatment T_2 (5670 kg/ha/year), T_1 (5285 kg/ha/year) and T_4 (3791 kg/ha/year). The vermin-compost production was higher in the treatment T_3 (3875 kg/ha/year) followed by the treatment T_2 (3700 kg/ha/year), T_1 (3518 kg/ha/year) and T_4 (2477 kg/ha/year) (**Table 7**). Also the generated biomass and vermi-compost production from different component crops which can be recycled in the coconut based INM system.

Table 7. Biomass generation, vermicompost production and light interception in coconut based integrated nutrient management system (Light intensity in Lux during 11.00 am to 1.00 pm) (2017-2018)

Treatments	Biomass generation (kg/ha/year)	Vermi-compost production (kg/ha/year)	Light intensity (Lux)	Light interception (%)
Open field	-	-	75850	-
T_1	5285	3518	27500	63.74
T_2	5670	3700	25350	67.89
T_3	5700	3875	26500	65.06
T_4	3791	2477	63500	16.28

The percent of light intensity was highest in treatment T_2 (67.89 %) and T_3 (65.06 %). Additional yield obtained by different crops in the system and additional biomass generated on the same piece of land, and other resource like space, height, irrigation etc. could be benefited to obtain higher income. Similar results were also reported by Bavappa and Jacob (1982) in coconut farming system.

Soil properties

The electrical conductivity of the soil (at 0–25 cm depth) did change due to the INM practices in the basins of the coconut, as seen during treatment initiation (2013-14) and the mean of 4th years after treatment initiation (2014-15 to 2017-18) (**Table 8**). After the 4th years of treatment initiation soil pH and organic carbon content differed among the treatments. With the application of vermicompost, there was change in the pH of the soil, and the T_1 treatment recorded higher pH (7.55) followed by T_2 treatment green manuring (7.24) as compared to the other two treatments. The soil organic carbon also higher with T_1 treatment (1.26 %) followed by T_2 treatment green manuring (1.24 %) as compared to the other two treatments.

The soil nutrient content (NPK) was also highest with T_1 treatment followed by T_2 treatment green manuring as compared to the other two treatments (Table 8). Increase in N, P and K, content of coconut cropping system from 2013-14 to 2017-18 could be attributed to organic recycling of biomass glycricidia leaf lopping, vermiwash application in the system. Krishnakumar and Maheswarappa (2010), Srinivasa Reddy

Table 8. Soil nutrient status as influenced by coconut based integrated nutrient management system

Soil depth	Parameter → / Treatment ↓	2013-2014						2017-2018					
		pH	EC (dS/m^2)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	OC (%)	pH	EC (dS/m^2)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	OC (%)
0-25	T_1	7.5	0.183	253	17	301	0.42	7.55	0.190	277	21.5	309.3	1.26
	T_2	7.1	0.149	248	18	289	0.54	7.24	0.158	262	25.6	293.1	1.24
	T_3	6.8	0.168	220	16	278	0.39	6.82	0.176	243	19.3	284.0	1.20
	T_4	6.7	0.186	265	17	312	0.30	6.71	0.196	284	20.3	318.0	0.89
25-50	T_1	7.4	0.170	234	17	277	0.31	7.43	0.181	248	21.6	286.0	1.22
	T_2	7.1	0.168	217	15	242	0.51	7.11	0.173	241	18.1	256.0	1.20
	T_3	6.9	0.178	167	9	269	0.44	6.9	0.181	178	13.0	276.1	1.18
	T_4	6.8	0.190	240	12	265	0.30	6.81	0.198	251	16.0	278.1	0.91
50-100	T_1	7.3	0.211	191	13	212	0.38	7.22	0.221	202	16.1	218.3	1.19
	T_2	7.0	0.151	143	9	228	0.43	7.10	0.168	151	13.0	233.1	1.18
	T_3	6.8	0.201	152	9	261	0.41	6.79	0.206	158	12.2	273.0	1.16
	T_4	6.7	0.192	210	10	215	0.32	6.41	0.198	221	13.4	226.1	0.78

Table 9. Leaf nutrient status (%) and soil microbial population (CFU/g dry soil) as influenced by coconut based integrated nutrient management system

