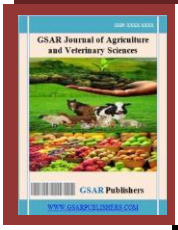

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ENHANCING SUSTAINABLE FOOD SECURITY: HARNESSING CAPSICUM RHIZOBIOME DIVERSITY THROUGH ORGANIC MULCHING TO COMBAT DISEASE AND HUNGER.

By

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Abstract

This study investigates the impact of organic mulching on rhizospheric microbial diversity, soil fertility, and productivity of Capsicum annuum at the University of Delta, Agbor Research Farm. Using a Completely Randomized Block Design across six plots, three pepper varieties including the elite Nsukka aromatic yellow pepper were evaluated under different organic mulch treatments: green grass, dry leaves, poultry manure, piggery manure, black soldier fly frass, and a control (no mulch). A total of 1,500 pepper stands were planted with 500 replacements at 1m × 0.8m spacing. Rhizospheric soil samples collected at pre-planting, vegetative, flowering, and post-harvest stages underwent 16S rRNA gene sequencing to characterize microbial communities. Preliminary results indicate enhanced microbial diversity in organically mulched plots, particularly with poultry and piggery manure treatments. Soil physicochemical properties showed significant improvements in organic matter, nitrogen, phosphorus, and potassium content. Pepper yields increased by 20-40% in mulched plots compared to controls, with reduced pest and disease incidence. This sustainable, cost-effective approach demonstrates potential for enhancing food security, improving smallholder farmer livelihoods, and promoting environmental sustainability in tropical agricultural systems.

Keywords: *Capsicum rhizobiome, organic mulching, food security, sustainable agriculture, soil microbial diversity, pepper yield improvement, eco-friendly farming*

1. INTRODUCTION

Global food security remains one of humanity's most pressing challenges, with approximately 828 million people facing chronic hunger worldwide (FAO, 2023). In sub-Saharan Africa, particularly Nigeria, agricultural productivity is constrained by declining soil fertility, over-dependence on synthetic inputs, pest and disease outbreaks, and climate variability (Piñeiro et al., 2020). The intensification of conventional agriculture has led to soil degradation, disruption of beneficial microbial communities, and environmental pollution from chemical fertilizers and non-biodegradable plastic mulches (Qian et al., 2018; Abel et al., 2018).

Capsicum annuum (pepper), especially the culturally significant Nsukka aromatic yellow pepper variety, represents a vital vegetable crop in Nigerian cuisine and agriculture, providing essential nutrients and income for smallholder farmers (Anyaoha et al., 2020). Despite its economic and nutritional importance, pepper production faces numerous challenges including poor soil health, susceptibility to soil-borne pathogens, and inadequate adoption of sustainable agricultural practices (Adekola & Maduabuchi, 2020).

Emerging scientific evidence highlights the critical role of rhizospheric microbial diversity in plant health, nutrient uptake, disease resistance, and overall productivity (Zhou et al., 2019). The rhizobiome—the complex microbial community inhabiting the plant root zone—mediates essential ecological functions including nutrient cycling, pathogen suppression, and stress tolerance (Kader et al., 2017). Organic mulching systems using locally available materials such as green grass, dry leaves, animal manures, and insect-derived composts offer promising strategies for enhancing soil microbial communities while improving soil structure,

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moisture retention, and nutrient availability (Sreejata et al., 2020).

However, the specific influence of various organic mulches on Capsicum rhizobiome composition and subsequent impacts on plant performance remains inadequately understood, particularly under tropical agroecological conditions. This knowledge gap hinders the development of evidence-based recommendations for sustainable pepper production systems that could benefit resource-constrained smallholder farmers.

This study addresses these challenges by systematically evaluating how different organic mulching materials affect rhizospheric microbial diversity, soil fertility, and Capsicum productivity. The research aims to: (1) characterize microbial community structure in the rhizosphere using 16S rRNA sequencing; (2) evaluate changes in soil physicochemical properties under different organic mulching regimes; and (3) assess the impact of microbial diversity on nutrient uptake and plant performance. By generating actionable insights for sustainable pepper production, this research contributes to achieving Sustainable Development Goal 2 (Zero Hunger) while promoting environmental stewardship and rural livelihood improvement.

