EFFECT OF MAIZE (*Zea mays* L.) VARIETIES AND FERTILIZER TYPES ON POSTHARVEST SOIL CHEMICAL PROPERTIES IN BENIN CITY, EDO STATE, NIGERIA

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R. Ahmadu* and U. Yakubu
Department of Crop Production and Protection, Federal University Wukari, PMB 1020, Taraba State, Nigeria
*Corresponding author: rimandeahmadu@yahoo.com

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Abstract: Field study was conducted at the experimental site of the Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria during the 2015 and 2016 cropping seasons to determine the effect of maize (*Zea mays* L.) varieties and fertilizer types on postharvest soil chemical properties. The experiment was laid out in 3 x 4 split plot arrangement fitted into a randomized complete block design (RCBD) with three replications. The main plots were SUWAN–I–SR, Oba 98 and Uselu local maize varieties and the subplots were control, poultry manure, cattle manure and NPK fertilizer. Data were collected on some growth parameters, grain yield components and some postharvest soil chemical properties. The results showed that application of fertilizer significantly ($p<0.05$) improved maize vegetative characters, yield components and grain yield. The results also showed that, plots cropped with SUWAN-1-SR and Oba 98 had higher organic carbon than "Uselu" Local plots. SUWAN-1-SR cropped plots had the highest available phosphorus (10.70 mg kg^{-1}), exchangeable H^+ (0.43 cmol kg^{-1}) and exchangeable Al^{3+} (0.13 cmol kg^{-1}) than soil cropped with Oba 98 and "Uselu" Local. Lead (Pb) was highest (0.19 mg kg^{-1}) in plots treated with cattle manure. Poultry and cattle manures improved soil fertility through increase in soil pH, organic carbon and exchangeable cations.

Keywords: Chemical properties, exchangeable cation, fertilizer type, manure, postharvest, varieties

Introduction

Maize (*Zea mays* L.) is the third most important cereal after wheat and rice (Mohamed and Hassan, 2011). It is highly productive, cheap, and less rigorous to produce (Law-Ogbomo and Ahmadu, 2018). The crop is commonly cultivated in the tropics and warm sub-tropics. It is one of the most important cereals both for human and animal consumption and is grown for grain and forage. According to Food and Agriculture Organization of United Nations (FAO) in 2009, the world production of the crop is about 785 million tonnes of grain from about 158 million /ha (FAO, 2009), and recently it was reported to be about 1099.61 million tonnes of grain (Shahbandeh, 2020). Maize is a major source of carbohydrate and is used as food, in livestock feed and also in pharmaceutical industry (Law-Ogbomo and Law-Ogbomo, 2009). Maize can also be grown to produce forage in dry seasons to solve problems of livestock feed shortage (Ipperisel *et al.*, 1989). In Nigeria, maize is an important food, fodder and industrial crop grown both commercially and at subsistence level (Ahmadu and Law-Ogbomo, 2019).

In Nigeria, the crop productivity is low as compared to other countries due to low nutrient status of most tropical soils and the use of unimproved varieties among other factors. Increasing the nutrient status of the soil may be achieved by boosting the soil nutrient content either with the use of inorganic fertilizers such as NPK or through the use of organic materials such as poultry or cattle manures. The maize crop requires an adequate supply of nutrients particularly nitrogen, phosphorus and potassium for optimum growth and yield (Agba *et al*., 2012).

The main objective of this study was to evaluate the effect of maize varieties and fertilizer types on postharvest soil chemical properties in Benin City, Edo State, Nigeria.

Materials and Methods

Description of study location

The study was conducted at the experimental site of the Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria. Edo State is located between latitude 5° 44' and 7° 34' North of the Equator and longitude 5° 04' and 6° 44' East of Greenwich Meridian; and in the rain forest zone of South–South Nigeria (NIFOR, 2015).

Experimental design and field study

The experiment was carried out during the 2015 and 2016 rainy season on a plot measuring 23 x 21.5 m. The experiment was laid out in split–plot arrangement fitted into randomized complete block design (RCBD) and replicated three times. The main plots treatments were the maize varieties (SUWAN-1-SR, Oba 98 and "Uselu" local) and the sub-plots treatments were the fertilizer types (poultry manure, cattle manure, and NPK 15:15:15 fertilizer) and the control. Each of the subplot measured 2 x 5 m with a spacing of 0.5 m between plots and 1 m between blocks. Poultry and cattle manures were applied on the subplots in each main plot at 15 t ha^{-1} four weeks prior to sowing for equilibration.

