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Evaluating the effectiveness of kitchen waste compost through soil quality indicators, nutrient status, and bacterial diversity using lettuce (*Lactuca sativa*) growth as a bioassay

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ABSTRACT: The challenge of managing burgeoning kitchen waste requires sustainable valorisation methods, with composting representing a solution for producing beneficial soil amendment. This study assessed the efficacy of locally-sourced compost against conventional chemical fertiliser and unamended soil based on its impact on soil characteristics and the subsequent growth response of lettuce (*Lactuca sativa*). The experiment involved three soil treatment groups: Compost-amended soil, chemically-fertilised soil, and non-compost control. A total of twenty-seven (27) soil samples which comprises of nine (9) soil samples each were collected from three different locations: Gusau Market, Bola Jeri and Gusau Hotel. Physicochemical analysis revealed that compost-amended soil maintained stable temperatures (26–28°C) and a slightly acidic to near-neutral pH (5.6–6.2), contrasting with the more alkaline profile of chemically fertilised (6.7–8.2) and non-compost soils (7.6–8.2). Furthermore, compost significantly enhanced moisture retention (23–28%), compared to chemically-fertilised (10–15%) and non-compost (5–10%) soils. Nutrient analysis showed that while phosphorus levels peaked in chemically fertilized soil (4.1%), compost-amended soil provided a competitive and stable nitrogen range (0.18–0.23%), consistently exceeding the control. The total bacterial load was highest in the compost soil (8.5 to 30.8×10^{-6}CFU/g), confirming it biological richness. The isolated species include *Bacillus cereus* (33.3%), *Micrococcus luteus* (33.3%), *Pseudomonas fluorescens* (22.2%), and *B. megatherium* (11.1%), all known for their roles in nutrient cycling and plant growth promotion. A bioassay using lettuce validated the non-toxic efficacy of the kitchen waste compost. All parameters, including germination rate, plant height, and leaf count, were within standard physiological ranges and significantly outperformed the control. Specifically, the kitchen waste treatment promoted superior seedling emergence and biomass compared to the control group, which was limited by low moisture (5–10%). These results confirm the potential of compost as an effective, sustainable soil amendment for improving soil health and promoting healthy lettuce growth.

Keywords: Kitchen waste compost, lettuce growth, physicochemical properties, nutrient dynamics, sustainable agriculture.

INTRODUCTION

The rapidly increasing generation of organic waste, particularly from domestic kitchens, presents a significant environmental and economic challenge globally (Hoornweg and Bhada-Tata, 2012). Kitchen waste is a heterogeneous mix primarily composed of food preparation residues, such as vegetable and fruit peelings, spoiled leftovers, and starchy trimmings. These materials are characterised by high moisture content and a low carbon-to-nitrogen (C:N) ratio, making them highly putrescible (Zhang *et al*., 2007). Sustainable waste management strategies are urgently required to mitigate the detrimental effects of landfill disposal. When kitchen waste is co-disposed with inorganic waste in landfills, it undergoes anaerobic decomposition, leading to the

emission of methane, a potent greenhouse gas with a global warming potential significantly higher than carbon dioxide. However, diverting this waste into composting provides a dual benefit for soil health. As organic matter decomposes, the release of organic acids and the formation of humic substances help neutralise alkalinity and stabilise the soil against sharp pH fluctuations (Bashir *et al.,* 2021). This buffering capacity is a critical soil quality indicator, as it ensures a stable environment for microbial activity and nutrient uptake in sensitive crops like lettuce (Dion *et al*., 2020; Neina, 2019).

Composting has emerged as a superior, biotechnological process for valorising kitchen waste, converting this discarded resource into a stable, nutrient-rich soil amendment (Dion *et al*., 2020). This process not only diverts waste from landfills but also facilitates the circular economy by returning essential minerals to the earth. Previous studies have highlighted that organic amendments are crucial for maintaining soil health; they improve soil structure, enhance microbial diversity, and provide a slow-release source of nutrients, which is vital for long-term agricultural sustainability in the face of soil degradation caused by intensive chemical fertilisation (Ayilara *et al*., 2020).

Composting is a managed aerobic biotechnological process that facilitates the biological decomposition and humification of organic substrates. It is formed through a complex microbial succession involving three distinct phases: the initial mesophilic stage, where primary decomposers break down readily available solutes; the thermophilic stage, characterised by high-temperature microbial activity that degrades complex polymers and sanitises the material of pathogens; and the final maturation or "curing" phase. During this maturation, the material is transformed into a stable, humus-like substance that is chemically distinct from the raw waste and biologically suppressed in its phytotoxicity (Ayilara *et al.,* 2020). The key parameters monitored in this study, including temperature, pH, and moisture content, are considered primary indicators of soil health following amendment (Hargreaves *et al*., 2008). pH directly governs nutrient availability, while moisture content is intrinsically linked to the soil's Water Holding Capacity (WHC), a vital physical property significantly enhanced by organic matter (Brady and Weil, 2017). Monitoring these parameters provides a practical and cost-effective measure of the short-term impact of compost application versus conventional chemical fertilisers.

