



INTEGRATED APPLICATION OF BIOFERTILIZER AND COMPOST AS IT IMPROVES CUCUMBER (*CUCUMIS SATIVUS* L.) GROWTH AND YIELD IN THE SUDAN SAVANNAH ECOLOGY OF NIGERIA

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ABSTRACT

The study evaluated the interactive effects of biofertilizer and compost on the growth, yield and yield components of cucumber (*Cucumis sativus* L.) under semi-arid conditions of northern Nigeria during the 2025 rainy season at the Research Farm of Bayero University, Kano (BUK) and Dambatta. The treatments consisted of four (4) biofertilizer levels (0, 3, 4, and 5 L ha⁻¹) and three (3) compost levels (0, 5, and 10 t ha⁻¹), these were combined and laid out in a split-plot design with three replications. The four levels of biofertilizer were assigned to the main plots and three levels of compost allocated to the subplots. The results revealed that, both biofertilizer and compost significantly influenced vine length, number of branches per plant, and yield attributes at both locations. The application of 4 L ha⁻¹ biofertilizer and 5-10 t ha⁻¹ compost consistently produced superior vegetative and reproductive performance, resulting in the highest fruit number, fruit length, and total fruit yield. Significant ($p < 0.001$) interactions were observed, with the combination of 4 L ha⁻¹ biofertilizer and 5 t ha⁻¹ compost (B₄C₅) recording the greatest number of fruits per plant (47.6) and total fruit yield (54.1 t ha⁻¹) in both sites. This synergy suggests that moderate compost rates enhance the nutrient mobilization, phytohormone production, and microbial efficiency of biofertilizers, thereby improving nutrient use efficiency and soil fertility. The study concludes that integrating biofertilizer and compost offers a sustainable nutrient management approach that boosts cucumber productivity while reducing chemical fertilizer dependence. Hence, the adoption of integrated nutrient management (INM) is recommended for sustainable vegetable cultivation in the semi-arid regions of sub-Saharan Africa.

Keywords: Cucumber, Integrated, Nutrient, Organic, Amendment, Soil.

INTRODUCTION

Global agriculture increasingly emphasizes sustainable nutrient management as concerns about environmental degradation, soil fertility decline, and the cost of chemical fertilizers mount. Biofertilizers, which are microbial inoculants that enhance the availability of essential nutrients such as nitrogen and phosphorus, together with organic compost, are at the forefront of sustainable agricultural practices (Nosheen *et al.*, 2023). These amendments provide both ecological and agronomic benefits by improving soil fertility and crop productivity. Bio-organic microbes within the biofertilizers play a pivotal role in fixing atmospheric nitrogen, solubilizing insoluble phosphorus, and producing phytohormones that stimulate plant growth (Shahzad *et al.*, 2025; Zhang *et al.*, 2025). Integrating these inputs aligns with the principles of integrated nutrient management (INM), which seeks to balance productivity with ecological resilience (Kumar *et al.*, 2025).

Cucumber (*Cucumis sativus* L.) is a high-value vegetable crop with substantial nutritional and economic importance worldwide. However, intensive cucumber cultivation, particularly in tropical and semi-arid regions, often depends heavily on synthetic fertilizers, leading to soil degradation, nutrient imbalances, and reduced long-term yield sustainability (Sallam *et al.*, 2021). Multiple studies have shown that organic amendments such as compost can improve soil physical and chemical properties, increase microbial activity, and thereby enhance crop yield (Oyege & Balaji Bhaskar, 2023). Furthermore, microbial composts (biofertilizers) have been demonstrated to improve stress resilience, nutrient acquisition, and plant biomass (Ahmed *et al.*, 2023). Despite these advantages, the combined (interactive) effects of biofertilizer and compost under field conditions remain under-explored for cucumber in West African agro-ecologies.



In northern Nigeria, cucumber production is constrained by low soil fertility, poor organic matter content, and inadequate nutrient retention due to sandy to loamy soil textures. Farmers largely rely on chemical fertilizers, which may provide immediate nutrient supply but do not sustainably build soil health. This dependency contributes to declining soil structure, reduced microbial diversity, and long-term yield decline. Although biofertilizer and compost have shown promise individually for improving soil fertility and crop performance, the synergistic effects of their combined application on cucumber yield components under these specific agroecological conditions have not been well quantified. Without such data, recommendations for integrated nutrient management (INM) in cucumber systems remain incomplete and underutilized.

