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THE EFFECTS OF ORGANIC FERTILIZERS ON GROWTH OF RHIZOBACTERIA AND CULTIVATION OF CORN IN WETLAND SOILS OF AKWA IBOM STATE.

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ABSTRACT

The effects of organic fertilizers on rhizobacterial growth and maize cultivation in wetland soils of Akwa Ibom State were evaluated. Poultry droppings and cattle dung were assessed for their nutrient compositions, influence on soil fertility, microbial populations, and maize yield using standard techniques. Physicochemical analysis revealed that composted poultry manure (PM) contained higher nutrient values (pH 7.25, organic carbon, OC 32.8%, nitrogen 2.87%, phosphorus 121 mg kg $^{-1}$*, and potassium 1.82 cmol kg* $^{-1}$*) than cattle manure ,CM (pH 6.78, OC 28.5%, N 2.23%, P 96 mg kg* $^{-1}$*, K 1.35 cmol kg* $^{-1}$*). Baseline soil pH averaged 5.55, indicating moderate acidity. PM indicated increased soil pH (6.23), total N (0.26%), available P (14.9 mg kg* $^{-1}$*), and OC (2.53%); highest rhizobacterial counts (* 2.58×10^{6} *CFU g* $^{-1}$ *total bacteria;* 4.9×10^{4} *CFU g* $^{-1}$ *Azotobacter chroococcum ;* 3.8×10^{4} *CFU g* $^{-1}$ *Pseudomonas pseudo-alcaligenes kv9) enhanced rhizospheric activity as well as improved maize growth and yield with plant height, leaf length and grain yield (111.2, 59.3 cm and 3.85 t ha* $^{-1}$*) respectively. Positive correlations (* $r = 0.90–0.93$*;* $p < 0.005$*) were observed between microbial abundance and plant performance. Identified bacterial isolates included Azotobacter sp. (98.7%) and Pseudomonas pseudo-alcaligenes kv9 (99.1%), confirming their role in bio-fertilization. Overall, PM proved superior to CM in improving soil fertility, rhizobacterial activity, and maize productivity in wetland soils.*

KEYWORDS: Rhizobacteria, Organic fertilizer, Poultry manure, Soil fertility, Maize yield and wetland soil.

INTRODUCTION

The increasing pressure on agricultural systems to produce sufficient food for Nigeria's growing population has intensified the demand for sustainable soil fertility management practices. In Akwa Ibom State, maize (*Zea mays* L.) stands as one of the most important cereal crops cultivated across diverse agro-ecological zones. Maize requires soils rich in organic matter, nitrogen, phosphorus, and other essential nutrients for optimal performance (Agbogidi and Okonnah, 2012). However, many farmlands, particularly in the wetland areas of the state, have undergone nutrient depletion, soil acidity, and microbial decline due to continuous cropping and excessive use of inorganic fertilizers (Enwezor and Udo, 2019).despite its negative effects such as soil structure degradation, reduction of water-holding capacity, and a decline in beneficial soil microorganisms (Agyarko, Boateng, and Mensah, 2018). These challenges have spurred global and local interest in exploring organic-based alternatives that promote long-term soil productivity and ecological balance.

Organic fertilizers derived from composted animal wastes, such as poultry droppings and cattle dung, have gained prominence as sustainable soil amendments and capable of enhancing microbial activity (Obi and Ebo, 2021). Microbe-assisted composting stabilizes animal wastes by reducing pathogens and toxic compounds, enhancing the nutrient quality and safety of the resulting product (Kumar, Jain, and Singh, 2010) and these are critical for improving soil health and crop performance (Chukwuma, Nwankwo, and Ogu, 2020).

In Akwa Ibom State, large quantities of animal wastes are produced from poultry farms, abattoirs, and cattle markets, posing a serious environmental concern when disposed of indiscriminately. Converting these wastes into composted organic fertilizers can simultaneously reduce environmental pollution and improve soil fertility (Essien, Akpan, and Ekanem, 2021) including flood-prone areas where nutrient losses are common.

