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Studies of soil properties and its relation with nut yield under INM practice of coconut (*Cocos nucifera* L.)

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Abstract
The present investigation was carried out during 2018-19 in the Department of Horticulture (Fruit and Fruit Technology), BAC, Sabour to studies the soil properties and its relation with nut yield under INM practice of coconut (*Cocos nucifera* L.). Soil pH, EC and available N, P and K content in the soil was recorded maximum under 100% of recommended dose of fertilizers (RDF) treatment (control) while decreased gradually with the reduction of RDF in the subsequent treatments. However, the soil organic carbon content was recorded maximum in the treatment having 100% organic recycling (T_4) (2.19 times higher than the control). Besides, the treatment consisting of 25-50% organic recycling (T_2 and T_3) also had significantly higher organic carbon content in the soil. The available micronutrient content (Fe, Zn, Mn and Cu) in the soil was also recorded maximum in 100% RDF treatment (control) with minimum in 100% organic recycling (T_4) treatment (14.58, 0.51, 6.69 and 0.95 mg kg^{-1} soil, respectively). The nut yield was recorded maximum in 100% organic recycling (T_4) treatment (5067 nuts ha^{-1}) with non-significant difference in 50% of RDF + 50% N through organic recycling (T_3) and 75% of RDF + 25% N through organic recycling (T_2) treatment. Hence, it can be concluded although the 100% RDF treatment increases the available N, P and K content in the soil but the treatments with organic amendments (25-100%) are most suitable for sustainable production as all these treatments increased the soil organic carbon content significantly.

Keywords: Coconut, INM, organic amendments, sustainability, yield

1. Introduction

Food and nutritional insecurity are the global issues, and they are especially severe in the countries which are in developing phase. It is mainly due to ever increasing growth of population in each and every developing countries with declining availability of all the resources particularly water, land with others (Ray *et al*. 2015). Therefore, it is the urgent need for all the developing countries of the world to re-orient the agricultural management system in such a way so that can be sustained for longer period of time to increase in total production of agricultural crops. This will ultimately help to upholds the countries with food and nutritional securities. There are large number of low-cost production technologies are available in different fruit crops *viz*. application of recommended dose of fertilizers, micronutrients, PGRs etc (Khatoon *et al*., 2021; Nandita *et al*., 2020; Khatoon *et al*., 2020; Kumari *et al*., 2019a; Kundu *et al*., 2013a; Kundu *et al*., 2013b; Kundu *et al*., 2013c) [6, 21, 7, 11, 13-15]. But the main drawback is the sustainability of all those production system in long run particularly due to continuous changing and uncertain climate climatic condition of the world (Wilke and Morton 2015; Tubiello *et al*. 2007) [29 ,26]. In addition, the increasing risks of soil degradation (Bai *et al*. 2008) [1] also creating huge pressure to the policy makers as well as researchers to implement any fruitful policy to make the agricultural system sustainable. On the other hand, soil quality is a strong determinant for yield potentiality of any crop. Conservation agriculture system enhance soil quality and also improve the productivity (Kumari *et al*. 2019b; Mikha *et al*. 2012) [12, 19]. Adaptation of INM practices by means of application of different organic source of nutrients is a handy option to improve the soil quality as well as the yield of the crop. Now, soil structure as well as the water infiltration capacity of the soil are the key soil physical characters that are relevant to control soil erosion particularly under erosive climate and erodible land of the tropics (Choudhury *et al*. 2014) [2] as well as in other regions (Kheyrodin and Antoun 2011) [8]. Further, application of organic source of nutrients for longer period of times helps to improves biological properties of the soil particularly with respect to microbial communities (Mathew *et al*. 2012) [18], growth of microbes and processes of decomposition (Franzluebbers *et al*. 1995) [4], availability of earthworms in the soil (Parmelee *et al*. 1990) [23], as well as different micro and macro fauna (Mutema *et al*. 2013) [20].

Further, it also helps to increase the organic matter content in the soil and soil organic carbon (SOC) content even in the surface layer; reduce soil erosion and improve soil chemical and biological properties which ultimately enhance soil fertility status (Kheyrodin and Antoun 2011) [8]. Organic matter content (SOM) present in the soil is a stable and long-lasting carbon source. Nearly all the nutrients required to the plants for their improved growth and development are mainly supplied from this soil organic matter. Therefore, it is a meaningful and most important index for evaluating fertility status of any type of soil in any part the world (Lin *et al*., 1996) [16]. The improvement of all these soil chemical and biological properties ultimately helps to improve the productivity of different agricultural crops significantly. Keeping all these views in mind, the present investigation was formulated to study of soil properties and its relation with nut yield under INM practice of coconut (*Cocos nucifera* L.).

