



ORGANIC AGRICULTURE PROFESSIONALS IN TERTIARY INSTITUTIONS IN NIGERIA

18TH ANNUAL CONFERENCE

T H E M E :

**ADVANCING ORGANIC AGRICULTURE
FOR FOOD SECURITY AND
ENVIRONMENTAL SUSTAINABILITY**

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**SUNDAY 21ST - WEDNESDAY 24TH
SEPTEMBER, 2025**

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DAILY**

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**UNIVERSITY OF PORT HARCOURT,
CHOBA, PORT HARCOURT, RIVERS STATE, NIGERIA**

UNIPORT 2025



**ADVANCING ORGANIC AGRICULTURE FOR
FOOD SECURITY AND ENVIRONMENTAL
SUSTAINABILITY**

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AGRICULTURE
“UNIPORT 2025”**

Held at

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National Officers OAPTIN- 2024

Prof. B. Kehinde – National Coordinator (Vice Chancellor, FUNAAB)

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- 3) Prof. U. D. Chima
- 4) Prof. U. E. Udensi (Host)
- 5) Prof. E. S. Erundu (Co-Host)
- 6) Prof. A. Henri-Ukoha
- 7) Prof. B. O. Agaviezor
- 8) Prof. U. Zakka
- 9) Dr. C. Ifeanyi-Obi
- 10) Dr. O. O. Tanimola
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- 6) Mr. Sam. U. Nwokugha
- 7) Mr. Boma Iriso
- 8) Dr. Henry Anozie
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- 1) Prof. B. O. Agaviezor (Chairman)
- 2) Dr. W. Orunaboka
- 3) Dr. Henry Anozie
- 4) Mrs. Irene Nwokolo



PROFILE OF PROFESSOR NKEREUWEM MICHAEL JOHN

Nkereuwem Michael John is a Professor of Soil Fertility and Organic Waste Management in the University of Calabar, Cross River State and gets involved in the research and manufacture of both Solid and Liquid Organic and Organo-mineral Fertilizers (OMF) for enhancing arable crop production in Nigeria.

Prof. John has served as the Head, Department of Soil Science and Departmental Coordinator of Year Four Practical programme; Chairman, Quality Assurance Committee in his Department and also as member of the same committee for two consecutive tenures in the Faculty of Agriculture, University of Calabar, Calabar, Nigeria, between June 2010 till October 2023. He has published over fifty (50) articles in reputable Journals locally and internationally. He has also successfully supervised and graduated eight (8) Ph.D students coupled with several undergraduate and Masters students.

Professor John is not only a Professor of Soil Fertility and Plant Nutrition, but also researched into organic waste recycling for the production of organic fertilizers for organic farmers and researchers on organic agricultural projects in Nigeria. The first set of the organic fertilizers attracted a National Award by Nigerian Universities Commission at Abuja in December 2004. The second and third Awards of Excellent in Organic and organo-mineral fertilizers manufacture were received during the First Made-in Akwa Ibom State Product Exhibition in 2007 and that of Ministry of Trade, Industry & Investment, Uyo, Akwa Ibom State in September 2023.

Professor Nkereuwem John has consulted for both the University of Calabar, Calabar. Cross River State and University of Uyo, Uyo, Akwa Ibom State in various aspects and facets of the environment, especially on Environmental Impact Assessment (EIA). Some of these EIA jobs undertaken include; NNPC, ALSCON, SPDC, and NOAC.

Outside the University Consultancies, Professor Nkereuwem John has also consulted for some frontline companies involved in different forms of Soil and or Agriculture in Nigeria. These include the following; E & T Environmental Consultants, PGM Nigeria Ltd. Environmental Consultants, International Management and Finance Institute (IMFI)/Ministry of Economic Development (MED)/United Nations Development/Biogas & Demonstration project, United Nations Institute for Training and Research (UNITAR). Pedoquarsphere International Ltd, Universal Scientific & Industrial Consultants Ltd., Ecosystem International Ltd., and BGI Resources Ltd Environmental Consultants.

Professor John also served as the Chairman/Organic Fertilizer Consultant, of the Technical Team on “One man One palm”, Etim Ekpo Local Government Area, Akwa Ibom State in October, 2007. He directed the training of farmers on Conversion of Organic Waste into Organic Manure for vegetable gardeners in, Uyo, Akwa Ibom State, Sponsored by UNDP/Akwa Ibom State Government in November to December 2007. He also Consulted for Chorleywood Farms, Karshi Development Area, Nassarawa State, on Soil fertility and Surface water studies in October 2013.

Professor N. M. John is a member of many professional bodies including; Soil Science Society of Nigeria (SSSN), National Environmental Sanitation Team (NEST), Organic Agriculture for Tertiary Institution in Nigeria (OAPTIN) and Nigeria Organic Agriculture Network (NOAN). He is a former Zonal Coordinator of OAPTIN, South-South, Nigeria. Professor John has attended both local and international academic Conferences, Workshops and Seminars, presenting papers in many of them.



ADVANCING ORGANIC AGRICULTURE FOR FOOD SECURITY AND ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT:

As global food demand is projected to increase by 70 % by 2050 while agricultural systems face mounting environmental pressures, the need for sustainable farming approaches has become critical. This address examines the imperatives of advancing organic agriculture for food security challenges and environmental sustainability goals through a comprehensive review of empirical evidence and comparative analysis of production systems worldwide. The major challenges of global food security include; yield gap and productivity, scale and land use requirements, economic and market barriers, climate change and environmental pressures, policy and institutional barriers, regional and development disparities. Organic agriculture demonstrates significant environmental advantages including, reduction in energy consumption, lower greenhouse gas emissions per hectare, and substantial improvements in soil organic carbon storage per hectare annually. Key constraints limiting organic agriculture expansion globally include; knowledge gaps, certification costs, market access barriers, and initial transition challenges. However, these limitations can be addressed through targeted policy interventions, including subsidies for organic conversion, investment in extension services, and development of local organic markets. Organic agriculture represents a viable strategy for enhancing global food security while delivering substantial environmental benefits. Successful scaling requires integrated approaches combining farmer education, policy support, market development, and continued research into yield optimization techniques. Support policy frameworks that provide incentives for organic agriculture adoption as part of broader sustainable intensification strategies can feed the world's growing population.

Keywords: Organic agriculture, food security, environmental sustainability, agroecology, biodiversity conservation, soil health.



ADDRESS BY THE NATIONAL COORDINATOR, OAPTIN PROF. O. B. KEHINDE, THE VICE-CHANCELLOR, FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA (FUNAAB) ON THE OCCASION OF THE 18TH ANNUAL CONFERENCE OF OAPTIN HOSTED BY UNIPORT

The Vice Chancellor of UNIPORT
Principal Officers of UNIPORT
The Deputy National Coordinator, OAPTIN
The Interim National Coordinating Scientist, OAPTIN
Deans and Directors of Colleges, Institutes and Academic Units in UNIPORT
The Zonal Coordinators, OAPTIN
The Local Organising Committee (LOC) members
The Keynote Speaker and other invited speakers
Participants at the 18th Annual Conference of OAPTIN
Members of the press

Distinguished ladies and gentlemen,

It is my pleasure to welcome you all to the 18th Annual Conference and Business Meeting of OAPTIN, being hosted at the University of Port Harcourt (UNIPORT). As you are all aware, OAPTIN has been consistent in organising and hosting the Annual Conference and Business Meeting. I would like to commend the Executive Committee members of OAPTIN for their relentless efforts in ensuring that the vision of the founding fathers was kept alive throughout the years despite the prevailing challenges in the country.

The 17th Annual Conference and Business Meeting was successfully held in Oye Ekiti last year by the Federal University, Oye Ekiti (FUOYE), Ekiti State, and I could recall vividly that the LOC members as at that time were able to organize a befitting Conference despite the prevailing economic challenges in the country.

I welcome you all to the 18th Annual Conference of OAPTIN with the theme **“Advancing Organic Agriculture for Food Security and Environmental Sustainability.”** I am sure you would have a memorable time here while deliberating on topical issues in Agriculture, specifically on sustainable agriculture, leveraging biological principles of biodiversity, resource use efficiency, and nutrient recycling.

In the last one year OAPTIN has been forging ahead in her mandate in building capacity among all the stakeholders in the country. OAPTIN is currently collaborating with the Association of Organic Agriculture Practitioners of Nigeria (NOAN) in their ongoing project on Knowledge Centre for Organic Agriculture (KCOA).

OAPTIN is 20 years old this year as the pioneer Organic Agriculture Movement in Nigeria. Although organic produce is sold at a premium price, the accruable financial benefit has not been encouraging in the short term compared to the conventional form of production. Therefore, there is a need to intensify advocacy on the benefits of organic agriculture in sustaining the fragile tropical soils, considering the long-term human and environmental benefits of this production system. This is where OAPTIN needs to bring more stakeholders into the fold to address the mirage of challenges confronting our resource-constrained farmers.

I am happy to inform you that FUNAAB, in conjunction with OAPTIN, FUNAAB, and the Association of Organic Agriculture Practitioners of Nigeria (NOAN), successfully hosted the first in-person session of the Agroecology and Organic Agriculture Leadership (AOAL) Course from September 15–19, 2025. The flagship programme marked a significant milestone in advancing sustainable agriculture and leadership development across Africa. It is structured as a Nine-Month Hybrid Initiative. The AOAL Course was designed to equip emerging and established leaders with the skills and knowledge to strengthen agroecology and organic agriculture systems.

The programme is being organised by the International Federation of Organic Agriculture Movements (IFOAM–International Organics) in partnership with the Association of Organic Agriculture Practitioners of Nigeria (NOAN), under the Agroecology Promotion Programme (APP) Capacity Building Project, with funding



support from the Swiss Agency for Development and Cooperation (SDC). OAPTIN is a financial member of IFOAM.

The only way OAPTIN members can remain relevant to all our stakeholders is to disseminate our research findings in the form of products, prototypes, patents, and policies. There is also a need to collaborate more with organisations across the country and abroad in organic agriculture. I commend OAPTIN for sustaining the Association's main research outlet, *Journal of Organic Agriculture and Environment (JOAEN)*.

To also inform that the retail of organic products in the world soared up to 136 billion euros, and the total organic land in the world was 98.8 ha, with Africa and Nigeria accounting for 3.4 mha and 157,019 ha, respectively. You will all agree with me that we still have a long way to go in tapping into the multifarious benefits of organic agriculture in Nigeria. I leave OAPTIN with that challenge to contribute significantly to the realisation of the country's dream of becoming a force to reckon with in Organic Agriculture in the global landscape of agriculture.

Long live the Federal Republic of Nigeria, long live UNIPORT, and long live OAPTIN.

Thank you very much for listening.

Prof. Olusola Babatunde Kehinde

Vice Chancellor, FUNAAB and National Coordinator of OAPTIN



WELCOME ADDRESS BY PROFESSOR UDENSI EKEA UDENSI, DEAN, FACULTY OF AGRICULTURE, UNIVERSITY OF PORT HARCOURT ON OCCASION OF THE 18TH ANNUAL CONFERENCE OF ORGANIC AGRICULTURE PROFESSIONALS IN TERTIARY INSTITUTIONS IN NIGERIA (OAPTIN) HELD AT CENTRAL BANK OF NIGERIA (CBN) CENTER OF EXCELLENCE , UNIVERSITY PARK CAMPUS, UNIVERSITY OF PORT HARCOURT FROM 21ST TO 24TH SEPTEMBER, 2025.

PROTOCOL

It is with immense pleasure that I welcome all of you to the 18th Annual Conference of Organic Agriculture Professionals in Tertiary Institutions in Nigeria (OAPTIN). Let me begin by appreciating our highly estimable and amiable Vice Chancellor, Professor Owunari Abraham Georgewill, who is known by the appellation “Digital Vice Chancellor” who graciously approved the hosting for the Faculty of Agriculture on behalf of UNIPOINT without much ado.

The journey to this event started when Professor E. S. Erundu conveyed a meeting of few academic staff in the Faculty of Agriculture to discuss the possibility of hosting this conference and its benefits. We were skeptical about it initially, but later accepted to host it. Thereafter, we sought the hosting right from our Golden and Digital Vice Chancellor, Professor Owunari A. Georgewill, which he graciously approved. Therefore, I want to thank the Vice Chancellor and the National Executives of OAPTIN for granting us the hosting right, and to our erudite Professor Ebere Samuel Erundu, Sir this is a dream come through and I salute you.

To all participants, I give God the glory for your safe arrival to UNIQUE UNIPOINT, in the Garden City of Port Harcourt, Rivers State (THE TREASURE BASE OF THE NATION). I will enjoy you to loosen up, and feel free to enjoy the hospitality of the Garden City and her amiable people.

The theme for this year’s Conference is “**Advancing Organic Agriculture for Food Security and Environmental Sustainability**”. In my view, the theme is not only apt but topical considering the need to enhance food and animal production sustainably through the use of non-synthetic growth enhancement products that is environment friendly and healthy for agrifood systems. .

Organic agriculture entails the production system that sustains the health of soils, biodiversity, ecosystems functions, services and livelihood resilience .

This system of production does not use synthetic fertilizers, drugs, pesticides, growth regulators, antibiotics, hormones, stimulants and feed additives to grow and produce food for human consumption. It combines traditional knowledge, innovation, modern science, technologies and practices to benefit the shared environment and promote fair relationship and a good quality of life for all involved. Organic agriculture is about our health, the environment and our future.

I have no doubt in my mind that at the end of this meeting we will all start thinking, talking and acting organically, for the purpose of our future well-being,... The presentations today will evoke a paradigm shift to solving or addressing the challenges confronting organic agriculture, especially in South-South, and Nigeria at large.

The Vice Chancellor Sir, respected colleagues from the academia, entrepreneurs, ladies and gentlemen, I sincerely appreciate you all for attending this conference despite the poor economic challenges in our country. Your presence is highly appreciated and will not be taken for granted. We sincerely promise you all a rewarding and memorable stay in Port Harcourt especially in our Unique University of Port Harcourt.

Distinguished ladies and gentlemen, esteemed participants and stakeholders, once again, I welcome you to the 18th Annual Conference of OAPTIN engineered by the Faculty of Agriculture and powered by our dynamic and amiable Vice Chancellor, and the University at large. In the beginning it was organic, and so shall it be to the end of time. **Thank you and God be with you all.**



Emergence and Seedling Vigor of Alligator Pepper (*Aframomon melegueta*) in the Nursery as Influenced by Soilless Media and Hydro priming in Owerri, Nigeria

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Abstract

Alligator pepper (*Aframomon melegueta*) is endangered due to deforestation. Fast loss is occurring throughout Africa commonly in the rain forest zone. This study was carried out in 2024 at the Teaching and Research Farm of School of Agriculture and Agricultural Technology, Federal University of Technology Owerri Imo State Nigeria. The aim was to evaluate the emergence and seedling vigour of Alligator pepper, which was influenced by soilless media and hydro priming in Owerri, Nigeria. Treatments consisted of 3 soilless media (cocopeat, farmyard manure, cocopeat + farmyard manure mix 50:50) and five levels of hydro priming (0, 6, 12, 16, 24 hours) in a 3 x 5 factorial arrangement fitted into a Randomised Complete Block Design replicated 3 times. Results indicated that emergence and mean emergence time (MET) did not record any significant ($p < 0.05$) effect. As the growth progressed, soilless media (farmyard manure), hydro priming (18 h) and interaction (cocopeat + farmyard manure mix and 18 h priming) manifested superior values significantly in most of the parameters measured. It was finally observed that cocopeat + farmyard mix and 18 hours hydro priming respectively, consistently improved early life growth of Alligator pepper in the nursery which resulted in achieving vigorous seedling at 16 weeks after sowing (WAS). Based on these findings, cocopeat + farmyard manure mix and 18 hours priming is hereby recommended for Alligator pepper and other nursery of herbaceous seedlings in Owerri, Nigeria.

Keywords: Alligator pepper, Hydro priming, Nursery, Seedling, Soilless media

Introduction

Aframomum melegueta (Alligator Pepper) is a species in the ginger family, *Zingiberaceae*, closely related to cardamom. Its trumpet-shaped, purple flowers develop into 5 to 7 cm long pods containing numerous small, reddish brown. Its seeds are used as a spice (ground or whole); they impart a pungent, black-pepperlike flavour with hints of citrus. It is a shrub with its seeds.

Soilless culture is any method of growing plants without using soil as a rooting medium. The substrates are all those materials, used alone or mixed appropriately, that can provide the rooting system with better conditions. Prominent authors (Baiyeri & Mbah, 2006; Ekwu & Mbah, 2007) had advocated for the replacement of natural topsoil as the growth medium of



floricultural crops with other available options due to some of its shortcomings, such as non-sustainability and being a non-renewable resource. Tariq et al. (2012) reported that although natural topsoil is acceptable as a growing medium for plants in gardens/fields, it is not the right choice for plants in pots or containers because the frequency of water demanded by the container plants will cause soil compaction, resulting in a tight and brick-like mass.

Recent reports suggest that hydro-priming of seed has the potential to up regulate plants' tolerance to multiple abiotic stresses by enhancing seed germination, seedling growth and development, modulating physiological activities and antioxidant response, as well as expression of genes and proteins. The work evaluated the emergence and seedling vigour of Alligator pepper as influenced by hydro priming and soilless media in Owerri, Nigeria.

Materials and Methods

The research was conducted at the Centre for Agricultural Research and Extension, Federal University of Technology Owerri, latitude $05^{\circ} 27'$ and $05^{\circ} 29'$ North and longitude $07^{\circ} 02'$ East and at an altitude of 55.6 m in the rainforest zone of southeastern Nigeria. The mean annual temperature (30°C - 32°C) is high. A 3×5 factorial fitted into a completely randomised design (CRD) with 15 treatment combinations replicated 3 times. It consisted of three soilless media (coco peat, farmyard manure, coco peat + farmyard manure mixes 50:50) and five hydro priming regimes (0, 6, 12, 18, 24 h) with three replications.

The fresh fruits were harvested from a healthy fruit bearing stand from Owerri in Imo state, Nigeria. One hundred and eighty (180) seed lots was subdivided into six seed lots per treatment of 3 replications. Each seed lot was introduced into a 500cc beaker containing distilled water for specific periods using a stop clock and decanted into a disposal sink. All hydro primed seeds were dried before seeding in the soilless media. The experiment lasted for 16 weeks Using appropriate techniques, data were collected for emergence indices and growth parameters at 8, 12 and 16 weeks after sowing. Some destructive sampling was carried out at 16 weeks after sowing (WAS). Seedling vigour was determined by calculating the percentage emergence multiplied by the seedling shoot height and dividing by 100. Data collected were analysed using Analysis of variance (ANOVA) and significant mean separation using Least Significant Difference (LSD) at 5 % probability (Obi, 1986)

Results and Discussion

In Table (1), the effect of hydropriming and soilless media did not record any significant differences on the percentage emergence and mean emergence time of *A. melegueta* seeds.

Results in Table 3 revealed that hydro priming for 12 and 5 h recorded significant differences at 8 WAS only. Media (FYM and FYM + CP mix) consistently showed significantly higher mean values than CP and FYM in 12 and 18 WAS of Alligator pepper in the nursery.

In plant height, media showed significant effects at 8 WAS only. At 8, 12, and 16 WAS, hydro priming manifested significant differences. Hydro priming for 18 h produced taller seedlings compared to other hydro priming regimes at 16 WAS. Interactions between FYM + 18 h produced more leaves than other treatments (Table 4).

The wet shoots from FYM and CP + FYM mix were significantly heavier than those from the CP medium. Also, hydro priming seeds for 18 h produced heavier shoots than other hydro priming regimes. Dry shoots from FYM and CP + FYM mix were heavier than those from CP.



Table 5 shows the effects of soilless media and hydro priming on the seedling vigour of *A. melegueta*. The CP+ FYM mix (27.60) significantly produced more vigorous seedlings than CP (12.90). Seedlings from 18 h hydro priming were more vigorous than those from 24 h, which recorded the least seedling vigour.

Discussion

Seeds are young plants generated from seeds. These seedlings are raised under a controlled environment for quality and high growth rate. Emergence indices did not record any significant differences. Bewley (1997) stated that germination starts with the uptake of water by the dry seed imbibition and is completed when a part of the embryo, usually the radical, penetrates the seed coat. Coco peat + farmyard manure mix at 16 WAP improved plant height and branches of *A. melegueta* in the nursery. Nweke *et al.* (2013) observed that applying different organic manure enhanced plant growth and development. Media and soilless interactions influenced the number of roots. This agrees with Balasundaran *et al.* (1991), which advised that raising quality seeds depends on appropriate growing media, containers, nursery hygiene and protection. Hydro priming influenced root length in *A. melegueta*, which conforms with Peter-Onoh *et al.* (2014), who stated that hydro priming produced vigorous seedlings in *Maeso barteri* (Red Maeso) with more root shoot length than unprimed seeds.

Seedling vigour is important for establishment and early vegetative growth and competitive ability in the field. Mukta and Sreevali (2010) suggested that the survival of any plant depends on the supply of quality planting material. Cocopeat + farmyard manure mix, followed by cocopeat and hydro priming for 18 h, produced more vigorous seedlings than other treatments. Each substrate has specific properties and usually differs from others. This is in line with Peter-Onoh *et al.* (2025), who affirmed that sawdust/poultry manure/biochar mix (3:2:3) provided the best conditions for effective growth of *G. latifolium*, followed by the 3:2:2 mix.

Conclusion

Growing Alligator pepper in pots/containers can be used as an ornamental for landscaping and environmental beautification. Cocopeat + farmyard manure mix and hydro priming for 18 h provided adequate conditions for effective growth regarding the number of leaves and plant height at 12 and 19 weeks after planting. These also influenced seedling vigour on the early life growth of Alligator pepper in the nursery; hence, they are recommended for practice on other herbaceous perennial shrubs.



Table 1: Effect of hydropriming and soilless media on percentage emergence and mean emergence time of *A. melegueta*.

