Original Research Article

Effects of Neem-Based Organic Fertilizer, NPK and their Combinations on Soil Properties and Growth of Okra (*Abelmoschus esculentus*) in a Degraded Ultisol of Calabar, Nigeria.

ABSTRACT

A field experiment was conducted at the University of Calabar Teaching and Research Farm to evaluate the effects of neem-based organic fertilizer, NPK and their combinations on soil chemical properties and growth of okra (*Abelmoschus esculentus*) on a degraded ultisols in Calabar. The experiment was laid out in a randomized complete block design with three replications comprising of six treatments. The treatments were control (no amendment), NPK applied at 120 kg N/ha, Neem applied at 120 kg N/ha, 60 kg N/ha NPK+ 60 kg N/ha Neem, 90 kg N/ha NPK + 30 kg N/ha Neem and 30 kg N/ha NPK + 90 kg N/ha Neem. Results showed that the soil chemical properties were influenced significantly ($P<0.05$) 60 90 kg Nha^{-1}NPK+ 60 90 kg Nha^{-1}Neem, 90 kg Nha^{-1}NPK + 30 kg Nha^{-1}, 120 kg Nha^{-1}NPK and 120 kg Nha^{-1} neem-based fertilizer. Soils treated with 60 kg N/ha NPK+ 60 kg N/ha Neem gave a significant ($P<0.05$) increase in plant height, number of leaves and stem girth at 4, 6 and 8 weeks after planting.

Keywords: Integrated nutrient management, Neem-based organic fertilizer, NPK, okra, soil properties, Ultisol

INRODUCTION

The focus of okra farmers in Nigeria is to improve the growth of crops at low cost in order to maximized income, but they are often faced with the challenge of maintaining soil fertility. Furthermore, the usual methods and practice engaged by them in ameliorating soil nutrient deficiency has solely been rested upon the use of organic or mineral fertilizers.

Soils of Calabar Metropolis in Cross River State are low in organic matter and available nutrients hence growth and sustainability of crops depreciates over long period of continual cultivation. In a way to curb the low nutrient content of these soils, luxurious application of mineral fertilizer has been practiced because of the sandy nature of the soils as the nutrients are easily prone to leaching which in turn have caused more harm than good.

Organic fertilizers improves the soils cation exchange capacity, nutrient stock, base saturation and improves water retention capacity whereas the inorganic fertilizer supplies the essential plant nutrient, nitrogen, phosphorus and potassium [1,2].

Neem cake is an organic fertilizer processed from neem seed kernel and contains adequate quantity of plant essential elements of 99.9% NPK and 0.01% micro-nutrients [3]. Neem -based fertilizer which is produced from neem-seed kernel has a narrow C/N ratio of 4.14 which is less than 25 separating index indicating that the rate of mineralization is high [4].

However, sole use of inorganic fertilizers have been reported to cause soil physical degradation, increased soil acidity, and soil nutrient imbalance while sole use of organic manures has, however, been reported inadequate, as they are required in rather large quantities to meet crops' nutrient requirements because of their relatively low nutrient content [5].

Contrastingly, combinations of both mineral and organic fertilizer have been encouraged by many researchers [6,7,8,2]

This method is experimented to curb the excessive leaching effect obtained in mineral fertilizer and the slow mineralization process of organic manures [9]. This study was conducted to determine the effect of sole and combined use of organic manure from neem and inorganic fertilizer, NPK on the soil chemical properties and growth of okra. It was also designed to establish the best combination of these nutrient sources for okra production in a degraded Ultisol of Calabar, Nigeria.

MATERIALS AND METHODS

The study area

The experiment was conducted in June 2016, at two locations within the University of Calabar Teaching and Research Farm with the coordinates of latitude N 04°57'035", and latitude E008°21'28.5" at an elevation of 39.39 m above sea level.

The study area is in humid tropical environment marked by two distinct seasons namely the rainy season and the dry season. Calabar is characterized by tropical wet (March to October) and dry (November to February) seasons. Annual rainfall in Calabar ranges from 1900 mm to 2650 mm, bimodally distributed with peaks in the months of July and September. There is usually a short dry spell in August which is referred to as 'August break'. The minimum and maximum temperatures ranged from 19 - 24^0 C and 28 - 34^0 C respectively. It rarely falls below 21^0 C except during the harmattan weather (December through January). The minimum and maximum monthly relative humidity ranges from 39 - 81 % and 52-87 % respectively in the area.