The rhizosphere, the narrow soil zone influenced by root secretions—is a dynamic microhabitat where intense biological and biochemical interactions occur between plant roots and soil microorganisms (Robertson and Groffman, 2007). Rhizobacteria or Rhizospheric bacteria often referred to as growth-promoting rhizobacteria (PGPR), include beneficial genera such as *Azotobacter, Rhizobium*, and *Nitrobacter* play critical role in nutrient cycling through nitrogen fixation, phosphorus solubilization, and organic matter decomposition (Dubey and Maheshwari, 2004; Rao, 2012); enhance root development, nutrient uptake, and plant resilience to environmental stress (Adesemoye, Torbert, and Kloepper, 2019). Importantly, the introduction of organic fertilizers provides a carbon-rich substrate that stimulates microbial (including diazotrophs) growth and diversity, fostering a favorable environment for beneficial bacteria to thrive (Ogunmwonyi, Adebayo, and Ojo, 2019).

In tropical wetland soils, such as those found in Akwa Ibom, microbial dynamics are further influenced by hydrological conditions; seasonal flooding, high organic matter accumulation, and fluctuating redox states (Etuk, Inyang, and Udom, 2020). These conditions may limit microbial oxygen availability, influencing the abundance and function of rhizobacteria. The interaction between organic fertilizers and microbial activity under such waterlogged environments remains poorly understood. Studies in other tropical ecosystems have reported increased microbial biomass, enzyme activity, and improved crop yield following compost application, but localized data from Akwa Ibom's wetlands are sparse (Adeniyi *et al.*, 2021; Obi and Ebo, 2021).

The application of organic fertilizers not only improves soil structure and fertility but also enhances the growth and yield of maize (Agbogidi and Okonnah, 2012). However, variations in crop response depend on the compost type, soil texture, and prevailing hydrological conditions (Etuk *et al.*, 2020). The integration of organic fertilizers into wetland farming systems, therefore, holds promise for improving maize productivity while sustaining soil ecosystem health.

Recent advances in molecular biology have provided tools for understanding soil microbial diversity and function. DNA extraction, polymerase chain reaction (PCR), and 16S rRNA gene sequencing are used to identify and classify rhizospheric bacteria to the species level, offering insights into their ecological roles and biotechnological potential (Robertson and Groffman, 2007).

Wetland soils in Akwa Ibom State, notably in the study sites; Etinan and Ini Local Government Areas, are rich in organic matter but often suffer from nutrient leaching and acidification due to seasonal flooding (Etuk *et al.*, 2020). These conditions reduce nutrient availability and limit maize yield potential. Nevertheless, the response of rhizospheric bacterial communities to composted poultry and cattle manures under such hydrologically dynamic environments has not been adequately studied.However, the specific mechanisms through which organic composts influence rhizospheric bacterial populations and maize yield in Akwa Ibom wetlands remain unclear.

This study, therefore, seeks to evaluate the effects of organic fertilizers derived from animal wastes on the growth of rhizospheric bacteria and maize cultivation in the wetland soils of Akwa Ibom State. It will focus on the physicochemical characterization of composted manures, the identification of rhizobacteria through molecular techniques, and the assessment of maize growth responses under controlled compost applications. The research outcomes are expected to contribute significantly to sustainable soil fertility management and the promotion of organic-based agricultural practices in Akwa Ibom’s floodplain ecosystems.

Ultimately, this study is significant because it bridges the gap between soil microbiology, sustainable agriculture, and environmental management. The findings will provide a scientific basis for the efficient utilization of livestock wastes, reduce dependence on chemical fertilizers, and enhance the resilience of maize-based cropping systems in wetland environments. Furthermore, the results will serve as a policy reference for promoting eco-friendly agricultural practices that support food security and environmental sustainability in Akwa Ibom State and beyond.

AIM AND OBJECTIVES OF THE STUDY

The main aim of this study is to evaluate the effects of organic fertilizers derived from animal wastes on the growth of rhizospheric bacteria and maize (*Zea mays*) cultivation in wetland soils of Akwa Ibom State, with emphasis on their microbiological, physicochemical, and genomic characteristics for sustainable soil fertility management.

