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Full Length Article

Poultry Manure Addition Affects Production, Plant Nutritional Status and Heavy Metals Accumulation in Green Amaranth (*Amaranthus hybridus*)

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Abstract

Poultry manure (PM) application may be critical as source of contaminants and may affect crop quality. Experiments were conducted in 2016 and 2017 cropping seasons to determine effects of PM on performance and quality of green amaranth including some minerals and heavy metals in soil and plant tissues. In both years, PM were applied at 0, 10, 20, 30 and 40 t·ha^{-1}. Application of PM increased soil chemical properties, leaf mineral content, growth and marketable yield of green amaranth compared with the control. Soil pH, organic matter, N and P and leaf mineral N and P were increased up to 40 t ha^{-1} PM, but soil and leaf K, Ca, Mg, ash, protein, fiber contents were increased up to 20 t ha^{-1} PM. The lowest fat was observed at 20 t ha^{-1} PM. Dry matter declined as PM level increased. The PM influenced soil and leaf As, Cu and Zn, the abundance of heavy metals in soil and green amaranth leaf increased as level of PM increased. In soil and green amaranth leaves, levels of As, Cu and Zn as affected by PM did not exceed maximum permissible limits. The best green amaranth quality was obtained at 20 t ha^{-1} PM and may likely provides a good balance between yield and economic outlay. © 2019 Friends Science Publishers

Keywords: *Amaranthus hybridus*; As; Cu; Leaf mineral content; Soil chemical properties; Zn

Introduction

In the tropics, fertile soil is one of the most important factors for sustainable crop production and hampered by low fertility associated with low organic matter, exchange capacity, nitrogen and phosphorous deficiencies (Sanguinga *et al*., 2001). The physical state of the soils in the savanna regions are poor (Salako *et al*., 2002) and soils are sandy with low organic matter (Salako, 2003).

Organic manuring is an important agronomic option for sustainable soil management and crop production in the tropics. PM is a good nutrient source for both subsistence and commercial crop producers. Its use reduces inputs thereby increasing profit (Ayoola and Makinde, 2008). Nutrients, especially N and P are higher in PM compared with other animal manures (Mikkelsen and Gillian, 1995). Typically, 50 to 60% of total N in fresh PM will be mineralized and become available for crop use in the first year (Reddy *et al*., 2008). Because of its low moisture content, high nutrient, and large amounts produced daily, PM is an important substitute to inorganic fertilizer (Moore *et al*., 1995). Application of PM to soils can increase concentrations of carbon, Ca, K, Mg, N and P of surface and subsurface soils (Adekiya *et al*., 2016). It also improves physical characteristics of soil (Adekiya *et al*., 2016).

Green amaranth (*Amaranthus hybridus* L.) is an important leafy vegetable crop in Nigeria. In Nigeria, and other tropical countries food consumed are mainly starchy food with little nutrient values, but vegetables are cheap and affordable sources of minerals and vitamins for the growing population (Okafor, 1983; Ladeji *et al*., 1995). Amaranth requires more nutrients than other vegetable crops. For large scale production of crops, best performance can be achieved by modification of various cultural practices (Sterrett and Savage, 1989) which can include application of organic manure to improve crop performance (Sanni *et al*., 2003).

Application of PM to amaranth may influence yield and quality including mineral and proximate compositions. Although PM has a positive effect on physical, chemical and biological soil properties in repeated application, or application above the required rate, may be a source of contaminants and may affect crop quality (Earhart *et al*., 1995; Moeskops *et al*., 2010). This aspect of manuring needs investigation especially for amaranth. Manure application should be such that will fill the gap between poor fertility level of the soil and meeting crop needs, any excess will result into defect in the soil and crop production (Quinton, 2006). To derive full benefit from the utilization

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of PM requires the knowledge of its chemical composition. PM may contain certain amounts of toxic metals, for example, arsenic (As), copper (Cu) and zinc (Zn) (Bolan *et al*., 2004). Yearly buildup of these heavy metals could have effect on soil and crop qualities (Guan *et al*., 2011; Wang *et al*., 2011). Application of PM is considered to be a way by which As gets to the soils (Bolan *et al*., 2004), which has to do with the amount organo-arsenic compounds used as a feed additive (Christen, 2001). Therefore, this study was conducted to determine the performance, quality of the crop, and contents of some minerals and heavy metal in soil and in amaranth treated with PM.