SM	Hours					MEAN
	0	6	12	18	24	
CP	88.9	200.0	66.7	77.8	88.9	84.4
FYM	66.6	100.0	77.7	88.9	66.7	80.0
CP+FYM mix	100.0	55.5	88.9	66.7	66.7	75.5
Mean	84.4	85.2	77.8	77.8	74.0	
LSD(0.05)	23.44 NS					
LSD(0.05)	30.27NS					
LSD(0.05)	52.42 NS					
CP	15.1	16.5	12.3	18.2	14.6	17.0
FYM	24.3	20.2	18.3	18.2	18.1	19.8
CP+FYM mix	18.3	18.6	15.3	9.8	23.6	17.1
Mean	19.3	18.4	15.3	18.2	18.8	
LSD(0.05) Media	6.64 NS					
LSD(0.05) Soilless media	8.58NS					
LSD(0.05) Media+hydro priming	14.85NS					

CP: Coco peat, FYM: farmyard manure, LSD: Least Significant Difference



Table 2: Effect of soilless and hydropriming on the number of leaves

SM	8 WAS						12 WAS						16 WAS					
	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs	Mean	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs	Mean	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs	mean
CP	2.67	2.67	2.67	3.33	1.67	2.60	3.67	4.00	4.33	4.33	4.33	4.13	3.33	2.33	3.33	4.00	2.33	3.07
FYM	2.33	2.33	2.67	2.00	2.00	2.27	5.67	5.33	6.33	6.67	5.67	5.40	6.00	6.00	6.00	9.33	6.00	6.67
CP+FYM	2.33	2.67	2.67	2.00	2.00	2.33	7.00	5.67	5.00	5.67	4.67	5.93	8.33	6.67	8.00	7.67	6.67	7.47
MEAN	2.44	3.56	3.67	2.89	1.44		5.44	5.00	5.22	5.22	4.89		5.89	5.00	5.78	7.00	5.00	
LSD _(0.05) Media	0.75NS						0.75						1.7					
LSD _(0.05) Priming	0.97						1.22NS						2.2					
LSD _(0.05) MXP	1.69NS						2.11 NS						3.9					

CP: Coco peat, FYM: farmyard manure, LSD: Least Significant Difference

Table 3: Effect of medium and hydropriming on plant height

M	6 WAS	8 WAS	16 WAS																		
	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs	Mean	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs	Mean	0 hrs	6 hrs	12 hrs	18 hrs	24 hrs				
P	3.33	6.33	5.00	7.33	6.33	5.67	10.33	12.33	10.67	11.67	14.33	11.87	15.33	16.33	16.00	18.67	11.33				
YM	11.83	5.33	4.17	7.00	2.67	6.20	13.17	9.67	9.33	17.00	6.33	11.10	14.83	16.00	14.33	22.67	10.17				
P+FYM	17.00	5.00	6.67	7.67	10.00	9.27	19.33	13.33	11.00	10.67	11.33	13.33	21.33	18.00	14.67	17.67	13.67				
Mean	10.72	5.56	5.26	6.33	6.33		14.28	11.78	10.33	13.11	10.67		17.70	16.78	15.00	19.67	14.39				
LSD _(0.05) Media	1.88						2.64NS						2.91NS								
LSD _(0.05) hydropriming	2.42						3.41						3.76								
LSD _(0.05) Media+hydro	4.20						5.91						6.51								

CP: Coco peat, FYM: farmyard manure, LSD: Least Significant Difference



Table 4: Effect of priming and soilless media on seedling vigour of *A. melegueta*

SM	Hours					MEAN
	0	6	12	18	24	
CP	5.6	10.3	10.4	27.8	10.1	12.9
FY	18.7	41.3	7.3	39.2	13.4	24.0
CP+FY	18.9	35.1	27.7	44.4	12.0	27.6
MEAN	14.4	28.9	15.1	37.1	11.9	
LSD (0.05) Media	12.32					
HP	15.90					
SM × P	27.55					

CP: Coco peat, FYM: farmyard manure, LSD: Least Significant Difference

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Effect of Organic and Inorganic Fertilisers on the Performance of Rice (*Oryza sativa*) in Ikorodu Agroecological Zone

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Abstract

Nigeria's dependence on imported rice to meet its consumption needs indicates its declining self-sufficiency. A field trial was conducted to evaluate the effect of organic and inorganic fertilisers on the performance of rice (*Oryza sativa*) in the Ikorodu Agroecological zone. The study consists of 5 tons/ha⁻¹ poultry manure, cow dung and NPK 15-15-15 arranged in a Randomised Complete Block Design (RCBD) with four treatments and three replicates to give 12 experimental plots. Data were collected on plant height and the number of leaves at 4, 6, 8, and 10 weeks after planting (WAP), number of days to panicle initiation and 50% flowering from 10 plants randomly tagged from each experimental unit. The result revealed that application of fertilisers significantly and gradually increased plant height and number of leaves with the plant age, with rice planted in plots without fertiliser application having the lowest value. At 4 WAP, the plant height of cow dung and poultry manure was non-significant. At 8 and 10 WAP, poultry manure produced taller plants, while plant height of NPK 15-15-15 and control were non-significant. At 6 WAP, the highest number of leaves was observed in 5t/ha⁻¹ cow dung (23.7cm), though not significantly different from poultry manure (22.70cm), and the control recorded the least number of leaves. The application of poultry manures significantly influenced 50% flowering and panicle initiation compared to NPK and the control; however, there was no significant difference between poultry manure and cow dung. The application of cow dung and NPK fertiliser did influence panicle initiation. The findings revealed that poultry manure significantly improves the growth performance of rice and could therefore be adopted by rice farmers in the Ikorodu agroecological zone as a substitute for the scarce and costly inorganic NPK 15-15-15 fertiliser.

Keywords: Cow dung, Fertilisers, Panicle initiation, Poultry manure, WAP

Introduction

Rice is one of the most important staple cereal foods in human nutrition. It is a significant food grain for about 75% of the world's population [1] and is considered the main driving force in many countries' economies. Rice is the third most important cereal grown and consumed globally after wheat and maize [2].

Nigeria is the largest producer of rice in Africa, producing about 8,435,000 tonnes annually, followed by Egypt, Madagascar, Tanzania and Mali [3]. Ironically, Nigeria is the world's third highest importer of milled rice, importing about 2 million metric tonnes of rice into the country [4]. In Nigeria, the total consumption of rice stands at about 5.4 million metric tonnes annually, with average per capita consumption between 24-28kg [5], and represents 9% of total caloric intake per annum [6], while output is about 3.8 million tons [4]. The deficit in production is



made up by massive importation of milled rice to bridge the gap between domestic demand and supply. Therefore, there is a need to improve rice production capacity.

In Nigeria, rice is cultivated in almost all ecological belts available, as they all provide favourable environments to support the crop. However, one of the significant challenges of rice farming in Nigeria is poor soil fertility, which can significantly impact yields [7]. Rice requires 100kg/ha Nitrogen, 40 - 50kg P₂O₅/ha and 30 - 40kg K₂O/ha [8]. The use of inorganic fertiliser in rice cultivation has been progressively increasing since its introduction. However, chemical fertiliser alone fails to maintain the desired yield, impairs soil physical condition and exhausts organic matter content [9]. The application of excess inorganic fertiliser leads to higher pest and disease attacks and destroys the soil microorganisms. Hence, sustainable farming looks to make the best use of natural resources without damaging the environment, and indigenous agricultural knowledge is a vital part of making agriculture sustainable [10].

Cow dung and poultry manure are the most popular and promising bulky organic manures produced from the liquid excreta of farm animals, which contain considerable amounts of essential nutrient elements required for plant growth. These are a kind of storehouse of nutrients of plants. Hence, an improvement and addition of a good amount of cow dung and poultry manure to the crop field is essential for fertility, productivity, and soil health maintenance [11]. Organic fertilisers such as cow dung, poultry manure, organic waste, crop residues and compost will increase grain yields and the efficiency of applied nutrients due to their favourable effect on the soil's physical, chemical and biological properties [12]. However, extensive application of nitrogen fertiliser, whether in the form of organic matter or chemicals, can negatively affect the soil because excess nitrogen is converted to nitrates, which are detrimental to the soil and human health [13]. Keeping this above fact in mind, the present study was designed to study the effectiveness of organic and inorganic fertiliser application on rice production in the Ikorodu agroecological zone, which is a rice belt in southwestern Nigeria.

Materials and Methods

The study was carried out on a 340m² area of land at the Teaching and Research Farms, Lagos University of Science and Technology, Ikorodu (Latitude 6° 36' N, Longitude 3° 30' E), arranged in a Randomised Complete Block Design (RCBD) with four treatments and three replicates to give 12 experimental plots. Before land preparation, core soil samples were randomly collected from different spots within the experimental plot, air dried at room temperature, crushed by hand, and passed through a 2-mm mesh sieve to determine their physical and chemical properties following standard laboratory procedures [14]. The land was manually cleared and seed beds prepared with each experimental plot marked out into 3.5m x 5m with a discard of 1m on both sides and between the experimental units. Cow dung and poultry manure were obtained from the livestock section of the University Teaching and Research Farms and applied at the rate of 5 t/ha⁻¹, two weeks before planting to allow for decomposition and mineralisation. Meanwhile, NPK 15-15-15 was used at a rate of 5 t/ha⁻¹ two weeks after planting. FARO 46 rice variety obtained from IITA was planted at two (2) per hole with a spacing of 30cm x 30cm using the dibbling method to produce 286 stands per plot. Weeding was done using a hoe when necessary. The following data were collected from 10 plants randomly tagged from each experimental unit: plant height and the number of leaves at 4, 6, 8, and 10 weeks after planting (WAP), number of days to panicle initiation and flowering. All data collected were subjected to analysis of variance (ANOVA), and significant treatment means were separated using Least Significant Difference at 5% probability level.



Results

Physical and Chemical Properties of the Soil

The analysis of the soil's physical properties before planting showed that it is loamy sand in texture. Chemically, it is slightly acidic (6.35) and low in organic carbon, basic nutrients, and exchangeable cations (Table 1). This implies that the soil is low in fertility, and soil amendment is needed to enhance soil fertility and crop productivity. The chemical property analysis of the manure source (Table 2) show that it contains major nutrient elements (N, P, K, Ca and Mg) required for the growth of cereal crop like rice, hence rice planted on the experimental site is anticipated to benefit from cattle dung and poultry manure, an organic source of nutrient.

Table 1: Physiochemical properties of the soil

Soil Properties	Values
Ph	6.35
Organic Carbon (gkg^{-1})	1.36
Nitrogen (gkg^{-1})	0.64
Available Phosphorus (mgkg^{-1})	9.78
Exchangeable Cation (cmolkg^{-1})	-
Calcium	1.69
Magnesium	1.90
Potassium	0.58
Sodium	0.39
Exchangeable acidity (H^+)	0.19
CEC	4.58
Particle size	-
Sand (g/kg^{-1})	80.8
Clay (g/kg^{-1})	7.6
Silt (g/kg^{-1})	11.6
Textural class	Loamy sand

Table 2: Laboratory analysis of major nutrients presents in the manure used

Manure	Organic matter (%)	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Calcium (%)	Magnesium (%)	pH
Cow dung	19.4	1.98	0.89	0.38	2.87	2.65	7.8
Poultry manure	21.54	2.96	1.25	1.34	1.22	3.12	7.2

Effect of Organic and Inorganic Fertilisers on Plant Height

Applying organic and inorganic fertilisers substantially affects plant height compared to the control. The result revealed that fertilisers significantly and gradually increased plant height with age, with rice planted in plots without fertiliser application having the shortest plants. At 4 WAP, plant height, in cow dung and poultry manure plots, was not significant. Poultry manure produced taller plants at 8 and 10 WAP, while plants in NPK 15-15-15 and control plots were non-significant.

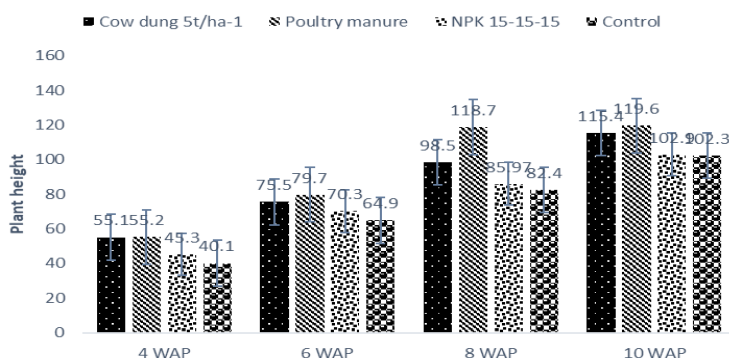


Figure 1: Effect of organic and inorganic fertilizers on plant height

Effect of Organic and Inorganic Fertilizers on the number of leaves

The application of organic and inorganic fertilisers significantly influences rice growth in terms of the number of leaves produced compared to rice plants on plots without fertiliser application. At 4 WAP, 5t/ha⁻¹ cow dung and poultry manure application did not significantly affect the number of leaves. The same trend was observed between control and NPK 15-15-15 fertiliser, but differed significantly from 5t/ha⁻¹ cow dung and poultry manure. At 6 WAP, the highest number of leaves was observed in 5t/ha⁻¹ cow dung (23.7cm), though not significantly different from poultry manure (22.70cm) and the control recorded the lowest number of leaves. Compared with control, fertiliser application significantly affects the number of leaves at 8 WAP, except for fertiliser 5t/ha⁻¹ cow dung and NPK 15-15-15 fertiliser, which was not significantly different. At 10 WAP, 5t/ha⁻¹ poultry manure produced the highest number of leaves and the least was recorded in the control plots.

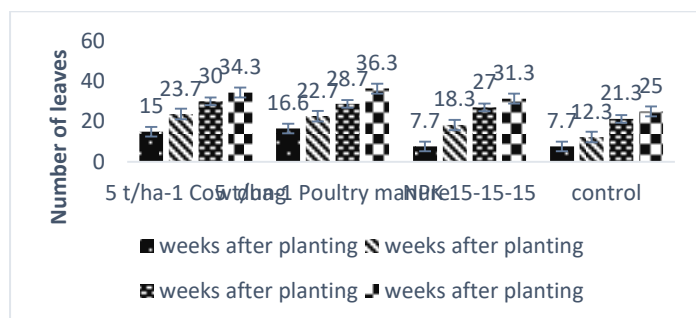


Figure 2: Effect of Organic and Inorganic Fertilisers on the number of leaves

Effect of Organic and Inorganic Fertilisers on days to 50% flowering and panicle initiation

Result in Figure 3 revealed that panicle initiation was first noticed in rice fertilised with poultry manure at 54.70 days. Other treatments, including control, initiated panicles within the range of 58 days. The application of cow dung and NPK fertiliser did not significantly influence panicle initiation. However, the application of poultry manure significantly influenced rice panicle initiation compared to other treatments. A similar trend was equally observed for the number of days to 50% flowering, with rice grown with poultry manure application being the first to attain 50% flowering at 71 days post planting and closely followed by cow dung and control being the last to initiate flowering at 75 days after planting. Significant differences in treatment means were observed in poultry manure, NPK and control. At the same time, a non-significant difference was recorded between poultry manure and cow dung.

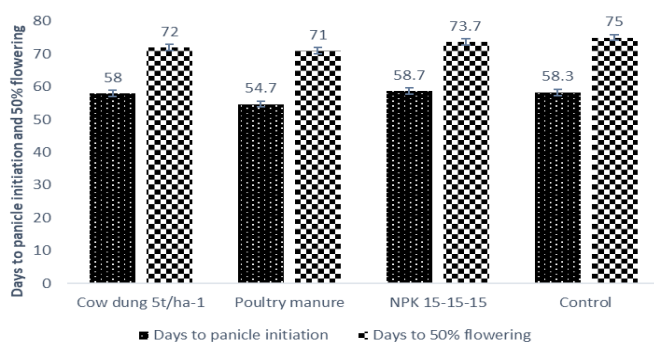


Figure 3: Effect of organic and inorganic fertilisers on days to 50% flowering and panicle initiation

Discussion

The significant improvement recorded in the plots after the application of fertilisers could be attributed to their nutrient supplies, mainly due to the experimental site's poor fertility status. This aligned with the findings of Sanni *et al* [15] who opined that increase in plant growth as a result of application of organic manure is expected in that manure contained and released considerable amount N and Mg for plant use during the process of mineralization. Traditionally, rice genotypes are tall. Plant height is a primary agronomic characteristic that indirectly affects rice plant yields.

The enhanced vegetative growth and additional nitrogen contribution that occurs in response to the application of organic and inorganic fertilisers could be the primary reason for the increase in plant height and number of leaves produced [16]. The availability of primary nutrients was likened to the variance in plant height caused by nutrient sources. Chemical fertilisers are readily soluble in soil solutions and are available to plants almost immediately. Microbial action and increased soil physical condition contribute to nutrient availability from organic sources. Bargaz *et al.* [17] agreed with these conclusions. Variations in the availability of key nutrients were thought to cause plant height variation due to the nutritional source. Setiawati *et al.* [18] reported similar results in rice crops. The variation in growth parameters due to organic nutrient sources was considered to be due to difference in the availability of major nutrients, because the faecal composition of cow dung and poultry manure varies depending on age of animal and its feed.

The significant earliness to 50% flowering and panicle initiation as witnessed in poultry manure compared to other nutrient sources might be due to poultry manure's ability to improve the soil physical, biological and chemical properties [19], which improved soil water holding capacity that enhanced rice growth. This result supports a previous study by Singh and Kawu [20], which concluded that poultry manure influenced okra plant height better than NPK fertiliser. Sanni and Adesina [21] postulated that the high nitrogen level in poultry manure enhances crops' physiological activities, thereby improving the synthesis of photoassimilates. They went further to state that the rise in crop vegetative parameters was mainly due to the translocation of nutrients and assimilation of photosynthetic activities during the growth stages, and this may be due to the nutrients - N, Zn, Fe, Mn supplied from the poultry manure. In comparison, Bhuma [22] opined that growth-promoting enzymes and hormones make organic manure sources essential for improving soil fertility and productivity.

Conclusion

The increase in parameters assessed in this study can be attributed to the increased availability of organic matter and nutrients released from multiple sources. The findings of this trial revealed that poultry manure significantly improves rice growth performance and could



therefore be adopted by rice farmers in the Ikorodu agroecological zone as a substitute for the scarce and expensive inorganic NPK 15-15-15 fertiliser.

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Analysis of Agricultural Biodiversity Practised by Crop Farmers in Imo State

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Abstract

The study analysed the agricultural biodiversity practised by crop farmers in Imo State. A simple random sampling technique was used to select 90 crop farmers and data was collected using a structured questionnaire. Data were analysed with statistical tools such as frequency, distribution, percentages and mean. The results of the study revealed the mean scores of the farmers' responses indicating that they have increasingly adopted agricultural biodiversity practices such as agroforestry (2.28), organic fertilizer (2.34), avoiding use of harmful pesticides/herbicides (2.31), among others, which contribute significantly to biodiversity conservation. The result of the study also revealed some perceived benefits of these practices, which include; enhanced pest control (73%), improved soil fertility (68%), improved crop yield (67%) and reduction of soil erosion (58%). It was concluded that recognising these benefits of agricultural biodiversity practices through their constant use will promote environmental balance and resilience. Also, to enhance biodiversity conservation, programmes and policies in the state should involve farmers in the rural communities who are the major actors in the development of agroresources and their conservation principles.

Keywords: Agroforestry, Agroresources, Biodiversity conservation, Crop farmers, Policy

Introduction

Biodiversity is one aspect of environment, which has recently received global attention. Agricultural biodiversity is the diversity of genetic resources (varieties, breeds, species, cultivated, reared or wild) used directly for food and agriculture; the diversity of species that support production (soil biota, pollinators, predators, etc.) and those in the broader environment that support agroecosystems (agricultural, pastoral, forest and aquatic), as well as the diversity of agroecosystems themselves (Food and Agriculture Organization, 2019). Agricultural biodiversity, encompassing the variety and variability of life forms within agricultural systems, plays a pivotal role in ensuring food security, ecosystem resilience, and the long-term sustainability of agricultural practices (Ansari *et al.*, 2020). This includes not only the diversity of crops but also the intricate web of organisms, from beneficial insects to soil microorganisms, that contribute to the functioning of agroecosystems (Moss *et al.*, 2020). Agricultural biodiversity also provides livelihoods and cultural values. Agricultural biodiversity is lost when it suffers a reduction in intrinsic qualities or a decline in its capabilities or complete extinction.



resulting from ‘a causative factor or a combination of factors which reduce its physical, chemical or biological status, hence restricting its productive capacity.

One of the constraints to the conservation of agricultural biodiversity by crop farmers is a lack of education (Fischer *et. al.* 2021). Other factors affecting conservation by crop farmers border on the conservation policies operating in the country and religious beliefs and practices. The conservation of agricultural biodiversity is crucial for maintaining ecosystem services, enhancing resilience to climate change and ensuring food security (Sayer *et. al.*, 2020). However, the knowledge on the level of involvement in agricultural biodiversity by crop farmers in Imo State is still not clear and precise. A gap still exists in knowledge on what constitutes the practices of agricultural biodiversity. Broadly, the study analysed the agricultural biodiversity practised by farmers and specifically determined the frequency of practice of agricultural biodiversity, and identified the perceived benefits of agricultural biodiversity practices.

Methodology

The research was carried out in Imo State, Nigeria. The State has a population of 3,934,899 and a population density of about 725 people per square kilometre (NPC, 2021). It is located at latitudes 4° 45'N and 7°15'N and longitudes 6° 50'E and 7° 25'E. The estimated volume of cassava processed annually in the state is 120 tonnes (Okoronkwo, 2020).

The study sample was drawn using a multi-stage sampling procedure. The study's population consisted of all crop farmers in Imo State. The first stage was the purposive selection of all three agro-ecological zones. This was to ensure effective representation, coverage and inclusion of the agricultural divides of the state. In the second stage, fifteen of the 34 Extension blocks in the state's three agroecological zones were selected using a simple random sampling technique. Thirty out of the 63 farm cells in the zones were selected in the third stage. That is, two cells were chosen randomly from each of the Extension blocks selected for a total of 30 cells. In the fourth stage, six crop farmers were selected using a purposive sampling technique from the list of registered cassava farmers in each cell to give a total of 180 crop farmers. A structured questionnaire was used for data collection. The frequency of use of agricultural biodiversity conservation practices was evaluated on a 1-3 rating scale (often, sometimes and never). Also a 2-1 rating scale (agree and disagree) was used for perceived benefits of agricultural biodiversity conservation practices. Data were analysed using percentage, mean and standard deviation.

A mean value of 2.0 and 1.5 for frequency of use and perceived benefits, respectively, were adjudged acceptable for the respective variables in the specific objectives above. In contrast, a mean below 2.0 and 1.5, respectively, was not accepted as often and as agreed upon.

Results and Discussion

Frequency of Agricultural Biodiversity Practices among Crop Farmers

Table 1: Frequency of Practice of Agricultural Biodiversity

Frequency Practice	of	Mean	SD	REMAR K
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Agroforestry	2.28	0.72	Agree
Crop Rotation	2.30	0.84	Agree
Use of Organic Fertiliser	2.34	0.76	Agree
Soil Erosion Control	1.56	0.80	Disagree
Water Management	1.57	0.78	Disagree
Protection of Natural Habitat	1.66	0.80	Disagree
Avoiding Harmful Pesticides/Insecticides	2.31	0.72	Agree

***Multiple response:** *Source: field survey data, 2024*

The most frequently practised methods include Agroforestry (3.38), crop rotation (3.61), use of organic fertilizers (3.24), and avoiding harmful pesticides/insecticides (3.38). Other conservation measures, such as soil erosion control (2.99), water management (1.32) and habitat protection (1.24), are also practiced but at a lower frequency. These results indicate that farmers are more likely to adopt methods that directly benefit their crops and soil quality. However, conservation techniques like water management and soil erosion control require further encouragement. Training and incentives can help integrate these practices into routine farming activities for long-term sustainability.

Perceived Benefits of Practicing Agricultural Biodiversity Conservation Strategies

The results in Figure I show that the majority of the farmers (73%) agreed that enhanced pest control, improve soil fertility (68%), improved crop yield (67%) and reduced soil erosion (58%) are the key benefits of biodiversity practices. Most of the farmers also indicated that better pollination of crops (79%) and preservation of natural habitats (63%) are not widely acknowledged and therefore disagree that they are benefits of practising biodiversity. This suggests that many farmers are unaware of the long-term ecological advantages of biodiversity practices.

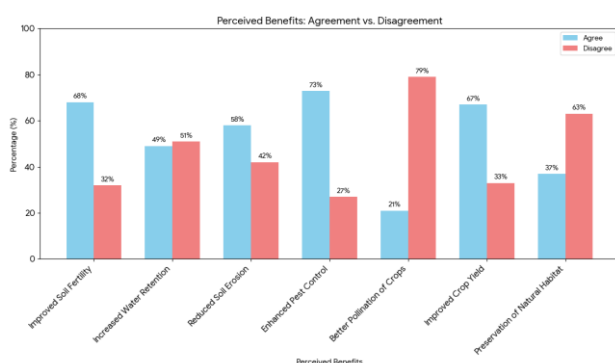


Figure 1: Perceived Benefits of Biodiversity Practices

Source: Field survey data, 2024

Also, Rolando *et. al.* (2023) discovered similar findings where he emphasising the need for more awareness through constant education for farmers to be acquainted with the benefits of biodiversity practices. Raising awareness through education and demonstration projects would help farmers understand the broader environmental and economic benefits of biodiversity practices, leading to greater adoption.

Conclusion

Biodiversity conservation is critical for sustainable agricultural productivity and ecological balance. The findings showed that farmers in Imo State have increasingly adopted agricultural biodiversity practices such as agroforestry, use of organic fertilizers and crop rotation, avoiding use of harmful pesticides, which contribute significantly to biodiversity conservation. In addition, the study explored some perceived benefits of these practices including enhancing pest control and water retention, increasing crop yield, improving soil fertility and carbon sequestration. They also serve to increase productivity in the long run while simultaneously promoting environmental balance and resilience.