Unlike the rapid nutrient 'flush' characteristic of synthetic inputs, high-quality compost provides a sustained nutritional benefit through slow-release mechanisms. Bashir *et al*. (2021) demonstrate that the maturation of organic waste leads to the stabilisation of nitrogen into complex organic pools, which are subsequently released via microbial mineralisation in a way that aligns with plant demand. By contrast, synthetic fertilisers provide an immediate spike in available P, often leading to rapid fixation or leaching (Adesemoye and Kloepper, 2009). A direct comparison between the Compost and Fertilised treatments using these specific nutrient parameters is critical for evaluating the long-term sustainability and efficiency of nutrient management.

While sophisticated assays such as enzyme activities are powerful tools for indicating microbial activity, they can be time-consuming and expensive for routine monitoring (Dion *et al.*, 2020). As noted by Bashir *et al.* (2021), although these biochemical indicators provide deep insights into the metabolic state of the soil, their requirement for specialised equipment and sensitive reagents often limits their application in large-scale compost quality assessments. Consequently, utilising more accessible indicators like total cultivable bacterial counts and plant bioassays offers a pragmatic yet reliable alternative for evaluating the effectiveness of kitchen waste compost in real-world agricultural settings (Soobhany *et al.,* 2017; Suvendran *et al*., 2025).

Bashir *et al*. (2021) demonstrate that microbial biomass and activity respond to kitchen waste compost applications far more rapidly than traditional physicochemical markers like bulk density or total carbon. This sensitivity allows for a near-immediate assessment of soil management efficacy. Furthermore, Ayilara *et al.* (2020) argue that these shifts in microbial abundance are not merely numerical; they represent a functional transition toward enhanced nutrient availability, which directly correlates with the improved vegetative performance of bioassay crops such as *Lactuca sativa*.

The total cultivable bacterial count directly reflects the capacity of the organic amendment to support a large microbial population, which is the engine of nutrient cycling and organic matter decomposition in the soil (Lui *et al.,* 2021). This microbial abundance is a primary driver in the transformation of kitchen waste into plant-available nutrients, essentially serving as a biological catalyst for soil fertility (Bashir *et al.,* 2021). The proliferation of these bacterial communities is a vital indicator of compost maturity and soil health, directly influencing the metabolic pathways that support crop productivity. Furthermore, robust microbial activity within the rhizosphere has been shown to enhance the biomass and nutrient uptake of sensitive leafy vegetables like lettuce (*Lactuca sativa*), highlighting the synergy between organic amendments and plant growth (Dion *et al*., 2020; Suvendran *et al*., 2025).

Moreover, the isolation and identification of dominant bacterial species (such as Bacillus and Pseudomonas) provide crucial qualitative data. The presence of these specific genera strongly suggests that the compost fosters Plant Growth Promoting Rhizobacteria (PGPR), which enhance nutrient uptake, produce phytohormones, and suppress plant pathogens (Glick, 2012). This direct microbiological assessment provides a clear link between

the organic amendment, the stimulated microbial community, and potential benefits to plant health, complementing the physicochemical data.

The ultimate measure of soil amendment efficacy is its ability to promote plant growth. Using lettuce (*Lactuca sativa*) as a standard model organism for a growth bioassay offers a direct, quantifiable assessment of the combined effects of nutrient availability, improved physical conditions, and potential phytotoxicity. Recent studies confirm that the rapid growth cycle and sensitivity of *Lactuca sativa* make it an ideal indicator for evaluating the maturity and safety of organic fertilisers before large-scale application (Dion *et al*., 2020; Suvendran *et al*., 2025).

The present study aims to provide a comparative assessment of the effects of kitchen waste compost and conventional fertilisation on soil quality. It seeks to evaluate the comparative effects on the physicochemical properties (pH, temperature, moisture content); analyse the dynamics of Total Nitrogen and Available Phosphorus; quantify the Total Bacterial Load and identify dominant species; and use lettuce growth analysis to validate the amendment's fertilising potential. While previous research has extensively documented the macronutrient benefits of large-scale industrial composts, there is a lack of comparative data on the biological "engine" of small-scale kitchen waste amendments compared to synthetic inputs. This study improves upon existing literature by integrating microbiological load and specific bacterial identification with physical soil indicators. By doing so, it demonstrates that KW compost does not merely act as a nutrient substitute, but as a biological catalyst that restores the soil's ecological functionality, a factor often overlooked in traditional fertiliser-focused studies. Consequently, these findings are expected to provide a validated, evidence-based framework for promoting domestic-scale waste circularity and sustainable urban agricultural practices, offering a viable alternative to the environmental costs of chemical intensification. The findings are expected to contribute significantly to the promotion of effective organic waste management and sustainable agricultural practices.