Materials and Methods

Experiments were conducted in 2016 and 2017 to determine effects of poultry manure on performance, quality, some minerals and heavy metal in soil and amaranth. The study was conducted at Landmark University, Omu-Aran, Kwara State, Nigeria which lies between Latitude 8°9'N and Longitude 5° 61'E. The soil was an Alfisol or Luvisol (Adekiya *et al*., 2018). Annual rainfall is about 1270 mm and temperature is about 32°C. The first raining season starts from March to July with a short dry spell in August called "August break", followed by the second raining season between September and November.

In years 2016 and 2017, the PM treatments were: 0, 10, 20, 30 or 40 t ha^{-1} arranged in a randomized complete block design having four replications. The PM was applied in excess of 15 t ha^{-1} recommended for amaranth cultivation (Mshelia and Degri, 2014). Each plot was 3 × 4 m with 1 m margin between plot and block. The same site and treatment were used in 2016 and 2017 experiments.

Land Preparation, Incorporation of Poultry Manure and Sowing of Amaranth Seeds

Land preparation in each year was in May when rain in each year was steady. This was done by plowing and harrowing the soil to a depth of about 20 cm. Plot size was 3 × 4 m. Poultry manure was obtained from the poultry unit of the Teaching and Research Farms. The PM was from the layers (cage system) unit of the farm. The PM was composted for 2 weeks to allow for mineralization. Composted PM was weighed and spread on plots at each rate. Rakes were used to spread the PM evenly on plots which was then incorporated to the soil to the depth of approximately 10 cm using shovels. The PM was left for 3 weeks in the soil before sowing of amaranth seeds. Before sowing, emerged weeds were removed manually. amaranth seeds were mixed with dried sand before drilling to ensure seed were not sown too close together for proper management of the seed rate (Iren *et al*., 2016). Seed were drilled with 10 cm between rows. Emerged plants were thinned to 1 plant with a distance of 10 cm between plants 7 days after sowing to give a plant population of 1,200 plants per plot and 1,000,000 plants·ha^{-1}. Weeding was done weekly during the experiment. No irrigation or extra fertilizer was applied. The same plot and treatment procedures were used in 2016 and 2017. Harvesting occurred 8 weeks after sowing.

Determination of Soil Properties

Before the experiment in 2016, soil samples from 0-15 cm depth were randomly collected from 10 points on the site of the experiment and later bulk together, dried and sieve using 2 mm sieve and analyzed for particle size, organic C, pH, N, P, K, Ca, Mg and heavy metals (As, Cu and Zn). Soil samples were analyzed as described by Carter and Gregorich (2007). Soil organic C was determined by the Wakley and Black sulphuric acid-dichromate digestion followed by titration with ferrous ammonium sulphate (Nelson and Sommers, 1996). Organic matter was calculated by multiplying C by 1.724. Total N was determined by digesting 0.3 g of the soil sample in a mixture of Se, $LiSO_4$, H_2O_2 and concentrated H_2SO_4 (Bremner, 1996). The N content was determined colorimetrically. Available P was determined by the Olsen method (Okalebo *et al.*, 2002). The K, Ca and Mg were extracted by leaching 5 g of soil with 50 mL ammonium acetate at pH 7 (Hendershot *et al*., 2008). The K was determined with a flame photometer; Ca and Mg were determined using a spectrophotometer. About 0.5 g of soil sample was digested with 0.5 mL H_2SO_4, 0.6 mL concentrated HNO_3 and 1.8 mL concentrated HCl for 2 h at 95°C. The sample when cooled was diluted to 10 mL with deionized water, this was analyzed for As, Cu and Zn using a spectrophotometer. Soil pH was determined using a 1:2 soil-water medium using a digital electronic pH meter. At the end of each year's experiment, soil samples were also collected on plot basis (with three samples from each plot and latter bulk together) and similarly analysed for soil chemical properties as described above.

Determination of Growth and Yield Parameters

Amaranth was harvested 8 weeks after sowing. Harvesting was on a plot basis by cutting the entire plant from the base very close to the soil. Plants height was measured from the base of the plant to the apical meristem of 10 randomly selected plants per plot. Stem diameter was measured with a Vernier caliper. Number of leaves were counted. Fresh weight of plant was determined by weighing a whole plant on a top loading balance to determine fresh weight. Leaf area (LA) was determined by multiplying leaf length (C) by leaf width (L) with a correcting co-efficient (a) of 0.7056 (Carvalho and Christoffoleti, 2007).