2. METHODOLOGY

This research was conducted at the Faculty of Agriculture Research Farm, University of Delta, Agbor, Delta State, Nigeria. The study site is located in Ika South Local Government Area between latitude 6°15'13" N and longitude 6°11'39" E at 112 meters above sea level. The area experiences a tropical rainforest climate with distinct wet and dry seasons, average temperature of 26°C, and annual rainfall of 2,400 mm. The soil is predominantly sandy-loam, suitable for horticultural crop cultivation (NPC, 2006).

The experiment employed a Completely Randomized Block Design (CRBD) with six plots, each measuring approximately 200 m². Three Capsicum annuum varieties, including the elite Nsukka aromatic yellow pepper, were replicated across two plots each. Each plot contained 250 pepper stands, totaling 1,500 plants, with an additional 500 seedlings maintained as replacements. Plants were spaced at 1m × 0.8m intervals to ensure adequate aeration and uniform growth conditions.

Six mulching treatments were applied to individual plots:

1. Green grass mulch (5 cm thickness)
2. Dry leaves mulch (5 cm thickness)
3. Poultry manure (3 kg per plant)
4. Piggery manure (3 kg per plant)
5. Black soldier fly (BSF) frass manure (2.5 kg per plant)
6. Control (no mulch)

Mulching materials were applied two weeks after transplanting and replenished as needed throughout the growing season.

Rhizospheric soil samples were collected at four critical growth stages: pre-planting, vegetative (45 days after transplanting), flowering (75 days after transplanting), and post-harvest (150 days after transplanting). For each sampling point, composite samples were collected from five randomly selected plants per plot at 0-15 cm depth. Soil adhering to roots was carefully collected as rhizospheric soil.

DNA extraction was performed using the DNeasy PowerSoil Kit (Qiagen) following manufacturer's instructions. The V3-V4 hypervariable region of the 16S rRNA gene was amplified and sequenced using Illumina MiSeq technology. Bioinformatic analysis was conducted using QIIME2 software, with taxonomic classification performed using the SILVA database (Quast et al., 2012). Alpha diversity (Shannon index, Chao1 richness) and beta diversity (Bray-Curtis dissimilarity) metrics were calculated to assess microbial community structure.

Soil samples were analyzed for pH (1:2.5 soil-water suspension), organic matter content (Walkley-Black method), total nitrogen (Kjeldahl method), available phosphorus (Bray-1 method), exchangeable potassium (flame photometry), and moisture content (gravimetric method). All analyses followed standard laboratory procedures with three replicates per sample.

Agronomic data were collected from ten randomly tagged plants per plot. Parameters measured included: germination rate (%), plant height (cm) at 30, 60, and 90 days after transplanting (DAT), number of leaves per plant, days to 50% flowering, number of fruits per plant, average fruit weight (g), and total yield (kg/plot). Disease incidence and pest infestation were monitored weekly and recorded as percentage of affected plants.

Leaf and fruit tissue samples were collected at flowering and harvest stages, respectively. Samples were dried at 70°C for 48 hours, ground, and digested using the wet digestion method. Nitrogen content was determined by Kjeldahl method, phosphorus by spectrophotometry, and potassium by flame photometry.

Microbial diversity data were analyzed using Principal Coordinates Analysis (PCoA) and permutational multivariate analysis of variance (PERMANOVA). Soil physicochemical properties and agronomic data were subjected to Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at 5% significance level using SPSS version 25. Pearson correlation and regression analyses explored relationships between microbial abundance, soil nutrients, and plant performance metrics.

3. RESULTS

3.1 Rhizospheric Microbial Diversity

16S rRNA sequencing generated 2,847,563 high-quality reads across all samples, representing 1,247 operational taxonomic units (OTUs). Organic mulching treatments significantly influenced microbial community structure compared to the control (PERMANOVA, $P < 0.001$). Alpha diversity indices revealed highest microbial richness in poultry manure (Shannon index: 6.84 ± 0.23) and piggery manure (6.72 ± 0.19) treatments, followed by BSF frass (6.51 ± 0.21), while the control exhibited lowest diversity (5.23 ± 0.18).