The soils of the area are classified as Ultisols [10]. The soils are low in base saturation and are referred to as highly weathered soils with low basic cations [11].

Collection of Research Materials

Neem – based organic fertilizer was obtained from Industrial Material Limited (IML) Kastina while the NPK fertilizer was sourced from Agricultural Development Programme office Calabar. The okra seed was also obtained from International Institute of Tropical Agriculture (IITA), Ibadan Oyo State.

Experimental Design, Treatments and Treatment Allocation

The Experiment was laid out in a randomized complete block design with three replicates comprising of six treatments. The treatments were control (no amendment), NPK applied at 120 kg N/ha, Neem applied at 120 kg N/ha, 60 kg N/ha NPK+ 60 kg N/ha Neem, 90 kg N/ha NPK + 30 kg N/ha Neem and 30 kg N/ha NPK + 90 kg N/ha Neem. The Neem- based organic fertilizer was incorporated into the soil bed 4 days before planting to allow mineralization of nutrients. The inorganic fertilizer source, NPK 20:10:10 was applied 2 weeks after planting.

Planting and Maintenance of the Experimental Units

The okra seeds were sown at a spacing of 50 x 50 cm to give 48 stands/plot.

Soils data were collected before and after experiment while the growth parameter was collected at 4, 6, 8, 10 and 12 weeks after planting.

Growth Data and Soil Sample Collection

Growth data such as plant height, Number of leaves and stem girth were collected on plant basis. From the Centre of each plot five plant were selected and tagged for determination of plant height, quantity of leaves per plant and stem girth diameter at 4, 6, 8, 10 and 12 weeks after planting.

Soil Analysis

The following analyses were carried out on the soil samples collected before and after experiment using standard procedures as described by [12]. Particle size distribution was determined by the Bouyoucous hydrometer method. Soil pH was determined using a ratio of 1:2 in soil-water medium and read with a digital pH meter. Organic carbon content was determined by Walkley-Black dichromate oxidation method. Organic matter was obtained by multiplying total carbon by a factor of 1.724. Total nitrogen (N) was determined by the micro-kjedahl method. Available phosphorus (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAII auto analyser (Technico, Oakland, Calif). Determination of exchangeable bases was by neutral ammonium acetate extraction and read with an atomic absorption spectrophotometer (AAS). Exchangeable acidity was determined by the 1 N potassium chloride (KCl) extraction method and titrated with 1 M sodium hydroxide (NaOH) using phenolphthalein as an indicator. The effective cation exchange capacity (ECEC) was the summation of total exchangeable bases and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100. The pH of the soil was determined using glass electrode pH meter at the ratio of 1:2.5 (20 g of soil to 50ml 0f distilled H_2O). Organic carbon was determined on 1g soil sample outline by [12]. Then the organic matter was obtained by multiplying the laboratory organic carbon content value with the factor 1.724. The total Nitrogen was determined by using the macro kjedahal digestion and distillation method. Available phosphorus was extracted with Bray-P-1 solution, the P concentration in the extract was obtained by the Vanado-molydate blue colour procedures. Exchangeable bases (Na and K) were determined using flame photometer after leaching with ammonium acetate solution. Exchangeable calcium and magnesium were

118 determined on the same extract by the method of titration with ethylene diamine tetra-
119 acetate.The neem based organic fertilizer was also analyzed using standard procedures.

120 **Statistical Analysis**

121 The data were subjected to statistically analysis using Genstat software and Duncan Multiple
122 Range Test was used to compare the mean data at 5% level.

123 **RESULTS AND DISCUSSION**

124 The physicochemical properties of the soil used for the experiment before treatment
125 application is shown in Table 1. The soil texture was sandy loam with pH in water value of 6.8
126 and pH in KCl value of 5.5 indicating near neutral and strongly acid reaction respectively based
127 on the ratings given by [13] . The soil was low in organic carbon content (4.0 g/kg), organic
128 matter (6.9 g/kg), exchangeable bases (Ca, Mg, K, and Na) and effective cation exchange
129 capacity (ECEC) but moderate in total nitrogen (2.2 g/kg), available phosphorus (12.9 mg/kg)
130 and high in base saturation (84.29 %) if compared with the critical levels given in Table 2. The
131 low levels of nutrients obtained in the experimental soils indicate low fertility status and may be
132 attributed to high temperature, high rainfall and leaching losses which characterize the tropical
133 areas [14, 15]. The low fertility status could also be attributed to continuous cropping which
134 necessitates the need for additional supply of nutrients.

