Research Article

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# Sustainable soil fertility management in coconut based multi-storeyed cropping system

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## Abstract

A field experiment was conducted at College of Agriculture, Padannakkad, Kasaragod, Kerala state during 2012 to 2015 to develop appropriate cost effective practices for enhancing productivity and profitability of coconut based multi-storeyed cropping system involving a combination of coconut, noni, banana and long pepper in coastal sandy soil. The treatments consisted of eight combinations of four levels of NPK (100 per cent, 2/3$^{rd}$, 1/3$^{rd}$of the recommended NPK and basin management in the organic pathway) for coconut and two levels of NPK (100 and 75 per cent of the recommended dose) for the component crops in addition to five sole cropping systems namely, coconut (100 per cent NPK), coconut (organic), long pepper (100 per cent NPK), banana (100 per cent NPK) and noni (100 per cent NPK). Pooled analysis of the data revealed that basin management with 75 per cent NPK for component crops was found favourable for increasing the nut yield from 43 to 53 nuts palm$^{-1}$ year$^{-1}$. Soil properties and BCR of the system also improved as a result of the same treatment. Highest copra content (160.6 g nut$^{-1}$) was recorded in the organic basin management treatment supplied with 100 per cent NPK for component crops. An improvement in the soil nutrient status was also observed compared to the control.

*Keywords:* BCR, coconut basin management, multi-storeyed cropping system, nutrient management, plant interferences

## Introduction

Coconut (*Cocos nucifera* L.) is a perennial palm that survives for more than 60 years. Nearly 60 per cent of space in 7.5 x 7.5 m spaced adult coconut gardens and 40 per cent of sunlight are left unutilized which provides ample scope for introducing compatible intercrops (Nelliat, 1979). In the humid tropics, higher efficiency of utilization of the basic resources of crop production *viz*., land, solar radiation and water can be achieved by adopting intensive cropping systems (Nelliat *et al*., 1973).

The poor resource base of coastal sandy soil being a major coconut growing tract, need to be upgraded in a sustainable manner for enhancing the productivity of coconut palms. The beneficial interactions of inter/mixed cropping of coconut with different crops in improving soil nutrient status of the system has been reported by Maheswarappa *et al*. (2005). Introduction of ideal cropping system especially, adoption of multi-storeyed cropping pattern with compatible crops favours better utilization of resources for augmenting returns besides alleviating inherent soil limitations. Adoption of such systems can provide food security through food self-sufficiency, employment generation through farm diversification and ecological stability. Hence, the study was conducted to assess the influence of nutrient management on the sustainability of coconut based multi-storeyed cropping system involving coconut, banana, noni and long pepper.

## Materials and methods

The present study involving a crop combination of WCT variety of coconut as main crop (C), local variety of noni, Njalipoovan variety of banana and Viswam variety of long pepper as intercrops (IC) was carried out at College of Agriculture Padannakkad, Kasaragod, Kerala from October

