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The Use of *Tithonia diversifolia* L. as Soil Amendment and Its Effect on the Growth and Yield of *Amaranthus cruentus* in a Tropical Rain Forest Belt

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OSS and OOO designed the study. Author OSS wrote the protocol and wrote the first draft of the manuscript. Authors MMO and AKS managed the literature searches and analyses of the study. Author OOO managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

The effect of the use of *Tithonia diversifolia* as soil amendments on the growth and yield of *Amarantus cruentus* was investigated under field conditions at the Teaching and Research Farm of Joseph Ayo Babalola University, Ikeji-Arakeji, Nigeria. *Tithonia diversifolia*, Pig slurry and Urea were used for soil treatments. *Tithonia diversifolia* and Pig slurry were applied at the rate of 4,500 kgh^{-1} while Urea was applied at the rate of 250 kgh^{-1}. The treatments were replicated three times using Complete Randomized Design (CRD). The soil of the experimental site was analyzed before planting and after harvesting of the vegetable. Agronomic data on plant height, stem girth,

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number of leaves, leaf area, leaf length and width were collected at 19, 22, 25 and 28 days after planting (DAP). Data collected were subjected to analysis of variance (ANOVA) and the means were separated using Duncan multiple range test at 5% probability level. The results showed that plant height, stem diameter, leaf width and leaf area index were significantly influenced by the application of both the organic manures and the urea fertilizer. At 19 days after planting (DAP), the plant height recorded were 14.22 cm, 12.87 cm, 12.53 cm and 10.52 cm for *Tithonia diversifolia*, pig slurry, urea and the control respectively. From the study, it was evident that organic manures compete favorably with the mineral fertilizer. *Tithonia diversifolia* performed better in most of the growth parameters taken while the performance of urea does not significantly different from that of pig slurry. The post-harvest pH values of the soil ranged from 6.70 to 6.78, indicating that the soil was slightly acidic. A slight increase in phosphorus content of the soil in the plot where *Tithonia diversifolia* and urea were applied was observed while a decrease trend was noticed in plots where Pig slurry was applied. The result from this study shows that it is expedient to make amendment to soils in the tropical regions using readily available local resources such as *Tithonia diversifolia* as organic manures to improve its fertility instead of spending huge amount of money on the purchase of synthetic fertilizer.

Keywords: Soil amendment; Amaranthus cruentus; Tithonia diversifolia; pig slurry; urea.

1. INTRODUCTION

The Federal Government of Nigeria since 2011 has continued with the implementation of the Agricultural Transformation Action Plan (ATAP) under the Growth Enhancement Support Scheme (GESS) with the aim of improving agricultural production as a measure toward socio-economic development. Several agricultural policies and institutional support programmes especially the creation of a reliable database for effective distribution of inorganic fertilizer and other agricultural input were lunched under the scheme. In 2012 the aggregate index of agricultural production increased by 4.0 per cent. The growth recorded in 2012 was lower than both the 5.7 per cent in 2011 and the national sectorial target of 8.0 per cent [1]. Decrease in soil fertility after few years of cropping and subsequent high rate of application of inorganic fertilizer without soil test are major limitation towards the achievement of sustainable high yield of crops and vegetables [2,3]. High rate application of inorganic fertilizer will adversely affects soil chemical and physical properties causing nutrient imbalance, increase in soil bulk density and low infiltration rate [4]. These above mentioned factors are hindrances toward the uptake of nutrients by plant. South west Nigeria soils, mainly Alfisols and Ultisols are composed of low activity clays characterized by low nutrient content, low PH, low organic matter content and high susceptibility to erosion [5]. In an attempt to correct the deficiencies of nutrient elements and boost production, application of inorganic fertilizer constitutes major practice by farmers. Demonstrated yield increase from the use of chemical fertilizer is reported widely [6,7,8,9], but its continuous use contributes significantly to soil acidity [10] which limits crop production in many tropical soils [11]. There is therefore the need to focus on alternative sources of soil amendments that will be less damaging to the soil and yet compete favourably with inorganic fertilizer in improving soil fertility. In Southwestern Nigeria, poultry manure has been used more than any other organic types of manure but recent increase in the cost of poultry feeds, transportation problems, poor returns and the risks of mortality associated with poultry farming in Nigeria, limit their use as fertilizer. In addition, the quantity of the organic waste required to raise soil fertility to the required level when compared with inorganic fertilizer make it not a suitable substitute. Consideration is therefore given to the use of plant residues as there is an increased interest in its use as source of plant nutrients [12]. Plant residues are often used because they are less likely to have detrimental effect on soil physical and chemical properties. One of such plant recommended by researchers is *Tithonia diversifolia* (Mexican sunflower) [13,14]. Olabode et al. [15] determined *Tithonia*'s N concentration as 1.76%; P, 0.82%; K, 3.92% and this support the report of Gaghenco et al. [16] that the leaves contain 3.5, 0.37 and 4.1% N, P and K respectively and that it decomposes very fast after incorporation into the soil. *Tithonia diversifolia* with its high nutrient status was seen as potential soil improver and recommended as a green manure or as a major component of compost manure by Olabode et al. [15]. Malama, [17] reported that *Tithonia* improved available soil phosphorous and its