Inorganic fertilizer (NPK 15:15:15) was applied at the rate of 0.4 t ha^{-1} at two weeks after sowing (WAS) and at tasseling.

Soil sample collection, organic manure and laboratory analyses

Before fertilizer application and cropping with maize, soil samples were randomly collected from each of the 36 sub-plots at a depth of 0–15 cm using auger and bulked to form composite sample for physiochemical analysis. After harvest, another 36 soil samples were collected from all the plots separately. The soil samples were air–dried and sieved through 2 mm sieve and used for soil physical and chemical properties determination. However, after harvest, soil samples from all plots were analyzed for their chemical properties only. Before the application of organic manure (poultry and cattle manures), they were sampled and air-dried in polythene bags for analysis.

Data collection

Data were collected on plant height, number of leaves, leaf area (length x width), and stem girth at 4 WAS, 50% tasseling and the third at 50% silking.

During harvest, five plants in each middle row of the 36 subplots were used to collect the following data: stover, number of ears, ear length, ear weight, cob weight, cob length, cob girth, number of rows per cob, number of grains per kernel row, grain weight per cob, 1000 grain weight per plot and on postharvest soil sample.

Data analysis

Data collected were subjected to combined analysis of variance by the use of GENSTAT programme, version 8.1 (GENSTAT, 2005). Significant differences among treatment means separated using least significant difference (LSD) at 5% level of significant (0.05 probability).

Results and Discussion

Physical and chemical properties of the experimental site before cropping with maize

Physiochemical properties of the soil before cropping with maize are presented in Table 1. The soils were highly acidic (pH of 4.40 and 4.60 for the 2015 and 2016 experimental site respectively), organic carbon moderate (20.65 and 21.40 kg^{-1}), total nitrogen content was low (0.96 and 0.88 g kg^{-1}), and available phosphorus low (8.22 and 7.96 $mgkg^{-1}$) in 2015 and 2016, respectively. Exchangeable cations (cmol kg^{-1}): calcium (Ca^{2+}), magnesium (mg^{2+}), potassium (K^+), and sodium (Na^+) values were low. Similarly, the exchangeable acidity (cmol kg^{-1}); hydrogen (H^+) were also present in both soil samples.

Table 1: Physiochemical properties of the experimental site before cropping with maize

Parameter	2015	2016
P^H	4.40	4.60
Organic C(g kg^{-1})	20.65	21.40
Total nitrogen (g kg^{-1})	0.96	0.88
Available P (mg kg^{-1})	8.22	7.96
Exchangeable cations (cmol kg^{-1})		
Ca^{2+}	0.42	0.46
Mg^{2+}	0.21	0.28
K^+	0.30	0.25
Na^+	0.18	0.16
Exchangeable acidity (cmol kg^{-1})		
H^+	0.81	0.62
Al^{3+}	0.40	0.10
Pb^{2+} (mg kg^{-1})	–	–
Sand	880.00	876.00
Silt	56.00	58.20
Clay	64.00	65.80

C = Carbon, P = Phosphorus, Ca^{2+} = Calcium cation ion, Mg^{2+} = Magnesium cation ion, K^{2+} = Potassium cation ion, Na^+ = Sodium cation ion, H^+ = Hydrogen ion, Al^{3+} = Aluminum ion, Pb^{2+} = Lead ion, '-' = not detected

Table 2: Chemical composition of organic fertilizer

Parameter	Organic fertilizer	
	Poultry	Cattle
pH	7.0	6.90
Organic C (g kg^{-1})	35.41	32.25
Total N (g kg^{-1})	16.50	10.40
Phosphorus (mg kg^{-1})	9.64	5.70
Ca^{2+} (cmol kg^{-1})	0.68	0.51
Mg^{2+} (cmol kg^{-1})	2.15	1.80
k^+ (cmol kg^{-1})	1.06	0.83
Na^+ (cmol kg^{-1})	0.54	0.51
Pb^{2+} (mg kg^{-1})	0.21	0.24
H^+ (mol kg^{-1})	0.03	0.03
Al^{3+} (mg kg^{-1})	0.08	0.64

N = Nitrogen, C = Carbon, Ca^{2+} = Calcium ion, Mg^{2+} = Magnesium ion, K^+ = Potassium ion, Na^+ = Sodium ion, Pb^{2+} = Lead ion, H^+ = Hydrogen ion, Al^{3+} = Aluminum ion

Chemical composition of organic fertilizer

Plant nutrient content of organic fertilizers such as poultry and cattle manures were neutral (7.00) and slightly acidic (6.90), respectively (Table 2). Both organic fertilizers contained high amount of organic carbon. They also contained available p, total N, exchangeable Ca, Mg, and k. However, appreciable amount of Pb was found in the fertilizers and exchangeable Al^{3+} was found in cattle manure.

