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Growth, Yield, Nutritional and Mineral Composition of *Solanum macrocarpon* L. as Affected by Fertilizer Application

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Abstract

Indigenous vegetables are plant species that are of great nutritional and medicinal importance. In a bid to ensure their domestication, availability and consumption, it is necessary to investigate their response to fertilizer treatment and other suitable agronomic practices that will enhance their cultivation and nutritional composition. In this study, an experiment was carried out to determine the effect of organic and inorganic fertilizers on the growth and yield of *Solanum macrocarpon*. The experiment was laid out in a Complete Randomized Design with four treatments: NPK 200 kg /ha, - T1, Poultry manure 6t/ ha - T2, NPK and Poultry manure 100 kg/ha + 3 t/ha - T3, Control, No Fertilizer - T4. Leaf area, plant height, number of leaves, and stem diameter were measured using standard methods. Proximate and mineral analyses were also carried out in accordance with standard chemical methods. The growth and yield of S. macrocarpon was improved by fertilizer application. All growth parameters measured increased with plant age and significant differences ($p < 0.05$) were observed among the treatments. Results obtained from this study also highlighted the potential of poultry as an alternative source of Nitrogen required for plant growth. Although both organic and inorganic fertilizers improved the growth performance of the vegetable, yet, the inorganic fertilizer produced the best results for all the parameters studied. Inorganic (NPK) and organic (Poultry manure) fertilizer increased soil fertility and improved the nutritional composition, but *Solanum macrocrapon* plants grown with inorganic fertilizer performed better.

Keywords: Growth parameters; Inorganic fertilizers; Indigenous vegetables; Poultry manure; *Solanum macrocarpon*,

1. Introduction

Incessant farming on a piece of land without replenishment or fallowing depletes the soil nutrient status, reduces soil fertility and productivity. African soils including that of Nigeria inclusive are usually deficient in essential macro nutrients such as phosphorus and nitrogen, but contain adequate amounts of micro nutrients such as boron, manganese, copper, sulphur and zinc [1, 2]. These elements play important roles in optimal plant development and their lack may lead to poor plant growth and eventual crop senescence. Such soils with low levels of nutrients therefore need to be boosted with soil amendments in order to improve crop production [3].

Fertilizers can be organic, inorganic or organo-mineral, which is a blend of both the organic and inorganic fertilizers. Organic fertilizers can be of plant or animal origin, such as crop residues, animal droppings and household wastes, they usually contain a great amount of organic matter which helps to improve soil fertility and decrease soil porosity. Supplementing the soil with organic manure helps to improve the soil structure, microbial mass and provide nutrients through mineralization [4]. However, the quality and source of the organic manure greatly determine how the contained nutrients are available for plant uptake and growth as some are often slowly mineralized and may not be available during the first season of application [3]. This explains why some farmers prefer inorganic fertilizers since they quickly become available to the plant after application, nevertheless, they may become toxic to soil, organisms and humans [5].

As opined by Farhad, *et al.* [6] manure application in crop husbandry is a veritable tool in ecosystem preservation as the substantial residual effect on the succeeding crop cultivation is noteworthy. As stated by Adeoye, *et al.* [7], an excellent soil management tactic for the low activity clay African soils, is the application of organic manure before planting commences with the aim of improving soil organic matter and promoting soil fertility. Inorganic fertilizers on the other hand are a group of chemical compounds containing one or more essential nutrients in the form of mineral salts applied to soils to provide nutrients for plants in appropriate proportions or percentages. Poultry manure is an organic-based fertilizer, which when properly applied to soil, enhances its physical and chemical properties [6]. However, preliminary evaluation of the properties of the manure must be carried out to ascertain its suitability for application to the soil. Poultry manure been reported by several authors to contains more nutrients than other organic manure sources such as those from other animals such as cow, goat and sheep manure [8, 9].

Currently, there is an increasing awareness of the value of leafy vegetables in that they contribute to balanced diet, particularly in areas where animal protein is deficient [2]. *Solanum macrocarpon* is an herbaceous leafy vegetable in the family Solanaceae grown in the tropical regions of the world. It is cultivated for its leaves some parts of Africa [10]. In Nigeria, *Solanum macrocarpon* is intercropped with staple food crops like yam and cassava and rarely cultivated singly by farmers for commercial purposes [11]. The authors also stated that despite the inherent genetic endowment of *Solanum macrocarpon*, inadequate soil nutrient availability usually suppresses its re-growth and prolific characteristics.