uptake by maize on acid soils of Northern Zambia and recommended it as a cheap and effective method of ameliorating soil acidity in Northern Zambia. However, information on the effect of *Tithonia diversifolia* as soil amendments on the growth and yield of *Amaranthus cruentus* in the tropical rain forest zone of western Nigeria is unavailable, hence the need for this investigation. This study is therefore aimed at evaluating the use of *Tithonia diversifolia* in Tropical Rainforest zone of Nigeria for soil fertility improvement with the intent of recommending to farmers and other end users the effect of these findings on the growth and yield of *Amaranthus cruentus*.

2. MATERIALS AND METHODS

2.1 Description of the Project Site

The study was conducted from May-July, 2014 in the Teaching and Research Farm of Joseph Ayo Babalola University, Ikeji-Arakeji, Osun State, Nigeria. Ikeji Arakeji lies between latitude 7°16' and 7°18' North and longitude 5° 09' and 5° 11' in the rain forest belt of the tropics. It is characterized by a gentle undulating elevation of about 1150 m - 1250 m and has a tropical climate with distinct wet and dry seasons. A warm rainy season spans April to October followed by a hot dry period from November to March. The annual rainfall ranges from 1405 to 2400 mm with August as the wettest month and November as the driest month. The average monthly temperature is 26.5°C; a maximum temperature of 36°C is recorded during the dry season while the minimum temperature is about 27°C. The town has humidity range of 56 and 59% during the dry season and about 51-82% during the wet season with average sunshine of 4.5 hours which varies between 1.8 hours and 5.9 hours. The shortest hours are in August while the longest is in September. Generally, the topsoil is composed of sand varying from 76-85%. Profile analysis (0-40 cm) from a number of locations within the study area shows clay-loam.

2.2 Treatments Preparation

2.2.1 *Tithonia diversifolia*

The *Tithonia diversifolia* used for the experiment was collected from the University environment. *Tithonia diversifolia* was chopped with table size knife into small pieces to aid decomposition and weighed before application. Sample of the *Tithonia diversifolia* was taken to the laboratory for analyses.

2.2.2 Pig manure

The pig manure used for the study was collected from the Animal Farm Unit of the Teaching and Research Farm of Joseph Ayo Babalola University (JABU). This manure was sun-dried for 10 days to prevent immediate decomposition, and then stored in bags under dry conditions following the method of Ikpe [18]. After sun-drying, the pig manure was thoroughly mixed together and the sub-sample taken to the laboratory for analyses. The sample was analyzed for total N, P and K, organic carbon, organic matter, C: N ratio, Ca and Mg.

