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Influence of Organic Fertilizers Application on Soil Bioactivity and Sustainable Maize Production in Nigeria Floodplain

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Scope Statement and Relevance

Agricultural lands are subjected to man-induced pollution and are seriously threatened by increasing environmental deterioration and eutrophication in aquatic ecosystem arising from heavy application of inorganic fertilizer and these chemicals affect microbial dynamics), economics and constitute health hazard. Thus proper management of the ecosystem by application of low-energy organic substance such as animal manures (composted poultry droppings & cattle dung) is necessary. In Akwa Ibom State, Nigeria, the problem of availability and reutilization of animal manures is being encountered. These constraints can be handled through organic farming, application of poultry droppings and cow dung manures. Most of the information on agricultural soils in Akwa Ibom State are focused on upland soils and other organic manures but not much has been reported on use of organic manure such as cow dung on flood plains. A field experiment was carried out to assess the influence of organic fertilizers application on soil bioctivity and sustainable maize production in Nigeria flood plain during two planting seasons.

Conflict of interest: there is no conflict of interest by any of the authors.

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ABSTRACT

The influence of organic fertilizers (cattle dung; CD & poultry droppings; PD) application on soil bioactivity and sustainable maize production in Nigeria floodplain was investigated. The experiment which was conducted at Ini wetland soil deployed the randomized complete block design with three treatments and two replications giving three main plots; cow dung- manured plots (CM), poultry manured plots (PM) and the control plots (C). Each plot was sectioned into nine subplots on which 81 mounds each were prepared for the cultivation of maize. Soil bioactivity was determined using standard bacteriological methods and the results revealed a higher activity in soil treated with 4500 kgha^{-1}of CD and PD with remarkable loads of Total heterotrophic bacterial counts, THBC = log 7.04and 8.82, actinomycetes count, AC = log 6.16& 6.58, diazotroph bacteria count, DBC = log 5.00 & 5.59 and fungal counts, FC = log 4.95 &5.59 cfug-1) in fertilized plots during the 1st & 2nd cropping season (CS) respectively than in the control with 6.57 & 7.57, 5.36 & 5.52 , 5.44 & 5.59,5.4 & 5.29 cfug-1of THBC, AC, DBC and FC respectively. The increased in bioactivity led to a better nutritional status of the wet soil, and higher maize growth/yield. However treatments with poultry manure (PM) derived compost had higher grain yield; 4.04 $\pm$ 0.10 t/acre compared to 3.61$\pm$0.31t/acre and 0.18$\pm$ 0.23t/acre recorded for cow dung (CM) derived composts and control respectively. Both manures gave remarkable improvements in soil quality and grain yield, and are recommended for sustainable production of crops (especially maize) in tropical wetlands.

Keywords: organic fertilizers, bioactivity, flood plain, sustainable production of maize, wetland soil.

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Introduction

Agricultural wetlands are subjected to man-induced pollution and are seriously threatened by increasing environmental deterioration and eutrophication due to heavy application of inorganic fertilizer (Kumar, Bisht, Joshi and Dhewa, 2011) and these chemicals affect soil microbial dynamics or bioactivity (Vinas, Sabate, Espuny and Solanas, 2005), economics and constitute health hazard. Thus proper management of the ecosystem by application of low-energy organic substance such as animal manures (composted poultry droppings & cattle dung, P.D &C.D) is necessary.

In Akwa Ibom State, Nigeria, the problem of availability and reutilization of animal manures is being encountered. These constraints can be handled through organic farming. The application of organic fertilizers which serves as source of nutrients for bacteria and other microbes , which in turn convert the nutrients into utilizable forms for plants (improve crop yield) can enhance the wetland soil quality and maintain agricultural sustainability (Wagner, 2012) by extension enhance food security. The present study was done in a field experiment of a tropical flood plain in Ini, Akwa Ibom State, Nigeria. Field experiments were carried out during two planting seasons to assess the influence of organic fertilizers on maiz

e grown in a wetland

2. **METHODOLOGY**

2.1 Study Area & Research Design

The tropical flood plain or wetland soil used in this study is located in Ogu Mbonuso in Ini Local Government Area. The area designated IW is situated between latitude 5° 02’ North and longtitude7° 35’ and 8° 35’ East of Akwa Ibom State, Nigeria (Figure 1). The climate of the area is humid tropical, annual rainfall (2500–3000mm), mean annual temperature (between 27 and 28°C) and relative humidity (75-80%) (Imelda, 2014) .

