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Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

The nutritional effects of green manure on soil and crop plants depends on residue quality. Hence field experiments were carried out during the cropping seasons of 2015 and 2016 to compare the impact of different green manures and NPK 15-15-15 fertilizer on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench). The experiment each year consisted of four green manure (GM) types {Pawpaw (*Carica papaya* L.) leaves, Neem (*Azadirachta indica* A. Juss.) leaves, Moringa (*Moringa oleifera* Lam.) leaves, and Mesquite (*Prosopis africana* Guill., Perr. & A. Rich) Taubert leaves}, NPK 15-15-15 fertilizer and a control. The six treatments were arranged in a randomized complete block design with four replications. Application of GMs reduced soil bulk density and increased soil organic matter (OM), N, P, K, Ca, Mg, growth and yield of okra compared with the control. NPK fertilizer did not reduce soil bulk density and increase soil OM, but did increase soil N, P, K, Ca, Mg, growth and yield of okra compared with the control. Mesquite increased growth and yield of okra compared with NPK fertilizer and other GMs. This was due to increased availability of N and K in the soil at the level of this treatment. Using the means of the two years and compared with the control and NPK fertilizer, Mesquite increased pod yield of okra by 214 and 53%, respectively. Also GMs and NPK fertilizer increased okra mineral and vitamin C contents compared with the control. Moringa had the best fruit quality in terms of higher K, Ca, Fe, Zn, Cu, and vitamin C contents compared with other GMs and NPK fertilizer. Therefore, for those that desire to grow okra for the quality of its fruits, Moringa (*Moringa oleifera*) is recommended, however for those that desire quantity, Mesquite (*Prosopis africana*) is recommended.

1. Introduction

Vegetables are important food for the maintenance of human health and prevention of body diseases. They contain valuable food ingredients, which can be successfully utilized and repair the body. Vegetables contribute substantially to food security (Yiridoe and Anchirinah, 2005). Overcoming food and nutritional insecurity among women, pregnant and lactating mothers, and children under 5 years of age, remains a challenge in many developing countries in sub-Sahara Africa (Andersen et al., 2003; Kamga et al., 2013). Okra (*Abelmoschus esculentus* (L.) Moench) is a common fruit vegetable grown for domestic consumption in tropical and sub-tropical countries of the world. It is grown in all agro-ecological zones in Nigeria mainly for it immature fruits, which is eaten as a cooked vegetable or added to soups and stews as a thickener (Tindall, 1983; Akanbi, 2002). Leaves, buds and flowers of okra plants are also edible (Olowoake et al., 2015). Potassium, sodium, magnesium and calcium are the principal elements in okra pods, which contain about 12% seeds. The presence of Iron, zinc, manganese and nickel also has been reported. Fresh pods also contain about 30% of recommended levels of vitamin C (16–29 mg), 10–20% of folate (46–88 mg) and about 5% of vitamin A (14–20 RAE) (Gemede et al., 2014; Moyin-Jesu, 2007).

The yield of okra in Nigeria is currently very low about 2 t ha^{-1} (FAO, 2007) owing to low native soil fertility status among other factors. It has been reported that the maintenance of soil organic

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matter (OM) is the basis of sustainable crop production in Nigeria and other tropical countries (Agboola, 1990; Oladipo et al., 2005). With continuous cultivation, soil OM content declines and nutrients are detached and leached out of the rooting zones. One of the ways to restore fertility and increase soil OM content of tropical soils is by green manuring. Green manures are the crops which are returned into the soil in order to improve the growth of subsequent crops. Green manure use has potential to increase production of okra under tropical conditions by maintaining soil density, soil fertility and productivity. Green manure plants are non-polluting, less toxic and biodegradable with no hazardous residues in soil, water and air. They are environmentally safe and generally do not leave residue in stored food product.

