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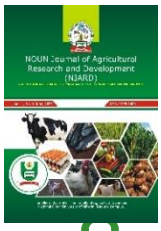

Original Article

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Influence of Different Organic Manures Used as Soil Amendments on the Yield and Potassium Uptake of Maize (Zea mays L.) at NOUN Research Farm, Rigachikun, Kaduna State, Nigeria

*Musa A., Shani B. B. & Petu-Ibikunle A.M.

Department of Crop and soil Science, Faculty of Agricultural Sciences
National Open University of Nigeria
**Corresponding author: email: aliyugusau2020@gmail.com*

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ABSTRACT

Declining soil fertility and limited access to synthetic fertilizers in Nigeria's Northern Guinea Savanna necessitate sustainable alternatives for soil nutrient management. This study evaluated the effects of various animal- and plant-based organic manures on maize (Zea mays L.) yield and potassium (K) uptake. Field trials were conducted during the 2022 and 2023 cropping seasons at the National Open University of Nigeria (NOUN) Research Farm, Rigachikun, Kaduna State. Treatments included poultry droppings (POD), cow dung (COD), pig waste (PIW), groundnut shells (GNS), millet husks (MIL), rice mill waste (RMW), and a control (no manure), all applied at 10 t/ha. A randomized complete block design (RCBD) with four replications was used. Data on grain yield and K uptake were subjected to analysis of variance (ANOVA), and means were separated using the least significant difference (LSD) at $p \leq 0.05$. Results showed significant yield differences among treatments. In 2022, the highest grain yield (7.90 t/ha) was from poultry droppings, while in 2023, pig waste (5.00 t/ha) outperformed other treatments. Potassium uptake followed a similar trend, with cow dung recording the highest values (33.53 kg/ha in 2022 and 29.28 kg/ha in 2023). The findings demonstrate that both animal- and plant-derived manures improve maize yield and K uptake, with poultry droppings and pig waste being the most effective. These results highlight the potential of organic manures as low-cost, sustainable inputs for restoring soil fertility and enhancing food production in the Northern Guinea Savanna.

Keywords: *Maize yield, organic manures, potassium uptake, poultry droppings, cow dung, pig waste, groundnut shell*

Introduction

The sustainable management of soil fertility is crucial for sustaining food production and safeguarding natural resources, particularly in sub-Saharan Africa, where agricultural intensification faces increasing limitations due to land degradation. Maize (Zea mays L.), a key staple crop in Nigeria and throughout the region, is vital for ensuring food security because of its broad adaptability, high energy content, and versatility in both human and animal diets.

The decline in soil fertility, caused by ongoing cultivation, erosion, and nutrient depletion, remains a significant challenge in the Northern Guinea Savanna of Nigeria. Alongside the escalating costs and environmental issues linked to synthetic fertilizers, there is an urgent necessity to investigate affordable, locally sourced, and environmentally friendly alternatives to rejuvenate soil productivity. Organic manures present a practical solution, especially for smallholder farmers who have limited access to chemical inputs (Pieri, 1989; Wezel & Rath, 2001).

Organic manures from animal origins—such as poultry waste, cow dung, and pig manure—are abundant in easily decomposable organic matter, which fosters microbial activity and boosts nutrient mineralization, particularly nitrogen (N), phosphorus (P), and potassium (K). Conversely, plant-based residues like groundnut shells, millet husks, and rice mill byproducts contribute

more inert organic matter, enhancing soil structure, aeration, and water retention over time (Parr et al., 1989; Adebiyi et al., 2004).

Potassium (K) is essential for crop growth, playing a vital role in enzyme activation, water use efficiency, carbohydrate movement, photosynthesis, and grain development (Khatir et al., 2013). A deficiency of potassium in maize can lead to poor root development, delayed maturation, reduced grain yield, and heightened vulnerability to biotic and abiotic stresses. Thus, assessing K uptake is crucial for understanding the nutrient contribution and effectiveness of organic manure sources.