The design of the experiment was randomized complete block design with two replications of 3 treatments plots (composted cow, poultry manure and control plots). A block consisted of 3 plots each having nine mounds in a row and nine in a column (i.e. a total of 81 mounds each with a stand of maize plants) in the flood plain. Thus, a total of seven hundred and twenty – nine (729) stands of maize (*Zea mays*) plant were cultivated on a plot of two thousand four hundred and twenty metre square and sixty four centimetres (2420.64 m^2) according to Ogban and Babalola (2009).

2.2 Sampling Techniques

2.2.1. Collection of Organic Fertilizers, Test Crop and Soil Samples:

Organic fertilizers: cattle dung, CD and poultry droppings, PD were respectively collected from a livestock market and private poultry farms in Uyo metropolis, Akwa Ibom State, Nigeria. Maize (TZSR-W: Tropical *Zea mays* Streak Resistant White species) seeds were obtained from Akwa Ibom State Agricultural Development Programme (AKADEP). Homogenized soil samples were collected at depths of 0 – 10 cm and 20 cm biweekly for all analyses during first & second cropping seasons (1st & 2nd C.S) (Okoroafor *et al.* (2013).

2.3 Bio-physicochemical Properties of the Soil

2.3.1Microbiological analysis of the wetland soil

Soil samples were serially diluted10-fold down the gradient to 10^{-5}, plated on nutrient agar medium by pour plate method and incubated at 37^{o}C(± 2) between 24-48 hours**.** Discrete colonies were sub-cultured and preserved in slants at 4^{o}C for further microbiological analysis. Colonial characteristics and cell biochemical reactions of pure cultures were done for characterization according to the methods described by Cheesebrough (2005) and were identified based on the taxonomic schemes of Holt *et al*. (1994).

2.3.2 Bio-physicochemical Properties of the Soil

The Ini wetland soil samples were analyzed for some physicochemical parameters at biweekly interval. The following physicochemical characteristics of the test soil were evaluated adopting standard methods: temperature, pH, moisture content, organic matter (OM), base saturation (BS), electrical conductivity (EC) and total organic carbon.

The *in situ* temperature reading of soil samples (10cm below surface) were taken manually using soil thermometer. The extracts of the test soil-water suspension (1:10w/v) were used to measure the pH using digital pH meter. Moisture content and base saturation were analysed following standard procedures described by FCQAO (1994). The organic matter contents were estimated by drying the soil sample to constant weight at 600^{o}C adopting methods described by Sparks (1996). The electrical conductivity of soil samples were determined by using digital conductivity bridge after mixing the sample in distilled water (1:10W/V) following methods of Sparks (1996). Also total organic carbon (TOC) were estimated by dividing percentage organic matter by the factor of 1.729 as described by Jackson (1975).

2.4 Application of organic fertilizers & Planting of Seeds

Prior to cultivation, the organic fertilizers were stabilized using the microbe-based active pile windrows composting methods described by Okoroafor *et al.* (2013).Single-plan manure application was adopted and manures were applied to planting holes according to methods of Vallejo, Skibba, Garcia-Torres, Arce *et al.* (2006).Two seeds (subjected to viability test) per mound (hole) were planted and thinned to one plant per hole (with spacing of one meter between mounds and 3 meters between plots) within 2 weeks according to methods described by Ogban and Babalola (2009).

2.4 Determination of Growth and Yield of Test Crop

The growth parameters (leaf length and width, dry weight mass and height of plant) and yield of maize crops (number of grains per cob, weight of grains) were assessed according to methods previously used by Agbogidi and Okonmah, (2012). Maize was harvested fresh at 13 weeks after planting (WAP) and the Harvest Index was evaluated after the methods of Pennington (2016).

