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Effect of Organo-Mineral Fertilizer on Soil Nutrient Flux and Maize (*Zea Mays* L.) Productivity on an Ultisol in Southern Nigeria

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Abstract **– A field experiment was conducted in the Department of Crop Science Experimental Farm of the University of Calabar in 2011 and 2012 main cropping seasons to evaluate the influence of Pacesetter Organo - mineral fertilizer (OMF) rates on some soil physico-chemical properties and productivity of a local maize variety (Ikom White) grown on an Ultisol. Treatments evaluated consisted of five rates (0, 2, 3, 4 and 5 t ha^{-1}) of the OMF, laid out in a randomized complete block design with three replications. Results obtained showed reduced soil acidity, depletion in total N, exchangeable Ca, Mg and ECEC, while organic Carbon and soluble Al contents increased in the post-harvest soil samples. All the OMF rates enhanced maize performance but the fertilizer was more effective in 2012 than in 2011 in the corresponding rates. However, maize plants fertilized with OMF at 5 t ha^{-1} were significantly taller, grew faster and attained the 50% tasseling 11 – 16 days earlier than all other rates. Plants under this treatment also produced cobs that were longer than those of the control plants by 3.5 – 12.6 cm in 2011 and 7.42 – 15.87 cm in 2012, had the highest shelling percentage (48.31 – 58.50 %), and produced the highest number of grains per cob (208.3 – 320.7). A grain yield of 2.58 t ha^{-1} was also recorded in 2011 and 3.20 t ha^{-1} in 2012 representing an increase of 0.71t ha^{-1} or 38 % and 2.04 t ha^{-1} or 176 % above the control with the application of OMF at the rate of 5 tha^{-1}. Application of Pacesetter OMF at 5.0 t ha^{-1}could be optimum for sustainable soil fertility maintenance and enhanced maize productivity in the Cross River Rainforest zone of Nigeria.**

Keywords **– Organo-Mineral Fertilizer, Maize, Rainforest, Soil Fertility, Ultisol.**

I. Introduction

Maize (*Zea mays* L.) is a native grain crop of South and Central America where it has been cultivated for over 500 years. It is cultivated in a wide range of environmental conditions from sea level up to about 300 meters altitude (Anonymous, 2002). It has the C4 metabolic pathway and is photosynthetically highly efficient under high temperature and light intensity conditions. Globally, maize is the third most important crop after wheat and rice (FAO, 2009) as it is adapted to a wide range of agro-ecologies.

The United States of America is the world's highest producer of maize with about 35 million hectares under its cultivation annually (FAOSTAT, 2013). The USA, China and Brazil are the top three world's producers of maize, which jointly accounted for 553.3 million metric tonnes or 63.13% of the global aggregate output of about 876.5 million metric tonnes in 2012 (FAOSTAT, 2013; IGC, 2013).

Maize is considered the most important cereal crop and an important staple for more than 1.2 billion people in sub-Saharan African and Latin America. In Africa, about 95% of maize produced annually is used for human consumption compared to developed countries where it is used mainly as livestock feed and for industrial products. Nigeria produces over 7 million metric tonnes of maize annually on about 2.5 million hectares with average yield of 1.4 metric tonnes per hectare to rank the first and 10th highest producer of the crop in Africa and in the world, respectively(*htpp://www.foranfera.com/index.php/investment-opportunities-in-nig*). The crop grows well in the forest zone and in the derived Savanna and southern Guinea savanna zones of the countries with principal areas in the northern states of Adamawa, Bauchi, Borno, Gombe, Taraba, Plateau, Sokoto, Kebbi, Katsina, Niger and Zamfara where it is used in various food forms and as a major source of income to many families (Tague *et al*; 2008).

Maize has the highest average yield of 8.6 tonnes per hectare among the cereals in developed countries but production in developing countries including Nigeria is till as low as 0.4 -1.7 tonnes per hectare (Lamarde, 1994). With its food and, economic potential, maize production is expanding in the Guinean savannah zone to the savannas of the entire West Africa, which occupy about 12 million hectares (Manyong *et al.*, 1996).

