Technical bulletin No. 5/2020

Integrated Nutrient Management in Coconut Based Cropping System under Konkan Region of Maharashtra

ICAR- AICRP on Palms
Regional Coconut Research Station,
Bhatye, Ratnagiri (M.S.) - 415 612
Dr. B.S. Konkan Krishi Vidyapeeth,
Dapoli, Dist. Ratnagiri

Integrated Nutrient Management in Coconut Based Cropping System under Konkan Region of Maharashtra

ICAR

AICRP on Palms (ICAR)

Regional Coconut Research Station, Bhatye,
Ratnagiri, (M.S.) - 415 612

Dr. B.S. Konkan Krishi Vidyapeeth,
Dapoli, Dist. Ratnagiri

Integrated Nutrient Management in Coconut Based Cropping System under Konkan Region of Maharashtra

Compiled and Edited by,
Dr. Vaibhav V. Shinde
Dr. Sunil S. Ghawale
Dr. Santosh M. Wankhede
Dr. R. G. Khandekar
Dr. B. R. Salavi
Dr. Maheswarappa H. P.
Dr. P. M. Haldankar

About Bulletin :
*This is Technical bulletin on **Integrated Nutrient Management in Coconut Based Cropping System under Konkan Region of Maharashtra.** This includes how the coconut ecology, economy & changes with interppin of spices, banana & pineapple in coconut orchard.*

About AICRP :

All India Coordinated Research Project on palms started on 1972 at Regional Coconut Research Station, Bhatye which was established on 01st July 1955. The project on crop improvement, crop production and pest management are being studied under the project.

About University :

The Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth agriculture university Dapoli Dist. Ratnagiri. This University was established on 18th May 1972 for Konkan region. The Mango, Cashew, Coconut, Arecanut and Spices are the major crops studied under this university.

Type Setting and Cover design :
Dr. Sunil L. Ghavale
Smt. Priyanka Nagwekar

Phtographs :
Dr. Vaibhav V. Shinde
Dr. Sunil L. Ghavale

Printing :
Satyshodhak Printing Press
Tilak Aali, Tal. & Dist. Ratnagiri,
Phone : (02352) 225965, 222312

CONTENT

INTEGRATED NUTRIENT MANAGEMENT IN COCONUT BASED CROPPING SYSTEM UNDER KONKAN REGION OF MAHARASHTRA

I) INTRODUCTION

Coconut is an important crop of economic importance to many of the Asian and Pacific countries in the world. The crop provides livelihood security and employment opportunities to a major segment of the rural mass of these countries. India being the largest coconut producing country in the world occupies 31% of global production. Widely acclaimed as Kalpavriksha or Tree of life, the coconut palm provides food security and livelihood opportunities to more than 10 million people in India. It is an important food crop for the major chunk of Indian population. Similarly it is an important cash crop for more than 10 million farm families and a fiber-yielding crop for more than 15,000 coir based industries which provides employment to nearly 6 lakhs workers of which 80 per cent are women folk. The coconut and coconut products are gaining global importance as a contributing factor to the health, nutrition and wellness of human beings. This is due to its multiple medicinal and nutraceutical properties being revealed day by day. This new development in health sector brought in unprecedented increase in demand of coconut products in domestic and international markets. It is estimated that there are 5 million coconut holdings and 12 million farmers in the country covering 17 states and 3 Union Territories.

Scenario of coconut cultivation in Maharashtra

The State of Maharashtra is a coconut growing state in the country with an extent of 27180 ha. with a production of 209 million nuts and productivity of 7687 nuts/ha (2018-2019). The coastal districts namely Sindhudurg, Ratnagiri, Raigad and Palghar covers the major coconut growing areas in the state. Within the state, these four districts command 94 percent of area under coconut.

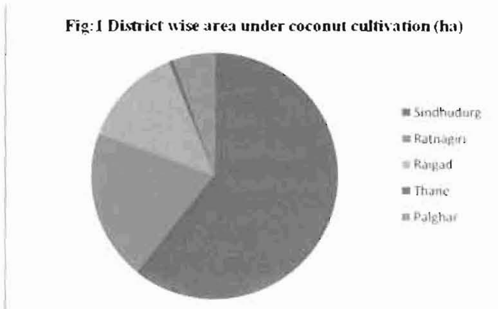


Fig. 1. District wise area (Ha) under coconut cultivation

Konkan region of Maharashtra is a long narrow strip of 720 kms, running North to South along the West coast of Maharashtra. The region comprises of Thane, Raigad, Ratnagiri, Sindhudurg and Greater Mumbai districts. It is characterized by hilly terrain receiving heavy rainfall ranging from 3000 to 4000 mm per annum usually during four months from June to September. The climate is warm and humid almost throughout the year. Coconut is a major irrigated horticultural crop of Maharashtra. The total productive area under Coconut cultivation in Maharashtra is 43320 ha with production of 209.87million nuts and productivity 4845 nuts/palm/year mainly grown in Konkan region of Maharashtra. Since 1990, the Government of Maharashtra has launched the Employment Guarantee Scheme (EGS) for number of horticultural crops which includes coconut plantation also. This helped to boost up area under coconut crop.