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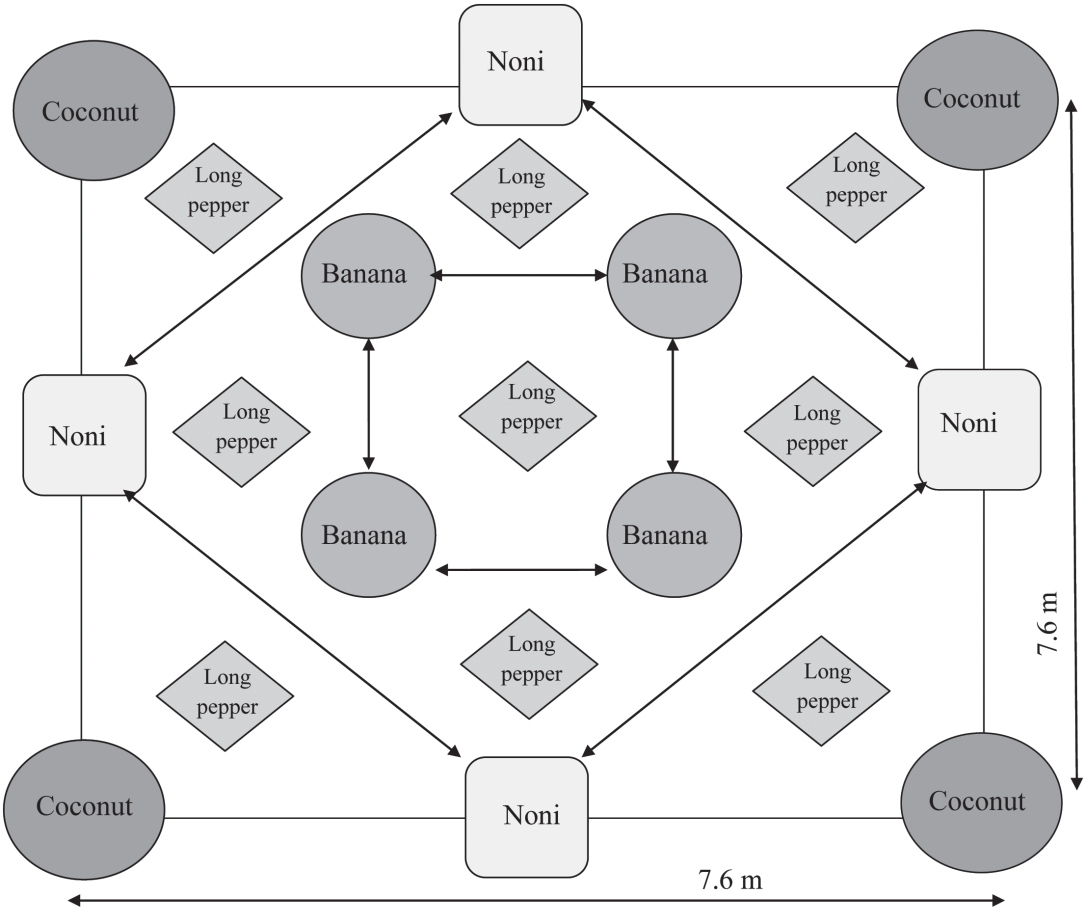


**Fig. 1. Lay out of a single plot of coconut based multi-storeyed cropping system**

2012 to March 2015. The area is located at $12^0 20' 30''$ N latitude and $75^0 04' 15''$ E longitude at an altitude of 20 m above MSL. Soil type of the experimental field is sandy with an organic carbon content of 0.38 per cent, particle density of 2.16 g $cc^{-1}$, bulk density of 1.34 g $cc^{-1}$, porosity of 47 per cent, field capacity of 16 per cent and permanent wilting point of 10 per cent. The area enjoys a warm humid tropical climate.

The experiment was conducted in randomized block design, replicated twice. Coconut palms planted in square systems at a spacing of 7.6 m x 7.6 m (KAU, 2011) considered as a single plot (Fig.1). Intercrops *viz*., noni (4 nos.), banana (4 nos.) and long pepper (16 nos.) were raised in the interspaces of the four coconut palms at spacing of 3.5 m x 3.5 m, 2.1 m x 2.1 m and 30 cm x 30 cm respectively, leaving 2 m radius from the base of palms (Fig.1). The effective root zone area partitioning by coconut, noni, banana and long pepper in a single plot of 57.8 $m^2$ (7.6 m x 7.6 m) were 12.6, 28.3, 4.5 and 12.4 $m^2$ respectively. The experiment consisted of 13 treatments. The treatments were $T_1$: 100 per cent NPK (C) + 100 per cent NPK (IC), $T_2$: 100 per cent NPK (C) + 75 per cent NPK (IC), $T_3$: $2/3^{rd}$ NPK (C) + 100 per cent NPK (IC), $T_4$: $2/3^{rd}$ NPK (C) + 75 per cent NPK (IC), $T_5$: $1/3^{rd}$ NPK (C) + 100 per cent NPK (IC), $T_6$: $1/3^{rd}$ NPK (C) + 75 per cent NPK (IC), $T_7$: Basin management (C) + 100 per cent NPK (IC), $T_8$: Basin management (C) + 75 per cent NPK (IC), $T_9$: sole crops of coconut under 100 per cent NPK, $T_{10}$: sole crop of coconut under organic basin management, $T_{11}$: sole crop of long pepper under 100 per cent NPK, $T_{12}$:sole crop of banana under 100 per cent NPKand $T_{13}$: sole crop of noni under 100 per cent NPK.Organic basin management practiced in $T_{10}$ consisted of *in situ* green manuring,

recycling of palm waste and application of farm yard manure @ 50 kg, ash at 5 kg and *Azospirillum* at 25 g per palm per year. Yield of coconut from 2012 to 2015 were recorded and pooled analysis carried out. In noni, mean fruit weight per plant was recorded by taking the average of fruit weight of four plants at bimonthly intervals and the yield was expressed in kg plant$^{-1}$ year$^{-1}$. In banana, the average bunch weight was worked out and expressed in kg plant$^{-1}$ at harvest. Data were statistically analyzed using MSTAT package.

