Effect of Soil and Foliar Applied Fertilizers on Soil Microbial Populations under Sweet Potato Cultivation

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ABSTRACT: Soil microbial communities play a vital role in nutrient cycling and plant health, yet limited studies examine how fertilizer application methods affect these populations in sweet potato cultivation. A field experiment was conducted at the Federal University of Technology, Akure (7°16'N, 5°12'E) between April and August 2025 using a Randomized Complete Block Design with nine treatments: Poultry Manure (PM), NPK (20:10:10), Liquid Organic Fertilizer (Super gro – SG), Urea, PM + SG, PM + Urea, NPK + SG, NPK + Urea, and a Control, each replicated three times. Soil samples were collected 12 weeks after planting for microbial analysis, while growth and yield data were measured throughout the growing season. Standard microbial enumeration techniques using dilution plate counts quantified bacterial, fungal, actinomycetes, and nematode populations. Results showed significant variations among treatments. NPK application maximized bacterial (3.57×10^{-5} cfu) and nematode populations (358.00 individuals/100g soil), while Urea favoured fungal (3.27×10^{-5} cfu) and actinomycetes (1.30×10^{-5} cfu) populations. Single fertilizer applications, particularly NPK and Super Gro, achieved the highest yields (11.93 and 11.76 t/ha, respectively), outperforming combinations. Super Gro foliar application produced superior vine length (285.3 cm) while maintaining moderate microbial disruption. The Poultry Manure + Super Gro combination significantly enhanced organic matter (1.82%) and calcium content (5.6 cmol/kg). The study reveals that fertilizer application method substantially influences soil microbial dynamics and sweet potato productivity, with single applications proving more effective than combinations under tropical conditions.

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Introduction

Soil microorganisms play a vital role in nutrient cycling, organic matter decomposition, and the maintenance of soil fertility and ecosystem stability (Singh *et al*., 2020). Among these microorganisms, bacteria, fungi, actinomycetes, and nematodes constitute important components of the soil biota that influence plant growth either directly or indirectly through their effects on soil biochemical processes (Nannipieri et al., 2017). The population and activity of these soil organisms are influenced by various soil management practices, including fertilizer type and application method (Zhang *et al*., 2019). Understanding how different fertilizer regimes affect soil microbial communities is critical for developing sustainable soil fertility management strategies.

Sweet potato (*Ipomoea batatas* L.) is a major root crop in tropical and subtropical regions, valued for its adaptability to marginal soils, nutritional quality, and role in food security (Woolfe, 1992; Laurie *et al*., 2015). Despite its resilience, sweet potato yield is often limited by low soil fertility, particularly nitrogen (N) and phosphorus (P) deficiencies common in tropical soils (Amoah *et al*., 2020). The application of fertilizers has therefore become a common practice to enhance soil fertility and increase yield. However, continuous use of inorganic fertilizers without organic amendments can degrade soil structure and reduce microbial biodiversity (Guo et al., 2019).

Organic fertilizers such as poultry manure are rich in organic matter and beneficial microbes, which improve soil physicochemical properties, enhance microbial activity, and promote nutrient mineralization (Masto *et al*., 2019). Poultry manure is particularly valued for its high nitrogen, phosphorus, and potassium content and its ability to stimulate microbial proliferation and enzymatic activity in soils (Adewumi *et al*., 2022). Conversely, synthetic fertilizers such as NPK (20:10:10) provide readily available nutrients to crops but may suppress microbial populations when used excessively, due to soil acidification and salt buildup (Liu *et al*., 2018).

Foliar fertilization applying nutrients directly to plant leaves has emerged as an efficient means of supplementing soil fertilization, especially under conditions of low nutrient availability or poor root uptake (Fernández & Eichert, 2009). Foliar-applied fertilizers such as urea or liquid organic formulations like Super Gro (SP) can enhance nutrient use efficiency, stimulate photosynthetic activity, and improve crop performance (Marschner, 2012; Raliya *et al*., 2016). However, their influence on soil microbial dynamics remains underexplored, particularly when combined with soil-applied fertilizers.

