ASIAN JOURNAL OF AGRICULTURE
Volume 8, Number 1, June 2024
Pages: 1-9

E-ISSN: 2580-4537
DOI: 10.13057/asianjagric/g080101

Evaluating the impact of poultry manure variants and swine manure on soil chemical properties and growth of maize (*Zea mays*)

KELVIN HARRISON DIRI[1,♥], ABAMU TRUSTEL KEDONEOJO[2]
[1]Saken Seifullin Agrotechnical Research University. Zhenis 62, 010011, Astana, Kazakhstan. Tel.: +7-776-0084946, ♥email: kelvin.h.diri@kazatu.edu.kz
[2]Niger Delta University. Wilberforce Island, Amassoma, 560103, Bayelsa State, Nigeria

Manuscript received: 13 August 2023. Revision accepted: 26 November 2023.

Abstract. *Diri KH, Kedoneojo AT. 2024. Evaluating the impact of poultry manure variants and swine manure on soil chemical properties and growth of maize (*Zea mays*). Asian J Agric 8: 1-9.* A greenhouse experiment was conducted at the Niger Delta University Teaching and Research Farm, Nigeria, to assess the impact of various organic manure sources on soil chemical properties and maize growth. The treatments included three variants of poultry manure (broiler manure (PB), layers poultry manure (PL), point of lay poultry manure (POL)), swine manure (SW), and combined treatments of swine manure with each poultry manure variant. Three application rates (0 (L_0), 10 (L_1), and 20t/ha (L_2)) were employed for each treatment. The experiment followed a 7×3×3 factorial fitted into a randomized complete block design, with treatments replicated thrice; the test crop used was maize (*Zea mays* L.). Soil samples were collected before and after the experiment to evaluate the effect of each organic treatment on soil chemical properties. Statistical Analysis of Variance (ANOVA) was conducted on the collected soil and plant data, with mean separation performed using Tukey's t-test. The results showed significant differences ($p < 0.05$) between the experimental and control treatments, with notable effects on soil chemical properties. In soils, the SWPL (L_2) treatment presented the highest average values for pH (6.06), organic matter (2.95%), calcium (0.96 cmol/kg), magnesium (0.77 cmol/kg), potassium (0.54 cmol/kg), base saturation (63%), and effective cation exchange capacity (3.68 cmol/kg). The highest mean value for total soil nitrogen corresponded to the PL treatment (L_2). Plant parameters also exhibited significant differences ($p < 0.05$) compared to the control, with the most pronounced effects observed in the PL (L_2) and SWPL (L_2) treatments. These findings suggest that utilizing poultry manure from layers, combined with swine manure, positively influences soil quality, productivity, and maize growth. Thus, maximizing the use of these organic manure sources as alternatives for fertilizer application is recommended.

Keywords: Fertilizers, soil fertility, maize growth, organic manure, soil chemical properties

INTRODUCTION

Food production in Nigeria is limited due to challenges from using synthetic fertilizers, including availability, cost, and environmental concerns. While the use of chemical fertilizers plays a crucial role in maintaining short-term productivity in Agro-ecosystems, studies have shown that its excessive and indiscriminate application can lead to a decline in soil fertility, soil organic matter (SOM), increase in soil acidification, cause nutrient imbalances, negatively impact enzymatic activity, and pose risks to the copiotroph community (Ansari and Mahmood 2017).

The soils in Bayelsa State, situated in the southern region of Nigeria, attracted attention due to their lower fertility status, unique characteristics, and increased soil acidity resulting from consistent crop cultivation practices and mineral fertilizers (Diri and Joseph 2020). While applying mineral fertilizers can certainly enhance crop productivity within these soils, it is crucial to recognize the potential downsides, such as a decline in soil quality and fertility. This could pose challenges to the long-term sustainability of the soil systems, as highlighted in previous studies (Agegnehu et al. 2016; Srivastava et al. 2016). As a result, there is an immediate need to explore alternative approaches that emphasize sustainability in various aspects, including crop yield, efficient resource utilization, soil health, soil quality, and practicality for local farmers (Agegnehu et al. 2016).

Organic manures have been proven over many years to be more affordable. They can effectively replace their inorganic counterparts by enhancing soil structure and water retention capacity, improving soil fertility and crop yield. The growing attraction towards adopting organic nutrient sources and soil amendments is of paramount significance, primarily driven by the recognition that they represent a valuable reservoir of carbon (C) (Rayne and Aula 2020). This carbon content is pivotal in enhancing soil quality and assumes additional significance regarding its potential contribution to the amelioration of climate change implications.

Based on the research conducted by Agyarko and Adomako (2007), as cited by Afriyie et al. (2013), the utilization of organic manures is primarily attributed to their cost-effectiveness, easy accessibility, and efficacy. Compared to synthetic fertilizers, organic soil amendments have clear advantages and fewer adverse effects on soil structure, human health, and the environment. According to Rao and Padmaja (2016), proper organic matter management practices optimize the soil's biological processes, ensuring adequate crop nutrition. Furthermore, organic manures are crucial in improving soil structure by binding soil aggregates and reducing nutrient leaching and erosion risks. Adekiya et al. (2016) argued that utilizing indigenous and available organic nutrient sources can enhance fertilizer efficiency and reduce the amount of chemical fertilizers needed.

Following that, extended investigations into the impact of fertilizers derived from organic sources, as conducted by Blanchet et al. (2016), in a long-term study have demonstrated that the utilization of organic manure yields enhancements in soil chemical attributes and imparts notable increments in phosphorus (P) and potassium (K) content. In alignment with these findings, Achiba et al. (2010) reported increased soil nitrogen (N) content attributed to applying organic manure. Similarly, Gopinath et al. (2009) undertook a comprehensive two-year study, revealing that the incorporation of manure substantially contributed to the elevation of soil pH compared to using chemical fertilizers. Overall, incorporating organic residues and manures into soil management practices is essential as they improve soil physical, chemical, and biological properties.

Despite recognizing poultry manure's efficacy, gaps exist in understanding specific types, such as broilers, point-of-lay birds, or laying birds, and potential synergies with other organic sources like swine manure. Thus, this research investigates the impacts of different poultry manure sources, alone and in combination with other organic sources, on soil chemical properties and maize growth.