Recent research has indicated that organic inputs can greatly enhance soil fertility and crop performance. For example, Okoroafor et al. (2013) found that poultry manure significantly boosted maize yield compared to inorganic fertilizers in field conditions, while da Costa et al. (2015) and Kashe et al. (2007) noted substantial increases in cereal productivity from manure and mulching practices. These results highlight the importance of advocating for organic materials as part of integrated soil fertility management (ICRISAT, 2016; Aune et al., 2007).

Despite the growing evidence in favor of organic manures, there is a lack of research comparing the relative effectiveness of various organic sources on maize productivity and potassium dynamics in the Northern Guinea Savanna agro-ecology. Identifying which amendments optimize yield and nutrient uptake will assist farmers in making informed, cost-effective decisions.

This study, therefore, seeks to assess the impacts of selected animal- and plant-based organic manures on maize yield and potassium uptake within the agro-ecological context of Rigachikun, Kaduna State, Nigeria.

Materials and Methods

This research was carried out during the 2022 and 2023 growing seasons at the Research Farm of the National Open University of Nigeria (NOUN), located in Rigachikun, Kaduna State. The location is situated within the Northern Guinea Savanna agro-ecological region of Nigeria (Latitude: 10°39′N; Longitude: 7°26′E; Elevation: approximately 650 m above sea level). The total area utilized for the experiment was 41 m × 23 m (around 942 m²), with specific plots designated for the trial execution.

Experimental Design and Treatments

The study was arranged in a randomized complete block design (RCBD) featuring four replications. Each plot measured 5 m × 5 m (25 m²), with 1 m pathways separating the plots and blocks. The seven treatments included six types of organic manures—cow dung (COD), poultry manure (POD), pig manure (PIW), groundnut husks (GNS), millet husks (MIL), and rice mill by-products (RMW)—alongside a control (no amendments). All organic manure treatments were uniformly applied at a rate of 10 tonnes per hectare (t ha^{-1}), two weeks prior to sowing to facilitate mineralization and incorporation into the soil using hand hoes.

Agronomic Practices

Maize seeds of the SAMMAZ 29 variety were obtained from the Institute for Agricultural Research (IAR) at Ahmadu Bello University, Zaria. The seeds were planted at a spacing of 1.0 m × 0.3 m (row × intra-row), with two seeds per hole, which were later thinned to one plant per stand at two weeks after planting. Manual weeding was conducted at 4 and 8 weeks after planting (WAP). In particular, prevalent weeds such as Panicum maximum were manually eliminated.

Soil Collection and Examination

Soil samples were gathered prior to manure application and following harvest from each individual plot utilizing a soil auger at a depth of 0–20 cm. Composite samples for each plot were air-dried, ground, and sifted through a 2-mm mesh for laboratory evaluation.

Soil chemical properties were analyzed to establish baseline fertility conditions prior to treatment application. The soil pH was determined in a 1:2.5 soil-to-water suspension using a calibrated pH meter, following the standard procedure outlined by Thomas (1996). Organic carbon content was measured using the Walkley–Black wet oxidation method (Walkley & Black, 1934), which provides a reliable estimate of soil organic matter. Total nitrogen was quantified using the Kjeldahl digestion technique (Bremner, 1965), suitable for assessing nitrogen availability in cultivated soils. Available phosphorus was extracted using the Bray-1 method, as described by Bray and Kurtz (1945), a technique appropriate for the acidic soils typical of the Northern Guinea Savanna. Exchangeable potassium was extracted with 1 M ammonium acetate and determined using a flame photometer, following the method of Chapman (1965).

These baseline values table1 were used to interpret the nutrient response of maize to the applied organic manures. The initial soil pH, organic carbon, nitrogen, phosphorus, and potassium levels informed the understanding of soil fertility limitations and the potential responsiveness of maize to nutrient amendments. For instance, low organic carbon and nitrogen content highlighted the importance of organic amendments in restoring soil fertility, while available P and exchangeable K levels influenced nutrient uptake efficiency. The variations observed in maize yield and potassium uptake across treatments were interpreted in the context of these initial soil conditions, underscoring the contribution of organic manures in amending specific deficiencies and enhancing nutrient cycling in the study area.

