Journal Of Agriculture & Ecosystem Management
Publishing Real Time
Journal homepage: www.jonages.com
JOURNAL OF AGRICULTURE AND ECOSYSTEM MANAGEMENT

Evaluation of different sources of organic amendments on Rhizome Yield of Curcuma longa, soil nutrient budget and uptake in coastal plain sands soils

[*]Eteng, Ernest U.[1], Okoro, Ikwuakonam G[2]. and Nwokeh, Uchenna J. [3]

Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike Nigeria.

ARTICLE INFO

Article history:
Received April 15, 2023
Received in revised form April 29, 2023
Accepted May 24, 2023
Available online June 14, 2023

Keywords:
Curcuma longa
Soil nutrient budget
Nutrient uptake
Rhizome
Biochar
OMF

Corresponding Author's E-mail Address:
ernstild6@gmail.com

https://doi.org/10.36265/jonages.2022.020206
ISSN– Online **2736-1411**
Print **2736-142X**

ABSTRACT

An experiment was conducted in 2021 to evaluate different sources of organic amendments on rhizome yield of *Curcuma longa*, soil nutrient budget and nutrient uptake. The treatments comprised of: Control (C), Biochar (BC), Poultry manure (PM), Organo-mineral Fertilizer (OMF), BC + PM, BC + OMF, PM + OMF and BC + PM + OMF. Soil and plants samples were collected and analyzed for K, Ca, Mg, Cu, Fe, Mn and Zn. The results of the study showed that, turmeric plants amended with BC+PM+OMF had the taller plant (80.82 cm) and maximum number of tillers per plant (8.33). BC+OMF had the maximum leaf number per plant (11.82) and total dry matter yield (12.33 tha^{-1}). BC+PM produced maximum rhizome number per plant (16.93) and rhizome fresh yield per plant (229.39 $gplant^{-1}$). Similarly, OMF produced maximum HI (66.56%). The abundance of soil nutrients budget were in the order of: $K^{1+} > Fe^{3+} > Ca^{2+} > Zn^{2+} > Mn^{4+} > Cu^{2+} > Mg^{2+}$ while, nutrients' uptake in the turmeric rhizomes were in the order of: $K^{1+} > Mn^{4+} > Fe^{3+} > Ca^{2+} > Zn^{2+} > Mg^{2+} > Cu^{2+}$. The correlation matrix between the growth and yield of turmeric and, the soil nutrients budget shows positive and highly significant (P<0.05). Thus, the application of organic amendments either as sole/or mixture could be recommended for turmeric cultivation.

1.0 Introduction

Turmeric (*Curcuma longa L.*) is an herbaceous perennial plant belonging to the family Zingiberaceae which can be grown in different tropical and subtropical regions around the world (Kumar *et al,* 2013). The main botanical characteristic is its rhizomes, which are oblong, ovate, pyriform, and shortly branched and is the one that has the main protagonism concerning its use in the food industry, medicine, cosmetics, among others (Amalraj *et al*., 2017). It develops as a large ovoid root stock that bears stalkless cylindrical tubes with distinct orange color. Rhizomes can be considered as underground stems having roots below and leaves growing above the surface.

The nutrient requirement of this crop is quite high. Due to its shallow rooting and the potential to produce a large quantity of dry matter per unit area, it requires heavy nutrients application and has a capacity to produce large amount of dry matter per unit area (Nwokocha *et al*., 2009). Considering the economic importance of turmeric and environmental problems caused by chemicals application, it is important to cultivate turmeric using organic fertilizer. The role of organic manures in improving soil structure and fertility is well understood (Kamal and Yousuf, 2012; Rajeev *et al*. 2013). Organic manures have a positive influence on soil texture and structure, better water-holding capacity, and drainage which in turn help for better growth and development of rhizomatous crops like turmeric (Kale *et al.,* 1991).

There are various sources of organic manures which are having a different effect on growth, yield and quality of turmeric (*Curcuma longa* L). Hence, it is necessary to know the best source of organic manure which could help in increasing the yield and quality of turmeric. In this context, the use of integrated organic nutrients; Biochar, Poultry Manure, and Organo-Mineral Fertilizer (OMF), in a balanced proportion is essential to sustain soil health and crop productivity (Zhang *et al.*, 2012; Wu and Ma, 2015).