Vegetables are considered one of the sources of mineral elements and these mineral elements are obtained from the soil on which the plants are cultivated. Fertilizer application rates in intensive agricultural systems have increased drastically in recent years in Nigeria and the cost implications of fertilizers can sometimes scare farmers and make them not to apply enough for good growth [12]. Dumas, *et al.* [13], have opined that fertilizer application in appropriate quantity and period is most favorable to production of eggplants and improvement of their phyto-nutritional attributes. Jones, *et al.* [14], also opined that vegetative production is better enhanced by phosphorus, an important nutrient element present in fertilizers.

There is the need for improvement in the cultivation practices of the leafy vegetable as production of good quality vegetables would promote national, regional and international market opportunities for indigenous vegetables of southwest Nigeria [15, 16]. Idowu, *et al.* [16], also opined that helping women who are vegetable farmers improve the productivity of more nutritious, high-value products such as vegetables, will not only increase family income but also promote ground-level nutrition by increasing the amount of healthy food available for home consumption. There is however little information on the response of *S. macrocarpon* to organic and inorganic fertilizer applications. This study therefore seeks to provide information on the effects of fertilizer application on the growth, yield and nutritional composition of this vegetable, this is with the aim of ensuring its domestication and thus promoting food security.

2. Material and Methods

The experiment was carried out in the greenhouse of the Department of Plant Science and Biotechnology, Ekiti State University, Ado Ekiti (Latitude 24^0 33'S and Longitude 25^0 54'E).

Soil was collected at the Parks and Gardens Unit of Ekiti State University, Ado-Ekiti, Nigeria. Soil samples were taken from a depth of 0 - 30 cm from different spots in the same area and bulked together to give a composite sample. The collected samples were thoroughly mixed, air dried and passed through a 2 mm sieve to remove stones and debris. A portion of the soil sample was also taken to the laboratory for the determination of soil physicochemical properties according to standard methods. The particle size of the soil was determined by hydrometer method. The pH was determined in 1:2 soils: water suspension using a pH meter. The organic carbon was determined by dichromate oxidation, total N was determined by Kjeldahl procedure and available P by the Bray P-1 method. The Ca and Mg contents were determined titrimetically. The K and Na contents in the extract were determined with atomic absorption spectrophotometer.

Mature fruits of *Solanum macrocarpon* were harvested from residential areas during field surveys in Ekiti State. The seeds were removed from their capsule, air-dried and then sown in germination trays. After a period of two weeks, seedlings at two-leaf stage with a height of about 10 – 15cm were transplanted from germination trays into experimental pots filled with 3kg topsoil. This was done at the early hours of the morning in order to reduce transplanting shock.

Organic fertilizer (poultry manure) was obtained from the egg facility of the poultry unit of the Ekiti State University Teaching and Research farm while inorganic fertilizer NPK (Nitrogen Phosphorus and Potassium, 15:15:15) was purchased from a local agricultural inputs dealer.

The physicochemical properties of soil and organic fertilizer (poultry manure) used for the experiment are shown in Table 1.

Table-1. The physico-chemical properties of the experimental soil and organic fertilizer

Parameters	Soil	Organic Fertilizer
pH	6.39	7.97
Bulk density (%)	1.44	1.22
CEC (meq/100g)	4.66	11.84
Organic Carbon (%)	4.94	0.86
Exchangeable acidity (Cmol/kg)	1.54	1.62
Exchangeable Aluminum (mol/kg)	1.00	1.29
Particle density (g/cm^3)	2.59	2.24
Acidity (mol/kg)	2.43	0.34
Electrical Conductivity (EC) (μS/cm)	32.17	45.00
Sand (%)	52.90	-
Silt (%)	16.00	-
Clay (%)	31.15	-
Nitrogen (mg/kg)	0.73	3.63

Available Phosphorus	14.06	25.70
Zn (mg/kg)	2.36	12.91
Mn (mg/kg)	0.67	1.01
Cu (mg/kg)	0.23	16.01
Na (mg/kg)	22.62	56.15
Fe (mg/kg)	6.46	26.15
Mg(mg/kg)	5.15	91.21
K (mg/kg)	12.34	81.21
Ca (mg/kg)	66.32	77.21
P (mg/kg)	16.74	71.14
Textural class	Sandy clay loam	-

2.1. Experimental Layout

Seedlings were arranged in Completely Randomized Design (CRD) with four treatments and four replicates, however each replicate consisted of 10 experimental units. Each unit represents a stand of *Solanum macrocarpon* in a pot containing 3 kg topsoil, making a total of 40 experimental pots. Both NPK and organic manure were applied to the soil at transplanting. NPK was applied by ring method at a distance of 5 cm from the plant stand and at a depth of 2 cm into the soil, the organic fertilizer was however applied by mixing with the topsoil [17].

