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# Response of quality, yield and growth of amaranth (*Amaranthus hybridus*) and soil chemical properties on application of organic and inorganic nutrients

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## ABSTRACT

Poultry manure (PM) is limited by large quantity required for large scale vegetable production, to avert this problem, integrating inorganic (urea) with organic (PM) fertilizers is recently been advocated. Hence, two field experiments were carried out in years 2016 and 2017 at Landmark University, Omu-Aran, Kwara State, Nigeria to evaluate the effects of sole and integrated applications of poultry manure (PM) and urea fertilizer (UF) on soil chemical properties, growth, yield and quality of green Amaranth (*Amaranthus hybridus*). The study was laid out in 2 × 4 × 4 factorial experiment with two years (2016 and 2017), four levels of PM (0, 40, 80 and 120 kg N/ha) and four levels of UF (0, 40, 80 and 120 kg N/ha) application. The sixteen treatment combinations were arranged in a randomized complete block design having four replications. Results showed that UF and PM alone or their integration improved soil organic matter (OM), N, P, K, Ca, Mg (urea alone did not increase OM, P and K significantly), yield and growth indices, minerals (urea alone only increased leaf N), moisture, fibre, protein, dry matter, ash and reduced fat content of *Amaranthus* leaves compared with the control. Although fresh plant weight /plot (yield), plant height, leaf N and moisture contents of *Amaranthus* increased up to 120 kg N/ha, for both sole UF and PM (yield was 280 kg in 2016 and 310 kg in 2017 for PM while yield for UF was 250 kg in 2016 and 247 kg in 2017, plant height was 0.75 m in 2016 and 0.81 in 2017 for PM while UF was 0.67 m in 2016 and 0.65 m in 2017, Leaf N was 2.98% in 2016 and 3.41% in 2017 for PM while UF was 2.50% in 2016 and 2.44% in 2017, moisture content was 87.60% in 2016 and 90.20% in 2017 for PM and 86.4% in 2016 and 89.60% in 2017 for UF), soil and leaf K, Ca and Mg, ash, protein, dry matter and fibre were increased only up to 80 kg N/ha for PM and 40 kg N/ha for UF. This levels (80 kg N/ha for PM and 40 kg N/ha for UF) correspond to the optimum level for the production of quality *Amaranthus* in the agro ecological zone or similar soil elsewhere. For improving the overall quality, integrating UF at 40 kg N/ha with PM at 80 kg N/ha is recommended.

**Key words :** *Amaranthus hybridus,* leaf quality, mineral composition, poultry manure, soil chemical properties, urea fertilizer

## INTRODUCTION

Green amaranth (*Amaranthus hybridus* L.) is a leafy vegetable crop that belongs to the family Amaranthaceae. In Nigeria, it is one of the most important leafy vegetable grown due to its high nutritional significance. The leaves and stems of *Amaranthus* are rich in protein, fat, calcium, phosphorus, riboflavin, niacin, sodium, iron and ascorbic acid (Miah *et al.*, 2013). It is considerably higher in calcium, iron and phosphorus than most other leafy vegetables (Kachiguma1 *et al.*, 2015). It also contains significant level of Vitamin A and C.

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*Amaranthus* has many health benefits, it contains phytosterols which reduce the cholesterol levels and so reduces cardiovascular diseases (Martirosyan *et al.*, 2007). It also prevents cancer (Su *et al.*, 2002).

Being a leafy vegetable, *Amaranthus* requires nitrogen in the soil more than other soil nutrients. According to Jangir *et al.* (2019), *Amaranthus* requires 60 N + 40 $P_2O_5$ + 00 $K_2O$ kg/ha. This is due to nitrogen being an important constituent of chlorophyll, protoplasm, protein and nucleic acids. Nitrogen also increases growth and development of living tissues (promote rapid vegetative growth) and improves the quality of leafy vegetables. However, Nigeria like any other tropical countries with high rainfall, nitrogen is the most limiting nutrient element in the soil. Therefore, for improved production of *Amaranthus*, use of fertilizer materials that contain high quantity of nitrogen is inevitable. To achieve this, in the past chemical fertilizer like UF was used. The use of urea fertilizer has been reported (Murdiono *et al.*, 2019) to increase *Amaranthus* growth and yields, but in Nigeria its use is limited by high cost, scarcity during the time of its need (planting season), soil acidity and nutrient imbalance. Because of these, the use of organic manure like PM has found favour in increasing *Amaranthus* production.