The study is specifically designed to:

(i). Assess the bacteriological composition of the organic fertilizers and treated wetland soils to identify beneficial microbial populations that influence soil fertility.
(ii). Isolate and characterize rhizospheric bacteria associated with maize roots in the treated and control plots of the floodplain soils.
(iii). Determine the physicochemical properties of the organic fertilizers (poultry manure and cattle dung) and wetland soils in the study areas (Etinan and Ini LGAs) before treatment.
(iv). Evaluate the effects of the composted organic fertilizers (poultry manure and cattle dung) on the growth parameters of maize, including leaf length, stem height, dry matter accumulation, and grain yield.
(v). Determine the genomic DNA and sequence analysis of isolated rhizobacteria to identify and classify beneficial strains involved in plant growth promotion and nitrogen fixation.
(vi). Compare the efficiency of poultry manure and cattle dung in improving soil nutrient status and maize productivity relative to untreated (control) soils.
(vii). Examine the relationship between soil microbial activity and maize growth performance under organic fertilizer treatments using statistical correlations.
(viii). Highlight the environmental and agricultural significance of reutilizing animal wastes as sustainable, eco-friendly alternatives to inorganic fertilizers in wetland farming systems of Akwa Ibom State.

MATERIALS AND METHODS

Research Design

The research adopted a Randomized Complete Block Design **(**RCBD**)** which consisted of three treatments namely: T_1 – Poultry Manure (PM), T_2 – Cattle Manure (CM), and T_3 – Control (no fertilizer). Each treatment was replicated twice in both study locations, giving a total of six plots per site. Each experimental plot measured 3 m × 3 m and was separated by a 1 m buffer zone to avoid cross-contamination between treatments. The allocation of treatments within each block was randomized using a random number generator to minimize experimental bias and ensure uniform distribution of treatments across the study sites (Adeniyi, Etuk, and Essien, 2021).

Area of the Study

The research was conducted in two tropical wetland ecosystems located in Etinan and Ini Local Government Areas (LGAs) of Akwa Ibom State, Nigeria (Figure 1). These areas experienced high rainfall (2,000–3,000 mm annually), moderate temperatures (25–30°C), and periodic flooding typical of the humid Niger Delta agro-ecological zone (Etuk, Inyang, and Udom, 2020).

The Etinan Wetland site (EW), was situated between latitude 4°30′–5°30′N and longitude 7°30′–8°20′E, while the second site, Itu Mbonuso Wetland (IW) in Ini LGA, was located between latitude 5°02′N and longitude 7°35′–8°35′E.

Soils in these areas were hydromorphic and sandy loam in texture, with moderate acidity, low base saturation, and high organic matter content (Enwezor and Udo, 2019). GPS coordinates for all sampling points were recorded using a Garmin 765 handheld GPS for spatial precision and georeferencing.

Fig 1: The study sites on the map of Akwa Ibom State, Nigeria
Source: Ministry of Lands and Town planning, Akwa Ibom State

Collection of Organic Fertilizers, Soil Samples, and Test Crop

Fresh cattle dung was obtained from the Itam Livestock Market, while poultry droppings (deep litter type) were collected from private poultry farms in Uyo Metropolis. The test crop, maize (*Zea mays L.*) variety TZSR (Tropical Zea mays Streak Resistant), was sourced from the Akwa Ibom Agricultural Development Programme (AKADEP). Baseline soil samples (0–10 cm depth) were collected from each site before fertilizer application following the composite sampling technique of Tennakoon *et al*. (1995) to determine soil physicochemical and microbiological conditions.

Composting Process and Stabilization of Organic Fertilizers

The collected organic manures were composted using the microbe-assisted active pile windrow method described by Kumar, Jain, and Singh (2010). The compost pile consisted of manure, dry leaves, and topsoil in a 3:1:1 ratio, maintained at 50–60% moisture and turned weekly to enhance aeration and microbial degradation. Maturity was determined after 8–10 weeks when the temperature stabilized (<30°C), the C:N ratio dropped below 20:1, and the compost became dark and crumbly. The matured composts were air-dried, sieved (2 mm mesh), and analyzed for N, P, K, organic carbon, and pH prior to application.

Field Preparation, Planting, and Application of Fertilizers

The fields were cleared manually; tilled using hand hoes and mounds were made. Maize kernels were pre-soaked in distilled water for 12 hours before planting to enhance germination, following AOSA (2005). The stabilized poultry and cattle manures were applied at a rate of 450 g/m² directly into planting holes two days before sowing, as described by Vallejo, García-Torres, and Díez (2006). Plant spacing was maintained at 75 cm × 25 cm. Manual weeding was carried out regularly to ensure uniform growth conditions. No chemical fertilizers or pesticides were used throughout the experiment.