MATERIALS AND METHODS

Greenhouse experiment

The experiment was carried out at the Screen House of the Niger Delta University Teaching and Research Farm (NDUTRF), Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. The site is located at Latitude 4º38'38'N, Longitude 6º21'41'E Equator. The mean annual rainfall ranges from 2,000-4,000 mm per annum and spreads over 8-10 months between April and November, coinciding with the wet season having a mean rainfall of 2,500 mm per annum coupled with a fairly constant temperature of 30ºC. The soils in the study area are predominantly silty clay loam (Diri and Joseph 2020).

The organic manure was obtained from NDUTRF. The treatment consists of two different sources of organic manure: poultry manure from broilers (PB), point of lay birds (POL), and layers (PL) and swine manure (SW), as well as combined treatment of; swine manure + poultry manure from broilers (SWPB), swine manure + poultry manure from point of lay birds (SWPOL), and swine manure + poultry manure from Layers (SWPL). Point of lay birds (POL): pullets within the age range of approximately 16-20 weeks, positioned to enter the phase of egg production. Layers (PL): mature hens that have reached the age of consistent egg production, usually around 20 weeks and beyond and are actively laying eggs. The experiment was carried out in a 7×3×3 factorial randomized complete block design with three treatment levels, replicated three times, 0 t/ha, 10 t/ha, and 20 t/ha.

Soil from 0-15 cm depth was obtained from the teaching and research farm, air-dried, ground, and passed through a 2 mm sieve. Next, 2 kg of sieved soils were filled into the experimental pots and mixed with 10g and 20g of organic manure (w/w), following Rao and Padmaja (2016). The pots were then watered to field capacity and incubated for one week before planting. Hybrid Maize variety (Sam Max 44) obtained from the International Institute of Tropical Agriculture (IITA) was planted 2-3 cm deep and thinned to 2 plants per pot 10 Days after planting (DAP).

Soil and plant analysis

Soil collected was analyzed for its chemical properties before planting and after harvest. Soil pH was determined in 0.01M $CaCl_2$ salt solution at a 1:2 (w/v) ratio with a glass electrode pH meter. Organic carbon (Org C) was determined by the dichromate wet oxidation method of Walkley and Black. Organic matter (Org M) was calculated by multiplying the percentage of organic carbon (van Bemmelen factor) by 1.724. Total Nitrogen (Total N) was determined by the macro Kjeldahl method. Available phosphorus (Avail P) was determined by the Bray P-1 method of Bray and Kurtz (1945). Exchangeable bases (EB) were extracted using 1N Ammonium acetate ($NH_4CH_3CO_2$). Ca^{2+} and Mg^{2+} were analyzed using a PGI 990 Atomic Absorption Spectrophotometer (PG Instruments Ltd., UK), while K^+ and Na^+ were determined using ATS 200S Flame Photometer (ATS-Technology, Cyprus). The exchangeable acidity (EA) was determined by leaching the soil using 1N KCl and the extract titrated with 0.01N NaOH. Cation exchange capacity was determined using the 1N NH_4OAc method, and Effective Cation Exchange Capacity (ECEC) was evaluated by summing up the exchangeable bases and the exchange acidity. Data on plant parameters, including plant height, leaf number, leaf area, and stem girth, was taken to record growth attributes.

Data analysis

Data from plant and soil collected were subjected to statistical Analysis of Variance (ANOVA) using Minitab v17 software. The treatment means were separated for significant differences using the Tukey T-test at a 5% probability level.

RESULTS AND DISCUSSION

Characterization of the soil and organic materials used in the experiment

The chemical properties of organic manure and soil are shown in Table 1. The result of the selected properties indicates that the pH of the bulk soil sample was strongly acidic, while that of the organic materials was slightly to moderately acidic. The results and values obtained indicate that these organic materials could potentially enhance the fertility of the soil and impact positively on the growth and yield of maize. Furthermore, the swine and layer manure (SWPL) combination exhibited the best chemical properties. In addition, Hadas et al. (2004) also reported similar results.

Effect of organic amendment on soil chemical properties

Soil pH and exchangeable acidity

Before applying organic soil amendments, the results obtained from soil analysis at the experimental site indicated a strongly acidic soil with a pH value of 4.53 (0.04). However, the application of organic amendments at various levels led to a significant increase ($p < 0.05$) in soil pH, shifting it from strongly acidic 4.53 (0.04) to slightly acidic 6.06 (0.06). Among the treatments, SWPL (L_2) had the greatest impact on soil pH, resulting in a pH value of 6.06 (0.06). This can be attributed to the high pH value of the organic amendment (SWPL, 6.97) used. While both SWPL (L_2) and PL (L_2) treatments increased soil pH, no significant difference ($p > 0.05$) was observed between them. This suggests that both treatments can be used as organic amendments or liming materials to elevate soil pH levels when applied at the same rate.

On the other hand, the soil pH levels with the lowest mean were observed in soils subjected to the lower treatment application (L_1). Among the L_1 treatments, PB exhibited the lowest pH value of 5.03(0.08), and no significant difference was found between SWPB, PB, and POL treatments. In addition, the interaction between treatment and treatment levels on soil pH was significant ($p < 0.05$).

This finding aligns with previous studies conducted by researchers such as Boateng et al. (2006), Busari et al. (2008), and Quansah (2010), who also reported similar increases in soil pH following the application of organic amendments. The pH elevation resulting from organic amendments, particularly poultry manure, is often attributed to the release and addition of basic cations during the decomposition and mineralization process (Ano and Agwu 2005; Melero et al. 2007), as well as the presence of organic anions in the manure which can neutralize hydrogen ions (Butterly et al. 2013). Ano and Ubochi (2007) also reported a consistent increase in soil pH for applying rabbit, swine, goat, chicken, and cow manures at different rates. This increase in the pH as a function of manure application has also been attributed to the calcium carbonate and bicarbonate found in manure (Eghball et al. 1996; Whalen et al. 2000).