The treatments consisted of:

1. NPK 200 kg /ha, - T1
2. Poultry manure 6t/ ha - T2
3. NPK and Poultry manure 100 kg/ha + 3 t/ha - T3
4. Control, No Fertilizer - T4

The experiment was allowed to stabilize for three weeks before the assessment of growth parameters commenced. Growth parameters such as plant height, stem collar diameter, leaf number, leaf length and leaf breadth were assessed weekly. Plant height was measured from the base of the plant to the tip of the apical bud using a ruler calibrated in centimeter, leaf length and breadth were also measured using a meter rule, stem diameter with the aid of a digital Vernier Caliper while leaf number was obtained by physical counting. Leaf area was determined using the non destructive method [18] and computed using the formula:

$$\text{Leaf area} = 0.75\ (\text{Leaf Length} \times \text{Leaf Breadth})$$

At nine (9) weeks after transplanting, the experiment was terminated and seedlings were carefully uprooted, washed and separated into shoot and root, after which they were weighed using an electronic weighing balance (Trooper Count TC15RS, Ohaus corporation, Pine Brook, NJ, USA). The shoot and root components were then put into separate envelopes for ease of identification. The envelopes together with their contents were oven dried for at 80 °C to constant weight. The samples were then removed and reweighed to get the dry weights.

2.2. Determination of the Proximate Composition

The proximate composition of *Solanum macrocarpon* viz moisture, fat, crude protein, ash, fibre and carbohydrate were determined by the method of the Association of Official Analytical Chemists [19]. Vitamin A was determined spectrophotometrically using the hexane method and vitamin C was also determined spectrophotometrically.

2.3. Determination of Mineral Composition

The mineral composition (Mg, Fe, Ca, Cu, Zn) were determined using atomic absorption spectrophotometer as described by Association of Official Analytical Chemists [20]. Flame photometer was used to analyze both sodium and potassium. Phosphorus was also determined according to the same method.

2.4. Statistical Analysis

Data obtained from various treatments were subjected to statistical analysis using SPSS 20. A one way analysis of variance was used to compare the means of each treatment. Means were segregated using Duncan's Multiple Range Test. The means were treated as significantly different at $P < 0.05$.

3. Results

3.1. Effect of Organic and Inorganic Fertilizer on Growth Parameters *of Solanum macrocarpon*

The effect of fertilizers on leaf area of *Solanum macrocarpon* is shown in Table 2. The mean leaf area was measured from 3 WAT to 9 WAT. The treatment varied significantly in the 4 WAT while no significant differences were obtained in the other weeks. Treatment means for the experimental period ranged from 208.40 cm^2 and 477.97 cm^2. The order of increase was observed to be T1 > T2 > T3 >T4. The mean leaf area was highest in T1 (477.97 cm^2) and lowest in T4 (297.18 cm^2).

The mean plant height of *Solanum macrocarpon* measured weekly after application of organic and inorganic fertilizer is presented in Table 3. A steady increase in plant height was observed from 3 WAT to 6 WAT, however a decrease was observed at 7 WAT across all the treatments. At 8 WAP, plant height continued to increase till the termination of the experiment at 9 WAT. The highest plant height (30.30 cm) was obtained in T1 while the lowest was obtained in T4 (19.58 cm). The order of increase of the plant height was also observed to be T1 > T2 > T3 >T4. Plant height varied significantly among the different treatments, the differences were shown to be statistically significant at 4, 5, 7 and 8 WAT.

Table 4 shows the stem diameter of *Solanum macrocarpon* as affected by fertilizer application. Mean stem diameter increased with plant age. Stem diameter was significantly affected by fertilizer application at 3 WAT and 9 WAT. The highest stem diameter was obtained in T1 (7.88 mm) and lowest in T3 (5.78 mm). Stem diameter was observed to increase in the following order T1 > T2 > T4 >T3.

The effects of fertilizer on number of leaves of *Solanum macrocarpon* are shown in Table 5. Significant differences were observed among the different treatments from the 3 WAT to 6 WAT. The number of leaves increased with plant age up till 6 WAT, however at 7 WAT, plant leaves reduced before they began to increase steadily from 8 WAT till the end of the experiment. The number of leaves was highest in T1 while the lowest was obtained in T3. Leaf number was observed to increase in the following order T1 > T2 > T4 >T3.