In Nigeria savanna, plants such as Neem (*Azadirachta indica* A. Juss.), Mesquite (*Prosopis africana* Guill., Perr. & A. Rich) Taubert, Moringa *(Moringa oleifera* Lam.) and Pawpaw (*Carica papaya* L.) are very common. The use of their leaves as green manure has not been documented. It was reported that application of fresh neem leaves at 5 t ha^{-1} or dry neem leaves at 1.25 t ha^{-1} with urea fertilizer resulted in higher N recovery percent and N response ratio and gave increased grain yield of low land rice compared to the yield obtained due to the application of urea alone (Santhi and Palaniappan, 1986). Moringa (*Moringa oleifera)* leaves have probably been one of the most popular plants in seed bank of underutilized tropical crops. It had been reported that incorporation of Moringa shoot as green manure increased the fertility level of agricultural soils (Fahey, 2005; Fuglie, 2005). Studies have showed the effects of Mesquite on soil reactivity amelioration and organic matter and nutrient enrichment (Nyberg and Högberg, 1995; Abrams et al., 1990; Geesing et al., 2000; Thompson et al., 2006).

Because plant materials used as green manure differ in their chemical composition, rate of decomposition and nutrient elements released to the soil and uptake by crops planted on such green manure. The nutritional effect of green manure on crop plants depends on residue quality. High quality materials improve plant nutrition by releasing nutrients. Low quality residues have relatively weak direct nutritional effect. Hence there is the need to study the potential of different plant materials as green manure and their relative effect on soil chemical properties and mineral composition of crops planted on each plant material. Therefore the present study reported in this article sought to compare the impact of different green manures and NPK fertilizer on soil properties, growth, yield, mineral and vitamin C composition of okra grown in derived savanna zone of Nigeria.

2. Materials and methods

2.1. Site description and treatments

Field experiments were carried out at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria during the 2015 and 2016 cropping seasons. Landmark University lies between Lat 8°9′N and long 5°61′E and is located in the derived savanna ecological zone of Nigeria. The rainfall pattern was bimodal, with peaks in June and October. The soils at the sites of the experiment is an Alfisol classified as an Oxic Haplustalf or Luvisol. The mean annual rainfall in the area is about 1300 mm and mean annual temperature is 32 °C.

Each year the experiment consisted of four green manure types {(a) Pawpaw (*Carica papaya* L.) leaves, (b) Neem (*Azadirachta indica* A. Juss.) leaves, (c) Moringa (*Moringa oleifera* Lam.) leaves, (d) Mesquite (*Prosopis africana* Guill., Perr. & A. Rich) Taubert leaves}, NPK 15-15-15 fertilizer and a control with no green manure or fertilizer. The six treatments were arranged in a randomized complete block design with four replications. Each block comprised 6 plots, each of which measured 3×3 m^2. Blocks were 1 m apart, and the plots were 0.5 m apart. Different locations were used for the experiment in 2015 and 2016.

2.2. Incorporation of green manures and planting of okra

After land preparation (ploughing and harrowing), the site was then laid out to the required plot size of 3 m × 3 m. The green manure crop leaves used for the experiment was harvested from nearby bushes in the Research Farm of the University. The various plant leaves were chopped and incorporated at 5 t ha^{-1} using hoe. The plots were left for 2 weeks before sowing okra seeds to allow for decomposition of the green manures. Sowing of okra variety NHAe-47-4 was done in May each year. Three okra seeds were sown per hole at inter-row spacing of 0.6 m and 0.6 m intra-row spacing using simple hand held grain driller. At two weeks after sowing (WAS), thinning to one plant per stand was done and this was followed by manual weeding using hoe. At this stage (2 WAS), 200 kg ha^{-1} of NPK 15-15-15 fertilizer was applied to okra plants by using ring method. Subsequent weeding was done as needed. Insect pests were controlled by spraying cypermethrin weekly at the rate of 30 ml per 10 l of water from 2 WAS till 4 WAS.

2.3. Determination of soil physical and chemical properties

Four weeks after incorporation of green manure, determination of bulk density in all plots commenced and was repeated at 6, 8, 10 and 12 weeks after green manure incorporation. Five undisturbed samples (0.04 m diameter, 0.15 m high) were collected at 0–0.15 m depth from the centre of each plot at random and 0.15 m away from each okra plant using core steel sampler. The samples were used to evaluate bulk density after oven-drying at 100 °C for 24 h. At the end of the experiment each year, soil samples were also collected from each experimental plot for chemical analysis. The soil samples collected were air dried, ground, and passed through a 2 mm sieve. The sieved soil samples were taken to the laboratory for chemical analysis as described by Carter (1993). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method. The organic matter was determined by multiplying organic carbon by 1.724. The total N was determined by micro-Kjeldahl digestion and distillation techniques, available P was extracted using Bray-1 solution and determined by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted using 1 N ammonium acetate. Thereafter, K was determined using a flame photometer and Ca and Mg by the EDTA titration method. Soil pH was determined by using a soil-water medium at a ratio of 1:2 using digital electronic pH meter.