## Results and discussion

### Coconut

Pooled mean over three years showed significant variation in nut yield (Table 1). The treatment comprising organic management of coconut basin with *in-situ* green manuring, recycling of palm waste, FYM application at 50 kg + 5 kg ash + 25 g *Azospirillum* per palm per year combined with the application of 75 per cent of the recommended dose of NPK for the component crops *viz*. noni, banana and long pepper of the multi-storeyed cropping system recorded the highest mean nut yield of 53.6 nuts palm$^{-1}$ year$^{-1}$and it was 13.2 per cent higher compared to sole crop of coconut under organic nutrition. Significant improvement in the copra content was also observed under organic management. However, oil content remains unchanged by treatment effects.

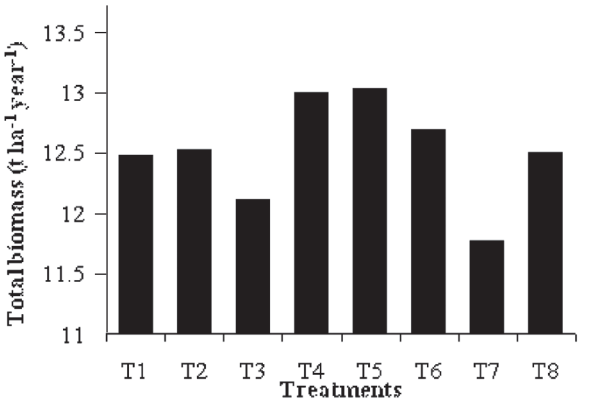


**Fig.2. Generation of total biomass as influenced by nutrient management in coconut based multi-storeyed cropping system**

**Table 1. Productivity of coconut and component crops, copra and oil content as influenced by nutrient management in a multi-storeyed cropping system**

| Treatments | Productivity (2014-15) | | | | | |
|---|---|---|---|---|---|---|
| | Coconut * (Nuts palm$^{-1}$ year$^{-1}$) | Long pepper (g plant$^{-1}$ year$^{-1}$) | Banana (kg plant$^{-1}$ year$^{-1}$) | Noni (kg plant$^{-1}$ year$^{-1}$) | Copra content (g nut$^{-1}$) | Oil content ( per cent) |
| $T_1$ (100 per cent C +100 per cent IC) | 44.8 | 14.9 | 5.1 | 15.1 | 156.7 | 60.2 |
| $T_2$(100 per cent C +75 per cent IC) | 45.4 | 21.0 | 5.6 | 16.5 | 145.8 | 60.3 |
| $T_3$(2/3$^{rd}$ C +100 per cent IC) | 47.0 | 26.6 | 5.9 | 18.4 | 156.9 | 63.6 |
| $T_4$(2/3$^{rd}$ C +75 per cent IC) | 49.6 | 18.6 | 5.6 | 15.1 | 156.3 | 59.4 |
| $T_5$(1/3$^{rd}$ C +100 per cent IC) | 50.1 | 11.0 | 5.6 | 16.8 | 159.7 | 61.4 |
| $T_6$(1/3$^{rd}$ C +75 per cent IC) | 49.0 | 12.4 | 5.6 | 16.7 | 144.8 | 60.0 |
| $T_7$(BM (C) + 100 per cent IC) | 52.6 | 14.7 | 5.68 | 16.3 | 160.6 | 60.4 |
| $T_8$(BM (C) + 75 per cent IC) | 53.5 | 21.1 | 5.6 | 18.2 | 158.9 | 59.8 |
| $T_9$(CC) | 45.5 | - | - | - | 158.9 | 58.6 |
| $T_{10}$(BMC) | 46.5 | - | - | - | 159.9 | 61.2 |
| $T_{11}$(CLP) | - | 15.2 | - | - | - | - |
| $T_{12}$(CB) | - | - | 5.7 | - | - | - |
| $T_{13}$(CN) | - | - | - | 18.1 | - | - |
| SEm (±) | 0.9 | 2.9 | 0.7 | 2.4 | 4.2 | 2.9 |
| CD (0.05) | 2.6 | 6.7 | NS | NS | 9.5 | NS |