MATERIALS AND METHODS

Study area

The study was conducted at the Microbiology Laboratory in Federal University Gusau, Zamfara State, Nigeria. The samples were collected within Gusau Metropolis.

Experimental design

The experiment followed a Completely Randomised Design (CRD**)**. The study evaluated three primary soil treatments: Compost-amended soil (Kitchen Waste Compost), Chemically-fertilised soil (NPK/Conventional fertiliser) and Non-compost soil (Control).

Collection of samples

Composite soil samples were collected from three different soil categories: compost-amended soils**,** non-compost soils**,** and **i**norganic fertiliser-treated soils (MPK 15:15:15)**,** representing both agricultural and household composting areas in Gusau Market, Bola Jari and Gusau hotel. Each composite sample was obtained by mixing equal portions of 3 sub-samples collected at a depth of 0–15 cm using a sterilised soil auger. Samples were placed in sterile polyethene bags, labelled, and transported in an ice-packed cooler to the Microbiology Laboratory, Federal University Gusau, for immediate analysis within 24 hours of collection. Lettuce seedlings were collected using sterile polyethene bags. The seedlings were kept in a shaded place to prevent direct solar radiation and maintain their turgor pressure. This is to control environmental stress and prevent wilting before planting.

Determination of physicochemical parameters

Soil pH

Ten grams of 2mm sieved air-dry soil were placed in a 50ml plastic beaker, and 25ml of distilled water was added. The suspension was stirred several times over a period of 30 minutes and then left to settle undisturbed for another 30 minutes. The pH meter was calibrated with pH buffers 4, 7, and 9. The electrode was carefully immersed in the soil without touching the bottom of the beaker. The pH was read after 30 seconds. The procedure was then repeated using a 0.01M CaCl2 solution, and the readings were carefully recorded

Temperature

The temperature of the samples was determined according to Campbell *et al*. (2014). The temperature was measured at the point of collection using a centigrade thermometer. The thermometer was dipped into the soil and allowed to stand for 15 minutes till the temperature reading was steady, and then the reading was recorded.

Moisture content

An empty dry moisture dishes were weighed and recorded as W_o. 2 g of each sample was weighed as W_1 and placed into the dish. The samples were oven-dried at 105°C for 24h. The samples were then allowed to cool, and the moisture content was calculated.

Nitrogen content

One (1) g of the sieved soil was weighed into a Kjeldahl flask (digestion tube). A few drops of water were added and left to stand for approximately 30 minutes. Five grams of the Kjeldahl catalyst mixture (a blend of 500 grams of Na2SO4, 50 grams of CuSO4, and 0.5 grams of finely ground selenium catalyst) were added. Then, 20 millilitres of concentrated sulfuric acid were introduced. The mixture was heated on a digestion block until frothing ceased, and the temperature was raised until the solution cleared. After cooling, a small amount of water was carefully added, and the contents were rinsed into a 100-millilitre volumetric flask. After allowing it to cool, the flask was filled to the mark. 10ml were pipetted from the digest into a distillation flask. Twenty millilitres of boric acid were measured into a 100-millilitre conical flask, and three drops of mixed indicator were added. Ten millilitres of NaOH and the 10 millilitres of the digest from the distillation flask were immediately introduced into the distillation unit to distil the digest, collecting approximately 60 millilitres of distillate. The distillate was titrated with 0.01N H2SO4 until the colour changed from green-blue to purple, indicating the endpoint (AOAC, 2000).

Phosphorus content

Two grams of soil samples were weighed and placed in a beaker. Fifty millilitres of distilled water were added and vigorously shaken until a uniform mixture was achieved. The mixture was then filtered through filter paper into a conical flask, which was subsequently transferred to a sterile beaker. Two millilitres of stannous chloride and two millilitres of ammonium molybdate were added. Immediate colour changes were observed, and the solution was analysed using a spectrophotometer to quantify the phosphorus concentration (Mayer *et al.,* 2017).

Bacteriological analysis

Bacterial population assessment was carried out to estimate the total heterotrophic bacteria.

Preparation of serial dilutions

Serial dilutions were prepared following the American Public Health Association (APHA) Standard Methods. One gram (1 g) of each soil sample was aseptically suspended in 9 mL of sterile physiological saline (0.85% NaCl) to create the initial homogenate. From this base, tenfold serial dilutions were performed by transferring 1 mL of each subsequent dilution into 9 mL of sterile diluent. This standardised approach was essential to reduce the high microbial density of the soil to a "countable range" of 30–300 colonies per plate.