Moreover, some authors, including Yaduvanshi (2003) and Balota et al. (2012), have reported decreases and no changes in soil pH following the application of swine manure; its effect on soil pH could be dependent on its specific characteristics, soil condition, and dietary composition. Furthermore, the capacity of the different manures to elevate soil pH aligns with the same sequence as their capacity to diminish exchangeable acidity. Consequently, it can be inferred that the manures' effectiveness in ameliorating soil pH is contingent upon their inherent capability to mitigate exchangeable acidity, encompassing both hydrogen (H^+) and aluminum (Al^{3+}) ions (Ano and Ubochi 2007). Following this observation, it could be observed that an increase in the application rate of these manures significantly decreased exchangeable acidity from control soil from 2.15 cmol/kg to 1.34 cmol/kg (Table 2). All organic amendments reduced EA below the critical limit (<2 cmol/kg -low-) given by Adamu et al. (2014). The Addition of SWPL (L_2) had a significant effect on EA, followed by PL (L_2). When organic materials in manure, compost, ash, biochar, and digestate are added to acid soils, they form strong bonds that chelate with H^+ and $Al^{3+,}$ reducing their solubility.

Organic carbon and organic matter

A significant setback in maintaining soil health arises from the gradual reduction of Soil Organic Matter (SOM) due to prolonged land cultivation. The pooled data analysis from this research revealed a significant increase in the organic carbon content of the soil. Initially, the soil had a low organic carbon content, increasing from 0.66% to 1.70% upon applying organic amendments. The combined treatment SWPL L_2 had the greatest impact on soil organic carbon (1.70%) and showed a statistically significant difference ($p < 0.05$) compared to all other treatments. Furthermore, higher treatment levels were associated with increased organic carbon levels, indicating that L_2 treatment was more effective in enhancing soil organic carbon. In contrast, SWPOL, POL and PB exhibited the least effect on soil organic carbon at (L_1), but was significantly different ($p < 0.05$) from control.

The SOM content increased concerning the increased treatment levels of all organic amendments and showed a statistically significant difference ($p < 0.05$) compared to the control. Incorporating organic manures into the soil resulted in a significant increase in organic matter, elevating it from 1.14% to 2.97%. Among the treatments, the combined treatment (SWPL) consistently exhibited a higher effect on SOM (2.97%) at L_2. Still, it did not show a statistically significant difference ($p > 0.05$) compared to all other treatments at the 20 t/ha level (L_2), except for PL, SWPOL, and SW. Furthermore, the treatments, level of application of organic manure, and the interaction between treatment and its level were significant ($p < 0.05$), bolstering that these amendments impacted SOC and SOM.

Table 1. Chemical properties of soil and organic manure used in this study

Sample	pH (water)	Org C (%)	Total N (%)	C/N Ratio	Avail P (mg/kg)	Ex. K (cmol/kg)
PB	5.60	1.13	1.83	1:1	3.81	0.32
SW	6.36	1.69	2.22	1:1	4.00	0.59
PL	6.66	1.79	2.27	1:1	4.27	0.47
POL	5.68	1.21	1.79	1:1	3.60	0.34
SWPB	6.17	1.48	2.26	1:1	4.23	0.50
SWPL	6.97	1.83	2.30	1:1	4.41	0.71
SWPOL	5.97	1.30	1.95	1:1	4.09	0.52
Soil	4.80	0.81	0.02	22:1	3.02	0.28

Note: PB: Broiler manure, SW: Swine manure, PL: Layer manure, POL: Point of lay manure, SWPB: Swine+Broiler manure, SWPL: Swine+Layer manure, SWPOL: Swine+Point of lay manure, Org C: organic carbon, Total N: total nitrogen, C/N Ratio: carbon/nitrogen Ratio, Avail P: Available phosphorus and Ex. K: extractable potassium

Studies conducted by Denton et al. (2020) also demonstrated an increase in organic carbon in soils when incorporated with organic manure. These results are consistent with Shi et al. (2009) and Deryqe et al. (2016), where poultry and swine were used as soil amendments. Furthermore, the rise in Soil Organic Carbon (SOC) can also be directly linked to the low C/N ratio found in different amendments used, as noted by Montemurro et al. (2010) and Stockmann et al. (2013). Therefore, it can be inferred that the combined treatment of swine manure and Layer manure can be considered effective in enhancing carbon sequestration and increasing the organic matter content in soils for agricultural purposes.

Total nitrogen

The preliminary assessment of the soil revealed that the concentration of Total N in the soils, before the incorporation of organic amendments, was generally deficient, falling below the critical threshold of 0.02% as determined by Chude et al. (2012). Previous research has also indicated low levels of Total N in these soils, attributed to a high C:N ratio and intensive mineralization caused by significant fluctuations in precipitation and temperature (Diri and Joseph 2020).

However, the soil N content increased in the amended plots after applying soil amendments compared to the unamended plots. Notably, utilizing the combined organic manure SWPL (L_2) and the manure from PL (L2) treatments resulted in a substantial elevation of soil N levels, reaching 0.70% and 0.78%, respectively. The increase observed in both treatments was statistically significant ($p < 0.05$) compared with other organic amendments, which can be attributed to the high N content in both PL and SWPL manure. Furthermore, the impact on soil Total N varied according to the treatment levels, with higher treatment levels (L_2) exhibiting a more pronounced effect than lower treatment levels (L_1). Additionally, the rise in soil Total N can be attributed to the subsequent decomposition and mineralization of the abundant organic matter content in all amendments. This finding aligns with the established knowledge that increased soil organic matter content is expected to enhance soil N status (Hadas et al. 2004). Similar results have been reported by Akbari et al. (2011).

It is well-established that releasing N and other essential nutrients from livestock manure depends on the mineralization rate. The quantity of a nutrient subject to mineralization within manure is contingent upon a confluence of factors, including manure composition, environmental variables, soil characteristics, and microbial enzymatic activity, as Eghball et al. (2002) outlined. In an empirical study conducted by Khan et al. (2007), which examined the influence of dairy manure application and tillage practices on maize cultivation, it was observed that the addition of 10 Mg/ha and 20 Mg/ha of dairy manure in conjunction with inorganic fertilizer yielded a notable increase of 24% and 27%, respectively, in soil N content, as compared to the utilization of inorganic fertilizer exclusively.