2. Materials and Methods

2.1 Materials

The experiment was carried out on 10 years old coconut (*Cocos nucifera* L.) plantation of the cultivar Shakhi Gopal (7.5 × 7.5 m spacing) under All India Co-ordinated Research Project (AICRP) on Palm. This coconut plantation was situated in the research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar (25°23'N, 87°07'E, 37.19 metre above the msl).

2.2 Treatment details

Four different treatment combinations were tested under the present investigation which are as follows – T_1:100% RDF (500:300:1200 g N: P2O5:K2Otree^{-1}); T_2:75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1}); T_3:50% of RDF + 50% N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash 2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring]; T_4:100% of N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash (2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring (*Sesbania*) and green leaf manuring (*Glyricidia* leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves.

The experiment was carried out in completely randomized block design (CRBD) with five replications and the observations were taken during 2018-19.

The treatments were applied to each and every coconut palm around the basin of 1.8 m radius in two equal splits – one in the month of July-August and another during January-February. In T_4 treatment, coconut leaves was used as organic mulch.

2.3 Soil sample collection and processing

Soil samples were collected during Mid-January, 2019 (before fertilizer application). The samples were collected from each experimental tree at four different depth *viz*. 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm. After collecting the soil samples with the help of screw augar, they were mixed thoroughly and placed in polyethylene bags and brought to the laboratory. In laboratory, one portion of these soil samples were weighted freshly and over dried for 24 hrs to measure soil moisture content however, the remaining portion of soil samples were air dried and passed through a 2-mm sieve for further analysis of different physic-chemical properties of the soil.

2.4 Observations recorded

2.4.1 Soil pH

To measure soil pH, a soil suspension was prepared by adding water in the soil sample at the ratio of 1:2.5 (Soil: Water) and pH was measured with the help of glass electrode digital pH meter (Systronics µ pH system 361).

2.4.2 Electrical conductivity

The soil water suspension was prepared in 1:2.5 (Soil: Water) ratio. The electrical conductivity (Jackson, 1973) [5] of filtrate of suspension was determined by electrical conductivity meter (Systronics conductivity meter 306).

2.4.3 Organic carbon

Organic carbon of soil was estimated by chromic acid wet digestion followed by titrimetric measurement of unreacted dichromate (Walkley and Black, 1934) [28].

2.4.4 Available Nitrogen content

The available soil N was measured by using Subbiah and Asija (1956) method. For this first we weighted 5gm soil sample on filter paper and was wrapped it carefully and put it into a Kjeldahl distillation flask. Then we moisten the sample with 20 ml distilled water and fixed it into Kjeldahl assembly. Thereafter, 25 ml of 0.32% $KMnO_4$ and 25 ml of 2.5% NaOH solution was added to it and quickly fit the cork. Now 10 ml of 0.02 N H_2SO_4 was pipette out in conical flask and about 3 mix indicator was added to it and dip the end of delivery tube into it. Thereafter, the heater/hot plate was switched on to distillate ammonia gas and collect 30 ml of the distillate in 0.02 N H_2SO_4. And finally the excess of H_2SO_4 in the conical flask was titrate against 0.02 N NaOH and noted the volume of 0.02 N NaOH used when changes from pink to yellow colour.

2.4.5 Available Phosphorus

The available P in soil sample was measured by the method suggested by Olsen *et al*. (1954). For that we have prepared the standard curve and then weighted out 1 gm of dry soil and transferred it into the 100 ml conical flask followed by addition of pinch of Darco-G 60 and 25 ml 0.5 M $NaHCO_3$. Then mixed and shaken the contents of the flask on an electric shaker at constant speed for half an hour and filter through Whatman No.1. Similarly, we have also prepared a blank. Therefore, 5 ml of filtrate was taken in a 25 ml of volumetric flask and then 5 ml of ammonium molybdate @ 1.5% was added to it and mixed and shaken thoroughly until the evolution of CO_2 was stopped. Then 10 ml of distilled water was added to it washing the neck of the flask, and then 4 ml of L-Ascorbic acidsolution was added in the flask and made the volume to the mark with distilled water. The blue colour of varying intensity was developed in all flasks containing P solution and measured at 660 nm in spectrophotometer.

2.4.6 Available Potassium content

Available potassium in soil was determined using neutral normal ammonium acetate (1N NH_4OAc, pH 7.0) extract. The extraction was carried out by shaking followed by filtration. The potassium was estimated by using Flame-Photometer.