Turmeric which is a new crop has potential as a high value crop in Nigeria. Information is lacking on the best source organic fertilizer requirement for high yield performance and nutrient concentration in the rhizome. The aim of the study was to evaluate the effect of different sources of organic manures on the productivity of rhizome, soil budgeted nutrient and nutrient uptake in *Curcuma longa*

2.0 Materials and Methods

2.1 Description of the study area

The study was conducted in September, 2021 at Umudike, Abia State. Umudike is located between Latitude 05^0 48' 21'N and Longitude 07^0 53' 94'E, with an altitude of 116 meter above sea level. The location has slope ranging from level to gentle slope. The study area falls within the tropical rain forest with mean annual rainfall of 2200 mm, distributed over nine to ten months in bimodal rainfall pattern; these are the early rain (April to July) and late rains (August to October) with five month dry season and short dry period in August popularly called August break. The relative humidity varies from 84% to 87% while, monthly minimum air temperature ranged from 20^0C to 24^0C and the monthly maximum air temperature ranged from 28^0C to 35^0C. The soil was acidic and, characterized as an ultisol (NRCRI, 2020) ()

2.2 Experimental design, treatments, and planting procedures.

The experiment which consisted of eight experimental treatments was laid out in a randomized complete block design (RCBD) with three replications. The treatments were as follows: -

T1. C = Control (C)

T2. BC = Biochar (BC)

T3. PM = Poultry manure (PM)

T4. OMF = Organo-mineral Fertilizer (OMF)

T5. BC + PM = Biochar x Poultry manure

T6. BC + OMF = Biochar x Organo-mineral Fertilizer

T7. PM + OMF = Poultry manure x Organo-mineral Fertilizer

T8. BC + PM + OMF = Biochar x Poultry manure x Organo-mineral Fertilizer

2.3 Amendments and planting operation

The study was conducted at the demonstration land beside the College of Crop and Soil Sciences. One week before planting, the experimental treatments were applied accordingly; Biochar was applied at the rate of 5 tons/ha, OMF was applied a 200kg/ha and the poultry manure was applied at 15 t/ha as single treatment while, for the different combined treatments, these were applied at the rate of half the full dose except for the OMF which was applied at a quarter of the full dose and the control had no treatment. All of the respective amendments were thoroughly mixed with the soil a week before planting.

A healthy sprouted primary rhizomes of variety NCL NVRI was used as the test crop for the study. Equal sizes of the sprouted turmeric rhizomes weighing about 30g were planted at a depth of 5 cm according to Kumar and Gill (2010). The seedlings were watered and grown for two weeks before a basal NPK 15:15:15 at 150 kg/ha was applied to the amended soils

2.4 Laboratory Analyses

The major net contents in the organic sources (Biochar, Poultry manure and Organo-mineral fertilizer) used for the study were subjected to standard chemical analysis according to (). The experimental initial soil samples (0-20cm depth) used for the study was collected, air dried and sieved with 2mm sieve and these were analyzed to determine, some soil chemical properties.

1) Soil pH was determined in a 1:2.5 in soil-water suspensions using a glass pH sensing electrode and a reference electrode (Thomas, 1996).

2) Soil organic carbon was determined by the dichromate wet oxidation method (Nelson and Somners, 1996).

3) Soil total nitrogen was determined using the micro-Kjedahl digestion procedure (Bremner, 1996).

4) The available phosphorus was determined using Bray II method, using a solution of 1M NH_4F and 0.5M HC1 in distilled water as the extractant (Kuo, 1996).

5) Calcium and Magnesium were determined using the EDTA titration method, while

6) Potassium and sodium were determined by flame photometry

7) The effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) and exchangeable acidity ($Al^{3+} + H^+$).

8) The percentage base saturation was determined using equation:

$$\text{Base saturation} = \frac{\text{Total exchangeable bases}}{\text{ECEC}} \times \frac{100}{1}$$

9) Amount of Fe, Cu, Mn and Zn: extracted with EDTA solution and analyzed with Atomic Absorption Spectrophotometry by adopting standard procedures (Lindsay and Norvell (1978).

Post-planting soil analysis: At 24 WAP (6 months), soil sample from each sub-plot was collected. The soil samples were air dried, grind and sieved at 2 mm and analyzed in the laboratory for pH, available Ca, Mg, K, Cu, Fe, Mn and Zn contents. The procedures are as outlined above.

Analysis of essential elements in rhizomes of turmeric: Rhizome samples were collected and were kept in paper bag before transport to laboratory and were rinse with clean water and dried in oven at 65-70 °C until it's completely dry for about 72hr. Then grinded with a stainless-steel Wiley Cutting Mill and sieved though 40 mesh and analyzed for:

1) Total potassium: Sample were digestion with HNO_3 and $HClO_4$ solution at 5:1 portion and analyzed with Flam Spectrophotometer

2) Total calcium and magnesium: Sample were digestion with HNO_3 and $HClO_4$ solution at 5:1 portion and analyzed with Atomic Absorption Spectrophotometer

3) Total Fe, Cu, Zn and Mn: Sample were digestion with HNO_3 and $HClO_4$ solution at 5:1 portion and analyzed with Atomic Absorption Spectrophotometer

2.5 Data Collection

1) Post planting soil samples were collected at depth of 0-15 cm from each sub-treatment for analysis.

2) Rhizome samples were harvested from each sub-treatment and were kept in paper bag before transport to laboratory

3) Growth parameter: At 170 days (6 months) after planting, when the turmeric had developed full canopy formation, the plant height was measured from base of the shoot at the soil surface to the tip of the tallest leaf apex using a ruler. The Stem girth was measured using a pair of vernier calipers. The numbers of fully developed leaves and tillers were counted.