The biomass yield of *S. macrocarpon* seedlings as affected by fertilizer application is shown in Table 6. In the present study, the highest fresh shoot yield was obtained in T1 followed by T2, however the lowest was obtained in T3, the highest fresh root yield was obtained in T2 while the lowest was obtained in T4.

Table-2. Effect of organic and inorganic fertilizer on leaf area (cm^2) of *Solanum macrocarpon*

Plant Age (WAT)							
	3	**4**	**5**	**6**	**7**	**8**	**9**
T_1	208.40 ± 7.98^a	361.36 ± 22.46^b	384.31 ± 21.83^a	430.31 ± 49.26^a	445.75 ± 57.09^a	453.19 ± 58.11^a	477.97 ± 56.07^a
T_2	273.19 ± 66.54^a	331.28 ± 67.08^b	355.12 ± 70.86^a	368.17 ± 74.03^a	373.37 ±75.79^a	384.05 ± 79.80^a	398.23 ± 84.70^a
T_3	233.31 ± 40.84^a	256.14 ± 51.58^b	293.07 ± 56.37^a	306.46 ± 52.62^a	328.00 ± 61.84^a	341.10 ± 64.99^a	354.50 ± 71.89^a
T_4	170.51 ± 39.35^a	150.21 ± 29.77^a	219.12 ± 37.43^a	248.07 ± 49.88^a	272.57 ± 52.03^a	288.98 ± 54.82^a	297.18 ± 56.45^a

* WAT: Weeks after Transplanting. Values shown are mean ± S.E. Means with different letters along the same column represent significant differences at P < 0.05.

Table-3. Effect of organic and inorganic fertilizer on plant height (cm) of *Solanum macrocarpon*

Plant Age (WAT)							
	3	**4**	**5**	**6**	**7**	**8**	**9**
T_1	17.58 ± 3.54^a	24.18 ± 3.12^b	25.90 ± 3.42^a	26.75 ± 1.82^a	26.68 ± 4.21^b	28.63 ± 4.66^a	30.30 ± 5.32^a
T_2	16.25 ± 1.61^a	19.45 ± 1.37^{ab}	20.18 ± 1.42^{ab}	24.53 ± 3.05^a	21.40 ± 1.34^{ab}	22.70 ± 1.64^{ab}	23.23 ± 1.79^a
T_3	16.23 ± 0.63^a	18.28 ± 0.98^{ab}	19.28 ± 1.21^{ab}	22.13 ± 2.19^a	19.93 ± 1.49ab	20.68 ± 1.41^{ab}	21.15 ± 1.42^a
T_4	12.68 ± 0.59^a	14.23 ± 1.11^a	15.85 ± 1.38^b	19.98 ± 2.38^a	17.28 ± 2.18^a	18.68 ± 2.78^b	19.58 ± 2.91^a

* WAT: Weeks after Transplanting. Values shown are mean ± S.E. Means with different letters along the same column represent significant differences at P < 0.05.

Table-4. Effect of organic and inorganic fertilizer on stem diameter (mm) of *Solanum macrocarpon*

Plant Age (WAT)							
	3	**4**	**5**	**6**	**7**	**8**	**9**
T_1	5.01 ± 0.62^b	5.52 ± 0.95 ^{a}	5.93 ± 1.05^a	6.52 ± 0.89^a	6.70 ± 0.94^a	7.36 ± 0.74^a	7.88 ± 0.81^b
T_2	4.31 ± 2.37^b	5.09 ± 0.36^a	5.60 ± 0.42^a	5.52 ± 0.64^a	5.68 ± 0.64^a	6.11 ± 0.60^a	6.59 ± 0.51^{ab}
T_3	2.74 ± 0.13^a	4.13 ± 0.19^a	4.61 ± 0.37^a	4.79 ± 0.49^a	5.02 ± 61.84^a	5.35 ± 0.63^a	5.73 ± 0.65^a
T_4	2.29 ± 0.24^a	3.73 ± 0.32^a	4.17 ± 0.23^a	4.76 ± 0.25^a	4.99 ± 0.31^a	5.42 ± 0.46^a	5.78 ± 0.49^a

* WAT: Weeks after Transplanting. Values shown are mean ± S.E. Means with different letters along the same column represent significant differences at P < 0.05.