Generating and establishing more sustainable cropping system is need of today's era. Multispecies and multistoried cropping system ensures maximum utilization of resources for higher yield per unit area. There are many coconut based cropping systems in various countries and states of the nation. Effective and efficient utilization of available resources for higher yield is the modern concept of cropping system. Improvement in the soil properties and biological activities in the rhizosphere due to intercropping results in the modification of soil environment for the benefit of the plant growth. Studies revealed that natural resources i.e. soil water; air space and solar reclamation are not fully utilized under the spacing schedule 7.5 m x 7.5 m. Many of the coconut workers have reported that a well designed high density multispecies crop model suited to a given agro-climatic situation generates returns biomass output, yields, more economic returns and higher total income, additional employment opportunities for family labours and meets diversified needs of the coconut farmers, such as food, fruit, vegetables, fuel etc. The coconut based cropping systems are gaining importance as there are serious market fluctuations for coconuts and coconut products. Systematic mixed cropping of compatible crops under coconut to compensate the economic losses of sole cropping by increasing income per unit of cultivable land has become a necessity.

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 practically feasible and environmental safe. In recent days, nutrient management through organic source of manures is gaining momentum for sustaining the productivity and conserving the natural resources. In coconut based cropping system it is necessary to fertilize coconut and component crops according to make the system more productive and competitive. Hence field experiment on impact of integrated nutrient management and organics including biomass recycling in coconut based cropping system was initiated in 30 years old D x T coconut plantation at Regional coconut Research Station, Bhatye, Ratnagiri (M.S) during the year 2013-14 to 2018-19. The component crops were nutmeg, cinnamon, banana and pineapple. The experiment consists 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.

T_4: Control: monocrop of coconut with recommended NPK and organic manure were imposed.

Table 2 : Physico-chemical properties of sandy loam soil at RCRS, Bhatye centre (Ratnagiri)

Content	Soil depth (cm)		
	0-30	**30-60**	**60-90**
Sand (%)	89.5	89.4	89.0
Silt (%)	3.4	3.6	3.9
Clay (%)	7.1	7.2	7.1
pH	5.58	5.52	5.38
Organic carbon (%)	0.22	0.19	0.10
Electrical conductivity (dsm-1)	0.186	0.171	0.164

2) COCONUT BASED CROPPING SYSTEM

a) Component crops

Current experiment was laid out in 32 year old coconut garden which was planted at a distance of 7.5 m × 7.5 m in a square system. The crops in the cropping system were managed with the recommended package of practices. The experimental block of each treatment was laid out in 0.11 ha. coconut garden and intercropping with released varieties of spices and fruit crops in Maharashtra State was adopted. The spice and fruit crops grown in the coconut garden are given in Table 3 and pictorial representation in Fig. 2 and Fig.3.

Table 3 : Details of the component crops in coconut based integrated nutrient management system

Sr. No.	Name of the crop	Varieties /hybrids	Number of plants/block	Number of plants/ha
1.	Coconut	D x T (COD x WCT)	20	175
2.	Nutmeg	KonkanSwad	12	135
3.	Cinnamon	KonkanTej	62	615
4.	Banana	KonkanSafedVelchi	62	615
5.	Pineapple	Kew	960	10800

b) Statistical design applied and system layout

As the experiment was laid out in a block of 0.45 ha area for each treatment, the weather parameters during the year influence the productivity of the system. Hence, in the analysis, year effect was taken as fixed effect in the ANOVA table, and treatment effect as error. The statistical analysis was performed using Statistical analysis system 9.3 computer software (SAS Institute Inc., 1995). DMRT procedure was used at P=0.05 level to determine the significance among the treatments.

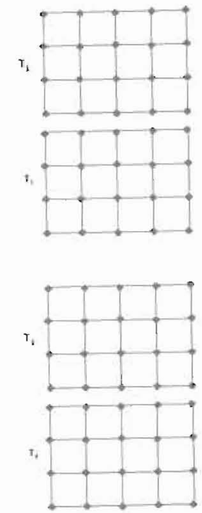


Fig.2- Layout of the experimental field

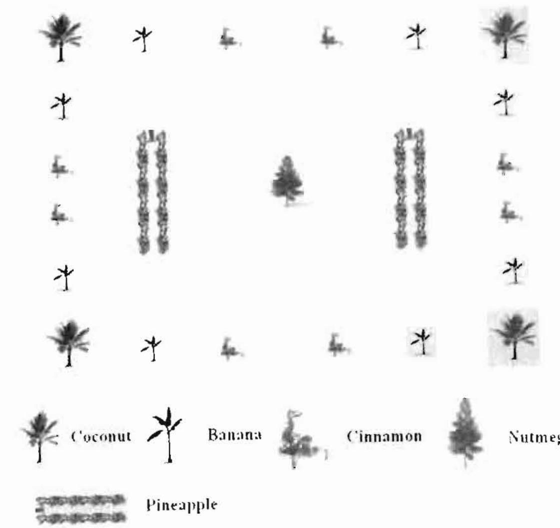


Fig. 3: Layout of single plot

c) Integrated nutrient management

Involves intelligent and judicious use of organic, inorganic and biological resources as source of nutrition to coconut plants so as to sustain optimum yield.

i) Fertilizer dose

The quantity of nutrient management for different crops in the system is presented in Table 4. The N, P and K were applied in the form of Urea, Single super phosphate and Muriate of potash respectively. As per the recommendation of the university fertilizers were applied in three splits to coconut viz. Full organic plus full phosphorous and one third (33%) nitrogen and potassium in June, Remaining one third Nitrogen and potassium in the month October and finally one-third Nitrogen and potassium in the month of January. However the component crops were applied with two split dose as shown below.