Analysis of Poultry Manure and Amaranth Leaves

The PM used was dried and sieved with 2 mm sieve for chemical analysis to determine its nutrient composition.

Table 1: Initial soil physico-chemical characteristics

Property	Value
Sand (%)	75.1
Silt (%)	13.9
Clay (%)	11.0
Textural class	Sandy loam
pH (H_2O)	5.45
Soil organic matter (%)	2.84
Total N (%)	0.18
Available P (mg kg^{-1})	9.5
Exchangeable K (cmol kg^{-1})	0.14
Exchangeable Ca (cmol kg^{-1})	1.80
Exchangeable Mg (cmol kg^{-1})	0.41
As (mg kg^{-1})	0.82
Cu (mg kg^{-1})	4.42
Zn (mg kg^{-1})	5.12

Table 2: Chemical analysis of the poultry manure

Property	2016	2017
pH (H_2O)	6.79	6.81
Organic C (%)	20.6	21.2
N (%)	2.89	2.90
C/N	7.13	7.31
P (%)	1.33	1.31
K (%)	1.70	1.68
Ca (%)	0.91	0.89
Mg (%)	0.55	0.56
As (mg kg^{-1})	1.28	1.26
Cu (mg kg^{-1})	180.6	181.2
Zn (mg kg^{-1})	91.2	90.6

Poultry manure was analyzed for organic C, N, P, K, Ca and Mg as described by Carter and Gregorich (2007). The As, Cu and Zn contents of the poultry manure were determined by the method of Crosby (1977). Ten leaves were collected per plot at harvest (8 weeks after sowing) of amaranth, oven-dried for 24 h at 75°C and ground in a Willey mill and analyzed for N, P, K, Ca and Mg as described by Tel and Hagarty (1984). The As, Cu and Zn contents of the amaranth leaves were determined by the method of Crosby (1977). Leaf samples were collected on a plot basis at harvest and taken for proximate (moisture, ash, protein, fiber, crude fat and dry matter) analysis. The moisture, ash, protein and fiber contents of amaranth were determined using standard chemical method (A.O.A.C., 2010). Total dry matter was determined by oven drying at 70°C to constant weight. Soxhlet extraction technique using petroleum ether (40–50°C) was used to evaluate the fat content of the samples.

Statistical Analysis

Data collected were subjected to analysis of variance (two-way ANOVA) using the Genstat statistical package (Genstat, 1993). If the interaction was significant it was used to explain results. If the interaction was not significant, treatment means were compared using Duncan's multiple range test at $P < 0.05$ significant level.

Results

The sandy loam soil was slightly acidic, adequate in Mg but low in exchangeable Ca and K, total N, available P and soil organic matter (Table 1). The heavy metals (As, Cu and Zn) in the composite soil sample were below permissible limits. The PM (Table 2) used in both years was slightly acidic and high in macro nutrients. The nutrient contents of the PM are expected to improve fertility of soil and performance of amaranth. The PM contained As, Cu and Zn are found in feed additives in Nigeria. Values of As, Cu and Zn were below permitted levels.

When considered as individual factor, in both years, PM increased OM, N, P, K, Ca and Mg compared to control (Table 3). However, PM did not influence pH significantly in 2016 while increased pH, OM, N and P from 0–40 t ha^{-1} PM during both years. The exchangeable K, Ca and Mg increased only up to 20 t ha^{-1} PM after which a reduction was observed. Also, year (Y), when considered alone influenced soil chemical properties (pH, OM, N, P, K, Ca and Mg) significantly ($P < 0.05$) with 2017 having higher values compared with 2016. Interactive effect of PM and year (PM × Y) was significant for pH, OM, N, P, K, Ca and Mg.

Response of Mineral Concentrations of Amaranth Leaves to PM

The PM in both years significantly increased Ca, N, K, Mg and P compared to the control. The increase in N and P was from 0–40 t ha^{-1} PM while Ca, Mg and K contents of amaranth leaves up to 20 t ha^{-1} after which there was a decrease. The values for 20, 30 and 40 t ha^{-1} were statistically similar. Year (Y) as individual factor influenced Mg, N, Ca, P and K significantly. The interaction PM × Y for all minerals were also significant (Table 4).