Table-5. Effect of organic and inorganic fertilizer on number of leaves of *Solanum macrocarpon*

Plant Age (WAT)							
	3	4	5	6	7	8	9
T_1	11.50 ± 1.44[b]	12.00 ± 1.47[b]	12.50 ± 1.26[ab]	11.75 ± 0.85[a]	8.25 ± 1.44[a]	9.50 ± 2.25[a]	9.75 ± 2.72[a]
T_2	14.00 ± 0.91[b]	14.75 ± 0.63[b]	13.50 ± 1.66[b]	13.00 ± 2.12[a]	11.75 ± 2.39[a]	9.50 ± 1.44[a]	9.00 ± 1.29[a]
T_3	8.00 ± 1.00[a]	8.75 ± 1.11[a]	9.50 ± 1.66[a]	8.00 ± 1.41[a]	8.25 ± 1.65[a]	7.25 ± 0.75[a]	6.75 ± 0.75[a]
T_4	7.50 ± 0.65[a]	8.25 ± 0.63[a]	8.50 ± 0.29[a]	8.25 ± 0.85[a]	8.25 ± 0.85[a]	8.25 ± 0.85[a]	9.25 ± 0.48[a]

* WAT: Weeks after Transplanting. Values shown are mean ± S.E. Means with different letters along the same column represent significant differences at $P < 0.05$

Table-6. Biomass production of *Solanum macrocarpon* under different fertilizer applications

Treatment	Fresh shoot	Fresh root	Dry shoot	Dry root
T_1	30.50 ± 11.18[a]	5.00 ± 1.29[a]	4.35 ± 0.002[a]	3.00 ± 0.001[a]
T_2	19.00 ± 3.87[a]	5.50 ± 1.71[a]	5.35 ± 0.001[a]	2.04 ± 0.001[a]
T_3	16.00 ± 4.24[a]	3.50 ± 0.50[a]	3.06 ± 0.001[a]	1.53 ± 0.001[a]
T_4	17.50 ± 4.99[a]	3.00 ± 0.58[a]	3.11 ± 0.001[a]	1.01 ± 0.001[a]

* Means within a row with same superscripts indicate that they are not significantly different ($P<0.05$)

3.2. Effect of Fertilizer Application on the Proximate and Mineral Composition of Leaves of *S. macrocarpon*

The proximate composition was significantly affected by fertilizer application (Table 7). Moisture concentration was highest in plants treated with a combination of both NPK and poultry manure (9.70 %) closely followed by the control plants (9.57 %). The ash content (17.13 %) was highest in plants treated with NPK only followed by those treated with poultry manure only (16.33 %) while the least was obtained in control (15.85 %). The fat content was much lower compared to the other proximate factors studied, among the fertilizer treatments, fat content was relatively high in plants treated with poultry manure only (3.88 %) followed by those treated with NPK only (3.64 %). Control plants produced plants with the lowest fat content (2.86 %). The highest protein value was obtained in plants treated singly with NPK (20.45 %) while the lowest was obtained in control (17.33 %). The crude fibre content was highest in poultry manure treated plants (9.85 %) closely followed by NPK and poultry manure (9.50 %) and NPK only (9.30 %) while the least was obtained in the control. However, carbohydrate (45.14 %) was highest in control plants with the least recorded in plants treated with NPK only (40.59 %). The carbohydrate content of *S. macrocarpon* ranked highest among the proximate factors studied.

The mineral composition of *S. macrocarpon* varied significantly among the different fertilizer treatments and the control (Table 8). The mineral composition value is presented in the following order K>Ca>P>Mg>Na. Among the macro-minerals, potassium (4875 mg/100g) and calcium (2930 mg/100g) recorded significantly higher values than to those of phosphorus (408.40 mg/100g), magnesium (384 mg/100g) and sodium (92.25 mg/100g) among the fertilizer treatments. The highest value of potassium was obtained in plants treated with a combination of NPK and poultry manure (4875 mg/100g) followed by plants treated with NPK only (4636.67 mg/100g) while the least was obtained in the control plants (2800 mg/100g). Furthermore, calcium was highest in control plants (2930 mg/100g) closely followed by plants treated with poultry manure only (2423.33 mg/100g) while plants treated with NPK only (1660 mg/100g) recorded the least value. Phosphorus recorded its highest value in plants treated with poultry manure only (408.40 mg/100g) while the least was control plants (365 mg/100g). However, control plants recorded the highest value of magnesium (384 mg/100g) followed by poultry manure treated plants (371 mg/100g) while the least value was that of NPK and poultry manure (366 mg/100g). Sodium was highest in poultry manure (92.25 mg/100g) treated plants while the least value was obtained in control plants (62.50 mg/100g).