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Enhancing the Productivity of Tomato (*Solanum lycopersicum*) using Mushroom Compost Tea (MCT) for Nutrigation and Induced Disease Resistance

Resistance

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Abstract

This paper evaluated the effect of Mushroom Compost Tea (MCT) used for Nutrigation and induced resistance in enhancing the productivity of Tomato (*Solanum lycopersicum*). The experiment was conducted in a screen house at Federal University of Technology Owerri Teaching and Research Farm. The experiment was laid out in a Completely Randomized Design with four treatments namely: T₀ (Tomato plants irrigated with water (control), T₁ (MCT brewed for 1 day), T₂ (MCT brewed for 5 days), T₃ (MCT brewed for 10 days) and T₄ (MCT brewed for 15 days). Data collected were analyzed using ANOVA at 5% probability level using SPSS version 20. The result obtained from this study revealed that the number of leaves were in the range (15.25-81.20), Plant height (78.12-94.22 cm), Leaf area (119.73-183.07 cm²), Number of Branches (2.25-5.25), Stem Girth (3.85-5.57 mm), while the Number of Insect Leaf Damage was in the range (0.25-1.75). The result obtained from the evaluation of yield and yield attributes were as follows: Days to first flower initiation (30.75-35.50), Days to flower opening (37.50-42.25), Days to first fruit formation (48.75-62.25), Number of fruits (12.0-33.25), Fruit weight (g) (5.52-27.25), Fruit girth (4.38-12.10 mm) and Dry biomass yield (62.83-102.52 g). The minerals composition of the MCT are as follows: Ca (784.57-1764.01 mg/l), Mg (402.75-551.33 mg/l), K (9.58-11.08 mg/l), P (153.8-2154.5 mg/l), N (5.78-14.65 mg/l), while the pH(H₂O) is 6.69-7.13. The result of the resistance elicitors are as follows: Lipids (1.21-1.89 %) and soluble Carbohydrate (27.68-31.06 %). The result of the disease severity showed that T₃ and T₄ had the lowest disease severity value of 0.25 and 0.27. These results were significantly different at 5% probability level. T₃ and T₄ were significantly different when compared with the other treatments. This result clearly revealed that T₃ and T₄ were outstanding in enhancing the growth and yield of Tomato when compared with other treatments and also recorded the lowest leaf damage by insects. The result further revealed that T₃ and T₄ contained the highest mineral composition and resistant elicitors. Based on the findings from this research, it is recommended that farmers should be encouraged to utilize MCT brewed for 5-15 days in the cultivation of Tomato.

Keywords: Compost Tea, Mushroom, Nutrigation, Disease, Resistance, Tomato



INTRODUCTION

Tomatoes (*Solanum lycopersicum*) are one of the most widely cultivated and economically important horticultural crops worldwide. They are a staple in human diets due to their versatility and nutritional benefits, providing essential vitamins, antioxidants such as lycopene, and dietary fiber (FAO, 2021). Tomato cultivation is predominantly carried out in open fields, although protected cultivation methods such as greenhouse and hydroponic systems have gained prominence in recent years (FAO, 2021). These systems offer better control over environmental conditions and resource use, resulting in improved yields and quality (FAO, 2021). Tomato (*Solanum lycopersicum*) is globally cultivated and consumed, valued for its nutritional content, economic importance, and versatility in culinary applications. It is a major source of vitamins A, C, K, and folate, as well as antioxidants like lycopene, which has been linked to numerous health benefits (Raiola *et al.*, 2014). Tomato production is, however, often challenged by factors such as nutrient deficiencies, suboptimal soil conditions, and susceptibility to diseases, which reduce yield and quality (Jones, 2020). These challenges necessitate innovative approaches to enhance tomato productivity sustainably.

In recent years, mushroom compost tea has gained attention as a promising bio-based solution to improve crop growth, nutrient uptake, and resistance to diseases (Noble and Coventry, 2005). Mushroom compost tea is an aqueous extract derived from spent mushroom substrate (SMS), a byproduct of mushroom farming. SMS is rich in organic matter, beneficial microorganisms, and essential nutrients, making it an excellent candidate for use in agriculture (Noble and Coventry, 2005). Mushroom compost tea is a liquid organic amendment produced by steeping mushroom compost in water to extract beneficial nutrients and bioactive compounds. Mushroom compost, is rich in essential nutrients like nitrogen, phosphorus, and potassium, as well as beneficial microorganisms and secondary metabolites (Zied *et al.*, 2022). When applied as a foliar spray or soil drench, mushroom compost tea has demonstrated potential to enhance plant growth, improve soil health, and increase crop resilience to biotic and abiotic stresses (El-Mahrouk *et al.*, 2018).

These nutrients are in soluble forms readily available for plant uptake, making the tea an effective fertigation medium. Furthermore, the organic compounds and microbial communities in mushroom compost tea can improve soil structure, enhance microbial activity, and increase the soil's water-holding capacity (Bai *et al.*, 2021). The use of mushroom compost tea aligns with the principles of sustainable agriculture, providing an environmentally friendly alternative to chemical fertilizers. It not only supplies essential nutrients but also introduces beneficial microbes that can suppress soilborne pathogens, thereby reducing the need for synthetic pesticides (Ros *et al.*, 2020).

The application of mushroom compost tea as a component of nutrigation -the combination of nutrition and irrigation-offers a sustainable alternative to chemical fertilizers, which are often associated with environmental issues such as soil acidification and groundwater contamination. Nutrient delivery through irrigation, commonly known as nutrigation, is an advanced agronomic practice that enhances nutrient use efficiency and supports optimal crop growth. Nutrification enables precise application of nutrients directly to the root zone, promoting efficient uptake and reducing nutrient losses to the environment (Kafkafi & Tarchitzky, 2011). This approach has



gained significant attention in modern agriculture for its ability to improve crop productivity and sustainability.

Another significant benefit of mushroom compost tea is its potential to induce systemic resistance in plants. The tea is rich in bioactive compounds, including phenolics, polysaccharides, and volatile organic compounds, which can act as elicitors of plant defense mechanisms (Zhang *et al.*, 2018). These compounds stimulate the production of defense-related enzymes such as peroxidase (POD), polyphenol oxidase (PPO), and chitinase, which play critical roles in strengthening plant cell walls and inhibiting pathogen growth (Ali *et al.*, 2017). One of the critical challenges in tomato cultivation is the high susceptibility of the crop to various diseases, including bacterial wilt, early blight, and late blight, which can cause significant yield losses (Rai & Mamta, 2021). Induced disease resistance is a promising plant defense strategy that involves activating the plant's innate immune system using biotic or abiotic elicitors. This approach enhances the plant's ability to resist or tolerate pathogen attacks, minimizing crop losses and reducing dependence on chemical fungicides (Walters *et al.*, 2013). Studies have shown that the application of compost tea can effectively reduce the incidence and severity of diseases such as early blight, late blight, and Fusarium wilt in tomato plants (Pane *et al.*, 2011; Pant, *et al.*, 2011, Raiola *et al.*, 2014). This biocontrol effect not only reduces the reliance on synthetic pesticides but also contributes to the overall sustainability of tomato production systems. This study is aimed at enhancing the productivity of Tomato using mushroom compost tea for Nutrigation and induced disease and pest resistance.

Materials and Methods

Experimental Site

The study was conducted in a screenhouse at the Teaching and Research Farm, School of Agriculture and Agricultural Technology, Federal University of Technology Owerri (Latitude 5 deg 20 deg N and 5° 27° N Longitude 7 deg 0 ^ - E and 7 deg 07' E), Southeast humid forest zone of Nigeria.

Experimental Design

The experiment was laid out in a Completely Randomized Design (CRD) composed of five (5) treatments with a control and replicated four (4) times. The treatments are as follows:

T₀: Tomato plants treated with water irrigation (Control).

T₁: Tomato plants treated with mushroom compost tea brewed for 1 day.

T₂: Tomato plants treated with mushroom compost tea brewed for 5 days.

T₃: Tomato plants treated with mushroom compost tea brewed for 10 days.

T₄: Tomato plants treated with mushroom compost tea brewed for 15 days.

Preparation of mushroom compost tea

Mushroom compost tea was prepared by stepping spent mushroom substrate (SMS) from *Pleurotus osteratus* in water in the ratio of 1L: 0.08 kg. SMS composted with sawdust, rice bran and wood ash were obtained from the Mushroom Research Unit of the Department of Crop Science and Technology, Federal University of Technology Owerri Imo State Nigeria. The SMS were used in the preparation of Mushroom compost tea after three months of fruit body production by soaking/stepping it in water at different intervals and later sieved.



Planting

The tomato plants are grown in bags as planting containers placed inside the screen house. Each bag contains 20 kg of soil. The plants are regularly watered with the mushroom compost tea (Nutrigation) for T1-T4 while ordinary water were used to irrigate/water T0 (control).

Data collection

Number of Leaves per Plant: The number of leaves per plant was counted manually for the selected plants in each treatment. This was done biweekly, and the total number of leaves was recorded during each observation.

Leaf Area (cm²): The leaf area of the selected plants was determined by multiplying the length and width with the correction factor of 0.75. The length and width of each leaf were measured using a ruler, and the leaf area was calculated using the formula.

Plant Height (cm): The plant height of the selected plants from each treatment were measured and recorded using a measuring tape.

Number of Branches: The number of branches on the selected plants were counted.

Number of Fruits per Plant: The number of fruits per plant were counted

Fruit girth (cm): The fruit girth was measured using a measuring tape in centimeters (cm).

Weight of Fruit per Plant(g): The total weight of fruits harvested per plant was determined using a digital weighing scale.

Days to First Flowering: The days to the first appearance of flowers were recorded by monitoring the plants daily from the day of transplanting until the first flower emerged.

Days to 50% Flowering The days to 50% flowering were recorded by observing the plants daily and noting when half of the plants in each treatment had flowers.

Days to 50% Fruiting: The days to 50% fruiting were recorded by monitoring the plants daily and noting when half of the plants in each treatment bore fruits.

Pre-plant Soil Analysis: Before planting, soil samples were collected from the experimental field. The samples were analyzed in the laboratory for physical and chemical properties, including pH, organic matter, nitrogen, phosphorus, and potassium.

Post-planting Soil Analysis: Soil samples were collected after harvesting from the experimental field. The samples were analyzed in the laboratory to determine changes in soil properties such as pH, organic matter, and nutrient content.

Shell Life: The shelf life of the tomatoes was collected after storage just before senescence

Dry Biomass: This was determined after uprooting and allowed to sun dry



Fresh Whole Plant Biomass: The fresh biomass of the entire plant was determined at harvest.

Assessment of Disease severity: Disease severity assessment was carried out at 2nd, 4th, 6th and 8th WAP. Severity of diseases was assessed by recording the extent of the disease in the infected plants based on a five-point scale of 0-5 (IRRI, 2006) where 0= No infection, 1= 1-20% of plants infected, 2= 21-40% of plants infected, 3= 41-60% of plants infected, 4= 61-80% of plants infected, 5= 81-100% of plants infected.

Results and Discussion

Effect of Mushroom Compost Tea on growth and growth attributes

The effect of mushroom compost tea on growth and growth attributes is presented in Table 1. The result showed that the number of leaves increased progressively across all treatments as the plants matured. At 8 weeks after transplanting (WAT), T3 recorded the highest number of leaves (81.20), followed by T4 with 38.25 leaves, T0 had 34.00 leaves while the least was observed in T1 and T2 with 28.25 and 15.25 leaves. Plant height varied significantly across treatments. T3 produced the tallest plants of 94.23 cm, followed by T4 (91.65cm) at 8WAT. While the control produced, the shortest plants. T4 and T2 The produced taller plants when compared with the control. The result of the leaf area revealed that at 8 WAT T2 had 395.03 cm² leaf area higher than the control with leaf area of 158.58 cm². The result of the number of branches showed that at 8 WAT, T1 had the highest value of 5.25, while T2 had the lowest value of 2.25 branches. These results were highly significantly different at 5% probability level. The effect of MCT on insect leaf damage was also evaluated, the result showed that the Control T0 recorded the highest leaf damage across of 1.74, while T3 consistently exhibited the lowest leaf damage of 0.50 during the sampling period. This result is also significantly different.

Table 1: Effect of mushroom compost tea on growth and growth attributes

Treatment	No. of leaves	Plant Height (cm)	Leaf area (cm²)	No. of Branches	No. of insect leaf Damage
T0 (control)	34.00	79.00	159.00	3.00	2.00
T1 (1 Day)	28.00	88.00	151.00	3.00	2.00
T2 (5 Days)	15.00	80.00	395.00	4.00	1.00
T3 (10 Days)	81.00	94.00	226.00	5.00	0.00
T4 (15 Days)	38.00	92.00	182.00	4.00	1.00
LSD(p=0.05)	6.16	4.19	250.95	0.97	0.73

Effect of Mushroom Compost Tea on Yield and Yield Parameters

The obtained from the evaluation of yield and yield attributes is presented in Table 2. The result showed that T3 had the shortest time to first flower formation (30.75 days), while T0 had the



longest of 35.50 days. Similarly, the first fruit formation was observed in T3 (53.50 days), whereas T2 exhibited the longest delay in first fruit formation of 62.25 days. The highest number of tomato fruits was recorded in T3 with the value 33.25 followed by T4 (25.50), and the lowest was observed in T0 with the value of 12.00. Notably, fruit weight and girth were highest in T3 (27.25 g and 12.1 cm), The result of the dry biomass yield also showed that T4 had the highest dry biomass yield of 102.52 g when compared with the other treatments. These values were also significantly different.

Table 2: Effect of mushroom compost tea on yield and yield parameters

Treatment	Days to 1st flower formation	Days to flower opening	Days to 1st fruit formation	No. of fruits	Fruit weight	Fruit girth(cm)	Dry biomass (g)
T0 (control)	36.00	42.00	49.00	12.00	6.00	4.00	63.00
T1 (1 Day)	32.00	42.00	53.00	20.00	7.00	5.00	79.00
T2 (5 Days)	33.00	40.00	62.00	24.00	26.00	10.00	63.00
T3 (10 Days)	31.00	38.00	54.00	33.00	27.00	12.00	102.00
T4 (15 Days)	33.00	40.00	57.00	26.00	19.00	7.00	103.00
LSD(p=0.05)	2.29	2.47	6.24	3.165	11.113	2.83	22.30

Evaluation of the nutritional composition and resistant elicitors in mushroom compost tea

The results obtained for the evaluation of the nutritional composition of the Mushroom Compost Tea is presented in Table 3. The result showed that T3 had the highest pH value of 7.12 followed by T2 with a pH value of 6.72 while the lowest value of 6.60 was obtained from T1. The result further revealed that T3 recorded the highest level of Ca (1764.01 mg/l), followed by T2 (1071.40 mg/l) while T1, recorded the lowest value of 754.58, the result also shows that T3 had the highest Mg value of 551.33 mg/l, followed by T2 with 458.25 mg/l, while T1 recorded the lowest value of 402.75 mg/l. The highest potassium (k) value was observed in T1 (11.03 mg/l), followed by T3 (10.01 mg/l), and T2 recorded the lowest value of 9.58 mg/l. T2 recorded the highest Phosphorus (P) value of 246.49 mg/l, followed by T3 with 215.45 mg/l, while T1 had the lowest value of 153.82 mg/l. T3 had the highest Nitrogen (N) value of 14.65 mg/l, followed by T2 with 12.89 mg/l, while T1 recorded the lowest value of 5.78 mg/l.



Table 3: Mineral composition of mushroom compost tea

Treatment	pH (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	P (mg/l)	N (mg/l)
1 day brewing	6.60	784.57	402.75	11.03	153.82	5.78
5day brewing	6.72	1071.40	458.25	9.58	215.49	12.89
10daybrewing	7.13	1764.01	551.33	10.01	246.45	14.65
15 days brewing	7.25	1798.09	597.87	9.67	220.90	13.04
LSD(p=0.05)	0.18	45.29	28.90	0.11	0.77	2.33

Evaluation of resistant elicitors in mushroom compost tea and diseases severity

The results obtained from the evaluation of the resistant elicitors in Mushroom Compost Tea are presented in Table 4. The results showed that T2 recorded the highest lipid concentration of 1.89%, followed by T4 with 1.60%, and T3 with 1.55% while the lowest lipid concentration of 1.21% was obtained in T1. Similarly, the results for soluble carbohydrates (CHO) revealed that T4 had the highest concentration of 31.40%, followed by T3 with 30.06%, and T2 with 30.15% while the lowest value of 27.68% was observed in T1. The values were highly significantly different. The result further showed that T0 (control) had the highest mean disease severity of 2.75%, followed by T1 with 1.95% and T2 with 1.25%. The lowest value was obtained from T3 and T4 with the values of 0.25 and 0.27%. These values were significantly different.

Table 4: Resistant elicitors of mushroom compost tea and severity

TREATMENT	Lipids (%)	Soluble CHO (%)	Mean disease severity (%)
T0 (Control) water	-	-	2.75
T1 (1 day brewing)	1.21	27.68	1.95
T2 (5 day brewing)	1.89	30.15	1.25
T3 (10 day brewing)	1.55	31.06	0.25
T4(15 day brewing)	1.60	31.40	0.27
LSD (p=0.05)	0.16	0.54	0.42

Discussion

The result obtained from this study clearly revealed that mushroom compost tea significantly influenced the growth and yield attributes of tomato. These results could be attributed to the high levels of essential nutrients and beneficial microbial interactions leading to more vigorous plant growth. These results are also consistent with the findings of Arancon *et al.* (2007) and



Pant *et al.* (2012), who reported that compost tea enhances fruit set and quality and maturation rates of tomato. These findings were also consistent with the studies by Zied *et al.* (2022), who also reported that organic compost tea application enhanced fruit yield and accelerated flowering in vegetable crops. The increase in fresh and dry biomass, further supports the role of compost tea in promoting plant resilience and productivity. These findings further support the findings of Ingham (2005), who reported that mushroom compost teas enhanced leaf area index and chlorophyll content, thereby promoting photosynthetic efficiency and overall plant vigor. The effect of MCT on number of insect leaf damage revealed that mushroom compost tea has insect-repellent or resistance-enhancing properties, likely due to bioactive compounds present as previously reported by Chaiphongpachara *et al.* (2018). This is also in agreement with the findings of Pant *et al.* (2011) and Arancon *et al.* (2007) who highlighted the role of mushroom compost tea in enhancing plant defenses through microbial activity and secondary metabolite production. The result is also consistent with the findings of Anith *et al.* (2004) who reported that the application of mushroom compost tea on plants can trigger defense mechanisms that deter or suppress pest feeding and reproduction which involve the production of secondary metabolites or signaling molecules that repel or inhibit pest. The low disease severity observed in T3 and T4 when compared with the control could be attributed to the proliferation of beneficial microorganisms and the release of nutrients and metabolites into the water which creates nutrient –rich liquid fertilizer as reported by Chadlia *et al.* (2017). This observation is also consistent with the findings of Purohit *et al.* (2017) who reported that MCT contains beneficial microorganisms such as fungi, bacteria and actinomycetes which may compete with and antagonize soilborne pathogens through mechanisms such as competition for nutrients, production of antimicrobial compounds and induction of systemic resistance in plants.

Conclusion

The findings from this study demonstrate that mushroom compost tea is a highly effective organic amendment for improving tomato productivity. The major findings from this study are as follows: MCT should be brewed for a period of 5-10 days for enhanced growth, yield and pest and disease resistance of tomato plant. However further work is highly recommended especially in the identification of the nutritional and bioactive compounds present in MCT.

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Effect of Soil Amendments on Selected Growth Properties of Maize (*Zea mays*)

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Abstract

Studies on the effect of different compost manures (*Pueraria phaseoloides*, *Centrosema pubescens*, *Vigna subterranea*, *Vigna unguiculata*, *Arachis hypogea*, *Calopogonium mucunoides*, and *Cajanus cajan*) on selected growth characteristics of maize (*Zea mays* L.) were carried out. Three hundred and fifty grams (150 g) of sun-dried plant materials were incubated in bags for one week to start decaying before incorporated into 10kg soil, and allowed for 2 weeks before planting. Results showed that average maize heights in 2 weeks after planting (WAP) varied between 17.87 cm in control and 36.87 cm in soil amended with *V. subterranea*. At 4 WAP, average plant height varied between 50.33 cm in control and 74.83 cm in *V. subterranea* and *C. mucunoides* and from 66.33 cm in control to 104.33cm in *C. mucunoides* at 6 WAP all the treatments showed progressive increases in plant heights however, the maize grown in soil amended with *C. mucunoides* performed better than other amendments. This followed by *C. cajan*, *V. subterranea*, and *P. phaseoloides*. There was no significant difference at $p \leq 0.05$ in maize height grown in the amended soils compared to control in week-2 and -3 however, in week-6 the maize grown in *P. phaseoloides*, *V. subterranea*, *C. mucunoides*, and *C. cajan* were significantly different from the control. This difference could be associated with the rate of decay and nutrient release. Also, there is significant difference in maize fresh weight and biomass at 6-weeks after planting. This indicates that the plant materials released more nutrient to the soil in week-6 and could mark the peak of decay of the materials.

Keywords: Compost, Manures, Maize, Soil Amendment, *Zea mays*

Introduction

Maize is one of the world largest cereals with wheat and rice (Jones, 1997) and is cultivated in most of the sub-Saharan African countries for different purposes such as animal feeds, food, and industrial uses (Amudalat and Ephraim, 2004; Abunyewa *et al.*, 2007; IITA, 2009; CIMMYT and IITA, 2010; Amudalat, 2015). Maize is commonly cultivated in the tropics and sub-tropical regions for food and/or milled into flour and serves as a valuable ingredient for baby food, cookies, biscuits, ice cream, pancake mixes, livestock feed and a variety of traditional beverages (Olaoye and Adegbesen, 1991; Okoruwa, 1998; Eleweanya *et al.*, 2005; Abdulrahman and Kolawole, 2006; Amudalat, 2015). It has been reported that low production of maize in sub-Saharan countries could result in starvation and famine (CIMMYT and IITA, 2010; Amudalat, 2015). In sub-Saharan Africa, Nigeria was the largest producer of maize in 2010 and has been divided into four main groups (low, medium, medium to high and high) based on the production



potentials and Rivers State falls into the region with low production potential of maize (ATA, 2011). In Nigeria, maize as an important food, fodder, and the industrial crop is grown both commercially and at subsistence level. (Eleweanya *et al.*, 2005; CIMMYT and IITA, 2010; Amudalat, 2015).

In many Sub-Saharan African countries and particularly Nigeria, maize production is confronted or faced with many challenges including poor soil fertility (De Jager *et al.* 1998; Azeez *et al.*, 2006;), pest and disease infestation (Lakoke *et al.*, 1991; IITA, 2009), removal of fertilizer subsidy by government (Shepherd, 1989; Amudalat, 2015), weed management and control (Fakorede, 2001; Olaniyan and Lucas, 2004) and drought (Menkir and Akintunde, 2001). Many researchers and authors have tried to fashion several ways to enhance the production of maize. Applications of organic materials such as livestock manure and crop residues have proven to bring about a gradual improvement in soil productivity and crop performance (Morteza *et al.*, 2011). Studies on the effects of organic manures on crop yield and soil properties have been documented (Ohshima *et al.*, 1998; Sahrawat, 2006 and Tiamiyu *et al.*, 2012).

Application of organic manure has been found to be more friendly and have little or no negative effect on the soil (Jinadasa, 1997; Abam *et al.*, 2006). Organic manure when properly applied to the soil has been reported to enhanced fruiting in maize and other growth characteristics (Asiegbu and Uzo, 1984). This present work focused on the effect of different compost manures on the growth characteristics of maize plant.

Materials and Methods

Study area: This research was conducted at the Ecological Centre, University of Port Harcourt.