Enumeration of microbial populations

Total bacterial count

This was carried out as described by Cheesbrough (2006). A nutrient agar plate was prepared according to the manufacturer's instructions and sterilised in an autoclave at 121°C for 15 minutes. It was allowed to cool and then aseptically dispensed into the petri dish. The spread plate method was used for bacterial isolation. Zero-point One millilitre of the dilution factor 10^6 was transferred to the agar plate and spread using a sterile glass rod. The plate was incubated at 37°C for a period of 24 hours. Each of the pure isolates was stored in a nutrient agar slant for identification.

Identification of bacterial isolates

The organisms were identified on the basis of their colour, shape, Gram reaction and biochemical characterisation (Cheesbrough, 2006). The following biochemical tests were carried out: Indole, Coagulase, Urease, Citrate test, Methyl Red and Vogues Prokauer (Cheesbrough, 2006).

Gram staining

A drop of water was added to a slide, and a small amount of the colony was transferred aseptically from the Petri dish using a sterile wire loop. A drop of water was placed on a clean microscope slide, and a small amount of the colony was aseptically transferred from the Petri dish using a sterile wire loop and mixed gently. With the use of an inoculating loop to make a thin smear. The smear was air dried, heat fixed and allowed to cool. Crystal violet was added over the fixed smear. It was allowed to stand for 60 seconds; the stain was drained off, and the excess stain was rinsed with water from a faucet. The basic objective of this step is to wash off the stain. Iodine solution was added to the smear. It was allowed to stand for 10 to 60 seconds.

The iodine solution was poured off, and the slide was rinsed under running water. Excess water was shaken off from the surface. A few drops of alcohol were added. It was rinsed with water after 5 seconds. It was counterstained with safranin. The slides were allowed to dry. The slide was examined under the microscope using an oil immersion objective. Gram-positive organisms appear purple to blue, while Gram-negative organisms appear pink or red (Dimri *et al*., 2020).

Biochemical tests

Catalase test

The catalase test was done as described by Cheesbrough (2006). A loopful of the organism was transferred into a

drop of hydrogen peroxide on a slide and was observed for the formation of bubble gas. The presence of bubble gas indicates catalase positive (oxygen), while the absence of bubbles indicates catalase negative.

Coagulase test

This test was done as described by Cheesbrough (2006). A drop of distilled water was placed on two slides; a colony from fresh culture was collected with an inoculating loop and was emulsified in the drop of water to make a thick suspension. A loop full of plasma was added to the thick suspension on one slide, it was then mixed gently and observed within 1 minute for clumping, which indicates a positive test, and no clumping indicates a negative.

Indole test

The indole test was done as described by Cheesbrough (2006). The indole test detects the ability of an organism to produce indole from the amino acid tryptophan. The test organism was inoculated into 5ml of sterile peptone water enriched with 1% tryptophan and was incubated at 37°C for 48 hours. 0.5 ml Kovac's (indole reagent) was added and gently shaken. In a positive test, indole (present in the culture) dissolved in the reagent, which becomes pink and forms a layer at the surface of the medium. A yellow layer at the surface of the medium denotes a negative result.

Urease test

The test organism was picked using a sterile wire loop and inoculated into the prepared urease medium. They were incubated at 37°C for 24-48 hours. A change in the colour of the medium from yellow to pink indicated urease positive test (Cheesbrough, 2006).

Citrate utilization test

This test is based on the ability of some organisms to utilize citrate as a sole source of carbon. The medium used was Simmon's citrate agar. It was carried out by inoculating the test organism in test tube containing Simon's citrate medium and incubate at 37°C for 48 hours. A deep blue color indicates a positive result (Cheesbrough, 2006).

Methyl Red

Pure colony of the test organisms was inoculated into a sterile buffered glucose-peptone broth and incubated at 37°C for 24 hours. Five (5) drops of methyl red reagent was added to the culture. Red color change was observed as positive result while yellow color change indicated a negative result (Chesbrough, 2006).

Voges Proskauer

The test organism was inoculated into the VP medium and incubated aerobically at 37°C for 24 hours. During the incubation process, 2 ml of the broth was aliquoted to a clean test tube. The remaining broth was re-incubated for an additional 24 hours. Six drops of 5% alpha naphthol were added and mixed well to aerate. Two drops of 40% KOH were added and mixed well to aerate. If it was positive, pink-red colouration surfaced within 30 minutes (the tubes were shaken vigorously during the 30-minute period). If it was negative, there was no color change.