Interactions between soil-applied organic and inorganic fertilizers and foliar nutrient sprays can lead to synergistic effects on both plant growth and soil microbial populations (Wang *et al*., 2020). Organic fertilizers supply substrates for microbial metabolism, while inorganic or foliar fertilizers enhance nutrient availability for both plants and microbes (Jindo et al., 2020). Such combined applications may create favorable soil conditions that enhance the population of beneficial microorganisms including bacteria, fungi, actinomycetes, and nematodes, thereby promoting soil health and crop productivity.

Assessing the impact of these fertilizer combinations on soil microbial populations under sweet potato cultivation is therefore essential for developing integrated nutrient management strategies that balance crop productivity with long-term soil fertility. This study aims to evaluate the effect of soil and foliar applied fertilizers poultry manure, NPK, Super Gro, and urea, alone and in combinations on soil microbial populations (bacteria, fungi, actinomycetes, and nematodes) under sweet potato cultivation in southwestern Nigeria.

Materials and Methods

Site Description and Experimental Design

The field experiment was conducted at the Teaching and Research Farm of the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria (7°16'N, 5°12'E) between April and August 2025. The site is located in the rainforest vegetation zone characterized by bimodal rainfall patterns with an annual mean of approximately 1300 mm. The soil is classified as an alfisol (USDA classification) with sandy clay loam texture.

The experiment was laid out in a Randomized Complete Block Design with nine treatments, and each treatment was replicated three times. Each treatment plot measured 17m^2 The alley- way measured 1m while adjacent treatments were separated with 0.5 inter-plot spacing Treatments evaluated were: (1) Poultry Manure (PM), (2) NPK (20:10:10), (3) Liquid Organic Fertilizer (Super gro – SG), (4) Urea, (5) PM + SG, (6) PM + Urea, (7) NPK + SG, (8) NPK + Urea, and (9) Control (no fertilizer).

Crop Establishment and Fertilizer Application

Ridges were manually constructed and sweet potato vines of 30 cm length were planted one per hole at 50 cm spacing. Poultry manure was applied two weeks before planting while NPK was applied two weeks after planting as sub-surface side dressing. Super Gro and urea were applied as foliar treatments at 4, 6, 8, and 10 weeks after planting using a knapsack sprayer (Polijet nozzles) calibrated to deliver 250 L/ha at 2.5 kg/cm² pressure. The experiment was rainfed and weeds control was performed manually throughout the growing season.

Data Collection

Plant growth parameters (vine length and leaf number) were collected from five randomly selected plants at 5, 7, 9, and 16 weeks after planting (WAP). Vine length was measured with a tape measure, and leaf numbers were determined by visual count. Yield data were collected at harvest (16 WAP), including tuber weight, length, and diameter measurements on a digital balance and measuring tape. Soil samples (0–15 cm depth) were collected 12 weeks after planting from each treatment plot using a composite sampling approach. Samples were transported in sealed, labelled polyethylene bags to the laboratory, sieved (<2 mm) to remove plant materials and debris, and stored at 4°C until analysis.