Treatment	Leaf nutrient status						Soil microbial population (CFU/g dry soil) (2017-18)		
	2013-2014			2017-2018			Bacteria	Fungi	Actinomycetes
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	(10^5 CFU/g soil)	(10^4 CFU/g soil)	(10^3 CFU/g soil)
T_1	1.50	0.12	1.2	1.75	0.18	1.31	95.0	153.0	134.0
T_2	1.40	0.14	1.0	1.71	0.16	1.26	89.0	148.0	136.0
T_3	1.38	0.13	0.9	1.53	0.11	1.24	77.0	166.0	112.0
T_4	1.48	0.14	1.1	1.49	0.10	1.20	42.0	59.0	67.0

Table 10. Earthworm population (No.'s/m^2) as influenced by coconut based integrated nutrient management system

Treat-ment	Soil depth																	
	0-10 cm						10-20 cm						20-30 cm					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	12.00	12.40	12.0	13.0	13.5	12.6	4.20	6.40	6.4	5.8	6.0	5.8	1.60	2.20	2.8	2.8	3.0	2.5
T_2	8.00	8.60	9.0	10.8	10.2	9.30	2.00	2.80	3.2	4.4	4.9	3.5	0.20	1.60	1.8	2.4	2.8	1.8
T_3	16.40	16.00	14.8	14.8	15.0	15.4	7.80	9.60	9.6	9.8	10	9.4	3.60	3.80	4.2	3.8	4.0	3.9
T_4	4.00	7.60	7.2	7.6	7.7	6.80	1.80	2.00	2.2	3.4	3.8	2.6	0.00	0.80	1.4	2.4	2.8	1.5

and Upadhyay (2002) and Maheswarappa *et al.* (2014) reported significant change in soil properties due to INM practices.

Leaf-nutrient status

The nutrient content in the index leaf in respect of N, P and K differed among the treatments (**Table 9**). After the 4th years of treatment initiation the mean N content was higher with T_1 treatment (1.75%) followed by T_2 treatment green manuring (1.71 %) as compared to the other two treatments. Also the P and K content were higher with treatment T_1 and T_2. It was observed that, as the recommended NPK was reduced, the leaf N, K content also found to be decreased, mainly because of the lower N and K supply through vermin-compost and reduced dose of recommended N.

In general, it was found that, there was improvement in leaf nutrient status in respect of major and micronutrients due to different treatments compared to pre-experimental nutrient status. This is mainly attributed to timely application of nutrients and irrigation for the crop. It was observed from the data that N, P, K content of coconut leaf increased after four years from system. Results analogous to these finding were recorded by Maheswarappa *et al.* (1998) in mix cropping of coconut.

Soil microbial population

The population of bacteria, fungi and actinomycetes did differ among the various treatments, when analysed at 0–25 cm soil depth (Table 9). Though the top soil (0–25 cm depth) is the zone of intensive microbial activity and therefore, should have reflected changes undergoing in microbial community structure in response to extraneous inputs, which in present study are organic and inorganic fertilizers.

However, the population of fungi were, in general, more in treatments T_3 maximum inputs was applied as compared to other treatments. The bacteria and actinomycetes present in top soil were higher in treatment T_1 and T_2 respectively. Also the earthworm population were highest in the treatment T_3 followed by the treatment T_1 and T_2 (**Table 10**). Results analogous to these finding were recorded by Maheswarappa *et al.* (2014) in the coconut based integrated nutrient management with vermi-composted coconut leaves.

Economics

The economics of coconut based INM system was worked out and presented in **Table 11**. The economics of the INM system revealed that the highest (2.57) benefit : cost ratio was recorded with T_1 treatment followed by (2.25 B:C) with T_2 treatment as compared to the other two treatments. The economic analysis of mixed farming system maintained at CPCRI, Kasargod for the period of 1989-90 to 1997-98, realized net return between ₹ 49,700 and 1,26,900 (Maheswarappa *et al.*, 2000).

Table 11. Economics (per ha.) of coconut based integrated nutrient management system

Treatment	Cost of production (₹/ha)						Gross return (₹/ha)					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	94439	208696	168671	168665	168780	161850.2	239616	830650	1281300	1712550	2479897	1308802.6
T_2	89424	154260	151920	152160	152250	140002.8	249985	784120	967800	1236750	1546836	957098.2
T_3	77229	276904	152122	148743	148850	160769.6	201557	781650	900450	1388100	1495072	953365.8
T_4	60195	57000	57000	57000	57000	57639.0	138600	214200	189000	258300	311682	222356.4

Contd....

