

EFFECT OF UREA FERTILIZER AND MAIZE COB ASH ON SOIL CHEMICAL PROPERTIES, GROWTH, YIELD, AND MINERAL COMPOSITION OF OKRA, *ABELMOSCHUS ESCULENTUS* (L.) MOENCH

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ABSTRACT

Field experiments were carried out at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria, in the cropping seasons of 2015 and 2016. The soil at the site of the experiment is an Alfisol classified as an Oxichaplustalf or a Luvisol. The trial consisted of sole and combined applications of urea fertilizer (U) applied at 0, 60, and 120 kg·ha⁻¹ and maize cob ash (M) applied at 0, 3, and 6 t·ha⁻¹. The results showed that U and M alone or in combinations increased the soil chemical properties, growth, yield, and mineral composition of okra compared with the control. M alone at 3 t·ha⁻¹ produced optimum soil chemical properties, yield, and mineral composition of okra fruit. U alone at 60 kg·ha⁻¹ produced optimum yield of okra, while growth and mineral composition were increased when urea fertilizer was applied at 120 kg·ha⁻¹. The treatment with U applied at 60 kg·ha⁻¹ in combination with M applied at 3 t·ha⁻¹ (U₆₀M₃) produced the highest values of okra yield, while U applied at 120 kg·ha⁻¹ in combination with M applied at 3 t·ha⁻¹ (U₁₂₀M₃) has the highest growth and highest N, K, Ca, Cu, and Fe contents of okra fruit. Compared with the control and using the mean of the two years, U₆₀M₃ increased okra fruit yield by 93.3%. Therefore, for viable production of okra in low nutrient soil of the Nigeria derived savanna or similar soils elsewhere, 60 kg·ha⁻¹ U + 3 t·ha⁻¹ M (U₆₀M₃) is recommended. However, for improved mineral quality of okra, 120 kg·ha⁻¹ U + 3 t·ha⁻¹ M (U₁₂₀M₃) is recommended.

Key words: urea fertilizer, maize cob ash, okra yield, okra growth, soil chemical properties, okra mineral composition

INTRODUCTION

Okra is a vegetable crop that belongs to the genus *Abelmoschus*, family Malvaceae and has two main species – *Abelmoschus esculentus* (L.) Moench and *Abelmoschus caillei* (A. Chev.) Stevels (Siemonsma 1982). Okra originates probably from East Africa and today is widely distributed in the tropics, subtropics, and warmer parts of the temperate region (Echo 2003). It is traditionally grown in Côte d'Ivoire, Ghana, Nigeria, Egypt, Sudan, Togo, Benin, Burkina Faso, Cameroon, Tanzania, Zambia, and Zimbabwe. The economic importance of okra cannot be overemphasized. Okra is a popular health

food because of its high fiber, vitamin C, and folate content. Okra has high amount of antioxidants. It is also a good source of calcium and potassium. It contains carbohydrate, proteins, and vitamin C in large quantities (Adeboye & Oputa 1996). Some of the problems encountered by okra farmers in Nigeria are the low soil fertility and lack of capital to buy chemical fertilizers for optimum crop productivity. Most African soils are inherently low in organic carbon, slightly acidic, and relatively sandy (Adewole & Dedeke 2012). Consequently, intensive crop production requires high rate of organic and inorganic fertilizers. As a result, the use of organic-based fertilizer has found favor in boosting crop production

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in Nigeria, because it is cheap and less likely to pollute the ground water compared with chemical fertilizer. It improves soil fertility status and enhanced yield. However, the quantities of the organic amendments available may not be sufficient for large-scale okra production. Integrated use of chemical fertilizers and organic material may be a good approach for sustainable production of crops (Agbede & Adekiya 2012). Corn ash from the combustion of maize cobs, especially after ginning, can be used as a fertilizing and liming material. Different woody ash improved soil and plant nutrition and increased the yield of crops (Abdulhamid & Mustafa 2009; Owolabi et al. 2003; Odedina et al. 2003; Awodun et al. 2007; Ewulo et al. 2009). However, its combined use with chemical fertilizer has not received research attention. Moreover, the effects of the integrated application of maize cob ash and urea fertilizer on the soil chemical properties, growth, yield, and mineral composition of okra have not been investigated; therefore, the objectives of this study are (1) to determine the effects of sole and integrated application of urea fertilizer and maize cob ash on soil chemical properties, (2) to determine the effects of sole and integrated application of urea fertilizer and maize cob ash on growth and yield of okra, and (3) to determine the effects of sole and integrated application of urea fertilizer and maize cob ash on mineral compositions of okra.

