INTERACTIVE EFFECTS OF COW DUNG AND FERTILIZER ON MAIZE SOIL PENETRATION RESISTANCE AND NITROGEN UPTAKE IN NORTHERN GUINEA SAVANNA

Khalid T. K.[1]*, Gaya M.I[3]., Kalu G[1]., A Ambi[1]., Adam J.J[1]., Abdulkadir K[1]., Malami M[2]. and Bilyaminu A.B[2].

1. *National Agricultural Extension Research and Liaison services (NAERLS), Ahmadu Bello University (ABU) Zaria, Nigeria.*
2. *Agricultural and Rural Management Training Institute (ARMTI), Ilorin, Nigeria. PMB. 1343*
3. *Division of Agricultural College (DAC) Samaru, Ahmadu Bello University (ABU) Zaria, Nigeria.*

***Corresponding E-mail:** tkhalid1991@yahoo.com

ABSTRACT

This study was conducted in the Samaru Northern Guinea Savanna of Nigeria to evaluate the effects of cow dung and nitrogen fertilizer on soil penetration resistance, nitrogen uptake, and maize (Zea mays L.) yield. The experiment was laid out in a Randomized Complete Block Design with three rates of cow dung (0, 3, and 6 t/ha) and four nitrogen rates (0, 50, 100, and 150 kg/ha), replicated three times. Soil penetration resistance was measured at 0, 10, 20 and 30cm depths. Measurement of nitrogen uptake in plant tissue and yield parameters (number of cobs, dry matter yield, grain yield, 1000 grain weight) of maize was collected at harvest. From the finding in this study, soil penetration resistance observed to increase with depth and significantly reduced by cow dung application, with the lowest values obtained at 6 t/ha. Nitrogen fertilizer alone had minimal effect on penetration resistance, while the combination of cow dung and nitrogen promoted better root penetration. Maize nitrogen uptake, number of cobs, dry matter yield, and grain yield were significantly enhanced by both cow dung and nitrogen fertilizer, with the highest performance observed at 3 t/ha cow dung and 150 kg/ha nitrogen. The interaction between cow dung and nitrogen was not significant, indicating that each amendment independently contributed to improved growth and yield. These results suggest that moderate cow dung application combined with appropriate nitrogen fertilization effectively reduces soil mechanical impedance, enhances nutrient uptake, and increases maize productivity in the Northern Guinea Savanna.

Keywords: Maize, cow dung, nitrogen fertilizer, soil penetration resistance, nitrogen uptake, Northern Guinea

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops cultivated worldwide and serves as a major source of food, feed, and industrial raw materials. It plays a significant role in food security and economic development in many developing countries. However, maize productivity is often limited by poor soil fertility and unfavorable soil physical conditions, which restrict plant growth and reduce yield potential (Lal, 2020).

Among the soil physical constraints affecting crop production, soil compaction is a major problem in intensively cultivated agricultural soils. Soil compaction reduces pore space, limits water infiltration, and restricts root development. These conditions reduce the ability of plant roots to explore soil for water and nutrients, thereby negatively affecting crop performance (Hamza and Anderson, 2005). Consequently, evaluating soil compaction is important for understanding soil conditions that influence crop growth. Soil penetration resistance is commonly used as an indicator of soil compaction and soil strength. High soil penetration resistance can restrict root elongation and reduce root penetration into deeper soil layers. This condition limits water and nutrient uptake by crops and can ultimately reduce crop productivity (Bengough et al., 2021). Therefore, improving soil physical conditions that reduce penetration resistance is essential for sustainable crop production. Organic amendments such as cow dung have been widely recognized for their ability to improve soil physical and chemical properties. The addition of cow dung increases soil organic matter content, improves soil aggregation, enhances soil porosity, and reduces soil bulk density. These improvements help to reduce soil penetration resistance and create a favorable environment for root growth and nutrient absorption (Blanco-Canqui and Lal, 2020).

In addition to improving soil structure, crops require adequate nutrient supply for optimal growth and development. Nitrogen is one of the most essential nutrients required for plant growth because it is a major component of chlorophyll, proteins, and enzymes involved in plant metabolic processes. Adequate nitrogen availability enhances vegetative growth, photosynthesis, and ultimately crop yield (Marschner, 2012). However, continuous reliance on inorganic nitrogen fertilizers alone may not sufficiently improve soil physical properties or maintain long-term soil productivity.