PM is cheap, environment friendly and also has residual effect and ability to improve soil structure compared with chemical fertilizers. It contains N and P and other essential elements important for *Amaranthus* production (Adekiya *et al.*, 2016). However, PM is limited by large quantity required for large scale vegetable production (Adekiya *et al.*, 2019). To avert this problem, integrating inorganic (urea) with organic (PM) fertilizers have recently been advocated. Apart from enhancing nutrient use efficiency, it reduces losses by converting inorganic nitrogen into organic forms (Adekiya *et al.*, 2020).

For *Amaranthus*, studies on the effects of integrated nutrient supply as opposed to sole application of soil amendments and its effects on soil chemical properties, growth and yield and quality of the crop is not common. Adekiya *et al.* (2019) reported sole application of PM at 0, 10, 20, 30 and 40 t/ha on soil chemical properties, leaf mineral content, growth and marketable yield of green amaranth (*Amaranthus hybridus*). In Ogbomoso southwest Nigeria, Olaniyi *et al.* (2008) investigated the effect of sole nitrogen fertilizer on the growth, yield, quality and chemical composition of grain amaranth varieties. The investigated treatments were two varieties of grain amaranth; NH84/593-1 and NH84/594 subjected into five levels of nitrogen fertilizer *viz.*: 0, 15, 30, 45 and 60 kg N/ha. Okokoh and Bisong (2011) investigated the Effect of sole and integrated applications of PM and UF on flowering occurrence and leaf productivity of *Amaranthus cruentus.* Their results showed that *Amaranthus* fertilized with sole PM were significantly taller, while application of a mixture of UF and PM produced the higher number of leaves per plant, the largest leaf area, highest number of branches per plant, longest vegetative life span, highest fresh leaf mass, highest fresh stem mass and highest fresh leaf yield. However, their studies neglected the response of soil chemical properties and *Amaranthus* qualities to integrated nutrient application. This aspect needs investigation. *Amaranthus* growth and marketable yield and quality indicators may respond differently to the same level of nutrient supply. Therefore, there is the need to investigate a UF-PM package that will optimize soil chemical properties, growth, yield and quality of *Amaranthus* on an Alfisol of derived savanna zone of Nigeria. Therefore, the objective of this study was to investigate the effects of sole and integrated application of urea fertilizer and PM on the growth, yield, mineral and proximate qualities of *Amaranthus hybridus* on Alfisol of derived savannah ecological zone of Nigeria.

## MATERIALS AND METHODS

Two field experiments were carried out in years 2016 and 2017 to evaluate the effects of PM and urea fertilizer on soil chemical properties, growth, yield and quality of green Amaranth (*Amaranthus hybridus*). The experiments were carried out at Landmark University, Omu-Aran, Kwara State, Nigeria which lies between Latitude 8°9'N and Longitude 5°61'E and is located in the derived savanna ecological zone of Nigeria. The soil at Landmark University, Omu-Aran is an Alfisol or Luvisol (Adekiya *et al.*, 2018). The 0- 15 cm layer of the experimental soil contains sand

76%, silt 12.9%, clay 11.0%, organic matter 2.24%, pH (water) 5.48, total N 0.17 %, available P 9.5 mg/kg, exchangeable K 0.14 cmol/kg, exchangeable Ca 1.90 cmol/kg and exchangeable Mg 0.43 cmol/kg. 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.

The study was made up of a 2 × 4 × 4 factorial experiment with two years (2016 and 2017), four levels of PM (0, 40, 80 and 120 kg N/ha) and four level of UF (0, 40, 80 and 120 kg N/ha) application. The sixteen treatment combinations were arranged in a randomized complete block design having four replications. 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, Sowing of Amaranth Seeds and application of urea fertilizer**

The site of the experiment was mechanically cleared before the sowing of the seeds. After initial ploughing and harrowing, the experimental plot was mapped out at 3 × 4 m beds with 0.5 m in-between plots.

PM used 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 according to the required treatments 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 *Amaranthus* seeds. Before sowing, emerged weeds were removed manually (Adekiya *et al.*, 2019). *Amaranthus* seeds were mixed with dried sand before drilling to ensure seed were not sown too close together for proper management of the seed rate. Seeds were drilled at distance of 10 cm between rows. The seedlings were later thinned to 1 plant per stand at 7 days after sowing to give a plant population of 1,000,000 plant/ha. UF at 0, 40, 80 and 120 kg N/ha was applied using band method at about 5 cm away from the seedlings at 10 days after sowing. Weeding was done manually during the planting season. No irrigation water was applied, in both years the experiments were rain fed.

