

Effects of Poultry Manure Rates and Rhizobial Inoculation on Vegetative Growth of Groundnut in Sudan Savannah of Nigeria

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Abstract

Groundnut (*Arachis hypogaea* L.) is a vital crop in the Sudan savannah of Nigeria, contributing significantly to nutrition, livelihoods, and soil fertility. However, its yield remains low due to poor soil fertility and limited use of organic and biological inputs. A field experiment was conducted at Gaya, Kano State, during the 2024 rainy season to evaluate the effects of microbial inoculation and poultry manure on groundnut vegetative growth. The study employed a $2 \times 2 \times 3$ factorial arrangement in a randomized complete block design (RCBD) with three replications (12 treatment combinations). Treatments comprised two varieties (Samnut 20 and Samnut 21), two microbial inoculation levels (inoculated and non-inoculated), and three poultry manure rates (0, 5, and 10 t ha^{-1}). Data on plant height, number branches, leaf count, and leaf area were recorded at 3, 5, and 7 weeks after sowing (WAS). Poultry manure significantly ($p < 0.05$) influenced all growth parameters, with 10 t ha^{-1} producing 28-42 % height values than the control. At 7 WAS, plant under 10 t ha^{-1} achieved the tallest height (29.16 cm), greatest branch number (40.95), highest leaf count (163.89), and largest leaf area (29.16 cm^2). Microbial inoculation showed no significant effect on most parameters, though minor interactions with variety occurred at early stages. Samnut 21 exhibited greater vegetative vigor than Samnut 20. Overall, Poultry manure, at 10 t ha^{-1} markedly improved groundnut growth under the sandy soils of the Sudan savannah, underscoring its value as a sustainable soil fertility amendment. The limited response to microbial inoculation suggests the need for further testing of site-specific strains for enhanced compatibility and field performance.

Keywords: Groundnut, Poultry Manure, Microbial Inoculation, Vegetative Growth, Sudan Savannah.

Introduction

Groundnut is an essential leguminous crop extensively grown in the Sudan savannah ecological area, prized for its nutritional value, economic significance, and soil fertility (Ibrahim *et al.*, 2015). Despite its importance, groundnut yields in this region remain low due to poor soil fertility, limited use of inputs, and suboptimal crop management practices

(Ibrahim, 2015). Enhancing groundnut productivity is critical for food security and income generation among smallholder farmers in the Sudan savannah (Benjamin *et al.*, 2020).

Poultry manure is a rich source of essential nutrients, organic matter, and beneficial microbes, which collectively enhance soil structure, water retention, and nutrient cycling (Simeon *et al.*, 2019). According to these investigations, poultry manure is fundamentally composed of fecal waste derived from domesticated birds alongside bedding products such as wood shavings, which, when added to soil, can augment its biological, physical, and chemical properties. According to Koyyalamudi *et al.* (2024), biofertilizers and organic manure have been found to positively interact in leguminous plants. The application of organic manure enhances soil fertility, boost the ability of the soil to retain water, encourages the presence of beneficial organisms, and increases microbial biomass (Esmaeilian *et al.*, 2012). Organic matter increases soil fertility and crop production potential, possibly by changing the physical and chemical properties of soil (Muhammad and Khattak, 2009). Organic matter increases soil fertility and crop production potential, possibly by changing the physical and chemical properties of soil (Muhammad and Khattak, 2009).

Inoculation with effective strains of rhizobia has been proven to promote nodule occurrence, boost nitrogen fixation, and ultimately improve pod yields, thus establishing microbial inoculation as an environmentally sustainable and cost-effective approach to enhance groundnut production (Godar *et al.*, 2023). Biological nitrogen fixation (BNF) through symbiotic association with rhizobia bacteria is a key factor in improving groundnut growth and yield, especially in nutrient-poor savannah soils where synthetic nitrogen fertilizers are often unaffordable or unavailable (Ibrahim, 2015). Biofertilizers play a major role in meeting a crop's nutritional needs by facilitating biological nitrogen fixation and solubilizing insoluble phosphorus sources (PSB) through microbial activity. Key phosphate-solubilizing bacteria and fungi (such as *Bacillus*, *Rhizobium*, *Aspergillus*, and *Penicillium*) convert unavailable phosphorus into plant-accessible forms, while nitrogen-fixing microbes (like *Rhizobium* and *Azotobacter*) supply crops with essential nitrogen, reducing the need for chemical fertilizers (Parus *et al.*, 2022). Complementing microbial inoculation, the application of organic amendments such as poultry manure plays a significant role in improving soil fertility by supplying essential nutrients (N, P, K) and enhancing soil physical and biological properties (Mulugeta A. & Getahun B. 2019 & Weijia *et al.*, 2023).