Available phosphorus and exchangeable potassium

Control soils indicated a deficiency in available phosphorus, with levels measuring 3.05 mg/kg, which fell below the critical threshold for phosphorus availability (Reddy et al. 2014). However, adding organic amendments did not significantly increase the soil's phosphorus status, although the mean values differed from those of the control group. Applying organic amendments at various treatment levels did not substantially impact the phosphorus status and availability. Phosphorus content in soil increased marginally from 3.05 mg/kg to 4.24 mg/kg, which remained below the critical threshold (Horneck et al. 2011). Poultry manure contains relatively high total and soluble P and low N:P ratios. Although PL, SW, SWPL, SWPB, and SWPOL had higher P content, the marginal increase of P in the soil could be a result of P-fixation by Al; Fe oxides linked primarily to the acidic nature of the soils as well as the EA concentration of the soils. This corroborates with studies by Boateng et al. (2006).

The increase in available P after manure application to soil is a function of various soil characteristics, including soil pH, organic matter content, and clay type (Chatterjee et al. 2014). Potassium (K) concentration in the soil before the addition of organic amendments was comparatively low (0.24 cmol/kg) concerning the critical rating for exchangeable K as specified by FAO (2006). SWPL (L_2) exhibited the highest K concentrations among the organic amendments, while the lowest values were observed for POL (L_1). These findings can be attributed to the relatively higher K contents in SWPL (0.71 cmol/kg) treatment than in POL (0.34 cmol/kg) as shown in (Table 1).

Calcium, magnesium, and effective cation exchange capacity

Calcium concentration in the soil was initially below the critical level (<2 cmol/kg), as indicated by FAO (2006) before the implementation of organic amendments. However, after applying organic amendments, a substantial increase in soil calcium content was observed for all treatment levels compared to the control, although it remained below the critical threshold. Notably, the combined SWPL treatment at L_2 significantly elevated soil calcium content, reaching 0.96 cmol/kg, followed by PL (L_2) at 0.84 cmol/kg, while POL (L_1) exhibited the least augmentation at 0.53 cmol/kg. These findings highlight the capacity of organic manures to enhance soil nutrient reserves, foster fertility development, and promote improved nutrient bioavailability (Brady and Weil 2005).

The magnesium (Mg) content of the soil (0.24 cmol/kg) was considered moderate, following the established range (0.3-0.1 cmol/kg). However, after applying organic amendments, a significant increase in soil magnesium content from 0.24 cmol/kg to 0.77 cmol/kg was observed for SWPL (L_2). Concerning sodium (Na) content, the baseline levels were low and below the critical limit of 0.10 cmol/kg. Applying organic amendments yielded significant distinctions ($p < 0.05$) compared to the control. Although there were significant differences ($p > 0.05$) detected among the various treatments, this can be negligible because manures generally have low sodium content.

Table 2. Effect of organic waste application on soil chemical properties

Treatment		**pH (CaCl$_2$)**	**Org C**	**Org M**	**Total N**	**Avail P (mg/kg)**	**EA**	**Ca**	**Mg**	**Na**	**K**	**BS (%)**	**ECEC (cmol/kg)**
			(%)				**(cmol/kg)**						
Control	L0	4.53 (0.04)e	0.66 (0.06)g	1.14 (0.11)f	0.01 (0.01)j	3.05 (0.18)f	2.15 (0.03)a	0.29 (0.03)e	0.24 (0.35)e	0.01 (0.00)d	0.24 (0.02)de	26 (0.95)h	2.93 (0.04)d
PB	L1	5.03 (0.08)de	1.30 (0.02)f	2.26 (0.03)e	0.23 (0.03)i	3.37 (0.11)de	1.56 (0.02)bcd	0.59 (0.02)cd	0.33 (0.02)de	0.04(0.01)c	0.26 (0.02)de	43 (1.38)g	2.78 (0.04)abcd
	L2	5.22 (0.09)bcd	1.53 (0.01)cd	2.66 (0.02)abcd	0.33 (0.03)h	3.44 (0.04)cde	1.55 (0.03)bcd	0.65(0.02)bc	0.37 (0.02)cde	0.04 (0.00)c	0.33 (0.01)cde	47 (0.84)	2.49 (0.07)abc
SW	L1	5.44 (0.06)abcd	1.49 (0.03)d	2.59 (0.05)bcd	0.48 (0.02)e	3.69 (0.04)bcd	1.83 (0.03)abc	0.55 (0.03)cd	0.44 (0.02)cd	0.06(0.01)abc	0.28 (0.01)de	42 (0.10)e	3.16 (0.05)bcd
	L2	5.70 (0.03)ab	1.61 (0.02)b	2.80 (0.03)ab	0.55 (0.02)d	3.65 (0.03)bcde	1.50 (0.04)bcd	0.63 (0.02)bc	0.66 (0.03)ab	0.07 (0.01)ab	0.35 (0.02)bcd	53 (0.75)c	3.21 (0.04)abcd
PL	L1	5.66 (0.03)abc	1.56 (0.00)bcd	2.71 (0.01)abcd	0.60 (0.02)c	3.91 (0.18)b	1.76 (0.02)acd	0.74 (0.02)ab	0.45 (0.01)cd	0.05 (0.01)c	0.37 (0.01)dcd	48 (0.49)d	3.37 (0.02)abcd
	L2	6.02 (0.09)a	1.61 (0.03)b	2.80 (0.06)abc	0.78 (0.04)a	4.24 (0.07)a	1.44 (0.01)cd	0.84 (0.03)ab	0.50 (0.02)bcd	0.06 (0.01)bc	0.45 (0.03)abc	56 (0.77)b	3.29 (0.06)ab
POL	L1	5.05 (0.09)cde	1.35 (0.02)ef	2.35 (0.04)de	0.27 (0.03)i	3.35 (0.07)ef	1.86 (0.04)ab	0.53 (0.03)d	0.32 (0.01)de	0.05 (0.01)c	0.19 (0.01)e	36 (0.94)f	2.95 (0.04)d
	L2	5.34 (0.04)bcd	1.51 (0.05)cd	2.62 (0.04)abc	0.37 (0.01)gh	3.56 (0.03)cde	1.72 (0.03b)cd	0.65 (0.02)cd	0.53 (0.02)bc	0.06 (0.00)bc	0.24 (0.01)de	46 (0.20)e	3.20 (0.04)cd
SWPB	L1	5.04 (0.13)cde	1.42 (0.02)e	2.47 (0.04)cde	0.40 (0.02)fg	3.34 (0.02)ef	1.84 (0.02a)bc	0.67 (0.03)bc	0.43 (0.01)cde	0.06 (0.01)bc	0.24 (0.02)de	43 (0.44)e	3.24 (0.06)abcd
	L2	5.25 (0.06)bcd	1.56(0.02)bcd	2.71 (0.03)abc	0.50 (0.02)e	3.53 (0.04)cde	1.65 (0.05)bcd	0.80(0.02)b	0.53 (0.02)bc	0.08(0.01)ab	0.36 (0.02)bcd	52 (0.48)c	3.42 (0.07)abcd
SWPL	L1	5.72 (0.03)ab	1.60 (0.02)b	2.78 (0.03)abc	0.51 (0.02)de	3.39 (0.05)de	1.65 (0.03bc)d	0.76 (0.01)ab	0.55 (0.03)bc	0.07 (0.01)ab	0.36 (0.01)bcd	51 (0.79)c	3.34 (0.01)abcd
	L2	6.06 (0.06)a	1.70 (0.02)a	2.97 (0.03)a	0.70 (0.02)b	3.76 (0.19)bc	1.33 (0.02)d	0.96 (0.07)a	0.77 (0.03)a	0.08 (0.02)ab	0.54 (0.02)a	63 (0.47)a	3.68 (0.00)a
SWPOL	L1	5.20 (0.16)bcd	1.38 (0.02)e	2.40 (0.04)de	0.35 (0.03)h	3.35 (0.03)ef	1.83 (0.01)abc	0.64 (0.03)cd	0.36 (0.01)cde	0.07 (0.01)ab	0.26 (0.03)de	42 (1.13)e	3.16(0.03)bcd
	L2	5.25 (0.03)bcd	1.58 (0.02)bc	2.74 (0.04)abc	0.44 (0.04)fg	3.53 (0.05)cde	1.66 (0.03)bcd	0.76 (0.03)ab	0.47 (0.01)bcd	0.09 (0.01)a	0.33 (0.00)cde	50 (0.05)cd	3.31 (0.05)abcd
T		**	**	**	**	**	**	**	**	**	**	**	**
L		**	**	**	**	**	**	**	**	**	**	**	**
T x L		**	**	**	**	**	ns	**	**	**	**	**	**