**Soil and Poultry Manure Analysis**

Surface soil samples (0-15 cm depth) were collected randomly from the field in 2016 for physical and chemical analysis before the start of the experiment. The soil sample were air dried, sieved with 2- mm sieve and kept for analysis. The sand, silt and clay contents were determined by hydrometer method (Gee and Or, 2002).The soil pH was determined using the pH-meter in a 1:2.5 soil/water ratio, total nitrogen content was estimated by micro-kjedahl method (Bremner, 1996), available phosphorus by Bray 1 method (Frank *et al.*, 1998), Calcium (Ca) and Magnesium (Mg) by the Atomic Absorption Spectrophometer (AAS) and potassium (K) and sodium (Na) by flame emission photometry (Association of Official Analytical Chemists, (AOAC, 2010). The organic carbon was according to Walkey and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996) and the organic matter was estimated by multiplying the percent organic carbon with a factor 1.724. At the end of the experiment each year 2016 and 2017, soil samples were also collected (now on plot basis) and similarly analysed for soil chemical properties as descried above. The PM used was dried and sieved with 2- mm sieve for chemical analysis to determine its nutrient composition. Poultry manure was analyzed for organic C, N, P, K, Ca and Mg as described by Carter and Gregorich (2007).

**Analysis of Amaranth Leaves**

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). Leaf N was determined by the micro-Kjeldahl digestion method. Ground samples were digested with nitric perchloric- sulphuric acid mixture for the determination of P, K, Ca and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method

(Horwitz and Latimer, 2005). 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 (AOAC, 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.

### Determination of Yield and Growth of Amaranthus

In both years, harvesting of Amaranth was done at 8 weeks after sowing. This was on a plot basis by cutting the entire plant from the base very close to the soil using a sharp knife. 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).

### Statistical Analysis

Data collected for *Amaranthus* yield and growth indices, soil chemical properties, and *Amaranthus* mineral and proximate compositions were subjected to analysis of variance (two-ways ANOVA) using the Genstat Statistical Package (Genstat, 1993), the standard error of difference between means (SEd) was used to compare the treatment means. Mention of statistical significance refers to P = 0.05 unless otherwise stated.

## RESULTS AND DISCUSSION

The experimental soil was sandy loam soil in texture, slightly acidic, adequate in Mg but low in exchangeable Ca and K, total N, available P and soil organic matter (OM). The PM used in both years (Table 1) was high in nutrient with N (2.88%) being the highest. The nutrients in PM are, therefore expected to enhance the growth of crop like *Amaranthus*.

**Table 1.** Chemical analysis of poultry manure

| Property | 2016 | 2017 |
|---|---|---|
| Organic C (%) | 21.5 | 21.9 |
| pH ($H_2O$) | 6.78 | 6.80 |
| N (%) | 2.88 | 2.89 |
| P (%) | 1.38 | 1.36 |
| K (%) | 1.72 | 1.73 |
| Ca (%) | 0.91 | 0.89 |
| Mg (%) | 0.55 | 0.55 |

### Effects of PM and Urea Fertilizer on Soil Chemical Properties

The response of soil chemical properties to PM and urea UF application in 2016 and 2017 significantly increased soil N, Ca and Mg compared with the control (Table 2). 120 kg N/ha UF has the highest value of N. Although not significant, urea fertilizer reduced P and K contents of the soil relative to the control. In both years, there were no significant differences between 80 kg N/ha and 120 kg/ha UF for K, Ca and Mg. Also, when PM is considered alone in both years, PM increased OM, N, P, K, Ca and Mg contents of the soil compared with the control. PM increased OM, N and P values from 0-120 kg N/ha rate, but K, Ca and Mg was only increased up to 80 kg N/ha level of PM after which there was a decrease. The interactive effect of Y×PM was significant for all soil chemical properties, Y× UF was not significant for any soil chemical properties. PM × UF was significant for N, P, K Ca and Mg but not significant for OM. The interaction Y × PM × UF was not significant.