Biomass and Yield Assessment

At the time of harvest, four maize plants were randomly chosen from the central rows of each plot for biometric analysis. The fresh weights of both marketable and unmarketable ears were recorded with a digital scale

(±0.01 kg accuracy). Subsamples were dried in an oven at 60–65°C until reaching a constant weight to assess dry matter yield. Total grain yield was extrapolated to tons per hectare.

Potassium Uptake Assessment

For potassium uptake analysis, dried plant samples (grain + stover) were ground and digested via wet acid digestion (HNO_3:$HClO_4$). The potassium content in the digests was determined using a flame photometer, and uptake was calculated by multiplying tissue potassium concentration by dry biomass yield.

Statistical Evaluation

All data underwent analysis of variance (ANOVA) utilizing IBM SPSS Statistics version 26. In cases where treatment effects were significant at $p \leq 0.05$, means were separated using the Least Significant Difference (LSD) test. Results are displayed with appropriate units and standard statistical symbols.

Results and Discussion

The use of organic fertilizers significantly influenced ($p \leq 0.05$) the harvestable weight of maize grain in both the years 2022 and 2023 (Table 1). In 2022, pig manure (7.90 t/ha), poultry waste (6.07 t/ha), and cow manure (6.08 t/ha) resulted in notably higher harvestable grain yields compared to other treatments and the control group. These outcomes are likely as a result of the abundant nutrients and microbial activity stemming from the rapid decomposition of animal manures. In 2023, pig manure again yielded the highest harvestable grain weight (4.68 t/ha), followed closely by poultry waste and rice mill byproducts. The observed differences between the years may be linked to variations in climate or the dynamics of nutrient release. These findings suggest that organic fertilizers, such as pig manure and poultry waste, which are rich in easily mineralizable organic matter, can improve early nutrient availability, thereby facilitating kernel development and grain production.

Table 1: Pre-Planting Soil Physico-Chemical Properties and Their Impacts on Maize Production at NOUN Research Farm

Soil Parameter	Value Obtained	Value Estimated	Units
pH (1:2.5 H_2O)	5.8	6.3	pH units
Organic Carbon (%)	0.85	1.2	%
Total Nitrogen (%)	0.09	0.12	%
Available Phosphorus (mg/kg)	7.4	8.5	mg/kg
Exchangeable Potassium (cmol/kg)	0.23	0.15	cmol/kg

Table 2: Effect of Organic Manures on Marketable Grain Yield of Maize (t ha^{-1})

Treatment	2022 (t ha^{-1})	2023 (t ha^{-1})	Mean (t ha^{-1})
Groundnut Shell (GNS)	3.73	3.02	3.37
Millet Husk (MIL)	2.30	2.58	2.44
Cow Dung (COD)	6.08	3.25	4.67
Poultry Droppings (POD)	6.07	4.58	5.33
Pig Waste (PIW)	7.90	4.68	6.29
Rice Mill Waste (RMW)	4.00	4.33	4.17
LSD (0.05)	2.46	2.32	—

Table 3: Effect of Organic Manures on Unmarketable Grain Yield of Maize (t ha^{-1})

Treatment	2022 (t ha^{-1})	2023 (t ha^{-1})	Mean (t ha^{-1})
Groundnut Shell (GNS)	0.58	0.83	0.71
Millet Husk (MIL)	0.33	0.66	0.50
Cow Dung (COD)	0.98	0.66	0.82
Poultry Droppings (POD)	0.77	0.92	0.84
Pig Waste (PIW)	0.80	0.83	0.82
Rice Mill Waste (RMW)	0.75	0.58	0.67
LSD (0.05)	0.55	0.55	—

Impact on Unmarketable Grain Production

No notable differences were observed among treatments regarding unmarketable grain weight throughout both seasons (Table 2). This suggests that the type of organic manure had a limited effect on aspects like pest or disease damage, as well as irregular ear formation.