Note: Means (SD) with different letters are significantly different ($p<0.05$), ** significant, ns: not significant. Org C: Organic carbon, Org M: organic matter, Total N: Total Nitrogen, Avail P: Available phosphorus, EA: Exchangeable acidity, Ca: Calcium, Mg: Magnesium, K: Exchangeable potassium, %BS: Percent base saturation, ECEC: effective cation exchange capacity

The effective cation exchange capacity of the soil before the incorporation of organic manure was low (3.06 cmol/kg) but increased with the application of organic amendments. ECEC significantly increased from 2.93 to 3.68 cmol/kg, significantly different from the control. Applying SWPL was most effective in increasing the ECEC value of the soil (3.68 cmol/kg), followed by PL (3.37 cmol/kg). However, an increase in ECEC was more effective when soils were amended with the various organic sources at the (L_2) treatment level. Cation Exchange Capacity (CEC) encompasses quantifying the soil's capacity to retain positively charged ions on its particle surfaces, elucidated by Goldberg et al. (2020). It is well-established that the CEC of soil exhibits a positive correlation with elevated proportions of clay content and organic material. Empirical investigations have consistently indicated a discernible ascending pattern in CEC values concurrent with higher manure application rates. The observed trend can be attributed to organic matter within the applied manure and the concurrent increase in soil pH resulting from manure application (Magdoff and Amadon 1980). The ECEC values are also reflected in the base saturation of the soils. SWPL treatment at (L_2) showed the highest percent base saturation (63%), followed by PL (L_2) at 56% and SW (L_2) at 53%. The high percent base saturation SWPL (L_2) exhibited indicates its high concentration of basic cations needed for plant growth and development (Brady and Weil 2005).

Effect of organic amendments on maize growth

The effects of various organic amendments on maize growth were investigated, and the results are presented in Tables 3-6. Throughout the study, maize plant height significantly increased, reaching its peak at 8WAP, with a maximum height of 64.80 cm. Notably, all treatments applying organic amendments presented greater heights than the control. The organic amendment PL had the most pronounced impact on the vegetative growth of maize, resulting in the highest mean plant height. This was followed by SWPL and SW (Table 3.). The increase in plant height was found to be statistically significant ($p <0.05$) with an elevation in treatment level. These findings align with the study conducted by Okoroafor et al. (2013), who also observed a similar trend in increased maize plant height as a result of single and combined application of poultry and swine manure. The higher plant height in PL, SW, and SWPL treatments may be attributed to its higher total N and avail P content than the other treatments, as supported by the study by Jjagwe et al. (2020).

The use of organic amendments led to an increase in the number of leaves, as indicated in Table 4. Nevertheless, not all organic amendments resulted in a noteworthy enhancement in number of leaves compared to the control group at 8 weeks after planting (8 WAP). Specifically, POL (L1) had the least impact on the number of leaves, while the application of SW (L2), SWPL (L2), and PL (L2) resulted in the highest leaf count.

Additionally, the leaf area of maize increased over time, peaking at 8 WAP (Table 5). The leaf area at this stage ranged from 127.23 cm^2 to 155.03 cm^2 for all treatment levels. These findings suggest that applying organic amendments at a higher rate positively contributes to an increase in the leaf area of maize. The stem girth of maize increased over time, reaching its highest mean value at 8 WAP. The mean stem girth ranged from 0.60 cm to 1.60 cm across all treatment and treatment levels (L_1, L_2) (Table 6). Similar to the observations in the leaf area, all treatments except POL and SWPOL exhibited greater girth than the control, and a pronounced effect on stem girth was observed in SW, PL, and SWPL treatment.

While plant height increased compared to the control group, the impact of organic amendments on other plant growth factors especially on the number of leaves, at the different stages of growth, was negligible, sometimes no different from the control. the reason for this can be attributed to slow release of nutrients from organic manures, unlike inorganic fertilizers that release nutrients quickly, organic amendments undergo slow mineralization, resulting in a gradual nutrient release. This observation corroborates with a similar finding reported by Kareem et al. (2017) and Rasool et al. (2023).