Worldwide, there is growing interest in the use of organic manures which are cheap and more environmentally-friendly compared to synthetic fertilizer (Delate and Camberdrella, 2004; Oad *et al*, 2004, Prabu *et al*, 2008). Organic manures release nutrients slowly and improve soil fertility status by activating the soil biomass, sustains cropping systems through better nutrient cycling, improved soil structure and increased soil moisture holding capacity, aeration and water infiltration (Deksissa *et al.*, 2008).

Complementary use of organic manure and mineral fertilizer has proved a sound soil fertility management strategy in many agro-ecological areas particularly in the rain forest zone of Nigeria where soils are acidic in nature (Ohiri *et al*., 1989; Brady and Weil, 1996) and are inherently low in nutrient contents with severe nutrient imbalance and complex nutrient deficiencies (Sanchez *et* *al.*, 1987). Apart from enhancing crop yields, organic manures have greater beneficial residual effects than inorganic fertilizer or organic manure when applied individually. The need to determine the optimum rate of Pacesetter Organo-mineral fertilizer for enhanced maize productivity in Calabar rain forest zone was therefore the objective of this trial.

II. Materials and Methods

The experiment was carried out in the main cropping seasons of 2011 and 2012 at the Crop Science Experimental Farm of the University of Calabar, with coordinates 04^0 57'N and 8^0 19.5' E with altitude of 32 meters above sea level (Weatherbase,2011). The area receives a total annual rainfall of about 3500 mm spread between the months of March and November, with monthly peaks in July and September. The annual temperature ranges from 21 to 29 ^{0}C while the relative humidity is about 70-85% (NIMET, 2012).

Treatments evaluated consisted of five rates of Pacesetter Organo-mineral fertilizer (OMF) at 0, 2, 3, 4 and 5 t ha^{-1}, laid out in a randomized complete block design with three replications. Land preparation was done manually and each experimental plot measured 2 m x 3 m with interplot space of 1.5 m. Pre-land preparation and post harvest soil samples (0 - 30 cm depth) were taken randomly from the gross plot using a soil auger to determine some soil physico-chemical the pre-planting and post-harvest soil properties. as described by (Kumar and Agarwal,1980). A popular local white maize variety known as 'Ikom White' was planted at 40,000 plants ha^{-1} during the main planting season on 10^{th} April, each year. Before sowing, seeds were soaked in clean water for 24 hrs to facilitate germination. Seeds were pre-treated with a nematicide-insecticide seed dresser (Apron Star ®) to protect them against attack by soil-borne pests and pathogens. The fertilizer was applied in a ring 5 cm away from the maize plants at three weeks after sowing (3WAS). The composition of the OMF was as followed: pH (H_2O) 6.1, organic matter 61.2 g kg^{-1}, organic carbon 35.5 g kg^{-1}, nitrogen 3.6%, while available phosphorus and exchangeable potassium contents were 372.5 and 14.77 mg kg^{-1}, respectively. All plots were manually weeded twice at 3WAS when fertilizer was applied and at the tasseling stage. Data taken included plant height, number $plant^{-1}$, leaf area (determined by the formula of Rajeshwori *et al*. (2007) : LA = C * L * W (where LA= leaf area, C = 0.75 (correction factor), L = leaf length, W = leaf width at the widest region), leaf area index (LAI), days to 50% flowering (taselling, number of grains cob^{-1}, cob length, grain/cob ratio,100-grain weight and grain yield ha^{-1}. Data analysis was done using analysis of variance) techniques and means compared using the Fisher's least significance difference (F-LSD) at 5% level of probability.

III. Result and Discussion

Influence of Organo-mineral Fertilizer on Soil Properties

The physico-chemical properties of the soil at the experimental site are presented in Table1. The soil was sandy-loam, acidic and low in fertility. The application of OMF did not change the sand content of the soil, whereas the content of silt was lower and clay higher in the post-harvest than in the pre-sowing soil samples. However, the textural class of the soil was not altered by the application of OMF. The size differences between the sand, silt/loam and clay textural classes is of paramount importance as they influence the pore size and cation exchange capacity which play vital role in storing and transporting water, gasses and nutrients in the soil (Hamza, 2008).

