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Observations on Cassava (Manihot esculenta Crantz) Root Yield and Soil Fertility under Different K - Sources

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Abstract
The lingering problem of scarcity and high cost of synthetic fertilizers in Nigeria, following changes in Government policies on subsidy, procurement and distribution of inorganic fertilizers, has made inorganic fertilizers unaffordable by the resource – poor farmers, who, incidentally, are the chief food producers in Nigeria. Therefore, the need arises to critically evaluate the potential of certain organic wastes in maintaining and improving soil fertility and crop productivity. To partly meet this need, hence, this paper reports the results of a two – year trial, aimed at evaluating efficacy of different K sources in improving fertility of an Alfisol and performance of cassava (*Manihot esculenta* Crantz).The experiment was laid out in a randomized complete block design with three replicates. The different K sources included: Muriate of potash (MOP); cocoa pod ash (CPA); NPK (15 – 15 – 15); bone ash (BA) and control or check (C). The results obtained indicated existence of significant (P = 0.05) differences among the K sources with respect to their effects on nutrient status of an Alfisol and cassava root yield. At the end of 2012 cropping season, K sources resulted in significant increases in soil organic carbon (SOC) from 0.40 g kg^{-1} for C to 0.47, 0.64, 0.51 and 0.59 g kg^{-1} for MOP, CPA, NPK, and BA, respectively. Similarly, at the end of 2013 cropping season, K sources significantly increased SOC from 0.22 g kg^{-1} for C to 0.40, 0.69, 0.45 and 0.63 g kg^{-1} for the respective MOP, CPA, NPK, and BA. At the end of 2012 cropping season, K sources significantly increased total N from 0.20 g kg^{-1} for C to 0.23, 0.46, 0.41 and 0.35 g kg^{-1} for MOP, CPA, NPK, and BA, respectively. At the end of 2013 cropping season, K sources significantly increased total N from 0.07 g kg^{-1} for C to 0.10, 0.52, 0.37 and 0.43 g kg^{-1} for MOP, CPA, NPK, and BA, respectively. Mean values of cassava root yield data across the two years of experimentation indicated that, K sources significantly increased cassava root yield from 4.52 t ha^{-1} for C to 6.70, 8.69, 5.97 and 6.28 t ha^{-1} for MOP, CPA, NPK, and BA, respectively.

Keywords. Cassava, fertility, observations, yield, sources.

Introduction

Cassava (*Manihot esculenta* Crantz) is a heavy feeder crop; exploiting large volume of soil for nutrients, especially, nitrogen and potassium and water (Obisegbor, 2014, Alasa, 2014). It follows therefore, that continuous cassava cultivation will result in nutrient depletion or exhaustion, except an adequate fertilizer input, involving addition of organic and/ or inorganic fertilizers is embarked upon. The ability of cassava plant to forage for nutrients from impoverished tropical soil has remained its chief attribute (Irwin, 2009; Baduf, 2011; Tera, 2014). The ability of cassava to maintain relatively high potassium and nitrogen in dry matter production and the ability to regulate its growth under low nutrient supply conditions, are the special features that are responsible for cassava adaptation to low fertility status (Irwin, 2009; Baduf, 2011; Tera, 2014). Cassava, however, benefits from fertilization, especially N – and K – fertilization (Obisegbor, 2014; Alasa, 2014).

The tremendous quantities of K removed in cassava tubers at harvest, the significant reduction in cassava root yield due to K deficiency, as well as the extraction of a lot of K by cassava from the soil system, testify to the significance of K in mineral nutrition of cassava (Ogedengbe, 2012; Melanby, 2013). High K concentration is known not only to sustain high root yield, but also resists cassava bacteria blight (CBB) (Ogedengbe, 2012) and cassava anthracnose disease (CAD) (Iyayi, 2008; Bada, 2013). K – fertilization has been reported to improve the quality of cassava by reducing the glucoside content of roots (Melanby, 2013). Sughai (2010) and Bada (2013) obtained 20 – 27% reduction in HCN content in cassava variety, TMS 60506 on application of 100 kg K_2O ha^{-1}.

Previous studies (Aseyin, 2009; Hassan, 2013; Restov, 2014) had demonstrated significant responses of soil nutrient status and cassava root yield to different K – sources. In all the studies, significant differences among the different K sources as regards their effects on soil nutrient status and cassava root yield performance were reported.