2.2.3 Inorganic fertilizer

The inorganic fertilizer i.e. urea used for the experiment was purchased from agrochemical retails store within the State.

2.2.4 Seed source

The *Amaranthus* seeds used were bought from a seed distributor shop.

2.3 Land Preparation, Experimental Design and Layout

The land was manually slashed. Flat beds measuring 2 m x 2 m were manually made using a spade. The experiment was laid in Complete Randomized design (CRD) with the three accessions representing three treatments. The plot size was 2m x 2m replicated three times with an alley of 1m between blocks and 1m between plots.

Treatments were randomly assigned to the plots in each block using the Table for Random Numbers. The organic manures (*Tithonia diversifolia* and pig manure) were incorporated into the soil at the rate of 4,500kgh^{-1} during seed bed preparation for speedy decomposition. The inorganic manure was applied at the rate of 250 kgh^{-1}, two weeks after planting.

Amaranthus seeds were sown using broadcasting method. The plots were watered before planting and immediately after planting to ensure and enhance sprouting. Sprouting occurred 4 days after planting. The seedlings were later thinned down to one plant per stand

few days after emergence with a spacing of 10 cm maintained between plants.

2.4 Management Practices

The management practice carried out on the experimental field is mainly weeding; routine hand picking of weeds as and when observed was carried out. There was minimal weed invasion on the plots due to sowing of seeds on the seed beds.

2.5 Data Collection and Analysis

Agronomic parameters such as plant height, Leaf Area Index (LAI), number of leaves, leaf length and leaf width were measured at two days interval right from two weeks after planting.

Plant height was measured with a meter rule as the height from the base of the crop (ground level) to the tip of the plant. The number of leaves was taken to be the fully opened leaves per plant while stem girth was measured using thread and meter rule method [19]. Thread was used to determine the circumference of the stem and then measure over a meter rule. Leaf area index was taken by multiplying the leaf length with the leaf width (A=L x W), where A is the area, L is leaf length and W is the width.

Analysis of variance was carried out on data collected and means separated using Duncan's multiple range tests at 5% level of probability.

2.5.1 Physical and chemical analyses of soil samples

Pre-cropping chemical analysis of the experimental soil was carried out before land preparation and repeated at the first, second and third harvests to determine the nutrient status of the soil. The soil samples were air dried, crushed and sieved to pass through a 2 mm sieve after which physical analysis was carried out using the hydrometer method. Total N was analyzed using the macro Kjeldahl procedure; Organic carbon analysis was done using the Walkley and Black procedure [20].

The organic matter content was derived by multiplying organic carbon content by 1.72; Soil pH was determined in soil/water ratio of 1:2 using a pH meter with glass electrode [21]; available phosphorus was by the Bray 1 method; exchangeable acidity was determined by the titration method, exchangeable K, Ca and Mg were determined by extraction with ammonium acetate at pH 7.0 and the amounts of K, and Ca in the filtrate were determined using a Corning flame photometer with appropriate filter, while Mg was determined by using a Perkin-Elmer Atomic Absorption Spectrophotometer (AAS); micronutrients: Cu, Zn, Mn and Fe were determined after extraction of the soil sample with 0.1 M HCl and the filtrate read on Perkin-Elmer AAS; and Effective Cation Exchangeable Capacity (ECEC) of the soil samples was determined by the summation of all the cations and the exchangeable acidity.

2.5.2 Treatment proximate analysis

Samples of *Tithonia diversifolia* and pig slurry were taken for proximate analysis in order to determine the nutrient content of the manure.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Effect of *Tithonia* diversifolia (T.D), Pig slurry and inorganic fertilizer on the height of *Amaranthus cruentus*

The effect of T.D, Pig slurry and urea fertilizer on the height of *Amaranthus cruentus* is presented in Table 1.