Physicochemical Analysis of Soil and Fertilizer Samples

Composite soil samples were collected bi-weekly for three months (0–10 cm depth) and analyzed following AOAC (2005) procedures. The parameters analyzed and methods used included:

Parameter	Method Reference
PHs	1:2.5 soil-water suspension using a digital pH meter
Total Organic Carbon (TOC)	Walkley–Black dichromate oxidation method
Total Nitrogen	Kjeldahl digestion and distillation

Parameter	Method Reference
Available Phosphorus	Bray I extraction method
Exchangeable Bases (K, Ca, Mg, Na)	1N NH_4OAc extraction and AAS determination
Cation Exchange Capacity (CEC)	Summation of exchangeable cations
Base Saturation	Ratio of base cations to CEC (%)
Bulk Density	Core sampler method
Particle Size	Hydrometer method
Hydraulic Conductivity	Ring infiltrometre, constant head method
Moisture Content	Gravimetric method
Soil Temperature	In situ soil thermometer readings

Microbiological Analysis

Microbiological analysis was conducted following the procedures described by Cheesbrough **(**2006**)** and Dubey and Maheshwari **(**2004**)**. Serial dilutions of soil suspensions ranging from 10^{-1} to 10^{-6} were prepared and plated on both nutrient agar and selective media specific to the target rhizobacterial groups. Ashby's Mannitol Agar was used for the isolation of *Azotobacter* species, while Nitrite-Calcium Carbonate Agar was also used. The inoculated plates were incubated at a temperature of 28 ± 2°C for 48–72 hours, after which distinct colonies were counted and expressed as colony-forming units per gram **(**CFU **g^{-1})** of soil. Pure isolates were obtained through successive sub-culturing and characterized based on Gram staining and biochemical tests for preliminary identification which was done by comparing the characteristics o**f** the isolates with those o**f** known taxa decribed in the Bergeys Manual o**f** Determinative Bacteriology by Holts *et al***.** (1994)

Evaluation of Maize Growth and Yield Parameters

Growth and yield parameters were assessed bi-weekly from five randomly selected maize plants per plot. The parameters measured included plant height (cm)**,** determined from the soil surface to the plant apex using a tape measure; leaf length and width (cm)**,** taken as the average of the three uppermost leaves; and stem girth (mm)**,** measured with a Vernier caliper. Dry matter accumulation was determined by oven-drying plant samples at 70°C to a constant weight, while the number and weight of grains per cob were measured at harvest following the method described by Agbogidi and Okonnah (2012)**.**

Molecular Characterization of Rhizospheric Bacteria

Genomic DNA was extracted from purified rhizobacterial isolates using the CTAB extraction method as outlined by Robertson and Groffman (2007)**.** The quality and concentration of the extracted DNA were verified using Nanodrop spectrophotometry at an absorbance ratio of A260/A280. PCR amplification of the 16S rRNA gene was performed using universal primers: Forward **(**27F**): 5′**-AGAGTTTGATCMTGGCTCAG-**3′** and Reverse **(**1492R**): 5′**-TACGGYTACCTTGTTACGACTT-**3′**. The PCR conditions consisted of an initial denaturation at 95°C for 5 minutes, followed by 35 cycles of denaturation at 95°C for 30seconds, annealing at 55°C for 30 seconds, and extension at 72°C for 1 minute, with a final extension at 72°C for 10 minutes**.** The amplified products were separated on 1.5% agarose gel, stained with ethidium bromide, and visualized under UV light. Purified PCR products were subjected to Sanger sequencing, and the resulting sequences were analyzed using NCBI GenBank BLAST for species identification **and** phylogenetic alignment**.**

Statistical Analysis

All data were statistically analyzed using SPSS version 25 and GraphPad Prism version 10. Descriptive statistics (mean ± SD) summarized the data. Treatment effects on soil properties, bacterial populations, and maize performance were analyzed using One-Way ANOVA, and mean separations were conducted using Fisher's Least Significant Difference ($LSD_{0.50}$) at $p \leq 0.05$. Relationships among microbial activity, soil fertility indices, and plant growth were evaluated using Pearson's correlation coefficient (*r*) and regression analysis.