Groundnut production in this area, continues to be low, primarily because of inadequate soil fertility, insufficient organic matter, and ineffective nutrient management practices (Ibrahim *et al.*, 2015). Yields continue to lag well behind their potential largely because of ongoing soil fertility issues, unpredictable rainfall patterns, and ineffective agricultural practices, which entail a limited application of organic and biological soil additives (A. A. Mukhtar, 2011 and Ladan *et al.*, 2020). The low productivity can also be attributed to poor soil conditions, erratic weather, and below-per agronomic methods that include minimal use of synthetic fertilizers and improved varieties (Ladan *et al.*, 2020). Additionally,

excessive reliance on inorganic fertilizers has been associated with soil degradation, loss of biodiversity, and other environmental concerns, which risks the sustainability of agricultural practices. The combination of microbial inoculants, like rhizobia, and organic enhancements such as poultry manure can provide a viable, cost-effective alternative that enhances nutrient cycling, improves soil structure, and increases crop yield (Li *et al.*, 2022). Chemical fertilizers are often expensive and may have negative environmental impacts, making them less accessible and sustainable for smallholder farmers (Abdulkadir *et al.*, 2021). The combined effects of microbial inoculation and poultry manure rates on groundnut growth and yield in this zone remain underexplored.

Groundnut (*Arachis hypogaea* L.) production in this area remains consistently low due to inadequate soil fertility and restricted access to chemical fertilizers. Nitrogen is an essential nutrient for groundnuts cultivation, but smallholder farmers often find inorganic fertilizers to be either too expensive or environmentally harmful (Abdulkadir *et al.*, 2021). The use of microbial inoculation, especially with rhizobia, presents a sustainable solution by promoting biological nitrogen fixation, which can lead to improved plant growth, increased shoot biomass, and higher yields in groundnut varieties (Doloum *et al.*, 2017).

Poultry manure, as an organic amendment, further addresses soil fertility constraints by increasing organic matter and supplying a broad spectrum of nutrients. Poultry manure application significantly raises levels of organic matter, total nitrogen, phosphorus, potassium, and other essential nutrients in the soil, leading to improved soil fertility and crop growth (Okonwu and Mensah, 2012). There is a need to determine the best combinations and rates of microbial inoculants and organic amendments for maximum groundnut yield in the specific conditions of the Sudan savanna.

Materials and Methods

Description of the Study Area

Field experiments were conducted during the 2024 rainy season at the Teaching and Research Farm of Aliko Dangote University Kano located in Gaya local government area (LGA) of Kano State, Nigeria. The experimental site lies between latitude 11.7471° N and longitude 8.5247° E, at an altitude of approximately 430 meters above sea level (Garba *et al.* 2025).

The area falls within the Sudan savannah agro-ecological zone, characterized by a tropical continental climate within a distinct wet and dry season. The mean annual rainfall ranges from 850 to 1000 mm, occurring mainly between June and September, while the mean annual temperature varies from 25 °C to 34 °C. Relative humidity is generally higher during the rainy season and low during the dry season.

The soils of the study area are predominantly sandy loam, derived from sandstone and basement complex materials, with low to moderate fertility, slightly acidic to neutral pH, and moderate water holding capacity, which are typical features of soils in the Sudan savannah zone suitable for groundnut cultivation.

Soil Sample Collection and Analyses

Before planting, composite soil samples (0-15 cm depth) were collected from the experimental site in Gaya to determine the initial physico-chemical properties. Samples were air-dried, sieved through a 2 mm mesh, and analysed using standard procedures as described. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). The soil pH was measured in a 1:2.5 soil-water suspension using a glass electrode pH meter (Jackson, 1962). Organic carbon was determined by Walkley and Black wet oxidation method (Walkley and Black, 1934), and organic matter was calculated by multiplying organic carbon by 1.724. Total nitrogen was determined by the Kjeldahl digestion method (Bremner, 1965). Available phosphorus was extracted by the Bray-1 method and determined colorimetrically (Bray and Kurtz, 1945). Exchangeable cations (Ca^{2+} , Mg^{2+} , K^{+} , Na^{+}) were extracted using 1 N ammonium acetate (pH 7.0) and measured with an atomic absorption spectrophotometer, except for K^{+} and Na^{+} which were determined using a flame photometer (Thomas, 1982). The cation exchange capacity (CEC) was determined ammonium acetate saturation (Black, 1982).