Furthermore, iron was highest in NPK (215 mg/100g) treated plants while the least value was obtained in control plants (186.43 mg/100g). Zinc was also highest in NPK (6.34 mg/100g) treated plants while the least value was obtained in NPK and poultry manure treated plants (62.50 mg/100g). However, copper (1.76 mg/100g) and magnesium (20.62 mg/100g) were both highest in plants treated singly with poultry manure and also lowest in plant treated with NPK only.

Generally, the vitamin A content was lower compared to the vitamin C content (Table 7). However, the vitamin A content was highest in the control plants (0.73 mg/100g) followed by plants treated with a combination of NPK and poultry manure (0.73 mg/100g) while the least was obtained in plants treated singly with NPK (0.54 mg/100g). The vitamin C content was highest in the control (92.57 mg/100g) followed by 82.31 mg/100g in poultry manure treated plants while the least was obtained in NPK treated plants (75.50 %).

Table-7. Proximate composition (%) of leaves of *Solanum macrocarpon* as affected by organic and inorganic fertilizer

	Fertilizer Application			
Parameters	**NPK (T_1)**	**PM (T_2)**	**NPK & PM(T_3)**	**CONTROL(T_4)**
Moisture	8.93 ± 0.02^b	8.18 ± 0.05^a	9.70 ± 0.04^c	9.57 ± 0.04^c
Fat	3.64 ± 0.02^c	3.88 ± 0.05^d	3.25 ± 0.09^b	2.84 ± 0.03^d
Ash	17.13 ± 0.04^d	16.33 ± 0.03^c	16.21 ± 0.03^b	15.89 ± 0.02^a
Protein	20.45 ± 0.06^d	18.07 ± 0.04^b	18.64 ± 0.02^b	17.33 ± 0.02^a
Crude fibre	9.31 ± 0.02^b	9.85 ± 0.02^d	9.50 ± 0.02^b	9.24 ± 0.02^a
Carbohydrate	40.59 ± 0.05^a	43.51 ± 0.04^c	42.68 ± 0.14^b	45.14 ± 0.01^d

*Values shown are mean ± S.E of triplicate analysis. Means with different letters along the same column represent significant differences at $p < 0.05$.

Table-8. Mineral Composition (mg/100g) of *Solanum macrocarpon* as affected by organic and inorganic fertilizer

	Fertilizer Application			
Parameters	**NPK (T_1)**	**PM (T_2)**	**NPK & PM(T_3)**	**CONTROL(T_4)**
Na	73.00 ± 0.29^b	92.25 ± 0.14^d	87.07 ± 0.47^c	63.50 ± 0.58^a
Ca	1660.00 ± 5.77^a	2423 ± 14.53^c	2210.00 ± 2.89^b	2940.00 ± 23.09^d
K	4636.67 ± 8.82^c	4370.00 ± 2.89^b	4875.00 ± 3.46^d	2750.00 ± 57.74^a
Mg	355.33 ± 2.91^a	371.00 ± 0.58^b	366.00 ± 3.46^b	380.00 ± 1.73^c
P	375.63 ± 2.80^b	408.40 ± 0.96^d	382.60 ± 0.70^c	378.13 ± 1.42^a
Fe	215.00 ± 2.89^d	195.00 ± 2.89^b	203.67 ± 1.45^c	186.43 ± 0.87^a
Zn	6.34 ± 0.06^a	5.35 ± 0.04^b	4.75 ± 0.03^c	5.30 ± 0.06^b
Mn	12.40 ± 0.03^a	20.62 ± 0.17^d	18.73 ± 0.09^c	13.37 ± 0.01^b
Cu	1.65 ± 0.01^a	1.76 ± 0.01^c	1.74 ± 0.01^{bc}	1.72 ± 0.01^b
Vitamin A	0.54 ± 0.01^a	0.64 ± 0.02^c	0.66 ± 0.12^b	0.74 ± 0.01^d
Vitamin C	75.50 ± 0.51^a	82.31 ± 0.18^b	80.47 ± 0.15^b	92.71 ± 0.09^c

* Values shown are mean ± S.E of triplicate analysis. Means with different letters along the same column represent significant differences at $p < 0.05$.