2.4.7 Available micronutrient (Fe, Cu, Mn, Zn)

The cationic micronutrients Fe, Cu, Mn and Zn were extracted by using 0.005*M* DTPA (Diethyl triaminepenta acetic acid), 0.01*M* calcium chloride dehydrate and 0.1 Mtriethanol amine buffered at 7.3 pH following the method of Lindsay and Norvell (1978) [17] and concentrations were analyzed by atomic absorption spectrophotometer.

2.4.8 Yield of coconut plantation
The yield data of each plant was recorded for the year 2018-19 and 2019-20 and converted to nut yield ha^{-1}.

2.5 Statistical analysis
The observations were subjected to statistical analysis by using completely randomized block design (CRBD) with five replications. Data were analyzed using statistical analysis software (SAS 9.2; SAS Institute, Cary, NC, USA) and the means separation test were compared using Duncan's multiple range test.

3. Results
3.1 Soil pH, EC and Organic Carbon content
The soil pH of the experimental coconut plantation was varied significantly among the treatments (Table 1) and it was recorded significantly higher in 100% RDF treatment (7.51) followed by 75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1}) treatment (T_2). However, the treatment consist of 50% and 100% organic recycling (T_3 and T_4), the soil pH was reduced drastically as compared to control (9.05 and 9.19% lower than the control, respectively). Similarly, soil electrical conductivity was also reduced significant in 50% and 100% organic recycling (T_3 and T_4) treatment (0.20 and 0.17 dsm^{-1}, respectively) as compared to control (0.29 dsm^{-1}). The treatment consist of 75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1})also had statistically at par soil electrical conductivity with the control. In contrary, the soil organic carbon content was recorded maximum in 100% organic recycling (T_4) treatment (2.81 g kg^{-1}) which was 2.19 times higher than the control (0.88 g kg^{-1}). Besides, 50% of RDF + 50% N through organic recycling (T_3) and75% of RDF + 25% N through organic recycling (T_2) treatment also increased the soil organic carbon content significantly over control.

Table 1: Effect of INM based cropping system on soil pH, EC and organic carbon content of coconut plantation

Treatment(s)	Symbol	pH	EC (dsm^{-1})	Organic Carbon (g Kg^{-1})
100% RDF (500:300:1200 g N: P_2O_5:K_2Otree^{-1})	T_1	7.51 ^{a}	0.29 ^{a}	0.88^d
75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1})	T_2	7.15 ^{b}	0.27 ^{a}	1.43^c
50% of RDF + 50% N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash 2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring]	T_3	6.83 ^{c}	0.20 ^{b}	1.84^b
100% of N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash (2.5 l tree^{-1}) + *Azospirillum* (500 g tree^{-1}) and in situ green manuring (*Sesbania*) and green leaf manuring (*Glyricidia*leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves	T_4	6.82 ^{c}	0.17 ^{b}	2.81^a

Value indicates mean of five replicates. Different letters in the same row indicate significant differences at P ≤0.05 (Duncan's Multiple Range Test)

3.2 Available soil N, P and K content
The status of available soil N, P and K content was also varied significantly in different treatment combination under the present investigation (Table 2). The available nitrogen content in the soil was recorded maximum in 100% RDF treatment (173.15 kg ha^{-1}) which was reduced gradually with the reduction of RDF doses and recorded minimum in 100% organic recycling (T_4) treatment (24.34% lower than the control). Similarly, the available soil phosphorous content was also recorded maximum in 100% RDF treatment (22.43 kg ha^{-1}) and minimum in 100% organic recycling (T_4) treatment (29.34% lower than the control). Similar pattern was also observed for available potassium content in the soil. The available potassium content was recorded maximum in 100% RDF (T_1) treatment (71.03 kg ha^{-1}) followed by75% of RDF + 25% N through organic recycling (T_2) treatment (57.03 kg ha^{-1}) and reduced gradually with the further reduction of RDF doses with minimum in 100% organic recycling (T_4) treatment (35.87% lower than the control).