### Effects of PM and Urea Fertilizer on Yield and Growth Indices of Amaranthus

Data in Table 3 shows the result of the response of yield and growth indices of *Amaranthus* to PM and UF. When urea fertilizer was considered alone in both years, fresh plant weight/plot, plant height, stem diameter, number of leaves and leaf area increased significantly with application of urea fertilizer compared with the control. The increases in these parameters were from 0 - 120kg N/ha. PM considered alone, yield and growth indices of *Amaranthus* were increased significantly compared with the control with 120 kg N/ha PM having the highest values. In both years using the same level, PM increased the growth and yield parameters of *Amaranthus* compared

**Table 2.** Effect of poultry manure and urea fertilizer on soil chemical properties

| Year/Amendment | Amendment (kgN/ha) | OM (%) | N (%) | P (mg/kg) | K (cmol/kg) | Ca (cmol/kg) | Mg (cmol/kg) |
|---|---|---|---|---|---|---|---|
| **2016** | | | | | | | |
| Poultry manure (PM) | 0 | 1.76 | 0.14 | 8.9 | 0.16 | 1.61 | 0.34 |
| | 40 | 2.61 | 0.22 | 10.5 | 0.19 | 2.42 | 0.56 |
| | 80 | 3.10 | 0.29 | 15.6 | 0.27 | 3.59 | 0.69 |
| | 120 | 3.66 | 0.33 | 19.9 | 0.26 | 3.56 | 0.69 |
| Urea fertilizer (UF) | 0 | 1.78 | 0.14 | 8.9 | 0.16 | 1.61 | 0.34 |
| | 40 | 1.81 | 0.21 | 8.6 | 0.15 | 1.73 | 0.39 |
| | 80 | 1.83 | 0.27 | 8.6 | 0.15 | 2.11 | 0.46 |
| | 120 | 1.87 | 0.31 | 8.5 | 0.14 | 2.11 | 0.45 |
| **2017** | | | | | | | |
| Poultry manure (PM) | 0 | 1.74 | 0.13 | 8.9 | 0.15 | 1.60 | 0.33 |
| | 40 | 2.81 | 0.24 | 11.4 | 0.20 | 2.58 | 0.62 |
| | 80 | 3.41 | 0.32 | 17.8 | 0.29 | 3.78 | 0.77 |
| | 120 | 3.94 | 0.36 | 23.6 | 0.28 | 3.67 | 0.76 |
| Urea fertilizer (UF) | 0 | 1.76 | 0.12 | 8.9 | 0.14 | 1.58 | 0.32 |
| | 40 | 1.80 | 0.20 | 8.4 | 0.13 | 1.69 | 0.37 |
| | 80 | 1.80 | 0.26 | 8.3 | 0.13 | 2.09 | 0.44 |
| | 120 | 1.86 | 0.30 | 8.3 | 0.13 | 2.08 | 0.44 |
| | SE± | 0.19 | 0.01 | 1.22 | 0.01 | 0.10 | 0.04 |
| Year (Y) | | * | * | * | * | * | * |
| Poultry manure (PM) | | * | * | * | * | * | * |
| Urea fertilizer (UF) | | Ns | * | ns | ns | * | * |
| Y×PM | | * | * | * | * | * | * |
| Y× UF | | Ns | ns | ns | ns | ns | ns |
| PM × UF | | Ns | * | * | * | * | * |
| Y × PM × UF | | Ns | ns | ns | ns | ns | ns |

*: Significant difference at P = 0.05; ns: Not Significant.

with UF. The interactive effect of Y×PM and PM × UF were significant for all growth and yield parameters of *Amaranthus*, Y× UF was not significant for any growth and yield parameters. The interaction Y × PM × UF was not significant.

### Effects of PM and Urea Fertilizer on Mineral Contents of Amaranthus Leaves

Table 4 shows the data on the effects of PM and UF on mineral contents of *Amaranthus* leaves in 2016 and 2017. When considered alone in both years, UF increased N content of *Amaranthus* leaves but did not increase significantly P, K, Ca and Mg contents compared with the control. However, P, K, Ca and Mg contents were optimum at 40 kg N/ha UF. When PM was considered alone, PM increased N, P, K, Ca and Mg contents significantly compared with the control. 120 kg N/ha has the highest values of N and P but K, Ca and Mg were optimum at 80 kg N/ha after which there was a decease at 120 kg N/ha. The interactive effect of Y×PM was significant for *Amaranthus* leaf nutrients, PM × UF was only significant for leaf N. The interaction Y × PM × UF was not significant.