Preparation of plant materials: The leaves of the legumes (*Pueraria phaseoloides*, *Centrosema pubescens*, *Vigna subterranea*, *Vigna unguiculata*, *Arachis hypogea*, *Calopogonium mucunoides*, and *Cajanus cajan*) were sun-dried, chopped into pieces. Three hundred and fifty grams (350 g) of the plant materials were weighed, incubated in the bag for one week to start decaying. Thereafter, the decaying legumes were incorporated into 10 kg soil, and allowed for two weeks before planting.

Soil analysis: Soil samples were collected and analyzed before the applications of the amendments. At the end of the experiment, soil samples were analyzed.

Measurement of growth characteristics: The plant height and number of leaves at 2, 4, and 6, weeks after planting (WAP), including fresh and biomass weight at 6 weeks were taken and subjected to statistical analysis using SPSS.

Results and Discussion

The effect of the soil amendments of plant heights showed that at week-2 after planting (2 WAP) the average plant heights varied from 17.87 cm in control to 36.87 cm in soil amended with *V. subterranea*. At week-4 after planting (4 WAP), it varied from 50.33 cm in control to 74.83 cm in *V. subterranea* and *C. mucunoides* while in week-6 after planting (6 WAP) it varied from 66.33 cm in control to 104.33 cm in *C. mucunoides* (Table 1). In all the treatments, there is



progressive increase in the plant height however, the maize grown in soil amended with *C. mucunoides* performed better than other amendments. This difference could be associated with the rate of decay. This followed by *C. cajan*, *V. subterranea*, and *P. phaseoloides*. There is no significant different in the height of the maize grown in the amended soils compared with the control in week-2 and -3 however, in week-6 the heights of the maize grown in *P. phaseoloides*, *V. subterranea*, *C. mucunoides*, and *C. cajan* were significantly different at $p \leq 0.05$ from the control. This indicates that the plant materials released more nutrient to the soil in week-6 and could mark the peak of decay of the materials.

Table 1: Effect of soil amendments on plant heights (cm)

Legumes	Plant height (cm)		
	2 WAP	4 WAP	6 WAP
Control	17.87 ± 3.68 ^{a,c}	50.33 ± 2.73 ^{a,d,e}	66.33 ± 2.33 ^{a,d,f}
<i>P. phaseoloides</i>	30.33 ± 3.22 ^{a,c}	69.00 ± 1.53 ^{a,d,e}	92.67 ± 5.46 ^{b,d,f}
<i>C. pubescens</i>	33.17 ± 2.13 ^{a,c}	73.83 ± 1.17 ^{a,d,e}	85.67 ± 4.26 ^{a,d,f}
<i>V. subterranean</i>	36.87 ± 1.62 ^{a,c}	74.83 ± 1.69 ^{a,d,e}	94.00 ± 0.58 ^{b,d,f}
<i>V. unguiculata</i>	31.83 ± 1.17 ^{a,c}	70.67 ± 2.80 ^{a,d,e}	88.00 ± 4.04 ^{a,d,f}
<i>A. hypogea</i>	21.27 ± 5.54 ^{a,c}	60.67 ± 2.67 ^{a,d,e}	65.33 ± 12.00 ^{a,d,f}
<i>C. mucunoides</i>	29.50 ± 7.75 ^{a,c}	74.83 ± 12.17 ^{a,d,e}	104.33 ± 1.76 ^{b,d,f}
<i>C. cajan</i>	35.07 ± 3.04 ^{a,c}	73.50 ± 5.80 ^{a,d,e}	99.67 ± 2.33 ^{b,d,f}

Values are mean ± Standard error mean (SEM). Values with the different superscript are statistically significant at ($p \leq 0.05$). Superscript (a, b) compares *P. phaseoloides*, *C. pubescens*, *V. subterranea*, *V. unguiculata*, *A. hypogea*, *C. mucunoides* and *C. cajan* to control down the column (1st letter), superscript (c, d) compares 4th week and 6th week to 2nd week (2nd letter) while superscript (e, f) compares 6th week to 4th week across the row (3rd letter). WAP= Weeks after planting

At six weeks after planting, we noted a significant increase in fresh weight and biomass. This however showed that all the plant materials investigated enhance the growth of maize (Table 2). The most effective plant materials include *V. subterranea*, *C. pubescens*, *P. phaseoloides*, and *C. mucunoides*. The control soil showed the least concentration of Nitrogen at six weeks while the soils amended with *P. phaseoloides*, *V. subterranea*, *V. unguiculata*, *C. mucunoides* and *C. cajan* had appreciable concentration of nitrogen compared to the control (Fig. 1).



Table 2: Effect of soil amendment on the number of leaves, fresh weight and biomass

Legumes	Number of Leaves			Fresh Weight (g)	Biomass (g)
	2 WAP	4 WAP	6 WAP		
Control	2.53 ± 0.29 ^{a,c}	5.00 ± 0.29 ^{a,c,e}	13.00 ± 0.58 ^{a,c,e}	18.88 ± 0.05 ^a	2.66 ± 0.04 ^a
<i>P. phaseoloides</i>	3.60 ± 0.21 ^{a,c}	5.83 ± 0.17 ^{a,c,e}	17.00 ± 0.58 ^{b,c,e}	41.79 ± 0.06 ^b	10.63 ± 0.42 ^b
<i>C. pubescens</i>	3.57 ± 0.23 ^{a,c}	6.17 ± 0.17 ^{a,c,e}	17.33 ± 0.33 ^{b,d,f}	40.46 ± 0.04 ^b	13.93 ± 0.60 ^b
<i>V. subterranean</i>	3.80 ± 0.20 ^{a,c}	6.33 ± 0.60 ^{a,c,e}	18.00 ± 0.58 ^{b,d,f}	48.43 ± 0.12 ^b	15.06 ± 0.31 ^b
<i>V. unguiculata</i>	3.27 ± 0.15 ^{a,c}	5.83 ± 0.17 ^{a,c,e}	17.00 ± 0.58 ^{b,d,f}	40.72 ± 0.15 ^b	8.88 ± 1.03 ^b
<i>A. hypogea</i>	2.77 ± 0.39 ^{a,c}	5.17 ± 0.33 ^{a,c,e}	14.00 ± 0.58 ^{a,c,e}	31.45 ± 0.19 ^b	5.58 ± 0.31 ^b
<i>C. mucunoides</i>	3.50 ± 0.50 ^{a,c}	5.67 ± 0.17 ^{a,c,e}	17.00 ± 0.58 ^{b,c,e}	40.24 ± 0.19 ^b	9.80 ± 1.80 ^b
<i>C. cajan</i>	3.10 ± 0.10 ^{a,c}	5.67 ± 0.17 ^{a,c,e}	17.00 ± 0.58 ^{b,d,e}	38.31 ± 0.06 ^b	9.02 ± 0.85 ^b

Values are mean ± Standard error mean (SEM). Values with the different superscript are statistically significant at ($p \leq 0.05$). Superscript (a, b) compares *P. phaseoloides*, *C. pubescens*, *V. subterranea*, *V. unguiculata*, *A. hypogea*, *C. mucunoides* and *C. cajan* to control down the column (1st letter), superscript (c, d) compares 4th week and 6th week to 2nd week (2nd letter) while superscript (e, f) compares 6th week to 4th week across the row (3rd letter). WAP= Weeks after planting

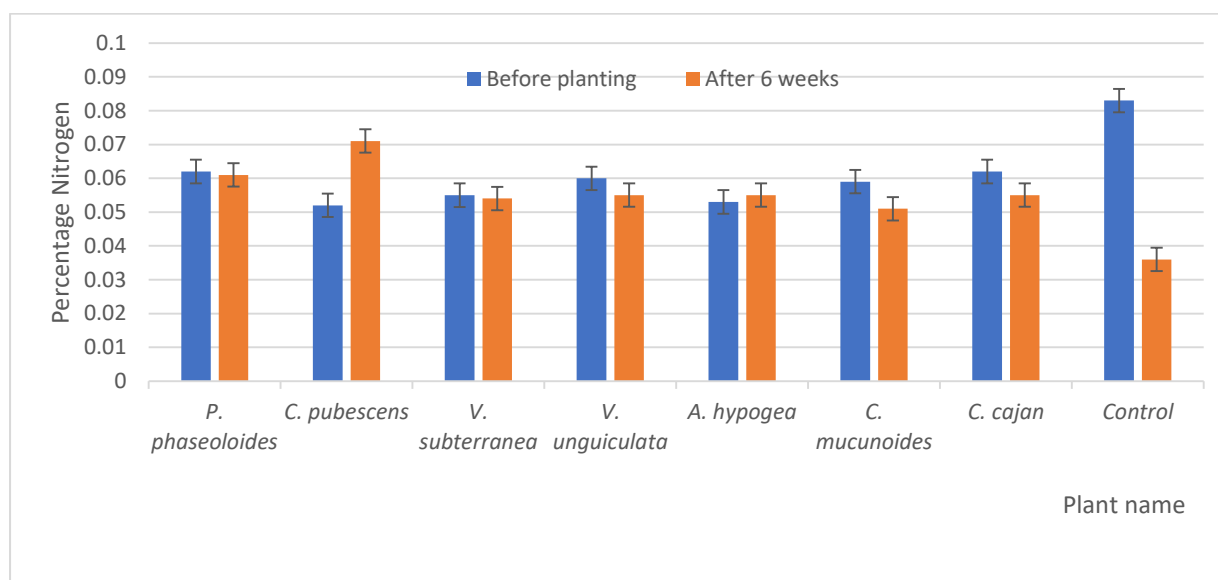


Figure 1: Soil nitrogen content before planting and 6 weeks after planting

Our findings in this present work showed that the different plant materials used enhanced the growth and development of maize especially at six weeks after planting which coincides with the peak of nutrient release by the decaying plants. However, due to the dry nature of the leaves, decay was slow. *Pueraria phaseoloides*, *C. pubescens*, and *V. subterranea* have hard leaves and needs a much longer period of time for decay to effectively take place. Existing literatures have



shown that organic amendments from manure (fresh, aged, composted) to bio-solids, pulp, and paper mill sludge and food processing wastes could enhance the yield of agricultural productivity (Larney and Pan, 2006) and when properly applied to the soil enhances fruiting in plants like maize and other growth characteristics (Asiegbu and Uzo 1984; Okoroafor, et al., 2013; Faisal *et al.*, 2017). This method of soil enhancement is more friendly and have little or no negative effect to the soil (Jinadasa, 1997; Abam *et al.*, 2006). The result of our work is in line with these previous findings. To optimize the use of these plant materials as compost, factors such as decomposition rate of individual legume, pH of soil at the initial stage, how conducive is it to initiate decay processes, pH of soil and legume after mixing, quantity of legumes and soil (ratio), age of the legumes at the time of harvest, time of the year -humidity/moisture, temperature of day and night and other weather factors like hours of sunlight and darkness, presence of decomposing microorganisms. Hence, these leguminous materials could be utilized by farmers to boost nitrogen demand as most cereals demand more nitrogen from sixth week for tasseling and cob formation and less of inorganic fertilizer.

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Evaluation of Growth and Yield of Sorghum Varieties Intercropped with Cassava as a Climate - smart Agriculture Strategy in the Forest-savannah Transition Agro-ecology

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Abstract

This study aimed to investigate the agronomic performance of three improved sorghum varieties intercropped with cassava variety (TME 419) in response to poultry manure application at the Institute of Food Security, Environmental Resources and Agricultural Research, FUNAAB from June to December, 2023). The experiment was a 3×7 factorial fitted into a randomized complete block design with three replications. Factor 1 - The poultry manure rates (3): 0, 2.5, 5.0 t ha⁻¹; Factor 2 - the cropping systems (7): SAMSORG 44/TME 419 Intercrop; SAMSORG-47/TME 419 Intercrop; SAMSORG-48/TME 419 Intercrop; SAMSORG 44 Sole; SAMSORG-47 Sole; SAMSORG-48 Sole; TME 419 Sole. Results revealed that the application of poultry manure significantly ($P>0.05$) enhanced the growth and yield of both cassava and sorghum, whether cultivated as sole crops or in intercropping systems. An application rate of 5.0 t ha⁻¹ was found optimal for maximizing growth and yield performance. Furthermore, cassava–sorghum intercropping proved to be more productive and economically viable than sole cropping systems. With high LER, ATER and MAI values, the intercropping systems demonstrated strong biological and economic efficiency. The SAMSORG 44/TME 419 intercrop combination was the most efficient, recording the highest MAI alongside robust biological productivity. In conclusion, cassava–sorghum intercropping, particularly with SAMSORG 44, represents a climate-smart, economically viable, and resource-efficient production strategy and is hereby recommended for resource-constrained farmers in the Forest–Savannah Transition agro-ecology of Nigeria.

Keywords: Climate-smart agriculture, Intercropping, *Sorghum bicolor*, Sorghum varieties, Sustainable agriculture

Introduction

The 13th Sustainable Development Goal (SDG) emphasizes the need for urgent action to combat climate change and its effects. In this context, Climate-Smart Agriculture (CSA) is essential to achieving sustainable crop production. Climate change has led to challenges such as, shifting rainfall patterns, sudden droughts, and overall reduced agricultural productivity (Onuk *et al.*, 2019). Sorghum plays a vital role in CSA due to its intrinsic drought tolerance, adaptability to



harsh arid and semi-arid environments, extensive root system, a waxy leaf coating that reduces water loss (Hadebe *et al.*, 2017). Cassava and sorghum differ in growth habits, root structures, and nutrient requirements, which facilitates efficient resource utilization when intercropped. Studies by Ibrahim *et al.* (2021) demonstrated that cassava-sorghum intercropping increased land equivalent ratios (LERs) by 30% compared to monocropping, indicating improved land productivity. Despite the potential benefits, specific studies on cassava-sorghum intercropping are limited. Existing research often focuses on general intercropping principles rather than the unique dynamics of this combination. Comprehensive field trials are needed to establish best practices and quantify long-term benefits (Singh *et al.*, 2018). Intercropping systems often improve soil health through complementary nutrient cycling. Sorghum's extensive root network enhances soil structure, while cassava reduces soil erosion due to its broad canopy. Research by Ayodele *et al.* (2019) revealed that cassava-sorghum intercropping increased soil organic carbon and reduced nutrient leaching by 25%, contributing to long-term soil sustainability. Cassava and sorghum exhibit high drought tolerance, making their intercropping system ideal for areas prone to erratic rainfall. A study by Mutegi *et al.* (2020) highlighted that intercropping these crops reduced the risk of total crop failure under drought conditions by 40% compared to monocultures, ensuring a consistent food supply. Consequently, the objective of this study is to evaluate the agronomic performance of selected sorghum varieties under organic soil fertility management with poultry manure in a cassava-based intercropping system, with emphasis on the potential of intercropping to enhance carbon sequestration through increased biomass production arising from higher foliar density of the component crops, thereby contributing to greater resilience in the Forest-Savannah Transition Agro-ecology under changing climatic conditions.

Materials and Methods

This trial was carried out at the certified organic farm of the Institute of Food Security, Environmental Resources and Agricultural Research, FUNAAB from June to December, 2023. The physico-chemical properties of the experimental site are shown in Table 1. Monthly rainfall distribution, mean temperature and relative humidity were recorded during the period of the study (Table 2). Three poultry manure treatments (0, 2.5, 5.0, t. ha⁻¹) were tested on three sorghum varieties (SAMSORG-44, SAMSORG-47 and SAMSORG-48) intercropped with the cassava variety, TME 419. The experiment was a 3 × 6 factorial with three replicates. Factor 1 - The poultry manure rates (3): 0, 2.5, 5.0 t ha⁻¹; Factor 2 - the cropping systems (7): SAMSORG 44/TME 419 Intercrop; SAMSORG-47/TME 419 Intercrop; SAMSORG-48/TME 419 Intercrop; SAMSORG 44 Sole; SAMSORG-47 Sole; SAMSORG-48 Sole; TME 419 Sole. The total treatment combination was 21. Tillage operation included ploughing and harrowing. Poultry manure was incorporated according to the experimental design and treatment after land preparation. Planting was done on the 29th of June, 2023. The plant spacing for cassava which was the base crop was 75 × 75 cm. Sorghum was intercropped simultaneously at a spacing of 75 × 25 cm using the additive model of intercropping. Manual weeding was carried out at 3, 6, 9 and 12 weeks after sowing (WAS). Data collected were on cassava (leaf area, stem girth, weight of tubers/plot and tuber yield) and sorghum (dry matter accumulation, plant height, stem girth, number of leaves, panicle length, panicle diameter, panicle weight, seed weight/plot, threshing



percentage and seed yield). Intercrop productivity and efficiency of the mixtures were assessed using the land-equivalent ratio (LER), area time equivalent ratio (ATER), and monetary advantage index (MAI). LER determines the total land productivity or agronomic advantage of the various crop combinations, determined as described by Willey and Rao (1980). Values of $LER > 1.00$ indicates advantage of intercrop components over their sole crops. ATER measures the biological efficiency of a crop by adjusting the differences in the growth duration of the crop components.

The MAI is used to quantify the economic advantage of the intercropping systems (Willey and Rao 1980). The higher the value of MAI, the higher the profitability of the cropping system (Ghosh 2004). The data collected were subjected to analysis of variance (ANOVA) and significant ($P > 0.05$, F-test) treatment means of main effects and interactions were separated using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Effects of poultry manure and cropping system on growth, yield and yield components of cassava in 2023

Poultry manure application significantly ($p > 0.05$) influenced the leaf area and stem girth of cassava across all observation periods (Table 3). These parameters increased with increasing poultry manure application. The 5.0 t ha^{-1} manure treatment resulted in the highest leaf area and stem girth compared to the control. The consistent improvement in these growth indices with increasing poultry manure rates indicates the critical role of soil fertility in cassava growth, with higher manure rates providing more nutrients (especially nitrogen, phosphorus, and potassium) which are vital for cell elongation and tissue growth in cassava (Akinyemi *et al.*, 2022). In this study, cropping system did not significantly ($p > 0.05$) affect the leaf area and stem girth of cassava at any point during both growing seasons (Table 4). All the intercropping systems involving cassava with SAMSORG 44, SAMSORG 47, and SAMSORG 48 were similar in their leaf areas and stem girths to those observed in sole cropping systems with TME 419. This lack of significant ($p < 0.05$) effect could be attributed to the low competition for nutrients and light between the crops in the intercropping systems, or the high adaptability of cassava to a variety of cropping systems. Previous studies have shown that cassava is a low-resource demanding crop and tends to show resilience in intercropping systems, maintaining good growth even when planted alongside other crops (Sakyi *et al.*, 2021). No significant ($p < 0.05$) interaction between poultry manure rates and cropping systems was observed for all WAP across both growing seasons. This suggests that manure had a similar positive effect on canopy height regardless of the cropping system, and sorghum plants grew similarly in both systems. This could be attributed to the uniform application of manure and the inherent capacity of cassava to tolerate intercropping conditions without significant ($p < 0.05$) negative impacts on growth parameters such as the leaf area and stem girth.

Poultry manure application significantly ($p < 0.05$) affected cassava tuber weight per plot and tuber yield (Table 4). Cassava plants fertilized with 5.0 t ha^{-1} poultry manure consistently produced the highest tuber weight and tuber yield, followed by 2.5 t ha^{-1} , while the control produced the lowest values. This aligns with previous findings by Ayoola and Makinde (2021)



and Law-Ogbomo and Egharevba (2020), who reported that poultry manure, rich in essential macro- and micronutrients, notably enhances cassava biomass accumulation and root yield. Poultry manure provides a slow but sustained release of nutrients, particularly nitrogen, phosphorus, and potassium, which are pivotal for root bulking (Akanbi *et al.*, 2021). Cropping system did not significantly ($p>0.05$) affect tuber weight or tuber yield. Whether cassava was grown alone or intercropped with different SAMSORG varieties, tuber yields were statistically similar. This suggests that cassava's yield potential is resilient to intercropping with cereals like sorghum, a finding that resonates those of Togola *et al.* (2019) and Sakyi *et al.* (2021). There were no significant ($p<0.05$) interactions between poultry manure rate and cropping system on cassava yield or yield components. This absence of significant interaction effect indicates that the benefits of poultry manure application are consistent across different cassava production systems. Whether cassava is grown alone or with sorghum, applying poultry manure substantially boosts yield performance.

Effects of poultry manure on and cropping system on growth, yield and yield components of sorghum varieties in 2023

The application of poultry manure had a significant ($p<0.05$) impact on plant height and dry matter accumulation (Table 4). Plots treated with 5.0 t. ha^{-1} poultry manure exhibited the highest measurements of plant height and dry matter accumulation, signifying the positive influence of poultry manure on sorghum growth likely due to improved soil structure, nutrient availability, and water retention capacity (Gupta *et al.*, 2020). However, cropping system did not show a significant ($p<0.05$) effect on all growth (dry matter accumulation, plant height, stem girth, number of leaves) parameters of the sorghum varieties, exemplifying the compatibility of these two test crops as complementary intercrop species (Adekunle *et al.*, 2014). Poultry manure significantly ($p < 0.05$) enhanced panicle weight, seed weight/plot, threshing percentage and seed yield (Table 5). The highest values were observed at 5.0 t ha^{-1} , highlighting the effectiveness of poultry manure in enhancing sorghum yield (Gupta *et al.*, 2020). Conversely, critical observation of the significant ($p < 0.05$) influence of cropping system on all measured yield and yield traits (Table 5) indicates a high level of biological compatibility between sorghum and the cassava variety (TME 419), supporting the feasibility of their intercropping in CSA systems (Adekunle *et al.*, 2014). Significant ($p<0.05$) interaction between manure and cropping system on seed yield production indicated the highest seed yield of 2816 kg/ha at 5.0 t ha^{-1} manure application particularly for SAMSORG 44 which is significantly higher than the average yield values of 924.8 kg/ha in Africa and 2534.2 kg/ha in the world (Khalifa and Eltahir, 2023) (Fig. 1), which highlights the importance of selecting most suitable varieties.

Intercrop productivity and efficiency

As indicated in Table 6, in this study, all cassava-sorghum intercropping systems exhibited LER values significantly ($p<0.05$) greater than 1.0, compared to the sole cropping systems that had baseline values of 1.00 (Table 5). This clearly indicates that intercropping cassava with sorghum produced 96–97% more yield per unit area than growing the component crops separately, validating the biological advantage of intercropping (Lithourgidis *et al.*, 2011). The observed LER value underscores cassava and sorghum demonstrated the often-reported complementarity and efficient use of available growth resources in the system (Adekunle *et al.* 2014; Onuk, *et al.*



2019). The ATER values suggest a marginal but positive gain in yield when the duration of crop growth is considered. Since ATER accounts for both land and time resource use, these values affirm that cassava-sorghum intercropping is not only spatially efficient but also temporally efficient, which is critical in rainfed systems where time windows are narrow (Hiebsch & McCollum, 1987). MAI ranged from N254,090 to N256,040 across the intercropping systems, with the highest value recorded in the SAMSORG 44/TME 419 combination. Since all intercrops had MAI values substantially greater than zero, this indicates that intercropping cassava with sorghum is economically beneficial over sole cropping systems. The MAI is especially relevant under market-driven agriculture, where farmers prioritize gross returns over biological yield. Notably, the highest MAI from the SAMSORG 44 intercrop suggests that the economic synergy with cassava was strongest with SAMSORG 44, likely due to better growth compatibility or less interspecific competition. These findings emphasize the importance of varietal selection in intercrop design, where biological compatibility can be more important than individual crop yield potential.

Effects of Weather Variability on Intercrop Performance

The productivity indices presented in Table 6 highlight the biological and economic efficiency of cassava-sorghum intercropping systems across both years. All intercropping treatments recorded significantly higher LER values compared to sole crops, indicating clear land-use advantage of the intercropping system. Despite the lower rainfall in August (Table), LER remained unaffected, indicating that the intercrop system demonstrated resilience to short-term climatic stress. This can be attributed to differential water use patterns, with cassava compensating for sorghum yield losses during drier conditions. ATER value in intercrop combinations, indicate efficient utilization of land and time under intercropping, particularly when both crops shared the field over an extended period. Higher ATER suggests that late-season water availability favored cassava tuber bulking and extended sorghum grain filling. MAI values were consistently high across intercrop combinations underscoring the profitability of intercropping over sole cropping. Despite fluctuations in rainfall and sunshine, the MAI remained stable, further supporting the economic viability and weather-buffering potential of cassava-sorghum intercropping. The high monetary returns reflect market value and yield stability, particularly due to cassava's ability to maintain productivity under variable moisture regimes.