As demonstrated in Table 3, the application of organic fertilizers notably increased total maize grain yield in both 2022 and 2023. Pig manure consistently achieved the highest overall yield (8.70 t/ha in 2022; 5.52 t/ha in 2023). The next best results were seen with poultry manure and cow dung.

These findings indicate that animal manures, particularly pig manure, provide a well-rounded supply of nutrients in forms that plants can readily utilize, thereby promoting both vegetative and reproductive growth more effectively than residues derived from plants.

Table 4**:** Effect of Organic Manures on Total Maize Grain Yield (t ha⁻¹)

Treatment	2022 (t ha⁻¹)	2023 (t ha⁻¹)	Mean (t ha⁻¹)
Groundnut Shell (GNS)	4.32	3.85	4.08
Millet Husk (MIL)	2.63	3.27	2.94
Cow Dung (COD)	7.07	3.92	5.49
Poultry Droppings (POD)	6.83	5.50	6.17
Pig Waste (PIW)	8.70	5.52	7.11
Rice Mill Waste (RMW)	4.75	4.92	4.83
LSD (0.05)	2.74	2.49	—

While there were numerical variations in potassium absorption (refer to Table 4), no statistically meaningful differences were detected among the treatments in either year. In 2022, cow dung exhibited the highest K absorption (33.53 kg/ha), whereas rice mill waste and pig waste showed moderate figures in 2023.

The absence of significant distinctions implies that K absorption might not be the key factor driving yield improvements. Rather, the combined effects of other nutrients and enhanced soil characteristics may have played a role in the yield increases.

Table 5: Effect of Organic Manures on Potassium (K) Uptake by Maize (t ha⁻¹)

Treatment	2022 (t ha⁻¹)	2023 (t ha⁻¹)	Mean (t ha⁻¹)
Groundnut Shell (GNS)	27.63	24.48	26.06
Millet Husk (MIL)	19.13	24.25	21.69
Cow Dung (COD)	33.53	29.28	32.41
Poultry Droppings (POD)	25.60	21.20	23.40
Rice Mill Waste (RMW)	25.15	26.68	25.92
Pig Waste (PIW)	22.15	26.68	24.42
LSD (0.05)	14.87	14.18	—

Summary Interpretation

Pig waste and poultry droppings provided the most consistent improvements in maize grain yield.

K uptake did not show a strong correlation with yield, implying that other nutrients (e.g., N or P) or improved soil health could be responsible.

Animal manures were more effective than plant residues, likely due to faster decomposition and higher nutrient content.

Key abbreviations:

GNS-Groundnut Shell, MIL- Millet Husks, COD- Cow Dung, POD- Poultry Droppings, RMW- Rice Mill Waste, PIW- Pig waste

Discussion

The outcomes of this study reveal that the application of organic fertilizers—specifically pig manure, poultry waste, and cow dung—significantly increased maize grain output during the 2022 and 2023 growing periods. These results confirm earlier research that indicates organic amendments can greatly improve soil fertility and crop yields in low-input settings, particularly in semi-arid and savanna agricultural regions (Okoroafor et al., 2013; Parr et al., 1989).

The slightly acidic pH (6.3) of the soil at the NOUN Research Farm was beneficial for nutrient availability, especially for key macronutrients such as nitrogen, phosphorus, and potassium, which are vital for maize development. An organic carbon level of 1.2% suggested moderate soil fertility and a degree of microbial activity adequate for facilitating the mineralization of nutrients from the applied organic manures. The total nitrogen content of 0.12% is common in many soils across the Nigerian savanna but is generally insufficient for optimal maize cultivation, underscoring the need for nitrogen-rich organic manures. Additionally, the available phosphorus was identified at a moderate level; since phosphorus is crucial for energy transfer and root growth, this may have aided the effective uptake of potassium by maize plants. However, the exchangeable potassium was relatively low (0.23 cmol/kg), highlighting the necessity of external potassium supplementation—particularly from animal-based manures—to enhance potassium absorption and, consequently, improve yields.

