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Application of Urea and Wood Ash on Soil Nutrient Composition, Growth and Yield of Okra Under Degraded Humid Tropical Alfisol of South Western Nigeria

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Abstract

Experiments were conducted at Teaching and Research Farm of the Federal University of Technology, Akure in 2017 and 2018 on a humid degraded alfisol in the rainforest zone of Nigeria to test the effect of sole application of urea fertilizer, and its combined use with wood ash at three different combinations of rates. Aside from the control (no treatment), five other treatment were 100 % urea (U) at 200 kg/ha, 100 % wood ash (W) at 4 t/ha, 75% U + 25 % W, 50 % U + 50 % W and 25 % U + 75 % W. The six treatments were replicated three times. Urea alone or combined with ash at reduced rates significantly increased okra growth, number and weight of pods, mean increases in number of pods given by urea was 54.2 % in two years, whereas, it was 56 % for 75 % U + 25 % W and 25 % U + 75 % W. Our findings confirmed that plant protein was increased by urea and its combinations with ash. Sodium was also increased. Ash and its combinations with urea significantly increased Mg in 2017. In both years, urea increased nutrients contents. It is recommended that combined application of urea (U), and wood ash (W) especially at 50 % U + 50 % W, and 75 % U + 25 % W be adopted for cultivation of okra for enhanced yield and nutritional quality and balanced soil fertility.

Keywords: Organic Waste, Urea, Wood Ash, Okra Yield, Tropical Alfisol

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a widely cultivated vegetable which is very important in the diet of Nigerians. Okra fingers are excellent source of minerals which impact resistance against many diseases [1,2,3]. The crop provides an excellent income and generates other opportunities for small scale farmers on the value chain of production, transportation, processing and marketing [4]. Okra is a warm loving plant that performs optimally in well drained fertile sandy loam soil with optimum nitrogen and potassium for improved growth and pod yield respectively [5]. Its cultivation therefore demands research in the management of soil fertility. The use of both organic and inorganic fertilizers has been reported to increase yield of okra [6,7]. The application of inorganic and organic fertilizers has been found to increase soil pH, nutrients content and yield of okra [7]. Also the use of N fertilizer solely has been found to increase soil acidity which led to adverse effect on okra performance [8,9,10]. Whereas, use of different organic manures individually, have been reported as good alternatives to inorganic fertilizers for improved ash up to 8 t/ha and wood ash had high K content and C: N ratio. This study seeks to examine complimentary efficiency of urea and wood ash on okra growth, yield, soil and plant nutrients composition as influenced by combined application of wood ash and urea.

Materials and Method

Description of the Study Area

The field experiments were two trials conducted at Teaching and Research Farm of Federal University of Technology Akure in the humid rainforest zone of southwest Nigeria, and these were done to determine the influence of combined application of wood ash and urea on soil nutrient composition, growth and yield of okra. The experimental site with soil textural characterised as sandy clay loam was used in early rainy season of 2017 and 2018. The soil at the experimental site belongs to the soil order alfisol classified as clayey skeletal oxic-paleustaif [11]. Akure lies between Lat. 7° 17'N and Long. 5° 18 'E of the Greenwich Mean Time (GMT), with a bimodal rainfall pattern consisting of long rainy season usually between March and July and a short rainy season extending from September to early November, after a short dry spell in August and a longer dry period from December to February. The location is about 351 m above the sea level, covered with an area of about 2,303 km^2, situated within the western upland area, the annual average precipitation is between 1000 and 2060 mm, while the annual average temperature of the area is between 29 and 37 °C, but between 21 and 31 °C during the experimental period as presented in Table 1. The soil is made up of ferruginous tropical soils [12], with exceptional clayey texture, but the drainage is good with adequate aeration, moderate moisture and nutrient retention capacity [13].