Conclusion

This study demonstrated that the application of poultry manure significantly enhanced the growth and yield of both cassava and sorghum, whether cultivated as sole crops or in intercropping systems within the Forest-Savannah Transition agro-ecology. An application rate of 5.0 t ha⁻¹ was found optimal for maximizing growth and yield performance. Among the sorghum varieties, SAMSORG 44 demonstrated superior productivity under organic amendment with poultry manure. Furthermore, cassava-sorghum intercropping proved to be more productive and economically viable than sole cropping systems. With high LER, ATER and MAI values, the intercropping systems demonstrated strong biological and economic efficiency. The SAMSORG 44/TME 419 intercrop combination was the most efficient, recording the highest MAI alongside robust biological productivity. Collectively, these findings highlight cassava-sorghum intercropping as a promising climate-smart strategy for sustainable



intensification in smallholder systems, emphasizing the role of variety compatibility and resource complementarity. The observed compatibility between cassava and sorghum underscores their potential as a resilient and sustainable cropping system in the Forest–Savannah Transition agro-ecological zone.

Table 1: Poultry manure and pre-treatment physico-chemical properties of the soil of the experimental site

Parameters	Poultry manure	Soil
<u>Physical properties</u>		
Sand (%)		85.2
Silt (%)		7.6
Clay (%)		7.2
Textural class		Loamy-sand
<u>Chemical properties</u>		
pH		5.92
Organic carbon (%)	10.8	3.36
Organic matter (%)		5.79
N (%)	4.10	0.34
Available P (mg/kg)	0.083	7.54
Ca (cmol/kg)	12.77	6.88
Mg (cmol/kg)	1.9	0.26
Na (cmol/kg)	2.4	0.3
K (cmol/kg)	0.48	0.34

Table 2: Meteorological data during the experiment in 2023

Month	Total Rainfall (mm)	Relative Humidity (%)	Temperature °C		Sunshine Hours
			Maximum	Minimum	
June	217.3	85.9	21.9	31.8	3.5
July	148.9	81.9	21.1	27.5	3.1
August	56.4	81.8	20.8	30.3	2.4
September	131.2	81.0	20.9	31.4	3.0
October	236.2	80.8	21.4	32.7	5.4
November	238.4	79.3	21.9	32.3	4.9

Source: Department of Agro Meteorology and Water Resources Management, Federal University of Agriculture, Abeokuta



Table 3: Growth, yield and yield components of as influenced by organic soil amendment with poultry manure and cropping systems in 2023

Treatments	Leaf area (cm ²)			Stem girth (cm)			Tuber weight/plot (kg)		
							WAS		
Manure rate (t. ha ⁻¹) (M)	6	8	10	6	8	10			
0	109.3 a	142.3 c	192.9 c	5.7 c	7.6 c	11.1 c	26.0 c	11569.4 c	26.0 c
2.5	144.4 b	164.3 b	229.0 b	7.6 b	10.2 b	15.0 b	32.2 b	14341.2 b	32.2 b
5.0	156.3 c	185.0 a	241.0 a	8.9 a	11.4 a	17.1 a	36.1 a	16024.4 a	36.1 a
SED± df (2)	3.4	3.0	3.5	0.2	0.3	0.4	0.9	34.2	0.9
Cropping System (C)									
Sole TME 419	137.1	165.3	221.1	7.6	9.6	14.5	32.3	14342.3	32.3
TME 419/ SAMSORG 44	136.4	163.7	221.2	7.1	9.9	14.4	32.2	14311.4	32.2
TME 419/ SAMSORG 47	136.2	163.7	220.9	7.4	9.9	14.1	32.1	14284.3	32.1
TME 419/ SAMSORG 48	137.0	162.7	220.7	7.4	9.4	14.5	32.0	14226.9	32.0
SED± df (3)	3.4	3.0	3.4	0.2	0.3	0.4	0.8	309.4	0.8
Interaction									
MXC	ns	ns	ns	ns	ns	ns	ns	ns	ns

In a column, means followed by similar letters are not significant different at 5% level of probability using Duncan's Multiple Range Test (DMRT). WAS = Weeks after sowing. ns = not significant (p> 0.05). * = Significant at 5 % level of probability (p=0.05). ** = Significant at 1% (p=0.01) level of probability.



Table 4: Growth of three sorghum varieties (SAMSORG 44, SAMSORG 47, and SAMSORG 48) as influenced by organic soil amendment with poultry manure in 2023

Treatments	Plant height (cm)			Number of leaves			Stem girth (cm)		
							WAS		
<u>Manure rate (t. ha⁻¹) (M)</u>	4	6	8	4	6	8	4	6	8
0	52.7	87.4 c	140 ab	5.4	7.9	11.4	7.9	10.2	22
2.5	53.4	100.3 b	160.6 a	4.8	8.3	12.8	8.1	14.3	24
5.0	45.1	105.2 a	128.3 b	4.9	7.9	11.2	8.4	11.4	21
SED ± (4 df)	2.1	3.7	5.0	0.1	0.2	0.4	0.7	1.0	0.
<u>Cropping System (C)</u>									
Sole SAMSORG 44	49.2	100.0 a	151.0 a	5.2	8.4	12.6	8.1	13.9	25
Sole SAMSORG 47	50.1	85.6 b	126.3 b	5.0	7.9	10.9	8.3	9.4	21
Sole SAMSORG 48	51.2	107.4 a	151.6 a	4.9	7.8	12.0	8.0	12.7	21
SAMSORG 44/ TME 419	49.1	98.9 a	149.9 a	5.0	8.2	12.0	7.8	13.3	25
SAMSORG 47/ TME 419	49.9	84.2 b	125.2 b	5.0	7.7	10.8	8.4	9.0	20
SAMSORG 48/ TME 419	49.4	106.2 a	150.8 a	5.0	7.8	11.8	8.2	12.2	22
SED ± (10 df)	1.4	2.5	3.5	0.1	0.1	0.2	0.6	0.7	0.
<u>Interaction</u>									
MXC	ns	**	**	ns	ns	ns			

In a column, means followed by similar letters are not significant different at 5% level of probability using Duncan's Multiple Range Test (DMRT). WAS = Weeks after sowing. ns = not significant ($p > 0.05$). * = Significant at 5 % level of probability ($p = 0.05$). ** = Significant at 1% ($p = 0.01$) level of probability.



Table 5: Effects of poultry manure and cropping system on yield and yield components of sorghum varieties intercropped with cassava in 2023

Treatments	Panicle length (cm)	Panicle diameter (cm)	Panicle weight (g plant ⁻¹)	Seed weight/plot (g plant ⁻¹)	Threshing percentage (%)	Seed yield (kg. ha ⁻¹)
<u>Manure rate (t. ha⁻¹) (M)</u>						
0	32.8a	6.6a	47.8 b	41.8 b	87.1 b	2228.1 b
2.5	37.1a	6.8a	48.4 b	44.3 b	91.7 a	2368.0 b
5.0	35.0a	6.2a	55.8 a	51.5 a	92.6 a	2748.4 a
SED ± (4 df)	1.4	0.2	0.9	1.0	0.6	52.9
<u>Cropping System (C)</u>						
Sole SAMSORG 44	26.7 c	5.8a	53.0 a	48.3 a	91.2	2584.9 a
Sole SAMSORG 47	45.2 a	6.4a	51.3 a	46.7 a	90.7	2485.3 ab
Sole SAMSORG 48	32.8 b	6.5a	47.3 b	42.7 b	90.3	2270.2 b
SAMSORG 44/ TME 419	26.3 c	5.8a	53.0 a	47.9 a	90.2	2583.4 a
SAMSORG 47/ TME 419	44.9 a	6.1a	51.0 a	46.6 a	90.6	2479.0 ab
SAMSORG 48/ TME 419	32.7 c	6.2a	46.3 b	42.3 b	90.4	2268.5 b
SED ± (10 df)	1.1	0.1	0.6	2.5	0.5	118.3
<u>Interaction</u>						
MXC	**	**	**	**	**	**

*In a column, means followed by similar letter are not significantly different at 5% level of probability using Duncan's. ** = Significant at 1% level of probability.



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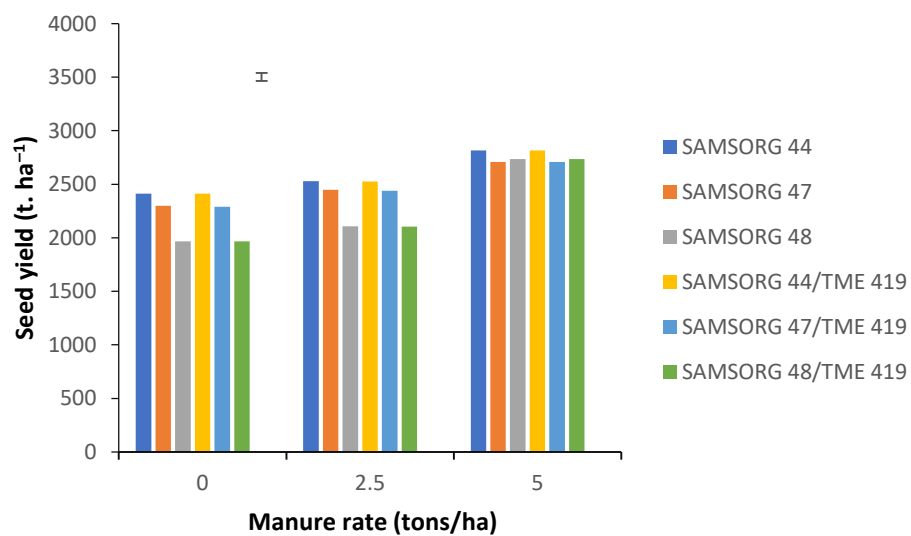


Figure 1: Interaction of manure rate and cropping system on seed yield of Sorghum in 2023



Table 6: Land-equivalent ratio (LER), area time equivalent ratio (ATER), and monetary advantage index (MAI) of cassava-sorghum intercropping in 2023

Cropping system	Cassava TY (kg. ha ⁻¹)	Sorghum SY (kg. ha ⁻¹)	LER	ATER	MAI (₦ 1,000)
Sole TME 419	13156	-	1.00 b	-	-
Sole SAMSORG 44	-	2584.9	1.00 b	-	-
Sole SAMSORG 47	-	2485.3	1.00 b	-	-
Sole SAMSORG 48	-	2270.2	1.00 b	-	-
SAMSORG 44/ TME 419	12836.7	2583.4	1.97 a	1.01	256.04
SAMSORG 47/ TME 419	12744.8	2479.0	1.96 a	1.02	254.69
SAMSORG 48/ TME 419	12684.2	2244.8	1.96 a	1.02	254.09
SED± (12 df)	0.2	0.3	0.2	0.1	1.2
F test	ns	ns	ns	ns	ns

Average procurement price (per t): cassava, ₦ 200,000; sorghum, ₦ 200,000; TY = Tuber Yield; SY = Seed Yield; (-) = not applicable; n.s.= not significant (P < 0.05); ** = significant at 1 % level of probability.

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Effects of Different Organic Mulches on the Growth and Yield of Okra (*Abelmoschus Esculentus L.*) in Port Harcourt, Rivers State, Nigeria

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Abstract

This study was conducted at the Faculty of Agriculture Teaching and Research Farm, University of Port Harcourt, Rivers State, Nigeria. The work evaluated the impact of different organic mulches (palm fibre, dry grass, and wood shavings) on the growth and yield of okra. A Randomised Complete Block Design (RCBD) was employed to compare the effects of these mulches. Results indicated that wood shavings significantly enhanced plant growth, resulting in the tallest plants (19.25 cm), largest leaf area (941.24 cm²), and highest biological weight (91.50 g) compared to other treatments. While palm fibre and dry grass positively influenced plant growth, their effects were less pronounced. Data analysis revealed a non-significant difference in pod weight, with wood shavings yielding 18.19 g, compared to dry grass (13.97 g), palm fibre (21.85 g), and the control (14.44 g). Similarly, there was no significant difference in pod girth, with wood shavings recording 5.69 cm, while dry grass had 6.48 cm, palm fibre had 6.14 cm, and the control had 5.84 cm. The most significant finding was the biological weight, with wood shavings demonstrating a significantly higher value of 91.50 g. Based on these findings, it is recommended that farmers use wood shavings as a mulching material to optimise okra growth and biomass. Further research is needed to explore the long-term impacts of wood shavings and other mulches on soil health and crop productivity.

Keywords: Growth, Okra, Organic Mulches, Yield

Introduction

Okra (*Abelmoschus esculentus L.*), ladies' finger, is a warm-season vegetable native to tropical Africa and Asia. This flowering plant within the Malvaceae family is cultivated globally for its edible green pods (Akpambane *et al.*, 2012). These immature pods are a valuable source of vitamins, minerals, and dietary fibre, making them a popular ingredient in various cuisines worldwide (Singh *et al.*, 2014). Okra cultivation plays a significant role in ensuring food security and income generation, particularly in developing countries. It thrives in warm climates with moderate rainfall and is well-suited for small-scale farming systems due to its short growing season and relatively low input requirements (Okigbo, 2014). Global okra production has been steadily increasing, with estimates reaching over 2 million metric tons in 2020 (FAOSTAT, 2022).

Despite its growing importance, okra production faces several challenges that limit yield potential. One of the major concerns is erratic rainfall and drought stress. Okra thrives in well-drained soil with consistent moisture availability. However, changing weather patterns and unpredictable rainfall can lead to periods of drought stress, impacting plant growth and pod development (Singh *et al.*, 2014). Continuous cultivation without proper nutrient



replenishment can deplete essential soil nutrients necessary for optimal okra growth and yield (Ekanayake *et al.*, 2014). Furthermore, weeds pose a significant threat by competing for vital resources like water, light, and nutrients. This competition can significantly reduce okra yield, especially with limited weed control practices (Olabode *et al.*, 2007). Finally, okra is susceptible to various fungal diseases like *Fusarium* wilt and damping-off, insect pests such as aphids, thrips, and fruit borers. These factors can cause substantial yield losses if left unchecked (Ateka *et al.*, 2012).

Organic mulch offers a promising and sustainable approach to address some of the challenges okra producers face. Here is a breakdown of its potential benefits: First, Mulch acts as a physical barrier that reduces surface evaporation (the loss of water from the soil surface to the atmosphere) and helps retain soil moisture in the root zone. This is particularly beneficial during dry periods and can enhance water use efficiency for okra plants (Adekiji, 2014). Second, as organic mulch decomposes over time, it releases essential nutrients into the soil. This gradual release provides a natural source of plant nutrients for okra growth and improves soil fertility over time (Ekanayake *et al.*, 2014). Third, a well-applied layer of mulch creates a physical barrier that hinders weed seed germination and growth. This reduces weed competition for vital resources like water, light, and nutrients, minimising the need for manual weeding or harsh chemical herbicides (Olabode *et al.*, 2007). Finally, organic mulch promotes the activity of beneficial soil microbes that contribute to organic matter decomposition and nutrient cycling. This improves soil health and overall ecosystem function within the cropping system (Adekiji, 2014).

While the potential benefits of organic mulch for crop production are widely recognised, research specifically investigating its impact on okra yield is somewhat limited. Most existing studies focus on the effects of mulch on other vegetable crops or explore the combined effects of mulch with other agronomic practices on okra production. More focused research is needed to understand the specific impact of organic mulch application on okra yield. By investigating this relationship, this study aims to address this knowledge gap and provide valuable insights for okra producers seeking sustainable and practical strategies to optimise their crop yields.

Materials and Methods

Experimental Site

The experiment was conducted at the Faculty of Agriculture Teaching and Research Farm, University of Port Harcourt, Rivers State. The experimental site is located between latitude 4° 31'N and 5° 00'N and longitude 6° 45' E and 7° 00'E, with an average temperature of 27°C, relative humidity of 78% and average rainfall that ranges from 2500 - 4000mm (Nwankwo & Ehirim, 2010). The meteorological data on relative humidity, hours of sunshine, wind speed, temperature and evaporation were recorded at Abuja Campus, University of Port Harcourt.

Soil Characteristics

Composite soil samples were collected randomly from selected sites in the experimental field at a uniform depth of 0-15cm using a soil auger. The soil samples collected on the experimental site were bulked, allowed to air-dry, and then sieved through a 2mm sieve and



analysed. The following parameters, Organic matter, Organic Carbon, Nitrogen, phosphorus, potassium, Soil texture, and Soil pH, were analysed.

Experimental Design

A Randomised Complete Block Design (RCBD) with replicates was employed to evaluate the effects of different organic mulches on okra yield and growth. This design helps control for variations within the field and ensures statistical validity of the results. The experimental area (15m x 15m) was manually cleared cutlasses and hoes, and the layout was marked using pegs, twines and tape. The bed size was 3m x 3m and sixteen (16) beds were prepared. Four mulch treatments were compared: Dry Grasses, Palm Fibre, Sawdust, and No Organic Mulch (Control). Each mulch treatment was randomly assigned to a designated plot within the experimental area.

Planting Procedure

The variety of okra seed used for the experiment was Angelina, which was obtained from the Agricultural Development Program (ADP), Rumuodomaya, Port Harcourt, Rivers State. The planting distance used was 50cm x 50cm. The seed rate planted was four seeds per hole in 6 rows per bed, with 30 holes per bed. Thinning was done to two plants per hole, resulting in a final stand of 60 plants per bed. The mulch materials were applied using the ring method, ensuring adequate coverage around the base of the plants. Maintenance operations, such as weeding, was carried out manually with the use of a hoe at different times of the experiment.

Data Collection

Results on physico-chemical properties of the soil were collected. Growth parameters (plant height, leaf area, number of leaves, girth) were collected by random selection and tagging of six plants from each treatment plot from the net plot. They were tagged by placing labelled pegs beside them to facilitate the identification. The yield parameters taken were the number of plants per plot, biological weight, the number of okra pods per plant, and fresh pod weight per plant. The results were analysed using GenStat statistical software, version 8.0.

Results

Physico-Chemical Properties of the Soil at the Experimental Site before Planting

Table 1 shows the chemical and physical properties of the soil at the experimental site just before planting. The result shows that Nitrogen (N) and Phosphorus (P) levels are below the critical level. This might be due to leaching that occurs because of high rainfall, which is a general characteristic of sandy loam soils. Continuous cropping and crop removal could also account for the low availability of nutrients.

Table 1: Physico-Chemical Properties of the Soil at Experimental Site before Planting.

Soil Properties	Values	Critical level	Sources of critical level
Nitrogen (%)	0.57	1.50	Adepetu <i>et al.</i> (1986)
P(mg/kg)	3.0	10.15	Adepetu <i>et al.</i> (1986)
K(cmol/kg)	6.5	0.24	Agboola & Ayodele (1987)
Organic Carbon (%)	1.4	1.90	
Organic Matter (%)	2.72	3.8	
pH	7.0		
Sand	70.4		



Silt	9.4
Clay	20.2
Soil Texture	Sandy Loam

Effects of Different Organic Mulches on Growth Parameters

Plant Height

Table 2 presents the effects of different organic mulches on the plant height of okra over eight weeks after planting (WAP). At 3 WAP, dry grass mulch resulted in the highest plant height (9.85 cm), followed by palm fibre (9.22 cm), wood shavings (9.19 cm), and the control (8.59 cm). A similar trend was observed at 4 WAP, with dry grass (10.63 cm) maintaining the tallest plants. However, by 5 WAP, the control treatment (10.91 cm) slightly surpassed the mulched treatments, although dry grass (11.25 cm) remained competitive.

From 6 WAP onwards, dry grass and wood shavings consistently increased plant heights compared to palm fibre and the control. By 8 WAP, wood shavings produced the tallest plants (19.25 cm), closely followed by dry grass (19.19 cm), while palm fibre (17.78 cm) recorded the shortest plants throughout the study (Table 2). No statistically significant differences were observed among treatments across all weeks.

Table 2: Effects of Organic Mulches on Plant Height of Okra

Source of Variation	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Treatment						
Palm Fibre	9.22±1.10	9.92±1.09	10.70±1.17	13.19±1.82	16.81±1.77	17.78±1.80
Dry Grass	9.85±1.72	10.63±1.47	11.25±1.17	15.03±0.83	18.19±0.85	19.19±0.85
Wood Shavings	9.19±1.14	10.03±1.59	10.88±1.30	14.81±0.75	18.25±1.77	19.25±1.77
Control	8.59±0.95	9.66±0.83	10.91±1.28	13.50±1.54	17.50±1.17	18.44±1.14
LSD	NS	NS	NS	NS	NS	NS

WAP = Weeks after planting; NS = Not Significant; LSD = Fisher's Least Significant Difference

Plant Girth

Table 3 outlines the effects of different organic mulches on the plant girth of okra from 3 to 8 weeks after planting (WAP). At 3 WAP, palm fibre and wood shavings both resulted in the most considerable plant girth (2.68 cm), followed closely by the control (2.60 cm) and dry grass (2.50 cm). By 4 WAP, palm fibre maintained the widest girth (2.86 cm), while the other treatments showed slightly lower values. From 5 to 7 WAP, the girth measurements across all treatments were relatively similar, with wood shavings and palm fibre consistently producing larger plant girths than dry grass and the control.



By 8 WAP, wood shavings had the highest recorded plant girth (4.30 cm), followed by the control (4.25 cm), dry grass (4.16 cm), and palm fibre (4.14 cm). Despite these differences, no significant variations in plant girth were observed between treatments at any point in the study, as indicated by the non-significant LSD values (Table 3). This suggests that the mulching treatments did not lead to statistically meaningful differences in plant girth throughout the growth period.

Table 3: Effects of Organic Mulches on Plant Girth of Okra

Source of Variation	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Treatment						
Palm Fibre	2.68±0.33	2.86±0.94	3.30±0.86	3.64±0.42	3.67±0.27	4.14±0.10
Dry Grass	2.50±0.21	2.66±0.37	3.25±0.57	3.46±0.17	3.58±0.20	4.16±0.40
Wood Shavings	2.68±0.22	2.73±0.41	3.24±0.69	3.49±0.09	3.72±0.25	4.30±0.25
Control	2.60±0.16	2.63±0.47	2.99±0.38	3.45±0.27	3.66±0.11	4.25±0.23
LSD	NS	NS	NS	NS	NS	NS

WAP = Weeks after planting; NS = Not Significant; LSD = Fisher's Least Significant Difference

Plant Leaf Area

Table 4 details the effects of different organic mulches on the leaf area of okra plants from 3 to 8 weeks after planting (WAP). At 3 WAP, palm fibre mulch resulted in the largest leaf area (189.58 cm²), followed by wood shavings (149.57 cm²), dry grass (124.03 cm²), and the control (113.84 cm²), and by 4 WAP, palm fibre (220.89 cm²) and wood shavings (213.26 cm²) maintained larger leaf areas than the other treatments. From 5 to 6 WAP, wood shavings mulch showed a noticeable increase in leaf area, reaching 509.06 cm² by 6 WAP, the largest among all treatments. By 7 WAP, wood shavings (714.76 cm²) continued to show superior leaf area development, followed by the control (576.10 cm²), palm fibre (532.00 cm²), and dry grass (510.22 cm²). At 8 WAP, wood shavings maintained the largest leaf area (941.24 cm²), while the control (767.34 cm²), palm fibre (754.38 cm²), and dry grass (687.89 cm²) lagged (Table 4).

Despite these variations, no statistically significant differences were detected among treatments throughout the study, as indicated by the non-significant (NS) LSD values, suggesting that the differences in leaf area between treatments were insignificant at any stage.