Microbial Enumeration

Numbers of microflora were estimated by soil dilution technique on Nutrient and Potato Dextrose Agars as isolation media for bacteria and fungi, respectively. To achieve serial dilution, 5 grams of soil was suspended in 150 ml Erlenmeyer flask containing 95 ml of sterilized distilled water to obtain a 10^{-1} dilution and was kept under shaking conditions at 120 rpm for 15 minutes. From the flask 1 ml of suspension was transferred to 9 ml water blank to make 10^{-2} dilution. The water blank was vortexed and then again 1 ml of the suspension was transferred to a new water blank (9 ml) tube to obtain 10^{-3} dilution. In the similar manner dilutions were made up to 10^{-8}. The nutrient agar medium was composed of peptone 5 g, meat extract 3 g, agar 15 g and 1000 mL distilled water. For bacterial count 0.1 ml aliquot of the dilution to 10^{-8} was spread and plated on nutrient agar medium Petri plates in triplicates. Then the plates were incubated in an inverted position at 28˚C for 2 days. The constituents of the Potato Dextrose Agar (gL^{-1}) were Peptone 5.0, potato extract 5.0, dextrose 10.0, Agar 20.0, and distilled water 1000.0 ml at pH 6.5. Starch Casein Agar was used for actinomycetes population enumeration A mixture of 1g soil and 10mL of saline solution was shaken on a mechanical shaker for 10 minutes to dislodge fungal propagules into the solution. This was followed by serial dilutions to the concentrations of 10^{-5}. 0.5 mL of the aliquot was spread on Potato dextrose extract agar to isolate fungal spores and this was incubated at 28^{0C} for 4 days. Dilution factors of 8 and 5 were used to determine the bacterial, actinomycetes colonies and fungal spore forming units, respectively. Soil nematodes were extracted using the Baermann funnel technique (Baermann, 1917; Hooper, 1986). A 300 g fresh soil sample was placed on a double layer of filter paper supported by a sieve suspended over sterile distilled water. The setup was left undisturbed for 48 hours to allow nematode migration into the water. After the migration period, the nematode suspension was collected, concentrated by sedimentation, and enumerated under a stereomicroscope. The results were expressed as the number of individuals per 100 g of dry soil.

Soil Chemical Analysis

Soil pH was determined in a 1:2 soil-to-water suspension using a calibrated pH meter standardized with buffer solutions of known pH. Organic carbon was analyzed using the Walkley–Black wet oxidation method. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) were extracted with 1 M ammonium acetate (pH 7.0) and quantified using an atomic absorption spectrophotometer.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using MINITAB 17 statistical software. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at the 5% probability level.

RESULTS

Effects on Plant Growth Parameters

Super Gro fertilizer foliar application produced the longest vines at harvest (285.3 cm), significantly exceeding NPK (259.0 cm) and NPK + Urea (241.4 cm), while the Control treatment produced the shortest vines (204.4 cm). Vine length increased progressively throughout the growing season under all treatments, with Super Gro maintaining superiority from 5 weeks after planting (WAP) (110.2 cm) through final harvest. Leaf production showed contrasting temporal patterns. The Poultry Manure + Urea liquid fertilizer combination produced the highest leaf counts at final harvest (690.1 leaves at 16 WAP), compared to 395.0 leaves for Super Gro and 305.3 for the Control. Early in the season (5 WAP), the Control treatment showed the highest leaf numbers (188.4), which subsequently declined to 96.0 by 7 WAP before recovering as season progressed.

Table 1. Effects of soil and foliar applied fertilizers on the Number of leaves of sweet potato

	Weeks after planting			
Treatment	5	7	9	16
PM	69.2bc	186.3bcd	276.6cd	306.6b
NPK	170.3a	299.1ab	490.0ab	442.4b
SG	86.8bc	306.6a	601.9a	395.0b
UREA	76.8bc	137.3cd	303.5cd	401.0b
PM + SG	83.3bc	187.5bcd	338.6cd	374.3b
PM + UREA	157.0a	251.6abc	333.5cd	690.1a
NPK + SG	107.0b	208.8abcd	403.2bc	379.6b
NPK + UREA	61.8c	266.0abc	242.9d	333.0b
CONTROL	188.4a	96.0d	242.4d	305.3b

Means followed by the same letter in the same column are not significantly different from each other by Tukey's HSD at 5% level of probability

Table 2. Effects soil and foliar applied fertilizers on the vine length of sweet potato
Means followed by the same letter in the column are not significantly different from each other by Turkey's HSD at

	Weeks after planting			
Treatments	5	7	9	16
PM	59.8c	106.8cd	200.2a	247.4bc
NPK	83.5b	146.7ab	206.3a	259.0ab
SG	110.2a	169.9a	206.4a	285.3a
UREA	41.8c	95.4d	182.7ab	222.0cde
PM + SG	93.5ab	106.3cd	210.2a	227.5cde
PM + UREA	102.3ab	152.3ab	210.7a	212.8de
NPK + SG	90.6ab	130.0bc	172.2ab	235.7bcd
NPK + UREA	53.9c	797.0d	141.4ab	241.4bcd
CONTROL	101.2ab	81.7d	104.2b	204.4e

5 % level of probability.