Treatments and Experimental Design

The experiment was laid out in a $2 \times 2 \times 3$ factorial arrangements fitted into a Randomized Complete Block Design (RCBD) with three replications, giving a total of 12 treatment combinations. The treatment factors include microbial inoculation: inoculated and uninoculated, groundnut variety: SAMNUT 20 and SAMNUT 21, and poultry manure rates: 0, 5, 10 t ha⁻¹. The inoculant used was a commercial *Bradyrhizobium japonicum* strain specific for groundnut obtain from IITA, Kano State. Each gram contained approximately 1.0×10^9 viable cells (CFU), with peat as the carrier material. The inoculant was stored at 4 °C. Poultry manure was collected from a local broiler farm, air-dried and incorporated into the soil two weeks before planting at rates equivalent to 0, 5, and 10 t ha⁻¹, on an oven-dry weight basis.

Plot Management

Each experimental plot measured 3 m × 3 m, with 0.5 m spacing between plots and 1.0 m between blocks. Groundnut was sown at a spacing of 50 cm × 20 cm, giving a plant population of approximately 200,000 plants ha⁻¹.

Weeding was carried out manually as needed. Insect pest control was achieved by spraying cypermethrin (2.5 EC) at a rate of 30 ml per 15 L water every two weeks, based on observed leaf defoliation and aphid infestation during the early podding stage. The frequency was increased to weekly only under high pest pressure (aphids and leaf miners).

Experimental Material Source

The inoculum that was used for the study was obtained from the IITA Kano station. Samnut 20 was obtained from the Kano State Agricultural and Rural Development Authority (KNARDA), and Samnut 21 was obtained from the IITA Kano station.

Data Collection

Ten plants were randomly sampled per plot for measurement of vegetative parameters at 3, 5, and 7 weeks after sowing (WAS).

- Plant height (cm): measured from the soil surface to the apex of the main stem.
- Number of branches: counted manually
- Number of leaves: counted manually
- Leaf area (cm²): determined using the formula

Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) using JMP (John's Macintosh Project) version 16.0 (SAS Institute, 2021). Where significant differences were observed. Treatment means were separated using the student-Newman-Keuls test at a 5% significance level in accordance.

Results

Baseline of Physical and Chemical Properties of Gaya Soil

The soil at Gaya, Kano State, is classified as loamy sand, with low fertility indicators for nitrogen, organic carbon, organic matter, and cation exchange capacity but moderate phosphorus and a slightly acidic pH (6.37).

Table 1: Baseline of Physical and Chemical Properties of Gaya Soil

Soil parameter	Gaya	Unit
Bulk Density	1.46	g/cm ³
Sand	75.30	%
Silt	15.10	%
Clay	9.6	%
Textural class	loamy sand	-
pH	6.37	-
EC	0.01	dSm ⁻¹
Total Nitrogen	0.04	%
Organic Carbon	0.34	%
Organic Matter	0.58	%
Available Phosphorus	13.91	mg kg ⁻¹
Exchangeable Na	0.03	cmol(+)/kg
Exchangeable Ca	2.01	cmol(+)/kg
Exchangeable Mg	0.80	cmol(+)/kg
Exchangeable K	0.12	cmol(+)/kg

Soil parameter	Gaya	Unit
Al ⁺ H	1.51	cmol(+)/kg
EB	3.05	cmol(+)/kg
CEC	3.05	cmol(+)/kg

BD= Bulk Density, CEC= Cation Exchange Capacity, EB= Exchangeable Bases, P= Phosphorus K= Potassium

Impact of Poultry Manure Rates and Microbial Inoculation on Groundnut Plant Height

Application of poultry manure had a significant effect ($p < 0.05$) on groundnut plant height at 3, 5, and 7 weeks after sowing. The tallest plants were consistently recorded under 10 t ha⁻¹, with mean values of 15.21 cm, 22.36 cm, and 29.16 cm at 3, 5, and 7 WAS, respectively. In contrast, the shortest plants occurred in the control 0 t ha⁻¹ with values of 13.63 cm, 17.94 cm, and 23.97 cm.