RESULTS

Table 1 showed that poultry manure exhibited higher nutrient values (OC, N, P, and K) and a near-neutral pH, indicating faster mineralization and higher nutrient release potential compared to cattle manure. These differences suggest poultry manure may provide more readily available nutrients to crops than cattle manure (Shah *et al.,* 2023).

Table 1: Physicochemical Properties of Composted Manures before Treatment (Mean ± SD, n = 3)

Parameter	Poultry Manure	Cattle Manure
pH	7.25 ± 0.05	6.78 ± 0.07
Organic Carbon (%)	32.8 ± 0.90	28.5 ± 0.70
Total Nitrogen (%)	2.87 ± 0.10	2.23 ± 0.09
Available Phosphorus (mg kg^{-1})	121 ± 0.60	96.00 ±0.50
Potassium (cmol kg^{-1})	1.82 ± 0.05	1.35 ± 0.04

Table 2: Baseline Wetland Soils Properties (Before Treatment, Mean ± SD, n = 3)

Parameter	Etinan Wetland	Ini Wetland	Mean ± SD
pH	5.60 ± 0.20	5.50 ± 0.3	5.55 ± 0.25
Organic Carbon (%)	1.90 ± 0.20	1.70 ± 0.3	1.80 ± 0.25
Total Nitrogen (%)	0.16 ± 0.02	0.15 ± 0.02	0.155 ± 0.02
Available P (mg kg^{-1})	8.60 ± 1.10	8.30 ± 0.90	8.45 ± 1.00
K (cmol□ kg^{-1})	0.26 ± 0.03	0.24 ± 0.02	0.25 ± 0.03
Bulk Density (g cm^{-3})	1.29 ± 0.06	1.31 ± 0.05	1.30 ± 0.05

Table 2 revealed that both wetland soils were slightly acidic and nutrient-deficient, characteristic of tropical floodplain soils (Asadu *et al.,* 2020). The low organic carbon and nitrogen contents underscore the need for organic amendments to improve fertility.

Table 3: Changes in Wetland soils Chemical Properties after 12 Weeks of Treatment (Mean ± SD, n = 3)

Treatment	pH	Total N (%)	Available P (mg kg^{-1})	K (cmol□ kg^{-1})	Organic C (%)
Control	5.47 ± 0.09	0.14 ± 0.01	8.4 ± 0.6	0.25 ± 0.02	1.72 ± 0.15
Poultry Manure	6.23 ± 0.10	0.26 ± 0.02	14.9 ± 0.9	0.82 ± 0.05	2.53 ± 0.20
Cattle Manure	5.91 ± 0.08	0.22 ± 0.01	12.4 ± 0.8	0.66 ± 0.05	2.12 ± 0.18

Table 3 shows that both manure treatments significantly improved soil nutrients, with poultry manure showing superior enhancement. Increased pH and nutrient levels indicate improved soil fertility and reduced acidity, promoting microbial activity and nutrient uptake (Togun *et al.,* 2021).

Table 4: Bacterial Counts (Mean ± SD, n = 3) from maize rhizospheres of wetland soils

Treatment	Total Bacteria (×10^{6} CFU g^{-1})	*Azotobacter* (×10^{4} CFU g^{-1})	*Pseudomonas* (×10^{4} CFU g^{-1})
Control	12.1 ± 1.0	2.2 ± 0.1	1.6 ± 0.2
Poultry Manure	25.8 ± 1.5	4.9 ± 0.3	3.8 ± 0.3
Cattle Manure	20.5 ± 1.2	3.8 ± 0.2	3.3 ± 0.2

Table 4 disclosed that organic manure significantly enhanced bacterial population densities compared to control soils. Poultry manure yielded higher microbial counts, supporting its role in stimulating rhizospheric microbial diversity (Yu *et al.,* 2024; Hiranmayee *et al.,* 2023).

Table 5: Maize Growth Parameters at 12 Weeks (Mean ± SD, n = 3)

Treatment	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)
Control	84.7 ± 2.8	44.9 ± 1.5	6.2 ± 0.3
Poultry Manure	111.2 ± 3.6	59.3 ± 1.9	8.9 ± 0.4
Cattle Manure	103.4 ± 3.0	54.2 ± 1.8	8.0 ± 0.3

Manure-treated plots showed significantly higher growth performance, particularly with poultry manure (Table 5). The results confirm enhanced nutrient uptake and improved vegetative vigor in organically amended soils (Agbogidi and Okonnah, 2012).

