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Research Paper

Productivity and nutrient status of coconut (*Cocos nucifera*) as influenced by integrated nutrient management with vermicomposted coconut leaves

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ABSTRACT

A long-term field investigation was carried out during 2001 to 2010 at Vittal (Karnataka) in a 22 year old coconut garden under laterite soil to study the impact of inorganic fertilizer substitutions by vermicompost (VC) on productivity and profitability of coconut (*Cocos nucifera* L.). The treatments, viz. recommended inorganic fertilizer (500 g N, 320 g P and 1200 g K/palm/year), 25% of N in the form of VC (9.6 kg/palm) + 75% of NPK, 50% N in the form of VC (19.2 kg/palm) + 50% of NPK, 75% in the form of VC (28.8 kg/palm) + 25% NPK and 100% N in the form of VC alone (38.5 kg/palm) were imposed in randomized block design. Annual leaf production did not differ significantly among the treatments; however, integrated treatments resulted in higher number of leaves (12 no.). Six years pooled data on nut yield indicated that, application of vermicompost in combination with inorganic fertilizer either at 25% of N + 75% NPK (64.5 nuts/palm/year) or 50% of N + 50% NPK (66.2 nuts/palm/year) resulted in significantly higher nut yield. There was improvement in the nutrient status of coconut leaves with integrated nutrient management practices compared to inorganic or organic manure alone application. The soil organic carbon build up was observed with application of 50% N or more in the form of vermicompost compared to the other treatments. Microbial population in respect of fungi and phosphate solubilizes were higher when vermicompost was applied.

Key words : Coconut, Crop production, INM, Nutrient status, Nut yield, Organic carbon, Vermicompost

India is the largest producer of coconut and the crop is mainly cultivated in coastal belt of west and east coast wherein, Kerala, Tamil Nadu, Andhra Pradesh and Karnataka are the major coconut-growing states, accounting for more than 90% of the area and production. Soil is not an inexhaustible source of nutrients and hence, the nutrient depletion over a period of time will adversely affect the nut yield, if the soil is not replenished with the nutrients. The crop with a density of 175 palms/ha requires 353 kg/ha of N, P and K as per Central Plantation Crops Research Institute (CPCRI) recommendation. This is based on general recommendation from CPCRI for fertilizing the matured bearing palms at 500 g N, 320 g P and 1,200 g K/palm/year, to be applied in 2 split doses, viz. one-third in May–June and two-thirds in September–October (Nelliat, 1973). The annual nutrient export by various parts of the palm, viz. nuts, fronds, trunk, bunch and spathe, reported by different workers vary from 20 to 174 kg N, 2.5 to 20 kg P and 35 to 249 kg K/ha (Ramadasan and Lal, 1966; Ollangnier and Ochs, 1978), but there appears to be a general agreement on the ratio of N and K removed by the palms (1: 1.44–1.75).

The nutrient supply from organic manure is slow and steady apart from very low nutrient loss and the availability of micronutrients coupled with the added advantage of improving soil physico-chemical and biological properties. Plantation crops produce huge amount of biomass for recycling in the form of suitable organic manure and account for more than 30–50% of the produce (Nampoothiri, 2001) and have sufficient potential to benefit from natural farming and sustain their yield with low external input, as they produce considerable quantities of biomass for recycling. Vermicomposting is the method of composting the organic matter by earthworms under favourable soil moisture and temperature conditions. Earthworms can mediate decomposition of lignin as well as poly phenol and thus accelerate the humification process. The CPCRI, Kasaragod (Kerala) has identified a local strain of earthworm (*Eudrilus* sp.), similar to African night crawler, which is quite efficient in composting coconut leaves into

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granular vermicompost (Prabhu *et al.,* 1998). Thus obtained vermicompost from coconut leaves has been found to play an important role in low external input resources, as one of the components of integrated nutrient management for sustaining soil health, fertility and crop productivity. Hence research work was initiated to study the impact of vermicompost substituting inorganic fertilizer on productivity and profitability of coconut. Maheswarappa *et al.* (2011) have described the effect of vermicompost in combination with inorganic fertilizer on yield components, yield and economics of coconut and in this paper its effect on growth, nutrient status, soil microbial population and sustainability of the yield is discussed.