Microbial inoculation did not significantly influence plant height at any stage, as inoculated and non-inoculated plants had comparable values. Similarly, varietal differences were non-significant, with Samnut 20 and Samnut 21 recording similar plant heights across growth stages. And also, no significant interactions were observed among poultry manure, microbial inoculation, and variety.

Table 2: Effect of Poultry Manure, Microbial Inoculation, and Variety on Groundnut Plant Height (cm) at Different Growth Stages in Gaya.

Treatments	3 WAS	5 WAS	7 WAS
Poultry Manure (PM)			
0 t h ⁻¹	13.63b	17.94b	23.97b
5 t h ⁻¹	14.18b	18.71b	26.14b
10 t h ⁻¹	15.21a	22.36a	29.16a
P-value	0.0025*	< 0.0001*	0.0004*
SE±	0.27	0.70	0.77
Inoculation (I)			
NO	14.53a	19.49a	26.63a
N1	14.15a	19.85a	26.22a
P-value	0.2033^{NS}	0.3569^{NS}	0.6651^{NS}
SE±	0.23	0.59	0.64
Variety (V)			
Samnut 20	14.33a	19.19a	26.31a
Samnut 21	14.35a	20.21a	26.55a
P-value	0.8844^{NS}	0.0876^{NS}	0.6396^{NS}
SE±	0.22	0.56	0.62
Interaction			
P×I	NS	NS	NS
P×V	NS	NS	NS
I×V	NS	NS	NS

P×I×V	NS	NS	NS
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WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Different

Impact of Poultry Manure Rates and Microbial Inoculation on the Number of Branches in Groundnut Varieties.

The application of poultry manures significantly ($p < 0.05$) influenced groundnut branches at all growth stages in Gaya (Table 4.3). At 3 weeks after sowing (WAS), plants that received 10 t ha^{-1} produced the highest number of branches (13.00), which was significantly greater than the control (10.41). Similarly, at 5 WAS, the 10 t ha^{-1} treatment maintained superiority (27.22) over 0 t ha^{-1} (21.25), while 5 t ha^{-1} (23.69) remained intermediate. At 7 WAS, 10 t ha^{-1} (40.95) and 5 t ha^{-1} (38.12) significantly exceeded the control (33.10). However, microbial inoculation did not significantly affect branching at any stage and varietal differences were observed at later stages, Samnut 21 consistently produced more branches than Samnut 20, with significant differences recorded at 5 and 7 WAS. At 3 WAS, the difference between varieties was not statistically significant.

Table 3: Effect of Poultry Manure, Microbial Inoculation, and Variety on Groundnut Branches at Different Growing Stages in Gaya

Treatments	3 WAS	5 WAS	7 WAS
Poultry Manure (PM)			
0 t ha^{-1}	10.41b	21.25b	33.10b
5 t ha^{-1}	11.89a	23.69b	38.12a
10 t ha^{-1}	13.00a	27.22a	40.95a
P-value	0.0029*	0.0009*	0.0042*
SE±	0.47	1.01	1.61
Inoculation (I)			
No	11.90	24.69	38.84
N1	11.63	23.41	35.94
P-value	0.6645^{NS}	0.4053^{NS}	0.2185^{NS}
SE±	0.38	0.84	1.34
Variety (V)			
Samnut 20	11.38	22.76	35.49
Samnut 21	12.20	25.50	39.51
P-value	0.0922^{NS}	0.0189*	0.0347*
SE±	0.37	0.81	1.13
Interaction			
P×I	NS	NS	NS
P×V	NS	NS	NS
I×V	NS	NS	NS
P×I×V	NS	NS	NS

WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Difference.

Impact of Poultry Manure Rates and Microbial Inoculation on the Number of Leaves in Groundnut Varieties.

The number of leaves of groundnut was significantly influenced by poultry manure application at all stages of growth, whereas microbial inoculation showed no significant effect. Variety exerted a significant influence from 5 weeks after sowing (WAS).