CC- control coconut; CLP-control long pepper; CB-control banana; CN-control noni: sole crops under 100 per cent NPK; BMC-control basin management (coconut sole crop only); C-Coconut, IC-Intercrops)

*Pooled mean over three years (2012-15)

Integrated nutrient management of multi-storeyed cropping system is beneficial for improving soil health in several ways as it creates an ideal rhizosphere for maintaining a proper balance among nutrient-moisture-oxygen for achieving higher productivity. Management of coconut basin in the organic pathway ensures slow and steady availability of essential nutrients over a considerable period of time. Apart from soil enrichment with primary, secondary and micronutrients, organic nutrition also improves the physical, chemical and biological properties of the soil. Coconut palm produces huge quantities of bio-wastes which can be effectively utilized for enriching soil fertility through organic recycling. The present study revealed that coconut bio-wastes release substantial quantities of plant nutrients to sustain the growth and productivity of coconut palms without external application of inputs (Table 3, Fig.2). Beneficial rhizosphere microflora observed in the active root zone of the different crops of the multi-storeyed cropping system, compared to sole cropping, might have also contributed towards higher productivity (Palaniswami *et al*., 2010; Krishnakumar *et al*., 2011; Maheswarappa *et al*., 2013) (Table 1).

**Table 2. Soil physical and biological properties as influenced by nutrient management in a multi-storeyed cropping system**

| Treatments | Maximum water holding capacity (%) | Rhizosphere microflora (cfu $g^{-1}$ soil) | | |
|---|---|---|---|---|
| | | Bacteria (x $10^6$) | Fungi (x $10^3$) | Actino-mycetes (x $10^4$) |
| $T_1$ (100% C +100% IC) | 20.5 | 7.7 | 25.0 | 1.6 |
| $T_2$(100% C +75% IC) | 19.8 | 11.6 | 20.4 | 2.4 |
| $T_3$(2/3rd C +100% IC) | 19.5 | 14.3 | 16.3 | 2.8 |
| $T_4$(2/3rd C +75% IC) | 21.4 | 16.1 | 20.9 | 2.6 |
| $T_5$(1/3rd C +100% IC) | 22.0 | 17.8 | 19.3 | 1.7 |
| $T_6$(1/3rd C +75% IC) | 20.7 | 19.7 | 13.8 | 2.4 |
| $T_7$(BM (C) + 100% IC) | 22.2 | 25.3 | 12.5 | 2.7 |
| $T_8$(BM (C) + 75% IC) | 22.8 | 27.0 | 13.6 | 2.9 |
| $T_9$(CC) | 20.6 | 11.6 | 18.7 | 2.0 |
| $T_{10}$(BMC) | 21.8 | 14.0 | 24.2 | 2.8 |
| $T_{11}$(CLP) | 20.2 | 3.6 | 33.1 | 3.3 |
| $T_{12}$(CB) | 20.5 | 7.1 | 29.4 | 5.1 |
| $T_{13}$(CN) | 19.2 | 5.6 | 30.4 | 4.1 |
| SEm (±) | 0.7 | 2.1 | 3.8 | 0.7 |
| CD (0.05) | 1.5 | 4.7 | 8.4 | 1.5 |

CC-control coconut; CLP-control long pepper; CB-control banana; CN-control noni; sole crops under 100 per cent NPK; BMC-control basin management (coconut sole crop only); C-Coconut; IC-Intercrops

**Productivity of component crops**

The yield of banana variety 'Njalipoovan' was not satisfactory but this intercrop contributed towards the biomass recycling. Yield of banana and noni were found unaffected by treatment effects; however, the performance of the crops in multi-storeyed cropping system was found better compared to sole cropping. Total dry spike yield in long pepper in the first year was found significant among treatments and the highest dry spike yield (26.6 g $plant^{-1}$ $year^{-1}$) was reported by the treatment comprising 2/3rd of NPK for coconut + 100 per cent NPK for component crops. Though not significant, the highest bunch weight of banana and fruit weight of noni was also recorded in the same treatment (Table 1). Nutrients applied in the form of inorganic fertilizers are easily available to plants and this might be the possible reason of yield increase in long pepper supplied with 100 per cent of NPK. Increased yield of intercrops in the coconut garden under 2/3rd of the recommended doses of NPK were reported by Reddy *et al*., 2002 and Palaniswami *et al.,* 2007. Intercrop yield in coconut based cropping system was found highest under 100 per cent recommended dose and the results were supported by Sadanandan *et al*. (1993) and Palaniswami *et al.* 2010.