In Nigeria, the ever increasing demand for cassava to meet the industrial and domestic needs of the people, has necessitated the need to accord cassava husbandry, research attention in order to raise the present level of cassava yield on farmers' farms. To partly meet this need, this study was designed to evaluate efficacy of certain K – sources in improving cassava root yield and soil fertility status.

Materials and methods

Study site: A two – year field experiment was conducted at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2010 and 2011 cropping seasons. The soil of the study site belongs to the broad group Alfisol (SSS, 2003). The site had earlier been cultivated to arable crops, among which were maize, cassava, sweet potato, cocoyam, melon etc before it was allowed to fallow for four years. During the fallow period, cattle, sheep, and goat used to graze on the fallow land. At the commencement of this study, the fallow vegetation was manually cleared, after which the land was ploughed and harrowed.

Collection and analysis of soil samples: Prior to 2012 cropping season, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of 2012 and 2013 cropping seasons, another sets of soil samples were collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with the soil analytical procedures, as outlined by the International Institute of Tropical Agriculture (IITA) (1989). The chemical analysis of cocoa pod ash and bone ash, used in the experiment was also carried

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different K sources included: Muriate of potash (MOP); cocoa pod ash (CPA); NPK (15 – 15 – 15); bone ash (BA) and control or check (C). MOP, CPA and BA were applied at the rates of 0.45, 12, and 14 t ha^{-1}, respectively (Hassan, 2013; Restov, 2014). CPA and BA were worked into the soil, three weeks before planting (WBP), while NPK 15 – 15 – 15 fertilizer (400 kg ha^{-1}) and MOP were applied in two split doses, at two and four months after planting (MAP). Each plot size was 4 m x 4 m.

Planting, weeding, collection and analysis of data: Planting was done on March 1 and March 3 in 2012 and 2013, respectively. Stem – cuttings (20 cm long each) of early maturing cassava variety, Tropical Manihot Series (TMS) 30572, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted at 1 m x 1 m (10,000 cassava plants ha^{-1}).

Weeding was done manually at 1, 2, 3, 4 and 5 MAP, using a hoe. At harvest (12 MAP), data were collected on cassava root yield and yield components. All the data collected were subjected to analysis of variance (ANOVA), and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

The chemical properties of the soil prior to 2012 cropping season.

Table 1: The chemical properties of the soil prior to 2012 cropping season.

Soil properties	Values
pH	6.3
Organic carbon (g kg^{-1})	0.89
Total nitrogen (g kg^{-1})	0.62
Available phosphorus (mg kg^{-1})	0.53
Exchangeable bases (cmol kg^{-1})	
Potassium	0.60
Calcium	0.54
Magnesium	0.51
Sodium	0.43
Exchangeable Acidity	0.26
Effective Cation Exchangeable Capacity (ECEC)	2.34

Table 2: Nutrient composition of organic K - sources used in the experiment

		Values	
Parameters		**CPA**	**BA**
Organic carbon	(g kg^{-1})	8.1	6.8
Total nitrogen	,,	0.84	0.63
C/N ratio		9.64	10.79
Phosphorus	,,	0.80	0.63
Potassium	,,	10.20	8.00
Calcium	,,	2.90	4.10
Magnesium	,,	0.52	0.66

CPA = cocoa pod ash; BA = bone ash

Changes in nutrient status of an Alfisol at the end of 2012 and 2013 cropping seasons

Tables 3 and 4 show nutrient status of an Alfisol as affected by different K sources after 2012 and 2013 cropping seasons. At the end of 2012 cropping season, K sources resulted in significant increases in soil pH from 3.6 for C to 4.6, 5.1, 4.1 and 5.6 for MOP, CPA, NPK, and BA, respectively. At the end of 2013 cropping season, K sources resulted in significant increases in soil pH from 3.2 for C to 4.3, 4.7, 3.8 and 5.2 for MOP, CPA, NPK and BA, respectively. At the end of 2012 cropping season, K sources significantly increased soil organic carbon (SOC) from 0.40 g kg^{-1} for C to 0.47, 0.64, 0.51 and 0.59 g kg^{-1} for MOP, CPA, NPK and BA, respectively. Similarly, at the end of 2013 cropping season, K sources significantly increased SOC from 0.22 g kg^{-1} for C to 0.40, 0.69, 0.45 and 0.63 g kg^{-1} for the respective MOP, CPA, NPK and BA, respectively. At the end of 2012 cropping season, K sources significantly increased total N from 0.20 g kg^{-1} for C to 0.23, 0.46, 0.41 and 0.35 g kg^{-1} for MOP, CPA, NPK and BA, respectively. At the end of 2013 cropping season, K sources resulted in significant increases in total N from 0.07 g kg^{-1} for C to 0.10, 0.52, 0.37 and 0.43 g kg^{-1} for MOP, CPA, NPK and BA, respectively.