4. Discussion

Critical to understanding the water and nutrient use of any plant species as well as their growth and yield potential is its leaf area [21]. A plant's surface area for sunlight impingement during photosynthesis is a function of its leaf area. In the present study, leaf area was highest in plants treated with inorganic fertilizer followed by those treated with poultry manure. In a similar study by Bvenura and Afolayan [3], the leaf area of *Solanum nigrum* was found to be highest (88.48 cm^2) in plants treated with 50 kg N/ha and 4.07 t manure/ha, this is lesser compared to the present study where plants treated with manure 100 kg/ha + 3 t/ha had a mean leaf area of 354.50 cm^2. The large difference can be attributed to the morphology of the leaves as *Solanum macrocarpon* posses very large leaves with extensive surface area when compared to the relatively small leaves of *Solanum nigrum*. Plant nutrition, plant-soil-water relations, plant protection measures, plant competition, respiration, light reflectance as well as heat transfer are usually determined by a plant's leaf area [22]. Therefore, in order to understand water and nutrient use, photosynthesis, light interception, crop growth and yield of a plant, it is important to estimate its leaf area. The leaf has been described as the main organ of the plant as it is involved in the photosynthetic activity and also the sink for plant nutrients [23].

Plant height was significantly affected by the different fertilizer treatments. The highest height was obtained in plants treated with inorganic fertilizer. This is contrary to the study of Farhad, *et al.* [6] where the highest plant height was recorded in soils treated with manure. It should be noted however that maize plant has been reported to respond positively to organic manure application by several authors [24]. Nitrogen, phosphorus and potassium present in the inorganic fertilizer are usually readily available to the plants as they get easily mineralized into the soil in order to promote vigorous vegetative growth. The lowest plant height obtained in the control plant may be due to the fact that the plant had to rely on the native minerals present in the soil since there was no fertilizer application to them. This agrees with the findings of Ng'etich, *et al.* [25] which stated that nitrogen fertilization enhanced the vegetative growth of plants especially by increasing the yield of most leafy vegetables.

Stem diameter was positively affected by fertilizer application. This observation is in line with the reports of Sowunmi [17] and Otitoju, *et al.* [24] who observed increase in stem diameters of *Cleome gynandra* and *Zea mays* respectively with fertilizer application respectively Bvenura and Afolayan [3] reported a stem diameter of 7.35 mm in *Solanum nigrum* and also Ondieki, *et al.* [26] obtained a smaller stem diameter (6.64 mm) in *Solanum scabrum* when compared with the highest stem diameter value (7.88 mm) reported in the current study. The transport of materials in plants are carried out within the stems and as such healthy plant stems are necessary to aid distribution of fluids to the root and shoot, store nutrients, support leaves and flowers as well as produce new tissues [27], plant stems also function to support and elevate leaves, flowers as well as fruits [28].

Leaf number increased with plant age. Increase in leaf number is a measure of a crop yield and productivity. Olatunji and Ayuba [29], opined that application of NPK fertilizer produced a higher yield of maize. In the same vein, Olaniyan and Nwachukwu [30] observed highest number of leaves in *Solanum macrocarpon* treated with inorganic fertilizer and the lowest in control, this is in agreement with the findings from this study. The authors stated further that the number of leaves affect dry matter production, edible and economic yields of *Solanum* *macrocarpon*. Adeyeye, *et al.* [31], also attributed the high shoot yield of *Solanum macrocarpon* to the ability of NPK fertilizer to release nutrient elements quickly for plant uptake. This agrees with the findings from this study as plants treated with NPK fertilizer also produced the highest number (9.75) of leaves and fresh shoot yield (30.30 g).

Several authors have reported effect of organic and inorganic fertilizer on proximate and mineral composition of plants [32-35]. The present study on effect of organic and inorganic fertilizers on proximate and mineral composition of *Solanum macrocarpon* revealed that inorganic fertilizer produced higher effects when compared with organic fertilizer and other treatments. The result of the present study is consistent with the findings of Bvenura and Afolayan [3] on *Solanum nigrum*. These higher effects could be due to the ease with which the nutrients in NPK fertilizers are released into the soil for absorption by the plants. However, the nutrients in organic material are less easily available as decomposition and mineralization must take place [36] before absorption by plants. A study by Nordeide, *et al.* [37] has also reported that variations in the nutrient compositions of edible plants are influenced by various factors including farming practices, prevailing environmental conditions including soil manipulation using organic and inorganic fertilizers and the age of the plants at harvest.