Effect of soil and foliar applied fertilizer on sweet potato yield

Single fertilizer applications achieved superior yields compared to combination treatments. NPK application produced the highest yield (11.93 t/ha), followed closely by Super Gro (11.76 t/ha), while the Control achieved 7.74 t/ha. Combination treatments generally underperformed, with PM + SG yielding 8.60 t/ha and PM + Urea yielding 8.99 t/ha. The Urea treatment produced the largest individual tubers (average weight 1.80 g, diameter 18.96 cm) but the lowest yield per hectare (2.33 t/ha), demonstrating a trade-off between tuber size and total productivity.

Table 3: Effects of soil and foliar applied fertilizers on the yield of sweet potato

Treatments	Average tuber weight	Tuber yield per plot	Tuber Length	Tuber Diameter	Marketable	Non - Marketable	Yield (t/ha)
PM	1.38abc	2.45c	15.19bc	18.06ab	12.33a	4.00b	8.21ab
NPK	1.37abc	3.58a	14.39bcd	17.88ab	12.00a	11.66a	11.93a
SG	1.42abc	2.47c	15.48bc	18.60a	15.00a	3.00b	11.76ab
UREA	1.80a	3.00abc	18.96a	18.07ab	14.66a	2.33b	9.38ab
PM + SG	1.53abc	2.58c	17.68ab	18.76a	14.67a	4.00b	8.60ab
PM + UREA	1.14c	2.60c	14.95bc	17.20ab	11.66a	3.00b	8.99ab
NPK + SG	1.17bc	2.70bc	14.07cd	15.82ab	11.95a	11.00a	9.99ab
NPK + UREA	1.66ab	3.53ab	13.60cd	16.14ab	11.68a	10.66a	10.67ab
CONTROL	1.09c	2.32c	11.46d	15.02b	11.00a	12.00a	7.74b

Means followed by the same letter in the same column are not significantly different from each other by Tukey's HSD at 5% level of probability

Effects of soil and foliar applied fertilizer on soil microbial populations

Bacterial populations were significantly influenced by fertilizer treatment. NPK application resulted in the highest bacterial counts (3.57×10^{-5} cfu/g soil), followed by the Control (3.17×10^{-5} cfu/g) and Super Gro (3.07×10^{-5} cfu/g). Urea treatment suppressed bacterial populations to 2.40×10^{-5} cfu/g, the lowest among treatments. Fungal populations demonstrated markedly different treatment responses. Urea application maximized fungal abundance (3.27×10^{-5} cfu/g), while NPK application dramatically suppressed fungi to 0.80×10^{-5} cfu/g. The PM + Urea combination showed the lowest fungal counts (0.60×10^{-5} cfu/g). Actinomycetes populations peaked under Urea (1.30×10^{-5} cfu/g) and NPK + Super Gro (1.30×10^{-5} cfu/g), while the PM + Super Gro combination produced the lowest counts (0.43×10^{-5} cfu/g), suggesting potential antagonistic interactions between these amendments.

Nematode populations ranged from 240 individuals/100g soil (Urea) to 358 individuals/100g soil (NPK). Most other treatments maintained intermediate populations between 258–318 individuals/100g soil, suggesting that nematode abundance closely tracked bacterial food resources across treatments.