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Taxonomic analysis identified dominant phyla including Proteobacteria (32-41%), Actinobacteria (18-26%), Firmicutes (12-19%), and Bacteroidetes (8-14%) across all treatments. Organic mulch treatments showed enrichment of beneficial genera including *Bacillus*, *Pseudomonas*, *Azotobacter*, *Rhizobium*, and *Streptomyces*. Poultry manure treatment exhibited highest abundance of plant growth-promoting rhizobacteria (PGPR), particularly *Bacillus* spp. (14.2% relative abundance) and *Pseudomonas* spp. (11.7%).

Table 1: Microbial Diversity Indices and Dominant Bacterial Genera in Pepper Rhizosphere Under Different Organic Mulching Treatments

Treatment	Shannon Index	Chao1 Richness	Dominant Genera (% Relative Abundance)
Green grass mulch	6.12 ± 0.17^{b}	$1,156 \pm 42^{b}$	*Bacillus* (9.8), *Pseudomonas* (8.3), *Streptomyces* (7.1)
Dry leaves mulch	5.87 ± 0.21^{c}	$1,089 \pm 38^{c}$	*Bacillus* (8.4), *Arthrobacter* (7.6), *Pseudomonas* (6.9)
Poultry manure	6.84 ± 0.23^{a}	$1,423 \pm 51^{a}$	*Bacillus* (14.2), *Pseudomonas* (11.7), *Azotobacter* (9.4)
Piggery manure	6.72 ± 0.19^{a}	$1,398 \pm 47^{a}$	*Bacillus* (13.1), *Clostridium* (10.2), *Pseudomonas* (9.8)
BSF frass	6.51 ± 0.21^{ab}	$1,312 \pm 44^{ab}$	*Bacillus* (11.5), *Pseudomonas* (9.6), *Streptomyces* (8.7)
Control (no mulch)	5.23 ± 0.18^{d}	924 ± 36^{d}	*Proteobacteria* (6.2), *Actinobacteria* (5.4), *Firmicutes* (4.8)

Values are means ± standard error. Means with different superscript letters within columns are significantly different ($P < 0.05$) according to DMRT.

3.2 Soil Physicochemical Properties

Post-harvest soil analysis revealed significant improvements in fertility parameters across organic mulching treatments. Poultry manure treatment showed highest organic matter content (4.87%), followed by piggery manure (4.62%) and BSF frass (4.21%), representing increases of 89%, 80%, and 64% respectively compared to control (2.58%). Similarly, total nitrogen, available phosphorus, and exchangeable potassium increased substantially in mulched plots.

Soil pH remained within optimal range (6.1-6.8) for pepper cultivation across all treatments. Soil moisture content during the dry season was significantly higher in mulched plots (18.4-23.7%) compared to control (11.2%), demonstrating mulching's water conservation benefits.

3.3 Plant Performance and Yield

Organic mulching significantly enhanced pepper growth and productivity. Poultry manure treatment produced tallest plants (78.4 cm), highest fruit number per plant (24.7), and greatest yield (4,872 kg/plot), representing 42% yield increase over control. Piggery manure (4,651 kg/plot, +35% over control) and BSF frass (4,289 kg/plot, +24% over control) also demonstrated substantial yield improvements.

Table 2: Effect of Organic Mulching on Growth Parameters and Yield Performance of Capsicum annuum

Treatment	Plant Height at 90 DAT (cm)	Number of Leaves	Fruits per Plant	Avg. Fruit Weight (g)	Yield (kg/plot)	Disease Incidence (%)
Green grass mulch	64.3 ± 2.1^{c}	42.6 ± 1.8^{c}	18.4 ± 1.2^{c}	22.8 ± 0.9^{bc}	$3,847 \pm 127^{c}$	8.4 ± 1.2^{b}
Dry leaves mulch	59.7 ± 1.9^{d}	38.2 ± 1.6^{d}	16.7 ± 1.1^{d}	21.3 ± 0.8^{c}	$3,562 \pm 118^{d}$	11.2 ± 1.5^{b}
Poultry manure	78.4 ± 2.4^{a}	54.8 ± 2.3^{a}	24.7 ± 1.6^{a}	26.4 ± 1.1^{a}	$4,872 \pm 156^{a}$	4.1 ± 0.8^{c}
Piggery manure	74.6 ± 2.3^{ab}	51.3 ± 2.1^{ab}	22.9 ± 1.5^{ab}	25.1 ± 1.0^{ab}	$4,651 \pm 148^{a}$	5.3 ± 0.9^{c}
BSF frass	68.9 ± 2.2^{bc}	47.4 ± 2.0^{b}	20.3 ± 1.3^{bc}	24.2 ± 0.9^{ab}	$4,289 \pm 142^{b}$	6.7 ± 1.1^{bc}
Control (no mulch)	52.1 ± 1.7^{e}	32.7 ± 1.4^{e}	14.2 ± 0.9^{e}	19.6 ± 0.7^{d}	$3,437 \pm 112^{e}$	18.9 ± 2.1^{a}