Postharvest soil chemical properties as influenced by variety and fertilizer type

They are presented in Table 3. In the 2015 season, variety only had significant effect ($P < 0.05$) on organic C, available phosphorus and exchangeable cation (potassium), and exchangeable acidity. Organic C was highest in plots cropped with SUWAN–1–SR and the least was "Uselu" local. The highest exchangeable K was observed in "Uselu" local (1.12 cmol kg^{-1}) and least was observed in Oba 98 (1.01 cmol kg $^{-1}$). Exchangeable Al^{3+} ranged from 0.07 – 0.17 cmol kg^{-1} for "Uselu" local and SUWAN–1–SR, respectively.

Fertilizer application had significant effect on the soil chemical properties except exchangeable (H and AL) and heavy metal (Pb) in the 2015 cropping season. The soil pH was lowest in untreated plots followed by lots treated with NPK and highest in cattle manure treated plots. This distribution trend was also repeated for organic content except that the highest organic carbon content was observed in poultry manure treated plots. Total N range from 0.76 – 2.76 g kg^{-1} for control and NPK treated plots respectively. This distribution trend was also observed for available P and exchangeable K.

Exchangeable Ca^{2+} was most abundant in cattle manure plot and least abundant in the untreated plot. This situation was also reflected for exchangeable Mg^{2+} in 2015. Exchangeable Na^+ was highest in plots treated with cattle and poultry manures and least in the untreated plots. Cattle manure was most contaminated with Pb and the least was observed in the untreated plots. Significant interaction of variety and fertilizer type was observed on pH, total N, available P, exchangeable Ca^{2+}, Mg^{2+}, K^+, and Na^+. In the 2016 cropping season, significant effect of variety was only observed on pH, exchangeable Al and Pb. All the soil P^{Hs} were moderately acidic, higher pH was observed in Oba 98 main plot while "Uselu" local had the least soil pH. The highest content of exchangeable Al^{3+} was observed in SUWAN–1–SR and "Uselu" local main plots while the least was observed in Oba 98 main plot. SUWAN–1–SR and Oba 98 main plots were more contaminated with Pb.

Fertilizer application had significant effect on soil chemical properties in 2016 cropping season. The pH of the organic fertilizer treated plots were higher than NPK plots and untreated plots. This distribution trend was also observed in organic carbon, exchangeable Ca^{2+}, Mg^{2+} and Na^+. Total N, available P, exchangeable K and Al were highest in NPK treated plots and least on control plots. Exchangeable H^+ was higher in control and NPK plots and least in organic fertilizer plots. The most heavy metal (Pb) contaminated plot was cattle manure plots and the least was observed on control plots. Significant interactions of variety and fertilizer type were only significant on P^H, exchangeable H^+, Al^{3+} and heavy metal (Pb).

On the combined analysis, variety only had significant effect on organic C, available P and exchangeable acidity (H^+ and Al^{3+}). Higher organic C were observed in SUWAN–1–SR and Oba 98 plots than "Uselu" local plots. The highest available P was observed on SUWAN–1–SR plots followed by "Uselu" local and Oba 98. Exchangeable acidity was more abundant on SUWAN–1–SR plots and less on Oba 98 and "Uselu" local.

Table 3: Effects of maize variety and fertilizer type on the postharvest soil chemical properties