Table 4 : Manures and fertilizers application : NPK, vermicompost, bio-fertilizer (Azotobacter), vermiwash, green manuring (cowpea) and glyricidia leaf pruning

Rec. Dose of fertilizers (g/plant/ year)	Crops/ variety	T1		T2					T3				
		75 % of Rec. NPK	Recycl. Biomass (vermi-compost) (kg/plant)	50% of rec. NPK	Recycl. Biomass (vermi com.) (kg/pl.)	Biofert. (ml/plant) Azotob.	In situ green manuring (kg/plant)	Vermi wash (lit/ha)	Recycl. Biomass (vermi com.) (kg/pl.)	Biofert. (ml/ plant) Azotob.	In situ green manuring (kg/pl.)	Vermi wash (lit/ha)	Glyricida prunings (kg/pl.)
1000 N 500 P 2000 K g/plant	Coconut (DxT)	750 N 375 P 1500K g/plant	50	500 N 250 P 1000 K g/plant	50	100 (40+30+30)	20	100 (40+30+30)	50	100 (40+30+30)	20	100 (40+30+30)	10
400 N 600 P 200 K g/plant	Banana (Safed Velchi)	300 N 450 P 150 K g/plant	5	200 N 300 P 100 K g/plant	5	20 (20+20)	5	10 (5+5)	5	20	5	10 (5+5)	5
12 N 6 P 12 K g/plant	Pineapple (Kew)	9 N 4.5 P 9 K g/plant	1.9	6 N 3 P 9 K g/plant	1.9	10 (5+5)	1.9	10 (5+5)	1.9	20	1.9	10 (5+5)	1.9
20 N 20 P 50 K g/plant	Nutmeg (Konkan Swad)	15 N 15 P 37.5 K g/plant	10	10 N 10 P 25 K g/plant	10	10 (5+5)	10	10 (5+5)	10	10 (5+5)	10	10 (5+5)	10
20 N 20 P 20 K g/plant	Cinnamon (Konkan Tej)	15 N 15 P 15 K g/plant	3	10 N 10 P 10 K g/plant	3	10 (5+5)	3	10 (5+5)	3	10 (5+5)	3	10 (5+5)	3

T4 : RDF for coconut-FYM @ 50 kg/palm/year with 1.5 kg Ormichem / palm / year and 1000:500:2000 g NPK/palm/year (Applied in three splits; First-June, Second--Oct. and third-Feb). Manure applied to the component crops in two split dose (June and January). Ormichem is recommended micronutrient complex (Zn 3.15%, Mg 1.8 %, Cu 0.65%, Fe 1.97%, Mn 2%, Mo 0.05% and B 0.68%).

The quantity of fertilizers and organic manures applied based upon the N content in the respective material is as under,

Treatment	Quantity of nutrient
T_1	1.62 kg Urea + 8.92 kg Vermicompost + 2.34 kg SSP + 2.5 kg MOP
T_2	1.08 kg Urea + 8.92 kg Vermicompost + 10.92 kg in situ green manuaring + 1.5 kg SSP + 1.66 kg MOP
T_3	17.84 kg Vermicompost + 10.92 kg green leaf manuring + 20.16 kg composted pith
T_4	2.22 kg Urea + 3.0 kg SSP + 2.0 kg MOP + 50 kg FYM

ii) Irrigation

Sprinkler irrigation was followed for irrigating coconut and intercrops during the dry period (October to May) at IW/CPE 1.00. Husk incorporation was applied as per treatment details. Husk burial in the trenches was followed in each set of four coconut palms. Dried coconut leaves were used for mulching in summer months (February - May).

iii) Pre-experimental yield of coconut

The pre-experimental nut yield data was recorded and presented in Table 5. The data revealed that initially nut, copra and oil yield didn't differ in the coconut plants under the study.

Table 5 : Pre-experimental yield of coconut (Average of 2011-12 to 2012-13)

Treatments	Nut yield (nuts/palm)	Copra yield (kg/palm)	Oil yield (kg/palm)	Oil yield (tonnes/ha)
T_1	104.6	17.78	12.09	2.12
T_2	103.9	17.67	12.01	2.10
T_3	102.7	17.46	11.87	2.08
T_4	103.8	17.64	12.00	2.10
Mean	103.7	17.63	11.99	2.10
SEm. ±	0.65	0.11	0.07	0.012
CD (P=0.05)	NS	NS	NS	NS
CV (%)	11.4	13.7	1.40	1.74

Experimental results

I) Effect integrated nutrient management on the growth characters of the coconut in coconut based cropping system

The data regarding to the number of leaves on the crown, rate of leaf production, number of spadices, number of buttons and setting per cent is presented in Table 6.There is no significant difference in the production of number of leaves on the crown, rate of leaf production, number of spadices among the treatments was noticed in INM under coconut based cropping system.

i) Number of buttons

Number of buttons produced per palm/year did differ among the treatments. It was found that the treatment T_1 produced significantly highest female flowers (326.04 nos.) in the integrated nutrient management treatments followed by treatment T_2 and T_3 whereas lowest number (312.39 nos.) of buttons production was recorded in the treatment T_4.

ii) Setting per cent

It was found that the treatment T_1 recorded highest setting of flowers to fruits (43.69 %.) in the integrated nutrient management treatments followed by treatment T_2 and T_3 whereas lowest setting (35.08 %) of buttons was recorded in the treatment T_4.

Table 6 : Effect of integrated nutrient management system on growth characters of coconut (pooled data 2014-15 to 2018-19)

Treatment	Number of leaves on crown (nos./palm)	Rate of leaf production (nos./palm/ year)	Number of spadices (nos./palm)	Number of buttons (female flowers) (nos./palm)	Setting percent (%)
T_1	30.9	11.7	11.4	326.0	43.69
T_2	29.9	11.7	11.3	320.6	40.21
T_3	29.9	11.7	11.2	320.4	37.36
T_4	29.2	11.6	11.1	312.3	35.08
Mean	30.0	11.7	11.3	319.8	
SEm. ±	0.88	0.57	0.61	1.13	
CD(P=0.05)	NS	NS	NS	3.39	
CV (%)	3.16	1.25	0.71	7.41	

iii) Coconut nut yield

Yield is the index of the experimental assessment in almost all investigation. The coconut nut yield recorded among the treatments over six years and the data are presented in Table 7.