MATERIALS AND METHODS

Field experiments were carried out at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria, in the cropping seasons of 2015 and 2016. Experimental field lies between Latitude 8° 9'N and Longitude 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 soil at the site of the experiment is an Alfisol classified as an Oxichaplustalf or Luvisol. The mean annual rainfall in the area is about 1300 mm, and the mean annual temperature is 32 °C.

The trial consisted of sole and combined applications of maize cob ash (M) applied at 0, 3, and 6 t·ha⁻¹ and urea fertilizer (U) applied at 0, 60, and

120 kg·ha⁻¹. The nine treatments were laid out in randomized complete block design with three replications. The following treatments were evaluated: (1) Control, no urea fertilizer or maize cob ash (U₀M₀); (2) no urea fertilizer + 3 t·ha⁻¹ M (U₀M₃); (3) no urea fertilizer + 6 t·ha⁻¹ maize cob ash (U₀M₆); (4) 60 kg·ha⁻¹ urea fertilizer + no maize cob ash (U₆₀M₀); (5) 60 kg·ha⁻¹ urea fertilizer + 3 t·ha⁻¹ maize cob ash (U₆₀M₃); (6) 60 kg urea fertilizer + 6 t·ha⁻¹ maize cob ash (U₆₀M₆); (7) 120 kg·ha⁻¹ urea fertilizer + no maize cob ash (U₁₂₀M₀); (8) 120 kg·ha⁻¹ urea fertilizer + 3 t·ha⁻¹ maize cob ash (U₁₂₀M₃); (9) 120 kg·ha⁻¹ urea fertilizer + 6 t·ha⁻¹ maize cob ash (U₁₂₀M₆).

Maize cob ash used for the experiment was prepared by collecting maize cob from maize farmers, sundried, and burnt into ash inside a bin. The ash was then sieved to remove pebbles and unburnt shaft. After land preparation (ploughing and harrowing), the site was then laid out to the required plot size of 3 m × 3 m. Sowing of okra cultivar NHAe-47-4 was done in May for both 2015 and 2016 cropping seasons. Three seeds of okra were sown per hole at interrow spacing of 0.6 m and intrarow spacing of 0.6 m, giving a plant population of 27.778 plants·ha⁻¹. Two weeks after sowing, thinning to one plant per stand was done followed by manual weeding, and maize cob ash and urea fertilizer were applied in ring form to the soil. Manual weeding was done during the planting season, and insect pest control was carried out using cypermethrin containing preprate applied at the rate of 1.0 kg·ha⁻¹ a.i.

The soil was analyzed before the start of the experiment and at harvest. The soil samples collected were bulked, air dried, and sieved using a 2-mm sieve and analyzed for particle size; soil organic matter; N, P, K, Ca, and Mg contents; and pH. Soil samples at harvest were collected from 0 to 0.15 m depth in 2015 and 2016 on an individual plot basis and similarly analyzed for chemical properties as described by Carter (1993). Particle size was determined by the hydrometer method (Gee & Or 2002). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson & Sommers 1996). Organic matter (OM) was calculated by multiplying C

by 1.724. Total N was determined by the micro-Kjeldahl digestion method (Bremner 1996). Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al. 1998). Exchangeable K, Ca, and Mg were extracted using 1 M ammonium acetate. Thereafter, K level was determined on a flame photometer, and Ca and Mg were determined by ethylenediaminetetraacetic acid EDTA titration (Hendershot & Lalande 1993). Heavy metals were determined by using the method of Udo et al. (2009). The Fe, Cu, Zn, Cr, and Cd levels were determined by atomic absorption spectrophotometer. Soil pH was determined using a soil–water medium at a ratio of 1 : 2 with a digital electronic pH meter.

The sample of about 2 g of the ash used was analyzed for N, P, K, Ca, and Mg as described by Tel and Hagarty (1984). N was determined by the micro-Kjeldahl digestion method. Samples were digested with nitric perchloric–sulfuric acid mixture for the determination of P, K, Ca, and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer, and Ca and Mg were determined by the EDTA titration method (Horwitz & Latimer 2005).