**Soil properties**

The highest maximum water holding capacity (22.8 per cent) was recorded in treatment $T_8$ (organic management of coconut basin + 75 per cent NPK for component crops) which was 15.7 per cent higher over control (Table 2). The recycling of palm waste after every harvest might have probably improved the physical properties of the soil and may resulted in an increase in the water holding capacity. Similar results were reported by Subramanian *et al.*

**Table 3. Soil chemical properties as influenced by nutrient management in a multi-storeyed cropping system**

| Treatments | Primary nutrients (kg ha$^{-1}$) | | | Secondary and micronutrients (ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | Ca | Mg | S | Fe | Mn | Zn | Cu |
| $T_1$ (100% C +100% IC) | 85.2 | 11.7 | 79.1 | 308.7 | 14.9 | 31.1 | 10.6 | 1.1 | 1.3 | 1.3 |
| $T_2$(100% C +75% IC) | 69.7 | 13.0 | 88.3 | 268.2 | 14.0 | 37.3 | 12.8 | 1.3 | 2.7 | 1.3 |
| $T_3$(2/3$^{rd}$ C +100% IC) | 74.5 | 15.8 | 85.4 | 358.8 | 20.1 | 27.3 | 10.1 | 1.6 | 2.5 | 1.3 |
| $T_4$(2/3$^{rd}$ C +75% IC) | 56.8 | 11.9 | 109.3 | 365.7 | 23.6 | 32.9 | 9.6 | 1.8 | 2.0 | 0.9 |
| $T_5$(1/3$^{rd}$ C +100% IC) | 67.5 | 11.2 | 77.8 | 406.0 | 19.2 | 36.0 | 10.4 | 0.9 | 1.9 | 1.1 |
| $T_6$(1/3$^{rd}$ C +75% IC) | 63.2 | 12.4 | 123.9 | 321.1 | 15.3 | 31.2 | 10.7 | 1.0 | 2.0 | 1.5 |
| $T_7$(BM (C) + 100% IC) | 84.2 | 14.0 | 102.8 | 518.0 | 26.2 | 25.5 | 9.2 | 1.5 | 1.5 | 0.9 |
| $T_8$(BM (C) + 75% IC) | 88.2 | 14.2 | 82.1 | 566.5 | 20.2 | 23.2 | 10.4 | 1.4 | 1.7 | 0.9 |
| $T_9$(CC) | 82.7 | 8.3 | 74.5 | 274.2 | 18.6 | 26.7 | 11.9 | 1.1 | 2.9 | 0.9 |
| $T_{10}$(BMC) | 80.6 | 11.6 | 71.2 | 300.0 | 21.1 | 27.3 | 8.7 | 1.2 | 2.3 | 0.9 |
| $T_{11}$(CLP) | 66.6 | 8.8 | 83.5 | 503.2 | 28.1 | 26.4 | 12.5 | 0.9 | 1.4 | 1.4 |
| $T_{12}$(CB) | 63.3 | 7.7 | 69.5 | 338.2 | 19.6 | 27.9 | 10.7 | 0.4 | 1.9 | 1.0 |
| $T_{13}$(CN) | 53.9 | 8.0 | 86.4 | 316.5 | 12.1 | 27.8 | 11.0 | 1.0 | 1.9 | 0.9 |
| SEm (±) | 14.2 | 1.9 | 17.8 | 59.2 | 3.6 | 6.3 | 3.9 | 0.2 | 1.3 | 0.7 |
| CD (0.05) | NS | 4.3 | NS | 129.0 | 7.9 | NS | NS | 0.5 | NS | NS |

CC-control coconut; CLP-control long pepper; CB-control banana;CN-control noni; sole crops under 100 per cent NPK; BMC-control basin management (coconut sole crop only); C-Coconut, IC-Intercrops.