This study is justified by its contribution to promoting sustainable, low-input agriculture through the integrated use of biofertilizer and compost. By quantifying their interaction effects, the research supports the development of eco-friendly fertilizer strategies that minimize dependence on synthetic inputs and mitigate environmental risks (Ammar *et al.*, 2022; Bouhzam *et al.*, 2025). The combined use of compost and biofertilizer enhances soil health by improving organic matter content, cation exchange capacity, microbial activity, and nutrient cycling key factors in restoring the fertility of coarse-textured, low-nutrient soils common in northern Nigeria (Ahmed *et al.*, 2023; Suvendran *et al.*, 2025). Economically, the resulting improvement in cucumber yield and quality can increase profitability for smallholder farmers, especially where the high cost of mineral fertilizers limits adoption. Furthermore, while individual effects of biofertilizer or compost have been widely studied, limited field-based evidence exists on their interactive influence in cucumber production under West African soil and climatic conditions. This research therefore addresses a critical knowledge gap and provides practical insights for developing effective integrated nutrient management (INM) strategies suited to sustainable vegetable production systems in the region.

The study aimed at evaluating the interactive effects of biofertilizer and compost on the growth, yield, and yield components of cucumber in the semi-arid soils of northern Nigeria.

MATERIALS AND METHODS

Experimental Sites

Field experiments were conducted during the 2025 rainy season at two locations: the Research Farm of the Faculty of Agriculture, Bayero University Kano (11°53'N, 13°16'E, 354 m above sea level) and Dambatta (12°26'N, 8°30'E, 418 m above sea level). Both sites are situated in the Sudan savanna agro-ecological zone of Nigeria, characterized by distinct wet and dry seasons. The fields were cleared, ploughed, harrowed to a fine tilth, and ridged prior to planting.

Treatment and Experimental Design

The experiment consisted of three compost levels (0, 5, and 10 t ha⁻¹) and four biofertilizer levels (0, 3, 4, and 5 L ha⁻¹), resulting in twelve treatment combinations. Treatments were arranged in a split-plot design with three replications. Biofertilizer levels were assigned to subplots, while compost levels were assigned to main plots.

Soil and Compost Analysis

Before the experiment, composite soil samples were collected from the 0-30 cm depth at each site to determine initial physicochemical properties. The samples were air-dried, sieved (2 mm), and analyzed using standard laboratory procedures. Compost samples were also analyzed for nutrient content prior to field application.

Compost Preparation

Compost was prepared using the pit composting method. A rectangular pit (2 m × 1.5 m × 1 m) was excavated in a shaded area to reduce nutrient loss through evaporation. Composting materials included crop residues (mainly maize stover and legume haulms), cattle dung, poultry litter, and household organic waste mixed in a 3:2:1:1 ratio. The materials were arranged in alternating layers of dry and moist components, each approximately 15-20 cm thick. Each layer was moistened with water to maintain adequate humidity for microbial activity. The pit was covered lightly with soil to conserve heat and moisture and turned every two weeks to improve aeration and ensure uniform decomposition.



After 8-10 weeks, the compost became dark brown, friable, and emitted an earthy odor, indicating maturity and readiness for use.

Description of Cucumber Variety

The cucumber variety used was F1 Tokyo, a vigorous hybrid producing uniform dark-green, cylindrical fruits measuring 18-32 cm in length with few spines. The variety is tolerant to downy mildew, powdery mildew, and cucumber mosaic virus, with a maturity period of 50-55 days after sowing.

Cultural Practices

Land Preparation

The land at each site was ploughed, harrowed and ridged at 0.75 m spacing between ridges. Each field was divided into 36 plots measuring 4.5 m × 3.0 m (13.5 m²) with a net plot size of 2.25 m × 3.0 m (6.75 m²), corresponding to the two inner ridges. A 1.0 m alley separated plots within replications, while a 2.0 m spacing was maintained between replications to facilitate movement and minimize nutrient interference.

Sowing

Two seeds of the cucumber were sown per hole along the ridges at a spacing of 0.75 m × 0.45 m. Thinning to one healthy plant per stand was carried out two weeks after sowing (2 WAS).

Weed Control

Weeds were controlled manually with a hoe as necessary to maintain weed-free plots throughout the growing season.