Integrated nutrient management, which involves the combined use of organic and inorganic nutrient sources, has been recommended as a sustainable strategy for improving soil fertility and maintaining soil quality. Organic materials such as cow dung contribute organic matter that improves soil structure, while inorganic fertilizers provide readily available nutrients required for crop growth (Vanlauwe et al., 2020. The integration of these nutrient sources can also enhance nutrient uptake by crops by improving root growth and soil nutrient availability. Despite the recognized benefits of organic and inorganic fertilizers, limited information is available on how their combined application influences soil penetration resistance and nitrogen uptake under maize production. Understanding these interactions is important for developing sustainable soil management practices that improve soil physical conditions and nutrient utilization efficiency. Therefore, this study was conducted to evaluate the effects of cow dung and nitrogen fertilizer on soil penetration resistance and nitrogen uptake under maize production.

Materials and Methods

Experimental Site

Experimental Farm of the Institute for Agricultural Research (IAR), Samaru, during the 2020 raining season. Samaru is located at the geographic coordinates of latitude 11º 11'N and longitude 07º 38'E, with an altitude of 686 m above sea level in the Northern Guinea Savanna Ecological zone of Nigeria. The climate of the study area is characterized by the occurrence of distinct wet and dry seasons (Oluwasemire and Alabi, 2004). The area has a mean annual rainfall of about 1011 ±1610 mm, with an average intensity of 50 mm/hr. A mean annual temperature of about 23°C has also been recorded for the area (IAR Met. Unit, 2017). The annual rainfall attains its highest value in August and drops rapidly to its lowest in October.

Pre-Planting Soil Sampling and Analysis

Before the establishment of the experiment, soil samples were collected to determine the initial soil properties of the experimental site. Composite soil samples were randomly collected from the topsoil (0–20 cm depth) using a soil auger across the experimental field. The samples were air-dried, crushed, and sieved through a 2-mm mesh prior to laboratory analysis. The soil samples were analyzed for selected physical and chemical properties to establish the baseline soil fertility status of the study area.

Particle size distribution was determined using the hydrometer method as described by Gee and Or, (2002), using distilled water and calgon (sodium hexametaphosphate) solution as dispersing agents. Textural classes were obtained using the textural triangle USDA (2022). The chemical properties of the soil samples were determined by using the following methods:soil pH was determined electrometrically in a soil solution ratio of 1:2.5, using the glass electrode pH meter. The organic carbon was analysed by wet oxidation method of Walkley and Black as modified by (Nelson and Sommers, 1982). Total nitrogen by the micro-Kjeldahl distillation procedure according to (Bremmer, 1996), available phosphorus was determined by the Bray No. 1 acid fluoride method (Nelson and Sommers, 1982).Exchangeable bases (Ca, Mg, K, and Na) were extracted in 1N NH_4OAC solution according to Chapman (1965). Ca and Mg were determined by the Atomic Absorption Spectrophotometer while K and Na was determined using the flame photometer (Juo, 1979).The micronutrients (Cu, Fe, Mn and Zn) content of the soil were extracted with 0.1 M HCl and determined by AAS, according to the method described by Bruce and Whiteside (1984). Effective cation exchange capacity was determined by summation of all exchangeable bases and exchangeable acidity.

Organic manure Collection and Preparation

The organic manure used for the field experiments were cow dung. The cow dung was obtained from the dairy cattle pen of the National Animal Production Research Institute (NAPRI), Shika, ABU Zaria. The wet fresh cow dung collected was heaped on the ground surface and then covered so as to protect it from the direct sunlight. The dried cow dung was sieved through 10 mm mesh sieve. Sub samples were taken and stored for chemical analysis.

The sub sample for the analysis was sieved through 2 mm mesh sieve. It was chemically characterized for N, P and K contents. The total N was determined by the Micro-kjeldhal wet digestion method Bremmer, (1996). The phoshorus in the digest was determined colorimetrically by the spectrometer and K was determined using the flame photometer.

Experimental Design and Treatments

The experiment consisted of two factors: cow dung and nitrogen fertilizer. Cow dung was applied at three rates: 0, 3, and 6 t ha^{-1}, while nitrogen fertilizer was applied at four rates: 0, 50, 100, and 150 kg N ha^{-1} in form of Urea, Single Super Phosphate (SSP) and Murate of Potash (MOP).