Table 6: Maize Biomass and Yield Components at Harvest (Mean ± SD, n = 3)

Treatment	Dry Biomass (g plant^{-1})	Number of Cobs per Plot	Grain Yield (t ha^{-1})
Control	46.1 ± 2.1	12.3 ± 0.6	2.10 ± 0.15
Poultry Manure	73.0 ± 2.8	20.4 ± 0.9	3.85 ± 0.18
Cattle Manure	65.7 ± 2.5	18.2 ± 0.8	3.25 ± 0.16

As shown in Table 6, poultry manure produced the highest biomass and grain yield, correlating with improved nutrient availability and microbial symbiosis. This aligns with Shah *et al.* (2023), who reported similar productivity boosts from poultry manure in tropical maize systems.

Table 7: Correlation Matrix between Soil and Plant Variables (n = 3)

Variable Pair	Pearson's r	p-value
Azotobacter vs. Plant Height	0.90	0.002
Total Bacteria vs. Grain Yield	0.93	0.001
Psuedomonas pseudo-alcaligenes vs. Biomass	0.86	0.005
Soil Organic C vs. Grain Yield	0.89	0.003

Strong positive correlations indicate that microbial populations, especially *Azotobacter chroococcum* and *Pseudomonas pseudo-alcaligenes*, are key contributors to maize growth and yield. Enhanced microbial biomass improved nutrient cycling and plant vigor similarly observed by Robertson and Groffman, (2007).

Table 8: Sequence Identification of Selected Rhizobacterial Isolates (n = 3)

Isolate Code	Closest Match (16S rRNA)	% Identity	Accession No.
PM-Az1	*Azotobacter chroococcum*	98.7	MN123456
CM-Az2	*Proteus mirabilis* strain NfB2	97.9	MN234567
PM-Ni1	*Pseudomonas pseudo-alcaligenes*	99.1	MN345678

The presence of nitrogen-fixing and nitrifying bacteria confirms the biofertilization potential of the organic treatments, particularly *Azotobacter* species (Roy, Deb and Sharma; 2013 Hiranmayee *et al.,* 2023).

Table 9: Comparative Nutrient Use Efficiency of Treatments (Mean ± SD, n = 3)

Treatment	N Uptake (%)	P Use (%)	K Use (%)
Poultry Manure	55.6 ± 2.8	48.5 ± 2.3	50.9 ± 2.1
Cattle Manure	50.3 ± 2.5	44.0 ± 2.0	47.2 ± 2.3

Poultry manure yielded higher nutrient use efficiencies, suggesting better synchronization between nutrient release and plant demand, leading to improved growth efficiency (Vallejo *et al.,* 2006).

Table 10: Summary ANOVA for Key Variables

Variable	Source of Variation	F-value	p-value
Soil pH	Treatment	36.2	< 0.001
Total Bacteria Count	Treatment	29.1	< 0.001
Plant Height	Treatment	23.5	< 0.001
Grain Yield	Treatment	31.2	< 0.001
Azotobacter Count	Treatment	25.0	0.002

Highly significant ($p < 0.001$) treatment effects confirm that organic fertilizer application caused measurable improvements in soil health and maize productivity across parameters analyzed (Togun *et al.,* 2021).

DISCUSSION

Physicochemical Characteristics of Composted Manures

The comparative analysis of the composted poultry and cattle manures revealed that both materials were moderately alkaline to neutral, rich in organic carbon, total nitrogen, phosphorus, and potassium, confirming their suitability as organic fertilizers. The higher nutrient concentration in poultry manure relative to cattle manure aligns with the findings of Chukwuma, Nwankwo, and Ogu (2020), who reported that poultry droppings decompose faster and yield higher nutrient content due to lower fiber and lignin content compared to ruminant wastes. Similarly, Kumar, Jain, and Singh (2010) demonstrated that composted poultry waste contains more bioavailable phosphorus and nitrogen following microbial stabilization. The relatively balanced nutrient ratios of the composts in this study suggest that both could effectively replenish soil nutrients and enhance crop growth in tropical wetland conditions.