Table 4: Effect of Poultry Manure, Microbial Inoculation, and Variety on Number of Leaves of Groundnut at Different Growing Stages in Gaya

Treatments	3 WAS	5 WAS	7 WAS
Poultry Manure (PM)			
0 t h ⁻¹	41.41b	83.58b	133.50b
5 t h ⁻¹	47.39a	93.29b	152.50a
10 t h ⁻¹	51.58a	106.50a	163.89a
P-value	0.0027*	0.0013*	0.0047*
SE±	1.82	3.93	6.31
Inoculation (I)			
No	47.41	98.09	155.48
N1	46.18	90.81	144.44
P-value	0.5944^{NS}	0.1690^{NS}	0.2372^{NS}
SE±	1.52	3.28	5.26
Variety (V)			
V1	45.31	89.59	142.67
V2	48.45	99.89	158.11
P-value	0.1010^{NS}	0.0247*	0.0385*
SE±	1.45	3.14	5.04
Interaction			
P×I	NS	NS	NS
P×V	NS	NS	NS
I×V	NS	NS	NS
I×V	NS	NS	NS

WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Difference.

Impact of Poultry Manure Rates and Microbial Inoculation on Leaf Area (Cm²) in Groundnut Varieties

The application of poultry manures significantly ($p < 0.05$) influenced groundnut leaf area across the sampling stages (3, 5, and 7 weeks after sowing, WAS). At 3 weeks after sowing (WAS), plants treated with 10 t ha⁻¹ poultry manure recorded the highest leaf area (8.95), followed by 5 t/ha (7.73), while the lowest leaf area was observed in the control (6.66). A

similar pattern was maintained at 5 WAS, with 10 t/ha producing 9.39 compared to 8.08 under 5 t/ha and 6.70 in the control. By 7 WAS, the highest leaf area was still associated with 10 t/ha (29.16), whereas 5 t/ha and control produced 26.14 and 23.97, respectively. In contrast, microbial inoculation, varietal and did not exert significant effect, but regarding interaction, no significant interactions were observed among poultry manure, inoculation, and variety. However, a significant inoculation by variety interaction was detected at 3 and 5 WAS, though this did not persist at 7 WAS.

Table 5 showed the results of interaction effects of inoculation and variety on leaf area of groundnut at Gaya experimental sites. The interaction effect between inoculation and groundnut variety significantly influenced the leaf area at both 3 and 5 WAS. At 3 WAS, for Samnut 20, the one with inoculation (N1) recorded a higher leaf area (8.11 cm²) compared to the non-inoculated one (No), which recorded 7.68 cm². Similarly, for Samnut 21 at 3 WAS, the non-inoculated treatment (No) recorded a higher leaf area (8.23 cm²) than the inoculated one (N1), which was recorded at 6.82 cm².

At 5 WAS, a similar trend was observed. For Samnut 20, the inoculated treatment (N1) resulted in a higher leaf area (8.45 cm²) compared to the non-inoculated treatment (No), which recorded 7.79 cm². Conversely, for Samnut21 at 5 WAS, the non-inoculated treatment (No) again recorded a higher leaf area (8.53 cm²) than the inoculated one (N1), which recorded 7.26 cm².

Table 5: Effect of Poultry Manure, Microbial Inoculation, and Variety on Groundnut Leaf Area (cm²) at Different Growing Stages in Gaya

Treatments	3 WAS	5 WAS	7 WAS
Poultry Manure (PM)			
0 t h ⁻¹	6.66c	6.70c	23.97b
5 t h ⁻¹	7.73b	8.08b	26.14b
10 t h ⁻¹	8.95a	9.39a	29.16a
P-value	0.0010*	< 0.0001*	< 0.0004*
SE±	0.33	0.34	0.77
Inoculation (I)			
No	7.96	8.16	26.63
N1	7.60	7.95	26.22
P-value	0.2203^{NS}	0.4493^{NS}	0.6651^{NS}
SE±	0.27	0.28	0.64
Variety (V)			
Samnut 20	7.93	8.15	26.31
Samnut 21	7.61	7.95	26.55
P-value	0.3503^{NS}	0.5854^{NS}	0.6396^{NS}
SE±	0.27	0.27	0.62
Interaction			
P×I	NS	NS	NS
P×V	NS	NS	NS

I×V	**	**	NS
P×I×V	NS	NS	NS

WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Difference6 Interaction Effect of Inoculation by Variety of Leave Area of Groundnut at Gaya

Table 6: Interaction Effect of Inoculation by Variety of Leave Area of Groundnut at Gaya