2.5 Statistical Analysis

The statistical package for Social Science version 20 (SPSS .20) with level of significance maintained at 95% for each test was adopted for statistical analysis (Sokal, and Rohlf, 1981).

3.0 RESULTS

3.1 Physicochemical Properties of Test Soil

The mean values of the physicochemical properties of the IW (Table 1) during both C.S revealed as follows: highest mean temperature (28.22 $\pm$0.01 & 29.08 ± 0.02**^{o}C** - IC) compared to (28.30 ± 0.01 & 30.20 ± 0.12^{o}C; 27.90 $\pm$ 0.05 & 29.38 $\pm$0.06 ^{o}C) from the ICM & IPM during 1st & 2nd C.S respectively. The pH value of the initial (IBSO) and IC soils were acidic (5.78$\pm$ 0.10 and 6.63$\pm$ 0.00) but the pH of the treated plots during both seasons increased towards neutral (6.98$\pm$0.02) at ICM. Electrical conductivity was lower in the treated soil. Higher values of total organic carbon, organic matter and base saturation were obtained in treatment plots than in the IC plots. However, there was slight decrease in concentrations of available phosphorous in the ICM plots than in the IC during 2nd C.S (*not shown here*).

Table 1: Physicochemical properties measured at Ini floodplain in the 0 – 15 cm surface layer and core sample during 1st and 2nd cropping seasons

Properties	Site IBSO1	IC1	IC2	IPM1	IPM2	ICM1	ICM2
Temp (°C)	28.20 ± 0.01	28.22± 0.01	29.08 ± 0.02	28.30 ± 0.01	30.20 ± 0.12	27.90 ± 0.05	29.38 ± 0.06
pH (H_2O)	6.00 ± 0.08	5.78 ± 0.10	6.63 ± 0.00	6.04± 0.09	6.80 ± 0.10	6.90 ± 0.06	6.98 ± 0.02
EC ($mScm^{-1}$)	0.10 ± 0.09	0.21 ± 0.04	0.25 ± 0.03	0.16± 0.03	0.19 ± 0.09	0.13 ± 0.04	0.14 ± 0.02
BS (%)	63.42 ± 0.21	69.82 ± 0.02	86.24 ± 0.09	31.03 ± 0.08	90.30 ± 0.13	85.61 ± 0.04	84.24 ± 0.12
Moisture content (%)	40.30 0.10	43.81 ± 0.05	46.52 ± 0.05	53.38 ± 0.09	56.11 ± 0.05	55.12 ± 0.011	52.34 ± 0.04
TOC (%)	1.93 ± 0.04	1.73 ± 0.09	0.92 ± 0.01	13.07 ± 0.10	12.38 ± 0.02	11.53 ± 0.05	12.94 ± 0.00
OM (%)	1.11 ± 0.20	2.29 ± 0.05	1.80 ± 0.01	10.55 ± 0.04	16.51 ± 0.07	13.10 ± 0.06	20.61 ± 0.01

3.2 Bioactivity Levels of Treated Soil

Results of the mean counts bacterial groups found in IW soils during 1st C.S showed the following trend of microbial abundance (log transformed values): THBC (7.04) >TAC (6.16) >TFC (5.00) > DBC (4.95) >TCC (2.06) $cfug^{-1}$respectively (Table 2). Thus, from the results, the most abundant of the microbial groups were THBC while the least was TCC. During 2nd C.S, similar pattern of microbial abundance as in the 1st C.S was obtained (Table 2).