Lettuce cultivation

The lettuce was cultivated on compost soil, chemically-fertilised soil and non-compost (control) soil. The experiment was conducted in a well-ventilated screen house to protect the plants from pests while maintaining natural light and temperature conditions. For each treatment, three seedlings were transplanted into each pot (3 seedlings/pot) to allow for adequate spacing and nutrient competition analysis. The lettuce seedlings were watered every morning at approximately 8:00 am with 150 mL of water to ensure consistent moisture levels. The growth of the seedlings was carefully monitored on a weekly basis by measuring plant height and leaf count. Finally, the lettuce was harvested after one month of planting for biomass evaluation.

RESULTS

Physicochemical parameters from different soil treatments used for lettuce growth are shown in Table 1. The temperature for compost soil ranged from 26 to 28°C, fertilised soil ranged from 26 to 30°C, and non-compost soil ranged from 25 to 26°C. pH for compost ranged from 5.6 to 6.2, fertilised pH ranged from 6.7 to 8.2, and for non-compost soil ranged from 7.6 to 8.2. Moisture content for compost soil ranged from 23 to 28%, fertilised soil ranged from 10 to 15%, and non-compost soil ranged from 5 to 10%. The percentage nitrogen for compost soil ranged from 0.18 to 0.23%, fertilised soil ranged from 0.17 to 0.22%, and non-compost soil ranged from 0.12 to 0.21%. The percentage phosphorus for compost soil ranged from 0.23 to 1.13%, fertilised soil ranged from 1.06 to 4.1%, and for non-compost soil ranged from 0.39 to 1.03%.

The physicochemical parameters of the compost is presented in Table 2. The pH of the compost soil is 5.6, the temperature is 22°C, color greenish-brown and the odour is earthy-smelling.

Table 1. Physicochemical parameters of different soil treatment used for lettuce growth.

Sampling locations	Soil type (treatment)	Temperature (ºC)	Ph	%Moisture content	%N (mg/kg)	P(mg/kg)
Gusau Market	Compost	27	5.6	28	0.18	1.13
	Fertilized	30	6.7	15	0.19	3.89
	Non-compost	25	8.2	5	0.12	0.39
Bola Jari	Compost	28	6.2	23	0.22	0.23
	Fertilized	26	7.1	10	0.17	1.06
	Non-compost	25	6.9	10	0.21	1.03
Gusau Hotel	Compost	26	6.1	25	0.23	0.73
	Fertilized	28	8.2	15	0.22	4.01
	Non-compost	26	7.6	10	0.19	0.43

Key: °C–Decree Celsius, %-Per cent, mg/kg- Milligram/kilogram.

Table 2. Physicochemical parameters of the compost.

Treatment	Temperature (ºC)	pH	Color	Odour
Compost	22	5.6	Greenish-brown	Earthly

Table 3. Total viable bacterial load of different soil treatments used for lettuce growth.

Sampling Locations	Treatments	Total Bacterial Count (CFU/g)
Gusau Market	Compost	9.2×10^6
	Fertilize	6.7×10^6
	Non-compost	22.0×10^6
Bola Jari	Compost	30.8×10^6
	Fertilize	30.4×10^6
	Non-compost	4.2×10^6
Gusau hotel	Compost	8.5×10^6
	Fertilize	6.5×10^6
	Non-compost	5.4×10^6

Key: CFU/g- Colony Forming Unit/ gram of soil sample.

Total bacteria for compost soil ranged from 8.5 to 30.8×10^{-6}(CFU/g), fertilized soil ranged from 6.5 to 30.4×10^6 (CFU/g), and non-compost soil from 4.2 to 22.0×10^6 (CFU/g) (Table 3).

The morphological and biochemical profiles of the bacterial isolates recovered from various soil treatments are summarised in Table 4. Three distinct species were identified based on their physiological responses: *Bacillus cereus*, *Bacillus megaterium* and *Micrococcus luteus*. Both *B. cereus* and *B. megaterium* were identified as Gram-positive rods, while *M. luteus* appeared as Gram-positive cocci. All three isolates tested positive for citrate utilisation and urease production. Furthermore, all isolates were non-motile, indole-negative, and failed to utilise sucrose or lactose, suggesting a specific carbohydrate fermentation profile. Despite these similarities, the isolates exhibited key differences in their enzymatic and fermentative behaviours: *B. cereus* was the only organism to test positive for catalase and coagulase production, while also demonstrating the ability to ferment glucose without gas production. *B. megaterium* shows unique characteristics by gas production during fermentation and a positive Voges-Proskauer reaction, though it tested negative for catalase and coagulase. *M. luteus* was distinguished by its hydrogen sulfide production and a positive Methyl Red test.

Table 5 shows the occurrence of bacteria isolated from different soil treatments used for lettuce growth. *Bacillus*

Table 4. Morphological and Biochemical characteristics of bacterial isolates from different soil treatments used for lettuce growth.