Time	Treatment	pH	Organic C	Total N	Available P	Exchangeable cations (cmol kg^{-1})				Exchangeable acidity (cmol kg^{-1})		Heavy metal (mg kg^{-1})
			(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	Ca	Mg	K	Na	H	Al	Pb
2015	**Variety**											
	SUWAN-I-SR	5.13	19.63	1.41	10.15	0.55	0.26	1.05	0.16	0.57	0.17	0.11
	Oba 98	5.23	18.40	1.45	9.18	0.54	0.27	1.01	0.19	0.28	0.08	0.11
	Uselu local	5.10	17.39	1.50	9.96	0.49	0.24	1.12	0.20	0.28	0.07	0.07
	$LSD_{(0.05)}$	ns	0.645	ns	0.636	ns	Ns	0.063	ns	0.153	0.041	ns
	Fertilizer Types											
	Control	4.77	14.36	0.76	5.16	0.41	0.21	0.26	0.12	0.43	0.13	0.01
	Poultry manure	5.28	22.85	1.20	9.14	0.59	0.28	0.61	0.22	0.37	0.12	0.07
	Cattle manure	5.56	20.66	1.08	7.80	0.65	0.31	0.57	0.20	0.29	0.08	0.23
	NPK	5.01	16.01	2.76	16.68	0.46	0.22	2.80	0.19	0.41	0.11	0.09
	$LSD_{(0.05)}$	0.262	1.075	0.067	0.439	0.040	0.043	0.052	0.027	ns	ns	ns
	$LSD_{(0.05)\ variety\ X\ Fertilizer}$	0.460	ns	0.131	0.814	0.071	0.106	0.091	0.058	ns	ns	ns
2016	**Variety**											
	SUWAN-I-SR	5.18	18.80	1.46	9.99	0.51	0.23	1.06	0.18	0.30	0.09	0.07
	Oba 98	5.32	18.94	1.39	9.10	0.66	0.24	1.03[a]	0.19	0.17	0.05	0.06
	Uselu local	5.17	17.26	1.46	9.47	0.56	0.25	1.55[A]	0.17	0.32	0.08	0.05
	$LSD_{(0.05)}$	0.064	ns	ns	ns	ns	ns	ns	ns	ns	0.015	0.005
	Fertilizer Type											
	Control	4.92	15.12	0.73	5.12	0.47	0.22	0.26	0.15	0.30	0.08	0.01
	Poultry manure	5.59	22.20	1.16	8.48	0.73	0.25	1.24	0.23	0.17	0.05	0.06
	Cattle manure	5.41	20.22	1.07	7.89	0.62	0.28	0.44	0.18	0.18	0.06	0.16
	NPK	4.97	15.80	2.79	16.60	0.5	0.20	2.92	0.16	0.41	0.10	0.05
	$LSD_{(0.05)}$	0.234	2.927	0.169	1.095	0.132	0.039	1.061	0.035	0.111	0.016	0.009
	$LSD_{(0.05)\ Variety\ X\ Fertilizer}$	0.354	ns	ns	ns	ns	ns	ns	ns	0.203	0.026	0.015
Combined	**Variety**											
	SUWAN-I-SR	5.15	19.21	1.44	10.70	0.53	0.25	1.06	0.17	0.43	0.13	0.09
	Oba 98	5.23	18.67	1.42	9.14	0.6	0.25	1.02	0.19	0.22	0.06	0.08
	Uselu local	5.13	17.32	1.48	9.61	0.53	0.24	1.34	0.19	0.30	0.07	0.08
	$LSD_{(0.05)}$	ns	0.847	ns	0.355	ns	ns	ns	ns	0.135	0.037	ns
	Fertilizer Type											
	Control	4.84	14.74	0.74	5.14	0.44	0.21	0.26	0.14	0.36	..01	0.01
	Poultry manure	5.43	22.53	1.18	8.81	0.66	0.29	0.92	0.22	0.27	0.08	0.06
	Cattle manure	5.48	20.44	1.08	7.84	0.64	0.28	0.51	0.19	0.23	0.07	0.19
	NPK	4.99	15.90	2.78	16.64	0.48	0.21	2.86	0.18	0.41	0.10	0.07
	$LSD_{(0.05)}$	0.170	1.481	0.097	0.554	0.026	0.030	0.512	0.022	0.096	0.024	0.009
	$LSD_{(0.05)\ Variety\ X\ Fertilizer}$	0.275	ns	ns	0.886	ns	0.061	ns	0.045	ns	ns	0.019

LSD =Least significant difference, ns = Not significance

Fertilizer application had significant effect on all the soil chemical properties when both 2015 and 2016 data were combined. The soil pH ranged from high acidic for control (4.84) and NPK (4.99) plots to moderately acidic for poultry (5.43) and cattle (5.48) manures. Organic C contents were higher on manures treated plots than NPK (15.90 g kg^{-1}) and control (14.74 g kg^{-1}) plots in that order. The highest total N, available P and exchangeable K were observed in NPK treated plots and the least were observed on control plots. Exchangeable Ca^{2+} and Mg^{2+} were more abundant on poultry and cattle manures treated plots and least on control and NPK plots. Exchangeable Na^{+} concentration was highest in poultry manure plots (0.22 cmol kg^{-1}) and least on control plots. NPK plots exhibited exchangeable H^{+} (0.41 cmol kg^{-1}) was statistically comparable to control plots and the least were observed on poultry (0.27 cmol kg^{-1}) and cattle (0.23 cmol kg^{-1}) plots. Exchangeable Al^{3+} was most abundant on NPK treated plots and least on control plots. The most contaminated heavy metal (Pb) plot was cattle manure plots and the least was control plots.