Table 4: Effects of Organic Mulches on Plant Leaf Area of Okra

Source of Variation	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Treatment						
Palm Fibre	189.58±111.56	220.89±64.40	281.65±81.09	353.29±44.67	532.00±66.13	754.38±50.96
Dry Grass	124.03±47.40	198.18±68.37	267.75±66.98	413.48±70.78	510.22±48.66	687.89±64.14
WS	149.57±54.78	213.26±42.76	305.81±89.24	509.06±111.17	714.76±171.89	941.24±209.8
Control	113.84±57.78	154.98±53.66	285.2±169.78	466.01±149.93	576.10±52.86	767.34±59.65
LSD	NS	NS	NS	NS	NS	NS

WS = Wood shavings; WAP = Weeks after planting; NS = Not Significant; LSD = Fisher's Least Significant Difference

Effects of Different Organic Mulches on Yield Parameters: Table 5 summarises the effects of different organic mulches on key yield components of okra, including pod length, pod girth, pod weight, and biological weight. Palm fibre mulch produced the longest pods (5.15 cm) and the second-largest pod girth (6.14 cm), with an average pod weight of 21.85 g. However, its biological weight (40.75 g) was moderate, comparable to other treatments except for wood shavings. Dry grass mulch resulted in shorter pods (4.41 cm) but had the most considerable pod girth (6.48 cm). Despite this, it showed the lowest pod weight (13.97 g) and biological weight (25.00 g). Wood shavings, although producing shorter pods (4.33 cm) and smaller pod girth (5.69 cm), yielded higher pod weights (18.19 g) and had the most significant biological weight (91.50 g), significantly outperforming other treatments in this component. The control treatment produced pods with an average length of 4.44 cm, a pod girth of 5.84 cm, and a pod weight of 14.44 g, while its biological weight (31.75 g) was like that of palm fibre and dry grass. No significant differences were found across the treatments for pod length, pod girth, or pod weight, as indicated by the non-significant LSD values. However, wood shavings demonstrated a significantly higher biological weight than other treatments, as reflected by the significant LSD value for this variable (Table 5).

Table 5: Effects of Organic Mulches on Yield Components of Okra

Treatment	Pod Length (cm)	Pod Girth (cm)	Pod Weight (g)	Biological Weight (g)
Palm Fibre	5.15±0.38	6.14±0.40	21.85±6.88	40.75±8.06 ^b
Dry Grass	4.41±0.67	6.48±0.74	13.97±5.22	25.00±18.35 ^b
Wood Shavings	4.33±0.14	5.69±0.31	18.19±6.19	91.50±36.63 ^a
Control	4.44±0.51	5.84±0.55	14.44±9.08	31.75±6.85 ^b
LSD	NS	NS	NS	32.60

NS = Not Significant; LSD = Fisher's Least Significant Difference



Discussion

This study evaluated the effects of different organic mulches on the growth and yield of okra, and the results emphasised the importance of mulching in crop production. The non-significant differences in plant height across treatments (palm fibre, dry grass, wood shavings, and control) suggest that all mulches created favourable conditions for okra growth by maintaining soil moisture and moderate temperature. Mulching is known to modify the microclimate around the root zone, which influences plant growth by reducing soil evaporation and improving water availability (Kader *et al.*, 2017). The control treatment performed similarly to the mulched treatments in terms of plant height, likely due to favourable initial soil conditions and the study's relatively short duration of the study, during which the absence of mulch may not have significantly stressed the plants. These findings are consistent with those of Dalorima *et al.* (2014), who also reported no significant differences in plant height between mulched and non-mulched okra. However, in this study, dry grass produced taller plants in the earlier weeks. At the same time, wood shavings surpassed it in the final weeks, indicating the gradual effectiveness of wood shavings over time.

The initial superiority of dry grass in promoting plant height can be attributed to its quicker decomposition and early release of nutrients due to its lower carbon-to-nitrogen ratio, as Olabode *et al.* (2007) noted. In contrast, wood shavings decompose more slowly, resulting in a delayed but sustained benefit to plant growth, which became evident in the later stages of the experiment. This explains the shift in plant height dominance from dry grass to wood shavings. Plant heights observed in this study (ranging from 17.78 cm to 19.25 cm) were lower than those reported by Thakur *et al.* (2020) (23.08 cm to 49.67 cm) for rice straw, sawdust, and plastic mulches but were higher than the values recorded by Puri *et al.* (2022) (9.42 cm to 13.32 cm). Similarly, no significant differences were observed in plant girth across treatments, possibly due to the uniform ability of all mulches to suppress weeds, improve soil structure, and reduce nutrient competition (Ramakrishna *et al.*, 2006). The comparable performance of the control treatment suggests that favourable weather conditions, including regular rainfall and moderate temperatures in the region, may have minimised the advantages typically associated with mulching. This contrasts with the findings of Olabode *et al.* (2007), who reported significant differences in stem diameter of okra due to mulch, with grass mulch performing best. However, the stem girths recorded in this study (4.14 cm to 4.30 cm) were much larger than those reported by Olabode *et al.* (2007) (0.42 cm to 1.58 cm).

While no significant differences were observed in plant height and girth, wood shavings showed a notable increase in leaf area during the later stages of growth, indicating their greater impact on water retention and nutrient availability. This increase in leaf area may have enhanced photosynthetic activity and overall plant vigour. The differences in leaf area between treatments, particularly the superior performance of wood shavings, can be attributed to the slower decomposition and sustained nutrient release from wood shavings (Ene *et al.*, 2018), which supported prolonged vegetative growth. In contrast, faster-decomposing materials like palm fibre may have provided an insufficient nutrient boost to sustain long-term growth, as reflected in their lower leaf area values. Yield components further highlighted the role of mulch in improving crop productivity, particularly biological weight. The significantly higher biological weight under wood shavings compared to the



other mulches suggests that slowly decomposing organic mulches can improve soil fertility and water retention, leading to enhanced growth and yield (Demo & Asefa, 2024; Ranjan *et al.*, 2017). The lack of significant differences in pod length, pod girth, and pod weight across treatments indicates that mulching primarily influences overall plant biomass rather than individual pod characteristics. However, the higher biological weight observed with wood shavings underscores its potential to boost okra productivity by enhancing soil health and moisture availability.

Conclusion

Based on the study, using organic mulches, particularly wood shavings, positively affected okra growth and yield. Wood shavings demonstrated the most substantial improvement in plant height, girth, leaf area, and number of fruits, which likely contributed to the significantly higher biological weight. However, no significant differences were observed in pod length, girth, or weight across the treatments. This suggests that while mulching can enhance overall plant biomass, it may not directly influence individual pod characteristics. Based on these findings, it is recommended that, for yield improvement, farmers cultivating okra in similar agro-ecological conditions should use wood shavings as mulch. This is due to its effectiveness in increasing plant biomass, leading to higher overall yields.

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Evaluation of the Potential of Some Pesticidal Plants in the Management of the Maize Army Worm (*Spodoptera frugiperda*) in Umudike, Southeastern Nigeria

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Abstract

This study investigated the effects of two pesticide plants (*Hunteria unbellata* commonly known as osu in Igbo land and negro pepper (*Xylopia aethiopica*) in the management of fall armyworm of maize (*Spodoptera frugiperda*). The study was conducted at the Michael Okpara University of Agriculture, Umudike, Abia State Nigeria in 2023. The treatments used include sole maize (control), maize + negro pepper, maize + osu, maize + osu + negro pepper, and maize + caterpillar force. A randomized complete block design was used in the study, with five (5) treatments replicated three (3) times. 15 experimental plots, each measuring 3 m x 3 m, were marked out for the experiment. Three seeds of the maize variety bende white were directly sown on the seed bed using a planting distance of 75 cm x 30 cm and was later thinned after seed germination resulting in 40 stands per plot. Data were collected on insect count, number of damaged leaves, number of damaged cobs, cob weight, and yield. Results obtained indicated that sole maize consistently recorded the highest mean number of insect count (33.0) and number of damaged leaves (65.3), while the treated plots significantly reduced insect infestation and leaf damage ($p < 0.05$). Growth performance varied across treatments. The plot treated with chemical pesticide recorded the lowest number of insect count (8.08) followed by Maize + osu + negro pepper (8.57). The combination of maize + osu + negro also recorded the lowest number of damaged cobs (1.33) and the highest cob weight (3.26 kg/plot) and yield (3.62 t/ha) while the control recorded the lowest. In conclusion, the combination of maize + osu + negro and the individual treatments proved to be an effective treatment, reducing pest damage and enhancing maize growth and yield. It is recommended for farmers as an integrated pest management strategy to improve maize production sustainably

Keywords: Armyworm, Caterpillar force, *Hunteria unbellata*, Negro pepper, Plant extracts

Introduction

Maize (*Zea mays* L.) is an annual crop belonging to the grass family, Poaceae. The family Poaceae consists of many important cereal crops cultivated and consumed worldwide (Gul *et al.*, 2021). After wheat and rice, maize is the third most important food crop globally (Tajamul *et al.*, 2016). In sub-Saharan Africa, tropical maize has traditionally been the main staple of the diet; 95 % of the maize grown is consumed directly as human food and as an



important source of income for the resource-poor rural population (Khaliq *et al.*, 2004). In 2017, the Institute of Tropical Agriculture (IITA) valued Nigeria's maize industry to be at \$6bn, which is about ₦2.5 trillion (Karki *et al.*, 2020). The global production of maize is highly affected by weeds, diseases, nematodes, insect pests, birds and environmental factors (Karavina *et al.*, 2014). They reduce maize yield up to 75% (Kumar, 2002). One of the most important pests of maize in Nigeria is the Fall Armyworm - *Spodoptera frugiperda* (Lepidoptera, Noctuidae) which is a serious pest of maize globally. (Dalvie *et al.*, 2011). It feed on leaves and stems of more than 80 plant species. Traditionally, most farmers rely on the use of synthetic pesticide in the control of this pest and this have a lot of negative effects on human health and the environment hence the need for a sustainable and environmentally friendly means to control this pest. In recent years, there has been an increasing concern in exploring alternative pest control methods such as pesticidal plants that are environmentally friendly and sustainable hence these plants present a potential solution to the problems associated with synthetic pesticides which has a lot of adverse effect both on the environment, humans' health and beneficial organisms. Despite the potentials of pesticidal plants, many species remain unexplored for their efficacy against agricultural pests. One such plant is *H. umbellata*, a species that has not been previously studied for its pesticidal properties in the management of agricultural pest and yet has been reported to have a lot of pesticidal potentials. *H. umbellata* commonly known as "Abere" in some West African countries and osu in Igbo land, is a bitter-tasting medicinal plant belonging to the family Apocynaceae. Adeneye *et al.* (2010) have reported that secondary metabolites such as saponin, glycosides, steroids, tannins, phenols and copious amounts of alkaloids are present in the seeds of *H. umbellata*. Therefore, the purpose of this research is to investigate the insecticidal potentials of *H. umbellata* and *Xylopiya aethiopica* (negro pepper) in the control of the maize armyworm a serious pest of maize in Nigeria.

Materials and Methods

Experimental Site Description

The study was conducted at the Michael Okpara University OF Agriculture, Umudike, Abia State in 2023. Umudike is located between latitude 5.4801° N and longitude 7.5437° E. The climatic conditions in Umudike include average annual temperatures ranging from 22.5°C to 36.2°C, a seasonal rainfall pattern with an average annual precipitation of 2153mm, high humidity levels, and a specific photoperiod influenced by its geographical location. The rainy season is known as the August break. Relative humidity varies between 75 and 90 %.

Agronomic Activities

The experimental field was measured using meter tape. The area was manually cleared, and the plot marked out with each plot size measuring 3m x 3m. Then it was manually harrowed and ploughed using hoe. On the raised beds, planting was done using a local maize variety at 75 cm x 30 cm with direct seeding. Three seeds were directly sown into the soil at a depth of 3 cm. This gave a total of 40 stands per plot and 10 plants per treatment were selected and tagged for data collection. Weeds were manually maintained.



Experimental Design

Randomized Complete Block Design was used in the study, with five (5) treatments which consisted of Sole maize (Control), Maize + *H. unbellata*, Maize + Negro pepper + *H. unbellata*, Maize + Chemical pesticide, Maize + Negro pepper, all replicated three (3) times and this gave 15 experimental plots.

Extract Preparation

The extracts were prepared according to (Nzanza and Mashela 2012). Matured and healthy Negro pepper (*X. aethopica*) and Osu (*H. unbellata*) seeds were obtained from a local environment. The seeds were dried, ground using a blender, sieved and stored in an airtight container and kept ready for use for the experiment. Three weeks after maize germination, 5kg of each plant powder was measured using the Camry™ weighing scale in the laboratory unto which 2 litres of distilled water was added and then stirred and this was kept for 3 days before application and thereafter, filtered through a 1.0 mm sieve into a plastic rubber and approximately 8g detergent was added as a sticking agent and was later transferred into a knapsack sprayer for immediate spraying in the maize field. Spraying was done early in the morning directly into the maize funnel and base.

Data Collection

The following data were collected: Insect count, Leaf damage, Cob number, Cob damage and crop Yield at harvest: Data collected were analyzed using Statistical Package for the social sciences (SPSS) version 23 and means were separated using least significant difference (LSD) at 5 % probability level.

Results

Table1: Effect of plant extracts and synthetic chemicals on insect count on maize plants

Treatments	Insect count				
	4 Weeks	6 Weeks	8 Weeks	10 Weeks	MEAN
Maize + Caterpillar force	17.33	12.67	1.33	1.00	8.08
Maize + negro	20.67	17.00	1.67	1.67	10.25
Maize + osu	19.00	14.33	2.00	1.33	9.17
Maize + osu+ negro pepper	18.33	13.00	1.67	1.33	8.58
Control	34.67	35.67	36.67	25.00	33.00
MEAN	22.00	18.53	8.67	6.07	
LSD (0.05)	5.48	5.34	1.69	1.15	



Results from Table 1 revealed that sole maize consistently recorded the highest mean number of insect count across all the weeks (33.0). Maize + caterpillar force significantly reduced insect count on the maize plant followed by maize+*H. unbellata*. All the treated plots recorded the lowest mean number of insects counts (10.25, 9.17 and 8.58) and these were significantly different ($p<0.05$) from the control plot and compared very effectively with the synthetic chemical which gave a mean population of (8.08).

Table 2: Effect of plant extracts and synthetic chemicals on number of cobs and damaged cobs

Treatment	Number of cobs	Number of damaged cobs
Maize + caterpillar force	41.00	3.00
Maize + negro	42.33	2.67
Maize + osu	42.67	3.00
Maize + osu+ negro	40.33	1.33
Control	16.67	14.33
MEAN	36.60	4.87
LSD (0.05)	4.77	3.15

Table 2 revealed the effects of treatment on the number of cobs and damaged cobs. The lowest cob number was recorded within the control plots (16.67) and this was significantly different ($P<0.05$) from the treated plots which recorded (41.00, 42.33, 42.67 and 40.33) respectively. However, no significant difference was recorded between the plant extracts and the synthetic chemicals. The following trend was observed in the number of damaged cobs. The control recorded the highest number of damaged cobs (14.33) while the treated plots recorded the least number of damaged cobs (3.00, 2.67, 3.00 and 14.33)



**Table 3: Effect of plant extracts and synthetic chemicals on cob weight and cob yield
(t/ha) of maize**

Treatment	Cob weight per plot (kg)	Yield per hectare (t/ha)
Maize + caterpillar force	2.76	3.07
Maize + negro	3.03	3.37
Maize + osu	2.67	2.96
Maize + osu+ negro	3.26	3.62
Control	1.60	1.78
MEAN	2.66	2.96
LSD (0.05)	0.6032	0.53

Table 3 presents the effect of different treatments on the cob weight per plot and yield per ton per hectare of maize plants. The highest cob weight was recorded from the plot treated with *H. unbellata*+negro pepper (3.62t/ha), followed by the plot treated with only negro pepper (3.37t/ha). Then followed by the plot treated with chemical pesticide(3.07t/ha) and finally followed by the plot treated with *H. unbellata*, while sole maize recorded the lowest (1.78 t/ha).

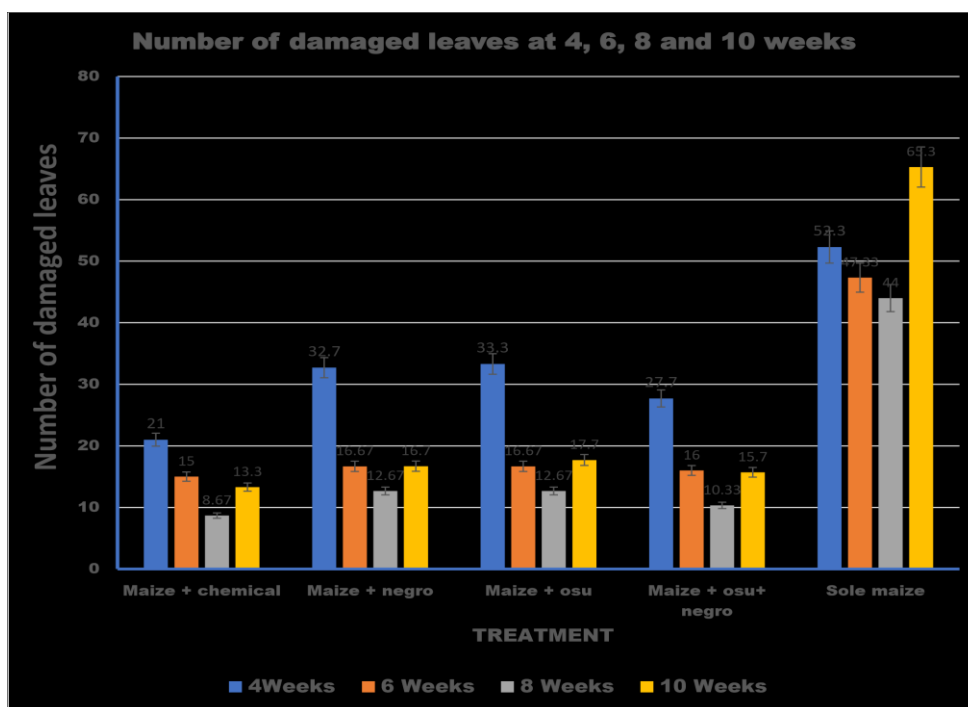


Figure 1: Effect of plant extracts and synthetic chemical on the number of damaged leaves

Figure 1: revealed the effects of treatments on the number of damaged leaves on maize plant. Sole maize recorded the highest number of damaged leaves at 10th week (65.30) significantly different from all the treated plots. This was followed by maize + osu (17.70), while maize + synthetic chemical had the lowest number of damaged leaves (13.33) all at 10 WAP. At 8WAP, synthetic chemical gave the best control (8.67). All the treated plots showed significantly lower damage across all the weeks when compared with the synthetic chemical.

Discussion

This study revealed the impact of fall armyworm infestation on maize and the effects of treatments with negro pepper and *H. unbellata* seed extracts on the armyworm. Higher infestation levels of the fall armyworm were consistently recorded on the untreated plots while the treated plots recorded lower infestation and greater yield. The study revealed the efficacy of these pesticidal plants in protecting the maize plant from armyworm. This result aligns with the study of Butu *et al.*, (2020) who also reported on the effectiveness of bio-pesticide in reducing the incidence of insect pests. The significant differences in insect counts across treatments highlight the effectiveness of these extracts in controlling the insect populations. The treated plots resulted in fewer damaged leaves reflecting their potential to mitigate damage through either resistance or reduced insect activity. The two extracts combined (*H. unbellata* + negro pepper) also proved very effective in reducing the armyworm infestation. This was in line with Biebel *et al.* (2003) who in their study found a similar result when combining two plant extracts (Tobacco and ginger). The active compounds contained in the different plant materials when combined with each other act



synergistically to enhance the toxic substance in the extract mixtures either by increasing or prolonging their effects. Momanyi *et al.* (2002) also reported on the effectiveness of the plant extracts' phytochemical composition in increased rice yield in rice while reducing pest attack. The substantial differences in yield indicate that effective pest control increased agricultural productivity according to Shen and Lu (2003). A comparison of maize yield treated with these botanicals showed that they were effective as cypermethrin. Therefore, an excellent alternative to synthetic pesticides in the management of the maize army worm and therefore are recommended as an alternative to synthetic pesticide management of maize army worm.

Conclusion

The results obtained from the study revealed that the plant extracts and their combinations tested against the maize fall army worm (*S. frugiperda*) showed insecticidal activity. The study showed that the number and weight of cobs were higher in treated plots than in the control plots. Significant difference was recorded in the level of damages caused by this pest between the treated and the untreated plots. Sole maize consistently underperformed across all metrics, underscoring the importance of treatment interventions. Some preliminary studies revealed that *H. unbellata* possess certain phytochemicals such as alkaloids, tannins etc which are known for their pesticidal potential and this could justify further investigation on this plant as a potential alternative to synthetic pesticide in the management of agricultural pests. Hence further research is needed to understand the extent of *H. unbellata*'s insecticidal properties, to explore its potential application in the management of pests of crops, and also to understand its mechanism of action fully and to explore its effectiveness in controlling specific insect pests in different settings. A comparison of maize yield treated with these botanical showed that they were effective as the synthetic chemical and therefore an excellent alternative to synthetic pesticide in the management of the maize armyworm and are recommended as an alternative to synthetic pesticide in managing this pest.

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Socioeconomic Determinants of Climate Change Adaptation Strategies Used in Vegetable (*Telfairia occidentalis*) Production in Oyigbo LGA, Rivers State, Nigeria

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(Sub theme 1: Climate smart agriculture for food security and nutrition)

Abstract

This study examined the socioeconomic determinants influencing climate change adaptation strategies among vegetable farmers in Oyigbo LGA, Rivers State, Nigeria. Data was collected through a structured questionnaire and interview schedule. Descriptive statistics and logit regression model were employed to assess the relationship between these determinants and the likelihood of adopting various adaptation strategies. The results indicate that the vegetable farmers had a mean age of 34.8 years, an average household size of seven persons, an average of 9.75 years of experience in vegetable farming, and a mean income of ₦14,625.00. Climate change adaptation strategies adopted by vegetable farmers include mixed cropping/multi-cropping (84.3%), early planting (81.4%), and early harvesting (68.60%). Logit regression results shows that farm experience (coefficient = 0.1097, $p < 0.01$), farm size (coefficient = 0.6929, $p < 0.01$), gender (coefficient = 0.1247, $p < 0.01$), income (coefficient = -6.13E-7, $p < 0.01$), and age (coefficient = 0.1063, $p < 0.10$) are critical socioeconomic factors affecting climate adaptation. The key challenges faced by the vegetable farmers include high cost of farm inputs (88.70%), lack of government support (84.50%), poor extension services (84.50%), and land and labour constraints (81.70%). The study recommends that the government should support extension agencies in implementing programmes aimed at educating and training farmers to enhance their awareness and comprehension of climate adaptation strategies.

Keywords: Adaptation strategies, production, sustainable agriculture, vegetation

Introduction

Climate change is a global concern and one of the most pressing challenges confronting both international and local communities. In the twenty-first century, the effects of global warming have become more pronounced than at any time in the past six decades (Abbas *et al.*, 2022). Its negative impacts pose a serious threat to development efforts across multiple sectors of society, particularly agriculture (Wood *et al.*, 2014).

Broadly defined, climate change refers to long-term shifts in average weather patterns that shape local, regional, and global conditions of the Earth. It stands out as a contemporary



global threat with profound and well-documented effects on agricultural production (Ajayi & Ajayi, 2014). As a complex intergovernmental challenge, climate change cuts across ecological, environmental, sociopolitical, and socioeconomic dimensions (Feliciano *et al.*, 2022). The United Nations Development Programme (UNDP, 2019) highlights its consequences, which include wildfires, droughts, floods, hurricanes, sea-level rise, ocean acidification, and permafrost melting. These hazards are accompanied by temperature fluctuations, irregular rainfall, and increased incidences of pests and diseases. Consequently, climate change undermines food security, health, livelihoods, and the natural environment. With declining natural resources, including food, its adverse effects ripple through economies, ecosystems, and human well-being. Smallholder farming systems are particularly vulnerable, despite their crucial role in providing food security for millions of people. Farmers already contend with declining productivity due to climate variability (Cohn & Bender, 2017; Jiri & Mafongoya, 2017). Agriculture, central to human survival, provides food, raw materials, shelter, fibre, and other essential products. Because agricultural productivity depends heavily on climate, the sector is highly exposed to climatic shocks. Vegetable farming, in particular, is highly sensitive to climate variability, as crop growth, yield, and quality are influenced by rising temperatures, shifting rainfall patterns, and extreme weather events. To sustain vegetable production, farmers must adopt climate-smart practices that minimize risks and enhance resilience.