Before the start of the experiment, soil physical property (bulk density) was determined as described above. Soil samples were also collected at a depth of 0–0.15 m randomly from different points to represent the experimental area and bulked together to make a composite soil for determination of particle-size and chemical analysis. Particle-size analysis was done using the hydrometer method (Gee and Or, 2002).

2.4. Analysis of green manure leaves and okra fruits

Leaf samples were collected from each green manure, oven-dried for 24 h at 80 °C and ground in a Willey mill. These samples were analysed for leaf 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

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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). At harvest 10 okra fruits of uniform sizes were randomly collected from each plot in each year and analyzed for mineral and vitamin C contents. Mineral elements of okra fruits were determined according to methods recommended by the Association of Official Analytical Chemists (AOAC, 2003). One gram of each sample was digested using 12 cm^{-3} of the mix of HNO_3, H_2SO_4 and $HCLO_4$ (7:2:1 v/v/v). Contents of Cu, Fe, Zn, K and Ca were determined by atomic absorption spectrophotometry and vitamin C content was determined by using the indophenol dye method (Singh et al., 2007).

2.5. Determination of growth and yield parameters

Collection of data started four weeks after sowing, and consecutively at one week interval after the first collection. Growth parameters measured were plant height (by the use of meter rule), number of leaves (by counting), and stem girth (use of venier caliper). The edible pods were harvested at 4 day intervals and weighed. The pod weight was evaluated based on the cumulative weight harvests per plot.

2.6. Data analysis

Data collected from each experiment were subjected to analysis of variance (ANOVA), using SPSS 21 and Microsoft Office Excel 2013 packages, and treatment means were compared using the Duncan's multiple range test (DMRT) at $p = 0.05$ probability level.

3. Results

3.1. Soil physical and chemical properties at the start of the experiment and chemical composition of green manures used for the experiment

Tables 1 and 2, respectively, showed the physical and chemical properties of the sites before the start of the experiment in 2015 and 2016 and the chemical composition of the green manures used. The soils are sandy loamy, high in bulk density, acidic, low in organic matter (OM), total N, available P, exchangeable K, Ca and Mg. The site for the experiment in 2015 was adequate in P and moderate in Ca according to the critical level of 3.0% OM, 0.20% N, 10.0 mg kg^{-1} available P, 0.16–0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca, and 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000). The chemical analysis of the green manures have no consistent pattern in the concentration of nutrients in the tissues. However, Neem had the highest organic C, P and C/N ratio values, and Moringa had the highest K and Ca values. Mesquite had the highest Mg and N values (Table 2).

Table 1
Physical and chemical properties of the experimental sites before experimentation.

Parameter	2015	2016
Sand (%)	76	74
Silt (%)	13	12
Clay (%)	11	14
Textural class	Sandy loam	Sandy loam
Bulk density (Mg m^{-3})	1.68	1.49
pH (water)	5.61	5.68
Organic OM (%)	2.24	2.27
Total N (%)	0.16	0.18
Available P (mg kg^{-1})	10.5	9.5
Exchangeable K (cmol kg^{-1})	0.14	0.13
Exchangeable Ca (cmol kg^{-1})	2.1	1.9
Exchangeable Mg (cmol kg^{-1})	0.36	0.34

3.2. Effect of green manures and NPK fertilizer on soil bulk density and chemical properties

Fig. 1 and Table 3, respectively, showed the results of the effect of green manures and NPK fertilizer on soil bulk density and soil chemical properties. In both years, incorporation of green manures reduced soil bulk density compared with the control and NPK fertilizer. There were no significant differences in bulk density between Moringa, Pawpaw, Mesquite and Neem leaves used as green manure. Also there were no significant differences between NPK fertilizer and the control in term of soil bulk density.