4) Yield parameters: At harvesting, 224 days (8 months) after planting, the individual plants were uprooted using a hand fork. The numbers of rhizomes per plant were counted and the fresh rhizome weights per plant of turmeric were recorded using a top loading weighing balance. The dry matter of the shoot biomass and the rhizomes were determined by drying the above ground plant in an oven at 60°C until constant dry weight was attained. The Harvest Index was calculated according to Reddy (2004) as:

$$\textbf{HI (\%)} = \frac{\text{Rhizome yield (kg)} \times 100}{\text{Shoot biomass + rhizome yield}}$$

The turmeric rhizome yield was recorded in gram/plant and converted to $kgha^{-1}$

$$\textbf{Yield (kgha}^{-1}\textbf{)} = \frac{\text{Yield (kg)} \times 10{,}000\ m^2}{\text{Soil volume } m^3}$$

Statistical Analysis

The growth and yield data collected after the experiment were subjected to One-way analysis of variance (ANOVA) for a CRD using the Genstat software package Version 15.1. The significant differences between treatments were determined using least significant difference (LSD) test at 5% level of probability. Correlations between the nutrients and the growth and yield of turmeric were worked out following the method suggested by Panse and Sukhatme (1978).

3.0 Results and Discussions

3.1 Chemical characteristics of soil and organic sources used for the study

The initial soil used for the experiment was very strongly acidic as compared to biochar and poultry manure. The OC status of the soil was equally low relative to the organic sources. P and K status were low and medium in status, respectively. The content of other nutrients' status in the soils as well as organic sources are presented in Table 1. The organic sources, supplied the required nutrients for the enrichment of the soil which enhances the growth and yield of the turmeric rhizome.

Table 1: Nutrient composition of soil and amendment materials used for the study

Nutrient composition	Soil	Biochar (BC)	Poultry manure (PM)	Organomineral Fertilizer (OMF
pH (H_2O)	4.32	8.92	7.58	5.4
Total org carbon (gkg^{-1})	5.32	70.55	31.65	40
Nitrogen (gkg^{-1})	2.81	9.63	43.88	28
Avail Phosphorus ($mgkg^{-1}$)	4.12	88.4	166.72	12
Potassium ($cmolkg^{-1}$)	1.14	34.9	46.44	22
Calcium ($cmolkg^{-1}$)	1.49	48.6	35.88	28
Magnesium ($cmolkg^{-1}$)	2.59	18.27	32.60	23
Iron ($mgkg^{-1}$)	2.63	42.12	63.21	54
Zinc ($mgkg^{-1}$)	4.49	21.17	45.14	65
Manganese ($mgkg^{-1}$)	2.24	32.54	54.19	40
Copper ($mgkg^{-1}$)	1.54	17.87	52.02	34

3.2 Effects of amendments on the growth and yield components of turmeric plants

Growth Parameter

The effects of organic amendments on the growth parameters of turmeric plants are presented in Figure 1. Addition of organic manure either sole and/or mixtures significantly ($P<0.001$) influenced the growth parameter of the turmeric. The plant height of turmeric plant increased substantially from 32.83 cm in control to 80.31 cm in the BC+PM+OMF, followed by PM+OMF with a height of 72.04 cm with the mean of 62.17 cm which, might be due to better response of turmeric crop to the added nutrients. The highest average leaf number (11.82 cm) was obtained from the combination of BC+OMF followed by BC+PM+OMF (10.60cm). The average number of tillers per plant ranged from 3.33 to 8.33 with an overall mean of 5.88. The organic sources (Table 1) provided the nutrients to the plants which improved the edaphic factors, resulting in higher vegetative growth parameters (Fig. 1). Previous studies by Mensah and Frimpong (2018), Kadam and Kamble (2020) indicated that combined amendments of compost and biochar enhanced soil quality, increased plant growth, provided positive synergistic effect on soil nutrient contents under field conditions, resulted in reduction of fertilizer input, improved nutrient use efficiency, stabilized soil structure, and improved water retention capacity.