Table 7: Effect of coconut based INM system on nut yield, copra and oil yield of coconut (pooled data 2014-15 to 2018-19)

Treatment	Nut yield (nuts/palm)	Nut yield (nuts/ha)	Copra yield (kg/palm)	Copra yield (tonnes/ha)	Oil yield (kg/palm)	Oil yield (tonnes/ha)
T_1	147.2	26054.4	25.73	4.55	17.11	3.03
T_2	138.4	24496.8	23.06	4.08	15.72	2.79
T_3	123.6	21877.2	20.37	3.60	13.60	2.41
T_4	97.2	17204.4	16.78	2.97	11.40	2.01
SEm. ±	5.14	1133.7	1.29	0.38	1.06	0.07
CD (P=0.05)	16.48	3402.1	3.88	1.15	3.18	0.21
CV (%)	6.87	11.14	7.87	3.21	6.46	5.67

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-experiment yields, which was mainly owing to the effect of nutrients supplied through treatments and irrigation provided to coconut palms. Application of 75% of recommended NPK+25 % of N through organic recycling with vermicompost treatment recorded significantly highest nut yield (147.2 nuts) followed by 50% of RDF+50 % of N through organic recycling with vermicompost+vermiwash application + bio-fertilizer application + in situ green manuring treatment and was differed compared to the other treatments. Increase in yield under these treatments might be owing to better availability of required nutrients which resulted in improvement in yield. 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.

iv) Copra and oil yield

The coconut copra and oil yield recorded among the treatments over the years and the data are presented in Table 8. 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 2014-2018, application of 75% of recommended NPK+25 % of N through organic recycling with vermicompost (T_1) recorded higher copra and oil yield and was at par with 50% of RDF+50% of N through organic recycling with vermicompost+vermiwash application + bio-fertilizer application + in situ green manuring (T_2) and was differed as compared to the other treatments. The copra and oil yield obtained under 75% of recommended NPK+25% of N through organic recycling with vermicompost (T_1) and 50% of RDF+ 50 % of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + in situ green manuring (T_2) was at par i.e. 25.73 and 23.06 kg/palm/year and 17.11 and 15.72 kg/palm/year respectively. Also the oil yield (tonnes/ha) obtained under 75% of recommended NPK + 25 % of N through organic recycling with vermicompost (T_1) and 50% of RDF+50 % of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + in situ green manuring (T_2) was at par i.e. 3.03 and 2.79 tonnes/hectare respectively. 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.

II) Effect of INM on growth characters of component crops in coconut based cropping system

The growth of component crops as influenced by coconut based INM system in coconut is presented in Table 8. It was observed that the height of nutmeg plants increases after the 6th year of treatment initiation and the significantly maximum height of nutmeg plants was 318 cm in T_2 whereas the minimum was in treatment T_3 (253 cm). The significantly maximum number of nutmeg branches was recorded in treatment T_3 (10.3 nos.) whereas minimum in treatment T_2 (5.8 nos.). The significantly maximum height of cinnamon plants was (228.9 cm) in T_1 whereas the minimum was in treatment T_2 (206.4 cm). The significantly maximum number of cinnamon branches was in treatment T_3 (15.33 nos.) whereas minimum in treatment T_2 (7.77 nos.).

Table 8 : Effect of coconut based INM system on growth characters of component crops as an intercrops in coconut orchard

Treatment	Nutmeg		Cinnamon	
	Height (cm)	No. of branches (nos.)	Height (cm)	No. of branches (nos.)
T_1	304	6.56	228.82	11.35
T_2	318	5.83	206.20	7.77
T_3	253	10.21	221.42	15.33
S.Em. ±	0.17	0.73	3.11	1.81
CD (P=0.05)	0.56	2.19	9.35	5.44
CV (%)	19.67	11.34	17.63	22.24

III) Output from component crops

The yield of component crops as influenced by coconut based integrated nutrient management system in coconut was recorded and presented for last three years as of nutmeg and cinnamon yield consistently recorded in last three years after plantation and presented in Table 9.

Highest mean yield of component crops namely pineapple and banana were in the treatment T_3 such as 52.7 kg/block and 411 kg/block respectively whereas highest mean yield of component crops cinnamon bark and cinnamon leaves were in treatment T_1 such as 21 kg/block and 54.8 kg/block respectively.

Table 9 : Output from different component crops under coconut based cropping system model at Regional Coconut Research Station, Bhatye, Ratnagiri

Treatment/crops	2016-17	2017-18	2018-19	Mean
Cinnamon bark (g/plant)				
T_1	269.10	277.23	285.36	277.23
T_2	234.14	238.61	240.65	237.81
T_3	232.52	234.55	236.59	234.56
SEm. ±	9.19	8.78	10.26	5.91
CD (P=0.05)	27.60	26.36	30.80	17.74
C.V. (%)	11.58	13.86	9.31	6.37
Cinnamon leaves (g/plant)				
T_1	843.90	864.22	872.35	860.15
T_2	770.7	782.9	762.3	771.96
T_3	762.6	770.7	735.12	756.14
SEm. ±	19.91	17.43	21.32	15.82
CD (P=0.05)	59.72	52.29	63.96	47.48
C.V. (%)	17.43	19.33	18.54	17.22
Nutmeg (no. of fruits/plant)				
T_1	334.2	361.4	356.8	350.8
T_2	302.3	310.0	308.3	306.8
T_3	263.6	283.3	278.5	275.1
SEm. ±	13.34	12.48	14.71	0.32
CD (P=0.05)	40.02	37.44	42.24	1.02
C.V. (%)	6.12	11.23	14.67	9.32
Banana (kg/bunch)				
T_1	10.7	7.12	12.70	10.17
T_2	9.13	6.14	11.6	8.95
T_3	8.55	5.46	10.4	8.13
SEm. ±	0.03	0.03	0.49	0.51
CD (P=0.05)	NS	NS	1.47	1.53
C.V. (%)	5.18	9.34	11.26	6.48
Pineapple(kg/fruit)				
T_1	1.9	1.4	2.5	1.9
T_2	1.8	1.4	2.4	1.9
T_3	1.8	1.3	2.0	1.7
SEm. ±	0.043	0.037	0.02	0.058
CD (P=0.05)	0.138	0.112	NS	0.174
C.V. (%)	9.12	7.54	11.78	10.27