The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications to minimize field variability. Cow dung was applied and incorporated into the soil 2 weeks before planting to allow partial decomposition and nutrient release, while nitrogen fertilizer was applied according to recommended agronomic practices. Urea was split applied at 2 and 6 weeks after planting (WAS) using basal application method, while muriate of potash and single super phosphate were applied with first split dose of N at 2 WAS

Land Preparation and Crop Establishment

The experimental field of 5m by 5m size was cleared and prepared using conventional tillage methods to obtain a suitable seedbed. Maize seed (Oba Supar 2) was planted at the recommended spacing (75 by 25cm) for optimal plant population. Standard agronomic practices including thinning, weeding, and pest control were carried out throughout the growing season to ensure proper crop growth.

Cow dung was applied and incorporated into the soil before planting, while nitrogen fertilizer was applied in split applications during the crop growth period to enhance nitrogen availability and reduce nutrient losses.

Measurement of Soil Penetration Resistance

Soil penetration resistance (PR), an indicator of soil compaction, was measured during the maize growing period. Measurements were taken when the soil was at field capacity to ensure consistency. A soil penetrometer was used to record PR at depths of 0–30 cm. The instrument was pushed vertically into the soil, and readings were taken at every 10 cm interval (0, 10, 20, and 30 cm) within each plot. Before measurement, the surface soil was carefully excavated to the desired depth to ensure accurate contact between the penetrometer and the soil profile. Each reading was recorded, and measurements were repeated across all experimental plots to assess the effect of cow dung and nitrogen fertilizer on soil mechanical impedance

Determination of Nitrogen Uptake

Samples of leaf and stem from 5 randomly selected plants were collected at the peak growth stage to determine nitrogen uptake by maize plants. The plant samples were oven-dried to constant weight and ground into fine powder for laboratory analysis. Nitrogen concentration in the plant tissue was determined using Kjeldehl method. Nitrogen uptake was calculated by multiplying the nitrogen concentration by the dry matter yield of the plant samples.

Determination of Maize Yield parameters

I. **Number of cobs**: total number of cobs obtained from each plot was recorded

ii. **Dry matter yield (kg/ha):** the dry matter (Dry matter) yield produced of the each plot was recorded in kilo gram. It was done by measuring remaining portion of the plant after cobs were removed. The measurement was done with beam balance after drying.

iii. **Grain yield (kg/ha):** The air dried cobs were threshed, cleaned and weight of grain recorded on the basis of grain yield per net plot. Grain yield per ha was calculated and expressed in tones per hectare.

iv. **1000-grain weight (g)*:*** The weight of thousand grains (g) was recorded from grain samples drawn from the produce obtained from each of the plot.

Statistical Analysis

Data collected from the experiment were subjected to analysis of variance (ANOVA) using SAS package (SAS, 2020). The analysis was performed to determine the effects of cow dung, nitrogen fertilizer, and their interaction on soil penetration resistance and nitrogen uptake. Where significant differences occurred, treatment means were separated using the Least Significant Difference (LSD) test at the 5% probability level**.**

Result and Discussion

Characterization of Cow Dung Used for the Study

The chemical analysis of the cow dung used in the experiment showed that it contained 14.5 g kg^{-1} nitrogen, 13.00 mg kg^{-1} phosphorus, and 0.68 cmol kg^{-1} potassium (Table 1). These results indicate that cow dung is a valuable source of essential macronutrients required for crop growth and soil fertility improvement. The relatively high nitrogen content suggests its potential to supply nitrogen gradually through mineralization, thereby supporting plant growth and improving nutrient availability in the soil. The presence of phosphorus and potassium further indicates that cow dung can contribute to improved root development, nutrient uptake, and overall crop performance. The application of organic manures such as cow dung has been widely reported to enhance soil nutrient status and improve soil productivity in cropping systems (Taiz, 2022; Vanlauwe et al., 2020).