135 TABLE 1

136 Soil physicochemical properties before experiment

Parameter	Value
Sand content	75.52
Silt content	12.48
Clay fraction	12.00
Textural class	Sandy loam
$pH_{(H_2O)}$	6.80
$pH(_{KCl})$	5.50

O.C	gkg^{-1}	4.00
O.M		6.90
N		2.20
Avail.P (mgkg^{-1})		12.9
K^+	cmol(+)kg^{-1}	0.18
Ca^{2+}		2.00
Mg^{2+}		0.90
Na		0.14
CEC		3.22
Exch. Al+ H		0.60
ECEC		3.82
Base saturation (%)		84.29

Chemical composition of the neem based organic fertilizer

The chemical analysis of the neem based organic fertilizer as presented in Table 4 showed that the organic fertilizer had a slightly alkaline pH (7.8) when measured in water and slightly acidic pH (6.4) when measured in KCl. The organic fertilizer had 12.4 % organic carbon, 21.58 % organic matter, 2.68 % total nitrogen, 1.82% total P, 2.75% total K, 1.46% Ca and 0.91% Mg; the C:N being 4.63. The low C:N value indicates the ability of the organic fertilizer to mineralized fast and release nutrients for crop uptake. The values of the micronutrient contents such as Zn, Cu, Fe and Mn in the organic fertilizer were high. This shows that the neem-based organic fertilizer was high in both macro and micro-nutrients required for growth of crops.

TABLE 2

. Chemical composition of the Neem based organic fertilizer used in the experiment

Parameter	Value
pH in water	7.8
pH in KCl	6.4
O.C (%)	12.4
O.M (%)	21.58
N (%)	3.00
C: N ratio	4.14
P (mgkg^{-1})	1.82

K	cmol(+)kg^{-1}	2.75
Ca		1.46
Mg		0.91
Zn (ppm)		360
Cu (ppm)		138
Fe (ppm)		420
Mn (ppm)		96
NH_4^-(mg/kg)		65.7

Effect of the treatment combinations on the soil chemical properties Soil reaction

There was a positive ($P < 0.05$) increase in the pH (KCl) of the soil amongst treatments applied with the highest pH value of 6.233 obtained from the combined application of 60 kg Nha^{-1}NPK + 60 kg Nha^{-1}Neem (Table 4). The least soil pH (KCl) value of 5.133 was obtained in plot amended with 30 kg Nha^{-1}NPK + 90 kg N/ha Neem. However, for soil pH (H_2O), there was no significant ($P > 0.05$) increase amongst treatments.

TABLE 4

Influence of rates of NPK, neem based organic fertilizer and their combinations on soil properties

Treatments (kg N/ha)	pH (KCl)	pH (H_2O)	O.M (gkg^{-1})	TN (gkg^{-1})	Av. P ($mgkg^{-1}$)	Exchangeable bases (cmol/kg)				CEC ($cmolkg^{-1}$)	ECEC ($cmolkg^{-1}$)	BS(%)
						K	Mg	Ca	Na			
Control	5.667 abc	6.967 a	2.527 ab	0.1433 de	23.00a	0.6700 a	2.267 a	3.167 cd	0.1200 a	6.223 bc	7.090 bc	88.03 abc
120 NPK 20:10:10	5.467 abcd	6.567 a	2.413ab	0.2300 a	25.50a	0.4067 efg	2.833 a	3.733 abcd	0.1400 a	7.113 abc	7.713 abc	92.27 ab
120 Neem	5.300 bcd	6.567 a	2.527ab	0.2200 ab	19.43a	0.5067 cd	3.167 a	4.600 ab	0.1667 a	8.440 a	8.973 ab	94.10 a
60 NPK + 60 Neem	6.233 a	7.333 a	2.180abc	0.1867abcde	30.20a	0.4267 def	2.567 a	4.667 a	0.1667 a	7.827 ab	8.660 a	81.07 cdef
90 NPK + 30 Neem	5.533 abc	6.633 a	2.757ab	0.1633 cde	20.73a	0.6167 ab	2.800 a	3.467 bcd	0.1033 a	6.987 abc	8.353 ab	83.57 cde
30 NPK + 90 Neem	5.133 bcd	6.467 a	1.377cd	0.2233 ab	21.27a	0.3933 efg	2.100 a	3.000 d	0.2067 a	5.700 c	7.233 bc	78.57 def