### Effects of PM and Urea Fertilizer on Proximate Composition of Amaranthus Leaves

UF and PM alone increased moisture, ash, protein and fiber contents of *Amaranthus* leaves compared with the control (Table 5). Dry matter and fat contents were reduced. Moisture was increased up to 120 kg N/ha for both UF and PM. In both years, UF has optimum ash, dry matter and fiber contents at 40 kg N/ha. Likewise, PM has the highest values of ash, protein dry matter, fiber and lowest fat content at 80 kg N/ha. The interactive effect of Y×PM was significant only for moisture, ash and fat, Y× UF was significant for moisture, dry matter, fiber and fat. PM × UF was significant for moisture, ash protein dry matter, fiber and fat. The interaction Y × PM × UF was only significant for moisture and fat.

Urea fertilizer significantly increased soil N, Ca and Mg compared with the control. The increase in N, as a result of application of UF to the soil, shows that the soils are deficient in N. Nitrogen is the most limiting nutrient

**Table 3.** Effect of poultry manure and urea fertilizer on yield and growth parameters of Amaranthus

| Year/amendment | Amendment (kg N/ha) | Plant height (m) | Stem diameter (cm) | Number of leaves | Leaf area ($m^2$) | Fresh plant weight/plot (kg) |
|---|---|---|---|---|---|---|
| **2016** | | | | | | |
| Poultry manure (PM) | 0 | 0.32 | 2.7 | 11 | 0.81 | 126 |
| | 40 | 0.49 | 3.5 | 18 | 1.64 | 195 |
| | 80 | 0.64 | 3.8 | 21 | 1.92 | 232 |
| | 120 | 0.75 | 4.2 | 24 | 2.36 | 280 |
| Urea fertilizer (UF) | 0 | 0.32 | 2.8 | 10 | 0.81 | 125 |
| | 40 | 0.46 | 3.2 | 15 | 1.41 | 166 |
| | 80 | 0.59 | 3.4 | 17 | 1.79 | 197 |
| | 120 | 0.67 | 3.9 | 22 | 2.10 | 250 |
| **2017** | | | | | | |
| Poultry manure (PM) | 0 | 0.30 | 2.6 | 11 | 0.80 | 124 |
| | 40 | 0.53 | 3.8 | 20 | 1.76 | 223 |
| | 80 | 0.69 | 4.3 | 25 | 2.15 | 262 |
| | 120 | 0.81 | 4.8 | 28 | 2.66 | 310 |
| Urea fertilizer (UF) | 0 | 0.31 | 2.7 | 9 | 0.79 | 122 |
| | 40 | 0.45 | 3.1 | 15 | 1.40 | 166 |
| | 80 | 0.58 | 3.4 | 17 | 1.78 | 196 |
| | 120 | 0.65 | 3.8 | 21 | 2.00 | 247 |
| | SE± | 0.04 | 0.15 | 1.42 | 0.14 | 14.98 |
| Year (Y) | | * | * | * | * | * |
| Poultry manure (PM) | | * | * | * | * | * |
| Urea fertilizer (UF) | | * | * | * | * | * |
| Y×PM | | * | * | * | * | * |
| Y× UF | | ns | ns | ns | ns | ns |
| PM × UF | | * | * | * | * | * |
| Y × PM × UF | | ns | ns | ns | ns | ns |

*: Significant difference at P = 0.05; ns: Not significant.