MATERIALS AND METHODS

The experiment was conducted at CPCRI, RS, Vittal (Dakshina Kannada district, Karnataka), (12° 15‘ N and 75° 25‘ E, 91 m above mean sea-level). The climate of the experimental site is humid tropical with mean annual rainfall of 3,670 mm and 120 rainy days. The mean temperature ranges from 21°C (minimum) to 36°C (maximum). The average relative humidity varies between 61 and 94%. The experimental site has a lateritic soil classified as Oxic haplustults with a pH of 4-6 and available soil nutrient status of 143 ppm N, 10.1 ppm P and 53 ppm K at a surface depth of 25 cm. The mechanical composition of soil was 60.8% sand, 4.6% silt and 34.6% clay at surface depth of 25 cm.

The experiment was laid out in a 22-year-old coconut garden (cv. ‘West Coast Tall’) which was planted at a distance of 7.5 m × 7.5 m in a square system during 2000–01. Each treatment consisted of 6 palms/plot (337.5 sq. meters), replicated 4 times in randomized block design. The treatments were: T_1, recommended N, P, K alone (500 N + 320 P + 1200 K g/palm/year); T_2, 25% N in the form of vermicompost (VC) + 75% NPK; T_3, 50% N in the form of VC + 50% NPK; T_4, 75% N in the form of VC + 25% NPK; and T_5, 100% N in the form of VC alone.

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, mussorie rockphosphate and muriate of potash were applied in 2 equal splits during April–May and September–October. Vermicompost was obtained by decomposing coconut leaves as per the procedure explained by Prabhu *et al.* (1998) from the palm of the experimental plot which was having nutritional composition of N: 1.3%, P_2O_5: 0.2 % and K_2O: 0.14 % (mean of 2 years) and was applied on N-equivalent basis.

Coconut palms were irrigated with drip system from November onwards to May as per the recommendations of the CPCRI during the experimental period (2001 to 2010). During December to January, 27 litres water and 32 litres water during February to May per palm/day was applied. Coconut basins were mulched with coconut leaves during summer months in order to reduce the evaporation of moisture from the soil.

Post-treatment (2010) soil and leaf samples were collected from 3 palms in each plot. Soil samples were collected from 0–25 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 (14^{th} 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, Ca, magnesium (Mg), copper (Cu), Zinc (Zn), Iron (Fe) and manganese (Mn) 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, actinomycetes, fungi, N_2 fixers, phosphate-solubilizers and fluorescent pseudomonads were determined in the collected soils. The samples were serially diluted in sterile water blanks to produce several dilutions and 1 ml aliquot was pour plated in different media. Three sets of samples were drawn from each treatment. Three replications for each group of microorganisms were maintained. Total numbers of culturable bacteria were counted on nutrient agar after incubating for 24–48 hr at 28°C, actinomycetes on Ken Knights and Munaier’s agar (1) counted after 5–7 days incubated at 28°C, fungi on Martin’s rose Bengal agar counted after 2–4 days incubated at 28°C. The nitrogen-fixing bacteria were counted after 4 days on N-free medium, phosphate-solubilizers were enumerated by locating the clear halo formed around the colonies on Pikovskaya agar, for fluorescent pseudomonads producing green or greenish blue fluorescence, King’s B agar was used and the colonies were counted under UV light after incubation for 24–48 hr at 28°C. 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. Nuts were harvested at maturity stage palm-wise and average for the year was worked out.

RESULTS AND DISCUSSION

Leaf production

Number of leaves produced per palm per year did not differ significantly among the treatments (Table 1). However, it was found that the leaf production was higher (12 Nos.) in the integrated nutrient management (INM) treatments compared to inorganic and organic treatment alone (11 Nos.). Nath *et al*. (2012) reported increase in leaf production owing to INM in coconut. The number of leaves present on the crown also did not differ significantly among the treatments. Being a perennial crop, effect of different treatments might not have significantly influenced the growth and development of the palms.