The result showed that there were significant differences (P>0.05) among the treatments. At 19 days after planting (DAP), the height values recorded were 14.22 cm, 12.87 cm, 12.53 cm and 10.52 cm for *Tithonia diversifolia,* pig slurry, urea and the control respectively. However, there was no significant difference in the mean values recorded for *T. diversifolia* and pig slurry at 22 DAP. At that 22 DAP the highest plant height of 17.85 cm was recorded for *T. diversifolia* while the least (15.13 cm) was recorded for the control. There was no significant difference in the mean values recorded for *T. diversifolia* and urea at 25 DAP while the least plant height of 19.20 cm was recorded for control. At 28 DAP, T.D had the highest plant height (24.06 cm) which was not significantly different from *Urea* (23.70 cm).

3.1.2 Effect of T.D, Pig slurry and inorganic fertilizers on number of leaves of *Amaranthus cruentus*

The effect of T.D, Pig slurry and urea fertilizer on the number of leaves per plant of *Amaranthus cruentus* is presented in Table 2.

Throughout the growing season, there was no significant difference in the number of leaves per plant among the treatments at the different dates. This indicates that the pig slurry, *Tithonia diversifolia* and the urea fertilizer applied had no effect on the number of leaves per plant.

3.1.3 Effect of T.D, Pig slurry and inorganic fertilizers on stem girth of *Amaranthus cruentus*

The effect of the T.D, Pig slurry and urea fertilizer on stem girth of *Amaranthus cruentus* is presented in Table 3.

There was no significant difference in the stem girth of *Amaranthus cruentus* at 19 days after planting. At 22 days after planting, there were significant differences in the stem girth with *T. diversifolia* having the highest value (1.39 cm) which was significantly higher than the mean values recorded for pig slurry (0.74 cm) and the control (0.87 cm). No statistically different means were recorded for the stem girth at 25 DAP and 28 DAP, *T. diversifolia* however recorded the highest stem girth 1.88 cm and 1.91 cm at 25 DAP and 28 DAP respectively.

3.1.4 Effect of organic and inorganic fertilizers on leaf width of *Amaranthus cruentus*

The effect of organic manures and urea fertilizer on the height of *Amaranthus cruentus* is shown in Table 4.

There was no significant difference in the leaf width of *A. cruentus* at 19 days after planting. At 22 days after planting, significant differences were observed in the leaf width with the T.D having the highest value of 4.43 cm which was

Table 1. Effect of T.D, Pig slurry and inorganic fertilizers on height (cm) of *Amaranthus cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	14.22[a]	17.85[a]	21.73[a]	24.06[a]
Pig slurry	12.87[ab]	16.72[ab]	19.50[b]	19.57[b]
Urea	12.53[b]	16.34[b]	21.07[ab]	23.70[ab]
Control	10.52[c]	15.13[c]	19.20[c]	19.30[c]

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

Table 2. Effect of T.D, Pig slurry and inorganic fertilizers on number of leaves of *Amaranthus cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	7.70[b]	7.80[a]	8.43[c]	18.5[b]
Pig slurry	6.80[b]	7.50[a]	8.57[c]	9.13[b]
Urea	7.30[b]	7.43[a]	9.06[c]	9.13[b]
Control	7.37[b]	7.47[a]	9.27[c]	9.37[b]

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

Table 3. Effect of T.D, Pig slurry and inorganic fertilizers on stem girth (cm) of *Amaranthus cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	1.96[b]	1.39[a]	1.88[c]	1.91[b]
Pig slurry	0.71[b]	0.74[c]	1.46[c]	1.36[b]
Urea	1.14[b]	1.12[ab]	1.61[c]	1.76[b]
Control	0.71[b]	0.87[b]	1.71[c]	1.79[b]

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

not significantly different from pig slurry (4.17 cm) while the least mean value of 3.51 cm was recorded for urea. There was no significant difference in the mean values recorded for leaf width at 25 and 28 DAP.

3.1.5 Effect of organic and inorganic fertilizers on the leaf length of *Amaranthus cruentus*

The effect of the organic manures and urea fertilizer on leaf length of *Amaranthus cruentus* is presented in Table 5.