Isolate	Gram Stain	Form	Catalase	Coagulase	Motility	Indole	Citrate	Urease	Methyl red	Voges Proskauer	Gas	Glucose	Sucrose	Lactose	Hydrogen sulfide	Suspected Organism
1	+	Rod	+	+	-	-	+	+	+	-	-	+	-	-	-	*Bacillus cereus*
2	+	Rod	-	-	-	-	+	+	+	-	+	+	-	-	-	*Bacillus megaterium*
3	+	Cocci	-	+	-	-	+	+	-	+	-	-	-	-	+	*Micrococcus luteus*

Key: + =Positive, - = Negative

Table 5. Occurrence of bacteria isolated from different soil treatments used for lettuce growth.

Bacteria Isolates	Compost soil N=3(%)	Fertilized soil N=3(%)	Non-compost soil N=3(%)	Frequency N=9(%)
Bacillus cereus	2 (66.3%)	1(33.3%)	0(0.0%)	3 (33.3%)
Bacillus megaterium	0(0.0%)	1(33.3%)	0(0.0%)	1(11.1%)
Pseudomonas flurescens	1(33.3%)	1(33.3%)	0(0.0%)	2 (22.2%)
Micrococcus leteus	0(0.0%)	0(0,0%)	3(100%)	3(33.3%)

Total p<0.05. **key**: N= Total number of samples analysed.

Table 6. Growth parameters of lettuce in different soil treatments from different locations.

Sampling Locations	Treatment	Germination	Plant height(cm)	Number of leaves
Gusau Market	Compost	4	7.4	12
	Fertilize	5	7.0	9
	Non-compost	7	4.8	9
Bola Jari	Compost	4	7.1	10
	Fertilize	6	6.9	10
	Non-compost	7	4.6	8
Gusau hotel	Compost	5	7.2	10
	Fertilize	5	7.0	9
	Non-compost	6	4.2	8

cereus was the most prevalent species in the compost soil, accounting for 66.3% of the isolates in that treatment. In contrast, the fertilised soil exhibited a more uniform distribution, with B. cereus, *B. megaterium,* and *Pseudomonas fluorescens* each occurring at an equal rate of 33.3%. Notably, the non-compost soil was dominated entirely by *Micrococcus luteus,* which showed a 100% occurrence within that treatment group. When evaluating the overall frequency across all nine samples (N = 9), *B. cereus* and *M. luteus* emerged as the most frequent isolates, each representing 33.3% of the total microbial recovery.

The growth parameters of lettuce in different soil treatments from different locations are shown in Table 6. In terms of germination**,** the compost treatment showed the fastest results (averaging 4–5 days), whereas the non-compost control lagged significantly, taking up to 7 days in some locations.

Regarding plant height, the compost-treated lettuce consistently outperformed the other groups, reaching a maximum height of 7.4 cm at the Gusau Market site. While the chemically fertilised plants maintained a competitive height (averaging 6.9–7.0 cm), they did not surpass the compost group. The most striking difference, however, was observed in the leaf count. The compost-amended plants produced up to 12 leaves per plant, indicating a

denser and healthier canopy compared to the fertilised and non-compost groups, which generally plateaued at 8–10 leaves.

DISCUSSION

The application of kitchen waste compost and chemical fertiliser resulted in distinct changes in the physicochemical properties and nutrient content of the experimental soils. The observed higher pH in the Fertilised and Non-compost soils (6.7– 8.2) compared to the Compost soil (5.6 – 6.2) suggests that the organic matter in the compost acted as a buffering agent. This buffering capacity likely maintained the more acidic to near-neutral profile observed in our compost-treated samples. This pH reduction towards neutrality in the Compost treatment is beneficial, as it optimises the availability of most micronutrients for plant uptake (Brady and Weil, 2017).

The higher temperature recorded in the Fertilised and Non-Compost soils (26 – 30°C) compared to the Compost soil (26 to 28°C) is likely attributable to the lower moisture content observed in these unamended and chemically-treated soils. The significantly higher moisture content in the compost soil (estimated 23-28 %) reflects the well-documented ability of humified organic matter to improve soil structure and increase its Water Holding Capacity (Brady and Weil 2017).