Different crops in integrated nutrient management system

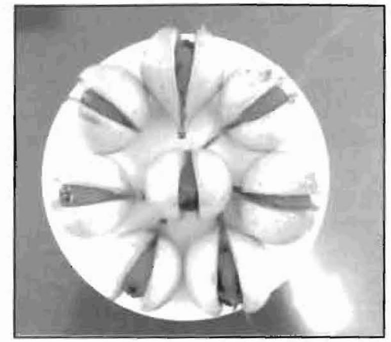
Coconut

Nutmeg

Cinnamon

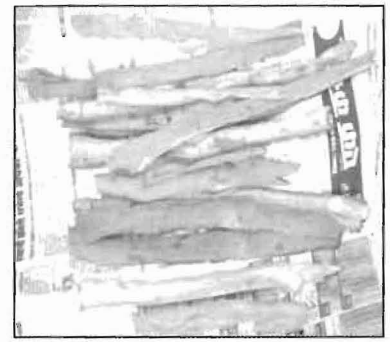
Pineapple

Banana



Nutmeg fruits

Nutmeg and mace



Cinnamon

Tej patta and black nagakeshar

IV) Biomass generation, vermicompost production and earthworm population in coconut based integrated nutrient management system

Table 10 : Biomass generation and vermicompost production in coconut based INM system

Treatments	Biomass generation (kg/ha/year)	Vermicompost production (kg/ha/year)
Open field	-	-
T_1	18654	10259
T_2	17670	9541
T_3	15708	8639
T_4	9344	4923
SEm. ±	2176	1611
CD (P=0.05)	6528	4833
C.V. (%)	19.43	22.65

a) Biomass generation, vermi-compost production

The biomass generation and accordingly vermi-compost production did differ significantly among the treatments (Table 10). Highest biomass production was registered with the treatment T_1 (18654 kg/ha/year) which is on par with the treatment T_2 (17670 kg/ha/year) and T_3 (15708 kg/ha/year) and lowest recorded in the monocrop T_4 (9344 kg/ha/year). Similarly the vermi-compost production was higher in the treatment T_1 (10259 kg/ha/year) which is on par with the treatment T_2 (9441 kg/ha/year), T_3 (8639 kg/ha/year) and significantly lowest was recorded in the treatment T_4 (4923 kg/ha/year). Also the generated biomass and vermi-compost production from different component crops which can be recycled in the coconut based INM system. The organic wastes are to be treated with cow dung at the rate of 10 per cent by weight in the form of slurry and must be allowed to undergo a preliminary decomposition for about 2 -3 weeks. The earthworms at the rate of 1000 worms per tonne of biomass are to be introduced. The compost bed should be mulched properly using any locally available plant material or gunny bags and has to be protected from direct sun light. Watering is to be done to maintain enough moisture. As full leaves are used for composting, compact mass is not formed, thus allowing free movement of air in the bed. In about 60-75 days compost will be ready. On an average, 70 per cent recovery of vermicompost was obtained. The same technology for vermicomposting was also tested in large pits taken in the inter spaces of four coconut palms in sandy loam soils and was found to work well.

b) Earthworm population

The data on earthworm population (nos./m^2) as influenced by coconut based integrated nutrient management system is presented in Table 11. The data indicated that the earthworm population did differ significantly at all soil depths. Significantly the highest number of earthworm population was noticed in the treatment T_3. This might be due to the availability of nutrients in form of 100% organic source.

Table 11 : Earthworm population (nos./m^2) as influenced by coconut based integrated nutrient management

Treatment	Soil depth		
	0-10 cm	10-20 cm	20-30 cm
T_1	12.56	5.7	2.4
T_2	9.36	3.6	1.7
T_3	15.38	9.4	3.8
T_4	6.7	2.7	1.4
SEm. ±	1.9	1.03	0.52
CD (P=0.05)	5.8	3.04	1.56
C.V. (%)	15.23	6.78	11.34

V) Influence on weather parameters

Treatment wise maximum and minimum temperature and humidity in integrated nutrient management under coconut based cropping system was recorded and presented in Table 12. Data revealed that there was mean reduction of temperature in the cropping system and mean increase in humidity. This may be due to the component crops in inter-space leads to microclimate modifications in the system.