At harvest, 10 okra fruits of uniform sizes were randomly collected from each plot in each year and analyzed for mineral contents. Mineral elements of okra fruits were determined according to the methods recommended by the Association of Official Analytical Chemists (AOAC 2003). N was determined by the micro-Kjeldahl digestion method. One gram of each sample was digested using 12 cm³ of the mixture of HNO₃, H₂SO₄, and HClO₄ (7 : 2 : 1 v/v/v). Contents of Cu, Fe, Zn, K, and Ca were determined by atomic absorption spectrophotometry.

Plant height, number of leaves, and leaf area at mid-flowering stage were determined by using the model $\{LA = 0.34(LW)^{1.12}\}$ developed by Omo-laiye et al. (2015), where LA = leaf area, L = leaf length, and W = leaf width. Pods were harvested at four days interval, counted, and weighed. Pod weight was evaluated based on the cumulative number of pods at eight harvests.

Data collected for okra yield and growth parameters, soil chemical properties, and okra mineral

compositions were subjected to analysis of variance (ANOVA) using SPSS 17.0, and means were separated using Duncan's multiple range test (DMRT) at $p = 0.05$ probability level.

RESULTS

Initial soil fertility status and chemical properties of the amendments used for the experiment

The physicochemical properties of the soil and the maize cob ash are given in Table 1. The soil was sandy loam in texture, high in sand, low in both silt and clay, acidic, and low in organic matter. Total N, available P, and exchangeable K, Ca, and Mg 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 meet the criteria recommended for crop production in ecological zones of Nigeria (Akinrinde & Obigbesan 2000). The values of heavy metals in the experimental soil before experimentation were all below the permissible limits of Fe 100 mg·kg⁻¹, Zn 300 mg·kg⁻¹, Cu 100 mg·kg⁻¹, Cr 100 mg·kg⁻¹, and Cd 3 mg·kg⁻¹ by WHO/FAO (Kabata-Pendis & Mukherjee 2007). The analysis of maize cob ash showed that the pH was strongly alkaline and it also contained high level of K, Ca, and Mg and trace values of N and P.

Table 1. Soil properties before experimentation and nutrient content of maize cob ash used for the study

Soil property	Soil values	Maize cob ash values
Sand (%)	76	
Silt (%)	13	
Clay (%)	11	
Textural class	Sandy loam	
pH (water)	5.25	11.3
Organic matter (%)	2.04	
Total N (%)	0.16	0.15
Available P (mg·kg ⁻¹)	6.5	0.20
Exchangeable K (cmol·kg ⁻¹)	0.14	5.6
Exchangeable Ca (cmol·kg ⁻¹)	1.8	1.8
Exchangeable Mg (cmol·kg ⁻¹)	0.36	3.5
Fe (mg·kg ⁻¹)	7.82	12.3
Zn (mg·kg ⁻¹)	17.2	250
Cr (mg·kg ⁻¹)	0.16	10
Cu (mg·kg ⁻¹)	12.2	21
Cd (mg·kg ⁻¹)	0.01	11