The significant yield increases observed with pig and poultry manures are likely attributable to their higher nitrogen content, essential for maize growth and grain formation. This aligns with the assertion by Okoroafor et al. (2013) that organic manures supply essential macronutrients like nitrogen and phosphorus in forms readily available for plant uptake. Moreover, the addition of animal-based organic materials typically enhances microbial activity within the soil, facilitating the breakdown of organic matter and the release of nutrients critical for crop development (Parr et al., 1989; Wezel & Rath, 2001).

Additionally, the effect of cow dung on improving soil physical properties—such as structure and moisture retention—may have contributed to enhanced root development and nutrient absorption. These improvements are particularly crucial in rain-fed systems characteristic of the Northern Guinea Savanna, where water and nutrient availability often limits crop productivity (Wezel & Rath, 2001; Pieri, 1989).

Notably, while all manure treatments resulted in better potassium absorption than the control group, there were no statistically significant differences among them. This suggests that the yield improvements may not depend solely on potassium availability. Instead, the combined influence of various macronutrients and enhanced soil conditions likely played a more critical role in fostering plant growth and yield outcomes (Okoroafor et al., 2013; Aune et al., 2007).

Comparison with Prior Research

The findings here align with those reported by Azeez and Van Averbeke (2012) and Olabode et al. (2007), who

observed enhanced maize production following the use of poultry and pig manure in tropical farming systems. Likewise, Adekiya et al. (2020) indicated that poultry waste considerably increased maize yields while also enhancing soil organic carbon and cation exchange capacity. On the other hand, contrary to some previous studies that highlighted a direct correlation between potassium absorption and yield (for instance, Isitekhale et al., 2019), this research did not reveal such a connection, implying that potassium may not be a limiting factor given the current soil conditions in Rigachikun.

Conclusion

This research assessed the effects of six types of organic fertilizers—three derived from animals (poultry manure, cow dung, and pig waste) and three from plants (groundnut shells, millet husks, and rice milling byproducts)—on maize production and potassium absorption in the agro-ecological context of the Northern Guinea Savanna at the NOUN Research Farm, Rigachikun, Kaduna State. The findings clearly indicate that animal-based organic fertilizers significantly boosted maize grain yield, with poultry manure and pig waste consistently outperforming the other treatments throughout the two growing seasons. Among the plant-derived materials, groundnut shells provided moderate yet consistent yield improvements, highlighting their potential for enhancing soil fertility in areas where animal manures are limited or costly. These results have crucial implications for smallholder farmers and agricultural policy makers. Utilizing locally accessible organic fertilizers presents a cost-efficient and environmentally sustainable alternative to synthetic fertilizers, which are frequently beyond the reach of resource-limited farmers. Encouraging the use of organic inputs can aid in decreasing dependence on chemical fertilizers, enhance soil health, and promote sustainable agricultural intensification in sub-Saharan Africa. In summary, the strategic employment of both animal and plant-based organic fertilizers offers a feasible route towards sustainable maize cultivation, better soil management, and improved food security in the Northern Guinea Savanna and comparable agro-ecological areas.

Recommendations

1. Prioritization of Poultry Manure: Farmers in the Northern Guinea Savanna should focus on using poultry manure as an organic soil amendment to attain optimal maize yield.
2. Use of Groundnut Shells: Groundnut shells, which are easily available in the area, should be incorporated to enhance soil fertility, particularly for resource-limited farmers.
3. Additional Research: Long-term investigations are suggested to assess the lasting impacts of these organic fertilizers on soil fertility and crop productivity over several growing seasons.

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