Table 3. Effect of organic amendments on plant height

Treatments		Plant Height (cm)			
		2WAP	**4WAP**	**6WAP**	**8WAP**
Control	L0	13.07±0.60i	20.00±0.10i	30.73±0.55f	43.87±0.41i
PB	L1	17.53±0.25fg	22.50±0.15h	37.63±0.32e	53.67±0.49de
	L2	18.73±0.25abc	24.70±0.43ef	37.96±0.15e	55.83±0.20cd
SW	L1	19.23±0.51ab	25.56±0.81cde	42.20±2.65c	56.03±1.20cd
	L2	19.70±0.30a	28.70±1.13a	43.06±1.00bc	50.33±1.20b
PL	L1	18.67±0.42abcd	25.20±0.98de	45.37±1.35a	50.50±0.87b
	L2	18.80±0.26abc	26.50±0.60bcd	46.26±0.86a	64.80±2.07a
POL	L1	16.13±0.20fg	23.90±0.85efg	39.60±0.79de	53.13±1.53def
	L2	17.77±0.25cde	25.20±0.98de	41.23±1.05cd	53.00±0.36def
SWPB	L1	17.00±1.00ef	23.36±0.49efg	38.90±1.11e	50.16±0.90fgh
	L2	17.36±0.35ef	23.20±0.98efg	42.33±1.10c	52.06±0.66efg
SWPL	L1	18.10±0.25bcde	27.03±2.15abc	41.37±0.96cd	54.13±1.00cde
	L2	19.73±0.25a	27.50±0.65ab	44.46±0.86ab	57.06±0.61bc
SWPOL	L1	17.10±0.26ef	24.57±0.66ef	41.53±1.56cd	53.23±0.75def
	L2	17.43±0.40de	25.37±0.71cde	41.20±0.00cd	54.13±0.40cde

Table 4. Effect of organic amendments on number of leaves

Treatments		**Number of Leaves**			
		2WAP	**4WAP**	**6WAP**	**8WAP**
Control	L0	5.00±1.00d	7.33±0.57d	11.33±0.57de	12±0.57d
PB	L1	6.00±0.00c	8.00±1.00cd	11.67±0.57de	13±1.00c
	L2	5.33±0.57d	7.67±0.57d	11.67±0.57de	13±0.57c
SW	L1	6.67±0.57bc	9.00±0.00ab	12.00±0.00cd	14±0.57b
	L2	6.33±1.15bc	8.67±0.57cd	12.67±0.57bc	15±0.00a
PL	L1	6.33±1.15bc	8.00±1.00cd	12.00±0.00cd	14±0.00bc
	L2	7.67±0.57a	10.33±0.57a	13.00±0.00b	15±0.00a
POL	L1	6.00±0.00c	8.67±1.15cd	11.00±0.00de	11±0.57e
	L2	5.67±0.57cd	8.00±0.00cd	11.00±1.00ef	12±0.57d
SWPB	L1	7.00±0.00ab	9.00±1.00ab	11.33±0.57de	12±0.00d
	L2	7.33±0.57ab	9.67±0.57ab	13.00±0.00b	13±0.00c
SWPL	L1	7.00±0.00abc	8.67±0.57cd	12.00±0.00cd	13±0.00c
	L2	7.67±0.57a	11.00±1.00a	15.33±0.57a	15±0.57a
SWPOL	L1	5.67±0.57cd	7.67±0.57d	11.00±0.00ef	12±0.00d
	L2	7.00±0.00ab	9.33±0.57ab	12.00±1.00cd	13±0.00c

Table 5. Effect of organic amendments on leaf area

Treatments		**Leaf Area (m^2)**			
		2WAP	**4WAP**	**6WAP**	**8WAP**
Control	L0	34.97±0.45i	50.90±0.36f	119.47±0.61gh	127.23±1.62i
PB	L1	39.43±0.81de	58.93±0.40de	135.43±0.61cdef	145.23±0.32ef
	L2	40.77±0.68c	60.03±0.95cd	133.53±0.45cdef	146.50±0.40def
SW	L1	42.77±0.49ab	64.03±1.99abc	140.83±1.33bcd	158.17±2.25bc
	L2	42.80±0.26ab	65.57±1.20ab	149.33±1.16ab	160.67±1.56b
PL	L1	41.77±0.25de	61.47±2.49abcd	141.73±1.60abcd	161.73±0.56b
	L2	41.83±0.20de	65.20±3.40ab	154.20±2.62a	169.93±0.15a
POL	L1	35.37±0.72hi	54.83±3.16ef	142.80±1.51abcd	149.97±0.37d
	L2	38.06±0.94ef	59.97±3.59cd	146.10±1.87abc	150.63±2.20d
SWPB	L1	36.20±0.36h	61.30±3.90abcd	122.37±1.07fgh	127.43±0.96i
	L2	38.96±1.00gh	61.40±3.64abcd	138.27±0.65bcde	143.40±0.78f
SWPL	L1	41.06±1.60de	64.00±1.67abc	141.47±1.89abcd	145.60±0.60ef
	L2	43.00±0.20a	67.10±1.51a	151.17±1.88ab	155.03±0.41c
SWPOL	L1	39.56±0.45de	62.43±4.76abcd	139.67±0.64bcde	144.17±0.55f
	L2	41.33±0.76de	63.60±3.92abcd	146.57±0.80abc	149.23±1.03de

Table 6. Effect of organic amendments on stem girth

Treatments		**Stem Girth (cm)**			
		2WAP	**4WAP**	**6WAP**	**8WAP**
Control	L0	0.60±0.05e	0.87±0.05f	1.26±0.05cde	1.36±0.05ef
PB	L1	0.70±0.00d	0.93±0.05e	1.33±0.11bcd	1.47±0.05cd
	L2	0.76±0.05cd	1.00±0.00d	1.36±0.05abc	1.56±0.05ab
SW	L1	0.83±0.00b	1.10±0.11bc	1.46±0.05ab	1.53±0.00abc
	L2	0.90±0.05ab	1.17±0.00abc	1.50±0.10a	1.60±0.05a
PL	L1	0.80±0.00bc	0.90±0.00e	1.30±0.00bcd	1.50±0.00bc
	L2	0.87±0.05b	1.10±0.00bc	1.50±0.00a	1.60±0.00a
POL	L1	0.76±0.00cd	1.00±0.05d	1.33±0.05bcd	1.30±0.00ef
	L2	0.80±0.05bc	1.06±0.00d	1.30±0.00bcd	1.30±0.00ef
SWPB	L1	0.70±0.00c	0.90±0.00e	1.20±0.00de	1.20±0.00g
	L2	0.90±0.00ab	1.10±0.00c	1.40±0.00abc	1.50±0.00bc
SWPL	L1	0.90±0.10ab	1.20±0.11b	1.40±0.00abc	1.50±0.10bc
	L2	0.97±0.05a	1.35±0.10a	1.50±0.00a	1.60±0.00a
SWPOL	L1	0.76±0.00bcd	1.00±0.00d	1.30±0.00bcd	1.30±0.00ef
	L2	0.80±0.05bc	1.10±0.00c	1.30±0.00bcd	1.30±0.00ef