Fertilizer Application

Compost was applied at the designated rates and incorporated into the soil two weeks before sowing to allow partial decomposition. The biofertilizer was applied at the specified rates two weeks after sowing (2 WAS) by soil drenching near the plant base. Control plots received no fertilizer throughout the experiment.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using SPSS version 2.0 and Duncan's Multiple Range Test (DMRT) was adopted in separating the means.

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Soils

The physical and chemical characteristics of the soils at the two experimental sites (BUK and Dambatta) showed marked variations in texture, nutrient status, and cation exchange capacities (Table 1). The BUK soil was predominantly sandy (810 g kg⁻¹ sand, 140 g kg⁻¹ silt, and 50 g kg⁻¹ clay), classified as loamy sand, while Dambatta had a higher clay fraction (680 g kg⁻¹ sand, 170 g kg⁻¹ silt, and 150 g kg⁻¹ clay), corresponding to sandy loam texture. This difference indicates a higher capacity for water and nutrient retention at Dambatta compared with BUK, which is consistent with the general relationship between finer texture and higher fertility in tropical soils (Ifeyinwa-Onyishi *et al.*, 2024). Soils dominated by sand fractions typically exhibit low cation exchange capacity and organic matter content, leading to rapid leaching losses during intense rainfall events common in the Sudan savanna zone of Nigeria.

Soil pH ranged from slightly acidic to near neutral across both sites. The pH(H₂O) at BUK and Dambatta were 6.67 and 6.37, respectively, while the corresponding pH (CaCl₂) values were 6.12 and 5.62. These results indicate that both soils are suitable for most arable crops, including cucumber, and pose no significant risk of aluminum toxicity. The slightly lower pH at Dambatta may be attributed to greater leaching of exchangeable bases and organic acid accumulation, as reported for similar soils in semi-arid regions of northern Nigeria (Abdulrashid *et al.*, 2024).

Electrical conductivity (EC) values were low at both sites (0.086 dS m⁻¹ at BUK and 0.372 dS m⁻¹ at Dambatta), confirming that the soils were non-saline. The relatively higher EC observed at Dambatta may be linked to its higher clay content and retention of soluble ions. Organic carbon (OC) was 0.733 % at BUK and 0.259 % at Dambatta, while total nitrogen (N) was 0.225 % and 0.247 %, respectively. These low values reflect the rapid mineralization of organic matter in sandy tropical soils



and limited organic inputs typical of intensively cultivated areas (Oyun *et al.*, 2025). The results underscore the need for external organic inputs to sustain productivity and soil structure.

Available phosphorus (P) values were 9.52 mg kg⁻¹ and 8.63 mg kg⁻¹ for BUK and Dambatta, respectively. These concentrations are below critical thresholds for optimal crop growth, suggesting P deficiency a common problem in West African savanna soils where phosphorus is strongly fixed by iron and aluminum oxides (McDowell *et al.*, 2024). The exchangeable bases were dominated by calcium (Ca²⁺) and magnesium (Mg²⁺), with lower levels of potassium (K⁺) and sodium (Na⁺). The CEC values (5.414 cmol kg⁻¹ at BUK and 7.082 cmol kg⁻¹ at Dambatta) were low to moderate, typical of sandy soils with limited organic matter and clay colloids. The higher CEC in Dambatta aligns with its finer texture and higher clay content. Exchangeable acidity (EA) was low (0.157 cmol kg⁻¹ at BUK and 0.234 cmol kg⁻¹ at Dambatta), confirming that soil acidity is not a major fertility constraint in these locations. These results are consistent with earlier findings that northern Nigerian soils possess low organic matter and base saturation, requiring organic and mineral supplementation to sustain high yield potential (Quispe *et al.*, 2023).

The chemical properties of the biofertilizer and compost used in this study (Table 2) demonstrated complementary nutrient characteristics. The biofertilizer had a low pH (4.3), whereas the compost was nearly neutral (7.62), indicating that the biofertilizer could facilitate nutrient solubilization during early crop establishment, while the compost would stabilize soil pH and enhance nutrient retention over time. The compost exhibited an exceptionally high cation exchange capacity (CEC = 93.78 cmol kg⁻¹), implying its ability to retain cations and improve soil buffering capacity, particularly in sandy soils with inherently low CEC (Bhat *et al.*, 2022).

