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Comparative effect of boiler ash-urea mixture on soil properties, growth, and yield of Cocoyam (*Colocasia esculenta*)

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Abstract

One major constraint in utilizing boiler ash in agriculture as fertilizer is its low nitrogen content. A field trial was conducted to evaluate comparatively the effect of integrating boiler ash with urea and two rates of NPK fertilizer on soil, growth, and yield of cocoyam *Colocasia esculenta* (Taro) in Iwollo, Southeastern Nigeria. The experiment was laid out in a randomized complete block design (RCBD) with three replications and five treatments which comprised of a control (no fertilizer), two levels of NPK 15:15:15 (100, 200kgha^{-1}) combinations of two levels of broiler ash (5, 10 t ha-$^{1)}$ with 70 kg ha^{-1} urea. The plots were planted with cocoyam cormels. Data on soil properties after harvest, growth, and yield characteristics were collected and subjected to one-way analysis of variance, and significant treatments mean separated by Fisher's least significant difference at 5% level of probability. Results obtained showed that the treatments did not exert significant influence on the soil physical properties evaluated, but differed significantly ($p<0.05$) in pH, phosphorus, and percent base saturation. Comparatively, integrating the low level of BA (10tha^{-1}) with 70 Kg ha^{-1} urea reduced soil acidity, increased soil available P, and percent base saturation but did not significantly influence growth and tuber yield of cocoyam. Application NP. K fertilizer at the rate of 200 Kg ha^{-1} was a higher number of cormels plant^{-1} (32.6), cormel yield (47.8 Mg ha^{-1}), and corm yield (4.53 Mg ha^{-1}). The fertilization effects of broiler ash – urea mixture at the rate applied in the study were masked by innate soil ability to supply plant-available nutrients, but significant reduction in pH and enrichment in available P suggest that the broiler ash – urea mixture may have a positive effect under more acidic and P deficient conditions.

Keywords: Boiler ash utilization; urea; NPK 15:15:15, cocoyam, soil pH.

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Introduction

Cocoyam (*Colocasia esculenta*) is a starchy tuber crop that has been widely cultivated and consumed in the southeastern agricultural zone of Nigeria for decades (Ndon *et al.,* 2003). The current level of cocoyam production in Nigeria estimated at 5 million metric tons (FAO, 2007) is grossly inadequate to satisfy the increasing demand for the crop (Shiyam *et al.,* 2007).

This low level of cocoyam production in Nigeria has been attributed to an increasing decline in soil fertility and lack of soil management practices for continuous cocoyam cultivation (Agbede and Adekiya, 2016). The use of mineral fertilizers in growing the crop has been high but the resulting soil physical degradation, increased soil acidity and soil nutrients imbalance has resulted in a decline in the crop yield (Ojeniyi, 2000. Mba and Mbagwu, 2006). Escalating cost and unavailability of mineral fertilizers (Suge *et al.,* 2011) have drawn the attention of researchers and farmers to the utilization of organic wastes as a nutrients source in crop production. Among the organic wastes recycled through agricultural utilization as a soil conditioner, boiler ash is the least researched for cocoyam production. Boiler ash is one of the essential organic wastes capable of supplying a sufficient amount of plant nutrients such as Mg, S, P, K, Fe, Mn, Zn, and Cu to soil (Anguissola *et al.,* 1999). Page *et al*. (1979) however, reported that the use of boiler ash in agriculture as fertilizer is constrained by its low or no nitrogen content, despite its high concentrations of K and P. We, therefore, hypothesized in this study that blending boiler ash with mineral nitrogen from urea fertilizer could be beneficial because of their contrasting and complementary chemical properties and nutrient contents. There is, however, a paucity of information on the optimum combining ratio and effect of such mixture on soil properties, growth, and yield of cocoyam *(Colocasia esculenta)*.

This work is expected to provide a framework for agricultural utilization of broiler ash and urea mixture for sustainable cocoyam production and improved soil fertility. Therefore, the general objective of this study is to determine whether nitrogen fertilizer application will have a synergistic effect and increase the benefits from boiler ash applications in agriculture. While the specific objectives are to:

1.determine the effect of boiler ash-urea mixture, reduced and recommended rates of NPK 20:10:10 on some physical and chemical properties of soil.