The results demonstrated that all organic sources studied positively affected the soil chemical properties evaluated. Specifically, adding organic amendments increased various soil indices, including pH, Total N, organic matter, and carbon content. Notably, the application of manure layers and their combination with swine manure exhibited the most significant impact on soil chemical properties and maize growth parameters compared to other organic treatments. Moreover, applying these manures at varying quantities (10 to 20 t/ha) demonstrated promising effects on both soil chemical properties, soil fertility, and maize growth parameters. Consequently, based on these findings, employing a single application of poultry manure from layers and its combination with swine manure as an alternative fertilizer source is recommended to enhance soil fertility and promote optimal maize growth.

ACKNOWLEDGEMENTS

No public, private, commercial, or non-profit organization supported this study financially. As a result, the author declares that this document is free from any conflict of interest.

REFERENCE

Achiba WB, Lakhdar A, Gabteni N, Laing GD, Verloo M, Boeckx P, Cleemput O, Jedidi N, Gallali T. 2010. Accumulation and fractionation of trace metals in a Tunisian calcareous soil amended with farmyard manure and municipal solid waste compost. J Hazard Mater 176 (1-3): 99-108. DOI: 10.1016/j.jhazmat.2009.11.004.

Adamu GK, Aliyu AK, Jabbi AM. 2014. Fertility assessment of soils under rice cultivation in Kadawa, Garun Mallam Local Government Kano State. Acad Res Intl 5 (1): 92-99.

Adekiya AO, Ojeniyi SO, Owonifari OE. 2016. Effect of cow dung on soil physical properties, growth and yield of maize (*Zea mays*) in a tropical Alfisol. Sci Agric 15 (2): 374-379. DOI: 10.15192/PSCP.SA.2016.15.2.374379.

Afriyie E, Mensah E, Lohri CR. 2013. Comparative study of composted and uncomposted digestates, chicken manure and cow dung as fertilizers and their effects on soil properties. Glob J Eng Des Technol 2 (4): 12-22.

Agegnehu G, Bass AM, Nelson PN, Bird MI. 2016. Benefits of biochar, compost and biochar-compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. Sci Total Environ 543(Pt A): 295-306. DOI: 10.1016/j.scitotenv.2015.11.054.

Agyarko K, Adomako WJ. 2007. Survey of the use of organic manure among vegetable farmers in selected districts in Ghana. J Sustain Dev Afr 9 (4): 1-15.

Akbari P, Ghalavand A, Sanavy AM, Alikhani MA. 2011. The effect of biofertilizers, nitrogen fertilizer and farmyard manure on grain yield and seed quality of sunflower (*Helianthus annus* L.). J Agric Technol 7 (1): 173-184.

Ano AO, Agwu JA. 2005. Effect of animal manures on selected soil chemical properties (1). Niger J Soil Sci 15: 14-19.

Ano AO, Ubochi CI. 2007. Neutralization of soil acidity by animal manure: Mechanism of reaction. Afr J Biotechnol 364-368.

Ansari RA, Mahmood I. 2017. Optimization of organic and bio-organic fertilizers on soil properties and growth of pigeon pea. Sci Hortic 226: 1-9. DOI: 10.1016/j.scienta.2017.07.033.

Balota EL, Machineski O, Matos MA. 2012. Soil microbial biomass under different tillage and levels of applied pig slurry. Revista Brasileira de Engenharia Agricola e Ambiental 16 (5): 487-495. DOI: 10.1590/S1415-43662012000500004.

Blanchet G, Gavazov K, Bragazza L, Sinaj S. 2016. Responses of soil properties and crop yields to different inorganic and organic amendments in a Swiss conventional farming system. Agric Ecosyst Environ 230: 116-126. DOI: 10.1016/j.agee.2016.05.032.

Boateng SA, Zickermann J, Kornahrens M. 2006. Poultry manure effect on growth and yield of maize. West Afr J Appl Ecol 9: 1. DOI: 10.4314/wajae.v9i1.45682.

Brady NC, Weil RR. 2005. The Nature and Properties of Soils. 13th Edition. Macmillan Publishing Company, New York.

Bray RH, Kurtz LT. 1945. Determination of total, organic and available form of P in soils. Soil Sci 59: 45-59. DOI: 10.1097/00010694-194501000-00006.

Busari MA, Salako FK, Adetunji MT. 2008. Soil chemical properties and maize yield after application of organic and inorganic amendments to an acidic soil in southwestern Nigeria. Span J Agric Res 6 (4): 691-699. DOI: 10.5424/sjar/2008064-362.

Butterly CR, Baldock JA, Tang C. 2013. The contribution of crop residues to changes in soil pH under field conditions. Plant Soil 366: 185-198. DOI: 10.1007/s11104-012-1422-1.

Chatterjee D, Datta SC, Manjaiah KM. 2014. Fractions, uptake and fixation capacity of phosphorus and potassium in three contrasting soil orders. J Soil Sci Plant Nutr 14: 640-656. DOI: 10.4067/S0718-95162014005000051.

Chude VO, Olayiwola SO, Daudu C, Ekeoma A. 2012. Fertilizer Use and Management Practices for Crops in Nigeria 4th Edition. Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja.

Denton OA, Fademi IO, Are KS, Ojo AO, Adeoyolanu OD. 2020. Effect of different manure sources on soil chemical properties, performance and yield of maize on a degraded land. Intl J Plant Soil Sci 32 (13): 48-58. DOI: 10.9734/IJPSS/2020/v32i1330358.

Deryqe JSA, Kader KAA, Albaba HB. 2016. Effect of poultry manure on soil phosphorus availability and vegetative growth of maize plant. J Agric Veter Sci 9: 12-18. DOI: 10.9790/2380-0911021218.