In terms of nutrient content, the biofertilizer contained very high concentrations of nitrogen (18.5 mg kg⁻¹), phosphorus (60,000 mg kg⁻¹), and potassium (60,000 mg kg⁻¹), far exceeding the compost (1.43, 4,226.5, and 15,428.4 mg kg⁻¹, respectively). This pattern is typical of microbial biofertilizers enriched with nutrient-solubilizing microorganisms such as *Azotobacter*, *Bacillus*, and *Pseudomonas* species, which enhance the availability of NPK to crops (Saeed *et al.*, 2021). Conversely, the compost's moderate nutrient levels reflect its slow mineralization and gradual nutrient release, contributing to long-term soil fertility maintenance (Xing *et al.*, 2025).

Exchangeable bases such as magnesium (1.50 cmol kg⁻¹) and sodium (2.23 cmol kg⁻¹) were relatively higher in the biofertilizer than in the compost, indicating its potential to contribute to soil base saturation. Micronutrient concentrations (Cu, Zn, Mn, and B) were low in both materials, although the compost contributed slightly more Zn and Mn, depending on the feedstock composition and degree of decomposition (Gao *et al.*, 2025).

The compost also contained higher organic carbon (4.67 %) and organic matter (8.05 %) than the biofertilizer, suggesting its capacity to improve soil structure, water retention, and microbial biomass when applied to coarse-textured soils. Increased organic matter input from compost enhances aggregate stability and nutrient cycling, contributing to improved soil physical conditions (Sharma *et al.*, 2021).

Table 1: Physical and Chemical Properties of Soils of the Experimental Sites

Properties	BUK	Dambatta
Physical (g kg⁻¹)		
Sand	810	680
Silt	140	170
Clay	50	150
Textural Class	Loamy sand	Sandy loam
Chemical		
pH (H ₂ O)	6.67	6.37
pH(cacl ₂)	6.12	5.62
EC (ds/m)	0.086	0.372
OC (%)	0.733	0.259
N (%)	0.225	0.247
P(mg/kg)	9.52	8.63
Exchangeable Bases (cmol kg⁻¹)		
K	0.19	0.17
Ca	3.671	2.236
Mg	1.719	1.077
Na	0.119	0.144
CEC	5.414	7.082
EA	0.157	0.234

Table 2: Chemical Properties of Biofertilizer and Compost

Chemical Property	Biofertilizer	Compost
Macronutrients (mg kg⁻¹)		
Nitrogen (N)	18.5	1.43
Phosphorus (P)	60,000	4,226.50
Potassium (K)	60,000	15,428.37
Exchangeable Bases (cmol kg⁻¹)		
Magnesium (Mg)	1.50	–
Sodium (Na)	2.23	1.44
Micronutrients (mg kg⁻¹)		
Cu	0.075	–
Zn	0.075	0.03
Mn	0.075	0.068
B	0.0315	–
Other Properties		
pH (H ₂ O)	4.30	7.62
CEC (cmol kg ⁻¹)	–	93.78
Organic Matter (%)	–	8.05
Organic Carbon (%)	–	4.67

Effect of Biofertilizer and Compost on Vine Length of Cucumber

Table 3 presented result of the vine length of cucumber as affected by varying levels of biofertilizer and compost at BUK and Dambatta during the 2025 rainy season. The results showed that, vine length was significantly influenced by different rates of biofertilizer and compost across both locations at 6 weeks after sowing (WAS). The significant ($p < 0.05$) increase in vine length at higher biofertilizer and compost levels indicates a positive response of cucumber to improved soil fertility and microbial activity.

At BUK, the application of 4 L ha⁻¹ biofertilizer recorded the longest vines (103.6 cm), which was statistically similar to 5 L ha⁻¹ but significantly higher than the control. Likewise, at Dambatta, 4 L ha⁻¹ biofertilizer produced the tallest vines (121.3 cm) at 6 WAS. The improved vine elongation observed with increasing biofertilizer rates may be attributed to enhanced root colonization by beneficial rhizobacteria, which promote nutrient solubilization, nitrogen fixation, and phytohormone



(auxin and gibberellin) synthesis essential for vegetative growth. This agrees with the findings of Gupta *et al.* (2023) and Pawar *et al.* (2024), who reported that the application of biofertilizers enhances vegetative growth and nutrient uptake in cucumber and other vegetable crops through rhizobacterial activity.