The pH and base saturation levels were lower in the pre-sowing than in the post-harvest soil samples. The decrease in soil acidity after the experiment was obviously due to the favourable influence of organo-mineral fertilizer despite the high concentration of the hydrogen ions in the soil. Soil pH plays a crucial role in soil as it affects the solubility of essential plant nutrients such as P, K, Ca, Mg, Mn and Fe and influences their absorption from the soil by plants (Lyocks *et al*., 2013). Most crops grow optimally in a moderate or slightly acid soil. The increase in the pH of the soil from 4.9 in the pre-sowing soil to 5.2 in the post-harvest soil is an indication that the application of organic-based plant nutrients on acid soils is beneficial and could reduce soil nutrient problems related to excessive acidity common in the high rainfall environments (Sanchez *et al.*,1987).

The total nitrogen, exchangeable calcium, magnesium and ECEC contents of the soil were higher in the pre-sowing soil than in the post-harvest soil samples. Sodium content did not change while organic carbon and aluminium increased in the post-harvest soil. The depletion of total nitrogen, exchangeable calcium, magnesium and ECEC in the soil could be attributed to uptake by maize which has been reported to be a heavy feeder particularly in terms of mineral N (Kamara, 2013). The slight increase in Al content of the post-harvest soil could be attributed to the solubility of the element under acidic soil condition and leaching of cations which is common in the area. Brady and Weil (1996) similarly reported the prevalence of Al toxicity in acid soils in other high rainfall areas.

Influence of Organo-mineral Fertilizer on the Growth of Maize

The application of OMF significantly increased maize height and days to 50% tasseling, but did not influence the number of leaves per plant, leaf area/leaf area index (LAI) in 2011 and 2012 except maize height and the number of days to 50% tasseling (Table 2). Maize increased as the OMF rates were increased, with tallest maize plants obtained in plots fertilized with the highest rate (5.0 tha^{-1}) of OMF, followed by plants in plots fertilized with 4.0, 3.0 and 2.0 tha^{-1}, while shortest plants were in the control plants in 2011 cropping season. A similar trend in plant height occurred in 2012. Though excess plant height is not desirable in maize due to high susceptibility of excessively tall plants to stem breakage and lodging under windy conditions, it could be a useful index in assessing growth rate in plants particularly of Poaceace family.

Attainment of the 50% tasseling stage also varied significantly among maize plants grown under different OMF rates and the control. All OMF rates had similar effect on tasseling which occurred significantly earlier in fertilized plants than in the control in 2011 but in 2012, there were significant differences in the effect of OMF rates on this parameter. Maize plants in plots fertilized with OMF at 3.0 – 5.0 t ha^{-1} reached the tasseling stage significantly earlier than those in plots fertilized with 2.0tha^{-1}, while control plants required significantly more days to attain the 50% ting stage. By applying 5.0 tonnes of OMF per hacter, attainment of tasseling was reduced by 16 days in 2011 and 11 days in 2012 cropping seasons. This result is consistent with those obtained by other researchers (Ayoola and Makinde,2009; Orosz *et al.*,2009; Uwah *et al.*,2011) who reported significant reduction in the number of days to 50% tasseling in maize with increasing rate of NPK fertilizer under similar agroecological conditions. Stimulated vegetative growth and high grain yield of maize attributed to availability of macronutrients in the soil as a result of optimal application of OMF has also been reported by Obi and Edo (1994).
Increased earliness of tasseling and hence shortening of the maize production cycle obtained in plots fertilized with OMF at 5.0 t ha^{-1} indicates that maize productivity could be increased substantially particularly in the Cross River rain forest area which has the potential for double cropping of maize under rainfed conditions.

Influence of Organo-mineral Fertilizer on Yield and yield componemts of Maize

Organo-minneral fertilizer rates significantly influenced maize cob length, shelling percentage, fresh cob weight, number of grains per cob and grain yield per hectare which increased as the fertilizer rates increased and maximized at the highest OMF rate (5.0 t ha^{-1}) in both cropping seasons (Table 3). Longest cobs were harvested in plots fertilized with OMF at 5.0 t ha^{-1}, followed by those obtained in plots fertilized with OMF at 4.0 and 2.0 – 3.0 t ha^{-1} while shortest cobs were obtained from control plots. The difference between the longest and shortest cobs ranged from 3.5 – 12.5 cm and 7.42 – 15.87 cm in 2011 and 2012, respectively. While cob length increased in all OMF applied plots irrespective of the cropping season, it rather reduced in the control plots after one year of cropping obviously due to declining soil fertility.