Table 4. Effects of soil and folia applied fertilizers on soil microbial population (10^{-5}) sweet potato

	Nematode	Actinomycetes(cfu)	Bacteria(cfu)	Fungi(cfu)
PM	302.000ab	1.26667ab	3.00000ab	2.50000b
NPK	358.000a	0.83333bcd	3.56667a	0.80000de
SG	308.000ab	1.06667abc	3.06667ab	1.16667cd
UREA	240.000b	1.30000a	2.40000b	3.26667a
PM+SG	286.000ab	0.43333d	2.86667ab	2.60000b
PM+UREA	258.000ab	0.80000cd	2.60000ab	0.60000e
NPK+SG	274.000ab	1.30000a	2.73333ab	1.50000c
NPK+UREA	276.000ab	1.03333abc	2.76667ab	2.23333b
CONTROL	318.033ab	1.26667ab	3.16667ab	1.26667cd

Means followed by the same letter in the same column are not significantly different from each other by Tukey's HSD at 5% level of probability

Effect of Soil And Foliar Applied Fertilizer on Soil Chemical Properties

Pre-treatment soil analysis revealed moderate acidity (pH 5.6) with relatively low nutrient status: organic carbon 0.25%, nitrogen 0.06%, phosphorus 3.42 mg/kg, and low exchangeable cations.

Fertilizer treatments produced variable effects on soil chemistry at harvest. Soil pH remained relatively stable across all treatments (4.93–5.90), indicating adequate buffering capacity. The PM + Super Gro combination significantly enhanced organic carbon (1.05%) and organic matter content (1.82%), compared to the Control (0.59% and 1.02%, respectively). NPK application dramatically elevated phosphorus to 14.47%, compared to 1.09% in Super Gro and 0.54% in Urea treatments. The PM + Super Gro combination substantially increased exchangeable calcium (5.6 cmol/kg) and magnesium (2.4 cmol/kg) compared to most other treatments (<2.9 cmol/kg and <1.6 cmol/kg, respectively).

Table 5: Pre-Treatment Soil Analysis of the Experiment Site

Soil Properties	Values
PH(1:2 H2O)	5.6
OC(%)	0.25
N(%)	0.06
P(mg/kg)	3.42
K(Cmol/kg)	0.28
NA(Cmol/kg)	0.46
CA(Cmol/kg)	1.5
MG(Cmol/kg)	0.9

Table 6: Effect of fertilizer treatment on Chemical properties at harvest of sweet potato

TREATMENT	PH	OC	N	P	K	Na	Ca	Mg
PM	5.42a	0.10c	0.08de	3.34d	0.17bc	0.27ab	1.7cd	0.8d
NPK	5.44a	0.25c	0.04f	14.47a	0.18b	0.25bc	1.4d	0.7d
SG	4.93a	0.29bc	0.12c	1.09e	0.14c	0.20cd	1.8cd	0.7d
UREA	5.71a	0.42bc	0.08de	0.54e	0.22a	0.32a	1.5d	0.8d
PM+SG	5.90a	1.05a	0.20a	3.27d	0.15bc	0.22bcd	5.6a	2.4a
PM+UREA	5.40a	0.29bc	0.10cd	5.60c	0.14c	0.19d	2.22	1.1c
NPK+SG	5.56a	0.19c	0.06ef	10.66b	0.17bc	0.26b	1.4d	0.7d
NPK+UREA	5.31a	0.38bc	0.10cd	1.63de	0.18b	0.23bcd	3.2b	1.6b
CONTROL	5.21a	0.59b	0.16	1.29de	0.16bc	0.22bcd	2.9b	1.4b

Means followed by the same letter in the same column are not significantly different from each other by Tukey's HSD at 5% level of probability