Table 2: Effect of INM based cropping system on available nitrogen (Kg ha^{-1}) in the soil of coconut plantation

Treatment (s)	Symbol	N (Kg ha^{-1})	P (Kg ha^{-1})	K (Kg ha^{-1})
100% RDF (500:300:1200 g N: P_2O_5:K_2Otree^{-1})	T_1	173.15 ^{a}	22.43 ^{a}	71.03 ^{a}
75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1})	T_2	156.45 ^{b}	20.23 ^{b}	57.03 ^{b}
50% of RDF + 50% N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash 2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring]	T_3	148.47 ^{c}	18.43 ^{c}	53.93 ^{c}
100% of N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash (2.5 l tree^{-1}) + *Azospirillum* (500 g tree^{-1}) and in situ green manuring (*Sesbania*) and green leaf manuring (*Glyricidia*leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves	T_4	131.0 ^{d}	15.85 ^{d}	45.55 ^{d}

Value indicates mean of five replicates. Different letters in the same row indicate significant differences at P ≤ 0.05 (Duncan's Multiple Range Test).

3.3 Available soil micronutrient content
The available micronutrient content in the soil was also differed significantly among the different treatment combination under the present investigation (Table 3). Available iron content was recorded maximum in 100% RDF (T_1) treatment (14.80 mg kg^{-1}) with non-significant variation in 75% of RDF + 25% N through organic recycling (T_2) treatment (14.75 mg kg^{-1}). However, the available zinc content was recorded maximum in 100% RDF (T_1) treatment (0.58 mg kg^{-1}) followed by75% of RDF + 25% N through organic recycling (T_2) treatment (0.55 mg kg^{-1})with minimum in 100% organic recycling (T_4) treatment (12.07% lower than the control). Further, the available manganese content in the soil was recorded maximum in 100% RDF (T_1) treatment (7.20 mg kg^{-1}) followed by 75% of RDF + 25% N through organic recycling (T_2) treatment (7.00 mg kg^{-1}) with minimum in 100% organic recycling (T_4) treatment (7.08% lower than the control). Similar pattern was also observed in the available

copper content in the soil with maximum in 100% RDF (T_1) treatment (1.17 mg kg^{-1}) followed by 75% of RDF + 25% N through organic recycling (T_2) treatment (1.12 mg kg^{-1}) with minimum in 100% organic recycling (T_4) treatment (18.80% lower than the control).

Table 3: Effect of INM based cropping system on micronutrients content in the soil of coconut plantation

Treatment(s)	Symbol	Fe (mg Kg^{-1})	Zn (mg Kg^{-1})	Mn (mg Kg^{-1})	Cu (mg Kg^{-1})
100% RDF (500:300:1200 g N: P_2O_5:K_2Otree^{-1})	T_1	14.80 ^{a}	0.58^a	7.20^a	1.17^a
75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1})	T_2	14.75 ^{a}	0.55^b	7.00^b	1.12^a
50% of RDF + 50% N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash 2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring]	T_3	14.60 ^{a}	0.52^c	6.87^c	1.07^a
100% of N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash (2.5 l tree^{-1}) + *Azospirillum* (500 g tree^{-1}) and in situ green manuring (*Sesbania*) and green leaf manuring (*Glyricidia*leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves	T_4	14.58 ^{a}	0.51^c	6.69^d	0.95^b

Value indicates mean of five replicates. Different letters in the same row indicate significant differences at $P \leq 0.05$ (Duncan's Multiple Range Test)

3.4 Nut yield

The entire coconut plantation was only 10 years old and they just started to produce nut after completion of eight years of juvenility. Hence the nut yield in terms of number of nuts ha^{-1} was significantly lower as compared to any commercial coconut plantation. However, the nut yield was recorded maximum in 100% organic recycling (T_4) treatment (5067 nuts ha^{-1}) with non-significant difference in 50% of RDF + 50% N through organic recycling (T_3) and 75% of RDF + 25% N through organic recycling (T_2) treatment (4931 and 4875 nuts ha^{-1}, respectively) (Figure 1); however the 100% RDF treatment (T_1) had significantly lower nut yield (4003 nuts ha^{-1}).