Shelling percentage and fresh cob weight were also highest at 5.0 t ha^{-1} and lowest in the control, with the values in 2012 being higher than the corresponding values in 2011.

The number of grains produced per cob followed the same trend with other cob yield indices and also increased significantly as the rates of OMF were increased and reached a significant peak at 5.0 t ha^{-1}, with correspondingly highest grain yield per hectare which was higher than the control by 0.71t ha^{-1} or 38% and 2.04 t ha^{-1} or 176% in 2011 and 2012, respectively.

The reason for the favourable growth and the best yield indices and grain yield obtained in plots fertilized with OMF at 5.0 t ha^{-1} may be attributed to adequate and balanced supply of plant nutrients which nourished the plants in such plots properly throughout their growth. Enhanced productivity of maize elsewhere attributed to the beneficial effect of optimum application of OMF have similarly been reported by others (Tamayo *et al.*, 1997; Farooqi ,1999; Shah and Arif, 2002).

Conclusion

The Pacesetter OMF rate at 5.0 t ha^{-1} had more favourable influence on soil pH and organic carbon content and produced the best effect on maize growth and yield and could be regarded as the optimum rate for sustainable soil fertility maintenance and enhanced productivity of white maize in the Cross River Rainforest zone of Nigeria.

Table 1: Soil Physico -chemical properties prior to and after cropping and the nutrient content of the OMF used.

Parameter	Values of Pre-cropping	Post-cropping	OMF
PH (Soil: H_2O)	4.9	5.2	6.5
Org. C (%)	1.16	1.19	40.3
Total N (%)	0.09	1.02	7.1
Average P (Mg/kg^{-1})	43.0	56.8	68.0
Basic Cations ($Cmolkg^{-1}$)			
Ca	1.0	1.3	4.8
Mg	0.6	0.3	3.0
K	0.8	0.2	0.17
Na	0.05	0.08	0.10
ECEC	6.45	4.13	19.2
Basic saturation (%)	20.0	51.0	43.0
Particle size analysis (%)			
Sand	80.0	80.0	
Silt	7.7	7.8	
Clay	12.3	12.2	

Table 2: Influence of OMF rates on growth of maize (Zea mays L.) in Calabar, Nigeria

	Plant Height (cm)		Leaves $plant^{-1}$		leaf area (cm^2)		LAI		Days to 50% tasseling	
OMF rate tha^{-1}	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012

0(control)	148.405	140.3	10.2	10.1	609.43	627.21	101.57	104.54	59.8	64.3
2.0	162.304	157.3	10.8	11.2	580.67	628.44	96.77	104.74	56.7	55.5
3.0	189.173	163.2	11.2	11.0	613.00	616.12	102.17	102.69	45.2	53.6
4.0	196.832	166.902	11.0	11.1	614.97	677.80	102.50	112.97	45.9	53.6
5.0	204.5	171.901	11.8	11.6	637.40	694.10	106.23	115.68	44.3	53.4
LSD (0.05)	6.50	4.80	Ns	Ns	Ns	Ns	Ns	Ns	2.8	1.15

Table 3: Influence of OMF on yield and yield components of maize (*Zea mays* L.) in Calabar, Nigeria

	Cob Length (cm)		**Shelling (%)**		**Grains cob^{-1}**		**Cob fresh wt (kg plot^{-1})**		**Grain yield (tha^{-1})**	
OMF rate (tha^{-1})	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
0 (control)	9.33	6.45	38.34	30.58	46.2	34.3	2.53	1.92	1.87	1.16
2.0	12.83	13.87	39.92	42.15	129.0	164.5	2.80	3.87	2.12	2.77
3.0	13.56	14.50	38.76	42.19	163.0	202.2	2.84	3.94	2.39	2.92
4.0	16.78	18.35	43.05	56.80	181.2	280.8	3.02	4.30	2.46	2.98
5.0	21.93	22.32	48.31	58.50	208.3	310.7	3.20	4.97	2.58	3.20
LSD(P=0.05)	3.65	3.35	2.80	5.20	21.6	20.8	0.13	0.15	0.10	0.18

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