Values are means ± standard error (n=10). DAT = Days After Transplanting. Means with different superscript letters within columns are significantly different ($P < 0.05$) according to DMRT.

Disease incidence, primarily bacterial wilt and fungal leaf spots, was significantly reduced in organic mulch treatments. Poultry manure treatment showed lowest disease incidence (4.1%), representing 78% reduction compared to control (18.9%).

3.4 Nutrient Uptake

Plant tissue analysis revealed enhanced nutrient uptake in organically mulched treatments. Leaf nitrogen content was highest in poultry manure treatment (4.21%), followed by piggery manure (3.98%) and BSF frass (3.67%), compared to control (2.84%). Similar trends were observed for phosphorus and potassium content. Fruit nutrient composition showed

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corresponding improvements, indicating efficient nutrient translocation from soil through microbial-mediated processes.

3.5 Correlation Analysis

Strong positive correlations were established between microbial diversity indices and yield parameters ($r = 0.83$, $P < 0.001$), soil organic matter content and bacterial abundance ($r = 0.79$, $P < 0.01$), and PGPR populations and disease suppression ($r = -0.76$, $P < 0.01$). These relationships confirm the mechanistic linkage between rhizobiome enhancement, soil fertility improvement, and crop productivity.

4. DISCUSSION

This study demonstrates that organic mulching significantly enhances rhizospheric microbial diversity, soil fertility, and Capsicum productivity, providing compelling evidence for sustainable pepper production systems. The superior performance of poultry and piggery manure treatments aligns with their high nutrient content and ability to support diverse microbial communities.

The enrichment of beneficial bacterial genera (*Bacillus*, *Pseudomonas*, *Azotobacter*) in organically mulched rhizospheres explains observed improvements in plant health and productivity. These PGPR taxa are well-documented for their roles in nitrogen fixation, phosphate solubilization, phytohormone production, and biological control of pathogens (Zhou et al., 2019; Sreejata et al., 2020). The 14.2% relative abundance of *Bacillus* spp. in poultry manure treatment is particularly noteworthy, as this genus produces antimicrobial compounds that suppress soil-borne pathogens, contributing to the 78% reduction in disease incidence observed.

The 20-42% yield increases in mulched plots compared to control validate organic mulching as an effective strategy for enhancing pepper productivity. These findings corroborate earlier reports by Awere and Omeje (2019) who documented significant growth and yield improvements in Nsukka yellow pepper with poultry manure application. The yield enhancement mechanisms include improved soil moisture retention (demonstrated by 53-111% higher moisture content in mulched plots), enhanced nutrient availability through microbial mineralization, and suppression of competitive weeds and pathogens (Kader et al., 2017).

The substantial improvements in soil physicochemical properties, particularly organic matter content (64-89% increases), demonstrate mulching's role in soil health restoration—a critical requirement for sustainable agriculture in tropical environments where soil degradation threatens food security (Piñeiro et al., 2020). Unlike synthetic fertilizers that provide nutrients without improving soil structure or biological activity, organic mulches deliver multiple benefits including carbon sequestration, improved water infiltration, and habitat for beneficial organisms.

The superior performance of black soldier fly frass, an emerging organic amendment, highlights opportunities for circular agriculture by valorizing organic waste streams. BSF frass combines nutritional benefits with environmental sustainability, addressing waste management challenges while providing farmers with cost-effective fertility inputs (Ruckli et al., 2021). This approach aligns with Sustainable Development Goals related to responsible consumption and production.