Table 2. Effect of urea fertilizer and maize cob ash on soil chemical properties

Year	Urea fertilizer (kg·ha ⁻¹)	Maize cob ash (t ha ⁻¹)	pH (water)	Organic matter (%)	N (%)	P (mg·kg ⁻¹)	K (cmol kg ⁻¹)	Ca (cmol kg ⁻¹)	Mg (cmol kg ⁻¹)	Zn (mg·kg ⁻¹)	Cu (mg·kg ⁻¹)	Fe (mg·kg ⁻¹)	Cr (mg·kg ⁻¹)	
2015	0	0	5.6 d ^a	1.97 d	0.12 e	5.8 h	0.12 d	1.4 g	0.31 g	17.0 b	11.9 c	7.78 b	0.15 d	
	0	3	6.5 ab	2.15 c	0.13 de	10.3 g	0.31 b	2.9 d	0.81 d	17.7 a	12.3 ab	7.95 ab	0.17 bc	
	0	6	6.8 a	2.19 b	0.13 de	11.7 e	0.3 b	2.8 d	0.80 d	17.9 a	12.6 ab	8.30 a	0.18 ab	
	60	0	5.5 d	2.01 b	0.25 c	9.6 g	0.13 de	1.9 f	0.38 f	17.2 ab	12.0 bc	7.80 ab	0.15 d	
	60	3	6.1 bc	2.41 ab	0.26 b	12.9 d	0.30 b	3.8 bc	1.25 b	17.9 a	12.5 ab	7.98 ab	0.18 ab	
	60	6	6.2 bc	2.47 a	0.26 b	14.2 c	0.25 c	3.5 c	1.20 c	18.3 a	12.1 a	8.40 a	0.18 ab	
	120	0	5.5 d	2.27 b	0.27 b	10.9 f	0.13 de	2.2 e	0.43 e	17.3 ab	12.1 bc	7.84 ab	0.16 c	
	120	3	5.7 cd	2.50 a	0.29 a	15.6 ab	0.35 a	4.2 a	1.36 a	18.0 a	12.7 ab	7.99 ab	0.18 ab	
	120	6	5.8 cd	2.58 a	0.29 a	16.2 a	0.31 b	4.1 a	1.35 a	18.4 a	13.4 a	8.88 a	0.19 a	
	2016	0	0	5.5 d	1.94 d	0.10 e	5.6 g	0.13 ef	1.4 g	0.29 f	16.8 c	11.3 c	7.70 c	0.15 c
		0	3	6.6 ab	2.16 c	0.11 de	10.4 e	0.35 ab	3.0 cd	0.82 c	18.2 ab	12.9 b	8.91 b	0.19 ab
		0	6	6.9 a	2.21 b	0.11 de	11.9 d	0.31 c	2.9 d	0.80 c	18.4 ab	13.6 a	9.10 ab	0.19 ab
60		0	5.5 d	2.00 b	0.24 c	9.5 f	0.12 f	1.8 f	0.36 e	16.9 bc	11.6 c	7.73 c	0.16 b	
60		3	6.2 bc	2.45 ab	0.27 ab	13.1 c	0.32 bc	3.5 b	1.26 b	18.4 ab	13.3 ab	9.00 ab	0.19 ab	
60		6	6.4 ab	2.49 a	0.26 b	14.6 b	0.28 d	3.4 b	1.22 b	18.7 a	13.8 a	9.45 a	0.20 a	
120		0	5.4 d	2.09 b	0.27 ab	10.4 e	0.13 de	2.0 e	0.40 d	17.0 bc	11.7 c	7.81 c	0.16 b	
120		3	5.9 bc	2.52 a	0.28 a	15.8 a	0.37 a	3.9 a	1.34 a	18.7 a	13.6 a	9.25 ab	0.19 ab	
120		6	6.0 b	2.60 a	0.28 a	15.9 a	0.34 ab	3.8 a	1.30 a	18.9 a	13.9 a	9.66 a	0.21 a	
		SE±		0.065	0.030	0.181	0.423	0.012	0.125	0.055	0.094	0.108	0.089	0.002
Source														
Year (Y)				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Urea U			0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.01	0.028	ns	ns	
Maize cob ash (M)			0.000	0.000	ns	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Y × U			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	
Y × M			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	
U × M			0.000	0.000	ns	0.000	0.000	0.000	0.000	ns	ns	ns	ns	
Y × U × M			ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	

^a The values in columns followed by the same letter are not significantly different at p = 0.05, ns = not significant

The values of heavy metals (Fe, Zn, Cr, Cu, and Cd) in the maize cob ash were lower than the values reported for wood ash in the literature – Fe 19.5 mg·kg⁻¹, Zn 700 mg·kg⁻¹, Cr 86 mg·kg⁻¹, Cu 145 mg·kg⁻¹, and Cd 21 mg·kg⁻¹ (Etiégni & Campbell 1991)

Effect of urea fertilizer and maize cob ash on the soil chemical properties

Table 2 shows the effect of urea fertilizer and maize cob ash on soil chemical properties at the end of the experiment in 2015 and 2016. Year (Y) as an individual factor did not influence soil chemical properties. Urea fertilizer (U) alone increased the amounts of soil elements, except K, Zn, Cu, Fe and Cr, and the increase in N, P, Ca and Mg contents of the soil in comparison with the not fertilized control. There were no significant differences in pH but organic matter contents increased due to 60 and 120 kg·ha⁻¹ urea application as a sole. Maize cob ash (M) alone increased the soil pH, organic matter, and P, K, Ca, Mg,