**Table 4.** Effect of poultry manure and urea fertilizer on mineral contents of Amaranthus

| Year/amendment | Amendment (kg N/ha) | N (%) | P (%) | K (%) | Ca (%) | Mg (%) |
|---|---|---|---|---|---|---|
| **2016** | | | | | | |
| Poultry manure (PM) | 0 | 1.65 | 0.29 | 1.15 | 0.28 | 0.54 |
| | 40 | 2.21 | 0.36 | 2.55 | 0.45 | 0.66 |
| | 80 | 2.51 | 0.55 | 3.41 | 0.52 | 0.71 |
| | 120 | 2.98 | 0.61 | 3.30 | 0.51 | 0.70 |
| Urea fertilizer (UF) | 0 | 1.65 | 0.28 | 1.15 | 0.15 | 0.41 |
| | 40 | 1.90 | 0.29 | 1.23 | 0.19 | 0.43 |
| | 80 | 2.30 | 0.29 | 1.24 | 0.19 | 0.43 |
| | 120 | 2.50 | 0.29 | 1.24 | 0.19 | 0.41 |
| **2017** | | | | | | |
| Poultry manure (PM) | 0 | 0.60 | 0.28 | 1.11 | 0.14 | 0.40 |
| | 40 | 2.46 | 0.39 | 2.84 | 0.51 | 0.59 |
| | 80 | 2.78 | 0.59 | 3.88 | 0.59 | 0.78 |
| | 120 | 3.41 | 0.68 | 3.78 | 0.54 | 0.71 |
| Urea fertilizer (UF) | 0 | 1.60 | 0.26 | 1.10 | 0.14 | 0.52 |
| | 40 | 1.88 | 0.28 | 1.15 | 0.18 | 0.54 |
| | 80 | 2.22 | 0.27 | 2.15 | 0.18 | 0.54 |
| | 120 | 2.44 | 0.27 | 2.14 | 0.17 | 0.50 |
| | SE± | 0.16 | 0.03 | 0.25 | 0.04 | 0.03 |
| Year (Y) | | * | * | * | * | * |
| Poultry manure (PM) | | * | * | * | * | * |
| Urea fertilizer (UF) | | * | ns | ns | ns | ns |
| Y×PM | | * | * | * | * | * |
| Y× UF | | Ns | ns | ns | ns | ns |
| PM × UF | | * | * | * | * | * |
| Y × PM × UF | | Ns | ns | ns | ns | ns |

*: Significant difference at P = 0.05; ns: Not significant.

**Table 5.** Effect of poultry manure and urea fertilizer on proximate contents of Amaranthus

| Year/Amendment | Amendment (kg N/ha) | Moisture (%) | Ash (%) | Protein (%) | Dry matter (%) | Fibre (%) | Fat (%) |
|---|---|---|---|---|---|---|---|
| **2016** | | | | | | | |
| Poultry manure (PM) | 0 | 82.55 | 1.11 | 1.11 | 12.0 | 0.83 | 2.29 |
| | 40 | 85.10 | 1.30 | 1.20 | 9.1 | 1.20 | 1.99 |
| | 80 | 86.30 | 1.35 | 1.28 | 8.6 | 1.19 | 1.41 |
| | 120 | 87.60 | 1.30 | 1.20 | 7.3 | 1.18 | 1.42 |
| Urea fertilizer (UF) | 0 | 82.61 | 1.10 | 1.11 | 12.1 | 0.81 | 2.27 |
| | 40 | 84.56 | 1.30 | 1.26 | 9.5 | 1.19 | 0.95 |
| | 80 | 85.80 | 1.26 | 1.20 | 10.2 | 1.1 | 1.68 |
| | 120 | 86.40 | 1.29 | 1.20 | 9.1 | 1.19 | 0.82 |
| **2017** | | | | | | | |
| Poultry manure (PM) | 0 | 79.25 | 1.11 | 1.07 | 13.0 | 0.90 | 2.31 |
| | 40 | 88.50 | 1.35 | 1.14 | 6.6 | 1.18 | 1.13 |
| | 80 | 89.60 | 1.35 | 1.27 | 6.4 | 1.17 | 0.22 |
| | 120 | 90.20 | 1.35 | 1.26 | 5.9 | 1.16 | 0.11 |
| Urea fertilizer (UF) | 0 | 79.31 | 1.14 | 1.07 | 13.0 | 0.90 | 2.31 |
| | 40 | 87.40 | 1.44 | 1.27 | 7.9 | 1.19 | 0.82 |
| | 80 | 88.30 | 1.40 | 1.27 | 7.2 | 1.18 | 0.65 |
| | 120 | 89.60 | 1.40 | 1.27 | 7.0 | 1.18 | 0.25 |
| | SE± | 0.85 | 0.02 | 0.15 | 0.59 | 0.03 | 0.19 |
| Year (Y) | | * | ns | ns | ns | * | * |
| Poultry manure (PM) | | * | * | * | * | * | * |
| Urea fertilizer (UF) | | * | * | * | * | * | * |
| Y×PM | | * | * | ns | ns | ns | * |
| Y× UF | | * | ns | ns | * | * | * |
| PM × UF | | * | * | * | * | * | * |
| Y × PM × UF | | * | ns | ns | ns | ns | * |

*: Significant difference at p = 0.05; ns: Not significant.