Similarly, compost application significantly ($p < 0.001$) affected vine length at both locations. At BUK, 10 t ha⁻¹ compost produced the longest vines (112.5 cm), while at Dambatta, the same rate also gave the maximum vine length (118.9 cm). The positive response of cucumber vine growth to compost application could be linked to improved soil structure, moisture retention, and gradual nutrient mineralization. This finding corroborates the report of Tong *et al.* (2023), who observed enhanced cucumber growth and biomass accumulation following compost incorporation, and that of Morais *et al.* (2023), who highlighted compost's role in boosting soil organic carbon and microbial activity in tropical soils.

Although both biofertilizer and compost significantly improved vine length, their interaction (B × C) was not significant ($p > 0.05$) at both sites, suggesting that the two acted independently. This is in line with Chaudhary *et al.* (2022), who noted that while the combined use of biofertilizer and organic manure enhances overall soil health, their interactive effects on growth parameters may not always be synergistic, particularly under moderate fertility conditions.

Overall, cucumber plants grown at Dambatta exhibited greater vine length compared to those at BUK, which could be attributed to the higher clay and silt contents of Dambatta soil that improved moisture-holding capacity and microbial activity. This agrees with the findings of Alghamdi *et al.* (2024), who emphasized that soil physical characteristics, especially clay fraction, enhance nutrient retention and microbial performance in vegetable systems.

Table 3: Effect of Biofertilizer and Compost on Vine Length of Cucumber at BUK and Dambatta during the 2025 Rainy Season

Treatment	BUK		Danbatta	
	Weeks after sowing (WAS)			
	4	6	4	6
Biofertilizer (B) L ha⁻¹				
0	50.9	81.1b	51.3	85.1c
3	41.6	96.7a	41.5	97.9b
4	51.5	103.6a	53.1	121.3a
5	51.3	101.4a	51.6	108.2b
p-value	0.2294	0.0101	0.1043	<0.001
SE±	3.89	4.68	3.48	3.76
Compost (C) t ha⁻¹				
0	41.2	77.3c	38.8b	80.5b
5	51.3	97.3b	51.2a	109.9a
10	53.9	112.5a	58.2a	118.9a
p-value	0.0322	<0.001	0.0005	<0.001
SE±	3.37	4.05	3.01	3.3
Interaction				
B × C	0.8565	0.8482	0.1013	0.6411

Means followed by the same letter are not significantly different at 5% level of probability using SNK

Effect of Biofertilizer and Compost on Number of Branches per Plant of Cucumber

The number of branches per plant of cucumber as influenced by varying levels of biofertilizer and compost at Bayero University Kano (BUK) and Dambatta during the 2025 rainy season is presented in Table 4. Results revealed that, number of branches was significantly ($p < 0.05$) affected by both biofertilizer and compost applications, particularly at 6 WAS in Dambatta. The significant increase in branching observed under these treatments indicates enhanced vegetative development and greater photosynthetic surface expansion, which may be attributed to improved nutrient uptake and hormonal stimulation.



At BUK, the number of branches did not differ significantly ($p > 0.05$) among biofertilizer levels across the sampling periods. However, at Dambatta, the application of biofertilizer at 3-4 L ha⁻¹ significantly increased the number of branches (15.5-16.1) compared to the control (9.8) at 6 WAS. This positive response could be due to the activity of beneficial microbial populations in the biofertilizer, which enhance nitrogen fixation, phosphorus solubilization, and phytohormone production processes that promote lateral growth and branching. These findings are consistent with the reports of (Dzvene & Chiduzza, 2024 and Wade *et al.*, 2025), who observed that biofertilizer application enhances branching and vegetative growth in cucumber and other fruit vegetables by promoting hormonal balance and efficient nutrient utilization.

Compost application also significantly ($p < 0.01$) influenced the number of branches per plant at both locations at 6 WAS. At BUK, plants treated with 5 and 10 t ha⁻¹ of compost recorded the highest number of branches (12.3 and 13.2, respectively), while the control produced the fewest (9.1). A similar trend was recorded at Dambatta, where the application of 5 and 10 t ha⁻¹ compost resulted in 14.6 and 16.2 branches per plant, respectively, compared to 10.5 in the control. The superior performance observed with compost treatments may be linked to the gradual release of essential nutrients such as nitrogen, phosphorus, and potassium, as well as enhanced microbial activity and improved soil structure. This observation aligns with the findings of (Suvendran *et al.*, 2025) and (Xing *et al.*, 2025), who reported that compost improves soil nutrient retention, moisture availability, and microbial colonization, leading to increased branching and canopy development in cucurbits. The B × C interaction was not significant ($p > 0.05$) at both sites across sampling periods.