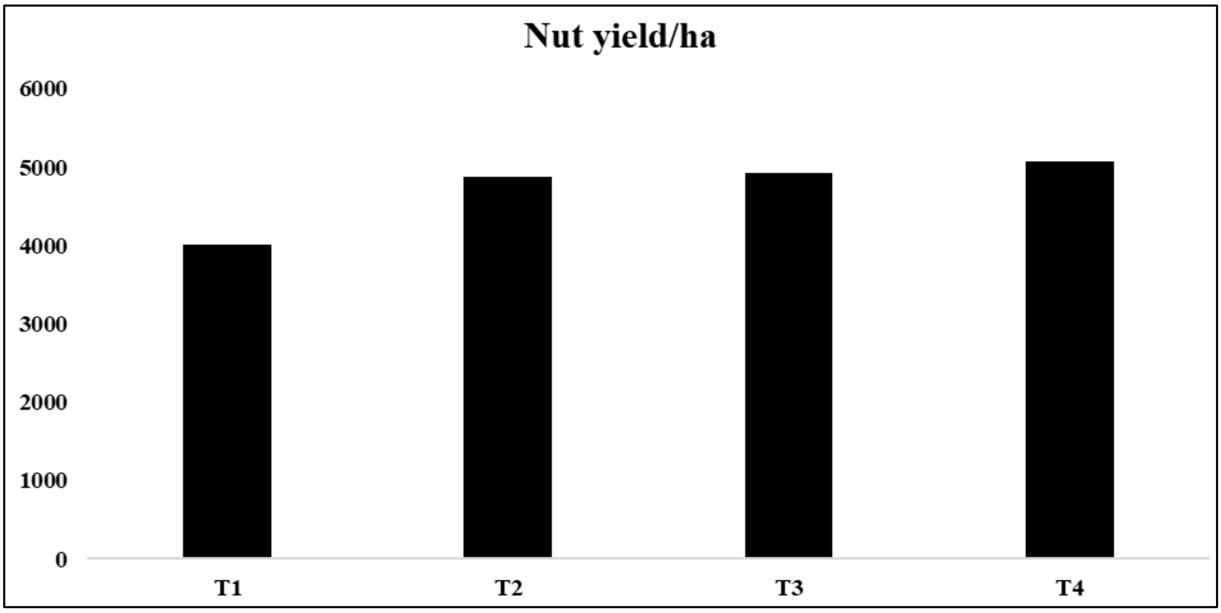

Fig 1: Effect of INM based cropping system on nut yield of coconut T_1: 100% RDF (500:300:1200 g N: P2O5:K2O tree^{-1}); T_2: 75% of RDF + 25% N through organic recycling with vermicompost (10 kg tree^{-1}); T_3: 50% of RDF + 50% N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash 2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring]; T_4: 100% of N through organic recycling with vermicompost (15 kg tree^{-1}) + vermiwash (2.5 l tree^{-1}) + Azospirillum (500 g tree^{-1}) and in situ green manuring (*Sesbania*) and green leaf manuring (*Glyricidia* leaves) + composted coir pith, husk incorporation (once in 3 years) and mulching with coconut leaves.

4. Discussion

The pH of soils loaded with organic amendments showed a significant reduction as compared to inorganic fertilizer application. The decrease in the pH of those treatments might be attributed to the decomposition of the organic residues which release acids over the 5-6years and decrease the pH of the soils. The EC of the soils loaded with 100% inorganic fertilizers were higher due to the ions released during the experimental tenure. Soil organic carbon was improved in the organic treatments because of the organic practices like green manuring and vermicompost addition. The percentage of soil organic carbon was estimated higher in the surface soil as compared to the subsoil layer which confirmed the earlier findings of Ukpebor *et al*. (2003) [27]. Available nitrogen in the soils are basically related to the organic carbon content in soils which were higher in the organic treatments. Nitrogen is localized in the top layers and highly prone to oxidation and reduction processes depending upon the oxic and anoxic environment. Even the Phosphorus content of the soils is lower in the organic amended plots and these could also indicate the storage of nutrients in organic forms which will be released slowly and will be available to the plants. Available potassium was higher in the inorganic treatments due to high supply of K fertilizers. Organic amendments provides exchangeable surfaces for the retention of potassium besides the dynamics of potassium is such that the potassium in soil solution moves towards the non-exchangeable fraction for which the determination is out of the scope of the study.

The DTPA extractable iron was not influenced by any of the treatment but the available Zn and Cu were affected. DTPA extractable Zn and Copper forms complex with the chelating agents released under the organic treatments and thus their values were lowered down. Similar findings were also observed previously by Dutta *et al*. (2016) [3] in mango plantation; Choudhary *et al*. (2014) [2] in cluster bean and Shah *et al*. (2014) [24] in peach orchards.
On the other hand, as the experimental coconut plantation was only ten years old and just started to fruiting after completion of eight years of juvenile phase; hence it is very early to come any impact of organic amendments application on the yield of coconut. However, its impact will be reflected in near future on nut yield.

5. Conclusion
From the present experiment, it can be concluded that 100% RDF increases the available N, P and K content in the soil while treatments with organic amendments are having less available nutrients. However, the soil organic carbon content was significantly higher in the treatments having higher organic amendments which can be considered as sustainable.

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