Response of Heavy Metals in Soil and Amaranth Leaves

The PM increased soil As, Cu and Zn significantly in 2017 but only influenced Zn significantly compared with the control in 2016. The quantity of these elements in the soil also increased as the levels of PM increased. Year did not influence heavy metals significantly ($P < 0.05$). The heavy metals present in both years were below the permissible limit in soils. Similarly, PM in both years, influenced As, Cu and Zn in amaranth leaves significantly compared with the control. Cu was not influenced significantly by PM in 2016. PM increased heavy metal from 0 – 40 t ha^{-1}, between 30 and 40 t ha^{-1} PM, no significant differences was recorded. Year did not influence heavy metal in amaranth leaves significantly. Also, the interaction of PM with year (PM × Y) for As, Cu and Zn was not significant. The levels of As, Cu and Zn as affected by PM in both years did not exceeded the allowable amount as set by FAO/WHO crops like vegetables (Table 5).

Table 3: Effect of poultry manure on soil chemical properties

Year	Poultry manure (t ha^{-1})	pH (H_2O)	Organic matter (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
2016	0	5.40d[b]	2.69e	0.15e	9.1e	0.13d	1.60d	0.39d
	10	5.48cd	2.97d	0.17d	10.8d	0.15b	2.38c	0.48b
	20	5.72bc	3.66bc	0.20c	13.6c	0.18a	2.96a	0.59a
	30	6.10ab	3.99ab	0.25b	17.4b	0.15b	2.65ab	0.41c
	40	6.31a	4.28a	0.31a	20.8a	0.14bc	2.34c	0.43c
2017	0	5.28e	2.51e	0.14e	8.9e	0.13d	1.58d	0.37d
	10	5.71d	3.20d	0.19d	11.8d	0.17b	2.59c	0.53b
	20	5.94cd	3.80c	0.22c	14.7c	0.20a	3.20a	0.63a
	30	6.30b	4.20b	0.28b	19.2b	0.17b	3.10a	0.53b
	40	6.44a	4.66a	0.34a	22.7a	0.16bc	2.95b	0.46c
Poultry manure (PM)		*	*	*	*	*	*	*
Year (Y)		*	*	*	*	*	*	*
PM × Y[a]		*	*	*	*	*	*	*

[a] Data in the interaction analysed with Least Squares Means and values separated with Least Significant Differences; * significant at p = 0.05.
[b] Values followed by the same letter in column are not significantly different at $P = 0.05$

Table 4: Interaction effect of poultry manure on mineral contents of amaranth

Year	Poultry manure (t ha^{-1})	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
2016	0	1.75e	0.32e	1.14d	0.16c	0.43c
	10	1.99d	0.44d	2.10c	0.32b	0.80b
	20	3.60c	0.52c	2.61a	0.62a	0.96a
	30	4.20b	0.61b	2.50b	0.61a	0.82b
	40	4.88a	0.68a	2.52b	0.61a	0.81b
2017	0	1.70e	0.30e	1.11d	0.14d	0.41d
	10	2.20d	0.49d	2.55c	0.36b	0.88c
	20	3.99c	0.61c	3.10a	0.68a	1.10a
	30	4.62b	0.69b	3.07a	0.56b	1.07a
	40	5.10a	0.77a	2.51b	0.56b	0.94b
Poultry manure (PM)		*	*	*	*	*
Year (Y)		*	*	*	*	*
PM × Y		*	*	*	*	*

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test
Note: *Significant difference at $P = 0.05$

Table 5: Effect of poultry manure on heavy metals in soil and amaranth leaves

		Heavy metals in soil			Heavy metals in amaranth leaf		
Year	Poultry manure (t ha^{-1})	AS (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	AS (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
2016	0	0.80c	4.20d	5.01d	0.11c	22.2c	9.7c
	10	0.84c	4.30d	5.12c	0.12b	22.8c	10.1b
	20	0.86bc	4.80bc	5.22b	0.12b	25.6b	10.5b
	30	0.91ab	5.10ab	5.32b	0.14a	29.3a	11.7a
	40	0.96a	5.34a	6.40a	0.15a	30.1a	11.9a
2017	0	0.70d	3.98e	4.91d	0.10c	21.8e	9.5e
	10	0.88c	4.37d	5.26c	0.13b	23.4d	11.2d
	20	0.91bc	4.88c	5.34bc	0.15a	27.8c	12.8c
	30	0.94ab	5.22ab	5.51ab	0.15a	30.8b	14.6b
	40	0.99a	5.42a	6.58a	0.15a	32.4	15.9a
Poultry manure (PM)		*	*	*	*	*	*
Year (Y)		ns	Ns	ns	Ns	*	*
PM × Y		ns	Ns	ns	Ns	*	*