Zn, Cu, Fe, and Cr levels of the soil significantly. In all treatments in which maize cob ash alone or combined with urea fertilizer were applied, there were no significant differences between maize cob doses, with some little exceptions. The interactive effects of Y × U and Y × M were not significant. Combining urea fertilizer with maize cob ash (U × M), urea fertilizer applied at 120 kg·ha⁻¹ + maize cob ash applied at 3 t·ha⁻¹ (U₁₂₀M₃), has significantly increased the values of N, K, Ca, and Mg. The values of these nutrients at U₁₂₀M₃ were not significantly different from that of urea fertilizer applied at 120 kg·ha⁻¹ + maize cob ash applied at 6 t·ha⁻¹ (U₁₂₀M₆). Urea fertilizer applied at 120 kg·ha⁻¹ + maize cob ash applied at 6 t·ha⁻¹ (U₁₂₀M₆) has the highest values of pH, organic matter, and P, which were also similar to those of U₁₂₀M₃. However, the values of Zn, Cu, Fe, and Cr were not significant for (U × M). Also, Y × U × M was not significant for soil chemical properties.

Table 3. Effect of urea fertilizer and maize cob ash on mineral composition of okra fruit

Year	Urea fertilizer (kg·ha ⁻¹)	Maize cob ash (t ha ⁻¹)	N (%)	K (%)	Ca (%)	Cu (%)	Fe (%)
2015	0	0	2.11 f*	95.4 h	88.6 f	0.31 g	7.2 f
	0	3	2.14 ef	155.1 de	140.4 c	0.75 cd	15.2 c
	0	6	2.15 ef	150.6 e	140.1 c	0.70 d	15.1 c
	60	0	2.54 d	110.6 g	103.4 e	0.40 f	12.9 e
	60	3	2.95 c	168.7 bc	159.6 b	0.60 b	16.2 b
	60	6	2.90 c	160.4 cd	154.8 b	0.59 b	16.1 b
	120	0	3.10 bc	128.5 f	120.1 d	0.51 e	14.1 d
	120	3	3.58 a	188.1 a	164.3 a	0.96 a	20.8 a
	120	6	3.50 a	174.2 ab	162.7 a	0.90 a	20.1 a
2016	0	0	2.09 f	90.6 f	84.4 f	0.30 g	7.1 f
	0	3	2.13 ef	154.2 c	136.6 c	0.75 bc	14.9 d
	0	6	2.12 ef	151.0 c	135.8 c	0.69 c	14.8 d
	60	0	2.54 d	109.1 e	100.7 e	0.40 f	12.4
	60	3	2.90 c	160.7 b	154.8 b	0.62 cd	15.8 c
	60	6	2.86 c	158.9 b	150.6 b	0.60 d	15.2 c
	120	0	3.05 bc	124.7 d	118.1 d	0.49 e	14.1 e
	120	3	3.47 a	180.6 a	164.6 a	0.92 a	19.2 a
	120	6	3.40 a	172.5 a	160.4 a	0.91 a	18.4 ab
		SE±	0.066	15.440	3.580	0.027	0.489
Source							
Year (Y)			ns	ns	ns	0.025	ns
Urea U			0.000	ns	0.000	0.000	0.000
Maize cob ash (M)			ns	0.025	0.000	0.000	0.000
Y × U			ns	ns	ns	ns	ns
Y × M			ns	ns	ns	ns	ns
U × M			ns	ns	0.000	0.000	0.000
Y × U × M			ns	ns	ns	ns	ns

*For explanation see Table 2

Effect of urea fertilizer and maize cob ash on mineral composition of okra fruit

The result of the effects of urea fertilizer and maize cob ash on mineral composition of okra fruit are presented in Table 3. Year (Y) as an individual factor did not influence okra mineral composition significantly except Cu. Urea fertilizer (U) increased okra mineral composition significantly, more at 120 kg·ha⁻¹ urea. With maize cob ash alone (M) K, Ca, Cu, and Fe contents of okra fruit increased significantly compared with the control but there were no difference between maize cob ash doses. The highest increase in the mineral elements in okra fruit were scored at the highest urea and both maize cob ash doses. The interactive effects of Y × U, Y × M and Y × U × M were not significant for okra fruit mineral compositions. Using the means of the two years and compared with the control, U₁₂₀M₃ increased N, K, Ca, Cu, and Fe contents of okra fruit by 68.1%, 98.3%, 89.0%, 203.2%, and 177.8%, respectively.