At the end of 2012 cropping season, K sources resulted in significant increases in available P from 0.47 mg kg^{-1} for C to 0.52, 0.67, 0.56 and 0.61 g kg^{-1} for the respective MOP, CPA, NPK and BA. At the end of 2013 cropping season, K sources resulted in significant increases in available P from 0.44 mg kg^{-1} for C to 0.49, 0.73, 0.61 and 0.67 g kg^{-1} for MOP, CPA, NPK and BA, respectively. At the end of 2012 cropping season, K sources resulted in significant increases in exchangeable K from 0.21 cmol kg^{-1} for C to 0.48, 0.55, 0.43 and 0.38 cmol kg^{-1} for the respective MOP, CPA, NPK and BA. At the end of 2013 cropping season, K sources resulted in significant increases in exchangeable K from 0.09 cmol kg^{-1} for C to 0.43, 0.59, 0.38 and 0.48 cmol kg^{-1} for MOP, CPA, NPK and BA, respectively.

At the end of 2012 cropping season, K sources resulted in significant increases in exchangeable Ca from 0.22 cmol kg^{-1} for C to 0.23, 0.33, 0.21 and 0.39 cmol kg^{-1} for the respective MOP, CPA, NPK and BA. At the end of 2013 cropping season, K sources resulted in significant increases in exchangeable Ca from 0.19 cmol kg^{-1} for C to 0.21, 0.37, 0.19 and 0.43 cmol kg^{-1} for MOP, CPA, NPK and BA, respectively. At the end of 2012 cropping season, K sources resulted in significant increases in exchangeable Mg from 0.24 cmol kg^{-1} for C to 0.22, 0.35, 0.21 and 0.42 cmol kg^{-1} for the respective MOP, CPA, NPK and BA. At the end of 2013 cropping season, K sources resulted in significant increases in exchangeable Mg from 0.20 cmol kg^{-1} for C to 0.18, 0.38, 0.18 and 0.46 cmol kg^{-1} for MOP, CPA, NPK and BA, respectively. At the end of 2012 cropping season, K sources resulted in significant increases in exchangeable Na from 0.19 cmol kg^{-1} for C to 0.21, 0.28, 0.19 and 0.35 cmol kg^{-1} for the respective MOP, CPA, NPK and.BA. At the end of 2013 cropping season, K sources resulted in significant increases in exchangeable Na from 0.16 cmol kg^{-1} for C to 0.17, 0.33, 0.16 and 0.40 cmol kg^{-1} for MOP, CPA, NPK and BA, respectively.

Table 3: Chemical properties of an Alfisol as affected by different K - sources after 2012 cropping season.

Treatments (K - sources)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1})			
					K	Ca	Mg	Na
Check	3.6e	0.40e	0.20d	0.47e	0.21e	0.22c	0.24c	0.19c
Muriate of potash	4.6c	0.47d	0.23d	0.52d	0.48b	0.23c	0.22c	0.21c
Cocoa pod ash	5.1b	0.64a	0.46a	0.67a	0.55a	0.33b	0.35b	0.28b
NPK	4.1d	0.51c	0.41b	0.56c	0.43c	0.21c	0.21c	0.19c
Bone ash	5.6a	0.59b	0.35c	0.61b	0.38d	0.39a	0.42a	0.35a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).

Table 4: Chemical properties of an Alfisol as affected by different K sources after 2013 cropping season.

Treatments (Nutrient sources)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1})			
					K	Ca	Mg	Na
Check	3.2e	0.22e	0.07d	0.44e	0.09e	0.19c	0.20c	0.16c
Muriate of potas	4.3c	0.40d	0.10d	0.49d	0.43c	0.21c	0.18c	0.17c
Cocoa pod ash	4.7b	0.69a	0.52a	0.73a	0.59a	0.37b	0.38b	0.33b
NPK	3.8d	0.45c	0.43b	0.61c	0.38d	0.19c	0.18c	0.16c
Bone ash	5.2a	0.63b	0.37c	0.67b	0.48b	0.43a	0.46a	0.40a

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).