in the Nigerian savannah zone (Enwezor *et al.*, 1990; Aduayi *et al.*, 2002). Application of N as fertilizer to soils in the Savanna is therefore essential in order to achieve high crop yields of good quality (Upendra *et al.*, 2003). The lowest N contents of the soil with lower N rates might be due to the consequence of higher uptake rate of N by the crop as the supply was not adequate according to demand. The increased in Ca and Mg contents of the soil as a result of UF application was due to the need for a cation-anion balance. The slight reduction of P in soil at higher urea levels might be due to the consequence of higher P uptake with higher crop growth induced by higher rate of N application (Hussain, *et al.*, 2017). Mugo *et al.* (2020) reported that increasing levels of N negatively correlated with plant P and positively correlated with Ca. The significant increase in soil OM, N, P, K, Ca and Mg content of the soil in due to PM was consistent with the analysis recorded for the PM (Table 2). Adekiya *et al.* (2020) 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 120 kg N/ha showed that the OM part of the PM decomposed, and soil nutrient were added. Ca, Mg and K reduced after 80 kg N/ha PM. This could be adduced to nutrient imbalance after 80 kg N/ha PM level preventing the availability of other nutrients (Adekiya *et al.*, 2019). The significant of Y × PM signifies that PM has residual effects. It is also inferred that nutrients in PM can still remain in the soil after the first cropping and might still be useful in the next cropping, which might be due to the slow-release patterns of their nutrients (Adeleye and Ayeni, 2010). Y × UF was not significant because UF did not have any residual effects on the soil. PM × UF was significant for N, P, K Ca and Mg. This can be adduced to the fact that the combination of PM and UF will reduced losses of nutrients especially N due to leaching by converting the inorganic nitrogen (N) into organic forms (Geng *et al.*, 2019; Adekiya *et al.*, 2020).

The increase in fresh plant weight/ plot, plant height, stem diameter, number of leaves and leaf area with application of UF compared with the control could be adduced to improved soil N content which led to improved leaf area, which determines the percentage of incident radiation intercepted for energy supply in photosynthesis (Woodrow *et al.*, 1990). Increased leaf area, as a result of an increase in the N rates is probably due to the increased availability of N for uptake resulted in higher accumulation of photo assimilates, consequently increasing the yield and growth indices of *Amaranthus*. Agbede (2009) reported that one of the major effects of N fertilizer is to improve root growth and development and above ground vegetative growth. Yield and growth indices of *Amaranthus* were increased significantly compared with the control with 120 kg N/ha PM having the highest values. This was due to increase in nutrient status of the soil because of the applied PM leading to absorption, hence significant improvement in growth and *Amaranthus* yield. Improved growth and yield of crops with PM have also been reported by other workers (Adekiya *et al.*, 2016; Adekiya *et al.*, 2019).

The increased growth of Amaranthus up to 120 kg N/ha levels for both UF and PM suggested that Amaranthus being a leafy vegetable requires a lot of N and will continue to absorb it in as much as the nutrient is available in the soil. Improved growth and yield of Amaranthus observed under high nitrogen rate suggested that increasing soil nitrogen to a high rate enables *Amaranthus* to produce their potential growth (Olaniyi *et al.*, 2008; Parmar and Patel, 2009). This result is also obvious in the soil N and leaf nutrient values of this treatment. Under normal condition, leafy vegetable like Amaranthus responds well in terms of growth and yield to supply of nutrients that promote vegetative growth. For this study (average of the two years), the correlation coefficients between N in the soil under UF and PM alone (Table 2) and leaf area and fresh plant weight (Table 3) under UF (The R values were 0.99 and 0.98 respectively at $P < 0.05$.) and PM alone (The R values were 0.99 and 0.97 respectively at $P < 0.05$) were positive and significant. Sufficient supply of nitrogen tends to improve growth and yield in *Amaranthus*. Similar findings were reported by Chakhatrakan (2003) and Olaniyi *et al.* (2008).