Table 12 : Treatment influence on temperature and humidity in integrated nutrient management under based coconut cropping system

Treatments	Standard Week	Period	Temperature (°C)		Relative humidity (%)	
			Max	Min	Max	Min
Open field	1	1-7 Jan	28.6	15.6	85.6	43.8
	24	11-17Jun	32.7	25.4	87.0	75.8
	52	24-31Dec	33.6	19.8	82.4	52.0
Average			31.6	20.3	85.0	57.2
T_1	1	1-7 Jan	27.2	14.3	87.2	44.4
	24	11-17Jun	31.6	24.6	90.0	77.4
	52	24-31Dec	31.8	19.2	84.3	54.5
Average			30.2	19.4	87.2	58.8
T_2	1	1-7 Jan	27.2	14.4	87.2	44.0
	24	11-17Jun	31.7	24.8	89.8	77.0
	52	24-31Dec	32.0	19.4	84.4	54.2
Average			30.3	19.5	87.1	58.4
T_3	1	1-7 Jan	27.4	14.5	87.0	44.2
	24	11-17Jun	32.0	24.8	89.8	77.2
	52	24-31Dec	32.1	19.4	84.2	54.2
Average			30.5	19.6	87.0	58.5
T_4	1	1-7 Jan	28.0	15.3	86.4	43.8
	24	11-17Jun	32.8	25.2	82.4	76.8
	52	24-31Dec	33.0	19.8	83.2	52.0
Average			31.3	20.1	84.0	57.5

VI) Soil nutrient status as influenced by coconut based integrated nutrient management system

The data from Table 13 revealed that electrical conductivity of the soil (at 0-25 cm depth) did change due to the integrated nutrient management practices in the basins of the coconut, as seen during the pre-experiment (2012-2013) and the mean of 6th years after treatment initiation (2012-13 to 2018-19). After the 6th 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 application of 75% of recommended NPK+25 % of N through organic recycling with vermicompost recorded higher pH (7.55) followed by the application of 50 % of RDF+50 % of N through organic recycling with vermicompost + vermiwash application +bio-fertilizer application+in situ green manuring (7.24) as compared to the other two treatments. The soil organic carbon also higher with the application of 75% of recommended NPK+25% of N through organic recycling with vermicompost (1.26%) followed by the application of 50% of RDF+50% of N through organic recycling with vermicompost+ vermiwash application+bio-fertilizer application+in situ green manuring (1.24%) as compared to the other two treatments. The soil nutrient content (NPK) was also highest with the application of 75% of recommended NPK+25% of N through organic recycling with vermicompost followed by the application of 50% of RDF+50% of N through organic recycling with vermicompost+ vermiwash application+ bio-fertilizer application+in situ green manuring as compared to the other two treatments. Increase in N, P and K, content of coconut cropping system from 2012-2013 to 2018-19 could be attributed to organic recycling of biomass glycricidia leaf lopping, vermiwash application in the system.

Table 13 : Soil nutrient status (coconut basin) as influenced by INM system

Soil depth	Treat-ment	Pre-experimental (2012-13)						Post-experimental (2018-2019)					
		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	T1	7.5	0.183	253	17	301	0.42	7.55	0.190	277	21.5	309.3	0.80
	T2	7.1	0.149	248	18	289	0.54	7.24	0.158	262	25.6	293.1	0.83
	T3	6.8	0.168	220	16	278	0.39	6.82	0.176	243	19.3	284.0	0.86
	T4	6.7	0.186	265	17	312	0.30	6.71	0.196	284	20.3	318.0	0.60
25-50	T1	7.4	0.170	234	17	277	0.31	7.43	0.181	248	21.6	286.0	0.78
	T2	7.1	0.168	217	15	242	0.51	7.11	0.173	241	18.1	256.0	0.81
	T3	6.9	0.178	167	9	269	0.44	6.9	0.181	178	13.0	276.1	0.83
	T4	6.8	0.190	240	12	265	0.30	6.81	0.198	251	16.0	278.1	0.58
50-100	T1	7.3	0.211	191	13	212	0.38	7.22	0.221	202	16.1	218.3	0.76
	T2	7.0	0.151	143	9	228	0.43	7.10	0.168	151	13.0	233.1	0.78
	T3	6.8	0.201	152	9	261	0.41	6.79	0.206	158	12.2	273.0	0.79
	T4	6.7	0.192	210	10	215	0.32	6.41	0.198	221	13.4	226.1	0.52

VII) Coconut leaf nutrient status and soil microbial population

Leaf nutrient status (%) and soil microbial population (CFU/g dry soil) in the coconut basin as influenced by coconut based INM system is

presented in Table 14. The nutrient content in the index leaf in respect of N, P and K differed among the treatments. After the 6th years of treatment initiation the mean N content was higher with the application of 75% of recommended NPK+25% of N through organic recycling with vermicompost (1.75%) followed by the application of 50% of RDF+50 % of N through organic recycling with vermicompost+vermiwash application + bio-fertilizer application + in situ 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 vermi-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.

Table 14 : Leaf nutrient status and soil microbial population (CFU/g dry soil) as influenced by coconut based INM system

Treat-ment	Leaf nutrient status						Soil microbial population (CFU/g dry soil) (2018-19)		
	2012-2013			2018-2019			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

VIII) Soil microbial population

The population of bacteria, fungi and actinomycetes in the basins of the coconut did differ among the various treatments, when analysed at 0-25 cm soil depth (Table 14). 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 where 100% of N through organic recycling with vermicompost + vermi-washapplication + bio-fertilizerapplication + in situ green manuring and green leaf manuring (glyricidia leaves) + composted coir pith, husk incorporation and mulching with coconut leaves 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 14).