Relative to the control in both years, incorporation of leaves of green manures and NPK fertilizer increased soil N, P, K, Ca and Mg, and the green manures, but not the NPK treatment, increased soil OM compared to the control (Table 3). There were no significant differences in the values of pH between the control, various leaves of green manures incorporated and NPK fertilizer. Although, green manures had slightly lower soil pH compared with the control, while Pawpaw had slightly lower pH compared with other green manures. Among green manures, Moringa had the highest soil pH. In both years, Pawpaw leaves incorporated as green manure increased soil OM, P, Ca and Mg significantly compared with other green manures. Also Mesquite had the highest N and K values.

3.3. Effect of green manures and NPK fertilizer on growth and yield of okra

Data presented in Table 4 are the results of the effect of various green manures and NPK fertilizer on growth and yield of okra in 2015 and 2016 and their mean values. Various green manures and NPK fertilizer increased plant height, stem girth, number of leaves and pod yield of okra compared with the control. Mesquite leaves had the highest values of growth and yield parameters of okra. Mesquite increased growth and yield of okra significantly compared with NPK fertilizer. In all cases of growth and yield except stem girth, the decreasing order among the various green manures and NPK fertilizer was Mesquite > Neem > Pawpaw > NPK fertilizer > Moringa > control. Using the means of the two years and compared with the control and NPK fertilizer, Mesquite increased pod yield of okra by 214 and 53%, respectively.

3.4. Effect of green manures and NPK fertilizer on the mineral composition and vitamin C level of okra fruits

Data presented in Table 5 are the mean values of the effect of various green manures and NPK fertilizer on the mineral and vitamin C contents of okra fruits in 2015 and 2016. Compared with the control, various green manures and NPK fertilizer increased K, Ca, Fe, Zn, Cu and vitamin C contents significantly. Moringa had the highest K, Ca, Fe, Zn, Cu and vitamin C contents compared with other treatments. There were no significant differences in Zn content between Moringa, Pawpaw, Mesquite, Neem and NPK fertilizer.

4. Discussion

The fact that in both years incorporation of green manures reduced soil bulk density compared with the control and NPK fertilizer could be attributed to increase in soil OM resulted from the degraded green manures by micro-organisms. The presence of the green manures should have increased activities of beneficial soil fauna in organic matter decomposition which led to enhancement of soil porosity and reduction in soil bulk density. The findings that incorporation of Moringa, Pawpaw, Mesquite and Neem leaves increased soil OM, N, P, K, Ca and Mg concentrations compared with

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Table 2
Chemical composition of various green manures used.

Green manure	OC	N (%)	C:N	P (%)	K (%)	Ca (%)	Mg (%)
Neem leaves	40a	1.30d	30.7a	0.83a	1.67 cd	0.77c	0.75b
Pawpaw leaves	35c	1.40c	25.0b	0.42b	1.51d	1.60b	0.48d
Moringa leaves	36bc	2.56ab	14.1d	0.43b	2.00a	2.62a	0.56c
Mesquite leaves	38ab	2.67a	17.8c	0.30c	1.82b	0.76c	0.85a

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test.