The significant Y × PM interaction implies that there was an increased growth and yield parameters of Amaranthus in 2017 relative with 2016 which could be attributed in part to the increased plant nutrients availability due to residual concentration from the first cropping season and the subsequent application of the organic manure in the second year (Agbede *et al.*, 2019). The interactive effect of PM × UF was significant for all growth, yield, mineral and proximate composition of *Amaranthus* due to the fact that PM improves soil physical properties (Agbede *et al.*, 2017). In addition to improving soil physical properties, the humus of PM may also allow retention of released nutrient from rapidly mineralizing UF within the rooting zone preventing it from leaching, thereby fostering greater efficiency of nutrient uptake and increase in growth and yield. Higher N mineralization occurs where two amendments were combined, compared to their sole forms, indicating a synergistic relationship between the inputs (Adekiya, 2019). The integration prevents N losses and conserves soil N by forming organic-mineral complexes, thus ensuring continuous N availability and greater yields (Souri, 2016). A positive interaction has been reported to occur between organic manure and urea as N source (Adekiya *et al.*, 2020).

The response of leaf N concentrations of *Amaranthus* to application of UF and PM alone was consistent with the values of soil chemical properties recorded for these treatments. There was increased N availability in the soil as a result of application of UF and PM leading to increased uptake by Amaranthus plant. Also, the result that growth and yield indices of *Amaranthus* increased with the increase of UF and PM doses up to 120 kg N/ha while K, Ca and Mg were increased with UF up to 40 kg N/ha and PM up to 80 kg N/ha can testify that in the experimental condition, the 40 kg N/ha UF and 80 kg N/ha PM doses were over optimal for mineral contents of Amarathus.

The reduced values of minerals (P, K Ca and Mg) above the optimum level could be due to nutrient imbalance as a result of excessive N application thereby preventing the absorption of other nutrients. The phenomenal of over-supply of N to vegetables especially leafy type like *Amaranthus* could make them absorb N at luxury and develop excessive vegetative growth with high water content. Such vegetable according to Agbede (2009) has dark green lanky growth and abnormal cells due to insufficiency of other elements such as K, Ca and Mg.

UF and PM treatments alone increased moisture, protein, fibre, and ash contents of

Amaranthus compared with the control. This might be as a result of increase in the nutrients in the soil due to application of UF and PM which consequently led to increased absorption of nutrients by the plants. This can also be because increase in Urea and PM applied led to increased soil N and N absorbed by the Amaranthus plant and hence increased in the number of foliage and photosynthetic activities and enhancing physiological processes leading to the production of more assimilates which led to increase in chemical composition of the plant. Also, the increase in protein content in response to increased N supply from both urea and PM application highlights the importance of N in protein synthesis in plants. As the amount of N increased, total N and crude protein contents in the leaves are increased but crude fibre content is reduced (Mengel, 1979).

The reduced fat content with applications of UF and PM was due to negative relationship between protein and fat content (Wang, *et al.*, 2008). Moisture increased to the highest doses of both urea and PM, this was due to effects of excessive moisture associated with crops especially leafy vegetable exposed to excessive nitrogen. Agbede (2009) reported that such crop with high water content has less flavor and becomes watery on boiling. The reduced dry matter was as a result of increased moisture content of the Amaranthus. In cabbages the dry matter content was reduced significantly with increased N supply (Sorensen, 1984).

As applicable to mineral contents of Amaranthus leaves, protein, fiber, ash and dry matter were at optimum at 40 kg N/ha UF and 80 kg N/ha PM. Too much N can diminish taste and flavour and reduce the biological value of protein (Hornicks, 1992). These levels of sole urea and PM seems to be adequate for best quality of Amaranthus.

## CONCLUSION

Urea fertilizer and PM alone or their integration improved soil OM, N, P, K, Ca and Mg content of the soil (urea alone did not increase OM, P and K significantly), yield and growth indices, minerals (urea alone only increased leaf N), moisture, fibre, protein, dry matter, ash and reduced fat content of *Amaranthus* leaves compared with the control. This study revealed that the combined use of UF and PM increased Amaranthus quality at reduced inorganic fertilizer input while maintaining the soil resource. Although yield, growth indices, leaf N and moisture contents of Amaranthus increased up to 120 kg N/ha, for both sole UF and PM, soil and leaf K, Ca and Mg, ash, protein, dry matter and fibre were increased only up to 80 kg N/ha for PM and 40 kg N/ha for UF. These levels correspond to the optimum level for the production of quality Amaranthus in the agro-ecological zone or similar soil elsewhere. For improve quality, in integrating UF at 40 kg N/ha with PM at 80 kg N/ha is recommended**.** The associated reduction in quality of leafy vegetables due to higher/repeatedly rate of application of poultry manure should be further investigated in the future.

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