*Mean values with the same letter within a column are not significantly different (P≥0.05) by Duncan Multiple Range Test

The highest pH value recorded from the combined application rate of neem-based organic manure and NPK, inorganic fertilizer in this study shows that complementary use of the two will be a rational economic strategy, a view which is also supported by ,[16,17,7,8] . [18]) pointed highlighted that chemical amendments, most peculiarly N, is added together with natural soil enhancer (organic manure), the manure raises the soil pH and enhances the capacity of the soil to release of nutrient elements. The result also, is the same with the report of [19] who observed that organic materials have overall tendency to move the pH towards neutrality.

Organic matter

Table 4 indicates that there was a significant ($P < 0.05$) effect in soil organic matter content of through the application of the treatments. The highest organic matter content value of 2.757 ~~gkg^{-1}~~ obtained from plot amended with combined application of 90 kg Nha^{-1}NPK + 30 ~~kg Nha^{-1}~~ neem-based organic fertilizer was significantly higher than the values of 2.527, 2.413, 2.183, 1.897, 1.377 gkg^{-1} obtained from plots amended with 120 kg Nha^{-1}NPK, 120 kg Nha^{-1}Neem and 30 kg Nha^{-1}NPK + 90 kg Nha^{-1}Neem correspondingly. Generally, organic matter contents of the treated soils were higher in plots amended with combined application of NPK and Neem. This agrees with findings of [20] who reported that combined use of pod ash derived from cocoa and industrial fertilizer (NPK 20:10:10) increased SOM fraction than pod ash sourced from cocoa and compound fertilizer applied solely. Positive influence of integrated use of organic and inorganic fertilizers in increasing soil organic matter has also been reported by several researchers[6, 21,8] (.

Total Nitrogen

The soil total N content was positively ($P < 0.05$) increased with fertilizer amendment. Application of 120 kg Nha^{-1}of NPK or Neem, 30 kg Nha^{-1}NPK + 90 kg Nha^{-1}Neem and kg Nha^{-1}

NPK + 60 kg Nha^{-1}Neem positively ($P < 0.05$) increased the soil total N content when compared with no fertilizer application (control). The highest value of 0.2300 gkg^{-1} obtained in plot amended with 120 kg Nha^{-1} NPK closely followed by plots amended with (30 NPK + 90 Neem) kg Nha^{-1} (0.2233 gkg^{-1}) and 120 kg Nha^{-1} Neem (0.2200 gkg^{-1}) while the least value of 0.1433 gkg^{-1} was obtained in the control plots. Generally, the soil total N contents after experiment were low indicating its uptake by the okra plant. This is in line with the report given by [22] that okra needs accurate and adequate quantity of N and K for fruit formation.

Available phosphorus (P)

Application of the amendments did not affect ($P > 0.05$) the soil available phosphorus fraction when compared with the control plot. Although all the values of available P obtained at the end of the experiment were generally above pre-treatment level (12.9 $mgkg^{-1}$) with the values ranging from 18.87 to 30.20 $mgkg^{-1}$.

Exchangeable bases

There were positive ($P < 0.05$) effects in the accumulation of soil exchangeable K and Ca at the conclusion of the study but no significant ($P > 0.05$) increase wasobserved for exchangeable Mg and Na. The highest K content was obtained in the plot not amended with fertilizer (control) and was significantly higher than all the other amended plots except the plot amended with 90 kg Nha^{-1} NPK + 30 kg Nha^{-1}Neem. This contradicts the findings by several researchers[23,24,25,20,3] that amended soils improve soil availability of K, Mg and Na.

The highest Ca mean value of 4.667 cmol(+)/kg was obtained in plot amended with 60 kg Nha^{-1} NPK + 60 kg Nha^{-1}Neem though not significantly higher than the values obtained in all the plots amended with sole rates of NPK and sole applied neem at 120 kg Nha^{-1} but was positively higher than the values obtained in the rest amended plots including the control.