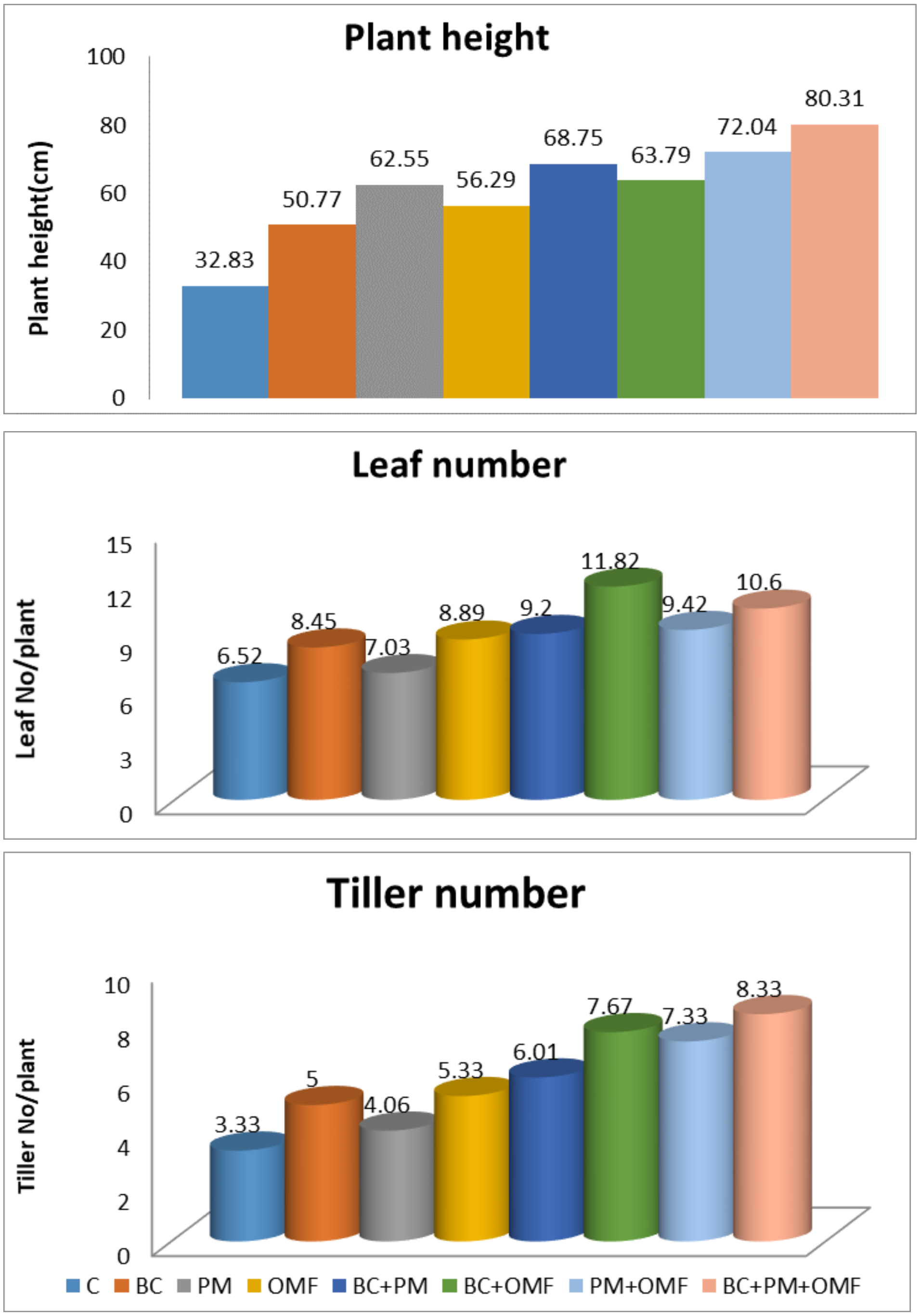

Figure 1: Effects of organic amendments on the growth parameters of turmeric plants

Yield Components

The results showing the effects of organic amendments on the yield components of turmeric rhizomes are presented in Fig. 2. There were significant differences ($P<0.05$) among the organic sources. The rhizome number per plant had values which ranged from 6.03 to 16.93 with the mean of 12.49. The turmeric rhizome yield per plant varied significantly ($P<0.001$) from 107.84 - 229.39 gplant^{-1} with the mean of 156.76 gplant^{-1}. Similar result was obtained for fresh rhizome yield of turmeric with the application of Ca and Mg by Sanghamithre *et al*. (2014) and Kamal *et al*. (2012). The increase in rhizome yield could also be due to cumulative increase in the rhizome finger weight and rhizome number by the addition of bio-organic nutrients which might have brought significant changes in the metabolic activities and photosynthesis. Similar findings have been reported by Kamal and Yousuf (2012) and Anuradha *et al.* (2018).

The single treatment of OMF (66.56%) had significantly ($P<0.001$) higher harvest index (HI) while, the control (27.23%) treatment had the lowest HI. The dry matter production of turmeric rhizome had values which varied significantly from 2.46 – 12.33 tha^{-1}. Similar results were obtained by Singh (2011) and Shubham *et al*. (2020). The organic amendments (Table 1) provided the nutrients to the plants and may improve edaphic factors, resulting in higher vegetative growth parameters (Fig. 1). Similar studies reported by Hossain and Ishimine (2007), Kamal and Yousuf (2012) and Singh *et al.* (2016) and Kadam and Kamble (2020) showed that organic fertilizer improved soil productivity and fertility, which improved yield and quality of crops. However, owing to the stability of biochar carbon, combined effects of biochar with other organic amendment can enhance soil properties, leading to higher added value and a much better carbon sequestration potential compared to individual mixing of biochar or compost with soil.