Table 1: Selected meteorological data during experimental period at Akure, Nigeria

Year/month	Average monthly precipitation (mm)	Average monthly temperature (°C) Max	Min	Mean daily radiation (Wm^{-2})	Average relative humidity (%)
2017					
March	02.66	31.02	23.16	132.32	83.06
April	04.95	29.72	23.28	141.48	86.76
May	06.85	28.84	23.04	147.45	89.54
June	08.25	28.23	22.37	137.75	89.72
July	12.09	27.51	21.65	121.23	90.32
August	8.11	27.35	21.47	115.56	90.60
2018					
March	01.97	30.28	22.87	137.07	84.38
April	02.20	29.44	23.09	140.17	86.76
May	04.80	28.66	22.80	145.63	89.10
June	13.30	27.52	22.07	138.10	90.95
July	10.09	27.41	21.59	119.55	90.52
August	11.70	27.11	21.33	111.91	90.82

Source: West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), the Federal University of Technology, Akure, Nigeria.

Sample Collection and Preparation

Bulked soil sample collected at a depth of 0-15 cm was analyzed with the aid of auger from each experimental site for both physical and chemical properties. Forty-eight (48) composite soil samples were collected before urea application at a depth of 0-15 cm and analyzed for physical and chemical properties. The soil samples were analyzed prior to treatment application.

Experimental Design and Procedure

The treatments were replicated three times using a randomized complete block design for the two trials. Each site was marked with three blocks, while each block was divided into six plots giving a total of 18 subplots, each being 2 m x 3 m. Three seeds were planted at a spacing of 50 x 60 cm, thinning was carried out to one plant per stand. Fertilizing materials were applied on soil surface three weeks after planting in ring form with urea and ash mixed at stated three ratios, in addition to sole applications of urea and ash, and a control. Weeding was done manually before application of treatments and at 4 and 7 weeks after planting. Six treatments were applied to okra (*Abelmoschus esculentus* (L) Moench) plant. The treatments were the following: (i) 100 % urea (200 kg urea fertilizer), (ii) 75 % urea + 25 % wood ash, (iii) 50 % urea + 50 % wood ash, (iv) 25 % urea + 75 % wood ash, (v) 100 % wood ash (4t/ha), (vi) control (no treatment).

Plant Data Collections

At three weeks after planting, five plants in replicates in all the treatments were randomly selected and tagged in each plot for determination of okra growth and yield parameters. Growth parameters included plant height, number of leaves, and stem girth. Yield parameters were number and fresh weight of pods, pod girth and length.

Soil Analysis

Soil samples were collected at harvest in each plot for analysis, and at harvest for chemical analysis [14]. Total N by micro kjedahl method was determined, available P was extracted using Bray P1 solution and determined using spectrophotometer, Exchangeable K, Ca and Mg were extracted with ammonium acetate, Na and K were determined using flame photometer and Ca and Mg by EDTA titration method. Organic matter was determined using Walkley Black dichromate method [15].

Leaf Analysis

Leaf samples collected at harvest in each plot were oven dried at 90 ° C for 24 hours and ground into powder and nutrients were extracted using nitric perchloric acid mixture [16]. Nitrogen was determined using micro kjeldahl digestion method [17], the Phosphorus was determined using molybdenum blue colorimetry and read on spectrophotometer, potassium by flame photometer, and Calcium and Magnesium by EDTA titration.