Coconut nut yield

The nut yield recorded among the treatments over the years and pooled data are presented in Table 1. 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 2009–10, application of 50% N through VC + 50% NPK (T_3) treatment recorded significantly higher nut yield and was on a par with 25% N through VC + 75% NPK (T_2) treatment and differed significantly compared to the other treatments. The yield obtained under NPK only (T_1), 75% N in the form of VC + 25% NPK (T_4) and 100% N in the form of VC alone (T_5) was at par and ranged from 55.3 to 57.6 nuts/palm/year. The increase in yield under T_2 and T_3 treatments was to the tune of 100 to 100.9 % during 2009–10 compared to pre-experimental yield, whereas in treatments T_1, T_4 and T_5, increase was in the range of 34.2–42.0% only.

Pooled data on nut yield for 6 years (2004–05 to 2009–10) indicated the significant differences among the treatments (Table 1). Application of 25% N through VC + 75% NPK (T_2) and 50% N through VC + 50% NPK (T_3) recorded significantly higher nut yield and were at par with each other and differed significantly 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. Experimental results in root (wilt) affected garden indicated that through an inte-

Table 1. Growth and yield of coconut as influenced by nutrient management

Treatment	Number of leaves on the crown (Nos./palm)		Leaf production (Nos./palm/year)		Nut yield				
	Pre-experimental (during 1999)	Post-experimental (during 2010)	Pre-experimental (mean of 1998–99)	Post-experimental (mean of 2008–2010)	Pre-experimental yield (1998–2000) (Nuts/palm)	Nut yield (2009–10) (Nuts/palm)	Nut yield (2009–10) (Nuts/ha)	Pooled data of 2004-05 to 2009-10 (Nuts/palm)	Pooled data of 2004–05 to 2009–10 (Nuts/ha)
T_1, Recommended NPK through inorganic (500 g N, 320 g P and 1200 g K/palm/year)	22.5	25.5	10	11	41.2	55.3	9,108	51.3	8,928
T_2, 25% N in the form of Vermicompost (VC) + 75% NPK	23.0	24.2	11	12	40.2	84.0	13,950	64.5	11,109
T_3, 50% N in the form of VC + 50% NPK	23.5	25.7	11	12	42.3	84.6	14,194	66.2	11,440
T_4, 75% N in the form of VC + 25% NPK	23.0	26.2	11	12	42.6	57.6	10,026	52.6	9,157
T_5, 100% N in the form of VC alone	22.1	24.1	11	11	40.5	57.5	9,717	51.6	8,935
SEm±	0.17	0.18	0.30	0.30	0.76	2.92	507.67	1.34	232.75
CD (P=0.05)	NS	NS	NS	NS	NS	6.36	1,106.21	2.67	463.98

grated nutritional management involving application of vermicompost, balanced fertilizer, soil health as well as health of palms could be improved over the years or maintained without further deterioration (Krishnakumar and Maheswarappa, 2010). Nut yield recorded under T_1, T_4 and T_5 treatments were at par with each other and ranged from 51.3 to 52.6 nuts/palm/year. 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.

Soil properties

The electrical conductivity of the soil (at 0–25 cm depth) did not change due to the INM practices in the basins of the coconut, as seen in the pre-experimental and post-experimental data (Table 2). Post-experimental soil pH and organic carbon content differed significantly among the treatments. With the application of vermicompost, there was significant change in the pH of the soil, and the application of 75% and 100% N in the form of VC recorded significantly higher pH (4.65 to 4.68) compared to the other treatments. Soil organic carbon also significantly higher with the application of 50% of N and above in the form of VC (1.33 to 1.34%) compared to NPK alone (1.26%) and 25% of N in the form of VC combined with 75 % NPK (1.23%). Krishnakumar and Maheswarappa (2010) and Srinivasa Reddy and Upadhyay (2002) reported significant change in soil properties due to INM.

Leaf-nutrient status

The nutrient content in the index leaf in respect of N, K and Mg differed significantly among the treatments, whereas the content of other nutrients did not differ significantly (Table 3).The N content was significantly higher under recommended N, P, K alone (500 N + 320 P + 1200 K g/palm/year) and 25% N in the form of vermicompost (VC) + 75% NPK treatments compared to other treatments. The K content was significantly higher with recommended NPK (T_1), 25% N in the form of VC + 75% of NPK (T_2) and 50% N in the form of VC + 50% of NPK (T_3) treatments compared to T_4 and T_5 treatments. 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 vermicompost and reduced dose of recommended N. With the

Table 2. Effect of integrated nutrient management on soil properties in coconut garden.