Table 2: Soil heterotrophic bacterial counts during 1st and 2nd planting seasons at Ini

Sample Code	**THBC ($x10^7$ $cfug^{-1}$)**	**Log Value**	**AC ($x10^6$ cfu g^{-1})**	**Log Value**	**DBC ($x10^5$ $cfug^{-1}$)**	**Log Value**	**TFC ($x10^5$ $cfug^{-1}$)**	**Log Value**	**TCC ($x10^3$ $cfug^{-1}$)**	**Log Value**	**FCC ($x10^2$ cfu g^{-1})**
IBSO	0.16±0.13	6.23	0.11 ± 0.12	5.06	0.77±0.28	5.89	0.15±0.44	4.18	3.50 ±0.20	2.54	ND
IC_1	0.16±0.40	6.21	0.23 ± 0.03	5.37	1.60±0.53	5.2	0.15±0.44	4.19	3.30±0.01	2.52	ND
ICM_1	2.15±0.65	7.33	0.26 ± 0.14	6..41	1.27±0.23	5.1	1.73±0.60	5.24	3.50± 0.00	2.54	ND
IPM_1	2.40±0.33	7.38	0.23 ± 0.44	6.37	1.33±0.25	5.12	1.89±0.62	5.04	3.00± 0.33	2.48	ND
IC_2	0.26±0.84	6.41	0.23 ± 0.34	5.36	2.17±0.15	5.34	0.16±0.15	4.2	3.00± 0.50	2.48	ND
ICM_2	3.19±0.10	7.5	3.43 ± 0.33	6.54	1.93±0.60	5.29	1.82±0.27	5.26	2.10± 0.20	2.32	ND
IPM_2	2.54±0.08	7.41	2.81 ± 0.34	6.58	2.17± 012	5.34	1.60±0.62	5.2	0.19 ±0.05	1.28	ND
IC_3	0.29± 078	6.46	0.25 ± 0.31	5.39	2.13±0.15	5.33	0.19±0.15	4.28	3.00± 0.57	2.48	ND
ICM_3	3.04± 014	7.48	3.67 ± 0.23	6.57	1.43±0.40	5.16	1.97±0.38	5.29	0.90± 0.11	1.95	ND
IPM_3	3.04±0.08	7.48	3.09 ± 0.45	6.52	1.70±0.44	5.23	2.20±0.63	5.34	0.60± 0.05	1.78	ND
IC_4	0.35±0.35	6.55	0.28 ± 0.30	5.45	2.30±0.44	5.36	0.22±0.30	4.35	2.70± 0.60	2.43	ND

ICM_4	3.40±0.70	7.53	3.73 ±0.50	6.57	1.88±0.64	5.27	2.50±0.59	5.4	0.30± 0.27	1.48	ND
IPM_4	3.35±2.43	7.53	3.10 ± 0.30	6.49	1.20±0.35	5.08	2.42±0.54	5.38	0.30±0.22	1.48	ND
IC_5	0.33±0.36	6.52	0.27 ± 0.31	5.44	0.35±0.49	4.54	0.23±0.45	4.3	2.6 ± 0.21	2.42	ND
ICM_5	3.53±0.14	7.55	3.79 ± 0.23	6.59	0.31±0.26	4.49	2.53±0.49	5.35	0.30± 0.43	1.48	ND
IPM_5	3.41±0.15	7.54	3.38 ± 0.35	6.54	0.30±0.05	4.48	2.70±0.24	5.35	0.40± 0.20	1.6	ND
IC_6	0.37±0.16	6.57	0.32 ± 0.27	5.5	0.37±0.15	4.57	0.19±0.05	4.2	2.40± 0.20	2.38	ND
ICM_6	0.38±0.44	6.6	4.26 ± 0.40	6.63 S	0.36±0.28	4.56	2.48±0.45	5.36	0.30± 0.17	1.48	ND
IPM_6	0.42±0.33	6.63	3.68 ± 0.24	6.57	0.36±0.29	4.53	2.24±0.18	5.35	0.50± 0.30	1.7	ND
Log T.V		7.O4		6.16	0.33±0.22	4.52	0.20±0.50	5.3	1.80± 0.20	2.26	ND

Key: IBSO = IC, ICM, IPM = Ini before sowing, control, cow manure- and poultry manure-treated respectively; subscripts 1 - 6 = 1st to 6th bi-weekly intervals; THBC = Total heterotrophic bacterial counts, AC, DBC, TFC, TCC and FCC = Actinomycetes, Diazotrophic bacterial, total fungal, total coliform and Fecal coliform counts respectively; cfug $^{-1}$ = colony forming units per gram of soil; ND = not detected.