2.evaluate and compare the effects of the boiler ash-urea mixture, reduced, and recommended rates of NPK20:10:10 on growth and yield of cocoyam.

2.0 Materials and methods

2.1 Experimental Site

The study was carried out at the Teaching and Research Farm of the Department of Agricultural Technology, Enugu State Polytechnic, Iwollo. It is located by latitude 6°27'N and longitude 7°17'E, in the tropical rain forest of the South East Agro-ecological zone of Nigeria. It is characterized by a bimodal rainfall pattern with peaks in July and September, with short dry spells in August. The average annual rainfall is 2281.2mm.

2.2 Boiler ash and Soil Sampling and Analysis

Boiler ash was collected from the power ash dumpsite at Nigeria Breweries Ama Plant Ngwo, Enugu State. Auger and core soil samples were collected from the experimental site at a depth of 0-20cm before planting and after harvest at the center of each plot according to the treatments. The auger samples were air-dried, passed through a set of 4.57 and 2mm sieves. The 4.57-2.0 mm aggregates were used for the determination of soil aggregate size distribution and stability, while the <2mm fine earth fractions and broiler ash samples were used for the determination of chemical properties using standard laboratory procedures. The soil pH was measured using the Beckman Zeromatic pH meter (Peech, 1965). Organic carbon was determined by Walkley and Black procedure as described by Nelson and Sommers (1982). Available phosphorus was determined by the Bray II method as described by Bray and Kurtz (1945). Exchangeable bases (Na^+, Ka^+, $Ca^{2+,}$ and Mg^{2+}) were determined by atomic absorption spectrophotometer following the procedures outlined by Wilde *et al.,* (1997). The CEC was determined using the method of Rhodes (1982). Total nitrogen was determined by the macro Kjeldahl method as described by Bremner (1996). Base saturation was obtained by dividing total exchangeable bases by cation exchange capacity and multiplying by 100.

Undisturbed core samples were collected with core rings (169.7cm^3) by hammering the sharp end carefully into a flat surface within each plot. The soil bulk density was determined by the core method (Blake and Hartage, 1986). Total porosity was calculated from the relationship between bulk density and particle density of 2.65gcm^{-3}(Forth, 1990). The method of Kemper and Rosenau (1986) was used to separate the aggregates (mean weight diameter). The water holding capacity of the soil was calculated using the formula:

Water holding capacity= (mass at saturation-oven dry mass)/ mass of dry soil x 100.

2.3 Experimental Design, Layout, Treatments, Land preparation and Crop Establishment

The experimental design was a Randomized Complete Block Design. The designated experimental field was cleared, ploughed, harrowed, ridged, and demarcated into 3 blocks and 5 plots per block. Each plot had a dimension of 5m long and 4m wide giving a total area of 20m^2, with 0.5m alley both inter and intra rows. The treatments were:

1.Control (no boiler ash – Urea mixture or NPK fertilizer)

2.200 kg ha^{-1} NPK, 20:10:10 (recommended NPK fertilizer for cocoyam in the area)

3. 100 kg ha^{-1} NPK20:10:10 (half recommended NPK fertilizer for cocoyam in the area),

4. 5 t ha^{-1}Boiler ash + 70 kg ha^{-1} Urea (equivalent nitrogen recommended for cocoyam in the area

5.10 t ha^{-1}. ^{1}Boiler ash + 70 kg ha^{-1} Urea (equivalent nitrogen requirement for cocoyam in the area.

Cocoyam cormels were planted at a spacing of 1m x 1m. Weeding was manually done when necessary. A fungicide (Ridomil) was spayed bi-weekly to control prevalent fungal diseases.

2.4 Data Collection on Cocoyam Growth and Yield

Data were collected on plant height, number of leaves per stand, leaf length and width per stand, number of cormels per stand, cormels weight per stand, and corms weight per stand. At four weeks after planting, five stands were randomly sampled from two rows at the centre of each plot and tagged. The plant height, leaf length, and width were measured to the nearest centimeter at 6 and 12 weeks after planting (WAP). The mean value from the randomly selected plants was taken as the score for each plot.