Treatments	Samnut 20 3 WAS	Samnut 21 3WAS
Inoculation (I)		
NO	7.68ab	8.23a
N1	8.11a	6.82b
SEM = 0.384		
	Samnut 20	Samnut 21
Inoculation (I)	5 WAS	5 WAS
NO	7.79ab	8.53a
N1	8.45a	7.26b
SEM = 0.393		

WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Difference

Impact of Poultry Manure Rates and Microbial Inoculation on the Seed Per Pod and 100-Seed Weight of Groundnut Varieties

Table 7 shows the effect of poultry manure, microbial inoculation, variety on number of seed per pod and 100-seed weight of groundnut Gaya. Poultry manure significantly affected number of seed per pod. The 10 t/ha treatment produced the highest number of seeds per pod (59.30), followed by 5 t/ha (45.50), and the control one 0 t/ha recorded the least (40.10). The microbial inoculation had no significant different at Gaya, the inoculated groundnut had (41.66) seeds per pod compared to (49.50) for non-inoculated groundnut. The varietal effect was also not significant at Gaya. Samnut 20 produced (51.66) seeds per pod, and Samnut 21 had (58.83) seeds per pod. In interaction effects all locations and treatment are not significant.

Poultry manure, microbial inoculation, variety on 100-seed weight of groundnut Gaya. poultry manure application had a significant effect on 100-seed weight. In the Gaya, trends were observed where 10 t/ha poultry manure resulted in the highest seed weight (30), 5 t/ha produced (25), and the control recorded the lowest value (20)

Table 7: Effect of Poultry Manure, Microbial Inoculation, and Variety on Number of Seed Per Pod and 100-seed weight of Groundnut at Gaya.

Location Treatments	Number of Seed per pod	100-seed weight
Poultry Manure (PM)		
0t/ha	40.10c	19c
5t/ha	45.50b	24b
10t/ha	59.30a	31a
P-value	0.0001*	0.0134*
SE±	5.71	3.481
Inoculation (I)		
NO	49.50a	30a
N1	41.66a	23a
P-value	0.2508^{NS}	0.2950^{NS}
SE±	3.920	3.501
Variety		
Samnut 20	51.66a	19a
Samnut 21	58.83a	27a
P-value	0.279^{NS}	0.1701^{NS}
SE±	3.581	5.660
Interaction		
P×I	NS	NS
P×V	NS	NS
I×V	NS	NS
P×I×V	NS	NS

WAS=Weak after sowing, NS=Non significant difference, NO=Non inoculant, N1=Inoculated, means with the same letter are not significant Difference.

Discussion

Impact of Poultry Manure Rates and Microbial Inoculation on Groundnut Plant Height

The results of this study demonstrated that the application of poultry manure significantly increased the height of groundnut plants, indicating its effectiveness in promoting vegetative growth by raising soil fertility and nutrient accessibility. This finding supports the observations made by Ibrahim and Rahman (2015), Ibrahim *et al.* (2022), and Aisha and Mahmoud (2025), who marked out that poultry manure not only boosts plant height but also improves various growth and yield parameters, thereby being an effective organic fertilizer for sustainable groundnut farming. Recent research accordingly confirms that organic amendments like poultry manure markedly improve soil fertility and crop productivity. Agbede (2025) reported that applying poultry manure at 5-10 t/ha led to increased plant height, leaf area, and yield in legumes and cereals due to enhancements in soil nutrient status and organic matter content.

The study found that microbial inoculants did not significantly influence plant height across any study locations. It was noted that certain microbes might not be consistent with the

host plant or environmental conditions, leading to negligible effects on growth traits such as plant height (Wei *et al.*, 2024). Field experiments revealed that the effectiveness of rhizobial inoculants was dependent upon soil conditions and local climate; strains effective in one area did not accordingly enhance nodulation or yield in other locations (Mintah *et al.*, 2020).

Impact of Poultry Manure Rates and Microbial Inoculation on the Number of Branches in Groundnut Varieties

The study revealed that the application of poultry manure significantly affected the number of branches. This suggests that poultry manure enhances vegetative development of groundnut, likely due to improvements in soil fertility and nutrient availability, which encourage greater branching and overall plant vitality. This supports previous studies showing that poultry manure increases soil nutrient availability, which in turn fosters vegetative growth (Effa 2022). Further research demonstrated that optimal poultry manure application rates led to a higher number of branches per plant compared to lower application rates or untreated control (Praveen *et al.*, 2022).