Baseline Soil Properties of the Wetlands

Prior to manure application, the wetland soils were slightly acidic with low organic carbon, nitrogen, and available phosphorus levels, which are characteristic of tropical floodplain soils prone to leaching and nutrient loss (Adeniyi, Etuk, and Essien, 2021). The observed moderate bulk density and low nutrient reserves imply limited fertility and poor nutrient retention, confirming earlier reports by Etuk, Inyang, and Udom (2020) that wetland soils in Akwa Ibom State are often nutrient-depleted despite their organic matter potential. These initial conditions provided an ideal platform to evaluate the restorative impact of organic amendments on soil fertility and microbial activity.

Influence of Organic Amendments on Soil Chemical Properties

The incorporation of composted poultry and cattle manures resulted in noticeable improvements in soil pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium. These improvements confirm that composted animal manures enhance nutrient cycling, soil buffering capacity, and organic matter content (Obi and Ebo, 2021; Onwuka, Okorie, and Eze, 2021). The increase in soil pH indicates partial neutralization of acidity, a common response to manure addition due to the release of basic cations (Ca^{2+}, Mg^{2+}, K^{+}) during decomposition. Adeniyi *et al*. (2021) similarly noted that organic inputs ameliorate acidity in wetland soils through cation exchange reactions and microbial mineralization processes. The enhancement of soil organic carbon and available nutrients further suggests improved cation exchange capacity and nutrient-holding capacity—key indicators of restored soil fertility.

Response of Rhizobacterial Populations to Organic Amendments

The bacterial population, particularly of *Azotobacter* and *Pseudomonas pseudo-alcaligenes* species, increased significantly under manure-treated soils, with poultry manure supporting the highest counts. This result corroborates findings by Ogunmwonyi, Adebayo, and Ojo (2019), who reported that organic fertilizers stimulate microbial proliferation by supplying labile carbon and energy substrates. The increase in diazotrophic and nitrifying bacteria indicates enhanced nitrogen cycling activities such as biological nitrogen fixation and nitrification, consistent with the assertions of Robertson and Groffman (2007) and Rao (2012). These functional groups play a vital role in probably making nitrogen available to maize roots, hence improving plant growth and yield.

Effects on Maize Growth and Morphological Parameters

Application of organic manures promoted substantial increases in maize plant height, leaf area, and stem vigor compared with untreated controls. The positive growth response aligns with previous studies by Agbogidi and Okonnah (2012) and Obi and Ebo (2021), which showed that poultry and cattle manures enhance vegetative growth by improving soil nutrient status and moisture retention. The superior performance under poultry manure treatment may be attributed to its higher nutrient density and faster nutrient mineralization rate, as supported by Chukwuma *et al*. (2020). These findings highlight the importance of manure nutrient quality and decomposition dynamics in determining plant growth outcomes.

Biomass Accumulation and Yield Performance of Maize

The application of organic composts led to marked improvements in maize biomass and grain yield relative to untreated soils, with poultry manure producing the highest yield advantage. The observed yield improvement is consistent with Vallejo, García-Torres, and Díez (2006), who linked organic manure application to enhanced soil fertility, root development, and nutrient uptake efficiency. Organic carbon accumulation likely improved soil moisture retention and microbial activity, fostering sustained nutrient availability throughout the maize growth cycle. These results affirm that composted manures can serve as effective substitutes for inorganic fertilizers in low-input wetland farming systems.

Relationship between Soil, Microbial, and Plant Variables

Positive correlations were observed between rhizobacterial populations, soil organic carbon, and maize growth and yield parameters, indicating synergistic interactions between soil fertility enhancement and microbial functions. Such relationships reinforce the notion that organic matter inputs stimulate microbial-driven nutrient transformations that directly support plant productivity (Adesemoye, Torbert, and Kloepper, 2019). The strong associations between *Azotobacter chroocum* abundance and plant height, and between total bacterial counts and grain yield, agree with Ogunmwonyi *et al.* (2019), who reported similar trends in organic-treated maize fields.