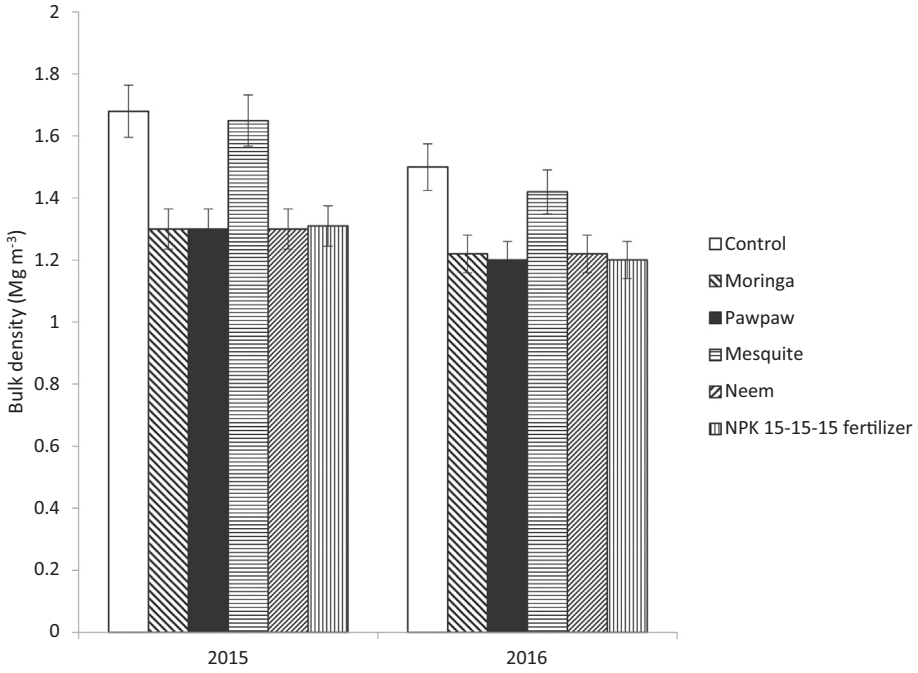

Fig. 1. Effect of various green manures and NPK fertilizer on soil bulk density in 2015 and 2016. Vertical bars show standard errors of paired comparisons.

Table 3
Effect of various green manures and NPK fertilizer on soil chemical properties at the end of the experiment in 2015 and 2016.

Treatment	pH (water)		OM (%)		N (%)		P (mg kg^{-1})		K (cmol kg^{-1})		Ca (cmol kg^{-1})		Mg (cmol kg^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Control	5.80a	5.70a	1.33e	1.37e	0.09d	0.10d	4.7d	5.5d	0.18d	0.19d	0.72e	0.80e	0.60d	0.59f
Moringa leaves	5.71ab	5.58ab	2.26d	2.36d	0.13a	0.20b	10.0c	11.1c	0.36c	0.42c	2.11c	2.06c	0.76b	1.32c
Pawpaw leaves	5.41ab	5.10ab	3.60a	3.56a	0.10c	0.18c	15.6a	14.9a	0.39bc	0.45c	2.82a	2.58a	1.90a	1.85a
Mesquite leaves	5.41ab	5.38ab	2.56c	2.76c	0.13a	0.24a	12.3b	12.8b	0.46a	0.54ab	2.41b	2.28b	0.78b	1.64b
Neem leaves	5.44ab	5.35ab	2.86b	2.96b	0.12b	0.21b	12.8b	12.2b	0.41a	0.52ab	2.10c	2.01c	0.67c	1.31c
NPK 15-15-15 fertilizer	5.49ab	5.41ab	1.36e	1.30e	0.10c	0.18c	10.8c	14.2a	0.35c	0.50b	0.82d	0.91d	0.78b	0.68e

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test.

Table 4
Effect of various green manures and NPK fertilizer on growth and yield of okra.

Treatment	Pod yield (t ha^{-1})			Plant height (m)			Stem girth (m)			Number of leaves per plant		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
Control	3.9f	3.3e	3.6f	0.29f	0.25e	0.27f	0.05c	0.04c	0.05d	7.5c	6.8c	7.2f
Moringa leaves	6.9e	6.6d	6.8e	0.39d	0.40d	0.40e	0.07ab	0.06b	0.07b	7.9c	8.9b	8.4e
Pawpaw leaves	8.6c	8.1c	8.4c	0.41c	0.47c	0.44c	0.08a	0.06b	0.07b	8.9bc	9.2b	9.1c
Mesquite leaves	10.9a	11.7a	11.3a	0.55a	0.61a	0.58a	0.08a	0.07a	0.08a	12.1a	11.5a	11.8a
Neem leaves	9.6b	10.1b	9.9b	0.48b	0.56b	0.52b	0.08a	0.07a	0.08a	9.3b	11.0a	10.2b
NPK 15-15-15 fertilizer	6.1e	8.6c	7.4d	0.33e	0.48c	0.41de	0.06b	0.06b	0.06c	7.9c	9.2b	8.6de

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test.

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Table 5
Effect of various green manures and NPK fertilizer on mineral and vitamin C contents of okra fruits in 2015 and 2016.