Effect of urea fertilizer and maize cob ash on growth parameters and yield of okra fruit

Figures 1–4 show the mean effects of urea fertilizer and maize cob ash on the growth and yield of okra. Maize cob ash alone at 3 and 6 t·ha⁻¹ increased the height of plants, area and number of leaves and fruit yield compared with the control without differences between doses.

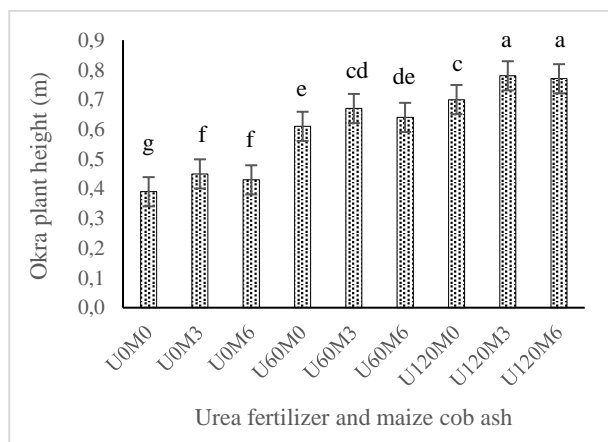


Fig. 1. Influence of urea fertilizer and maize cob ash on the height of okra plants based on the means from two years. U = Urea fertilizer in kg·ha⁻¹; M = Maize cob ash in t·ha⁻¹; vertical bars show standard errors; bars marked with different letters show means significantly different at 5% level using Duncan's multiple range test

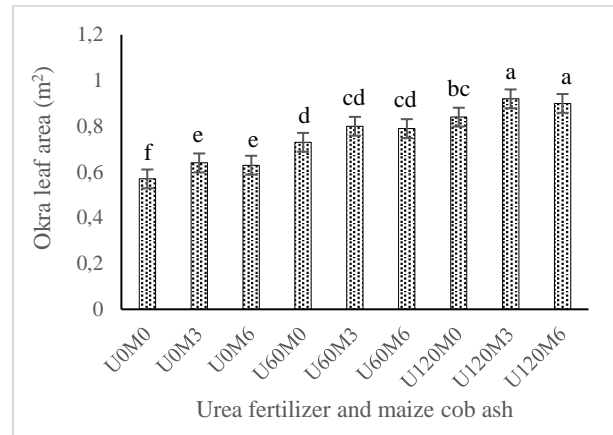


Fig. 2. Influence of urea fertilizer and maize cob ash on okra leaves area based on the means from two years. For explanation see Fig. 1.

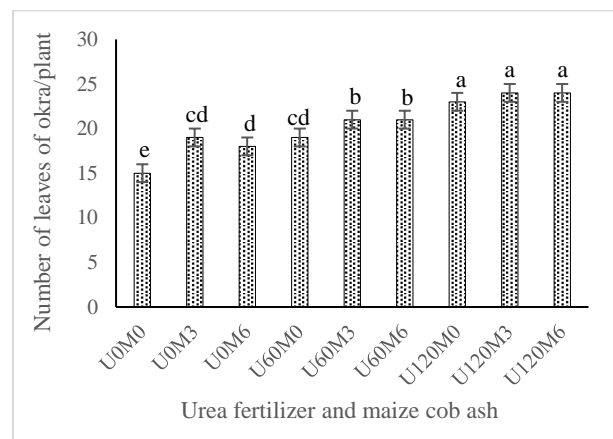


Fig. 3. Influence of urea fertilizer and maize cob ash on okra leaves number based on the means from two years. For explanation see Fig. 1.