Throughout the growing season there was no significant difference in the leaf length among the treatments. This result shows that the organic and inorganic fertilizers applied had no effect on the length of leaves of *Amarantus cruentus* at the different dates.

3.1.6 Effect of organic and inorganic fertilizers on leaf area index of *Amaranthus cruentus*

Table 6 shows the effect of organic manures and urea fertilizer on the leaf area index of *Amaranthus cruentus*. The result showed that there were significant differences (P>0.05) in the mean values of the treatments at 19 days after planting (DAP). The plot treated with pig slurry had the highest mean value (22.53cm^2) which was not significantly different from the value recorded for urea (20.53 cm^2) while the least value (15.34 cm^2) was recorded in the control plot. At 22DAP, *T. diversifolia* had the highest leaf area index of 30.67 cm^2 which is not significantly different from urea (30.23 cm^2) while the control plot had the least leaf area index (23.29 cm^2).

At 25DAP, the highest leaf area index was recorded for the plot treated with pig slurry (45.23 cm^2) while *T. diversifolia* had a mean value of 37.99 cm^2 which was slightly higher than the leaf area index recorded for urea. The least leaf area index (30.76 cm^2) was recorded for the control. At 28 DAP *T. diversifolia* had the highest mean value which was not significantly different from Pig slurry and Urea while the least value was recorded for control.

3.1.7 Pre-planting physical and chemical properties of the soil in the experimental site

The soil of the area is slightly acidic and has low percentage of organic carbon (0.46%) (Table 7). Similarly, the total nitrogen of the area is low as well as available soil phosphorus. The texture of the soil in the area is sandy, clay and loamy. Calcium, magnesium, potassium and effective cation exchange capacity (ECEC) were low but the value of exchangeable acidity was fairly high (1.36 cmol/kg of soil).

Table 4. Effect of organic and inorganic fertilizers on leaf width (cm) of *Amaranthus cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	3.27^{b}	4.43^{a}	5.35^{c}	5.65^{b}
Pig slurry	2.87^{b}	4.17^{ab}	3.28^{c}	4.69^{b}
Urea	3.36^{b}	3.51^{c}	4.10^{c}	5.63^{b}
Control	3.52^{b}	4.03^{b}	4.49^{c}	4.89^{b}

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

Table 5. Effect of organic and inorganic fertilizers on leaf length (cm) of *Amaranthus cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	5.89^{b}	7.46^{c}	8.16^{c}	8.81^{b}
Pig slurry	5.19^{b}	6.98^{c}	7.74^{c}	7.80^{b}
Urea	5.98^{b}	6.41^{c}	9.07^{c}	9.37^{b}
Control	6.31^{b}	6.38^{c}	9.16^{c}	9.20^{b}

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

Table 6. Effect of organic and inorganic fertilizer on leaf area index (cm^2) of *A. cruentus*

Treatment	Days after planting			
	19 DAP	22 DAP	25 DAP	28 DAP
T. D	17.79[b]	30.67[a]	37.99[ab]	52.96[a]
Pig slurry	22.53[a]	29.22[b]	45.23[a]	49.69[a]
Urea	20.53[ab]	30.23[ab]	37.09[b]	47.09[ab]
Control	15.34[c]	23.29[c]	30.76[c]	37.98[c]

**Means in the same column followed by the same letter are not significantly different at P<0.05 according to Duncan multiple range test, T.D = Tithonia diversifolia*

Table 7. Pre-planting physico-chemical properties of the soil of the experimental site

Soil properties	Values
pH (Water)	5.900
Organic carbon (%)	0.460
Organic matter (%)	0.800
Total nitrogen (%)	0.067
Available phosphorus (mg/kg)	3.440
Sand (%)	64.000
Silt (%)	24.000
Clay (%)	12.000
Calcium (cmol/kg of soil)	0.800
Magnesium (cmol/kg of soil)	0.350
Potassium (cmol/kg of soil)	0.150
Sodium (cmol/kg of soil)	0.170
Exchangeable acidity (cmol/kg of soil)	1.360
ECEC	2.830