In Rivers State, Nigeria, including Oyigbo Local Government Area, smallholder farmers are especially susceptible to climate change, largely because of their reliance on rain-fed agriculture (Nnodim *et al.*, 2023). Older farmers, compared with younger ones, are less likely to adopt innovative practices such as irrigation and improved crop varieties (Nnodim *et al.*, 2023; Aroyehun *et al.*, 2024). Limited access to information, traditional farming methods, and low education levels further constrain their adaptive capacity. Education has been identified as a critical factor in shaping farmers' responses to climate change; educated farmers tend to be more aware of its effects and have better access to adaptation information. Household size also influences adaptation decisions: larger households are more likely to adopt irrigation and crop diversification because of the greater labour supply (Akter & Ahmed, 2015). Similarly, income plays a determining role: farmers with higher earnings are more likely to invest in climate-smart strategies such as improved seed varieties and crop insurance (Akudugu *et al.*, 2023).

Globally, climate change has emerged as a major driver of food insecurity by reducing agricultural productivity. In Nigeria, low and erratic rainfall, pest and disease outbreaks, and limited use of improved technologies undermine smallholder vegetable production. The World Bank (2019) notes that rural and urban communities alike remain highly vulnerable to flooding, temperature increases, aridity, and soil erosion, particularly poor and marginalized groups. Extreme climate events such as droughts and floods disproportionately affect rural smallholders who depend on crop farming for their livelihoods. Despite adaptation efforts, poverty, hunger, and malnutrition persist, with more than 70% of smallholders living below the poverty line (World Bank, 2019).

Increasing the production of traditional crops such as vegetables, adapted to a wide range of agro-ecological conditions, may provide a pathway for strengthening resilience, especially in Oyigbo LGA. Vegetables are widely cultivated in Nigeria, but yields are declining due to reduced rainfall and worsening climatic stress. Given that vegetable production relies on water availability, reduced rainfall further threatens its sustainability. The Federal Ministry of Environment (FME, 2021) warns that without effective adaptation, climate change could reduce Nigeria's GDP by 2–11% by 2020 and by as much as 6–30% by 2050. The 2012



floods in Nigeria provided stark evidence of climate-related damages, exposing the vulnerability of farmers and highlighting the urgency of adaptation.

To address these challenges, smallholder farmers need to adopt context-specific adaptation strategies. However, the adoption of such strategies is shaped by socioeconomic factors, including education, income, access to resources, gender, landholding, and credit availability (Asfew *et al.*, 2014; Olayide & Alabi, 2018). Despite their significance, there remains limited empirical evidence on how these factors interact to shape farmers' adaptive choices. This study, therefore, seeks to fill this gap by analyzing the socioeconomic characteristics that influence adaptation strategies among vegetable farmers in Oyigbo LGA, Rivers State. The specific objectives are to identify the socio-economic characteristics of vegetable farmers, identify the climate change adaptation strategies adopted by vegetable farmers, determine the factors influencing the choice of adaptation strategies in vegetable production, and identify challenges encountered by vegetable farmers in adapting to climate change in the study area.

Theoretical Framework

The theory underlying this research is the theory of utility maximization. According to this theory, a farmer is a rational economic agent who makes decisions based on expected benefits or satisfaction (Abid *et al.*, 2016). Based on the theory, a farmer makes a rational decision by choosing an adaptation strategy that will give him or her the highest utility (Aroyehun *et al.*, 2024). Income theory is also relevant in this study. Households' income affects adaptation strategies, with higher income levels, small-scale farmers respond to these challenges positively in farm input use, crop-livestock integration, and water conservation practices. Smallholder groups may also have an impact on the economy by increasing farm household income and their decision to adapt management strategies in response to climate change (Abdullahi & Adewale, 2019).

The rational choice theory of utility maximization uses an individual method to simulate how an economic actor might behave while making a choice (Scott, 2000). People, including vegetable farmers, act in their own best interests by making decisions that are consistent with their highest-benefit goals. This suggests that a rational economic agent will choose option(s) whose advantages outweigh the costs among the available alternatives to maximize economic rewards with the constrained resources at his/her disposal. This theory holds that the decisions made by economic agents are their own. This means that if the relative benefits decrease below the incurred costs, either no choice decision will be made or an alternate option or options of comparable benefits will be selected. Therefore, the decision-making process is not influenced by outside forces like coercion, environmental pressure, cultural tradition, or unconscious motivation. This is because the rational choice theory does not take into consideration instinctive behaviour, intuitive reasoning, or fixed learning principles, which may potentially influence decision-making under larger costs, meaning this theory has a limited range of applications. Notwithstanding, rational utility theory is appropriate for evaluating how vegetable farmers behave in order to maximize productivity in connection with their selection of climate change adaptation practices while operating within a constrained budget. A rational vegetable farmer is expected to select a set of adaptation strategies that have lower costs but greater productivity potentials in order to maximize the economic reward of adaptation in vegetable farming, even if these activities have adverse effects on the environment. When making adaptation decision, it will be irrational, and hardly possible, for a smallholder farmer to prioritize soil preservation and fertility enhancement options over profit maximization objective. However, increased farming rewards are possible if a farmer prioritizes improving both the crop's productivity and the benefits to the



environment when choosing adaptation practice(s). This increases the likelihood of selecting multiple adaptation practices to maximize farming profits (Gebre *et al.*, 2023).

Materials and Methods

The research was carried out in Oyigbo LGA of Rivers State, Nigeria. Its coordinates are latitude 4.8868" N and longitude 7.1252" E. The major occupations in the area are trading and Farming. Oyigbo is made up of two districts comprising 18 villages/towns. The towns and villages in Oyigbo LGA include: Asa district; Komkom, Obeama, Mmirinwayi, Izuoma, while for the Ndoki district they include Mgboji, Afam Uku, Afam, Afam Nta. Obeakpu, Umuosi, Obunku, Egberu, Ayama, Azuogu, Marihu, Obete, Okponton, Umuagbai. Traders and peasant farmers constitute a very high number of the indigents. This study targeted all vegetable farmers in Oyigbo LGA of Rivers State, Nigeria.

A multi-stage sampling procedure was used for the study. In the first stage, the study adopted a purposive sampling method to select five (5) communities in the study area the communities are Komkom, Obeama, Mgboji, Afam, and Obeakpu. The reason for this purposive was to select the highest community with vegetable production. Secondly, 14 vegetable farmers were randomly selected from each community, given a total of 70 sample size vegetable farmers for this research. The aim of purposive selection, equal numbers from all five communities, was to ensure that each of the selected communities was equally represented in the study, regardless of size, so that community-specific experiences, perceptions, and adaptation strategies could be captured without being overshadowed by the larger communities. In contexts, like this study, where the objective is to explore variability and generate an in-depth understanding across different social or ecological settings, purposive equal allocation is considered acceptable (Creswell, 2014). Thus, while proportionate sampling enhances statistical representativeness, the purposive method adopted here aligns with the exploratory and comparative nature of the study. Primary and secondary data were used in this study. Primary data was collected using a structural questionnaire and interview schedule from the sampled vegetable farmers, while secondary source was obtained from published sources such as journals, textbooks, the internet, and other relevant documents. Descriptive statistics such as percentage, frequency, and mean, as well as a logit regression model, were used to achieve the objectives. The use or non-use of adaptation strategies was a dummy variable which was assigned (1) if it was used by the households and (0) if otherwise.

Model specification

$$Y_i = \log \left(\frac{p_i}{1-p_i} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \mu_i$$

Where:

p_i = probability (event), that is, the probability that the event will occur (probability of the household using the climate change adaptation strategy).

$1-p_i$ = probability (non-event), that is, the probability that the event will not occur (i.e., the non-probability of the household using the climate change adaptation strategy).

β_0 = Constant term

β_1 to β_7 = Parameters to be estimated

X_1 to X_7 = Independent variables in the model

Where:

X_1 = Age (years)



X₂ = Gender (dummy: male = 1; female = 0)

X₃ = Marital status (categorical: single, married, widows/ widowers, divorced)

X₄ = Household size (number)

X₅ = Farming experience (years)

X₆ = Average income (in Naira)

X₇ = Farm size (hectares)

Results and Discussion

Socioeconomic characteristics of vegetable farmers

Table 1: Socioeconomic characteristics of vegetable farmers

Variables	Frequency	Percentage	Mean
Age (year)			
20 and below	10	14.29	34.8
21-30	14	20.00	
31-40	13	18.57	
41-50	19	27.14	
51 and above	14	20.00	
Gender			
Male	31	44.29	
Female	39	55.71	
Marital status			
Single	24	34.29	
Married	31	44.29	
Widow/Widower	13	18.57	
Divorced	2	2.86	
Occupation			
Farmer	23	32.86	
Trader	17	24.29	
Civil servant	4	5.71	
Student	8	11.43	
Artisan	5	7.14	
Others	13	18.57	
Farming experience (year)			
5 and below	20	28.57	7
6-10	28	40.00	
10 and above	22	31.43	
Household size (number)			
5 and below	28	40.00	7
6-10	38	54.29	
10 and above	34	48.57	
Farm size (hectares)			
0.1 and below	33	47.14	
0.11-1.0	22	31.43	
1.1 and above	15	21.43	
Source of land			
Owned	40	57.14	
Leased	18	25.71	
Both	12	17.14	
Vegetable production experience (year)			



5 and below	8	11.43	
6-10	17	24.29	9.75
11-15	24	34.29	
16 and above	21	30.00	
Income (Naira)			
10,000 and below	1	1.43	
10,001-15,000	23	48.57	14,625
15,001-20,000	16	22.86	
20,001 and above	19	27.14	
Total	70	100.00	

Source: Field Survey, 2024

Table 1 shows the socioeconomic characteristics of vegetable farmers. The majority of vegetable farmers (27.14%) were between the ages of 41 and 50, followed by those aged 21 to 30 (20.0%) and 51 and above (20.0%), with a mean age of 34.8 years. This suggests that the majority of vegetable farmers are in their economically active years, which is consistent with Adeoye et al. (2019), who found that vegetable farmers in Southwest Nigeria were largely in their middle years, a demographic deemed productive and amenable to adopting new agricultural methods. Similarly, Oladoyin et al. (2023) reported that farmers in the economically active age range (41-50 years) are more energetic and capable of doing labour-intensive jobs, signifying productivity improvements through experience and physical ability. Female vegetable farmers (55.71%) considerably exceeded male farmers (44.29%). This indicates that women predominate in vegetable farming within the studied region. This result agrees with Ayanwale and Amusan (2014), who emphasise women's essential role in smallholder farmers who grow vegetables. Approximately 44.29% of the vegetable farmers were married, 34.29% were single, 18.57% widows/widowers, and 2.86% divorced.

Farming was the most common occupation (32.86%), followed by trading (24.29%), civil service (5.71%), and artisans (7.14%) were under-represented. This distribution indicates that agriculture continues to be the primary source of income in the region. According to Oluwatayo and Adedeji (2019), rural households frequently switch between farming and small trade as a coping strategy for income unpredictability. The small proportion of civil servants is consistent with the rural employment system, which is characterised by informal and agricultural work. The general farming experience of the vegetable farmers was 40% between 6-10 years, with a mean of 7 years. This suggests that farmers are relatively experienced, which enhances their technical know-how. A large share (54.29%) lived in homes with 6-10 individuals, with an average of 7 people. This suggests a preference for large household sizes, which can offer farm work. However, larger household sizes have been linked to lower food security, suggesting that the greater work may be compensated by increasing demand for food and income resources (Oluwatayo, 2009). The mean of 7 people was greater than the Nigeria Living Standards Survey report by the National Bureau of Statistics (2020), which said that the average household size in Nigeria is 5 people, with rural homes being considerably larger at roughly 6 people per family.

Almost half of the vegetable farmers (47.14%) operated on 0.1 hectares or less, with only 21.43% cultivating more than 1 hectare. This implies that vegetable production is dominated by smallholders, which is consistent with the FAO (2018), which reported that Nigerian household farmers have a mean agricultural land of only 0.5 hectares, illustrating the country's reliance on small-scale farming. According to FAO data, approximately 84% of household farms worldwide are less than 2 hectares. Over fifty percent (57.14%) owned their farmland, with 25.71% leasing. This indicates considerable land security, and this is critical



for sustaining investments in vegetable production. This supports Sun et al. (2025) notion that land ownership promotes sustainable usage policies, as opposed to rented property, where tenure uncertainty could limit investment decisions. About 34.29% of vegetable farmers had 11-15 years of producing experience, with 30% having more than 16 years. The average experience was 9.75 years, indicating considerable expertise and resilience. Oladejo (2020) observed similar findings, arguing that long-term vegetable farmers use both traditional knowledge systems and contemporary technology. Almost half (48.57%) made between ₦10,001-₦15,000 each month, with a mean of ₦14,625, while 27.14% earned more than ₦20,000. This suggests a relatively low agricultural revenue, owing to small farm holdings and poor marketing. This result is consistent with Abayomi and Adebayo's (2018) observation that small-scale vegetable farmers in Nigeria usually earn less than the living standards, restricting investments in the agricultural sector.

Climate change adaptation strategies practiced by vegetable farmers

Table 2: Climate change adaptation strategies practiced by vegetable farmers in the study area

Adaptation strategies	Frequency	Percentage
Mixed cropping/multi-cropping	59	84.3
Change in time of planting	46	55.7
Use of Improved Seed Varieties	32	45.7
Mulching	32	45.7
Tillage	42	60.0
Use of cover cropping	42	60.0
Early planting	57	81.4
Early harvesting	48	68.6
Planting drought-resistant crop varieties	33	47.1

Source: Field survey, 2024

Table 2 shows the climate change adaptation strategies used by vegetable farmers in the research region. The results show that the most often used tactics are mixed cropping/multi-cropping (84.3%) and early planting (81.4%). This implies that farmers rely largely on diversity and time-based adaptations to mitigate the hazards associated with unpredictable rainfall and protracted dry periods. This finding is consistent with Nhemachena and Hassan (2007), who found that mixed cropping improves resilience by distributing hazards across various crops. Likewise, Fadina and Barjolle (2018) noted that early planting is a typical practice in Nigeria for dealing with unexpected rainfall patterns. The adoption of early harvesting (68.6%), adoption of tillage practices (60%), and cover cropping (60%) indicates efforts to conserve soil moisture and improve soil fertility. These adaptation strategies align with the conclusions of Ali and Erenstein (2017), who noted that soil management strategies remain vital to African small-scale farmers to adapt to climate change. Meanwhile, the adoption of improved seed varieties (45.7%), mulching (45.7%), and drought-resistant varieties (47.1%) seems to be less common than conventional approaches. According to Mabe et al. (2014) and the FAO (2021b), this could be due to farmers' constrained accessibility to farming inputs, high cost, and low knowledge. The limited adoption of varieties that are drought-tolerant emphasises the disparity between research discoveries and farmer-level application.



Results of logit regression of socioeconomic factors influencing climate adaptation strategies practiced

Table 3: Results of logit regression of socioeconomic factors influencing climate adaptation strategies practiced in the study area.

Factors	Coefficient	Std Err	z	p-value	95% Conf	Interval
Age	0.1063*	0.0247	4.31	0.078	0.0523	0.3522
Gender	0.1247***	0.0658	1.4	0.000	-0.0022	0.6552
Marital status	-0.1034	0.1187	-0.87	0.384	-0.2685	0.6554
Household size	0.1097	0.0891	1.23	0.418	-0.0364	0.2844
Farm experience	0.1097***	0.0891	1.23	0.001	-0.0255	0.5526
Average income	-6.13E-7***	1.98E-6	-0.31	0.000	-0.5486	0.0366
Farm size	0.6929***	0.3942	1.76	0.004	-1.6649	0.0456
Constant	60439	1.6380	0.37	0.712	-1.3656	1.5488

Log likelihood Chi square = 51.65; Hosmer and Lemeshow test = 37.65; ***, **, and * means significant at 1%, 5% and 10%, respectively.

Source: Field survey, 2024

Table 3 shows the results of a logit regression model of the socioeconomic factors influencing climate adaptation strategies among vegetable farmers in the study area. The model has a Chi-square of 51.65, suggesting an excellent fit, and the Hosmer and Lemeshow test (37.65) indicates that it accurately predicts vegetable farmers' adaptation behaviour. Climate adaptation strategies practiced were positively linked with age (coefficient = 0.1063, $p < 0.10$), suggesting that older farmers are more inclined to use climate adaptation strategies. This result is similar to Fadina and Barjolle (2018), who found that older farmers frequently rely on their expertise to adjust to climatic variability. Gender had a positive and highly significant influence (coefficient = 0.1247, $p < 0.01$), indicating that male farmers are more likely to apply adaptation strategies than female farmers. This confirms Asfaw and Maggio's (2017) observation that women frequently encounter hurdles such as restricted land rights, access to extension services, and financial resources, which limit their adaptive potential. Farm experience has significant positive effects (coefficient = 0.1097, $p < 0.01$), suggesting that experienced farmers are better positioned to implement adaptation strategies due to their accumulated understanding and familiarity with both conventional and current methods. This matches Oladejo's (2020) argument that long-term vegetable farmers combine traditional knowledge with scientific approaches. Farm size was another important factor (coefficient = 0.6929, $p < 0.01$). Larger farms often give farmers greater resources and freedom to experiment with adaptation strategies, including mixed cropping, irrigation, and enhanced seed usage. This finding is consistent with Ayanlade et al. (2017), who discovered that resource endowments such as land area had a major effect on adaptation strategy options. Surprisingly, average income was negatively significant (coefficient = -6.13E-7, $p < 0.01$), indicating that farmers with higher non-farm income are less likely to participate in agricultural adaptation. This might be because such households diversify away from farming, relying less on agricultural resilience techniques. This finding is consistent with that of Below et al. (2012), who demonstrated that non-farm income can limit agricultural adaptation efforts. In contrast, marital status and family size were not statistically significant, suggesting that these factors may not have a direct impact on adaption in the study area. This is similar with Mabe et al.'s (2014) findings in Ghana, where household size was not a significant predictor of adaptation strategies.



Constraints to vegetable farmers' production

Table 4: Constraints vegetable farmers face while adapting to climate change adaptation strategies in the study area

Constraints	Frequency	Percentage
Land and labor constraints	58	81.7
Lack of support from the government	60	84.5
Scarcity of improved vegetable varieties	46	64.8
Transportation problem	38	53.5
Low soil fertility	33	46.5
High cost of farm and land inputs	63	88.7
Inadequate knowledge of climate-related strategies	41	57.7
Inadequate farm land	44	62.0
Lack of credit facilities	53	74.6
Poor extension services	60	84.5

Source: Field survey, 2024

Table 4 shows the challenges faced by vegetable farmers in using climate adaptation strategies. The majority of the farmers face a high cost of farm and labour inputs (88.7%). They also face a lack of governmental support (84.5%), which serves as a constraint because of the ineffectiveness of some schemes established to help farmers. Poor extension services (84.5%) as also one of the major challenges. Inadequate or lack of credit facilities (74.6%), this is usually due to the stringent measures that are usually required for obtaining loans from a fiscal institution, or to some extent, ignorance of the farmers about the existence of the credit that is available in Agricultural Banks. Other challenges include scarcity of improved vegetable varieties (64.8%), which might be a result of ignorance of improved varieties or the high cost of purchasing improved vegetable seed varieties, low soil fertility (46.5%), inadequate farm land (62%), and transportation problems (53.5%).

The problems of inadequate finance would not enable the vegetable farmers to acquire the necessary irrigation equipment and facilities, which might be too expensive for them to acquire from the proceeds from their farming activities. Also, inadequate knowledge and technical know-how in operating the modern irrigation equipment will, to a greater extent, limit the farmer's use of irrigation as an adaptation strategy to the effects of climate change in the study area. It was further revealed that poor agricultural extension services, high cost, and lack of facilities, as well as pests and diseases, were the major constraints militating against the choice of planting cover crops as a coping strategy to combat the effects of climate change in the study area. This implied that inadequate dissemination of information as a result of poor extension services limits the level of awareness of the farmers on the potential of the planting of cover crops in reducing the effect of adverse climatic conditions (e.g., drought) on vegetable crops in the study area. This conforms to the findings of (Satishkumar & Tevari, 2013). Also, the high cost of fertilizer and other inputs required in planting and maintaining cover crops constrained some of the arable crop farmers from using the planting of cover crops to combat the adverse effects of climate change in the study area.

Conclusion and Recommendations

The study focuses on Oyigbo LGA in Rivers State, Nigeria, examining socio-economic characteristics, adaptation strategies of vegetable farmers, and constraints they face. Primary data was collected through structured questionnaires and interviews. The data were analyzed using descriptive statistics, and a logit regression model. The logit model in data analysis



reveals that age, education, farm experience, average income, and farm size significantly influence the use of climate adaptation strategies. More educated farmers are more likely to adopt these strategies. The constraints faced by farmers include land and labor constraints, lack of government support, and the high cost of farm inputs, among others. The following recommendations were made:

- i. Implement programmes that provide education and training for farmers to increase their awareness and understanding of indigenous climate adaptation strategies. Organize community workshops where experienced farmers can share their knowledge and strategies with others. Encourage peer-to-peer learning.
- ii. Ensure that these farmers have access to the necessary resources, such as improved seeds, organic fertilizers, and tools, which can enhance the effectiveness of their adaptation strategies.
- iii. Develop systems to provide timely and accurate weather information to help farmers make informed decisions on when to plant, irrigate, or harvest. Offer financial support or microloans to farmers to invest in adaptation practices such as drought-resistant seed varieties and pest control measures.

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Determination of the Technical Efficiency of Pineapple Production in Awgu Local Government Area of Enugu State, Nigeria

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Abstract

This paper presents the analysis of technical efficiency of pineapple production in Awgu Local Government Area of Enugu State, Nigeria. It specifically analyzed the socio-economic characteristics of the pineapple farmers, the level of technical efficiency and inefficiency among pineapple farmers and identified the constraints of pineapple production in the study area. The data for the study were obtained from a total of 68 farmers and were analyzed using stochastic frontier production function model and descriptive statistics. Primary data was collected using structured questionnaire and schedule interview. Two-stage sampling procedure (purposive & simple random) was used to select the sample size. The results revealed that majority were males mainly in the age bracket of 40 – 49 years with (44.1%) having farming experience of 11 years and above. The mean technical efficiency of the pineapple farmers indicated that an average farmer could obtain about 95% of output. The gamma coefficient was 0.16 which implied that 16% of the variation of pineapple output from the production frontier was accounted by the technical inefficiency of the farmers. Factors that affected farm technical efficiency were farm size, labour and planting material (sucker) while farming experience has a significant effect on the efficiency level. The major problem faced by the farmers were pest and diseases infestation, insufficient fund, high cost of production and poor state of road. The study therefore recommends that Government, NGOs and Local leaders should help in the provision of basic infrastructural facilities and more capital inputs should be made available to the farmers.