Discussions

The present study demonstrated that fertilizer type and mode of application markedly influenced vine growth, yield, soil microbial populations, and soil chemical properties under sweet potato cultivation. Foliar application of Super Gro fertilizer produced the longest vines throughout the growth period, indicating its effectiveness in promoting vegetative growth. Foliar fertilizers provide rapid nutrient absorption through the leaves, bypassing soil-related nutrient limitations and enhancing photosynthetic efficiency (Fernández *et al*., 2013). The superior vine elongation observed under Super Gro treatment compared to NPK or Urea may thus be attributed to enhanced foliar nutrient uptake and hormonal stimulation of vegetative tissues (Fageria *et al*., 2009). Although Super Gro promoted vine growth, the highest leaf count was obtained with the Poultry Manure + Urea treatment, suggesting that combining organic and inorganic fertilizers enhanced canopy development. Organic amendments such as poultry manure improve soil structure and microbial activity, leading to gradual nutrient release that sustains leaf production at later growth stages (Abou El-Magd *et al*., 2012). The initial dominance of the Control in leaf count at 5 WAP followed by a decline may reflect an early stress-induced compensatory response, which diminished as soil nutrients became depleted (Ojeniyi *et al*., 2010).

Yield results revealed that single fertilizer applications, particularly NPK and Super Gro, outperformed combination treatments. The high yield under NPK is consistent with previous reports that mineral fertilizers provide immediate nutrient availability critical for root and tuber development (Osunde *et al*., 2019). However, the Urea treatment, though producing the largest individual tubers, resulted in the lowest yield per hectare, indicating a trade-off between tuber enlargement and total yield, a pattern similarly reported by Agbede (2010). Combination treatments underperformed, possibly due to nutrient antagonism or imbalanced nutrient release between organic and inorganic components (Ayeni *et al*., 2012).

Soil microbial responses reflected distinct nutrient and substrate effects. NPK application enhanced bacterial abundance, likely due to increased nutrient availability stimulating copiotrophic bacterial growth (Zhao *et al*., 2014). In contrast, Urea application suppressed bacterial counts but stimulated fungal proliferation, suggesting shifts in microbial community composition driven by altered C:N ratios and ammonium accumulation (Geisseler & Scow, 2014). The elevated actinomycete counts under Urea and NPK + Super Gro indicate that moderate nitrogen enrichment and organic inputs favored this group, known for decomposing complex organic matter (Wang *et al*., 2016).

Nematode populations correlated with bacterial abundance, indicating the role of bacterial-feeding nematodes in nutrient cycling (Ferris *et al*., 2012). The lowest nematode density under Urea treatment likely resulted from ammonia toxicity or reduced bacterial prey availability (Gupta & Yeates, 1997).

Soil chemical analyses revealed that fertilizer treatments significantly improved soil fertility indicators. The PM + Super Gro combination enhanced organic carbon, calcium, and magnesium, consistent with reports that organic fertilizers improve soil cation exchange capacity and nutrient retention (Ayeni *et al*., 2012). In contrast, NPK drastically elevated phosphorus, reflecting its soluble phosphate formulation. However, persistent soil acidity suggests potential long-term implications for nutrient availability and microbial balance (Brady & Weil, 2017).

Overall, results indicate that while inorganic fertilizers (particularly NPK) optimized yield, organic–inorganic combinations improved soil quality. Integrated nutrient management involving judicious use of both fertilizer types can therefore sustain productivity while maintaining soil health.

CONCLUSIONS

This study reveals that different fertilizer application methods produce distinct effects on soil microbial communities in sweet potato cultivation. Each microbial group (bacteria, fungi, actinomycetes, and nematodes) responded differently to treatments, confirming the complexity of soil biological systems. Single fertilizer applications, particularly NPK and Super Gro, proved more effective than combinations for maximizing both crop productivity and maintaining favourable microbial populations. Super Gro foliar application demonstrated consistent benefits for vegetative growth parameters while maintaining moderate impacts on soil microbial communities, suggesting that foliar fertilization can support plant development with reduced disruption to soil biological systems. It is therefore recommended that sweet potato farmer should prioritize single fertilizer applications (NPK or Super Gro) over complex combinations for superior yields with lower input costs and management complexity.

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