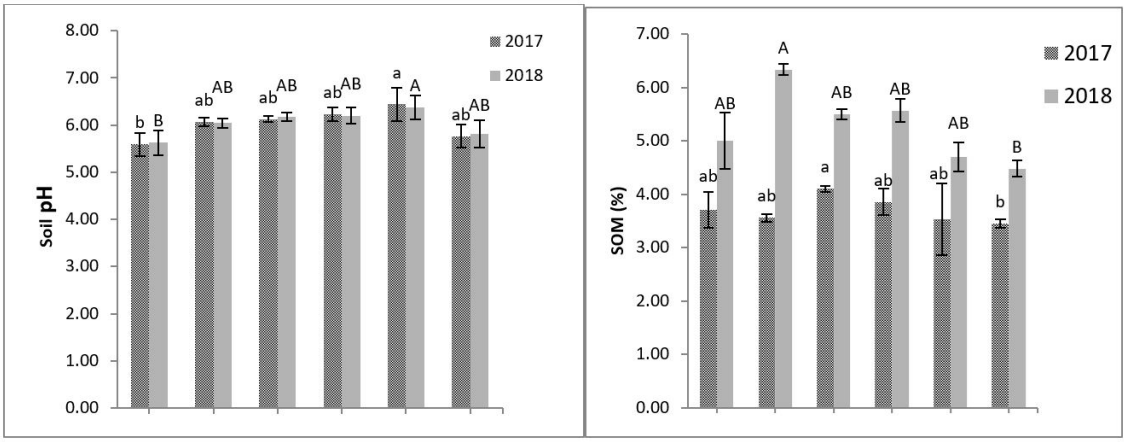
Statistical Analysis

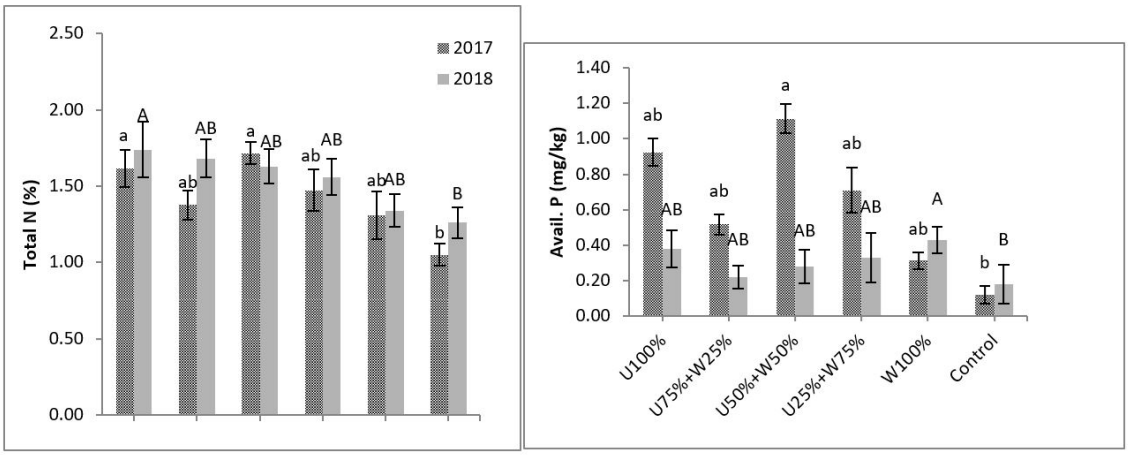
All the data collected were subjected to analysis of variance as described by [18]. Duncan's multiple range tests [19] at 5 % probability level was used to separate significant differences in the means of the treatments.