The increase in growth of turmeric plant (Fig. 1) and rhizome yield (Fig. 2), might have been as a result of increase in the nutrient budget (Table 3) as influenced by the soil amendments with organic sources (Table 1)

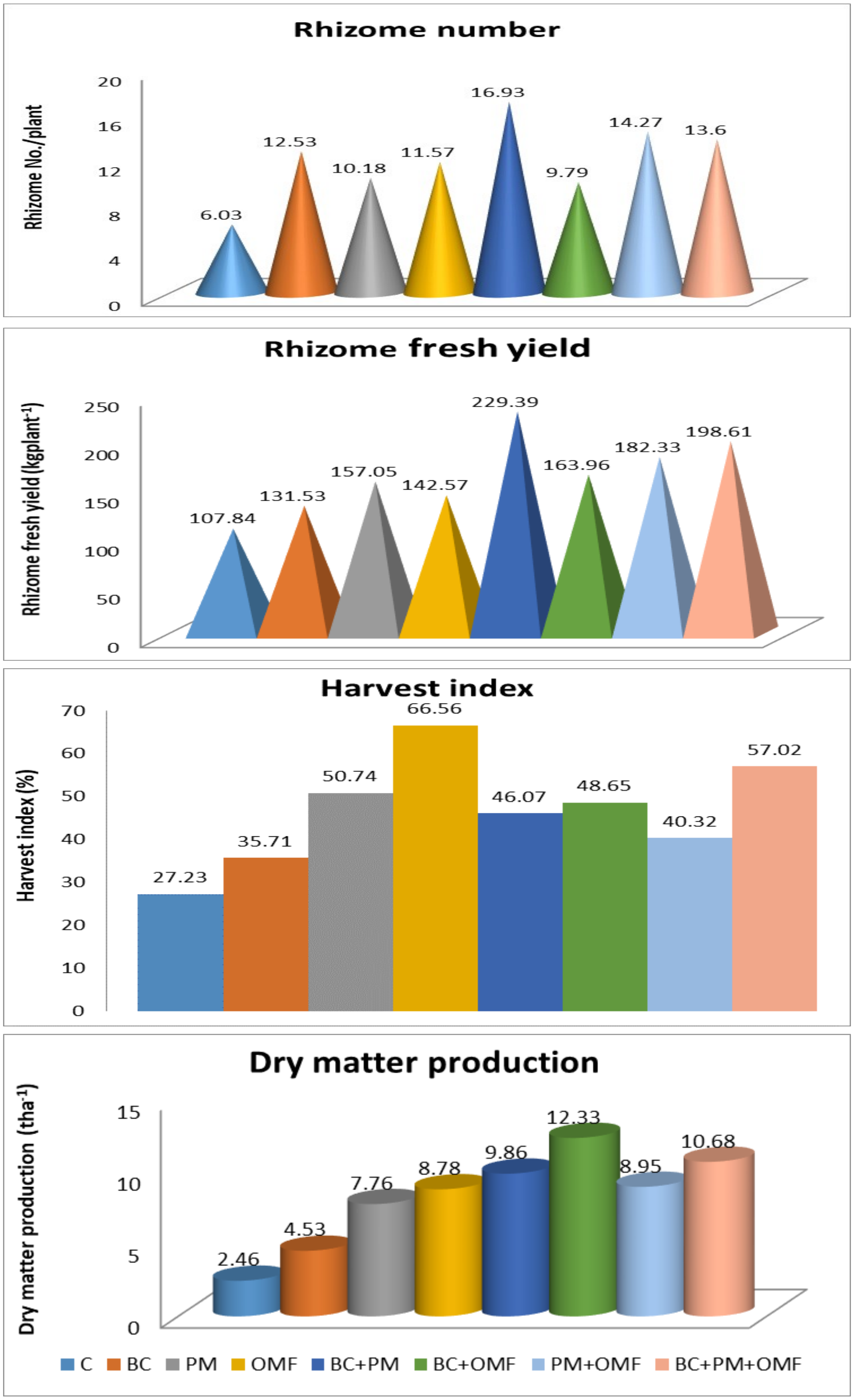

Figure 2: Effects of organic amendments on the yield components of turmeric rhizomes

3.3 Effects of organic amendments on soil pH and available nutrient budget after harvest

The data pertaining to the soil pH, and available nutrient budget after harvest of turmeric as influenced by organic amendments are presented in Table 2. The soil application of the organic amendments significantly (P<0.05) influenced, soil pH, available Ca, available Mg, available K, available Cu, available Fe, available Mn, as well as available Zn.

3.4 Effects of organic amendments on soil nutrient budgets: The highest soil pH (6.82) was recorded in soils treated with sole biochar, followed by the combined biochar and PM treatments (6.72). Soils with no amendments applied had significantly the least soil pH of 4.06 (Table 4). The increases in soil pH due to sole application of biochar could be attributed to the high pH of the biochar used in the experiment. The pH of the biochar was 8.9 compared to that of the compost which was 7.5 (Table 1). The findings agree with those of Nigussie *et al*. (2012) who attributed increased soil pH in biochar-amended soil to the high surface area and porous nature of biochar that increases the cation exchange capacity (CEC) of soils, which binds Al and Fe with the soil exchange sites. Zwieten *et al*. (2010) pointed out that incorporated biochar can increase soil pH through its liming effects. The pH values observed in this study are also consistent with those found by Nigussie *et al*. (2012) and Zheng *et al*. (2010), who concluded that biochar application, can improve soil quality by increasing soil pH, which suggests that biochar could be used as an alternative option to lime materials to raise pH of acidic soils.