Cation exchange capacity (CEC)

The treatments applied significantly influenced the CEC of the soil with the highest value of 8.440 cmol/kg obtained in plot amended with 120 kg N/ha Neem which is equivalent to 4000 kg/ha neem-based organic fertilizer. However, the value was not significantly higher than the values obtained in all the plots amended with sole rates of NPK, the plots amended with combined application of (60 NPK + 60 Neem) kg $Nha^{-1}$and (90 NPK + 30 Neem) kg Nha^{-1} but was higher than the values obtained in other amended plots including the control. Generally, all the values of CEC obtained at the end of the experiment were generally above pre-treatment level (3.22 cmol/kg) with the values ranging from 5.350 to 8.440 cmol/kg.

Effective cation exchange capacity (ECEC)

The treatments applied significantly ($P < 0.05$) increased the ECEC of the soil with the highest mean value of 8.973 cmol/kg obtained from the application of 120 kg N/ha from sole Neem although not significantly ($P > 0.05$) higher than the values obtained in other amended plots except plots amended with 30 NPK + 90 Neem kg Nha^{-1} and control (Table 4). Generally, all the values of ECEC obtained at the end of the experiment were generally above pre-treatment level (3.82 cmol/kg) with the values ranging from 7.090 to 8.973 cmol/kg.

Base Saturation

The base saturation content of the soil at the conclusion of the field study was significantly influenced by the amendments applied with the highest mean value of 94.10% obtained in plot amended with 120 kg N/ha Neem (≡ 4000 kg/ha neem-based organic fertilizer) which was significantly higher than all the other amended plots except plots amended with 120 kg N/ha NPK and control.

Effects of Neem-Based Organic Fertilizer, NPK and their Combinations on Growth parameters of Okra

Plant height

The influence of rates of NPK, neem-based organic fertilizer and their combinations on okra plant height are as shown in Table 5. There was a significant ($P \leq 0.05$) increase in okra plant height at 4 and 6 weeks after sowing (WAS) while at 8, 10 and 12 WAS, plant height was not significantly ($P \geq 0.05$) affected. At 4 WAS, application of 120 kg N/ha from sole NPK, significantly ($P \leq 0.05$) enhanced the height of okra plants compared with the control. The tallest plant at 4 WAS was obtained from plot amended with 60 kg N/ha NPK + 60 kg N/ha Neem. There was no significant ($P \geq 0.05$) difference in plant height between the control plots and other rates of application of amendments.

TABLE 5

Influence of NPK, Neem based organic fertilizer and their combinations on plant height (cm) of okra

Treatments (kg N/ha)	Plant height (cm)				
	4 WAS	6 WAS	8 WAS	10 WAS	12 WAS
Control	11.97e	16.23e	28.95a	24.45a	25.40a
120 NPK 20:10:10	15.57 abcd	19.90 cde	27.80 a	36.62 a	40.01 a
120 Neem	14.11 abcde	22.63abc	31.68a	42.53a	46.27a
60 NPK + 60 Neem	17.53a	25.83a	38.10a	48.51a	51.43a
90 NPK + 30 Neem	12.87cde	16.67e	23.13a	29.67a	33.20a
30 NPK + 90 Neem	13.57abcde	17.47e	25.32a	32.83a	35.20a

Means followed by the same letter within a column are not significantly different ($P \geq 0.05$) by Duncan Multiple Range Test

At 6 WAS, 120 kg N/ha Neem, 60 kg N/ha NPK + 60 kg N/ha Neem significantly ($P \leq 0.05$) increased the height of okra plants compared with the control. The tallest plant at 6 WAS was

also obtained from plot amended with 60 kg N/ha NPK + 60 kg N/ha Neem. At 8 – 12 WAS fertilizer application irrespective of the type, rate and combination did not cause any significant ($P \geq 0.05$) increase in height compared with the control. The non-significant increase in plant height by treatments at 8, 10 and 12 WAS may be as result of high impact of rainfall leading to leaching of the basic plant nutrients required for growth of crops as pointed out by[26]) although according to [27], growth parameters such as plant height and number of branches are enhanced by genetic factor.

Generally, at all growth stages, the tallest plants were obtained in plots amended with 60 kg N/ha NPK + 60 kg N/ha Neem. The increase in okra plant height obtained in this study agrees with the work of [28] who reported an increase in okra plant height with the application of inorganic and organic fertilizers at Ibadan.[29,30] also recorded increase in okra plant height as a result of treatments applied when compared with control.