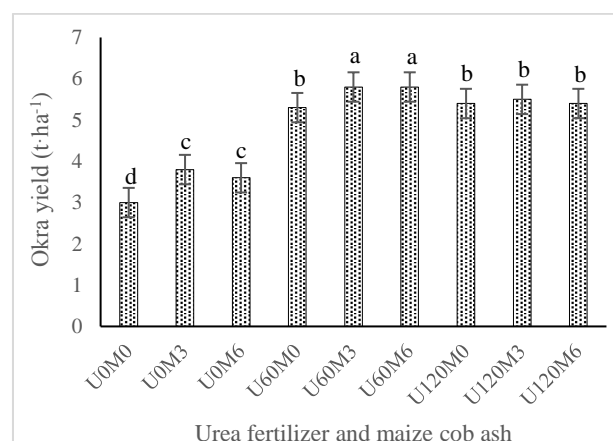


Fig. 4. Influence of urea fertilizer and maize cob ash on okra yield based on the means from two years. For explanation see Fig. 1.

Using the mean of the two years, it increased the yield, plant height, leaf area, and the number of leaves of okra by 26.7%, 15.4%, 12.3%, and 26.7%, respectively. Similarly, urea applied alone increased more than cob ash the growth of okra plants. The growth increase depended on the urea dose contrary to the yield, which did not depend on the urea dose. Urea fertilizer applied at $60 \text{ kg} \cdot \text{ha}^{-1}$ in combination with maize cob ash applied at 3 and $6 \text{ t} \cdot \text{ha}^{-1}$ ($U_{60}M_3$ and $U_{60}M_6$) caused the highest yield of okra fruit, while urea fertilizer applied at $120 \text{ kg} \cdot \text{ha}^{-1}$ in combination with maize cob ash applied at 3 and $6 \text{ t} \cdot \text{ha}^{-1}$ ($U_{120}M_3$ and $U_{120}M_6$) resulted in the highest growth parameters. Compared with the control and using the mean of the two years, $U_{60}M_3$ increased okra fruit yield by 93.3%.

DISCUSSION

The fact that maize cob ash or urea fertilizer alone or in combinations increased soil organic matter and N, P, K, Ca, and Mg contents can be explained by the low initial soil fertility status of the experimental field (Table 1), which confirms the earlier findings (Park et al. 2004; Ewulo et al. 2009; Abdurraheem & Ojeniyi 2015). Urea fertilizer alone increased soil organic matter and N, P, K, Ca, and Mg relative to the control, probably because of the enhanced microbial activity that led to enhanced production and mineralization of organic matter from natural (native) source in soil (Ewulo et al. 2009). Increased soil organic matter and nutrients caused by urea fertilizer can also be related to the addition of carbon through okra root biomass and crop residues. Maize cob ash improved the basal status of the soil through the increase in soil pH. The calcium oxide content of soil turns into calcium hydroxide in the presence of water. Calcium hydroxide reacts with the carbon dioxide in the air, which results in the formation of calcium carbonate. As a result, wood-ash enhances the lime content of the soil (Steenari et al. 1999). However, urea reduces soil pH because of its acid producing nature.

The soil nutrient status increased at $3 \text{ t} \cdot \text{ha}^{-1}$ maize cob ash and usually did increase with $6 \text{ t} \cdot \text{ha}^{-1}$.

The exception was found for P and K because their content was higher at the higher dose. The combination of urea and maize cob ash increased N availability important for microbial action that released of nutrients. In general, the combination of urea fertilizer and maize cob ash increased soil nutrient concentration more than their sole use.

The significant increase in the growth and yield of okra in response to maize cob ash or/and urea fertilizer compared with the control could be adduced to the fact that the soil was low in nutrients. Higher amounts of N, P, K, Ca, and Mg and higher soil pH are essential for the growth and yield of okra (Abdurraheem & Ojeniyi 2015). On an average, yield of $20 \text{ t} \cdot \text{ha}^{-1}$ of okra removes from a soil about 60, 25, and 90 kg of N, P_2O_5 , and K_2O ha^{-1} (Prabhakar 1996). The result that maize cob ash at $3 \text{ t} \cdot \text{ha}^{-1}$ increased the growth and yield of okra most implies that this amount corresponds with other soil factors and okra requirements. Nitrogen strongly stimulates growth through expansion of the crop canopy and better interception of solar radiation (Milford et al. 2000). It also strengthens plant roots, enabling plants to take in more water and nutrients, which allows a plant to grow more rapidly (Solangi et al. 2015).