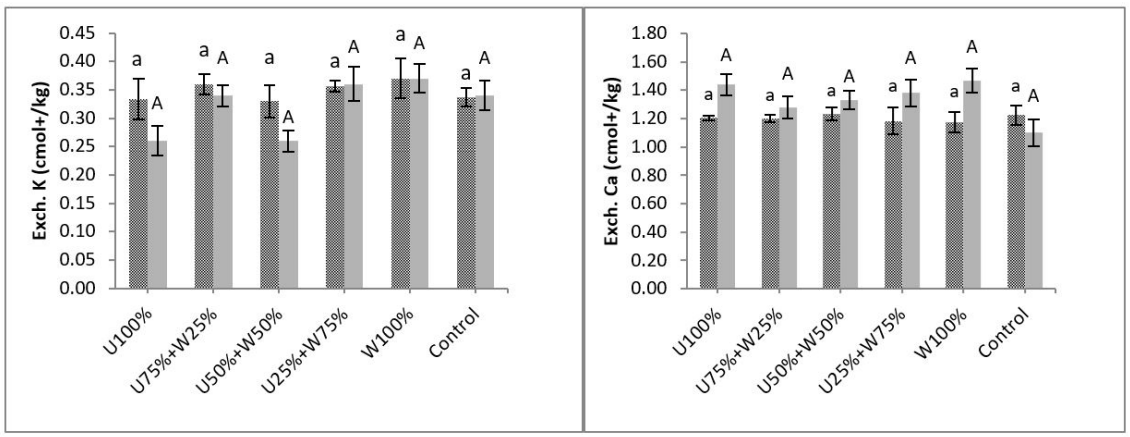
Results

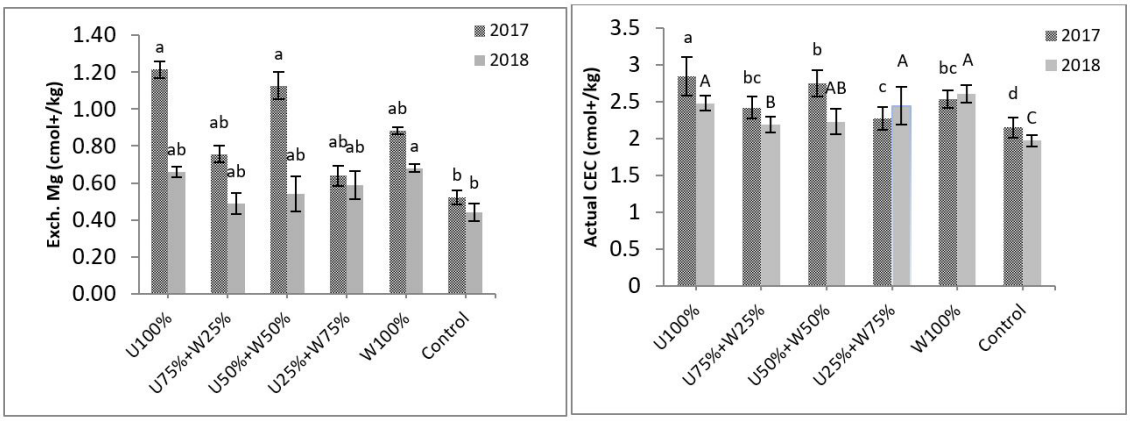
Soil Nutrient Composition

The figure 1 shows data on soil chemical properties relative to control, urea, ash and their combinations increased organic matter, pH, N, P, Mg, actual CEC and base saturation. Exchangeable Ca was also increased in 2018. Ash (W) and its combinations with urea (U 50 % + W 50 %, U 25 % + W 75 %) also increased K in 2018 though insignificantly.


Soil pH
SOM (%)
2017
2018


Total N (%)
Avail. P (mg/kg)
2017
2018
U100%
U75%+W25%
U50%+W50%
U25%+W75%
W100%
Control


Exch. K (cmol+/kg)
Exch. Ca (cmol+/kg)
U100%
U75%+W25%
U50%+W50%
U25%+W75%
W100%
Control


Exch. Mg (cmol+/kg)
Actual CEC (cmol+/kg)
2017
2018
U100%
U75%+W25%
U50%+W50%
U25%+W75%
W100%
Control

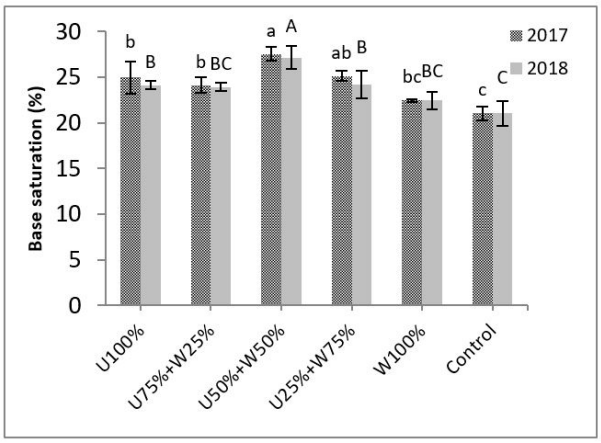


Figure 1: Values are given as mean ± standard error (n=5). Different lowercase and uppercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, P ≤0.05)

Growth Parameters

Wood ash significantly increased okra plant height in 2017 and 2018 as from three weeks after planting (WAP). At 6, 7 and 8 WAP, ash significantly increased number of leaves but the increases in the third, fourth and fifth weeks were not significant. In 2017, stem girth was increased by ash between 4 and 8 WAP though insignificantly. However in 2018, the increases were significant (P ≥ 0.05). The combined application of the materials significantly increased stem girth at 4, 5, 6, 7 and 8 WAP. Increases in the number of leaves due to combination of ash and urea showed as from 3 WAP but significant increase showed between 6 to 8 WAP. It is affirmed that urea or combinations of urea and ash significantly increased the growth parameters of okra (Table 2, 3 and 4).

Table 2: Effect of combined urea (U) and wood ash (W) on okra plant height

Treatments	Plant height (cm) (weeks after planting)					
	3	4	5	6	7	8
	2017					
U100%	8.75ab	11.05ab	16.35ab	24.10ab	35.10ab	50.57ab
U75%+W25%	8.45ab	10.39b	16.49ab	25.16ab	36.60ab	50.00ab
U50%+W50%	9.24ab	13.02a	21.13a	30.74a	45.10a	56.63a
U25%+W75%	9.29ab	10.91ab	17.08ab	25.45ab	35.13ab	46.90ab
W100%	9.51a	13.19a	19.32a	28.13a	38.93ab	46.67ab
Control	7.06b	9.80b	14.11b	19.53b	28.27b	37.80b
	2018					
U100%	18.67a	26.67a	27.17a	33.67abc	43.00b	59.37abc
U75%+W25%	17.00ab	19.50ab	26.67a	35.17ab	43.00ab	62.23ab
U50%+W50%	17.00ab	20.00a	29.50a	36.83a	44.57a	64.67a
U25%+W75%	16.00ab	18.67ab	26.00ab	32.17bc	39.67abc	56.43bcd
W100%	17.33ab	28.67a	28.83a	31.43c	36.23bc	53.43cd
Control	12.33b	15.33b	22.00d	27.33d	82.83c	48.83d

Values are given as mean ± standard error (n=5). Mean values in the same column followed by different lowercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, P ≤0.05).

Table 3: Effect of urea plus wood ash on number of okra leaves

Treatments	Number of leaves per plants (weeks after planting)					
	3	4	5	6	7	8
	2017					
U100%	5.67a	5.67a	7.33a	10.33ab	13.67a	20.00a
U75%+W25%	5.00a	5.33a	6.67a	10.33ab	13.33ab	19.33a
U50%+W50%	6.00a	6.67a	8.33a	11.33a	14.33a	19.67a
U25%+W75%	6.00a	5.67a	7.33a	9.67ab	13.00ab	18.00a
W100%	5.00a	5.33a	7.33a	8.67ab	12.00ab	17.00ab
Control	5.00a	5.33a	6.33a	8.00b	10.00b	11.33b
	2018					
U100%	5.33a	6.00bc	8.33a	10.33b	12.33b	16.00b
U75%+W25%	5.00a	6.67ab	10.33a	12.67a	14.67a	19.00a
U50%+W50%	5.33a	7.00a	10.67a	13.67a	15.67a	19.67a
U25%+W75%	5.60a	6.00bc	8.67bc	10.33b	12.33b	15.33bc
W100%	5.00a	6.00bc	8.00bc	9.33b	11.00bc	13.67cd
Control	5.00a	5.67c	7.33c	7.67c	9.67c	12.00d

Values are given as mean ± standard error (n=5). Mean values in the same column followed by different lowercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, P ≤0.05).

Table 4: Effect of urea plus wood ash on stem girth of okra

Treatments	Stem girth (cm) weeks after planting					
	3	4	5	6	7	8
	2017					
U100%	1.53a	1.79a	2.99a	3.52ab	4.20ab	5.27ab
U75%+W25%	1.48a	1.85a	2.67a	3.41ab	4.23ab	4.80ab
U50%+W50%	1.75a	2.21a	3.33a	4.09a	4.90a	6.00a
U25%+W75%	1.68a	1.91a	3.03a	3.88ab	4.66a	5.43ab
W100%	1.45a	1.83a	2.83a	3.35b	4.11ab	4.57b
Control	1.47a	1.75a	2.75a	3.20b	3.46b	4.23b
	2018					
U100%	1.57a	1.83a	2.20a	2.70ab	3.00a	3.60a
U75%+W25%	1.65a	1.83a	2.07a	2.33ab	2.63ab	3.27ab
U50%+W50%	1.66a	1.83a	2.10a	2.77a	3.10a	3.80a
U25%+W75%	1.40a	1.57ab	1.83ab	2.30ab	2.63ab	3.20ab
W100%	1.63a	1.90a	2.10a	2.40ab	2.70ab	3.23ab
Control	1.10a	1.33b	1.53b	1.93b	2.23b	2.77b

Values are given as mean ± standard error (n=5). Mean values in the same column followed by different lowercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, P ≤0.05).

Response on Yield Parameters

Data on pod yield are shown in Table 4. Relative to control, urea alone or combined with ash at different rates significantly increased number of pods and weight of pods. Increases in pod dimensions (length and diameter) were not significant. With respect to number and weight of pods, 100 % urea, combined application of U 75 % + 25 % W, and U 50 % + W 50 % most increased values in 2017 and 2018. The mean increases in number of pods given by urea was 54.2 % in the two years, and it was 56.8 % for 75 % U + 50 % W. The pod yield (t/ha) in 2017 and 2018 respectively were 8.84, 6.52 and 8.55, 7.15 which were 36.76 %, 14.26 % and 33.33 %, 20.28 % over the control. The U 100 % and U 75 % + W 25 % gave the highest pod yield in 2017 and 2018 respectively, but no significant differences ($P \leq 0.05$) were obtained compared with U 50 % + W 50 % and U 25 % + W 75 % in 2017 and 2018.

Nutritional Quality of Okra Plant

Combined effect of urea and ash gave higher nutritional quality of plant relative to control i.e. higher protein, Na, Ca and Mg contents, this is attributable to uptake of readily available nutrients released from urea and ash and more balanced nutrients supply. Hence the integrated nutrients supply is not only limited to crop growth and yield in its effect, it also enhanced nutritional quality of okra plant. This is important since okra leaves are also utilised as vegetable. In this work, higher protein, Na, Ca and Mg contents were recorded in two years of the study due to combination of urea and ash (Table 5).

Table 5: Effect of urea (U) and wood ash (W) on yield parameters of okra

Treatments	Yield parameters of okra				
	No of pods	Pod girth (cm)	Pod length (cm)	Pod weight (g)	Pod yield (t/ha)
	2017				
U100%	237a	4.27a	9.90a	377a	10.78a
U75%+W25%	224a	3.83ab	10.50a	344a	9.84a
U50%+W50%	237a	4.37a	13.60a	310ab	8.84a
U25%+W75%	156ab	4.17a	11.50a	228ab	6.52ab
W100%	147ab	4.37a	11.77a	185c	5.27c
Control	129b	3.63b	10.13a	196c	5.59c
	2018				
U100%	196ab	4.05a	11.80a	271ab	7.72a
U75%+W25%	208a	3.88a	11.17a	287ab	8.18a
U50%+W50%	208a	3.79a	12.40a	300a	8.55a
U25%+W75%	177ab	4.10a	11.59a	251ab	7.15ab
W100%	169ab	3.91a	11.66a	248ab	7.07c
Control	157b	3.96a	11.32a	200b	5.70c

Values are given as mean ± standard error (n=5). Mean values in the same column followed by different lowercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, $P \leq 0.05$).