Number of leaves

The results of the effects of application of different rates of fertilizer types and their combinations on the number of leaves produced per okra plant almost followed the trend of plant height (Table 6). At 4 and 6 WAS, the highest number of leaves produced per okra plant was obtained from plot amended with 60 kg N/ha NPK + 60 kg N/ha Neem. At 8 – 12 WAS, fertilizer application did not significantly ($P > 0.05$) increase the number of leaves produced by okra plants compared with the control plots. Similar results have been reported by[29,30] on increase in number of leaves per okra plant as a result of treatments applied when compared with control.

Generally, at all growth stages, the combination of 60 kg N/ha NPK + 60 kg N/ha Neem produced plants with the highest number of leaves. Differences in the number of leaves do affect

the overall performance of okra as the leaves serve as photosynthetic organ of the plant.[31] reported that the nitrogen content in the organic fertilizers has been known to enhance leaf production, flowering, seed formation and root formation which will lead to higher metabolic activities and consequently higher fresh fruit yield in okra.

Stem girth

The results of the effects of application of different rates of NPK, neem-based organic fertilizer and their combinations on the stem girth of okra plants are presented in Table 7. Sole application of NPK and neem-based organic fertilizer at the rate of 120 kg N/ha, produced plants with significantly ($P \leq 0.05$) wider girth than the control plants. Almost at all growth stages, application of 60 kg N/ha NPK + 60 kg N/ha Neem produced plants with widest girths. At 4 WAS, the widest stem (2.44 cm) was obtained from plot amended with 60 kg N/ha NPK + 60 kg N/ha Neem while the least value of 1.21 cm was obtained from the control plot.

TABLE 6

Influence of NPK, Neem based organic fertilizer and their combinations on number of leaves per okra plant

Treatments (kg N/ha)	Number of leaves				
	4 WAS	6 WAS	8 WAS	10 WAS	12 WAS
Control	4.33c	8.33cd	10.33a	11.67 a	7.33 a
120 NPK 20:10:10	7.00 ab	9.33bcd	12.33a	17.33 a	15.67 a
120 Neem	6.00 abc	11.00abcd	14.33a	21.33 a	22.00 a
60 NPK + 60 Neem	7.67a	14.33a	16.67a	21.33 a	20.33 a
90 NPK + 30 Neem	4.67c	9.33bcd	9.00a	13.00 a	12.33 a
30 NPK + 90 Neem	6.00abc	9.33bcd	10.00a	15.67 a	14.67 a

TABLE 7

Influence of NPK, Neem based organic fertilizer and their combinations on stem girth (cm) of okra plant

Treatments (kg N/ha)	Stem girth (cm)				
	4 WAS	6 WAS	8 WAS	10 WAS	12 WAS
Control	1.21 d	3.21 a	2.69 a	2.97 a	3.03 a
120 NPK 20:10:10	1.95 abc	2.59 a	3.27 a	4.19 a	4.49 a
120 Neem	2.17 abc	3.26 a	3.77 a	4.41 a	4.61 a
60 NPK + 60 Neem	2.44 a	3.49 a	4.64 a	5.19 a	5.47 a
90 NPK + 30 Neem	1.70 bcd	3.33 a	2.49 a	3.19 a	3.55 a
30 NPK + 90 Neem	1.51cd	3.16 a	2.61 a	3.22 a	3.55 a

Means followed by the same letter within a column are not significantly different (P≥0.05) by Duncan Multiple Range Test

Similar results have been reported by [28, 29] in Nigeria where fertilizer treatments resulted in higher okra plant girth values compared to control. There were no significant ($P > 0.05$) differences in stem girth of okra plant at other stages of growth (6 - 12 WAS) showing that treatments applied only influenced okra stem girth at the early stage of growth. This may be attributed to the early utilization of the applied nutrients in the development of the xylem and the cambium tissues, which plays the role of nutrient and water transportation within a plant.

CONCLUSION

The study showed that balanced use of both organic amendments and inorganic fertilizer improved the chemical properties of the soil and enhanced optimum okra growth compared to sole application of either of them. The combined treatments were able to neutralize the possible acidifying effect of nitrogen in the inorganic fertilizer while assuring balanced plant nutrition and

improved soil fertility. Coupled with the results obtained, it can be inferred that the soils amended with 60kg N/ha NPK + 60 kg N/ha Neem significantly ($p< 0.05$) increased the growth of okra in the study area while for the sole application of NPK or neem-based organic fertilizer, the application rate of 120 kg Nha-1 is favourable.

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