Percentage moisture content and potassium were significantly highest in plants treated with combination of both organic and inorganic fertilizer when compared to sole application of both fertilizer types alone and the control, this is consistent with the findings of Ayinla, *et al.* [38] in their study on *Corchorus olitorius*. In a study by Makinde, *et al.* [35] application of organic fertilizer alone and in combination with inorganic fertilizer (NPK) significantly increased crude protein and ash while crude fibre was reduced. The inorganic fertilizer only gave least values of crude protein, crude fibre and ash compared with organic mineral applied. This is contrary to the findings of the present study as the crude protein and ash content was highest in plants treated with NPK only. Their study established that organic material alone or integrated with NPK increased nutritive quality of *Amaranthus*. The present study stated that the highest protein value was obtained in plants treated singly with NPK, this is consistent with the findings of Oyedeji, *et al.* [39] who reported higher crude fibre, lipid and protein content in *Amaranthus deflexus, Amaranthus hybridus and Amaranthus cruentus* grown in NPK-treated soil was significantly higher than that of other treatments. The carbohydrate contents in the *Amaranthus* grown with NPK were significantly lower than the control and poultry manure. The moisture contents were also significantly lower than the control, these results were found to be consistent with the findings of the present study.

The mineral compositions and quality of vegetables is dependent on the interactions of many factors which include genetic makeup, climatic conditions, stage of maturity, soil and type of fertilizer used for cultivation, harvesting, handling, storage and processing of the vegetable plants [40]. These factors may possibly have led to differences in lipid concentrations reported in the present study. In the current study, the mineral composition of *S. macrocarpon* was significantly affected by different fertilizer application. Funda, *et al.* [34], studied the effect of organic and inorganic fertilizers on yield and mineral content of onion and reported that the treatments influenced K content, but did not influence of major elemental composition of onion bulb. Also Fatma, *et al.* [41] in their study observed that the mixture of chicken manure and biofertilizer increased the yield of onion and enriched nutrient content in tuber. Arisha, *et al.* [33], stated that organic manures activate many species of living organisms which release phytohormones and may stimulate the plant growth and nutrients, and these organisms need nitrogen for multiplication [42]. In the same vein, Abdelrazzag [43] found that increasing the rate of sheep and chicken manure increased nitrogen content of onion significantly, while P and K contents had low level. In the present study, the highest value of K was obtained in plants treated with a combination of NPK and poultry manure, this is in agreement with the findings of Ilupeju, *et al.* [44] who reported highest values of K and P in *Lycopersicon esculentum* treated with a combination of organic and inorganic fertilizer. As stated by Jones, *et al.* [14], the availability of phosphorus in the fertilizers helps to enhance the nitrogen absorption in order to promote vegetative production

Combined application of poultry manure and inorganic manure has been shown to integrate the beneficial attributes of both [45]. In the current study, calcium and magnesium were highest in control plants, this agrees with the findings of Aliyu [46] who observed that calcium and magnesium concentrations in fruits were not affected by fertilizer application. This corroborates the assertion that functioning leaves and fruits is a characteristic of the crop and fairly independent of the soil or fertilization [47].

Bvenura and Afolayan [3], have opined that vitamin C is the most important vitamin in fruits and vegetables for human nutrition and that the addition of inorganic fertilizer increased the vitamin C content as compared to organic fertilizer alone. However in this study, a higher concentration of vitamin C was recorded in the control compared to vitamin C. Vitamin C is known to be natural anti-oxidant agents with rich sources of metabolites [3]. Hallberg, *et al.* [48], opined that high concentration of vitamin C promotes absorption of soluble non-haemolytic iron through chelation or by maintaining the iron in the reduced Fe^{2+} form. Vitamin A in *S. macrocarpon* is fat-soluble and its presence will help aid good vision, reproduction and promote the functioning of the heart, liver and kidney of man when consumed.

5. Conclusion

Consequent on the results obtained in this study, it can be concluded that different fertilizer rates had different effects on the growth and yield of *Solanum macrocarpon*. The results further indicate that the application of fertilizers in *Solanum macrocarpon* cultivation indeed improves the yield and quality of the plant and also enhances development. Furthermore, the single application of 200 kg /ha of inorganic fertilizer significantly improved the leaf area, yield (number of leaves), stem diameter and plant height. The application of organic fertilizer therefore produced good results in terms of the growth parameters studied, and thus serves as good alternative to resourcepoor small scale farmers who may not be able to purchase inorganic fertilizers in large quantities as required during cultivation, however for optimum economic yield and increased market value of *Solanum macrocarpon*, inorganic fertilizer is advised. Furthermore, both inorganic fertilizer (NPK) and organic (PM) increased soil fertility and improved the nutritional composition, but *Solanum macrocrapon* plants grown but inorganic fertilizer performed better.

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