The number of cormels per plant was determined by direct counting. Cormels weight per plant was done by taking a record of the weight of the harvested cormels from each plant of the sample plants. Corms weight was also calculated by taking a record of the weight of the harvested corms from each of the sample plants.

2.5 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using GEN STAT Discovery Version (GENSTAT 2009). Differences between means of treatment were compared using Fisher's Least Significant Difference (F-LSD) at 5% levels of probability.

3.0 Results and Discussion

3.1 Physico-chemical characteristic of the experimental soil and boiler ash

The soil of the experimental site was sandy loam in texture, had a bulk density value of 1.63 Mgm^{-3}, pH value of 5.8, organic matter content 0.92%, and available P and K content 20.5 mg kg^{-1} and 0.36 cmolkg^{-1}, respectively (Table 1). Total N content was low (0.03%). Its available P and exchangeable K were more than 10 mg kg^{-1} and 0.2 cmolkg^{-1}, respectively, and considered optimal for most crops using established critical levels for these nutrients (Kayode and Agboola, 1994). The above data reveals that the experimental soil was inherently rich in available P, exchangeable K, and Mg, and as such, may mask the effects of these nutrients in the added fertilizers. Boiler ash was very low in nitrogen (0.14%) and calcium (1.6 cmolkg^{-1}) with a high pH value (9.2). It contained high P (198.1 mg kg^{-1}) and K (11.2 cmolkg^{-1}) and abundant magnesium (7.8 cmolkg^{-1}). The broiler ash used was very low in nitrogen. Therefore, blending it with nitrogen-rich-urea may play a complementary role in boosting its fertilization potentials.

3.2 Effect on Soil Physical Properties

The data on changes in soil physical properties following the

Table 1: Physico-chemical characteristics of the experimental soil and boiler ash

Properties	Soil	Broiler ash
Sand (gkg^{-1})	707.0	
Silt (gkg^{-1})	120.8	
Clay (gkg^{-1})	172.2	
Textural class	Sandy loam	
Bulk density ()		
pH (H_2O)	5.80	9.0
Total nitrogen (%)	0.24	0.14
Organic carbon (%)	0.92	13.2
Available Phosphorus (mg kg^{-1})	20.56	198.1
Exchangeable Potassium ($cmolkg^{-1}$)	0.36	11.2
Exchangeable Magnesium ($cmolkg^{-1}$)	2.62	7.8
Exchangeable Calcium ($cmolkg^{-1}$)	2.78	1.6
Exchangeable Sodium ($cmolkg^{-1}$)	2.84	13.1

application of the treatments (Table 2) revealed that they did not exert significant influence on the soil bulk density, total porosity, water holding capacity, and structural stability (mean weight diameter) relative to the control. The finding was in tandem with that of Skousen *et al.* (2013) which observed that the extent of changes in soil physical conditions in ash amended soil would depend on the amount applied and physical properties of the soil and boiler ash. The 5 and $10tha^{-1}$ applied in this study may not have exerted significant influence on the textural composition of the soil. Similarly, Adriano and Weber (2001) observed that coal fly ash (CFA) application had no effect on soil bulk density, and attributed this finding to the texture and density of the CFA used being similar to that of most agricultural soils (2.16 g cm^{-3}).

3.3 Effect on Soil Chemical Properties

Soil pH was higher under the effect of BA_{10} + UR fertilization source which was 21% higher relative to the control while contrasting decreases of 5 and 10 % for NPK_{100} and NPK_{200} respectively were observed (Table 3). This can be ascribed to the addition of basic cations through the application of alkaline broiler ash (Adriano et al., 1980). However, it is well known that the urea component may result in net increases in soil acidity. The pH of the control plot (5.2) was lower than the soil pre-cropping value (5.8). The decrease may be attributed to decreases in exchangeable bases, due perhaps, to leaching or uptake by cocoyam. Osundare (2012) reported a similar observation. The soil pH data demonstrates the significant acid-neutralizing capacity of boiler ash and the acidifying property of NPK fertilizer. Within the first year of application, BA_{10} + UR increased the pH of a low pH (5.8) soil to a range considered optimal for nutrient availability and crop growth (pH 6.0-6.5).