Cassava root yield and yield components as affected by different K sources at harvest.
Table 5 shows the effects of different K sources on cassava root yield and yield parameters at harvest. Mean values of cassava root yield data indicated that, K sources significantly increased cassava root yield from 4.52 t ha^{-1} for C to 6.70, 8.69, 5.97 and 6.28 t ha^{-1} for MOP, CPA, NPK and BA, respectively. Similarly, K sources significantly increased cassava root length from 8.11 cm for C to 13.32, 15.90, 12.82 and 13.06 cm for the respective MOP, CPA, NPK and BA. K sources significantly increased cassava root diameter from 6.78 cm for C to 8.06, 8.71, 6.95 and 7.51 cm for the respective MOP, CPA, NPK and BA.

Table 5: Cassava root yield and yield components as affected by K - sources at harvest

Treatments	Cassava root yield (t ha^{-1})			Cassava root length (cm)			Cassava root diameter (cm)		
(K - sources)	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Check	4.67e	4.36e	4.52	8.22e	8.00e	8.11	6.88e	6.68e	6.78
Muriate of potash	6.77b	6.62b	6.70	13.40b	13.24b	13.32	8.12b	8.00b	8.06
Cocoa pod ash	8.60a	8.78a	8.69	15.80a	15.94a	15.90	8.64a	8.78a	8.71
NPK	6.03d	5.90d	5.97	12. 86d	12.78d	12.82	6.99d	6.90d	6.95
Bone ash	6.22c	6.33c	6.28	12.99c	13.12c	13.06	7.40c	7.62c	7.51

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT).

Discussion
The chemical properties of soil in the study site, prior to cropping, indicated that the soil was slightly acidic, with a pH of 6.3. The soil organic carbon (SOC) value of 0.89 g kg^{-1} was below the critical level of 7.6 g kg^{-1} for soils in Southwestern Nigeria (Adenle, 2010; Abbet, 2012). The total nitrogen content of 0.62 g kg^{-1} was below the critical level of 1.20 g kg^{-1}, according to Abbet (2012) and Lege (2012). The K status of 0.60 cmol kg^{-1} was above the critical level of 0.38 cmol kg^{-1} (Lege, 2012). The Ca, Mg and Na contents were all below the established critical levels for soils in Southwestern Nigeria (Abbet, 2012; Liya, 2013).

Relative to the control (check) treatment, the significant increases in soil pH, after cropping, adduced to K sources, are in consonant with the findings of Atete (2012) and Liya (2013), who noted significant increases in soil pH, after cropping, following application of different K sources. These observations can be ascribed to significant increases in the exchangeable basic cations on the exchange sites of the soil, due to their release by the K sources. The lowest soil pH value for NPK fertilizer, of all the K sources, can be attributed to acidifying effects of NPK fertilizer, as a result of its acid – forming nature, due to its N and P content (Heald, 2009; Aritoff, 2012). Asides, the lowest pH value of soil in the NPK fertilizer plots, was due perhaps, to leaching of exchangeable basic cations due to low organic matter content of soil in the NPK fertilizer plots, unlike what obtained in the plots of cocoa pod ash, and bone ash, where the exchangeable bases would not have leached off, but would have been retained due to aggregate or structural stability of the soil, occasioned by addition of these organic sources of K.

The significant increases in SOC values, observed in the plots of those K sources, are in agreement with the reports of Heald (2009); Aritoff (2012) and Atete (2012), who noted significant increases in SOC, after cropping, following application of these K sources. The observed increases in SOC, associated with cocoa pod ash, and bone ash, can be attributed to release of nutrients contained in these organic materials on decomposition, as organic matter has been noted to be a reservoir or store – house of plant nutrients (Arigbede, 2011; Galeb, 2012). The SOC value for NPK fertilizer was significantly higher than that for the control, even though, NPK fertilizer is not an organic fertilizer, which otherwise, like its organic counterparts, would have released nutrients into the soil on decomposition. However, the higher SOC value, adduced to NPK fertilizer, relative to the control, can be attributed to higher organic matter content of soil in the NPK fertilizer plots. This is because, the NPK fertilization resulted in formation of good vegetative structure of cassava, as a result of which a lot of leaf litter was produced, and which on decomposition, resulted in formation of organic matter. This implies that, inorganic fertilization, through its positive effects formation of good vegetative structure in plants and attendant organic matter turnover, can indirectly contribute to amelioration of once – badly degraded land.