Textural class: Sand clay loam
ECEC: Effective cation exchangeable capacity

Table 8. Proximate analysis of the treatments

Treatment	% total N (mg/kg)	% total P (ppm)	% total k^+ (cmol/kg)	% total Ca^{2+} (cmol/kg)	% total Na^{2+} (cmol/kg)	% total Mg (cmol/kg)
T.D	1.10	12.08	1.98	0.76	0.57	0.22
Pig manure	1.761	4.76	18	0.005	4.8	-

T.D= Tithonia diversifolia

Table 9. Post-harvest soil physical and chemical properties

Soil properties	Values			
	TD	Pig slurry	Urea	Control
pH	6.500	6.700	6.740	6.200
Organic carbon (%)	1.250	1.364	1.240	1.210
Organic matter (%)	2.156	2.351	2.338	2.110
Total nitrogen (%)	0.196	0.106	0.106	0.061
Available phosphorus (mg/kg)	4.060	2.820	3.520	2.970
Sand (%)	15.000	15.000	15.000	15.000
Silt (%)	85.000	85.000	85.000	85.000
Clay (%)	0.000	0.000	0.000	0.000
Calcium (cmol/kg of soil)	0.024	0.027	0.0225	0.023
Potassium (cmol/kg of soil)	0.008	0.039	0.0026	0.001
Sodium (cmol/kg of soil)	0.005	0.005	0	0

TD- Tithonia diversifolia

3.1.8 Post-harvest physical and chemical properties of the soil

The physical and chemical properties of the soil of the experimental site after harvesting of the vegetable, *Amaranthus cruentus*, is shown in Table 9.

The post- harvest pH values of the soil ranged from 6.20 to 6.74, indicating that the soil was slightly acidic. The result indicates that there was no clay content in the soil sample. It also showed a reduction in sand content from 64% to 15% while there was an increase in silt content from 24% to 85%. Also there was an increase in the organic carbon content as well as organic matter, though still low. There was an increase in the percentage total nitrogen, though this was also low. A slight increase in the phosphorus content of the soil in the plot where *Tithonia diversifolia* and urea were applied was observed but a decrease of the nutrient was noticed in plots where pig slurry was applied.

For calcium, potassium and sodium, the compositions were very low while magnesium content was not traceable by the equipment used for the analysis (PFP7 Jenway Flame Photometer) except for *T. diversifolia*.

3.2 Discussion

The result of application of organic manures (*Tithonia diversifolia* and pig slurry) and urea fertilizers on agronomic parameters of *Amaranthus cruentus* (plant height, stem diameter, leaf width and leaf area index) showed that there were significant differences in the treatments i.e. all the treatments increased the plant height, stem diameter and leaf area index compared to the control. However, application of these treatments did not significantly influence the number of leaves and leaf length of the vegetable.

The post-harvest pH values ranged from 6.50 to 6.74, indicating that the soil was slightly acidic. This promoted good crop growth and development as vegetables generally thrive well on mildly acidic soil [22]. The result obtained from this study is also in consonance with the findings of Mungai et al. [23] who reported optimum growth and development of shallow-rooted crops such as vegetables in slightly acidic soils. Organic matter which was in the range of 2.156 and 2.338 though fairly low was acceptable for excellent vegetable growth [22]. The increase in post-harvesting organic matter content noticed in the treated plots over the pre-planting soil analysis may be due to enrichment by the remains of dead leaves of *T. diversifolia* and decomposition of the pig slurry. This is because these materials enhance the activities of beneficial soil organisms such as earthworms. The higher mean values recorded in the plots treated with *T. diversifolia* and urea may be due to higher percentage of total nitrogen present in the fertilizers as previous studies carried out by Babatola and Olaniyi [24] revealed that 120-160kg Nha^{-1} through urea produced the best growth and yield of *Celosia argentea. The* significant increase in growth and yield attributes with increased nitrogen rate agreed with the findings of Naidoo [25]. The increase may be associated with increase in the rate of photosynthesis as a result of higher leaf chlorophyll synthesis and nutrient efficiency of the vegetable.