Table 4: Effect of Biofertilizer and Compost on Number of Branches per plant of Cucumber at BUK and Dambatta during the 2025 Rainy Season

Treatment	BUK		Dambatta	
	Weeks after sowing (WAS)			
	4	6	4	6
Biofertilizer (B) L ha⁻¹				
0	6.9	11.9	5.9	9.8b
3	7.0	11.8	6.9	15.5a
4	6.7	12.3	6.3	16.1a
5	7.1	10.9	7.2	13.8a
p-value	0.9707	0.6358	0.5146	0.0001
SE±	0.74	0.85	0.62	0.86
Compost (C) t ha⁻¹				
0	6.4	9.1b	5.6	10.5b
5	6.9	12.3a	6.7	14.6a
10	7.4	13.2a	7.5	16.2a
p-value	0.548	0.001	0.058	<0.001
SE±	0.64	0.73	0.54	0.75
Interaction				
B x C	0.9985	0.9191	0.9004	0.0780

Means followed by the same letter within treatment column is not significantly different at 5% probability level using SNK.

Effect of Biofertilizer and Compost on Yield Attributes and Fruit Yield of Cucumber

Table 5 presented results of the effects of biofertilizer and compost on number of fruits per plant, fruit length, fruit diameter and total fruit yield of cucumber at BUK and Dambatta during the 2025 rainy season. The results revealed that, both biofertilizer and compost applications had significant ($p < 0.001$) effects on all yield and yield-related parameters at both locations.

At BUK, biofertilizer application significantly enhanced the number of fruits per plant, fruit length, fruit diameter, and total fruit yield compared with the control. The highest fruit number (36.1 fruits per plant), fruit length (21.5 cm), and fruit diameter (18.9 cm) were obtained with 4 L ha⁻¹ of biofertilizer, producing a corresponding yield of 34.8 t ha⁻¹. Similarly, at Dambatta, the same



treatment resulted in superior performance, recording 33.1 fruits per plant, 20.6 cm fruit length, and 18.1 cm diameter, with a yield of 31.3 t ha⁻¹. These results suggest that biofertilizer at 4 L ha⁻¹ optimally enhances cucumber productivity, likely through improved nutrient mobilization and growth-promoting substances synthesized by beneficial microorganisms such as *Rhizobium*, *Azotobacter*, and *Pseudomonas* species. These microbes enhance nitrogen fixation, phosphorus solubilization, and phytohormone (IAA, gibberellins, and cytokinins) production, thereby stimulating flowering, fruit set, and yield formation. This observation is in line with the findings of Ammar *et al.* (2022) and Vojnović *et al.* (2023), who reported that biofertilizer application significantly improved fruit yield and quality in cucumber by enhancing nutrient uptake efficiency and reproductive growth.

Conversely, the lowest yields were recorded at 0 and 5 L ha⁻¹ of biofertilizer at both locations, indicating that either nutrient deficiency or excessive microbial concentration at higher doses could lead to nutrient imbalance or competition, negatively affecting yield. Similar trends were observed by Han *et al.* (2021), who found that excessive biofertilizer levels beyond optimal thresholds could suppress fruit yield due to rhizosphere competition and altered nutrient dynamics.

Compost application also significantly ($p < 0.001$) affected all measured parameters at both sites. At BUK, the application of 5 and 10 t ha⁻¹ compost recorded higher fruit number (32.3 and 27.7), fruit length (17.6 and 20.2 cm), and fruit diameter (16.5 and 18.9 cm), resulting in yields of 28.1 and 28.5 t ha⁻¹, respectively, compared to the control (13.9 t ha⁻¹). Similar improvements were observed at Dambatta, where the highest compost rates (5 and 10 t ha⁻¹) produced the most fruits per plant (30.5 and 24.8) and yields (25.3 and 26.6 t ha⁻¹). These findings highlight the role of compost in providing a slow and sustained release of essential nutrients while enhancing soil structure, moisture retention, and microbial activity all of which support fruit formation and development. This agrees with the findings of Xu *et al.* (2025) and Oueld Lhaj *et al.* (2024), who reported that compost improved cucumber yield and fruit quality by enhancing nutrient synchronization with crop demand and stimulating beneficial soil microflora.