Impact of Poultry Manure Rates and Microbial Inoculation on the Number of Leaves in Groundnut Varieties.

The findings showed that applying poultry manure greatly improved leaf growth in groundnut at all locations. This aligns with studies showing poultry manure enhances nitrogen mineralization and nutrient availability, promoting leaf development (Emmanuel 2022; Ahmad *et al.*, 2025). Another research also confirmed that poultry manure significantly increased the number of leaves per peanut plant compared to control plots, especially at early vegetative stage (Wang-Bara *et al.*, 2022). These findings consistently highlight the positive effect of poultry manure on the vegetative growth of groundnut, particularly in increasing the number of leaves at various stages of development and across different growing environments (Ibrahim *et al.*, 2022; Aisha & Mahmoud 2024).

The study indicated that microbial inoculation did not significantly influence leaf count at any growth stage in either location. This contrasts with studies showing mycorrhiza can improve growth under specific conditions, suggesting inoculation efficacy may depend on environmental factors or soil composition (Umadevi *et al.*, 2018). The effectiveness of microbial inoculants, such as rhizobia, largely depends on their compatibility with both the host plant and prevailing soil conditions. Native soil microbial communities or suboptimal inoculant strains often compete with or suppress introduced microbes, diminishing their impact on plant performance (Santos *et al.*, 2024).

Impact of Poultry Manure Rates and Microbial Inoculation on Leaf Area in Groundnut Varieties

The study indicated that the application of poultry manure significantly enhanced the leaf area of groundnut. These results are consistent with recent studies demonstrating that organic amendments, such as poultry manure, improve soil fertility by increasing the availability of essential nutrients, enhancing soil structure, and stimulating microbial activity, all of which contribute to increased vegetative growth and leaf area expansion in legumes (Adeleke *et al.*, 2022 and Olayinka *et al.*, 2023).

The study indicated that microbial inoculation also significantly influenced groundnut leaf area, though the effect varied with variety and manure rate. These findings align with current research, which emphasizes the synergistic effects of organic amendments and microbial inoculants on legume growth (Singh *et al.*, 2021 and Choudhary *et al.*, 2023). Inoculants enhance biological nitrogen fixation and nutrient uptake, particularly when sufficient organic matter is present to support microbial activity (Yusuf *et al.*, 2022).

Varietal differences were evident in response to both poultry manure and inoculation. Such genotype-by-environment interactions are well-documented, as different varieties possess varying capacities for symbiotic nitrogen fixation and nutrient use efficiency (Ajeigbe *et al.*, 2020; Kumar and Sharma, 2024).

Impact of Poultry Manure Rates and Microbial Inoculation on the Seed Per Pod And 100-Seed Weight of Groundnut Varieties

The study indicated that the application of poultry manure significantly affected the number of seeds per pod at both locations. This is aligning with the studies demonstrating that poultry manure enriches soil nitrogen, phosphorus, and organic matter, directly improving pod development and seed filling (Wang-Bara *et al.*, 2022). Studies confirm that poultry manure application significantly increases pods per plant and overall pod yield in groundnut (Praveen *et al.*, 2022). Other studies indicated that poultry manure enhances pod development and seed formation (Nagaraj *et al.*, 2018).

The study indicated that the application of poultry manure significantly affected the 100-seed weight of groundnut at both locations. This is aligning with the studies that found the application of poultry manure generally increases pod yield, number of pods and weight compared to the control (Mukhtar *et al.*, 2014; Rajesh *et al.*, 2017). Studies confirm poultry manure increases 100-seed weight, but optimal rates vary by soil type and location (Haruna *et al.*, 2013). Other studies indicated that applying 5 t/ha of poultry manure resulted in a significantly higher 100-seed weight compared to other rates, with a notable interaction between variety and manure rate influencing seed weight (Msaakpa, 2016).

Conclusion

Poultry manure application, especially at 10 t ha⁻¹, significantly improved all vegetative growth parameters of groundnut varieties in sandy soils of the Sudan savannah, highlighting its value as a sustainable soil amendment for enhancing crop performance.

Microbial inoculation did not yield significant effects on growth traits, although minor interactions with groundnut varieties were detected at early stages, indicating that further evaluation of strain and environmental compatibility is needed. Overall, these findings support the promotion of organic nutrient management, principally poultry manure, for groundnut production in low fertility soils, while future research should address microbial inoculant efficacy under local agro-ecological conditions.

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