3) CARBONSEQUESTRATION UNDER COCONUT BASED CROPPING SYSTEM

a) Above ground carbon sequestration of crops

From the data (Table 15) it was observed that, among the different integrated nutrient management systems, the above ground standing biomass (SDW) and above ground carbon stock (353.25 kg/plant and 31.06 t/ha, respectively) was significantly the highest in the treatment T_1 followed by T_2 (345.10 kg/plant and 30.34 t/ha) and T_3 (310.33 kg/plant and 27.27 t/ha), respectively. The lowest above ground biomass and carbon stock were observed in coconut monocrop (288.8 kg/plant and 25.6 t/ha, respectively). This is because the intercrops in coconut based cropping system have added additional biomass production than monocrop, hence the carbon stock was the highest in the cropping system plots compared to monocrop of coconut. Furthermore, the CO_2 sequestered also followed the same trend and accordingly, the highest CO2 sequestration was recorded in the treatment T_1 (114.02 t/ha) followed by T_2 (111.35 t/ha) and T_3 (100.22 t/ha). The lowest CO_2 sequestration was noticed in coconut monocrop (93.8 t/ha). Trees are carbon reservoir on earth and in nature, forest ecosystem act as a reservoir of carbon and store huge quantity of carbon and regulate the carbon cycle by exchange of CO_2 from the atmosphere. Thus, forest ecosystem plays significant role in the global carbon cycle by sequestering a substantial amount of carbon dioxide from the atmosphere by storing it in the biosphere.

Table 15 : Influence of intercrops and integrated nutrient management practices on above ground carbon sequestration under coconut garden

Crop	Treatment	Plant height (m)	Plant girth (m)	Stem dry weight (SDW) (Biomass) (kg/plant)	Carbon stock (kg/plant)	Carbon stock (t/ha)*	CO2 sequestered (t/ha)*
Coconut	T1	11.8	0.84	343.5	171.8	30.4	111.6
	T2	10.7	0.89	335.6	167.8	29.7	109.0
	T3	11.6	0.79	303.4	151.7	26.8	98.5
	T4	10.4	0.81	288.8	144.4	25.6	93.8
	Mean	11.1	0.83	317.8	158.9	28.1	103.2
	SE d±	0.39	0.05	5.8	3.07	0.7	0.67
	CD (P=0.05)	1.24	0.17	18.6	9.82	2.24	2.14
Nutmeg	T1	3.04	0.28	9.7	4.87	0.66	2.42
	T2	3.18	0.26	9.5	4.75	0.64	2.35
	T3	2.53	0.23	6.9	3.46	0.47	1.72
	Mean	2.92	0.26	8.73	4.36	0.59	2.16
	SE d±	0.16	0.01	0.35	0.25	0.02	0.17
	CD (P=0.05)	0.56	0.04	1.22	0.86	0.06	0.58

Note : * indicates 177 palms ha-1 in coconut and 135 nutmeg trees ha-1 coconut garden. . SDW = stem dry weight, C = carbon

b) Soil bulk density and organic carbon

The data presented in Table 16 represents bulk density of soil (g/cm^3), soil organic carbon (%) and soil carbon stock (t/ha) at 0-30 and 31-60 cm depth in the rhizosphere of different crops in the system. With respect to bulk density, there was no significant difference found among the different cropping system and INM practices at both the depths during the course of study. Whereas, the organic carbon (OC) content differed significantly among the treatments at both thedepths. Among the different crops, the significantly the highest soil organic carbon (0.86% and 0.81%) was documented in coconut basin at 0-30 and 31-60 cm depth in the treatment T_3 which was on par with treatment T_2 and T_1. The coconut basin in the monocropping recorded significantly the lowest organic carbon at both the depths (0.60 and 0.51 %). The rhizosphere of intercrops like nutmeg, cinnamon, pineapple and banana also recorded higher organic carbon content, whereas in the interspace of monocropping, it was significantly lower (0.46 and 0.44 %). Growing intercrops in the coconut garden has lead to addition of recyclable biomass from the intercrops and which has resulted in improvement in the organic carbon content.

Table 16 : Effect of intercrops and integrated nutrient management practices on organic carbon, soil bulk density and soil carbon stock under coconut based cropping system

INM practices	Crop	Organic carbon (%)		Bulk density (gcm-3)		Soil carbon stock (t/ha)	
		0-30 cm	31-60 cm	0-30 cm	31-60 cm	0-30 cm	31-60 cm
T_1	Coconut	0.81a	0.77a	1.62	1.64	39.36a	37.88a
	Nutmeg	0.64b	0.61bc	1.60	1.63	30.72b	29.82b
	Cinnamon	0.61cd	0.56c	1.61	1.63	29.46bc	27.38c
	Banana	0.63b	0.57cd	1.62	1.64	30.61b	28.04cd
	Pineapple	0.60cd	0.54cd	1.60	1.62	28.80cd	26.24d
T_2	Coconut	0.83a	0.78a	1.63	1.64	40.58a	38.37a
	Nutmeg	0.66b	0.62bc	1.62	1.63	32.07b	30.31b
	Cinnamon	0.63cd	0.58d	1.62	1.64	30.61bc	28.53c
	Banana	0.67b	0.61cd	1.63	1.64	32.76b	30.01bc
	Pineapple	0.62cd	0.56d	1.60	1.62	29.76bc	27.21d
T_3	Coconut	0.86a	0.81a	1.64	1.64	42.31a	39.85a
	Nutmeg	0.67b	0.62b	1.62	1.63	32.56b	30.31bc
	Cinnamon	0.66b	0.60cd	1.62	1.64	32.07b	29.52c
	Banana	0.68b	0.63b	1.62	1.64	33.04b	30.99b
	Pineapple	0.65bc	0.60cd	1.62	1.64	31.59bc	29.52c
T_4	Coconut (monocrop)	0.60cd	0.51cd	1.58	1.60	28.44cd	24.17d
	Interspace	0.46e	0.44e	1.59	1.60	21.94e	21.12e
	CD (P=0.05)	0.048	0.79	NS	NS	2.14	3.32