Regarding nutrient dynamics, the Compost soil showed the highest levels of Total Nitrogen (0.18 - 0.23%), while Available Phosphorus was highest in the Fertilised soil (1.06 to 4.1%). Suvendran *et al.* (2025) similarly observed that organic amendments significantly boost soil fertility by increasing organic matter, which acts as a reservoir for nitrogen. This elevated Nitrogen is a direct result of the organic matter input, where it is primarily in organic forms that are slowly mineralised by soil microbes, providing a sustained release (Dion *et al.,* 2020; Suvendran *et al*., 2025). Furthermore, while compost supports long-term nutrient stability, peak available phosphorus is often higher in mineral-fertilised soils due to the immediate solubility of inorganic phosphorus sources (Wierzbowska *et al*., 2020)

A key finding of this study was the significantly higher total bacterial load in the Compost soil (8.5 to 30.8×10^{-6}(CFU/g)), compared to the other two treatments. This supports the early assumption made by Tiquia (2010), who reported that organic amendments provide a more complex and continuous source of C, N, and other growth factors, which act as a profound stimulant for the size and activity of the soil microbial community. The indigenous microbiota thrives on the diverse, easily decomposable organic substrates present in mature compost.

The isolation of Gram-positive bacteria, specifically the rod-shaped *Bacillus species* and the spherical *Micrococcus luteus*, suggests that the kitchen waste compost created an environment conducive to resilient, metabolically active microorganisms. The presence of *Bacillus cereus* and *Bacillus megaterium* in compost-amended soils may be attributed to high nutrient cycling efficiency. Morphologically, their ability to form endospores allows them to survive the thermophilic phases of composting that often eliminate pathogens (Ultanbekova *et al.,* 2025).

B. megaterium is widely recognised as a Phosphate Solubilizing Bacterium. Its presence likely explains the improved phosphorus uptake observed in the lettuce (*Lactuca sativa*) tissue (Lopez *et al*., 2021).

The isolated bacterial species further underscore the biological benefits of the compost. The identification of *Bacillus cereus* (33.3%) and *B. megatherium* (11.1%) is significant, as species from the genus Bacillus are well-known Plant Growth Promoting Rhizobacteria (PGPR). Glick (2012) reported that *Bacillus cereus* and *B. megatherium* contribute to soil fertility through P-solubilization, N-fixation and the production of hormones and antibiotics. This is because these bacteria solubilise phosphorus by secreting organic acids that break down insoluble mineral phosphates into forms plants can absorb. They enhance nitrogen availability through atmospheric N-fixation and stimulate root development by synthesising signalling hormones, such as indole-3-acetic acid (IAA). Additionally, they produce natural antibiotics and siderophores that suppress soil-borne pathogens, effectively acting as a biological shield for the plant. Similarly, *Pseudomonas fluorescens* is a potent Plant Growth-Promoting Bacteria (PGPR) noted for its ability to enhance nutrient uptake and suppress plant pathogens through the production of siderophores (Vessey, 2003). The presence of Micrococcus luteous, though often considered a general saprophyte (Dworkin *et al*., 2006), indicates the active degradation of organic polymers. The proliferation of these beneficial bacteria in the Compost soil suggests that the compost treatment not only supplies nutrients but also establishes a biologically active and potentially disease-suppressive soil environment.

Despite the differences in soil physicochemical properties and microbial loads, the observation that all lettuce growth parameters were within the normal range across all treatments indicates that neither the compost nor the chemical fertiliser induced phytotoxicity, and both provided sufficient nutrients for acceptable plant development. This lack of phytotoxicity aligns with the findings of Paradelo *et al*. (2019), who suggest that normal lettuce development is a definitive indicator of compost maturity. Furthermore, the fact that growth parameters matched chemical treatments supports the view of Hargreaves *et al*. (2008) that kitchen waste compost serves as an effective, non-limiting nutrient source The enhanced microbial population and sustained nutrient release, particularly TN, in the Compost soil would suggest its superior potential for long-term soil health and productivity compared to the immediate, but potentially less sustainable, nutrient spike provided by the synthetic

fertiliser. The integration of high microbial activity with improved physical parameters (moisture content) strongly supports the utility of kitchen Waste compost as a comprehensive and sustainable soil management strategy.

Conclusion

This study demonstrates that kitchen waste compost is a superior and more sustainable alternative to chemical fertilisers for the cultivation of *Lactuca sativa*. Our findings show that while chemical fertilisers provide a rapid nutrient spike, compost creates a more stable "living soil" by maintaining optimal moisture retention and a balanced pH. These physical improvements, combined with a steady, slow-release nutrient profile, effectively mitigate the risks of leaching and over-fertilisation.

Furthermore, the significant enrichment of beneficial microbial populations, specifically PGPR such as *Bacillus* and *Pseudomonas* species, suggests that compost does more than just feed the plant; it establishes a biologically active environment capable of nutrient cycling and potential pathogen suppression. Ultimately, transitioning to kitchen waste compost-amendment strategies offers a dual benefit: it provides a high-quality growth medium for urban agriculture and presents a viable, ecologically sound solution for organic waste management.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

Adesemoye, A. O., & Kloepper, J. W. (2009). Plant–microbes interactions in enhanced fertiliser-use efficiency. *Applied microbiology and biotechnology*, *85*(1), 1-12.