Treatment	pH		EC (µmhos/cm)		OC (%)	
	Pre-experimental	Post-experimental	Pre-experimental	Post-experimental	Pre-experimental	Post-experimental
T_1, Recommended NPK through inorganic (500 g N, 320 g P and 1200 g K/palm/year)	4.50	4.58	232.15	238.20	1.23	1.26
T_2, 25% N in the form of Vermicompost (VC) + 75% NPK	4.60	4.60	203.32	206.13	1.22	1.23
T_3, 50% N in the form of VC + 50% NPK	4.51	4.54	189.95	194.55	1.20	1.33
T_4, 75% N in the form of VC + 25% NPK	4.53	4.68	199.50	203.50	1.19	1.34
T_5, 100% N in the form of VC alone	4.56	4.65	196.90	205.70	1.20	1.39
SEm±	0.038	0.080	1.10	0.09	0.01	0.02
CD (P=0.05)	NS	0.17	NS	NS	NS	0.05

Table 3. Effect of integrated nutrient management on coconut leaf nutrient status (post-experimental, 2010)

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
T_1, Recommended NPK through inorganic (500 g N, 320 g P and 1200 g K/palm/year)	1.74	0.10	1.24	0.26	0.15	8.67	233.67	305.77	3.02
T_2, 25% N in the form of Vermicompost (VC) + 75% NPK	1.72	0.11	1.28	0.21	0.18	8.55	157.62	335.90	5.15
T_3, 50% N in the form of VC + 50% NPK	1.53	0.09	1.19	0.27	0.23	9.77	188.20	346.02	2.17
T_4, 75% N in the form of VC + 25% NPK	1.54	0.10	0.80	0.27	0.24	9.47	211.55	391.60	2.50
T_5, 100% N in the form of VC alone	1.49	0.11	0.81	0.26	0.26	10.32	205.40	335.32	2.92
SEm±	0.013	0.003	0.08	0.011	0.006	0.37	15.76	19.55	0.32
CD (P=0.05)	0.028	NS	0.021	NS	0.023	NS	NS	NS	NS

Table 4. Microbial population (CFU/g dry soil) as influenced by nutrient management (2010)

Treatment	Bacteria ($\times 10^5$)	Fungi ($\times 10^3$)	Actinomycetes ($\times 10^4$)	Phosphate-solubilizers ($\times 10^4$)	Fluorescent pseudomonads	Free-living N_2 fixers ($\times 10^2$)
T_1, Recommended NPK through inorganic (500 g N, 320 g P and 1,200 g K/palm/year)	72.5	77.5	104.8	17.61	56.7	64.60
T_2, 25% N in the form of Vermicompost (VC) + 75% NPK	60.9	100.3	92.8	19.49	25.6	63.47
T_3, 50% N in the form of VC + 50% NPK	81.1	86.7	98.3	21.13	15.0	66.40
T_4, 75% N in the form of VC + 25% NPK	66.6	88.3	97.9	20.12	42.1	63.32
T_5, 100% N in the form of VC alone	71.3	86.0	96.5	20.96	94.0	62.65
SEm±	13.45	15.55	18.04	5.74	18.61	8.39
CD (P=0.05)	NS	NS	NS	NS	NS	NS

vermicompost application, there was improvement in the Mg content of the leaves indicating benefit of VC in contribution to micronutrients for plant growth. There was higher content of Zn and Mn also under VC treated palms compared to the other treatments. 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.

Soil microbial population

The population of bacteria, fungi, actinomycetes, phosphate-solubilizers, nitrogen fixers and fluorescent pseudomonads did not differ significantly among the various treatments, when analysed at 0–25 cm soil depth (Table 4). 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 vermicompost and inorganic fertilizers. However, the population of fungi and phosphate-solubilizers were, in general, more in treatments where vermicompost was applied alone or in combination with inorganic fertilizers, as compared to only inorganic fertilizer application. The treatment where 100% N was supplied in the form of vermicompost only, had highest count of fluorescent pseudomonads. Fluorescent pseudomonads are an important component of soil microbiota, as they are implicated both in plant-growth promotion and disease control.

It can be concluded that, application of vermicompost in combination with inorganic fertilizer either in 25% N through vermicompost (VC) (9.6 kg) + 75% NPK or 50% N through VC (19.2 kg) + 50% NPK combination 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.

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