Table 2: Effect of boiler ash – urea mixture and NPK fertilizer on changes in soil physical properties

Treatment	Bulk density	Total Porosity	Water holding capacity	Mean weight diameter
Control	1.76	33.8	39.57	1.60
NPK_{100}	1.76	33.4	41.37	1.55
NPK_{200}	1.72	32.1	40.20	1.52
BA_5 +UR	1.68	35.9	37.10	1.60
BA_{10} UR	1.62	42.0	41.13	1.59
F-$LSD_{(0.05)}$	n.s	n.s	n.s	n.s

F-LSD $_{(0.05)}$ Fisher's Least Significant Difference at 5% level of probability

The level of available P in BA_5+UR (48 mg kg^{-1}) and BA10 + UR (54mg kg^{-1}) plots did not differ significantly from each other but were significantly higher than the NPK treated and control plots (13.5 mg kg^{-1}). The high level of available P observed in the BA + UR mixture may be attributed to the high concentration of phosphorus in the ash (Table 1) and increase in soil pH which may have increased phosphorus solubility. The increased available P content of the soil with the application of BA could be attributed to the release of P from complexes of Al and Fe under increasing soil pH (Mbah *et al.,* 2010). The finding is, however, contrary to that of Naylor and Schmidt (1989) and Patterson

(2001) that ash applications had little or no effect on available P. The NPK fertilization resulted in a reduction in percentage base saturation in line with its acidifying effects observed in pH. There was a non-significant difference among the treatments in respect of the organic matter, total nitrogen, and exchangeable K, Na, Ca, and Mg.

3.4

Table3: Effect of boiler ash – urea mixture and NPK fertilizer on changes in soil chemical properties after cropping

Treatment	pH	OM	N	Na	K	Ca	Mg	P	CEC	BS
Control	5.2	3.36	0.11	0.07	0.74	2.2	0.8	13.5	14.8	25.6
NPK_{100}	4.9	2.38	0.18	0.06	0.08	1.7	0.5	14.9	14.0	16.7
NPK_{200}	4.7	2.64	0.10	0.06	0.07	3.2	1.84	15.8	13.6	15.2
BA_5 +UR	5.7	3.47	0.25	0.07	1.10	2.1	1.5	48.0	11	33.1
BA_{10} UR	6.3	3.40	0.19	0.08	1.20	2.1	1.0	54.0	13.2	41.3
$F\text{-}LSD_{(0.05)}$	0.26	n.s	n.s	n.s	n.s	n.s	n.s	29.17	n.s	16.04

C.E.C= Cation exchange capacity, B.S= Base saturation, F-LSD (0.05) = Fishers least significant difference at 5% level of probability

Effect of boiler ash-urea mixture and NPK fertilizer on growth and yield of cocoyam

Initial plant establishment mostly depends on the food storage reserves, and later growth depends on photosynthesis and anabolism, which are affected by the number of leaves, leaf length, and width. Subsequent growth is therefore expected to be affected by any changes in the availability of nutrients. The cocoyam growth characteristics determined by height, leaf length, width, and number as influenced by the treatments were presented in Table 4. The results show that BA_5+UR and NPK_{200} significantly ($p<0.05$) increased shoot height relative to the control at 6 WAP, but at 12 WAP only NPK_{200} induced a significant increase. Plots amended with BA_{10} + UR recorded the least cocoyam shoot height of 20.0cm that was not significantly different from the control plot that recorded 28.0cm height.

Among the fertilizer sources, soils amended with NPK_{200} recorded the highest leaf length and width of 16.39 and 17.9cm, respectively. This was followed by plots amended with BA_5+UR (13.8 and 11.6cm), respectively. Neither of the fertilization sources affected the number of leaves determined at both 6 and 12WAP. An average of 6 and 9 respectively, was achieved for all species irrespective of treatment.

The BA_5cUR and NPK_{200} were found to be conducive, which enhanced the general growth of cocoyam. Whereas, plots amended with NPK_{100} and BA10 + UR did not differ significantly from the control. Higher values of shoot height, leaf length, and width recorded with the application of NPK_{200} could be due to higher and balanced essential nutrients in the fertilizer.