According to Olaniyi et al. [8], vegetable cropping system requires a greater degree of management and utilizes a higher nitrogen than most agronomic cropping systems, suggesting that increase in nitrogen rate increases cell size and cell number as a result of cell division and expansion, thus leading to increased stem growth and other vegetative parts of the plant. The positive effect of applied nitrogen rates agrees with the report of Olaniyi [26], where NPK was found to be effective in increasing final yield of melon.

The highest plant height and diameter recorded in the plot where *Tithonia diversifolia* was applied may be due to the fact that *T. diversifolia* accumulates large amounts of nitrogen and phosphorus from the soil when growing and when cut and incorporated into the soil, it releases nearly all its nitrogen to the soil very quickly, even though it is not a legume and this makes it an important source of nutrients and organic matter for soil rejuvenation [27].

The texture of the research plot was an aggregate of sand, clay and loam and this may be attributed to the lithology of the parent material. The distribution of the sand contents in the area might be due to the rate of weathering. Nitrogen, phosphorus, potassium, calcium, magnesium and sodium were low in the study area. This effect may be due to over cropping, leaching of the cations, soil erosion and lack of proper land management practices in the area. The low value of organic carbon may also result

from continuous cropping of the soil without addition of organic matter.

Significant differences were noticed in the pH values of the plot where treatments were applied compared with the control. This may result from specific absorption of humid materials and organic acids (the products of decomposition of organic materials) unto hydrous surfaces of the aluminum and iron oxides by exchange with corresponding release of hydroxyl ion (OH-) [28]. The higher value of organic carbon in the plots where pig slurry was applied may be due to the decomposition of the slurry which may lead to build up of organic matter. Generally, the macro nutrients in the project site are at low levels. This effect might take its source from over cropping, leaching of the cations and soil erosion, based on the cropping history of the plot.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The effects of fertilizer application on the growth, development and yield of *Amaranthus* were visible in the study as shown in the results. From the study, it was evident that organic manures compete favourably with the mineral fertilizer. *Tithonia diversifolia* performed better in most of the growth parameters taken while the performance of urea is not significantly different from that of pig slurry. Indiscriminate application of mineral fertilizers poses great risk on the fragile soils in the tropical regions. Besides, these fertilizers are not readily available and the prohibitive cost limits affordability by the peasant farmers engaged in vegetable production. The risk of accumulation of these chemicals in the farm produce also has a lethal effect on the produce consumers. Thus, organic farming is now being widely advocated all over the world as the sustainable alternative to the use of inorganic fertilizers in crop production. It is therefore expedient to make amendment to soils in the tropical regions using readily available local resources such as *Tithonia diversifolia* to improve its fertility since they compete favourably well with mineral fertilizer.

4.2 Recommendations

i. The use of *Tithonia diversifolia as* organic manure should be encouraged among vegetable farmers for good yield.

ii. Farmers need technical education on how to make use of the available land for crop production through judicious use of organic manure in order to preserve the soil. This can be accomplished through on-farm adaptive research.

iii. Governments at all levels are advised to make scientific findings released by researchers as one of the priorities in their agricultural policies and programs.

iv. There is need to stop wasting organic materials that could be used to increase soil nutrients. *Tithonia diversifolia*, for instance, eliminates the bulkiness and dirtiness associated with animal droppings and it is also readily available for use. As such, there is a need to create awareness on its utilization as manure.

v. Further investigation should be carried out on the influence *Tithonia diversifolia* has on nutritional quality of *Amarantus cruentus*.

vi. Further investigation should also be carried out on the effect of *Tithonia diversifolia* as organic manure on other crops in the Tropics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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