The interaction between biofertilizer and compost (B × C) was highly significant ($p < 0.001$) for all measured parameters at both locations, indicating a strong synergistic effect when both amendments were combined. The combined use of biofertilizer (4 L ha⁻¹) and compost (5-10 t ha⁻¹) consistently produced the highest yield and fruit quality attributes, suggesting that integrated nutrient management offers a balanced supply of macro- and micronutrients while promoting beneficial microbial activity. This result supports the earlier reports of Luan *et al.* (2020) and Wu *et al.* (2021), who observed that integrating organic and microbial fertilizers enhances nutrient-use efficiency, improves soil fertility, and maximizes cucumber productivity.

Overall, the results confirm that moderate application of biofertilizer (4 L ha⁻¹) in combination with compost (5-10 t ha⁻¹) optimizes yield performance and fruit quality of cucumber under the agroecological conditions of Northern Nigeria. This integrated nutrient approach ensures sustainable productivity by improving soil health and reducing reliance on inorganic inputs.



Table 5: Effects of Biofertilizer and Compost on Number of Fruit per plant, Fruit length, Fruit diameter and Total fruits yield on Cucumber at BUK and Dambatta during the 2025 Rainy Season

Treatment	BUK				Danbatta			
	Number of fruits plant ⁻¹	Fruit length (cm)	Fruit diameter (cm)	Total fruit yield (t ha ⁻¹)	Number of fruits plant ⁻¹	Fruit length (cm)	Fruit diameter (cm)	Total fruit yield (t ha ⁻¹)
Biofertilizer (B) L ha⁻¹								
0	20.2d	14.2c	12.9c	21.7b	23.7b	13.8c	12.3c	20.3b
3	29.2b	16.6b	16.0b	24.3b	25.6b	16.0b	15.3b	22.7b
4	36.1a	21.5a	18.9a	34.8a	33.1a	20.6a	18.1a	31.3a
5	25.1c	14.3c	15.2b	13.2c	19.0c	13.9c	14.6b	12.4c
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SE±	1.04	0.46	0.73	1.12	0.86	0.39	0.60	1.01
Compost (C) t ha⁻¹								
0	23.0c	12.1c	11.8c	13.9b	20.7c	11.6c	11.7c	13.0b
5	32.3a	17.6b	16.5b	28.1a	30.5a	17.0b	15.5b	25.3a
10	27.7b	20.2a	18.9a	28.5a	24.8b	19.7a	18.0a	26.6a
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SE±	0.90	0.40	0.63	0.97	0.75	0.34	0.52	0.88
Interaction								
B x C	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter in the same column is not significantly different at 5% probability level using SNK



Interaction of Biofertilizer and Compost on Fruit Yield and Yield Components of Cucumber

Table 6 presented results of the interaction of biofertilizer and compost on the number of fruits per plant, fruit length, fruit diameter, and total fruit yield of cucumber at BUK and Dambatta during the 2025 rainy season. The results revealed that the $B \times C$ interaction was highly significant ($p < 0.001$) for all yield parameters at both locations, indicating strong synergistic effects of combining these organic and microbial amendments on fruit productivity and quality traits.

The combination of 4 L ha^{-1} biofertilizer and 5 t ha^{-1} compost (B_4C_5) produced the highest number of fruits per plant (47.6-44.3), longest fruit length (28.7-26.9 cm), widest fruit diameter (24.3–22.7 cm), and consequently, the highest total fruit yield ($54.1\text{-}47.8 \text{ t ha}^{-1}$) across both sites. This suggests that moderate compost levels supplemented with an optimal rate of biofertilizer enhance nutrient availability and uptake efficiency, thereby improving vegetative vigor, flowering, and fruit set. The superior performance of these combinations could be linked to the complementary roles of both inputs: biofertilizers enhance nitrogen fixation, phosphorus solubilization, and production of growth-promoting hormones, while compost improves soil structure, organic carbon content, and microbial habitat, ensuring a steady nutrient supply during the fruiting stage. Similar synergistic interactions have been documented by Omara and Farrag. (2022), Shittu (2024) and Shittu *et al.* (2025), who observed that integrating microbial inoculants with organic manure significantly improved cucumber growth, fruit development, and yield in tropical environments.