3.5 Effects of organic amendments on soil nutrient budgets: The nutrient budgets for the growth and yield of turmeric rhizomes as influenced by the organic amendments are presented in Table 4. The nutrient budget of Ca varied significantly (P<.05) from 36.82 – 88.17 $kgha^{-1}$ with the mean values of 68.94 $kgha^{-1}$. The nutrient budget of Mg ranged significantly (P<.05) amongst the organic amendments from 5.41 to 10.11 $kgha^{-1}$ with the mean value of 8.17 $kgha^{-1}$. The nutrient budget of K varied significantly (P<.05) from 36.39 to 101.01 $kgha^{-1}$ with the mean value of 30.8976.05 $kgha^{-1}$. Comparing the organic sources, the highest mean nutrient budgets for Ca, Mg and K was obtained from a combination of poultry manure and organomineral fertilizer (PM+OMF) followed by a combined effects of biochar and poultry manure (BC+PM) while, the lowest comes from the control treatment with a CV of 24.2%. The cations nutrient budgeted by the organic amendments are in the order of: $K^{1+} > Ca^{2+} > Mg^{2+}$.

The values obtained from the Cu nutrient budget ranged significantly from 4.4 to 12.25 $kgha^{-1}$ with the mean value of 8.67 $kgha^{-1}$. The highest value was obtained from the combined effects of BC+PM. The values of Fe nutrient budget varied between 46.17 and 92.53 $kgha^{-1}$ with the mean value of 73.74 $kgha^{-1}$. The highest value was recorded from BC+OMF. The nutrient budget of Mn was significantly (P<.05) higher in the combined effects of PM+OMF (16.20 $kgha^{-1}$) relative to the other treatments, having a mean value of 11.04 $kgha^{-1}$. In the case of Zn, the nutrient budget ranged from 16 to 35.11 $kgha^{-1}$ with the mean value of 26.24 $kgha^{-1}$. The highest and the lowest uptake were obtained from the single OMF and control treatments, respectively. The micronutrients abundance of the nutrient budgeted by the organic amendments are in the order of: $Fe^{3+} > Zn^{2+} > Mn^{2+} > Cu^{2+}$. Turmeric is considered as nutrient exhaustive crop, hence the omission of micronutrients in the fertilizer schedule will reduce growth and yield attributes of the crop (Chitdeshwari, 2019). The various amendments (Table 4.1) might have been the direct absorption of the nutrient elements resulting of increase in the nutrients released by the organic manure (Table 4.2) which could be attributed to the increase in growth of turmeric plant and rhizome yield. Similar results were reported by Kamal and Yousuf (2012), Obi and Udoh (2012), Rajeev *et al*. (2013) and Anuradha *et al.* (2018).

Table 2: The effects of organic amendments on soil pH and soil budgeted nutrient elements after harvest

Organic amendments	pH (H_2O)	Available macronutrients ($kgha^{-1}$)			Available micronutrients ($kgha^{-1}$)			
		Ca^{+2}	Mg^{+2}	K^{+1}	Cu^{+2}	Fe^{+3}	Mn^{+4}	Zn^{+2}
C	4.06	36.82	5.41	36.39	4.41	46.17	7.45	16.45
BC	6.82	47.60	6.93	101.01	6.93	66.45	10.31	30.63
PM	6.59	63.86	9.17	68.40	9.17	70.60	8.25	27.94
OMF	5.43	79.97	8.60	75.25	8.60	80.98	9.13	35.11
BC+PM	6.72	78.85	7.25	89.49	12.25	74.22	11.42	20.71
BC+OMF	5.20	72.37	9.01	69.76	9.01	92.53	12.45	23.47
PM+OMF	5.36	83.91	10.11	84.66	8.91	72.16	16.20	26.79
BC+PM+OMF	6.42	88.17	8.91	63.43	10.11	86.82	13.09	28.78
Mean	5.83	68.94	8.17	76.05	8.67	73.74	11.04	26.24
LSD (0.05)	0.67	34.20	0.99	3.13	0.99	3.09	4.73	0.77
CV (%)	7.9	2.7	7.6	2.2	6.70	2.80	23.7	2.10
Probability	**	***	***	***	***	***	**	***