Values followed by similar letters under the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test
Note: *Significant difference at $P = 0.05$: ns = not significant at $P = 0.05$

Response of Growth and Marketable Yield of Amaranth

The PM increased plant height, stem diameter, number of leaves, leaf area and fresh plant weight per plant and fresh plant weight per plot significantly in both years. Application of PM increased the growth and marketable yield of amaranth from 0–40 t ha^{-1} PM. Year (Y) also influenced the growth and marketable yields of amaranth significantly with 2017 having higher yield compared with 2016. PM × Y interaction was significant for all parameters (Table 6).

Effects on Proximate Composition of Amaranth

Compared with the control, PM in both years influenced significantly moisture ash, protein and fibre of amaranth leaf. In both years, increasing the levels of PM increased moisture content of amaranth. Ash, protein and fibre increased up to 20 t ha^{-1} PM level after which there was a reduction. Dry matter and fat reduced with level of PM (the correlation between PM and dry matter and crude fat were significant with R values of -0.95 and -0.76 respectively at $P < 0.05$), but the lowest fat was obtained at 20 t ha^{-1} PM. Year did not influence proximate composition of amaranth significantly. Also, the interaction PM × Y was not significant (Table 7).

Discussion

The SOM and nutrient contents of the soil increased as a result of the applied PM, this can be related to the chemical composition of the PM (Table 2). The soil was deficient in these nutrient elements and nutrient elements considered (OM, Ca P, K, Mg N and P) were below the critical levels required for production of crops in Nigeria. Nottidge *et al*. (2005) and Opara-Nadi and Lal (1987) found that Alfisol was low in OM and soil nutrients. Adekiya and Agbede (2009) and Adekiya *et al*. (2016) also showed that PM increased SOM and nutrients. The increase in SOM, P and N increased as the rate of the manure increased up to 40 t ha^{-1} shows that the OM part of the PM decomposed, and soil nutrient were added. The higher the level of PM, the higher the OM and hence the soil nutrient (N and P) released to the soil. The cations (Ca, Mg and K) reduced after 20 t ha^{-1} PM. This could be adduced to nutrient imbalance after 20 t ha^{-1} PM level preventing the availability of other nutrients (Adekiya and Agbede, 2009).

The significant increase in soil pH due to PM as a result of its liming effect (Odedina *et al*., 2011; Adekiya *et al*., 2016), which can be adduced to calcium ions released into the soil solution during the microbial decarboxylation of manure (Natschner and Schwetmann, 1991). Kang and Balasubramania (1990) reported that high rate of OM addition is needed to solve the soil acidity problem arising from continuous cropping of West African Alfisol.

The significant increase in soil nutrients in 2017 compared with 2016 could be as result of its residual effect. The interactive effect PM × Y for soil chemical properties can be adduced to the residual effects of PM on the soil. It means that the nutrients in PM can accumulate in the soil and still be useful after the application: this might be due to the slow release patterns of their nutrients (Adeleye and Ayeni, 2010).

The improvement in the mineral contents of amaranth leaf as a result of the applied PM was attributed to improved nutrients availability in the soil resulting to increase uptake by amaranth plant. In both years, the correlation coefficient between soil and leaf N, soil and leaf P, soil and leaf K, soil and leaf Ca, soil and leaf Mg were all significant with R values of 0.95, 0.97, 0.81, 0.88 and 0.80, respectively at $P < 0.05$. This is also consistent with the use of PM as fertilizer for crop production (Adekiya *et al*., 2016). The increase of Mg, Ca and K up to 20 t ha^{-1} PM is related to the soil chemical properties of these treatments in this experiment. Adekiya and Agbede (2009) found that tomato leaves reduced Ca, Mg and K with high rates of PM application. This can be adduced to excess of N from PM that hindered the absorption of other nutrients. Sexana *et al.* (1975) and Bar-Tal *et al.* (2001) found that oversupplying of N reduced Ca uptake in tomato and pepper respectively.