**Table 4. Quantity of nutrients added through biowaste recycling (kg ha$^{-1}$) as influenced by nutrient management in a multi-storeyed cropping system**

| Treatment | Nitrogen (kg ha$^{-1}$) | Phosphorus (kg ha$^{-1}$) | Potassium (kg ha$^{-1}$) |
|---|---|---|---|
| $T_1$(100% C +100% IC) | 192.3 | 20.9 | 80.6 |
| $T_2$ (100% C +75% IC) | 193.7 | 18.2 | 71.3 |
| $T_3$ (2/3$^{rd}$ C +100% IC) | 170.7 | 19.3 | 69.8 |
| $T_4$ (2/3$^{rd}$ C +75% IC) | 242.0 | 20.2 | 79.5 |
| $T_5$(1/3$^{rd}$ C +100% IC) | 199.6 | 17.7 | 76.3 |
| $T_6$ (1/3$^{rd}$ C +75% IC) | 210.3 | 18.4 | 72.5 |
| $T_7$(BM (C) + 100% IC) | 154.8 | 17.6 | 72.2 |
| $T_8$ (BM (C) + 75% IC) | 204.9 | 22.1 | 78.7 |
| SEm (±) | 32.4 | 3.5 | 10.1 |
| CD (0.05) | NS | NS | NS |

C-Coconut; IC-Intercrop

(2007). Among the nutrients, available phosphorus, calcium, magnesium and manganese were found significantly influenced by the treatment effects, but no remarkable trend was observed (Table 3).

Population of rhizosphere microflora was enumerated as an index of sustainability of the system. Bacteria, fungi and actinomycetes were found to be significantly influenced by the treatment effects and the population was highest in $T_8$, $T_{11}$ and $T_{12}$ respectively. In $T_8$, the quantity of fertilizer applied was least where the highest bacterial population was found. Control plot of long pepper promoted fungal growth and sole crop of banana favoured the growth of actinomycetes. Similar results were reported by Nair and Rao(1977) and Potty and Jayasankar (1983).

Total recyclable biowaste generated in the system was to the tune of 13.0 t ha$^{-1}$. Though not significant,$T_5$ recorded the highest quantity of

**Table 5. Economic analysis of the system as influenced by nutrient management in a multi-storeyed cropping system**

| Treatment | Cost of cultivation (₹ ha$^{-1}$) | Gross returns (₹ ha$^{-1}$) | Net returns (₹ ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|
| $T_1$ (100 per cent C +100 per cent IC) | 196572 | 348822 | 133500 | 1.6 |
| $T_2$(100 per cent C +75 per cent IC) | 194805 | 395209 | 188385 | 1.9 |
| $T_3$(2/3$^{rd}$ C +100 per cent IC) | 193331 | 423769 | 211687 | 1.9 |
| $T_4$(2/3$^{rd}$ C +75 per cent IC) | 191565 | 385110 | 181526 | 1.9 |
| $T_5$(1/3$^{rd}$ C +100 per cent IC) | 190091 | 373024 | 164182 | 1.8 |
| $T_6$(1/3$^{rd}$ C +75 per cent IC) | 188325 | 371287 | 170943 | 1.8 |
| $T_7$(BM (C) + 100 per cent IC) | 185452 | 394071 | 189869 | 1.9 |
| $T_8$(BM (C) + 75 per cent IC) | 183685 | 429723 | 234019 | 2.2 |
| SEm (±) | | 22997 | 16884 | 0.17 |
| CD (0.05) | | 50111 | 36790 | 0.15 |

C-Coconut; IC-Intercrop

recyclable biowaste followed by $T_4$ and $T_6$ (Fig. 2). Treatment $T_4$ (242.0 kg ha$^{-1}$ year$^{-1}$), $T_8$ (22.1 kg ha$^{-1}$ year$^{-1}$) and $T_1$ (80.6 kg ha$^{-1}$ year$^{-1}$) added maximum quantity of nitrogen, phosphorus and potassium to the soil through organic recycling (Table 4).

### Economic analysis

Economic analysis revealed profitability in terms of gross return, net return and BCR. The treatment $T_8$ recorded the highest value of 4.3 lakh ha$^{-1}$, 2.3 lakh ha$^{-1}$ and 2.2, respectively. With respect to gross return, net income and BCR. The lowest BC ratio was recorded in $T_1$ (1.6) (Table 5). Treatment $T_8$ recorded the highest gross income and the lowest cost of cultivation, which might have resulted in the highest BC ratio. The highest productivity of the main crop coconut was also recorded in treatment $T_8$. Similar results were reported by Sairam *et al*., 2004 and Palaniswami *et al.,* 2007.

The present study has indicated that basin management of coconut with *in situ* green manuring, recycling of palm waste, FYM application @ 50 kg + 5 kg ash + 25 g *Azospirillum* per palm per year combined with the application of 75 per cent of the recommended dose of NPK each for the component crops *viz*. noni, banana and long pepper was found worthwhile for popularization in relation to productivity, profitability and sustainability of the coconut based multi-storied cropping system in coastal sandy soil.

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