c) Soil carbon stock

The soil carbon stock was significantly influenced by the coconut based cropping system and INM practices (Table 16). Among the different crops under investigation, the coconut rhizosphere in the treatment T_3 had significantly higher soil carbon stock (42.31 t/ha and 39.85 t/ha) in the depths of 0-30 and 31-60 cm followed by treatment T_2 (40.58 t/ha and 38.37 t/ha) and T_1 (39.36 t/ha and 37.88 t/ha). The lowest soil carbon stock of 28.44 t/ha and 24.17 t/ha at 0-30 and 30-60 cm depth was noticed in the coconut rhizosphere in monocrop (T_4). Among the different integrated nutrient management practices in coconut based cropping system, significantly the highest soil carbon stock was observed in the treatment T_3 at 0-30 and 31-60 cm depth in the rhizosphere of different crops followed by T_2 and T_1. The lowest soil carbon stock in the coconut monocrop (T_4) might be due to absence of intercrops in the interspace which might not have contributed to soil carbon pool. Furthermore, the coconut basin rhizosphere has recorded higher carbon stock at both depths (0-30 and 31-60 cm), which might be due to increase in organic carbon in the soil owing to decomposition of root system over a period of time as compared to other crops and organic manure incorporation to the coconut crop and interaction effect of organic manure and green manure incorporation.

4) ECONOMICS AND EMPLOYMENT GENERATION UNDER COCONUT BASED CROPPING SYSTEM

a) Economics

The total cost involved in maintaining the system under various integrated nutrient management was ranged from Rs. 123769.60 (T3) to 63639.00 (T_4). The net returns (Rs. 131605.8) were highest in treatment T_1 i.e. application of 75% of recommended NPK +25% of N through organic recycling with vermicompost with the highest cost benefit ratio of 1: 2.69.

Table 17 : Economics (per ha) of coconut based INM system
(Average of five years data from 2013-14 to 2017-18)

Treatment	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C
T_1	105185	283456	131605	2.69
T_2	113026	259871	122868	2.29
T_3	123769.6	238529	114759	1.92
T_4	63639.0	102374	38735	1.60

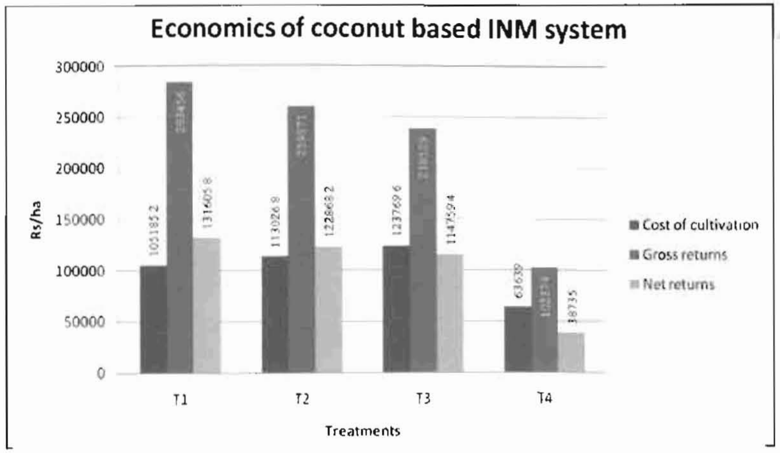


Fig 4: Economics of coconut based INM system

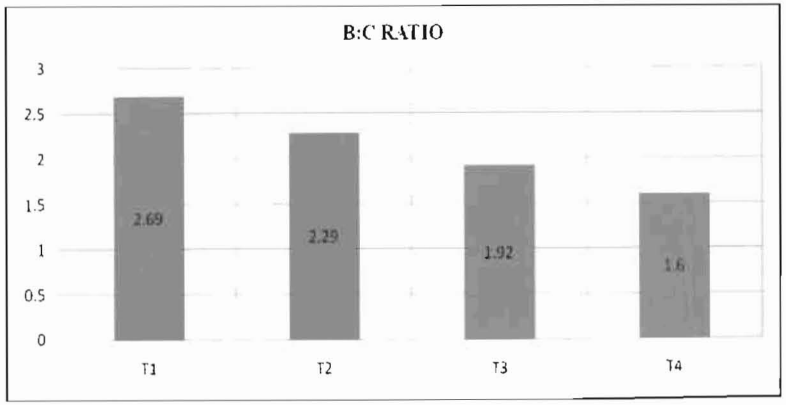


Fig 5: Benefit: cost ratio of coconut based INM system

b) Employment generation -

The employment potential of the coconut based cropping system is observed to be very high. The labour input utilization of irrigated monocrop of coconut (at its stabilized yield stage) is 157 man days/ha/year. The labour utilization in the coconut cropping system with banana, pineapple, cinnamon and nutmeg was 297 days/ha/year. In percentage term, the increase was about 189 per cent over the sole crop system. Since it is expected that the bulk of the labour force is available from the family source of the farmer, family labour income could therefore be considerably raised when coconut based cropping system was adopted.

5. CONCLUSION

Integrated nutrient management by using 2/3rd recommended fertilizer dose along with recycling of biomass by vermin composting gives the best economic benefit in a sustainable manner. INM on coconut based cropping system demonstrated model to the farmer to integrate nutrient management in a cropping system. The system is more sustainable and production and productivity will increase without affecting the ecosystem. There is a positive impact through improvement of soil health by recycling of waste products in the system as organic manures. Further it will be eco-friendly with nature which will enable to increase the production and productivity of the system.

Aerial view

1991

2019

ICAR- AICRP on Palms, Regional Coconut Research Station,
Bhatye, Ratnagiri (M.S.) 415 612

Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri