Effects of cocoa pod ash and urea on soil chemical properties and the performance of kale (Brassica oleracea L.) in derived savanna zone of Nigeria

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Effects of cocoa pod ash and urea on soil chemical properties and the performance of kale (*Brassica oleracea* L.) in derived savanna zone of Nigeria

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Potted experiments were carried out at the Teaching and Research Farm, Landmark University, Nigeria between January and March (1st crop) and April and June (2nd crop), 2015. The aim was to investigate the effects of sole and integrated application of cocoa pod ash (CP) and urea fertilizer (UF) on soil chemical composition and performance of kale (*Brassica oleracea* L.). There were 12 treatments comprising 3 levels of UF (0, 100, 200 kg/ha) and 4 levels of CP (0, 5, 10 and 15 t/ha). The treatments were arranged in a Completely Randomised Design, replicated three times. For the 1st and 2nd crops of kale, CP alone and integration with UF, increased soil chemical properties compared with the control where neither CPA nor UF was applied. Treatments with 5 t/ha cocoa pod ash + 100 kg/ha urea fertilizer (CP_5U_{100}) and 5 t/ha cocoa pod ash + 200 kg/ha urea fertilizer (CP_5U_{200}) consistently had the higher values of N, K Ca and Mg in the soil after both the 1st and 2nd kale crops and the mean values of both crops. Treatments with CP_5U_{100} and CP_5U_{200} had significantly higher and similar values of plant height, number of leaves and other yield parameters (root weight, stem weight, leaf weight, stem girth and stem length) of kale compared with other treatments. Compared with the control, CP_5U_{100} and CP_5U_{200} increased the leaf weight of kale by 243 and 268%, respectively. Therefore, integration of cocoa pod ash at 5 t/ha with 100 kg/ha urea fertilizer may be recommended in the production of kale in the derived savanna zone of Nigeria to cut down on the use of urea and its rising cost. More research is, however, needed involving field experimentation and additional soil types to make a firm recommendation.

Keywords: Cocoa pod ash, urea fertilizer, kale, soil chemical composition

Vegetables are important in meeting the nutritional needs of humans and maintaining healthy daily living. Among the popular vegetables is kale (*Brassica oleracea*). Kale is a leafy green vegetable that belongs to the Brassica family, which comprises vegetables such as cabbage, collards and brussel sprouts. It is an annual crop, with sizes which vary with variety. Most possesses leaves that are about 12-36 inches in width, 12-24 inches in height. The time to maturity is approximately 2 months depending on temperature (Damrosch 2004). Although it is a low temperature crop, its recent introduction into hot tropical countries like Nigeria may be due to the nutritional and health benefits people derived from it, compared with other leafy vegetables. Kale has been recognised as a good source of vegetable fibre which helps to reduce high cholesterol level thus helping in the prevention of atherosclerosis. It also helps to keep the blood sugar levels under control and is an excellent vegetable for people with diabetes. The high protein content of kale confers on it the advantage as a rich source of vegetable protein over other less grown vegetables in Nigeria (Emuebu and Anyika 2011). According to Emuebu and Anyika (2011), the proximate compositions of kale are carbohydrate 2.36%, fat 0.26%, crude protein 11.67%, moisture 81.38%, crude fibre 3.00%, ash 1.33% and energy 58.46 K cal/100g.

For optimum yield of kale, good, fertile soil that supplies nutrients for the growth and development of the crop is required. However, in Nigeria, fertile arable land is on the decline, and this therefore necessitates the use of fertilizers to supplement soil nutrients, especially N, which is required for succulent leaves of kale. Over the past two decades, urea has replaced ammonium sulphate and calcium ammonium nitrate as a single N source used in

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crop production in Nigeria (Omolayo and Ayodele 2007). The use of an inorganic fertilizer, like urea, has proven to be more convenient than the use of organic fertilizers. Chemical fertilizers have, however, become very scarce in Nigeria and prices have become prohibitively high for average farmers to afford. Hence there is the need to use organic amendments as an alternative source of nutrients in kale production. The use of organic amendment is also limited by the large quantity needed to meet crop requirements. Judicious application of inorganic fertilizer along with organic manure is one of the concepts gaining importance as it forms the integrated soil fertility management (Iren et al. 2014).

Like every other crop, kale fresh weight, root fresh weight, stem dry weight and root weight have been reported to increase with application of encapsulated urea fertilizer in Thailand (Pinpeangchan and Wanapu 2015). Also, Gebeyehu and Kibret (2013) reported increase in kale yield using compost manure compared with chemical fertilizer in Ethiopia. Ash derived from cocoa pod husk has been found to be a useful source of both micro and macro nutrients for various crops in Nigeria (Ajayi et al. 2007; Akanbi et al. 2013). However, the effects of integrated nutrient supply as opposed to sole application of soil amendment and its effects on soil chemical properties and kale performance have not been investigated. It is expected that integrating the two amendments would have better effect on soil chemical properties and growth and the yield of kale. This study investigates the sole and integrated application of cocoa pod ash and urea fertilizer on soil chemical composition and performance of kale in Omu-Aran, derived savanna zone of Nigeria.

Materials and methods

Location and soil

The experiments were conducted at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria between January and March 2015 and repeated again between April and June in 2015 to validate the results. Landmark University lies between Lat 8^o 9' N and long 5^o 61' E and is located in the derived savanna ecological zone of Nigeria (Derived savanna is evolved from the rain forest by human activities such as regular fire, deforestation and farming activities. Only a few fire tolerant trees are found and the area can advance to forest if communal burning is stopped). There are two rainy seasons, one from March to July and the other from mid-August to November. The study area has a mean annual rainfall of about 1300 mm and mean annual temperature of 32^{o}C. The soil at Omu-Aran is an Oxic Haplustalf from the USDA soil order Alfisol or Luvisol from the FAO soil classification. Soil samples were taken from an area that has been exposed to maize cultivation for two years.

Sample preparation

Soil samples were collected randomly from 0-15 cm depth at the Research Farm using a soil auger, mixed thoroughly and sieved with a 2 mm sieve to remove stones and debris. 10 kg of the sieved soil were weighed into a poly bag (30 x 17 cm), perforated at the bottom to allow for air and water movement. The poly bags were randomly placed under a shed for unbiased application of amendments. The experiment comprised 12 treatments with 3 levels of urea fertilizer (0, 100, 200 kg/ha) and 4 levels of cocoa pod ash (0, 5, 10 and 15 t/ha) in a 3 x 4 factorial experiment. These were combined to have 12 treatments, viz; (a) Cocoa pod ash 0 t/ha + Urea 0 kg/ha (CP_0U_0), (b) Cocoa pod ash 5 t/ha + Urea 0 kg/ha (CP_5U_0), (c) Cocoa pod ash 10 t/ha + Urea 0 t/ha ($CP_{10}U_0$), (d) Cocoa pod ash 15 t/ha + Urea 0 kg/ha (CP_{15} U_0), (e) Cocoa pod ash 0 t/ha + Urea 100 kg/ha (CP_0U_{100}), (f) Cocoa pod ash 5 t/ha + Urea 100 kg/ha (CP_5U_{100}), (g) Cocoa pod ash 10 t/ha + Urea 100 kg/ha ($CP_{10}U_{100}$), (h) Cocoa pod ash 15 t/ha + Urea 100 kg/ha (CP_{15} U_{100}), (i) Cocoa pod ash 0 t/ha + Urea 200 kg/ha (CP_0U_{200}), (j) Cocoa pod ash 5 t/ha + Urea 200 kg/ha (CP_5U_{200}), (k) Cocoa pod ash 10 t/ha + Urea 200 kg/ha ($CP_{10}U_{200}$), (l) Cocoa pod ash 15 t/ha + Urea 200 kg/ha ($CP_{15}U_{200}$). The treatments were arranged in a Completely Randomised Design replicated three times.

Nursery and transplanting of kale

Kale seeds were pre-germinated in a germinating tray in a mixture of 50% top soil 50% grinded coconut fibre as a germinating media for 21 days, in a covered and protected nursery. Seedlings were later transplanted to the poly bags on the 4th of January for the first experiment and 6th of April for the repeated experiment to validate results. One healthy seedling was transplanted in each poly bag. Watering was done immediately after transplanting and thereafter every morning to maintain water content at approximately field capacity throughout the duration of the experiment. Weeding was done by hand picking emerged weeds from each pot.

Application of amendment

Quantities of 25 g, 50 g and 75 g of cocoa pod ash were incorporated into the soil in the poly bags representing the equivalent 5, 10 and 15 t/ha, respectively. The treatments were incorporated into the soil using hand trowel and allowed to decompose for one week before transplanting kale into the poly bags. Watering was done immediately and continued every morning. 0.5 g and 1 g of urea fertilizer equivalent to 100 and 200 kg/ha were applied to the poly bags one week after transplanting kale.

Soil analysis

Soil physical and chemical analyses were performed on the 2 mm sieved initial samples before incorporation of amendments. Soil chemical analyses were also conducted on treated samples at the end of the experiments using methods as described by Carter (1993). The particle size analysis was done using the Bouyoucos hydrometer method (Sheldrick and Wang 1993). The soil organic matter content was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommer 1996); total N was determined by the micro-Kjeldahl digestion method and distillation techniques (Bremner 1996), available P was extracted using Bray-1 solution and determined by molybdenum blue colorimetry (Frank et al. 1998). Exchangeable K, Ca and Mg were extracted using 1 N ammonium acetate. Thereafter, K level was determined using a flame photometer and Ca and Mg by the EDTA titration method (Hendershot et al. 2007). Soil pH was determined using the digital electronic pH meter on a soil-water medium at a ratio of 1:2.

Preparation and chemical analysis of cocoa pod ash

Dried cocoa pod husk was collected from a cocoa farm, burnt to ash and sieved with a 2 mm sieve before application. Samples from the cocoa pod ash used for the study were taken for laboratory analysis to determine their nutrient compositions. The samples were analysed for organic C, N, P, K, Ca and Mg as described by Okelabo et al. (2002).

Determination of growth and yield components

The height and number of leaves of each plant per ploy bag were measured at 4 and 6 weeks after transplanting. The height was measured using a meter rule from the soil level to the top of the highest growing point. The leaf number was determined by counting the number of fully expanded leaves. Two months after transplanting, the whole plant for each treatment was harvested and partitioned into 3, the leaves, the stem and the roots which were weighed separately. The fresh weight of the leaves, stem and roots was taken using a weighing balance known as Ohau model PA2102. Soil was removed from the roots using clean water after which they were allowed to dry for 24 hrs at room temperature before the weight was taken. The stem length was taken with a meter rule while the stem girth was measured using the vernier caliper.

Statistical analysis

Data collected were subjected to statistical analysis of variance (ANOVA) using SPSS 17. The treatment means were compared using the Duncan's multiple range test (DMRT) at 0.05 level of probability.

Results

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

The physical and chemical properties of the soils (0-15 cm) potted in bags before cropping and the chemical properties of the cocoa pod ash used for kale production are shown in Table 1 and 2, respectively. The particle size analysis indicated that the soils were sandy loam in texture with high sand values and low values of both silt and clay. The soils were acidic and low in organic matter (2.24%; 2.21%), total N (0.14%; 0.16%), available P (9.5 mg/kg; 9.6 mg/kg) and exchangeable K (0.13 cmol/kg; 0.14 cmol/kg), Ca (2.0 cmol/kg; 2.1 cmol/kg) and Mg (0.32 cmol/kg; 0.36 cmol/kg) according to the critical levels of 3.0 % organic matter, 0.20% N, 10.0 mg/kg available P, 0.16-0.20 cmol/kg K, 2.0 cmol/kg exchangeable Ca and 0.40 cmol/kg exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan 2000). This indicates that the soils are unable to sustain crop yield without the addition of external input. Cocoa pod ash was high in K, Ca and Mg and low in N and P, while urea was high in N only and other nutrients. Therefore application of cocoa pod ash and urea fertilizer is expected to improve soil fertility and yield of kale.

Table 1: Mean ± standard deviation of soil physical and chemical properties of the soils used for the experiment

Property	1st crop	2nd crop
Sand (%)	76 ± 1.5	76 ± 1.6
Silt (%)	13 ± 1.3	13 ± 1.2
Clay (%)	11 ± 1.1	11 ± 1.0
Textural class	Sandy loam	Sandy loam
pH (water)	5.25 ± 0.02	5.36 ± 0.02
Organic matter (%)	2.24 ± 0.04	2.21 ± 0.03
Total N (%)	0.14 ± 0.01	0.16 ± 0.01
Available P (mg/kg)	9.5 ± 0.3	9.6 ± 0.3
Exchangeable K (cmol/kg)	0.13 ± 0.01	0.14 ± 0.01
Exchangeable Ca (cmol/kg)	2.0 ± 0.1	2.1 ± 0.1
Exchangeable Mg (cmol/kg)	0.32 ± 0.01	0.36 ± 0.01

Table 2: Nutrient composition of cocoa pod ash used as soil amendment

Nutrient	N (%)	P (%)	K (%)	Organic C (%)	C/N	Ca (%)	Mg (%)
Cocoa pod ash	1.27	1.22	14.01	16.97	13.36	3.33	2.1
Urea fertilizer	45	-	-	-	-	-	-

Effect of sole and integrated application of cocoa pod ash and urea fertilizer on soil chemical properties

The results of the effect of sole and integrated application of cocoa pod ash and urea fertilizer on soil chemical properties are presented in Table 3. For both crops of kale (1st and 2nd crops), cocoa pod ash alone and integration with urea fertilizer increased significantly the values of measured soil chemical parameters compared with no application of either cocoa pod ash (CP) or urea fertilizer i.e CP_0U_0. Treatments $CP_{15}U_0$, $CP_{15}U_{100}$ and $CP_{15}U_{200}$ significantly increased soil organic matter and P values compared with other treatments, although the values of these treatments are not significantly different from each other in terms of soil organic matter and P. Using the mean value, treatments $CP_{15}U_0$, $CP_{15}U_{100}$ and $CP_{15}U_{200}$ have the highest values of soil organic matter and P while CP_0U_0 has the least. Similarly, treatments CP_5U_{100} and CP_5U_{200} significantly increased soil N, K, Ca and Mg values compared with others. The treatments consistently have the higher values of N, K, Ca and Mg in both times of cropping kale and the mean values of both crops. However, there were no significant differences in the application of CP at 5, 10 and 15 t/ha with all its combination with urea fertilizer. Also there were no significant differences in the soil organic matter, N, P, K, Ca and Mg values between urea fertilizer applied at 100 and 200 kg/ha.

Effect of sole and integrated application of cocoa pod ash and urea fertilizer on plant height and number of leaves of kale

The results of the effect of sole and integrated application of CP and urea fertilizer on plant height and number of leaves of kale are shown in Figures 1 and 2, respectively. Results revealed that when the effect of CP was considered at fixed rate of urea fertilizer, application of CP increased plant height and number of leaves of kale relative to the control, there were however no significant differences between 10 and 15 t/ha CP. Similarly, when urea was considered at fixed rate of CP, plant height of kale increased relative to no application of urea and CP, however 100 and 200 kg/ha urea produced similar values. When CP and urea were integrated, CP_5U_{200} and CP_5U_{100} have significantly higher but similar values of plant height and number of leaves compared with other treatments, with CP_0U_0 having the least values. In all cases, $CP_{10}U_0$ and $CP_{15}U_0$ have similar values of plant height and number of leaves of kale. $CP_{10}U_{100}$ and $CP_{15}U_{100}$ also have similar values. Similarly, $CP_{10}U_{200}$ and $CP_{15}U_{200}$ also have statistically similar values of plant height and number of leaves of kale.

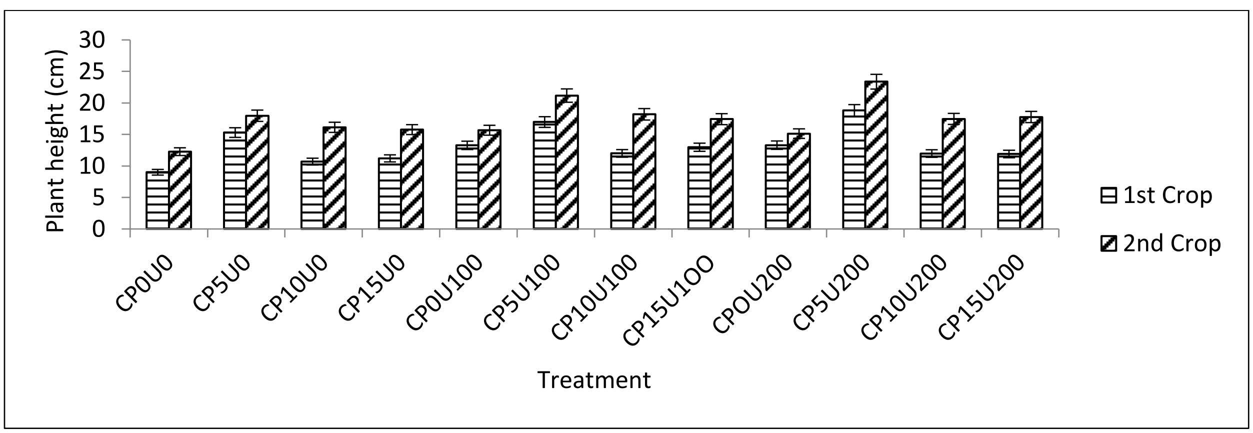

Figure 1: Effect of cocoa pod ash (CP) and urea fertilizer on plant height of Kale in the 1st and 2nd crops

Table 3: Effect of sole and integrated application of cocoa pod ash and urea fertilizer on soil chemical properties at the end of 1st and 2nd crops of kale

	SOM (%)			N (%)			P (mg/kg)			K (cmol/kg)			Ca (cmol/kg)			Mg (cmol/kg)		
	1st crop	2nd crop	Mean	1st crop	2nd crop	Mean	1st crop	2nd crop	Mean	1st crop	2nd crop	Mean	1st crop	2nd crop	Mean	1st crop	2nd crop	Mean
CP_0U_0	2.10c	1.96c	2.03	0.15f	0.14g	0.15	9.1b	8.3d	8.7	0.13e	0.12d	0.13	1.9b	1.6d	1.7	0.33d	0.31d	0.32
CP_5U_0	3.91ab	3.56b	3.74	0.31c	0.26d	0.29	13.6ab	10.1bc	11.9	0.18bc	0.20ab	0.19	2.8a	2.4a	2.6	0.44a	0.40a	0.42
$CP_{10}U_0$	4.40a	3.72ab	3.91	0.32c	0.27cd	0.30	13.8ab	10.8ab	12.3	0.17cd	0.20ab	0.19	2.8a	2.4a	2.6	0.43ab	0.40a	0.42
$CP_{15}U_0$	4.12a	3.89ab	4.01	0.32c	0.27cd	0.30	13.9a	11.1a	12.5	0.17cd	0.19b	0.18	2.9a	2.4ab	2.7	0.43ab	0.40a	0.42
CP_0U_{100}	2.11c	1.96c	2.04	0.18e	0.16f	0.17	9.2b	9.4c	9.3	0.16d	0.12d	0.14	1.9c	1.7cd	1.8	0.35cd	0.31d	0.33
CP_5U_{100}	3.93ab	3.58ab	3.76	0.43ab	0.33ab	0.38	13.9a	10.4ab	12.2	0.20a	0.21a	0.21	2.8a	2.5a	2.7	0.46a	0.41a	0.44
$CP_{10}U_{100}$	4.10a	3.71ab	3.92	0.36bc	0.29c	0.33	14.1a	10.8ab	12.5	0.18bc	0.21a	0.20	2.9a	2.5a	2.7	0.46a	0.41a	0.44
$CP_{15}U_{100}$	4.14a	3.86a	4.00	0.35bc	0.30	0.33	14.2a	11.3a	12.8	0.19ab	0.20ab	0.20	2.9a	2.4a	2.7	0.45a	0.40a	0.43
CP_0U_{200}	2.13c	1.97c	2.05	0.21d	0.19e	0.20	9.4b	8.5d	8.9	0.17cd	0.13cd	0.15	1.9b	1.7cd	1.8	0.35cd	0.31d	0.33
CP_5U_{200}	3.95ab	3.58ab	3.77	0.44a	0.34a	0.39	13.8ab	10.7ab	12.3	0.20a	0.21a	0.21	2.9a	2.5a	2.7	0.45a	0.42a	0.44
$CP_{10}U_{200}$	4.15a	3.73ab	3.94	0.40b	0.34a	0.37	14.2a	10.9ab	12.6	0.18bc	0.20ab	0.19	2.9a	2.5a	2.7	0.45a	0.41a	0.43
$CP_{15}U_{200}$	4.14a	3.90a	4.02	0.39b	0.33ab	0.36	14.2a	11.3a	12.8	0.18bc	0.19b	0.19	2.9a	2.4a	2.7	0.44a	0.41a	0.43

Mean in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using the Duncan Multiple Range Test (DMRT)

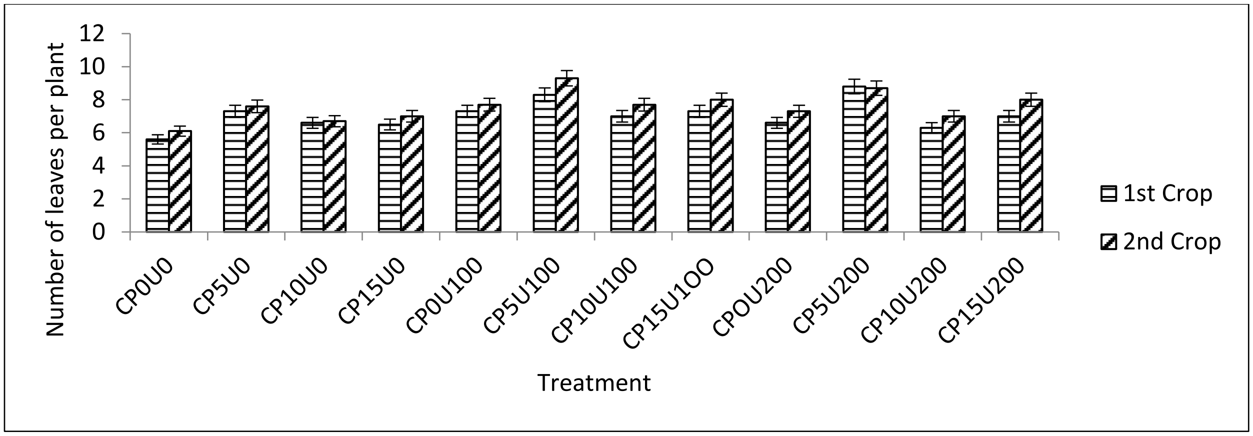

Figure 2: Effect of cocoa pod ash (CP) and urea fertilizer on number of leaves of Kale in the 1st and 2nd crops.

Effect of sole and integrated application of cocoa pod ash and urea fertilizer on yield parameters of kale

The results of sole and integrated application of CP and urea fertilizer on mean yield parameters of 1st and 2nd crops of kale are presented on Table 4. Cocoa pod ash or urea alone and the integration of both significantly increased the yield parameters of kale (root weight, stem weight, leaf weight, stem girth and stem length) compared with no application of CP or urea fertilizer i.e. CP_0U_0. Treatments CP_5U_{200} and CP_5U_{100} had the highest values of yield parameters, although their values were statistically not significant. Also $CP_{10}U_0$ and $CP_{15}U_0$ have statistically similar values. Likewise treatments $CP_{10}U_{100}$ and $CP_{15}U_{100}$ and treatments $CP_{10}U_{200}$ and $CP_{15}U_{200}$ have statistically similar values for all yield parameters. Compared with no application of CP or urea fertilizer (CP_0U_0), CP_5U_{100} and CP_5U_{200} increased the leaf weight of kale by 243 and 268%, respectively.

Table 4: Effect of sole and integrated application of cocoa pod ash and urea fertilizer on mean yield parameters of 1st and 2nd crops of kale

	Root weight (g)	Stem weight (g)	Leaf weight (g)	Stem girth (cm)	Stem length (cm)
CP_0U_0	0.22f	0.69g	11.10f	0.26g	4.2e
CP_5U_0	0.98cd	1.76bc	26.56cd	0.44cd	5.53bc
$CP_{10}U_0$	0.50ef	1.27e	17.90de	0.37bf	5.10d
$CP_{15}U_0$	0.47e	1.20e	15.65e	0.29f	5.13d
CP_0U_{100}	0.73cd	1.07f	19.65cd	0.33def	5.97ab
CP_5U_{100}	1.58ab	2.48ab	38.08ab	0.48ab	6.33a
$CP_{10}U_{100}$	1.21ab	1.98bc	28.78bc	0.46abc	5.70b
$CP_{15}U_{100}$	1.08abc	1.79cd	28.45bc	0.36cf	5.55bc
CP_0U_{200}	0.55ef	1.03f	17.38de	0.313f	5.40bc
CP_5U_{200}	1.61a	2.96a	40.82a	0.52a	6.77a
$CP_{10}U_{200}$	1.22b	1.81bc	28.45bc	0.42c	5.63b
$CP_{15}U_{200}$	1.20b	1.89bc	31.93ab	0.42c	5.67b

Mean in a column under any given treatment followed by the same letter(s) do not differ significantly at 0.05 level of probability using the Duncan Multiple Range Test (DMRT)

Correlation between soil chemical properties and growth and yield parameters

The correlation coefficient (r) values between soil organic matter (SOM), N, P, K, Ca and Mg and growth and yield parameters of kale plant (plant height, number of leaves, root weight, stem weight, leaf weight, stem girth and stem length) are shown in Table 5. The Table shows that SOM was only moderate for stem weight, leaf weight and stem girth, and weak for plant height, number of leaves, root weight and stem length. N and K were strong for root weight, stem weight, leaf weight, stem girth and moderate for stem length and plant height. P, Ca and Mg were also weak for plant height, number of leaves and stem length and moderate for root weight, stem weight leaf weight and stem girth.

Table 5: Correlation between soil chemical properties and growth and yield parameters of kale

	Plant height	Number of leaves	Root weight	Stem weight	Leaf weight	Stem girth	Stem length
SOM	0.395	0.347	0.553	0.811	0.598	0.594	0.222
	(0.61)	(0.56)	(0.78)	(0.03)	(0.02)	(0.03)	(0.71)
N	0.680	0.643	0.819	0.825	0.850	0.799	0.518
	(0.031)	(0.028)	(0.002)	(0.001)	(0.001)	(0.003)	(0.04)
P	0.427	0.400	0.604	0.607	0.647	0.619	0.275
	(0.65)	(0.58)	(0.03)	(0.02)	(0.04)	(0.04)	(0.41)
K	0.704	0.655	0.787	0.816	0.830	0.818	0.509
	(0.029)	(0.027)	(0.002)	(0.002)	(0.002)	(0.001)	(0.04)
Ca	0.494	0.445	0.637	0.665	0.676	0.666	0.312
	(0.71)	(0.51)	(0.03)	(0.04)	(0.04)	(0.02)	(0.67)
Mg	0.565	0.519	0.706	0.734	0.742	0.741	0.391
	(0.64)	(0.59)	(0.01)	(0.03)	(0.03)	(0.03)	(0.78)

Discussion

The increase in soil organic matter (SOM), N, P, K, Ca and Mg concentrations due to the application of CP and urea fertilizer was consistent with the analysis recorded for the two soil amendments in this study and the use of CP and urea fertilizer for improving soil fertility in crop production (Ayeni 2008; Odedina et al. 2003). Sobamiwa and Longe (1994) also showed that CP contains N, P, K, Ca, Mg and micronutrients. The non-significant differences in the application of CP at 5, 10 and 15 t/ha in combination with 100 and 200 kg/ha urea fertilizer suggested that 5 t/ha CP is sufficient for kale in the derived savanna soils. Also, the non-significant difference between 100 and 200 kg/ha urea fertilizer suggested that 100 kg/ha urea is sufficient for kale production.

Cocoa pod ash or urea fertilizer alone and the integration of both increased growth and yield parameters of kale compared with no application of either CP or urea fertilizer i.e CP_0U_0. This showed that soil in the area lacked essential nutrients especially those that enhance growth and development in kale. This is supported by the result of the initial fertility of the soils before experimentation. The results indicated low content of organic matter and other nutrients.

Treatments CP_5U_{100} and CP_5U_{200} have the highest values of kale growth and yield parameters. This result is also consistent with the soil chemical properties of these treatments. In all cases of the growth and yield parameters the values of CP_5U_{100} and CP_5U_{200} are similar. This implies that CP_5U_{100}, that is application of CP at 5 t/ha and urea fertilizer at 100 kg/ha is adequate for growth and yield of kale. Any addition of CP or urea fertilizer above these rates of CP and urea fertilizer will be luxurious and will contribute less to growth and yield of kale. Tisdale and Nelson (1995) had noted that plant response to fertilizer is higher in soil with low nutrient content than soil with high nutrient reserve, consequently when the soil nutrient level has been raised to high level for kale, further increase in rate brings about low or no response. High levels of some nutrient elements have been reported to inhibit the availability of others especially micronutrient elements (Harper, 1983). The positive and strong correlation of all growth and yield parameters of kale considered in this study with N and K suggests that N and K are important nutrients in kale production.

Conclusion

For both crops of kale (1st and 2nd crops), cocoa pod ash alone and integration with urea fertilizer increased the values of soil chemical parameters and hence the fertility of the soil when compared with no application of either cocoa pod ash or urea fertilizer. Treatments with 5 t/ha cocoa pod ash + 100 kg/ha urea fertilizer (CP_5U_{100}) and 5 t/ha cocoa pod ash + 200 kg/ha urea fertilizer (CP_5U_{200}) consistently have significantly higher values of N, K, Ca and Mg in both crops of kale.

Similarly, treatments CP_5U_{100} and CP_5U_{200} have significantly higher and similar values of plant height, number of leaves and other yield parameters (root weight, stem weight, leaf weight, stem girth and stem length) of kale compared with other treatments. The positive and significant correlation of all growth and yield parameter of kale considered in this study with N and K suggests that N and K are important in kale production. Therefore, for viable production of kale crop in low nutrient soils of the Nigerian derived savanna and similar soils elsewhere, 5 t/ha with 100 kg/ha urea fertilizer is recommended. This will not only maximize production, but will also lower the cost of production and keep resource poor farmers in production in the face of scarcity and prohibitive prices of inorganic fertilizers. However, further tests are necessary for field evaluation of these amendments and evaluation on other soils before it can be recommended for use in other locations.

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