	K (%)	Ca (%)	Fe (%)	Zn (mg 100 g^{-1})	Cu (%)	Vitamin C (%)
Control	115.2c	98.0d	8.1e	3.20c	0.84ab	4.9f
Moringa leaves	145.1a	185.1a	20.6a	3.95a	0.91a	13.6a
Pawpaw leaves	116.1c	155.3c	18.1b	3.85ab	0.86ab	8.1de
Mesquite leaves	117.6c	153.3c	15.1d	3.88ab	0.80b	8.9c
Neem leaves	127.7b	177.6b	17.5c	3.89ab	0.91a	7.9e
NPK 15-15-15 fertilizer	117.6c	156.4c	14.8d	3.85ab	0.83ab	9.7b

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Duncan's multiple range test.

the control showed that the green manures are rich in these nutrients and affirmed that these nutrients are released into the soil by decomposed green manures. Several authors reported higher soil OM, N, P, K, Ca and Mg contents due to incorporation of green manure (Biswas and Mukherjee, 1991; Mandal et al., 2003; Herrera-Arreola et al., 2007). NPK fertilizer did not increase soil OM because it did not contain organic matter or decaying matter necessary to improve soil structure. The slightly lower soil pH in plots incorporated with green manure compared with the control may be attributed to the production of CO_2 and organic acids during decomposition of incorporated green manure. Swarup (1991) and Salahin et al. (2013) also reported that decrease in soil pH resulted from the application of green manure in soils. Incorporation of green manure and NPK fertilizer increased growth and pod yield of okra compared with the control. The increase in the performance of okra as a result of green manure could be due to reduced soil bulk density and increased availability of soil OM, N, P, K, Ca and Mg concentrations from the manures. Reduced soil bulk density will enhanced root growth and better water and nutrient uptake and yield. The better performance of okra under NPK fertilizer plots compared with the control was due to release of nutrients (N, P and K) from the fertilizer which are absorbed by the okra plants. The fact that incorporation of Mesquite increased the performance of okra compared with NPK fertilizer and other green manures was due to increased availability of N and K in the soil at the level of this treatment (Table 3). Majanbu et al. (1985) had shown that N and K are the most important macronutrients that okra required for proper performance. Nitrogen is a major constituent of chlorophyll, carbohydrate utilization, root growth and development, above ground vegetative growth and stimulation of uptake and utilization of other nutrient elements such as K, P and S (Agbede, 2009). K stimulates translocation of photosynthates to sites - to okra pods. The lower performance of okra under NPK fertilizer compared with Mesquite, Neem and Pawpaw could be adduced to leaching and erosion.

The fact that green manures and NPK fertilizer increased okra mineral and vitamin C contents compared with the control was attributed to increased availability of the nutrients in soil as a result of the mineralization of the manures leading to increased uptake by okra plants. Moringa had the highest mean values of K, Ca, Fe, Zn, Cu and vitamin C in the okra fruit compared with other green manures and NPK fertilizer. This can be adduced to the slightly higher pH of its soil (Table 3). Soil OM is a source of natural acids such as oxalate, malates, citrate and tartarate acids (Tsado et al., 2008), aside from the fact that these acids can neutralize cations, they can increase soil acidity thereby injuring roots and reducing nutrients uptake. In strongly acidic soils, availability of macronutrients (Ca, Mg, K, P, N and S) are curtailed (Brady and Weil, 1999). Results of this study provided evidence that locally available plant species can be used as a green manure to improve soil and crop quality.

5. Conclusions

Results of the experiments revealed that application of green manures (Pawpaw, Neem, Moringa and Mesquite) reduced soil bulk density and increased soil OM, N, P, K, Ca, Mg, growth and yield of okra compared with the control. NPK fertilizer did not reduce soil bulk density and increase soil OM, but did increase soil N, P, K, Ca, Mg, growth and yield of okra compared with the control. Mesquite increased growth and yield of okra compared with NPK fertilizer and other green manures. This was due to increased availability of N and K in the soil at the level of this treatment. Also green manures and NPK fertilizer increased okra mineral and vitamin C contents compared with the control. Moringa had the best fruit quality in terms of K, Ca, Fe, Zn, Cu, and vitamin C contents compared with other green manures and NPK fertilizer. This can be adduced to the slightly higher pH of its soil. Therefore, for those that desire to grow okra for the quality of its fruits, Moringa is recommended, however for those that desire quantity, Mesquite is recommended.

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