Treatment	Net return (₹/ha)						B:C ratio					
	2013-14	2014-15	2015-16	2016-17	2017-18	Mean	2013-14	2014-15	2015-16	2016-17	2017-18	Mean
T_1	145177	621954	1112629	1543885	2311117	1146952.4	1.79	2.11	2.86	2.98	3.10	2.57
T_2	160561	629860	815880	1084590	148743	567926.8	1.53	1.94	2.14	2.76	2.87	2.25
T_3	104328	504746	748328	1239357	1346222	788596.2	1.35	1.63	1.88	2.11	2.41	1.88
T_4	78405	157200	132000	201300	254682	164717.4	1.30	1.61	1.69	1.91	2.14	1.73

CONCLUSION

It can be concluded that, application of organic manures in combination with inorganic fertilizer either in 75 % of recommended NPK + 25 % of N through organic recycling with vermicompost or 50 % of RDF+ 50 % of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + *in situ* green manuring found to be beneficial in respect of maintaining nutritional status of coconut and improving the soil microbial population and coconut yield over a period of time.

REFERENCES

Bavappa K V A and Jacob VJ. 1982. High intensity multispecies cropping – A new approach to small scale farming in the tropics. *World Crops*. **34** (2) **:** 47-50.

Kalpana M, Srinivasulu B, Rao D V R, Arulraj S and Jayabose C. 2008. Impact of integrated nutrient management on nut yield and quality of coconut under coastal ecosystem. *Journal of Plantation Crops*. **36** (3) **:** 249-253.

Krishnakumar V and Maheswarappa H P. 2010. Integrated nutrient management for root (wilt) diseased coconut (*Cocos nucifera*) palms. *Indian Journal of Agricultural Sciences.* **80** (5) **:** 394–98.

Maheswarappa H P, George V Thomas, Ravi Bhat, Palaniswami C and Jayasekhar S. 2011. Impact of inorganic fertilizer substitutions by vermicomposted coconut leaves on productivity and economics of coconut. *Journal of Plantation Crops*. **39** (1) **:** 30–34.

Maheswarappa H P, Hegde M R, Dhanapal R and Biddappa C C. 1998. Mixed farming in coconut garden: Its impact on soil physical and chemical properties, coconut nutrition and yield. *Journal of Plantation Crops*. **26** (2) **:** 139-143.

Maheswarappa H P, Sairam C V, Dhanapal R, Vidhan Singh T, and Hegde M R. 2000. Economic analysis of coconut based mixed farming systems. *CORD*. **XVI** (1) **:** 37-46.

Maheswarappa H P, George V. Thomas, Alka Gupta, Ravi Bhat and C. Palaniswami. 2014. Productivity and nutrient status of coconut (*Cocos nucifera*) as influenced by integrated nutrient management with vermicomposted leaves. *Indian Journal of Agronomy*. **59** (3) **:** 455-459.

Nampoothiri K U K. 2001. Organic Farming–Its relevance to plantation crops. *Journal of Plantation Crops.* **29** (1) **:** 1–9.

Nath J C, Arulraj S and Maheswarappa H P. 2012. Integrated nutrient management of COD × WCT hybrid coconut under alluvial clay-loam soil of Assam. *Journal of Plantation Crops.* **40** (2) **:** 105–10.

Nelliat E V, Bavappa K V A and Nair P K R. 1974. Multi-storeyed cropping – A new dimension in multiple cropping for coconut plantation. *World Crops.* **26** (6) **:** 262-266.

Ollangnier M and Ochs R. 1978. Mineral exportation of the hybrid coconut PB 121. *Oleagineux.* **33 :** 437–43.

Prabhu S R, Subramanian P, Biddappa C C and Bopaiah B M. 1998. Prospects of improving coconut productivity through vermiculture technology. *Indian Coconut Journal.* **29** (4) **:** 79–94.

Ramadasan A and Lal S B. 1966. Exhaust of nutrients from coconut garden – Factors affecting production. *Coconut Bulletin.* **20 :** 173–75.

Srinivasa Reddy D V and Upadhyay A K. 2002. Impact of integrated nutrient management on the mineral nutrition and yield of WCT coconut in littoral sandy soil at Kasaragod. (*In*:) *Proceedings of PLACROSYM-XV,* Central Coffee Research Station, Balehonnur, Karnataka. pp. 274–81.

Talashilkar S C, Nagwekar D D, Akhave S R and Dabke D J. 2008. Effect of integrated use of manures and fertilizers on coconut yield and changes in available nutrient content and N, P and K fractions of inceptisols of Konkan region. *Journal of Plantation Crops.* **36** (2) **:** 112–116.

□