Table 1. Characterization of cow dung used for the study

Nitrogen (%)	Phosphorus (%)	Potassium (%)
1.45	0.0013	0.0266

Pre-planting Soil Characterization

Result of the pre-planting soil is presented in Table 2. The result showed that the texture of the soil was **loamy**, composed of 500 g/kg sand, 400 g/kg silt, and 100 g/kg clay, which indicates a balanced soil structure that supports adequate aeration, water retention, and root penetration factors shown to positively influence nutrient availability and crop establishment (Chang Ye *et al.*, 2024). Soil pH was slightly acidic (6.05 in H_2O and 4.98 in $CaCl_3$), typical of tropical soils; this acidity can affect nutrient solubility and availability, particularly phosphorus, which tends to be less available under lower pH conditions.

Organic carbon was moderate at 4.2 g/kg, reflecting a soil with some capacity for sustaining soil structure and microbial activity, while total nitrogen was low at 2.1 g/kg, suggesting limited initial nitrogen reserves for maize growth (Agono Awwal, Angyu & Afolabi, 2025). Available phosphorus (14.71 mg/kg) was at a low to moderate level, consistent with findings that tropical soils often have limited plant-available P due to fixation by iron and aluminum oxides in acidic conditions. Exchangeable potassium was low (0.09 cmol/kg), indicating potential potassium limitation for crop growth without amendment.

Electrical conductivity (1.35 dS/m) suggests moderate salinity, but at this level maize growth is typically not adversely affected. Overall, these results suggest a **moderate fertile but nutrient-limited soil**, justifying the experimental application of cow dung and nitrogen fertilizer to improve nutrient supply, enhance soil fertility, and support maize growth.

Table 2. Characterization of field soil prior to treatment

Parameter	
Sand (g/kg)	500
Silts (g/kg)	400
Clay (g/kg)	100
Texture	loam
pH (H_2O)	6.05
pH ($CaCl_3$)	4.98
Org. Carbon (g/kg)	4.2
Total N (g/kg)	2.1
Av. P (mg/kg)	14.71
EC (dms^{-1})	1.35
K (C mol/kg)	0.09

3.3 Effect of Cow Dung and Nitrogen Rates on Soil Penetration Resistance

Result of the soil penetration resistance presented in Table 3 indicate an increased with depth across all treatments, reflecting the natural trend in cultivated soils where upper layers are less dense due to tillage and surface management, while deeper layers resist cone penetration. Application of cow dung significantly reduced PR at all depths, with the lowest values recorded at 6 t/ha. This reduction is likely due to the loosening effect of the organic amendment on the soil matrix and its contribution to improved water retention, which decreases the mechanical resistance of the soil to root penetration (Blanco-Canqui & Lal, 2020; Zong *et al.*, 2025). Cow dung also provides essential nutrients that can stimulate early root development, enabling roots to penetrate the soil more easily, which indirectly lowers PR values in plots receiving higher rates.

Nitrogen fertilizer alone had minimal effect on PR, as its primary function is nutrient supply rather than altering the soil's mechanical properties (Keller et al., 2020). However, the interaction between cow dung and nitrogen fertilizer was significant at several depths, suggesting that the combined application promotes more vigorous root growth. Enhanced root proliferation in nutrient-rich conditions allows roots to explore deeper layers more effectively, contributing to lower measured soil resistance. Therefore, the observed reductions in PR under integrated cow dung and nitrogen treatments likely result from improved root development and enhanced water availability, rather than direct changes to soil structure. These findings indicate that integrated organic–inorganic nutrient management can effectively reduce soil mechanical impedance, facilitating deeper root growth and potentially improving nutrient and water uptake by maize (Vanlauwe *et al.*, 2010; Liu *et al.*, 2023).

Table 3: Effect of Cow Dung and Nitrogen Rates on Soil Penetration Resistance

Treatments	Penetration Resistance (Kgf/cm²)			
	0cm	10cm	20cm	30cm
Cow dung (t/ha)				
0	0.79[a]	1.21	1.48[a]	1.56[a]
3	0.69[ab]	1.07	1.36[ab]	1.41[ab]
6	0.62[b]	1.05	1.19[b]	1.37[b]
Mean	0.69	1.11	1.34	1.43
S.E±	0.07*	0.07	0.07*	0.06*
N rate (kg/ha)				
0	0.64	1.10	1.41	1.51
50	0.75	1.21	1.37	1.35
100	0.74	1.11	1.28	1.34
150	0.67	1.03	1.31	1.53
Mean	0.69	1.11	1.34	1.43
S.E±	0.08	0.08	0.08	0.07
Interaction				
CD×N	**	NS	*	**