The fertilized plots contained more nutrient reserve than unfertilized plot. This could probably due to enrichment of the soil with added nutrients from applied fertilizers. This is a reflection of plant nutrient availability in organic (cattle and poultry manures) and inorganic (NPK) fertilizers. However, the soil organic carbon was lower in unfertilized plots and NPK treated plots. The exhibition of higher exchangeable acidity (Al^{3+} and H^{+}) by the unfertilized plots is as a reflection of the exhaustion of the soil nutrient and low organic carbon content. The higher soil pH in plots treated with poultry and cattle manures showed in this study agreed with Ano and Agwu (2005). The higher pH associated with organic fertilizer application was probably due to ionic exchange reaction which occurred when terminal OH^{-} of K or Al were replaced by organic anions such as tartrate, malate and citrate (Bell and Besho, 1993). The ability of organic fertilizer to increase soil pH could be attributed to the enrichment of the soil through mineralization of cations particularly calcium.

The content of lead (Pb) in the soil after harvest might have resulted from the inclusion of the fertilizer which led to the Pb content in the soil. The Pb concentrations in the fertilizer treated plots were within these permissible limits of 2 – 60 mg kg^{-1} (Alloway, 1990). Lead was significantly most concentrated in plots treated with cattle manure. This could probably be due to the nomadic rearing of cattle thereby giving them the opportunity to feed and drink water anywhere provided they are available. This will make them have access to lead (Pb) from contaminated food material.

Conclusion

This study has showed that the soils of the study sites were of low fertility status evidenced through the exhibition of deficiencies of some essential nutrients (total N, available P and exchangeable bases (Ca^{2+} and Mg^{2+}). It was also observed that fertilizer application had significant effect on soil chemical properties by an increased in plant nutrients in the soil after harvest. The chemical composition of cattle and poultry manures indicated that they contained essential plant nutrients in appreciable quantity. The high organic carbon content of the organic fertilizer is an indication of abundant organic matter which plays an important role as reservoir of soil nutrients. This implied that reasonable yield could only be achievable through the use of fertilizers.

Conflict of Interest
Authors declare that there is no conflict of interest reported in this work.

References
Agba OA, Ubi BE, Abam P, Ogbech J, Odey S & Ogar N 2012. Evaluation of agronomic performance of maize (*zea mays* L.) under different rates of poultry manure application in an ultisol of Obubra, Cross River State, Nigeria. *Int. J. Agric. and Forestry*, 1 – 10.

Ahmadu R & Law-Ogbomo KE 2019. Effects of some soil amendments on the growth and yield of maize (*Zea mays* L.) Varieties in an Ultisols of Benin City. *FUW J. Agric. and Life Sci.*, 3(2): 1-11.

Alloway BJ 1990. Heavy Metals on Soil. New York. John Wiley and Sons. Inc, pp. 50 – 280.

Ano OA & Agwu JA 2005. Effect of animal manure on selected soil chemical properties. *Journal of Soil Science*, 15: 14 – 19.

Bell BC & Besho T 1993. Assessment of aluminum detoxification by organic materials in an ultisol using soil solution characterization and plant response. In: IC Milongoy & Rmerck e(eds). *Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture.* John Wiley and Sons. New York, pp. 317 – 330.

Food & Agricultural Organization (FAO) 2009. Maize, Rice and Wheat; Area Harvested, Production, Quantity, Yield. FAO of the United Nations, Statistics Division.

GENSTAT 2005. Genstat Release 8.1. Statistical Software. VSN, International Limited. Rothamsted UK

Ipperisiel D, Ali I, Machenze AF & Mehuys GR 1989. Nitrogen distribution, yield and quality of silage corn after foliar nitrogen fertilization. *Agronomy Journal,* 18: 187- 786.

Law-Ogbomo KE & Ahmadu R 2018. Comparative effect of varieties and fertilizer types on nutrient content and uptake of maize in a low fertile soil environment. *FUW J. Agric. and Life Sci.*, 2(2): 251 – 261.

Law-Ogbomo KE & Law-Ogbomo JE 2009. The performance of *Zea mays* L. as influenced by NPK fertilizer application. *Notulae Scientia Biologicae,* 1(1): 59 – 62.

Mohamed E & Hassan A 2011. Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). *J. Saudi Soc. Agric. Sci*., 10(1): 17 – 23.

National Population Commission (NPC) 2006. Population census figure of the Federal Republic of Nigeria, Abuja.

Shahbandeh M 2020. Worldwide Production of Grain in 2018/2019, by Type.

Statistics Division 2015. Nigeria Institute for Oil Palm Research, Benin City, Edo State, Nigeria.