3.6 Effect of organic amendments on nutrients uptake in Turmeric rhizome

The nutrient uptake of turmeric rhizomes as influenced by the organic amendments are presented in Table 3: The value of Ca uptake varied significantly (P<0.01) from 7.47 to 25.00 $kgha^{-1}$ with the mean value of 16.09 $kgha^{-1}$. The highest Ca uptake was obtained from a single treatment of poultry manure (PM) followed by a combined effects of poultry manure and organomineral fertilizer (PM+OMF). The Mg uptake ranged significantly (P<0.05) amongst the organic amendments from 6.09 to 17.16 $kgha^{-1}$ with the mean value of 11.87 $kgha^{-1}$. The K uptake varied significantly (P<0.001) from 14.9 to 46.9 $kgha^{-1}$ with the mean value of 30.89 $kgha^{-1}$. The highest uptake was obtained from a single treatment of biochar (BC) followed by a combined effects of biochar and poultry manure (BC+PM) while, the lowest value comes from the control treatment with a CV of 24.2%. The cations uptake due to the nutrient budgeted by the organic amendments are in the order of: $K^{1+} > Ca^{2+} > Mg^{2+}$.

The values of Cu uptake of the rhizomes ranged significantly from 6.52 to 16.46 $kgha^{-1}$ with the mean value of 11.13 $kgha^{-1}$. The highest value was obtained from the combined effects of BC+PM+OMF which, resulted in a high CV of 39.7%. The values of Fe uptake of the rhizomes varied between 14.94 and 26.45 $kgha^{-1}$ with the mean value of 18.95 $kgha^{-1}$. The highest value was recorded from BC+OMF. The Mn uptake of the rhizomes was significantly (P<.05) higher in the combined effects of PM+OMF (30.03 $kgha^{-1}$) relative to the other treatments, having a mean value of 22.81 $kgha^{-1}$. In the case of Zn, the uptake ranged from 9.88 to 18.63 $kgha^{-1}$ with the mean value of 14.23 $kgha^{-1}$. The highest and the lowest uptake were obtained from the single OMF and control treatments, respectively with a CV of 31.8%.

The study further show that, the bioavailability of the nutrient elements in soils (Table 4.2) and in the rhizome (Table 4.4), were as the result of the addition of organic amendments. The cations uptake due to the nutrient budgeted as influenced by the organic amendments are in the order of: $Mn^{2+} > Fe^{3+} > Zn^{2+} > Cu^{2+}$.

The increased uptake might be due to higher rhizome yield coupled with better availability of all the micronutrients for plant absorption. Lower uptake of micronutrient by turmeric crop could be explained by the lower yield obtained from poor soil fertility status. As uptake is multiply of yield and concentration of nutrient and if the yield is less, lesser will be the uptake of nutrient. Similar increase in uptake due to the addition of micronutrients might be due to higher availability and synchronized with crop uptake which was reported by several researchers (Kumar *et al.,* 2011; Singh, 2011; Kamal and Yousuf, 2012; Srinivasan *et al*. 2016; Datta *et al.*, 2017; Chitdeshwari (2019).

Table 3: Effect of organic amendments on nutrients uptake in Turmeric rhizome

Organic Amendments	Macronutrient's uptake ($kgha^{-1}$)			Micronutrient's uptake (gha^{-1})			
	Ca^{+2}	Mg^{+2}	K^{+1}	Cu^{+2}	Fe^{+3}	Mn^{+4}	Zn^{+2}
C	7.47	6.09	14.9	6.52	14.94	20.78	9.88
BC	12.27	9.67	46.9	8.32	17.76	24.64	15.28
PM	18.23	14.43	16.9	10.62	19.63	22.03	10.12
OMF	15.40	12.90	26.5	11.42	15.95	19.02	18.63
BC+PM	11.04	7.87	42.4	16.46	18.01	17.38	16.14
BC+OMF	17.11	11.57	27.6	10.93	26.45	20.91	17.05
PM+OMF	22.23	15.24	37.5	11.07	17.50	30.03	12.73
BC+PM+OMF	25.00	17.16	34.4	13.73	21.34	27.72	14.02
Mean	16.09	11.87	30.89	11.13	18.95	22.81	14.23
LSD (0.05)	4.23	3.62	13.06	6.97	4.93	1.04	3.95
CV (%)	15.1	17.40	24.2	39.7	16.60	2.7	31.8

Effects of organic amendments on the budgeted nutrient elements interaction with growth and yield components of Turmeric plant

Table 4 showed the correlation between the available soil nutrients (Ca, Mg and K) and the turmeric growth and yield components as influenced by organic amendments. It was observed that, Ca showed positive and significant (P<0.05) higher correlation with plant height (R = 0.804**), tiller number (R = 0.748**), rhizome fresh yield (R = 0.750**), harvest index (R = 0.778**) as well as other parameters but, with less significant. Available soil Mg had positive and significant (P<0.05) higher correlation with plant height (R = 0.728**), rhizome fresh yield (R = 0.727**) as well as other parameters but, with less significant. Available soil K showed positive and significant (P<0.05) higher correlation with leaf number (R = 0.788**), tiller number (R = 0.858**), rhizome fresh yield (R = 0.750**) as well as other parameters which are less significant. Earlier, Singh *et al.,* (1998) reported that increasing the level of K in soils had positive effect on growth of rhizomes. The insignificant correlation coefficient of Ca and leaf number (R = 0.393ns), K and rhizome number (R = 0.472ns) indicated that individually nutrient element might not be playing any significant role in the respective growth and yield of turmeric components.