The strong correlations between microbial diversity, soil fertility, and crop performance confirm the mechanistic linkages underlying observed productivity gains. Enhanced rhizobiome diversity facilitates multiple beneficial processes simultaneously—nutrient cycling, pathogen suppression, stress tolerance, and plant growth promotion—creating synergistic effects that surpass outcomes achievable through single-function interventions (Quast et al., 2012).

From an economic perspective, the yield increases of 20-42% translate to substantial income gains for smallholder farmers. Assuming conservative market prices of ₦1,000-1,200/kg for fresh pepper, farmers could realize ₦410,000-1,435,000 additional revenue per plot through organic mulching. Given that most mulching materials (grass, leaves, animal manures) are locally available at minimal cost, the return on investment is highly favorable, particularly for resource-constrained farmers (Alwedyan & Taani, 2021).

However, successful adoption requires addressing implementation challenges including labor requirements for mulch collection and application, potential nitrogen immobilization with high C:N ratio materials (dry leaves), and farmer knowledge gaps regarding appropriate mulching practices. Extension services and farmer training programs should emphasize proper mulch application timing, thickness, and material selection based on local availability and crop requirements (Semuroh & Sumin, 2021).

5. CONCLUSION AND RECOMMENDATIONS

This study conclusively demonstrates that organic mulching, particularly with poultry manure, piggery manure, and black soldier fly frass, significantly enhances rhizospheric microbial diversity, improves soil fertility, and increases Capsicum annuum productivity by 20-42% compared to conventional practices. The enrichment of beneficial plant growth-promoting rhizobacteria creates favorable conditions for nutrient cycling, pathogen suppression, and enhanced plant performance, offering a sustainable pathway to address food insecurity, soil degradation, and environmental challenges in tropical agriculture.

Recommendations:

1. Adopt organic mulching using locally available materials (animal manures, green grass, leaves) to improve pepper yields, reduce input costs, and enhance soil health sustainability.
2. Develop training programs on proper organic mulching techniques, emphasizing material selection, application rates, timing, and integration with other sustainable practices.
3. Incentivize organic farming through subsidies on quality organic inputs, establish collection and

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distribution systems for organic materials, and integrate organic agriculture into agricultural development programs.

4. Conduct long-term studies evaluating cumulative effects of organic mulching on soil health and productivity, investigate synergies between organic mulching and other sustainable practices (cover cropping, crop rotation), and develop region-specific recommendations for various crops and agroecological zones.
5. Promote circular agriculture by encouraging utilization of agricultural and livestock wastes (poultry manure, piggery waste, crop residues) as organic amendments, reducing reliance on synthetic inputs and non-biodegradable plastic mulches.

This research provides evidence-based support for organic mulching as a climate-smart, economically viable, and environmentally sustainable approach to enhancing food security while promoting ecosystem health. Widespread adoption of these practices can contribute significantly to achieving Sustainable Development Goals related to zero hunger, sustainable agriculture, and environmental conservation in developing regions.