Results showed significant levels of heavy metals (As, Cu and Zn) in soil and leaf of amaranth in both years compared with the control. The higher contents of the elements in poultry manure may be associated with their addition to poultry feeds for disease control, for rapid growth and enhanced feed efficiency. Bellows (2005) reported that most of the As used as feed additives or as drugs in poultry production did not stored in the meat of the poultry, but defecated out by such poultry birds. Thus, most of the As added to poultry feeds are defecated out as litter. Copper is an important nutrient element for human, however, when the amount becomes too high, it may cause damage to the liver and even cause anemia (Ekop *et al*., 2011). Zinc is an essential nutrient element in normal growth, DNA synthesis, bone formation, wound healing and brain development (Shah *et al*., 2013). According to Adelekan and Abegunde (2011), at high rates zinc is neutrotoxin. Similarly, As is one of the most toxic nonessential elements which can cause carcinogenic effects and teratogenic imbalances in human even at a very low concentration (Nazar *et al*., 2012). The As, Cu and Zn added with PM were absorbed by the amaranth plant. The uptake of these elements increased proportionally with the availability of these elements in the soil. There was significant and positive correlation between As, Cu and Zn in the soil and of the amaranth leaf. The R values were 0.95, 0.98 and 0.74 for As, Cu and Zn respectively at $P < 0.05$. Year effect was significant for Cu and Zn, this could be as a result of bioaccumulation of these elements in the soil due to the addition of fresh PM in the second year. In this experiment, for soil, the levels of the heavy metals were below the international maximum allowable standard (Kabata-Pendias and Mukherjee, 2007). Likewise, for Amaranth leaf, the values obtained were below the maximum allowable limits of heavy metals for vegetables. However, continuous checking and assessment of soil applied with PM is crucial to evaluate their accumulation effects.

The increase in growth and marketable yields of Amaranth in this study was due to increase in nutrient status of the soil because of the applied PM leading to absorption, hence significant improvement in mineral levels, growth and amaranth yield. The PM contains macro and micronutrients (Stephenson *et al*., 1996). Increase of amaranth growth and marketable yield by PM in this study

Table 6: Effect of poultry manure on growth and marketable yield of amaranth

Year	Poultry manure (t ha^{-1})	Plant height (m)	Stem diameter (m)	Fresh plant weight (kg)	Number of leaves/plant	Leaf area/plant (m^2)	Fresh plant weight/plot (kg)
2016	0	0.46e	0.03e	0.11e	16e	0.94e	132e
	10	0.71	0.05d	0.19d	22d	2.07d	228d
	20	0.77c	0.06c	0.25c	29c	3.21c	300c
	30	0.89b	0.07b	0.28b	30b	3.88b	336b
	40	0.98a	0.09a	0.31a	35a	4.18a	372a
2017	0	0.44e	0.02e	0.09e	13e	0.74e	108e
	10	0.84d	0.06d	0.23d	25d	2.37d	2.76d
	20	0.96c	0.07c	0.28c	33c	3.47c	336c
	30	1.07b	0.08b	0.32b	34b	4.20b	384b
	40	1.18	0.10a	0.36a	39a	4.66a	432a
Poultry manure (PM)		*	*	*	*	*	*
Year (Y)		*	*	*	*	*	*
PM × Y		*	*	*	*	*	*

Values followed by similar letters under the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test; Note: *Significant difference at $P = 0.05$

Table 7: Effect of poultry manure on proximate composition of amaranth

Year	Poultry manure (t ha^{-1})	Moisture (%)	Ash (%)	Protein (%)	Dry matter (%)	Fiber (%)	Crude Fat (%)
2016	0	83.96d	1.11c	1.16c	10.66a	0.99c	2.12a
	10	85.11c	1.25b	1.28b	9.91b	1.16b	1.29b
	20	86.20b	1.29a	1.30a	9.31cd	1.19a	0.71e
	30	87.90a	1.29a	1.30a	9.41d	1.18a	0.92d
	40	87.11a	1.28a	1.30a	7.24e	1.17ab	0.88c
2017	0	82.62e	1.10c	1.15c	11.11a	1.01c	3.01a
	10	85.18d	1.23b	1.29ab	9.82b	1.18ab	1.30b
	20	86.32c	1.30a	1.31a	9.28b	1.20a	0.59e
	30	87.23b	1.27ab	1.31a	8.20c	1.19a	0.68d
	40	88.10a	1.26ab	1.31a	7.30d	1.18ab	0.85c
Poultry manure (PM)		*	*	*	*	*	*
Year (Y)		ns	ns	ns	ns	Ns	ns
PM × Y		ns	ns	ns	ns	Ns	ns

Values followed by similar letters under the same column are not significantly different at $P = 0.05$ according to Duncan's multiple range test; Note: *Significant difference at $P = 0.05$: ns = not significant at $P = 0.05$

was also attributed to poultry manure having low C: N ratio (7.3) which is expected to hasten faster decomposition and nutrient release for amaranth uptake and hence growth. The improved growth as the rates of manure increases can be adduced to better soil nutrient especially N that is needed by leafy vegetable like amaranth. N is known to promote rapid growth, increasing leaf sizes and above ground vegetative growth.