Ayilara, M. S., Olanrewaju, O. S., Babalola, O. O., & Odeyemi, O. (2020). Waste management through composting: Challenges and potentials. *Sustainability*, 12(11), 4456.

Bashir, O., Ali, T., Baba, Z. A., Rather, G. H., Bangroo, S. A., Mukhtar, S. D., Naik, N., Mohiuddin, R., Bharati, V., & Bhat, R. A. (2021). Soil organic matter and its impact on soil properties and nutrient status. In *Microbiota and biofertilizers, Vol 2: Ecofriendly tools for reclamation of degraded soil environs* (pp. 129-159). Cham: Springer International Publishing.

Brady, N. C., & Weil, R. R. (2017). *The Nature and Properties of Soils*. Pearson Education Limited. (15th ed.). Pp. 530-545.

Campbell, J. A., Thompson, H. J., & Roberts, M. P. (2014). Techniques for measuring soil temperature: Methods and applications. *Journal of Soil Science and Environmental Management*, 5(2), 45-52.

Cheesbrough, M. (2006). *District Laboratory Practice in Tropical Countries*. Cambridge, UK: Cambridge University Press. Part 1, 2nd edition. Pp. 97-115.

Dion, P. P., Jeanne, T., Thériault, M., Hogue, R., Pepin, S., & Dorais, M. (2020). Nitrogen release from five organic fertilizers commonly used in greenhouse organic horticulture with contrasting effects on bacterial communities. *Canadian Journal of Soil Science*, *100*(2), 120-135.

Dworkin, M., Falkow, S., Rosenberg, E., Schleifer, K. H., & Stackebrandt, E. (2006). *The Prokaryotes: Archaea. Bacteria: Firmicutes, Actinomycetes*. Springer Science and Business Media, 3, 961-971.

Glick, B. R. (2012). Plant growth-promoting bacteria: mechanisms and applications. *Scientifica*, Volume 2012, Article ID 963401, 15 pages.

Hargreaves, J. C., Adl, M. S., & Warman, P. R. (2008). A review of the use of composted municipal solid waste in agriculture and horticulture. *Agriculture, Ecosystems & Environment*, 123(1-3), 1-14.

Hoornweg, D., & Bhada-Tata, P. (2012). *What a Waste: A Global Review of Solid Waste Management*. Urban Development Series; Knowledge Papers no. 15. World Bank, Washington, DC.

Lopez Marin, M. A., Strejcek, M., Junkova, P., Suman, J., Santrucek, J., & Uhlik, O. (2021). Exploring the potential of *Micrococcus luteus* culture supernatant with resuscitation-promoting factor for enhancing the culturability of soil bacteria. *Frontiers in Microbiology*, 12, 685263.

National Population Commission of Nigeria (NPCN) (2022). Nigeria Data Dissemination Service (NDDS).

Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. *Applied and Environmental Soil Science*, 2019(1), 5794869.

Paradelo, R., Basanta, R., & Barral, M. T. (2019). Water-holding capacity and plant growth in compost-based substrates modified with polyacrylamide, guar gum or bentonite. *Scientia Horticulturae*, *243*, 344-349.

Soobhany, N., Mohee, R., & Garg, V. K. (2017). Comparative assessment of heavy metals content during the composting and vermicomposting of municipal solid waste processed in laboratory condition. *Environmental Science and Pollution Research*, 24(10), 8634–8644.

Suvendran, S., Acevedo, M. F., Smithers, B., Walker, S. J., & Xu, P. (2025). Soil fertility and plant growth enhancement through compost treatments under varied irrigation conditions. *Agriculture*, *15*(7), 734.

Tiquia, S. M. (2010). Reduction of compost phytotoxicity during the process of decomposition. *Chemosphere*, 79(5), 506-512.

Ultanbekova, G., Jumakhanov, B., Nussupov, A., Faleev, D., Satymbekov, R., Kulymbet, K., ... & Mamytova, N. (2025). The role of *Bacillus megaterium* PEF-1 in stimulating the growth of organic cotton under environmental stress conditions. *Scientific Reports*, 15(1), 45729.

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, 255(2), 571-586.

Wierzbowska, J., Sienkiewicz, S., Zalewska, M., Żarczyński, P., & Krzebietke, S. (2020). Phosphorus fractions in soil fertilised with organic waste. *Environmental Monitoring and Assessment*, 192(5), 1–14.

Zhang, R., El-Mashad, H. M., Hartman, K., Wang, F., Liu, G., Choate, C., & Gamble, P. (2007). Characterization of food waste as feedstock for anaerobic digestion. *Bioresource Technology*, 98(4), 929-935.