3.4 Effect of Cow Dung and Nitrogen Rates on Maize Nitrogen uptake and Yield Parameters

The results indicate that both cow dung and nitrogen fertilizer positively influenced maize growth, yield components, and nitrogen uptake, though their interaction was not significant. Application of cow dung at 3 t/ha significantly increased nitrogen uptake (59.50 kg/ha), number of cobs (292), dry matter yield (5794.4 kg/ha), and grain yield (3349.2 kg/ha) compared to the control (0 t/ha). The slight reduction in uptake and grain yield at 6 t/ha, compared to 3 t/ha, may indicate that excessive organic input does not proportionally increase nutrient availability or could have delayed nutrient mineralization, a phenomenon reported in similar studies (Mollier & Pellerin, 2022). Overall, the application of moderate levels of cow dung improved plant nutrient uptake and supported higher yield formation, likely due to a combination of nutrient supply and improved soil conditions.

Nitrogen fertilizer significantly enhanced all measured parameters, with the highest values observed at 150 kg/ha (nitrogen uptake 59.11 kg/ha, 298 cobs, 6063.5 kg/ha dry matter yield, 3580.1 kg/ha grain yield). The steady increase in nitrogen uptake and yield with increasing N rates reflects the essential role of nitrogen in promoting vegetative growth, photosynthetic efficiency, and grain formation in maize (Marschner, 2012; Liu *et al.*, 2023). The absence of a significant interaction between cow dung and nitrogen fertilizer suggests that each factor independently contributed to yield improvement, with cow dung mainly supplying slow-release nutrients and improving soil fertility, while nitrogen fertilizer provided readily available N to support rapid growth

These findings highlight that integrated nutrient management combining moderate levels of organic amendment with appropriate N fertilization can optimize maize growth and yield. The significant improvements in nitrogen uptake, cob number, and grain yield emphasize the importance of adequate nutrient supply for enhancing both aboveground biomass and harvestable yield components in maize under Northern Guinea Savanna conditions (Vanlauwe *et al.*, 2020; Zong *et al.*, 2025).

Table 4: Effect of cow dung and nitrogen rates on maize yield parameters

Treatments	Uptake (kg/ha)	Number of cobs	1000 Grain Weight (g)	Dry matter Yield (kg)	Grain Yield (kg)
Cow dung (t/ha)					
0		50.94[b]	245[b]	4335.6[b]	2557.8[b]
3		59.50[a]	292[a]	5794.4[a]	3349.2[a]
6		54.36[b]	288[a]	5229.0[ab]	3235.8[a]
Mean		54.96	275	5119	3047.6
S.E±		5.69**	276**	359**	1.03**
N rate (kg/ha)					
0		46.89[b]	234[b]	4003.2[b]	2273.1[c]
50		56.41[a]	277[a]	5184.0[a]	3027.2[b]
100		57.33[a]	291[a]	5228.1[a]	3309.9[ab]
150		59.11[a]	298[a]	6063.5[a]	3580.1[a]
Mean		54.96	275	5119	3047.6
S.E±		4.93**	239**	409	161**
Interaction					
CD×N		NS	NS	NS	NS

Conclusion and Recommendation

The study demonstrated that both cow dung and nitrogen fertilizer significantly enhanced maize growth, nitrogen uptake, and yield, while cow dung also reduced soil penetration resistance. Moderate cow dung application (3 t/ha) improved root penetration and water availability, whereas nitrogen fertilizer (150 kg/ha) maximized growth and yield components. Although their interaction was not statistically significant, each amendment independently contributed to improving maize performance and soil conditions.

Based on these findings, farmers in the Northern Guinea Savanna are recommended to adopt **integrated nutrient management**, applying moderate cow dung (3 t/ha) alongside appropriate nitrogen fertilizer to optimize maize growth, nitrogen uptake, and grain yield. Regular use of organic amendments can help alleviate soil compaction, promoting deeper root growth and better access to nutrients and water. Additionally, long-term studies are encouraged to evaluate the cumulative effects of repeated cow dung and nitrogen applications on soil physical properties, nutrient use efficiency, and sustainable maize production across different agro-ecological zones.

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