3.3. Effects of Organic Fertilizers Application on Growth / Yield of Maize Plants

Higher growth and yield parameters (plant height, ear weight, seed weight, average number of grain per cob, harvest index) of the maize crops on the organic fertilizers amended plots than those on control plots were observed (Table 3)

Table 3: Effect of organic fertilizer application on growth/yield of maize plants

Site	Av. Plant Ht. (cm)	Av. LA (cm^2)	Av. No. of Leaves	Av. Stem girth(cm)	Av. LAI
			1st Cropping Season		
IC	79.30±0.01	521.33±0.70	7.20±1.10	7.01±0.10	6.12±0.04
IPM	266.10±0.15	811.8± 0. 34	12.28±0.40	9.00±0.10	51.73±0.03
ICM	274.32±0.20	819.62 ±10.6	10.83 ± 1.44	9.10±0.25	38.92±0.02
			2nd Cropping Season		
IC	67.40±0.01	314.02±17.22	6.50±1.00	6.21±0.09	3.46± 0.05
IPM	330.79±0.25	921.7 ±37.16	13.10 ±1.00	9.92±0.04	60.45±0.09
ICM	303.06±0.18	838.87±25.34	11.85±0.30	9.30±0.05	52.61±0.05

Table 3: Effect of organic fertilizer application on growth/yield of maize plants cont'd.

Site	Fresh Corn ear Mean Wt(g)	HS Wt(g)	Av.GNC^{-1}	Green yield (tonnes/acre)	Stover yield (Tonnes/acre)	H.I (GY/SY+GY)
			1st Cropping Season			
IC	95.10± 0.05	23.1±0.09	85.11±0.05(10)	0.31 ±0.13	0.59±0.03	0.34±0.24
IPM	221.04±0.07	43.12±0.06	501.05±0.30(4)	3.10±0.06	3.06±0.01	0.50 ±0.15
ICM	200.35 ±0.17	39.17±0.07	499.10±0.01(34)	2.16 ±0.01	1.86 ±0.02	0.54±0.50
			2nd Cropping Season			
IC	70.03±0.04	19.5 ±0.11	61.14±0.05(6)	0.18 ±0.06	0.70±0.22	0.20±0.01
IPM	263.11 ±0.08	46.00 ±0.10	608.05 ±0.09(43)	4.04 ±0.13	3.01±0.10	0.57±0.64
ICM	245.13±0.03	40.10±0.06	544.04±0.02(35)	3.61±0.04	2.01±0.23	0.64±0.09

Key: Av. = average, Ht. = height, LA=leaf area, No. = number, LAI = leaf area index, Wt=weight, HS=hundred seed, GNC-1=Grain number per cob, HI=Harvest index, GY=Grain yield, SY=stover yield, Numbers in bracket = Numbers of row ear-^{1}. Average of ten crops were used for each analysis except for seed weight and grain number per cob.

4.0 DISCUSSION

The soil pH was within optimum range of 5.5 to 7.0 for greatest microbial activity and availability of nutrients, also at lower or higher pH range plants symptoms of nutrient deficiency or toxicity appear as reported by (Traunfeld, 2013).

According to the classification of University of Uyo Consult Limited (2002) on Soil Potentials of Akwa Ibom State, the organic matter contents of the soils were rated slightly low, thus the soil may be said to be non-organic soils since the organic matter content was < 20% to a depth of 0 – 15cm as opined by Indian Ocean Agro LLC (2018). However, the treatment with organic fertilizers had significantly improved the organic matter contents of the wetland soil, similarly reported by Wang and Zhang (2016) who opined that treatment with organic fertilizers such as animal wastes can improve soil organic matter. Moisture content of soil is an important edaphic factor for dissolution of nutrients. Needelman (2013) observed that the amount of water with dissolved nutrients released to plant roots is a function of amount of moisture in the soil as well as the clay and silt components of the soil. The soil moisture content (M.C.) was higher in the treatment plots than in the control during both C.S. The range of M.C. of the treatment plots falls within the optimum content necessary for microbe population growth (Iken and Amusa, 2004).