Conversely, the control (B_0C_0) and the highest biofertilizer–compost combinations (B_5C_{10}) consistently recorded the lowest fruit number and yield across both sites. The decline under excessive biofertilizer levels could be due to microbial competition or nutrient imbalance, which may have altered the rhizosphere nutrient dynamics and reduced assimilate partitioning to reproductive organs. These findings are consistent with Daniel *et al.* (2022) and Shi *et al.* (2023), who reported that high doses of biofertilizer or organic inputs may suppress beneficial microbial interactions and reduce yield efficiency.

Overall, the findings demonstrate that combining moderate compost rates ($5\text{-}10 \text{ t ha}^{-1}$) with an optimal biofertilizer level (4 L ha^{-1}) markedly improved cucumber yield and its components compared to sole applications. This validates the integrated nutrient management (INM) approach, where organic and microbial inputs synergistically enhance soil fertility, nutrient synchronization, and crop productivity. Consistent with Marzouk *et al.* (2024) and Yusuf *et al.* (2025), INM practices strengthen cation exchange capacity, root activity, and microbial biomass, thereby improving nutrient use efficiency and yield stability under rain-fed conditions.

Table 6: Interaction of Biofertilizer and Compost on Number of Fruit per Plant, Fruit length, Fruit diameter and Fruit yield per hectare of Cucumber at BUK and Danbatta during the 2025 Rainy Season

Treatments	Number of fruits plant ⁻¹ _BUK			Fruit Diameter (cm)_BUK		
	Compost (t ha ⁻¹)					
	0	5	10	0	5	10
Biofertilizer (L ha⁻¹)						
0	16.0g	22.7ef	27.3de	8.5f	12.1def	15.1cd
3	20.3fg	28.0cd	32.6c	10.3ef	18.8b	19.0bc
4	27.7cde	47.6a	39.3b	18.0bc	24.3a	19.8b
5	25.0def	28.0cd	17.3g	13.4de	18.9b	10.8ef
SE±		1.81			1.26	
Danbatta						
0	15.0g	21.0 ef	24.3de	8.5f	10.4ef	17.2bc
3	17.7fg	25.7cd	29.3c	10.1f	17.6bc	18.4b
4	25.0cde	44.3a	34.0b	14.6cd	22.7a	19.1b
5	24.0de	25.7cd	18.0fg	13.3de	18.2b	10.8ef
SE±		1.49			1.05	
Fruit length (cm)_BUK						
0	6.6h	14.7e	16.1de	9.3f	10.7ef	19.6d
3	11.7f	18.1cd	21.6b	19.4d	29.6bc	30.7bc
4	16.6de	28.7a	21.9b	19.8d	54.1a	34.1b
5	15.4e	19.1c	9.1g	14.9de	28.3c	11.5ef
SE±		0.80			1.93	
Danbatta						
0	6.1h	14.8e	15.5e	8.2f	15.6de	18.0d
3	11.3f	18.1cd	20.8b	10.4ef	28.0bc	28.2bc
4	16.2de	26.9a	21.3b	18.2d	47.8a	32.2b
5	14.9e	18.8c	8.5g	17.8d	24.4c	10.8ef
SE±		0.68			1.75	

Means followed by the same letter(s) are not significantly different at 5% probability level using SNK.

CONCLUSION AND RECOMMENDATION

The combined application of biofertilizer and compost proved to be highly effective in improving the growth and yield performance of cucumber under semi-arid soil conditions. The 4 L ha⁻¹ biofertilizer and 5 t ha⁻¹ compost treatment (B₄C₅) consistently enhanced vine length, branching, fruit size, and yield across both locations, demonstrating a strong synergistic effect between microbial inoculants and organic amendments. This integrated approach not only optimized nutrient availability and soil biological activity but also provided an eco-friendly alternative to chemical fertilizers. Therefore, the study recommends the adoption of integrated nutrient management (INM) using 4 L ha⁻¹ biofertilizer and 5–10 t ha⁻¹ compost as an optimal combination for sustainable cucumber production in semi-arid regions of northern Nigeria. Further research should explore the long-term effects of such combinations on soil fertility dynamics and economic returns across multiple cropping cycles to strengthen their applicability in smallholder farming systems.

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