Diri KH, Joseph TO. 2020. Assessing the macronutrient status of some selected soils in Bayelsa State, South-South Nigeria. Adv J Grad Res 8 (1): 105-114. DOI: 10.21467/ajgr.8.1.105-114.

Eghball B, Binford GD, Baltensperger DD. 1996. Phosphorus movement and adsorption in a soil receiving long-term manure and fertilizer application. J Environ Qual 25: 1339-1343. DOI: 10.2134/jeq1996.00472425002500060024x.

Eghball B, Wienhold BJ, Gilley JE, Eigenberg RA. 2002. Mineralization of Manure Nutrients. Biological Systems Engineering: Papers and Publications, University of Nebraska, Lincoln.

Food and Agriculture Organization (FAO). 2006. World Reference Base for Soil Resources. FAO, Rome, Italy.

Goldberg N, Nachshon U, Argaman E, Ben-Hur M. 2020. Short term effects of livestock manures on soil structure stability, runoff and soil erosion in semi-arid soils under simulated rainfall. Geoscience 10: 213. DOI: 10.3390/geosciences10060213.

Gopinath KA, Saha S, Mina BL, Pande H, Kumar N, Srivastva AK, Gupta HS. 2009. Yield potential of garden pea (*Pisum sativum* L.) varieties, and soil properties under organic and integrated nutrient management systems. Arch Agron Soil Sci 55 (2): 157-167. DOI: 10.1080/03650340802382207.

Hadas A, Kautsky L, Goek M, Kara EE. 2004. Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. Soil Biol Biochem 36 (2): 255-266. DOI: 10.1016/j.soilbio.2003.09.012.

Horneck DA, Sullivan DM, Owen JS, Hart JM. 2011. Soil test Interpretation Guide. Oregon State University, Oregon, USA.

Jjagwe J, Chelimo K, Karungi J, Komakech AJ, Lederer J. 2020. Comparative performance of organic fertilizers in maize (*Zea mays* L.) growth, yield, and economic results. Agronomy 10 (1): 69. DOI: 10.3390/agronomy10010069.

Kareem I, Jawando OB, Eifediyi EK, Bello WB, Oladosu Y. 2017. Improvement of growth and yield of maize (*Zea mays* L.) by poultry manure, maize variety and plant population. Cercetări Agronomice în Moldova 4 (172): 51-64. DOI: 10.1515/cerce-2017-0035.

Khan AU, Iqbal M, Islam KR. 2007. Dairy manure and tillage effects on soil fertility and corn yields. Bioresour Technol 98 (10): 1972-1979. DOI: 10.1016/j.biortech.2006.07.041.

Magdoff FR, Amadon JF. 1980. Yield trends and soil chemical changes resulting from N and manure application to continuous corn. Agron J 72: 161-164. DOI: 10.2134/agronj1980.00021962007200010031x.

Melero S, Madejón E, Ruiz JC, Herencia JF. 2007. Chemical and biochemical properties of a clay soil under dryland agriculture system as affected by organic fertilization. Eur J Agron 26 (3): 327-334. DOI: 10.1016/j.eja.2006.11.004.

Montemurro F, Vitti C, Diacono M, Canali S, Tittarelli F, Ferri D. 2010. A three-year field anaerobic digestates application: Effects on fodder crops performance and soil properties. Fresenius Environ Bull 19 (9b): 2087-2093.

Okoroafor I, Okelola E, Edeh O, Nemehute V, Onu C, Nwaneri T, Chinaka G. 2013. Effect of organic manure on the growth and yield performance of maize in Ishiagu, Ebonyi State, Nigeria. IOSR J Agric Vet Sci 5: 28-31. DOI: 10.9790/2380-0542831.

Quansah GW. 2010. Effect of Organic and Inorganic Fertilizers and Their Combinations on the Growth and Yield of Maize in the Semi-Deciduous Forest Zone of Ghana. [Doctoral Dissertation]. Kwame Nkrumah University of Science and Technology, Kumasi. [Ghana]

Rao PC, Padmaja G. 2016. Soil quality and enhanced productivity through soil organic matter. Intl J Econ Plants 3 (3): 117-119.

Rasool A, Ghani A, Nawaz R, Ahmad S, Shahzad K, Rebi A, Ali B, Zhou J, Ahmad MI, Tahir MF, Alwahibi MS, Elshikh MS, Ercisli S. 2023. Effects of poultry manure on the growth, physiology, yield, and yield-related traits of maize varieties. ACS Omega 8 (29): 25766-25779. DOI: 10.1021/acsomega.3c00880.

Rayne N, Aula L. 2020. Livestock manure and the impacts on soil health: A review. Soil Syst 4 (4): 64. DOI: 10.3390/soilsystems4040064.

Reddy SA, Goroji PT, Ravalan BM. 2014. Assessment of soil NPK status under *Ceiba pentandra* plantation in Theni district of Tamil Nadu. Soil Environ 33 (1): 72-78.

Shi Z, Chen L, Cai C, Li Z, Liu G. 2009. Effects of long-term fertilization and mulch on soil fertility in contour hedgerow systems: A case study on steeplands from the Three Gorges Area, China. Nutr Cycl Agroecosyst 84: 39-48. DOI: 10.1007/s10705-008-9223-x.

Srivastava P, Singh R, Tripathi S, Singh H, Raghubanshi AS. 2016. Soil carbon dynamics and climate change: current agro-environmental perspectives and future dimensions. Energy Ecol Environ 1: 315-322. DOI: 10.1007/s40974-016-0024-9.

Stockmann U, Adams MA, Crawford JW et al. 2013. The knowns, known unknowns and unknowns of sequestration of soil organic carbon. Agric Ecosyst Environ 164: 80-99. DOI: 10.1016/j.agee.2012.10.001.

Whalen JK, Chang C, Clayton GW, Carefoot JP. 2000. Cattle manure amendments can increase the pH of acid soils. Soil Sci Soc Am J 64: 962-966. DOI: 10.2136/sssaj2000.643962x.

Yaduvanshi NPS. 2003. Substitution of inorganic fertilizers by organic manures and the effect on soil fertility in a rice–wheat rotation on reclaimed sodic soil in India. J Agric Sci 140 (2): 161-168. DOI: 10.1017/S0021859603002934.