Of the two organic sources of K (cocoa pod ash, and bone ash), bone ash gave a lower SOC value, after cropping, and this can be attributed to the relatively lower rate of decomposition of bone ash, due to its higher lignin content, as attested to by its higher value of C/N ratio (Table1).

The lowest available P value for the check or control treatment, can be attributed to the lowest pH value of soil in the check plots. This is because, the availability of P in the soil, depends on the pH of the soil medium, with available P decreasing with decreasing pH (Galeb, 2012). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils

(Lege, 2012; Galeb, 2012).

The significant increases in all the plant nutrients, observed under K sources, can be explained in the light of the significant increases in SOC under K sources. This is because SOC or soil organic matter (SOM) has been variously described as a reservoir of plant nutrients, that is, other plant nutrients are integrally tied to it, and hence, the maintenance of SOM is paramount in sustaining other soil quality factors (Robertson *et al.* 1994; Galeb, 2012; Ase, 2014).

The higher values of SOC, total N, available P and exchangeable bases, recorded in the plots of cocoa pod ash, and bone ash, at the end of the second year (2013) cropping activities, compared to what obtained at the end of the first year (2012) cropping activities, can be adduced to the residual effects of application of cocoa pod ash, and bone ash during the first year, coupled with additional application of these organic sources of K in the second year. However, values of these nutrients in all the plots of NPK fertilizer, at the end of the second year cropping activities, were lower than what obtained at the end of the first year cropping activities, suggesting that, application of NPK fertilizer, unlike its organic fertilizer counterparts, did not produce any residual effects on soil. This implies that, soil fertility cannot be maintained or sustained on a long term basis through inorganic fertilization. Thus, to avert this problem of declined soil fertility, associated with inorganic fertilization, there is need for integrated application of organic and inorganic fertilizers to achieve sustainability of crop production.

The significantly higher values of all the nutrients for cocoa pod ash, compared to its bone ash counterpart, suggest that, although, these two organic K sources can release nutrients into the soil, on decomposition, however, the quantity of nutrients released depends on the source(s) of the ash.

The significantly higher root yield and yield components of cassava, adduced to cocoa pod ash, and bone ash, compared to their NPK fertilizer counterpart, agree with the observations of Atete (2012) and Tera (2014), who reported significantly higher cassava root yield under cocoa pod ash, and bone ash, relative to root yield, recorded in the plots of NPK fertilizer. These observations can be ascribed to the long – term effects of these organic nutrient sources on improving both the physical, chemical and biological properties of the soil, unlike the inorganic fertilizers, whose effects on soil properties are shallow and short – lived (Adenle, 2010; Arena, 2012; Aseni, 2014). The significantly higher cassava root yield and yield parameters for cocoa pod ash than NPK fertilizer and muriate of potash, confirm the reports of Arena (2012) and Aseni (2014), who noted that, cocoa pod ash gave significantly higher cassava root yield and yield components than its NPK fertilizer and muriate of potash counterparts. These observations can be ascribed to the regulatory action of calcium and magnesium, contained in cocoa pod ash, on soil chemical properties, especially, reduction of soil acidity and attendant prevention of Aluminium toxicity, which would have resulted in stubbiness of cassava plants (due to interference effects of Aluminium toxicity on phosphorylation of sugars); a condition that would have consequently resulted in low cassava root yield (Tera, 2014; Aseni, 2014). Asides, cocoa pod ash, being a lime, reduces soil acidity; a condition that results in increased availability of plant nutrients as well as promotion of microbial decomposition of soil organic matter, with resultant increased release of nutrients into the soil system (Arena, 2012; Ase, 2014).

The higher values of cassava root yield and yield indices, obtained in the plots of those organic sources of K (cocoa pod ash and bone ash), at the end of the second year (2013), compared to what obtained at the end of the first year (2012), can be explained in the light of more nutrient release or availability during the second year cropping season, due to the residual effects of application of those organic sources of K during the first year, coupled with additional application of the organic sources of K during the second year cropping season. On the contrary, values of cassava root yield and yield components were lower at the end of the second year than the first year in the plots of muriate of potash and NPK fertilizer, and this can be adduced to declined soil fertility during the second year, as a result of nutrient removal by cassava during the first year cropping season. These observations testify to the assertions of Aseni (2014) and Ase (2014), who established that, soil fertility and crop yield tend to decline under continuous cropping, with or without application of inorganic soil amendment(s).

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