The impact of organic amendments on soil micronutrients (Cu, Fe, Mn and Zn) interaction with growth and yield components of Turmeric plant is presented in Table 5. Available soil Cu showed positive and significant (P<0.05) higher correlation with rhizome number (R = 0.791**) and rhizome fresh yield (R = 0.750**) as well as other parameters but, with less significant. Available soil Fe showed positive and significant (P<0.05) higher correlation with plant height (R = 0.732**), leaf number (R = 0.711**) as well as other parameters but, with less significant. Available soil Mn showed positive and significant (P<0.05) higher correlation with plant height (R = 0.816**), leaf number (R = 0.794**), rhizome fresh yield (R = 0.878**) as well as other parameters but, with less significant. Available soil Zn showed positive and significant (P<0.05) higher correlation with tiller number (R = 0.772**), rhizome fresh yield (R = 0.821**), harvest index (R = 0.880**) as well as other parameters but, with less significant. This result generally, indicates that the concentrations of Cu, Fe, Mn and Zn in the turmeric rhizome vary proportionately with each other.

It also suggests that the minerals distribution and concentration ratios within the turmeric tissues are related. Such strong correlations suggest that Cu, Fe, Mn and Zn levels in the turmeric plants can be estimated through its other tissues, when the rhizomes are not extractable. The high positive correlation between the micronutrients and the turmeric plant implies that these significantly influenced their relationship, indicating a significant increase in the accumulation of the nutrient with increase in the growth and yield of turmeric rhizome.

The positive and non-significant correlation between the budgeted nutrients in soils and in the growth and yield components, may be due to their partial distribution in the turmeric plants as a result of the mobilization of protective mechanisms in plants, which inhibit the transport of metals to other tissues and organs.

However, the insignificant correlation coefficient of Cu and rhizome DMY (R = 0.433ns) and harvest index (R = 0.381ns); Fe and rhizome DMY (R = 0.404ns) and harvest index (R = 0.467ns); Mn and rhizome DMY (R = 0.243ns); Zn and leaf number (R = 0.228ns) and rhizome DMY (R = 0.344ns) indicated that individually micronutrient element might not be playing any significant role in the respective growth and yield of turmeric components.

The synergistic interaction between various nutrients with the growth of turmeric plants and yield of Turmeric rhizomes leads to better development of rhizomes and subsequent accumulation of curcumin. The results further indicated that, sufficient quantity of Ca, Mg, K, Cu, Fe, Mn, and Zn in the organic mixtures might have also favoured the accumulation of curcumin in the rhizomes (Hnamte *et al.,* 2018; Anuradha *et al.,* 2018).

This study suggests that, the primary source of the Ca, Mg, K, Cu, Fe, Mn, and Zn in the turmeric rhizome could be linked to its direct uptake from the soils incorporated with organic amendments.

Table 4.4: Effects of organic amendments on the budgeted nutrient elements interaction with growth and yield components of Turmeric plant

	Ca	**Mg**	**K**	**Cu**	**Fe**	**Mn**	**Zn**
Plant height	0.804**	0.728**	0.664*	0.639*	0.732**	0.816**	0.660*
Leaf No	0.393ns	0.605*	0.788**	0.678*	0.711**	0.794**	0.228ns
Tiller No	0.748 **	0.548*	0.858**	0.667*	0.585*	0.620*	0.738**
Rhizome No	0.602*	0.630*	0.472ns	0.814**	0.325 ns	0.541*	0.772**
Rhizome yield	0.750**	0.727**	0.757**	0.791**	0.649*	0.878**	0.821**
Rhizome DMY	0.544*	0.528*	0.679*	0.433ns	0.404ns	0.243ns	0.344ns
Harvest index	0.778**	0.699*	0.596*	0.381ns	0.467ns	0.760**	0.880**

4.0 Conclusion

The experiment was conducted to evaluate the effect of different organic amendments on growth and rhizome yield of turmeric (*Curcuma longa* L.), soil nutrient budget and nutrient uptake. The results of the study showed that, the application of biochar, poultry manure and OMF either as sole/or mixture significantly increased the growth and rhizome yield of turmeric. The abundance of soil nutrients budget was in the order of: $K^{1+} > Fe^{3+} > Ca^{2+} > Zn^{2+} > Mn^{4+} > Cu^{2+} > Mg^{2+}$ while, nutrients' uptake in the turmeric rhizomes were in the order of: $K^{1+} > Mn^{4+} > Fe^{3+} > Ca^{2+} > Zn^{2+} > Mg^{2+} > Cu^{2+}$. The correlation matrix between the growth and yield of turmeric and, the soil nutrients budget shows positive and highly significant ($P<0.05$). The organic sources could hence be recommended for turmeric cultivation in coastal plain soils.

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