Results of the study revealed that the values recorded for each treatment increased as the number of weeks after planting increased from 6 to 12 weeks and the highest value for each stage was obtained from plots treated with NPK_{200}.

3.5 Effects on Cocoyam Yield

Table 4: Effect of boiler ash – urea mixture and NPK fertilizer on cocoyam crop growth

Treatment	6 LL	6 LW	6 NL	6 PH	12 LL	12 LW	12 NL	12 PH
Control	10.7	8.9	6.0	17.6	14.6	12.5	9.0	28.0
NPK_{100}	11.8	10.5	7.0	17.3	12.9	11.5	10.1	24.3
NPK_{200}	16.39	17.9	5.0	23.4	19.2	16.8	9.1	30.9
BA_5 +UR	13.8	11.6	6.0	21.0	13.0	11.2	8.8	24.3
BA_{10} UR	11.7	9.5	6.0	16.6	12.7	11.3	9.4	24.0
$F\text{-}LSD_{(0.05)}$	1.87	1.64	n.s	3.32	2.05	1.60	n.s	4.21

LL= Leaf length (cm), LW= Leaf width (cm), NL = Number of leaves, PH = Plant height (cm) F-LSD (0.05) = Fishers least significant difference at 5% level of probability

At harvest, results showed that the number of cormels plant^{-1}, the weight of cormels ha$^{-1,}$ and the weight of corms ha^{-1} statistically varied with the type of fertilization (Table 5). Soils amended with NPK_{200} recorded the highest number of cormels (32.6) plant^{-1}. This was followed by the plot amended with $NPK_{100,}$ which did not differ significantly from the rest of the treatments and control (18.7). Plots treated with NPK_{200} also recorded the highest cormel yield of 47.8tha$^{-1,}$ and the sequence of performance was BA_5 + UR > NPK_{100} >BA_{10} + UR > Control. Soils amended with NPK_{200} recorded the highest corm yield of 4.53tha$^{-1,}$ and the trend of performance was controlled> BA_{10} + UR > NPK_{100} > BA_5 + UR.

Generally, cocoyam grown in control plots did not statistically differ from all the treatments except NPK_{200}. The non-significant difference may be attributed to the fact that the experimental soil was inherently rich in available P, exchangeable K, and Mg (Table 3) and as such may have masked the effects of these nutrients in the amended plots. The yield obtained from all the treatments were higher than the total yield of 6.16 and 8.94tha^{-1} reported by Uwah *et al*. (2011) and Onwudike *et al*. (2015), respectively. The higher yield may be attributed to the conducive environment for cocoyam production in this area, as reported by Ogbonna and Nwaeze (2012).

Application of NPK fertilizer at the general recommended dose (200kg ha^{-1}) significantly increased both growth and tuber yield of cocoyam. This agreed with the finding of other researchers elsewhere (Mare and Modi, 2009; Ogbonna and Nwaeze, 2012). The significant effect caused by the application of NPK_{200} fertilizer to the cocoyam plots showed that the reduced rate, urea enriched broiler ash, and control soil lacked sufficient essential nutrients, especially those that enhance growth and development in cocoyam. They failed to meet the optimum requirement.

Table 5: Effect of boiler ash – urea mixture and NPK fertilizer on cocoyam tuber yield

Treatment	Number of cormel plant $^{-1}$	Weight of cormels ha^{-1}	Weight of corms ha^{-1}
Control	18.7	15.8	1.24
NPK_{100}	19.5	25.0	1.18
NPK_{200}	32.6	47.8	4.53
BA_5 +UR	16.5	26.8	1.07
BA_{10} +UR	15.9	20.4	1.24
F-LSD$_{(0.05)}$	5.18	5.62	0.56

F-LSD (0.05) = Fishers least significant difference at 5% levels of probability

4.0 Conclusion

The fertilizer effects of boiler ash-urea mixture at the rate applied in this study were masked by innate soil ability to supply plant-available nutrients. However, a significant reduction in pH and enrichment in available P suggest that the boiler ash-urea mixture may have a positive effect under more acidic and P deficient conditions.

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