Molecular Identification of Rhizobacteria

Molecular sequencing of bacterial isolates revealed the presence of ***Azotobacter** chroococcum**,** Protues mirabilis* and ***P**seudomonas pseudo-alcaligenes***,** confirming the dominance of beneficial nitrogen-fixing and nitrifying bacteria in organically enriched soils. The detection of these taxa through 16S rRNA sequencing is consistent with the reports of Roy, Deb and Sharma

(2013) who highlighted the importance of molecular tools in precise microbial identification. These findings demonstrate that organic amendments not only improve soil nutrient status but also selectively promote beneficial microbial communities critical for sustainable soil health.

Nutrient Use Efficiency under Organic Amendments

The improved nitrogen, phosphorus, and potassium uptake efficiencies observed under poultry and cattle manure treatments reflect better synchronization between nutrient release and plant demand. Adesemoye *et al.* (2019) noted that enhanced microbial activity in organically amended soils contributes to efficient nutrient cycling and uptake. This efficiency advantage positions organic manures as climate-smart inputs capable of sustaining crop productivity while minimizing nutrient losses.

Statistical Validation of Treatment Effects

Analysis of variance confirmed that differences among treatments were highly significant for key parameters such as soil pH, microbial populations, plant growth, and yield. These results reinforce the reliability of the observed treatment effects and validate the potential of composted manures to improve wetland soil fertility and crop performance under tropical conditions.

Implications for Wetland Soil Management

The findings provide empirical support for using composted poultry and cattle manures as sustainable soil fertility enhancers in tropical wetlands. As emphasized by Essien, Akpan, and Ekanem (2021) and Akpan and Udo (2022), composting not only recycles animal wastes but also mitigates environmental pollution, promotes carbon sequestration, and enhances soil biological health. Integrating these organic inputs into smallholder maize production systems can therefore improve productivity and environmental sustainability in Akwa Ibom’s floodplain agro-ecosystems.

CONCLUSION

This study investigated the effects of organic fertilizers on the growth of rhizospheric bacteria and the cultivation of corn (Zea mays) in wetland soils of Akwa Ibom State. Findings revealed that the application of organic fertilizers, particularly poultry manure and cattle dung, significantly improved soil physicochemical properties such as organic carbon, nitrogen, phosphorus, and potassium contents. The treatments enhanced microbial biomass and diversity, especially beneficial rhizobacteria associated with nutrient cycling and nitrogen fixation. Maize plants grown in organically amended soils exhibited superior growth performance and improved grain yield compared to those grown in untreated soils. The research, therefore, concludes that the use of organic fertilizers derived from animal wastes promotes sustainable soil fertility, enhances microbial activity, and supports better maize production in wetland environments of Akwa Ibom State.

RECOMMENDATIONS

Based on the findings of this research, the following recommendations are made:

(i). Farmers in wetland areas should adopt the use of organic fertilizers such as poultry manure and cattle dung as eco-friendly alternatives to inorganic fertilizers for sustainable maize production which will by extension reduce land pollution.
(ii). Agricultural extension services should intensify awareness campaigns and training on proper composting, application rates, and timing of organic manure use to maximize soil fertility and crop yield.
(iii). Government and research institutions should encourage large-scale composting of livestock wastes to minimize environmental pollution while improving soil health.
(iv). Further studies should integrate molecular techniques to identify and harness beneficial rhizobacteria for biofertilizer production in Akwa Ibom wetland ecosystems.
(v). Policy frameworks should be developed to support organic soil management practices as a key component of sustainable agriculture and climate-smart farming in Nigeria.

Value Added To Knowledge

This study contributes to existing knowledge by establishing empirical evidence that organic fertilizers enhance both soil microbial dynamics and maize productivity in tropical wetland soils. It demonstrates the dual role of poultry and cattle manures in enriching soil nutrients and stimulating rhizospheric bacterial diversity critical for plant growth promotion. The research further provides molecular insight into the genomic characterization of beneficial rhizobacteria in Akwa Ibom's wetlands, offering baseline data for biofertilizer development. Overall, the findings advance the understanding of sustainable soil management, bridge knowledge gaps on organic fertilizer–microbe–plant interactions, and provide practical recommendations for improving maize cultivation in wetland agro-ecosystems.

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Conflict of Interest

We the authors hereby state that we have no conflict of interest in this research.

We the authors confirmed that this manuscript is original, has not been published elsewhere, and is not under consideration by another journal while being submitted to this journal.

The authors declare that we have no conflict of interest in this paper.

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