Discussion

Soil Nutrients Composition

Result (Figure 1) shows the status of the soil in the experimental site after application of treatments. Wood ash alone and its combination with urea increased soil organic matter, pH, N, P, Mg, K, and Ca which led to significant increases in growth parameters, pod yield and nutrients status of okra plants. The works by [20, 21, 22, 23, 24] have asserted ash was effective in improving soil nutrients contents and fertility. As in the present work, these references also asserted that ash has liming effect by increasing availability of basic nutrients in soil and hence soil pH. [6] also reported that sawdust ash had liming and fertilizing effects in crops production. The present work found that ash and its combination with urea increased soil pH, organic matter and nutrients, thereby confirming findings of previous studies. The increasing soil pH and reduction in soil acidity is attributable to release of base elements by ash. Also increase in organic matter due to application of ash should have contributed to increase of soil nutrients, including base elements which have liming effect (Ca, Mg, K).

Growth Parameters

The results of the growth parameters of okra in this study corroborated the findings reported by [26, 27] that additions of ash from wood have also increased growth parameters of Okra. Wood ash increased plant height in 2018 and 2019 especially at week 6, 7 and 8. This is because, ash was reported to have improved soil chemical characteristics and subsequent okra yield [28] compared with the control. Improving soil acidity status due to addition of wood ash would have resulted into an increased in the growth and yield of the okra.

Yield Characteristics

Previous studies conducted in different locations in southwestern Nigeria also asserted that ash increased productivity of different crops [29] crops such as Soybean has also been reported by [30], Sorghum [22], cassava [31], cocoa [23] and okra [24]. The okra yield data has shown that combinations of organic manure in form of wood ash and urea at U50 + W50 maximized number of pods in 2017 given 54 % increase in number of pods. In 2018, it also gave maximum increase in number of pods (32 %) and pod weight (50 %) relative to control (no treatment). The positive impact of the integrated plant nutrition management was supported by the results of our study. The findings from this work further clarify the application of integrated plant nutrition based on combined application of organic and chemical fertilizers especially in tropical agriculture. The high cost, scarcity and low efficiency make use of organic fertilizers unprofitable for farmers. Also, continuous use of N or NPK fertilizers leads to soil acidification, nutrient imbalances and possibly soil physical degradation [32]. According to [33], it is more efficient to combine organic and inorganic nutrient sources than to use either separately. In terms of residual effect, the effect of inorganic fertilizers may not extend beyond two seasons. Because of the advantages adduced to integrated soil fertility or plant nutrition management, recent development focuses on utilization of nutrients supplied from organic and inorganic sources as supported by this work. This is emphasized in the FAO's approach to soil fertility and productivity maintenance in past decade. One of the objectives of FAO's IPNS (Integrated Plant Nutrients System) is to maintain or enhance soil productivity through a balance use of mineral fertilizers combined with organic sources including the use of crop residues and domestic wastes. The concept of organic nutrient cycling to make nutrients available for soil fertility maintenance is sound and needs encouragement particularly in small holder production systems of the tropics.