Electrical conductivity (EC) is a measure of ionic concentrations in the soil and is, therefore, related to dissolved solutes (Oyem and Oyem, 2013). The E.C. values of the control were higher than those of the treatment plots. This result is also in agreement with earlier findings by Ngouajio and McGiffen Jr. (2002) but disagrees with those of Roy and Kashem (2014) who reported higher E.C. values for treated soils than control. The low EC in the study sites is also an indication that there will be no salinity hazard to both plants and microbes as opined by Iken and Amusa (2004). According to standards of required quantities of soluble salts in soils, the E.C. of the study sites are below the designated injurious salinity degree (1.61 – 2.40 mm hos cm^{-1}) as reported by

Gruttadauiro, Mattson and Petrovic *et al*. (2013). Higher EC in soils may cause plant drought stress as water will tend to be drawn away from tender plant roots to the nearby higher soluble salt areas in the soil. This may cause plant cells to dehydrate, stem to wilt and root may burn (Gruttadauiro, Mattson and Petrovic *et al*., 2013).

The soil pH of this present study was within optimum range of 5.5 to 7.0 for greatest microbial activity and availability of nutrients as reported by Traunfeld (2013). At lower or higher pH above this range (5.5 – 7.0) plants symptoms of nutrient deficiency or toxicity appear (Traunfeld, 2013). The total microbial counts of the soils are important microbiological parameters and indicate the fertility and the activity of the soil. Higher microbial abundance was observed in the treated plots than in the control and higher in 2nd C.S than in the 1st C.S. Previous investigations have also demonstrated that animal compost increase microbial abundance by increasing the carbon pool of the soil thus improving the living conditions for indigenous microbial populations (Zhen *et al*., 2014).This result corroborates with the findings of (Malik and Chauhan,2014). The microbial count values were statistically different at $P = 0.05$. Mandic *et al*. (2011) had similar observations of higher microbial load during the 2nd planting season than the 1st cropping season.

The different microbial groups isolated during this study are of some significance. The total heterotrophic bacteria are the primary decomposers of organic matter in soil, thus, release nutrients and enhance plant growth as well as soil health (Hoorman, 2016). The *Actinomycetes* improve soil structure, thus, aid in infiltration and aeration (Frac *et al*., 2018). The fungal group are capable of breaking down of all kinds of organic material, decomposing soil components and thereby, regulating the balance of carbon and nutrients (Zifcakova *et al* 2016). The total coliforms suggest presence of harmful pathogens, though they may not generally be harmful. However, coliforms can partake in natural decomposition of organic matter in the soil. They are important for soil health (Li and Liu, 2019). The diazotrophs are microorganisms which fix nitrogen to plant utilizable forms (Hirel and Krapp, 2021).

The results of the greater ear mean weight (Ear Wt) of plants on manured plots than on control during both C.S is consistent with the findings of Okoroafor *et al* (2013).The observed grain yields of maize (4.04 tonnes/acre), though lower than the standard real yield potential of 4.6 tha^{-1}(Pennington, 2016) had shown positive yield potential (grain yield greater than stover yield) in both treatment plots. This research indicates that organic fertilizers improve the maize growth & yield and that the PM gave higher effect than the CM and control. The Harvest Index (0.51 to 0.64) of the studied plants especially on the PM and CM is within the recommended range (0.50) (Pennington, 2016) and could be attributed to organic fertilizer application (Ion, Deu, Dumbrawa *et al*., 2015)

5. CONCLUSION AND RECOMMENDATION

A two year experiment at the Ini flood plain provided a unique opportunity for the assessment of effects of the utilization of organic fertilizers (C.D & P.D) on soil physicochemical properties, bioactivity and maize growth &yield. The one time application of the organic fertilizers resulted in higher beneficial microbial density as well as increased physico-chemical soil properties (e.g. TOC, organic matter) in 2nd C.S than the 1st. Thus, the utilization of stabilized organic fertilizers especially (poultry droppings) which showed (better effects) than cow dung on the wetland soil would enhance sustainable agriculture and the much needed food security.

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