The result that poultry manure increased soil and leaf Ca, Mg and K up to 20 t ha^{-1} PM implies that this amount is sufficient for amaranth production. Although, results showed that growth and yield increased up to 40 t ha^{-1} that seems not optimum for amaranth production. At high N rate from excessive rate of PM, amaranth produced many leaves with dark green flourishing big growth and abnormal cell as a result of lack of other elements such as Mg, K and Ca (Agbede, 2009). There can be falling over of stems (lodging) due to slender cell wall as a result of reduce Ca in soil and plants. The amaranth has high water content but fewer flavors and become watery on boiling (Agbede, 2009). Earhart *et al.* (1995) also found that PM applied in excess of the recommended rate decrease crop yield. The reduced yield that is found in crop with excess or over application of PM may be due to the toxic substances like NH_3, NO_3-N and some soluble salts produced in the soil by the manure (Edwards and Daniel, 1992). Mshelia and Degri (2014) recommended 15 t ha^{-1} for the cultivation of amaranth in Bama, Borno State of Nigeria.

Results showed that in both years PM application increased moisture, ash protein and fibre. This can be adduced to improve nutrient supply due to PM application. The manure applied would have increased N supply to the soil and consequently absorbed by the amaranth plant and hence increased number of leaves and photosynthetic activity and enhancing physiological processes leading to the production of more assimilates which leads to increase in chemical composition of the amaranth leaf. Moisture in the amaranth plant increased because N in the poultry manure is known to stimulate better growth and development of roots, good vegetative growth thereby stimulating greater absorption of water. The increase in protein content of amaranth can be adduced to the fact that N is known to be an integral component in plants including amino acids that are building blocks of protein and enzymes that are involved in catalyzing most biochemical processes (Brady and Weil, 2008). There was a reduction in fat contents of amaranth with application of PM from 0–40 t ha^{-1}, Blumenthal *et al.* (2008) also reported a reduced oil content in soybean and groundnut as the level of N increases. It has also been reported (Blumenthal *et al*., 2008) that there is a negative correlation between oil and protein content. High nitrogen application reduced oil and increased protein content.

For this experiment, best quality (proximate contents) was attained at 20 t ha^{-1} PM which is in agreement with the optimum soil and mineral contents of amaranth leaf. In developing countries, it is common that excessive N fertilizer (in form of poultry manure) are applied to vegetable garden to attain high yield (Moeskops *et al*., 2010). However, proper N balance is required for optimum growth and development of vegetables since excessive N increases their susceptibility to diseases and reduced quality (Collingwood, 1988). This means that appropriate levels of manure should be applied to provide optimum N to vegetable (Baitilwake *et al*., 2011). For this study, the optimum rate for better soil productivity and crop quality was 20 t ha^{-1} PM.

Conclusion

PM improved soil OM and nutrients, leaf mineral contents, plant height, stem diameter, number of leaves, leaf area and fresh plant weight per plant and fresh plant weight per plot significantly of amaranth compared with the control. Soil pH, OM, N and P and leaf mineral N and P were increased up to 40 t ha^{-1} PM, but soil and leaf K, Ca, Mg, ash, protein, fiber contents were increased up to 20 t ha^{-1} PM. The lowest fat was also at 20 t ha^{-1} PM. Poultry manure also influenced both soil and leaf As, Cu and Zn significantly, the abundance of the heavy metals in both soil and amaranth leaf increases with levels of PM. For both soil and amaranth leaf, the levels of As, Cu and Zn as affected by PM did not exceed the maximum permissible limits set by FAO/WHO. However, regular checking and evaluation of soil amended with poultry manure is important to be able to evaluate their accumulation effects. Although amaranth according to this study increased in growth and marketable yield as the level of PM increases from 0–40 t ha^{-1}, but for amaranth of good quality 20 t ha^{-1} PM is recommended.

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