Nutritional Quality of Okra

Combinations of urea and ash significantly increased protein and mineral content of okra in 2017 and 2018 (Table 6). Higher plant protein and mineral, Na, Ca and Mg contents were given by combinations of urea and ash relative to control and urea alone. Application of 75 % U + 25 % W recorded the highest protein content which differs significantly in 2017 and 2018. However, urea gave the highest protein content in 2018, which tallies with the fact that nitrogen is the building material for protein. The higher nutritional quality given by combined applications of ash and urea is consistent with the finding that the combined treatments (especially U 50 % + W 50%) most increased soil nutrients and especially in 2017. The soil nutrients dictated mineral composition of okra leaf. It is concluded that combined application of urea and ash most enhanced soil fertility, performance and nutritional quality of okra.

Table 6: Effect of urea (U) plus wood ash (W) on protein and mineral content of okra

Treatments	Protein and mineral contents					
	Protein	Sodium (mg)	Calcium (mg)	Potassium (mg)	Magnesium (mg)	Phosphorus (mg)
	2017					
U100%	1.72a	7.22ab	69.11a	327.34a	54.32b	50.82a
U75%+W25%	1.89a	8.28ab	62.71a	291.81a	60.17a	49.58a
U50%+W50%	1.57ab	7.09ab	60.43a	300.27a	56.18ab	51.90a
U25%+W75%	1.59ab	7.12ab	64.52a	292.14a	57.25ab	49.91a
W100%	1.58ab	9.10a	66.23a	301.73a	60.18a	50.79a
Control	0.87b	6.93b	57.56b	303.88a	54.22b	49.93a
	2018					
U100%	2.37a	6.03ab	56.91a	326.42a	52.60a	51.07a
U75%+W25%	2.03a	5.95ab	54.25ab	318.10a	52.17a	51.87a
U50%+W50%	2.14a	5.64ab	52.61ab	320.87a	53.65a	50.94a
U25%+W75%	2.25a	5.34ab	51.18ab	323.65a	51.12a	51.00a
W100%	1.91a	6.25a	55.48ab	325.33a	54.70a	50.80a
Control	1.30b	4.56b	49.75b	302.56a	51.22a	48.73a

Values are given as mean ± standard error (n=5). Different lowercase letters indicate significant differences among the treatments in 2017 and 2018 respectively (Tukey's HSD test, P ≤0.05).

Conclusion

The study therefore evaluated combined effect of urea and wood ash on soil and plant nutrients composition, growth and yield of okra, at Akure in the rainforest transition ecology of southwestern Nigeria. Soil chemical properties such as pH, OC, OM, N, available P, exchangeable Ca and Mg were improved significantly. The result showed superior okra growth in terms of plant height, number of leaves and stem girth of okra with application of 50 % urea + 50 % wood ash in 2017 and 2018. Similar observation was made with respect to okra yield components such as number of pods and pod weight. Urea (75 % U + 25 % W and 50 % U + 50 % W increased number of pods by 83.5, 73.4 and 83.5 % respectively in 2017, the equivalent values for number of pods in 2018 were 25.0, 32.4 and 32.4 %. The values for pod weight were 42.2, 75.6, and 53.0 % for 100 % U, 75 % U + 25 % W and 50 % U + 50 % W respectively in 2017, and equivalent values for pod weight in 2018 were 35 %, 43.2 % and 49.4 %. The pod yield (t/ha) in 2017 and 2018 respectively were 8.84, 6.52 and 8.55, 7.15 translated to 36.76 %, 14.26 % and 33.33 %, 20.28 % over the control. Nutritional constituents of okra pod such as protein, sodium, calcium and magnesium were significantly improved with combined application of

urea and wood ash. Protein was increased by urea and combinations of urea and wood ash in 2017 and 2018. In both years of study, urea increased nutrient contents. Amending degraded humid tropical soils with nutrients from organic and inorganic sources should be appropriately considered. It is therefore recommended that combined application of urea and wood ash, especially at 50 % urea + 50 % wood ash and 75 % U + 25 % W be adapted for cultivation of okra for enhanced yield and nutritional quality and balanced soil fertility.

Conflict of Interest

The authors agreed that there is no conflict of interest in the manuscript.

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