REFERENCES

1. Abel, D., Kloas, W., Zarfl, C., Stefan, H., & Matthias, C. (2018). Microplastics as an emerging threat to terrestrial ecosystems. *Global Change Biology*, *24*, 1405–1416. https://doi.org/10.1111/gcb.14020
2. Adekola, O. F., & Maduabuchi, I. C. (2020). Studies on performance of "Nsukka aromatic yellow pepper" (*Capsicum annuum* L.) under varying population and organomineral fertilizer regimes. *Scientific Journal of Agricultural Sciences*, *2*(2), 38–48. https://doi.org/10.21608/sjas.2020.34557.1031
3. Alwedyan, S., & Taani, A. (2021). Adoption of sustainable agriculture practices by citrus farmers and its determinants in the Jordan valley: The case of Northern Ghor. *Potravinarstvo Slovak Journal of Food Sciences*, *15*, 768–775. https://doi.org/10.5219/1676
4. Anyaoha, C. O., Ademoyegun, O. T., & Afuape, S. O. (2020). Agro-morphological and nutritional variability among elite Nsukka yellow spice pepper breeding lines. *International Journal of Vegetable Science*, *26*(5), 516–531. https://doi.org/10.1080/19315260.2019.1667470
5. Awere, S. U., & Omeje, T. E. (2019). Effect of poultry manure and N.P.K. 15:15:15 fertilizer on the growth and yield of Nsukka yellow pepper (*Capsicum annuum*). *International Journal of Environment, Agriculture and Biotechnology*, *4*(1), 111–115. https://doi.org/10.22161/ijeab/4.1.18
6. Braunack, M. V., Adhikari, R., Freischmidt, G., Johnston, P., & Filipovi, V. (2020). Initial experimental experience with a sprayable biodegradable polymer membrane (SBPM) technology in cotton. *Agronomy*, *10*, 584. https://doi.org/10.3390/agronomy10040584
7. Diaz, R. T., Osorio, D. P., Hernández, E. M., Pallares, M. M., Canales, F. A., Paternina, A. C., & Echeverría-González, A. (2021). Socioeconomic determinants that influence the agricultural practices of small farm families in northern Colombia. *Journal of the Saudi Society of Agricultural Sciences*. Advance online publication. https://doi.org/10.1016/j.jssas.2021.12.001
8. Food and Agriculture Organization (FAO). (2023). *The State of Food Security and Nutrition in the World 2023*. Rome: FAO.
9. Husenov, B., Otambekova, M., Muminjanov, H., Morgounov, A., Asaad, S., Garkava-Gustavsson, L., & Johansson, E. (2020). Constraints and perspectives for sustainable wheat production in Tajikistan. *Frontiers in Sustainable Food Systems*, *4*, 27. https://doi.org/10.3389/fsufs.2020.00027
10. Kader, M. A., Senge, M., Mojid, M. A., & Ito, K. (2017). Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research*, *168*, 155–166. https://doi.org/10.1016/j.still.2017.01.001
11. Looft, T., Johnson, T., & Allen, H. (2012). In-feed antibiotic effects on the swine intestinal microbiome. *Proceedings of the National Academy of Sciences of the USA*, *109*, 1691–1696. https://doi.org/10.1073/pnas.1120238109
12. National Population Commission (NPC). (2006). *Population and Housing Census of the Federal Republic of Nigeria*. Abuja: NPC.
13. Piñeiro, V., Arias, J., Durr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, *3*, 809–820.
14. Qian, H., Meng, Z., Liu, G. F., Lu, T., Qu, Q., Du, B., & Pan, X. (2018). Effects of soil residual plastic film on soil microbial community structure and fertility. *Water, Air, & Soil Pollution*, *229*, 261. https://doi.org/10.1007/s11270-018-3883-0
15. Quast, C., Pruesse, E., Yilmaz, P., Gerken, J., Schweer, T., Yarza, P., & Peplies, J. (2012). The SILVA ribosomal RNA gene database project: Improved data processing and web-based tools. *Nucleic Acids Research*, *41*, D590–D596. https://doi.org/10.1093/nar/gks1219
16. Ruckli, A. K., Dippel, S., Durec, N., Gebska, M., Guy, J., Helmerichs, J., Leeb, C., Vermeer, H., & Hörtenhuber, S. (2021). Environmental sustainability assessment of pig farms in selected European countries: Combining LCA and key performance indicators for biodiversity assessment. *Sustainability*, *13*, 11230. https://doi.org/10.3390/su132011230

*Corresponding Author: **Ugboh, O.**

17. Semuroh, J., & Sumin, V. (2021). Factors affecting the intention of sustainable agriculture practices among pepper farmers in Sarawak, Malaysia. *Food Research*, *5*(Suppl. 4), 92–100. https://doi.org/10.26656/fr.2017.5(S4).005
18. Sreejata, B., González, J., Henderson, K., Anunciado, M., Hayes, D., & DeBruyn, J. (2020). Soil microbial communities associated with biodegradable plastic mulch films. *Frontiers in Microbiology*, *11*, 587074. https://doi.org/10.3389/fmicb.2020.587074
19. Zhou, D., Feng, H., Schuelke, T., De Santiago, A., Zhang, Q., & Zhang, J. (2019). Rhizosphere microbiomes from root knot nematode non-infested plants suppress nematode infection. *Microbial Ecology*, *78*, 470–481. https://doi.org/10.1007/s00248-019-01324-5

*Corresponding Author: **Ugboh, O.**