Also the result that growth parameters of okra increased with the increase of urea doses up to $120 \text{ kg} \cdot \text{ha}^{-1}$ while yield was increased with urea dose of $60 \text{ kg} \cdot \text{ha}^{-1}$ can testify that in the experimental condition, the $120 \text{ kg} \cdot \text{ha}^{-1}$ dose was over optimal for yield of fruits. This result agrees with that of Verma et al. (1970) who found that okra fruit production was depressed as N rate was increased and concluded that fruit yield at this excessive N rate was declined due to reduction in fruit number per plant. Chauhan and Gupta (1973) cited by Majanbu et al. (1986) reported that dry matter yield in okra significantly increased with N fertilization but it was not correlated with fruit yield increase. Majanbu et al. (1986) fixed the optimum N requirement for okra production to be $50 \text{ kg} \cdot \text{ha}^{-1}$. From our experiment, it is possible to conclude that $U_{60}M_3$ was most adequate for the okra production in this soil-climatic zone.

Table 4. Correlation coefficient between soil chemical properties and mineral composition of okra

Soil chemical property	Okra mineral composition				
	N	K	Ca	Cu	Fe
pH	-292 (ns)	0.460 (ns)	0.453 (ns)	0.385 (ns)	0.279 (ns)
Organic matter	0.77* (0.015)	0.912* (0.001)	0.940* (0.000)	0.796* (0.010)	0.861* (0.003)
N	0.900* (0.001)	0.783* (0.030)	0.730* (0.042)	0.759* (0.039)	0.746* (0.040)
P	0.839* (0.005)	0.922* (0.000)	0.937* (0.000)	0.840* (0.005)	0.957* (0.000)
K	0.563 (ns)	0.913* (0.001)	0.874* (0.002)	0.903* (0.001)	0.923* (0.000)
Ca	0.707* (0.033)	0.983* (0.000)	0.987* (0.000)	0.886* (0.001)	0.921* (0.000)
Mg	0.677* (0.045)	0.947* (0.000)	0.963* (0.000)	0.818* (0.007)	0.852* (0.004)

* $p < 0.05$; ns = not significant at $p < 0.05$. Included in brackets are p values

The application of urea fertilizer and maize cob ash alone or in combination increased N, P, K, Ca, Cu, and Fe contents in okra fruits compared with the control and is consistent with the soil chemical properties in this experiment; the correlation between soil chemical properties and mineral composition of okra fruit were positive and significant (except for pH) (Table 4).

Maize cob ash increased N, P, K, Ca, Cu, and Fe contents of okra fruits only up to $3 \text{ t}\cdot\text{ha}^{-1}$ level. Urea fertilizer applied at $60 \text{ kg}\cdot\text{ha}^{-1}$ in combination with maize cob ash applied at $3 \text{ t}\cdot\text{ha}^{-1}$ ($U_{60}M_3$) has the highest N, P, K, Ca, Cu, and Fe contents of okra fruits. This was adduced to maximum availability of nutrient especially N from urea fertilizer and P, K, Ca, and Mg from maize cob ash at a balanced proportion.

CONCLUSION

Urea fertilizer and maize cob ash alone or in combination increased soil chemical properties, growth, yield, and mineral composition of okra compared with the control. Maize cob ash applied alone at $3 \text{ t}\cdot\text{ha}^{-1}$ produced optimum soil chemical properties, yield, and mineral composition of okra fruit. Urea fertilizer alone at $60 \text{ kg}\cdot\text{ha}^{-1}$ produced optimum yield of okra while growth and mineral composition was increased at $120 \text{ kg}\cdot\text{ha}^{-1}$ urea fertilizer. Treatment with urea fertilizer applied at $60 \text{ kg}\cdot\text{ha}^{-1}$ in combination with maize cob ash applied at $3 \text{ t}\cdot\text{ha}^{-1}$ produced the highest values of okra yield while urea fertilizer applied at $120 \text{ kg}\cdot\text{ha}^{-1}$ in combination with

maize cob ash applied at $3 \text{ t}\cdot\text{ha}^{-1}$ has the highest N, K, Ca, Cu, and Fe contents of okra fruit. Therefore, for viable production of okra in low nutrient soil of the Nigeria-derived savanna or similar soils elsewhere, $60 \text{ kg}\cdot\text{ha}^{-1}$ urea fertilizer + $3 \text{ t}\cdot\text{ha}^{-1}$ maize cob ash is recommended.

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