Keywords: Determine, Frontier, Pineapple, Stochastic, Technical efficiency

Introduction

Pineapple *Ananas comosus* is a horticultural crop. It is a perennial herbaceous plant with shallow root. In Nigeria, this crop not only contribute to the share of agriculture in national economy, but possess a great potential and comparative advantage to compete in liberalized economy (Oguniyi and Oladejo, 2011). Nigeria, Kenya, Democratic Republic of Congo, Ivory Coast, Guinea and South Africa are the major pineapple producing countries in Africa (United Nations Conference on Trade and Development (UNCTAD) in Hossain and Hossain (2016). Pineapple is used mainly as snacks and fruit juice, while in most part of the



world the fermented juice is used to make vinegar and alcoholic spirit. Pineapple leaves are used to make cloth and rope, while the whole plant is used as a source of energy. Technical efficiency is the ability of a farmer to produce the highest level of output with a given bundle of inputs (Ndubueze-Ogaraku et al. (2020). Efficiency analysis is an issue of interest given that the overall productivity of an economic system is directly related to the efficiency of production of the components within the system. Thus, analysis of technical efficiency could contribute to the identification of production constraints at farm level and there by improves the food security and income sources in the farm sector and the rest of economy (Yohannis, 2020). However, not much studies have been carried out on technical efficiency in pineapple production in Nigeria. It is on this background that the study was carried out to determine the technical efficiency of pineapple (*Ananas comosus*) production in Awgu Local Government Area of Enugu State of Nigeria. The specific objectives were; to describe the socio- economic characteristics of pineapple farmers in the study area, determine the technical efficiency of pineapple farmers in the study area, determine the technical inefficiency of pineapple farmers in the study area and identified the constraints of pineapple production in Awgu Local Government area of Enugu state.

Materials and Methods

The study was conducted in Awgu Local Government Area of Enugu State, Nigeria. Awgu Local Government Area is one of the major producers of pineapple in Enugu State. The local government is situated in the eastern part of Enugu State, located approximately between latitude 06 00' and 06 19' North of the equator and longitudes 07 23' and 07 35' East of the Greenwich Meridian. According to the provisional 2006 population census it has a population size of 197,292 (NPC, 2006) with a projection of 283,200 in 2022 (<https://www.citypopulation.de/en/nigeria>). The people are predominantly farmers, cultivating mostly cash crops, food crops, fruits and vegetables as well as livestock production.

Two-stage sampling procedure was used to select the sample size. In the first stage, Purposive sampling was used to select three (3) communities (Amoli, Agbudu and Ihe). The three (3) communities are predominantly involved in the production of pineapple out of the 20 communities in Awgu local Government Area in Enugu State. In the second stage, simple random sampling technique was used to select thirty (30) farmers from Amoli community, twenty (20) farmers from Agbudu and twenty (20) farmers. Thirty farmers were selected from Amoli, twenty from Agbudu and twenty from the community making a total number of seventy (70) farmers but sixty-eight (68) questionnaires were retrieved and the analysis of the data was based on the 68 respondents. Primary data was collected using a structured questionnaire and schedule interview. Literature was reviewed from secondary source which included the use of newspapers, journals, reviewed literature materials, records from cooperatives, previous research project, internets and other materials which were of importance to the research study.



Data Analysis

Descriptive statistics such as frequency counts and percentage was used to achieve objectives (1, 2 and 4) while Cobb-Douglas stochastic frontier production function model was used to analyze the technical efficiency and inefficiency of pineapple production.

Model Specification

Stochastic Frontier Production Model

The stochastic frontier production function for pineapple production adopted in this study as specified by the Cobb Douglas functional form is defined as $Y = f(x)$

$$\text{Log } Y = b_0 + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + V_i - U_i$$

Where;

Y = Output/quantity of pineapple produced by farmer (kg), X_1 = Farm size (ha) , X_2 = Planting materials (sucker) (kg), X_3 = Labour (mandays), b_1 b_3 = slope coefficients of respective independent variables

V_i = Random error that is assumed to be normally distributed with zero mean and constant variance ($\sigma_2 v_i$). U_i = technical inefficiency effects which are independent of V_i and have half normal distribution with mean zero and variance $\sigma_2 V_i$. The inefficiency production U_i was modeled in terms of the factors which are assumed to affect the efficiency of production of the farmers. These factors are related to the socioeconomic variable of farmers and these variables are assumed to influence technical inefficiency of farmers. Following Battese and Coelli (1995), the mean of farm specific technical inefficiency U_i is defined as $U_i = \sigma_0 + \sigma_1 Z_{1i} + \sigma_2 Z_{2i} + \sigma_3 Z_{3i} + \sigma_4 Z_{4i} + \sigma_5 Z_{5i}$

Where; U_i = Technical inefficiency, Z_1 = age of farmer (years), Z_2 = educational level (years spent in attaining formal education), Z_3 = household size (count), Z_4 = experience of farmer (years), Z_5 = pineapple variety used (Local=0, Improved=1)

Results

Table 1: Distribution of socio-economic characteristics of pineapple farmers in the study area.

Socioeconomic variables	Frequency	Percentage
Gender		
Male	43	63.2
Female	25	36.8
Age		
20 – 29 years	11	16.2
30 – 39 years	25	36.7
40 – 49 years	21	30.9
50 – 59 years	8	11.8



60 and above	3	4.4
Years of formal education		
No formal education	4	5.9
6 years	16	23.5
12 years	40	58.8
16 years	8	11.8
Household size		
1 – 5	37	54.4
6 – 10	30	44.1
11 and above	1	1.5
Farming experience		
1 – 5 years	15	22.1
6 – 10 years	23	33.8
11 years and above	30	44.1
Varieties		
Local	21	30.9
Improved	47	69.1
Other occupation		
Petty trading	24	35.3
Craft work	11	16.2
Hunting	17	25.0
Carpentry	6	8.8
White collar job	9	13.2
Others	1	1.5
Total	68	100

Source: Field survey, 2019

The result in Table 1 revealed that greater percentage (63.2%) of the respondents were male which implied that pineapple production in the study area was largely dominated by the males. The predominance of male farmers in the study area could be attributed to the labour intensive nature of pineapple farming. This agreed to the findings of Baruwā (2013) who reported that pineapple production is male dominated. Majority of the farmers (36.7%) were within the range of 40-49 years. It also revealed that higher proportion (69.1%) of the farmers cultivated improved variety while 30.9% cultivated local variety of pineapple. Since the majority of the farmers cultivated improved variety of pineapple, there is high production of pineapple thus serving as a major source of income for farmers. This may also encourage farmers in the area to go into pineapple production.



Determinants of Technical Efficiency and Inefficiency of Pineapple Farmers

Table 2: Result of maximum likelihood parameter estimates of stochastic production frontier

Efficiency Variables	Parameters	Coefficient	Standard error	t ratio
Constant	β_0	2.0619	0.3586	5.7498***
Farm size (X_1)	β_1	0.2820	0.1002	2.8141***
Sucker (X_2)	β_2	0.5829	0.0774	7.5360***
Labour (X_3)	β_3	0.1743	0.0783	2.2248**
Inefficiency Variables				
Constant	Z_0	0.3526	0.1887	1.8686
Age	Z_1	-0.0009	0.0033	-0.2766
Educational level	Z_2	-0.0040	0.0047	-0.8572
Household size	Z_3	-0.0083	0.0080	-1.0365
Experience	Z_4	-0.0234	0.0078	-2.9811***
Variety	Z_5	-0.0169	0.0345	-0.4883
Variance parameters				
Sigma squared	σ^2	0.0068	0.0018	3.7575***
Gamma	γ	0.1571	0.1863	0.8434
Log likelihood function		75.5134		
LR test		9.8796		
No. of observations	68			

Note: ***=significant at 1%, **=significant at 5% level of probability, *=significant at 10% level
 Source: computer printout of FRONTIER 4.1c, using field survey data, 2019

Technical Efficiency

Result from table 2 revealed that the coefficients of variables related to farm size (X_1) and sucker (X_2) were positive and are significant at 1% level of probability while total quantity of



labour used (X_3) was significant at 5% level of probability. The inefficiency variables were specified as those relating to farmers' socio-economic characteristics. The estimated parameters of the inefficiency model in the stochastic frontier production function of pineapple farmers in the study area were presented in Table 2. The estimated coefficient of the inefficient function provides some explanation for the efficiency levels among the farmers revealed that only farming experience (Z_4) showed negative and statistically significant at 1% indicating that an increase in farming experience of the farmer will lead to a decrease in technical inefficiency and increase efficiency by 2.98%. This result is in line with the findings of Orewa and Izeke (2012) who stated that as farmers' years of experience increases their efficiency also increases.

Table 3: Frequency distribution of technical efficiency estimates of pineapple

Efficiency level	Frequency	Percentage
81 – 85	1	1.5
86 – 90	8	11.8
91 – 95	20	29.4
96 – 100	39	57.3
Total	68	100
Minimum value	0.85	85
Maximum value	1.00	100
Mean technical efficiency	0.95	95

Source: Field survey 2019

The result revealed that estimated technical efficiencies of the pineapple farmers ranged between 0.85 to 1.00 with a mean technical efficiency of 0.95, this implied that on the average, farmers are able to obtain 95% of potential yield from a given mix of production inputs. However, the mean technical efficiency recorded was high, therefore in the short run there is a possibility for increasing pineapple yield by 1% through the adoption of the most techniques and technology employed by the most technically efficient pineapple farmer in the study area at no additional cost. This result conforms with the findings of Adegbite and Adeoye (2015) and Ndubueze-Ogaraku and Ogbonna, (2016).

Table 4: Constraints of pineapple production in the study area

Perceived constraints	SA	A	D	SD	Mean	Remark
Insufficient fund	57(83.8)	9(13.2)	1(1.5)	1(1.5)	3.79	Serious
Poor access to land	48(70.6)	14(20.6)	6(8.8)	Nil	3.61	Serious



Pest and disease infestation	42(61.8)	18(26.5)	7(10.3)	1(1.5)	3.49	Serious
Unavailability of good varieties	10(14.7)	8(11.8)	48(70.6)	2(2.9)	2.38	Not serious
Weather variation	26(38.2)	23(33.8)	16(23.5)	3(4.4)	3.05	Serious
High cost of sucker	6(8.8)	8(11.8)	49(72.1)	5(7.4)	2.22	Not serious
Unimproved farm equipment	38(50.0)	23(33.8)	10(14.7)	1(1.5)	3.32	Serious
High cost of production	28(41.1)	18(26.5)	15(22.1)	7(10.3)	2.99	Serious
Poor state of road	39(57.3)	15(22.1)	10(14.7)	4(5.9)	3.31	Serious
Poor access to healthcare	33(48.5)	14(20.6)	11(16.2)	10(14.7)	3.03	Serious
Far distance of site from home	29(42.6)	13(19.2)	12(17.6)	14(20.6)	2.84	Serious
Scarcity of labour	21(30.9)	15(22.1)	18(26.5)	14(20.5)	2.63	Serious

Source: field survey (2019)

Note: the values in parenthesis indicate percentages

The result in Table 4 revealed that 83.8% of the farmers agreed that insufficient fund is a serious constraint to pineapple farmers in the study area. This indicates that fund is a problem faced by majority of the pineapple farmers because they depend on their personal savings for the production of pineapple. This finding is in agreement with the report of Famogbiele (2013) who states that lack of or poor finance is the greatest limiting factor to agricultural development in Nigeria. The result also showed that agreed that pest and diseases infestation and weather variation is a problem to pineapple farmers in the study area. High cost of production and scarcity of labour were also a serious problem. This result agreed to the findings of Dennis and Okpeke (2018) who reported that the cost of engaging labour in the farm to cultivate and maintain new pineapple farm is quite high. The result also showed that unavailability of varieties and high cost of sucker were not a serious problem to the pineapple farmers in the study area.

Conclusion

The study concludes that factors such as quantity of suckers, labour and farm size used were significant and important variables which influenced technical efficiency of pineapple farmers in the study area. It is therefore recommended that Government, NGOs and local leaders should help in the provision of basic infrastructural facilities such as construction of good road network for easy transportation of produce. More capital inputs should be made available through provision of more organic manure to increase the output of pineapple. This could be facilitated through establishment of channels that will enable the farmers access credit facilities for procurement of the capital inputs and also hiring of labour.



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Assessment of Incidence and Severity of Seedling Rot Disease of Fonio (*Digitaria* species) in Abeokuta, Ogun State, Southwestern, Nigeria

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Abstract

Fonio (*Digitaria* species) is a drought-tolerant, nutrient-rich cereal that plays a key role in food security in West Africa but threatened by seedling rot disease. This study tested the susceptibility of twenty-nine fonio accessions to seedling rot disease under natural infection. Field experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. Each of the species were dibbled at the spacing of 50 cm in row sowing. Disease incidence and severity were recorded at physiological maturity stages. The data collected were subjected to Analysis of Variance (ANOVA) through Minitab Version 17 and the significant means were separated using Tukey at $P < 0.05$. The results showed that seedling rot disease was first reported on fonio accessions tested with varying wide differences in disease incidence and severity. *Digitaria exilis* did not show any seedling rot symptom. However, Amundel (53.33 %) had the highest disease incidence, followed by Nasheleng with 50.00 % disease incidence while Ganawuri, Nanagai, Dampep and Danto show no symptom of seedling rot. The disease severity ranged from 0.00 – 4.17 throughout the entire growing season. The resistant levels among the twenty-nine accessions showed that sixteen accessions were Highly Resistant (HR), one was Moderately Resistant (MR), six were moderately susceptible (MS) while six were Susceptible (S). The study concluded that the highly resistant accessions could be further planted in other agroecological zones for possible breeding line for disease-resistant fonio varieties.

Keywords: Disease, Fonio, Infection, Rot, Seedling

Introduction

Fonio (*Digitaria* species) is an indigenous cereal crop native to West Africa, particularly Nigeria, Benin, Togo, and parts of Ghana which belong to the Poaceae family (Yilmaz, 2023). Fonio is valued by smallholder farmers for its ability to thrive under harsh environmental conditions such as poor soils, low rainfall, and high temperatures (Adoukonou-Sagbadja *et al.*, 2007; Cruz *et al.*, 2016). This resilience makes fonio a vital resource for food security in regions where conventional staples like maize or rice struggle to yield satisfactory harvests (Dansie *et al.*, 2012). Fonio is rich in essential amino acids, particularly methionine and cysteine, that are often lacking in more commonly consumed



cereals (Jideani and Jideani, 2011). Its gluten-free nature and low glycemic index have increased its appeal as a potential "superfood" in global markets (Bvenura and Afolayan, 2015). Despite these advantages, Fonio has been under-researched and is often classified as an "orphan crop", leading to gaps in understanding its genetic diversity, pest and disease resistance, and optimal cultivation practices (Tadele, 2019). A major challenge in fonio production is its vulnerability to seedling rot, primarily caused by soil-borne fungal pathogens such as *Sclerotium rolfsii*, *Rhizotonia solani*, *Pythium* species and *Fusarium* species. The disease attacks the basal stem and root tissues, resulting in symptoms like water-soaked lesions, white mycelial growth, and the formation of sclerotia that enable disease recurrence (Ajayi and Adebawale, 2008). Environmental factors common in fonio farming (high humidity, poor soil drainage, and monocropping) further intensify the impact of stem rot (Singh *et al.*, 2019). The use of resistant varieties is the most economical and effective way of controlling fungal diseases mainly on resource constrained farmers' fields. However, with this small millet, a holistic approach is needed to address challenges related to diseases. Consequently, there is limited scientific data on its disease incidence and severity, disease resistance, insect pests, diseases and insect pest management, genetic diversity and optimal agronomic practices. This knowledge gap hinders efforts to improve yields and promote fonio as a sustainable crop in the face of climate change and population growth (Padulosi *et al.*, 2014). To achieve this goal, a good management strategy of the fungal pathogen requires selection of productive and resistant fonio accessions. Therefore, the studies aim to determine the incidence and severity of seedling rot of fonio on the accessions.

Materials and Methods

Location

The experiment was conducted at the dry upper valley of FADAMA, Federal University of Agriculture Abeokuta, (FUNAAB). The farm is located within latitude 7°20 N and longitude 3°23 E with an altitude of 76 m above sea level. The study area is located in the forest-savanna transition zone.

Source of thirty fonio seeds

The twenty-nine fonio accessions were sourced from National Cereal Research Institute (NCRI), Acha House Station, Jos Plateau State, Nigeria (Table 1).

Table 1: List of the thirty fonio accessions

S/N	Accessions	S/N	Accessions	S/N	Accessions
1	Guzuk 2	11	Gong-arandong	21	Nanagai
2	Achimawai	12	Dicksun	22	Dinat
3	Mboseke	13	Gotip	23	Zor
4	Mawoi	14	Chu	24	Pelking
5	Nyamat	15	Fang-roi	25	Machach
6	Badama	16	Nebang	26	Jarab
7	Dipya	17	Jakalak	27	Dampep
8	Siken	18	Amundel	28	Sunpiya
9	Loma	19	Nasheleng	29	Danto
10	Chen	20	Ganawuri		

Experimental design and treatments



The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times. The total experimental plots area (73 m x 8 m) and plot size 2 m x 2 m. Two species of the fonio used were *Digitaria exilis* Stapf-white fonio and *Digitaria iburua* Stapf-black fonio. Each of the species were dibbled at the spacing of 50 cm in row sowing.

Disease assessment

At physiological maturity, the data were collected on disease symptoms with seedling rot on the incidence and severity using the disease severity rating scale (Table 2).

$$i. \quad DI (\%) = \frac{\text{Number of diseased plant}}{\text{Total number of plants per plot}} \times 100$$

Disease Severity (DS) is calculated using the formula of adopted from Gwary *et al.*, (2009).

$$ii. \quad \text{Disease severity} = \frac{\Sigma n \times 100}{N \times S}$$

Where, Σ = Summation, n = number of infected leaves, N = number of leaves assessed
S = maximum numerical grade.

Table 2: Severity scale of seedling rot disease of fonio

Grade/Numerical value	Plant tissue damage (%)	Rating
0	0	Highly Resistant (HR)
1	1 – 20.9 seedling rot	Resistant (R)
2	21 – 40.9 seedling rot	Moderately Resistant (MR)
3	41 – 60.9 seedling rot	Moderately Susceptible (MS)
4	61 – 80.9 seedling rot	Susceptible (S)
5	81 – 100 seedling rot	Highly Susceptible (HS)

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using Minitab software version 17 and the mean was separated using Tukey test at $P < 0.05$.

Results and Discussion

Fonio foliar diseases observed on the field

The results revealed that seedling rot was observed on fonio for the first time in Abeokuta, Ogun State, Nigeria during the growing season. The symptom of seedling rot started with water soak on the leaf, followed by the rotten on leaves. The rot continues with any contact leaf until the entire seedlings rotten and died (Figure 1a). The accessions *D. iburua* are susceptible while *D. exilis* were totally immune to the disease. The disease incidence and severity differed across the twenty-nine fonio accessions for the symptom. The highest



incidence and severity values was found in *D. iburua* which showed that this species is more vulnerable to fonio seedling rot. This may be due to environmental conditions such as temperature, relative humidity and level of soil fertility. Manza *et al.* (2013) reported highest disease incidence and severity of *Curvularia* leaf spot occurrence in Riyom, Plateau State of Nigeria.

Percentage disease incidence and resistant level of twenty-nine accessions screened for fonio seedling rot disease under natural infection

The results for percentage disease incidence and resistant level of twenty-nine accessions screened for fonio seedling rot disease under natural infection during 2024 planting season revealed that there was a significant difference among the twenty-nine fonio accessions. *D. exilis* did not show any seedling rot symptom. However, Amundel (53.33 %) had the highest disease incidence, followed by Nasheleng with 50.00 % disease incidence while Ganawuri, Nanagai, Dampep and Danto show no symptom of seedling rot. The disease severity ranged from 0.00 – 4.17 throughout the entire growing season. Aouali and Douici-Khalfi (2013) reported that disease severity depends on the climatic conditions, the variety and the stage of development of the plant at the time of the attack. Percich *et al.* (1997) stated that these factors influence the expression of the disease aggressiveness. The resistant levels among the twenty-nine accessions showed that sixteen accessions were Highly Resistant (HR), one was Moderately Resistant (MR), six were moderately susceptible (MS) while six were Susceptible (S) (Table 3).



Figure 1(a): Seedling rot on *D. iburua* (b): Healthy fonio on *D. exilis*

Table 3: Percentage disease incidence and severity of twenty-nine fonio accessions screened for seedling rot disease under natural infection

Accessions	Disease incidence (%)	Disease severity	Status
Guzuk 2	0.00i	0.00e	HR
Achimawai	0.00i	0.00e	HR
Mboseke	0.00i	0.00e	HR
Mawoi	0.00i	0.00e	HR
Nyamat	0.00i	0.00e	HR
Badama	0.00i	0.00e	HR
Dipya	0.00i	0.00e	HR
Siken	0.00i	0.00e	HR



Loma	0.00i	0.00e	HR
Chen	0.00i	0.00e	HR
Gong-arandong	0.00i	0.00e	HR
Dicksun	0.00i	0.00e	HR
Gotip	22.87fgh	3.00a-d	MS
Chu	33.17cde	4.17a	S
Fang-roi	45.00ab	3.67abc	S
Nebang	14.20h	4.17a	S
Jakalak	27.57def	2.83bcd	MS
Amundel	53.33a	4.00ab	S
Nasheleng	50.00a	3.17abc	MS
Ganawuri	0.00i	0.00e	HR
Nanagai	0.00i	0.00e	HR
Dinat	36.40bcd	4.00ab	S
Zor	17.33gh	3.33abc	MS
Pelking	40.00bc	3.50abc	S
Machach	26.67efg	2.50cd	MS
Jarab	35.00cde	1.83d	MR
Dampep	0.00i	0.00e	HR
Sunpiya	35.00cde	2.83bcd	MS
Danto	0.00i	0.00e	HR
Means	15.05	1.483	
SE	2.00	0.188	
CV (%)	123.67	117.99	

Means in the same column followed by different alphabets are significantly different ($P < 0.05$) using Tukey. SE means Standard Error while CV means Coefficient of Variation. Note: Highly Resistant (HR), Moderately Resistant (MR), Moderately Susceptible (MS) and Susceptible (S)

Conclusion

The study revealed the occurrence of seedling rot on fonio for the first time in this agroecological zone. The disease occurred on fonio plant at various stages, beginning at five weeks after sowing. The study also revealed that *D. ibruua* (black fonio) accessions are more susceptible to seedling rot infection than *D. exilis* (white fonio). The resistant levels for seedling rot disease showed that sixteen accessions were highly resistant, one was moderately resistant, six were moderately susceptible while six were susceptible.

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Improvement of Quality and Shelf life of Tomato (*Lycopersicon esculentum* Mill) Fruits Stored with Powdered *Jatropha* Leaves in Different Storage Media

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Abstract

Tomato (*Lycopersicon esculentum* Mill) fruits are classified to be a climacteric fruit with high respiration rate. It is highly perishable due to high water content, postharvest diseases, continued ripening, and senescence that many are accounted to losses. The experiment was conducted in the laboratory of Horticulture department, Federal University of Agriculture, Abeokuta (7°16'N, 3°24'E) to study the nutrient and proximate content of tomato (*Lycopersicon esculentum* Mill) fruits as influenced by different storage media with powdered *Jatropha* leaves. This experiment was a 2 × 3 factorial experiment in a Completely Randomized Design and was replicated 3 times. Tomato fruits (Cobra F1) harvested at breakers stage stored with powdered *Jatropha* leaves in evaporative coolant structure, charcoal cooling chamber and ambient (open shelf). The proximate and nutrient analysis of the samples for moisture content, dry matter, total soluble solid, crude fibre, ash content, crude protein, vitamin A, vitamin C, lycopene was carried out using the method described by AOAC. Data collected were subjected to Analysis of Variance and mean separated using standard error at p<0.05. The study concluded that tomato fruits harvested at breaker stage stored in with powdered *Jatropha* leaves in different storage media increased its shelf life and nutritional quality as compared to control that had greater compositional changes with maximum quality loss during storage.

Keywords: Powdered *Jatropha* leaves, Quality, Shelf life, Storage media, Tomato fruits

Introduction

Tomato (*Lycopersicon esculentum* Mill) is an important fruit crop with high nutritional value, rich in antioxidants, vitamins, dietary fiber and a range of bioactive compounds such as lycopene, flavonoids, and phenolics, which contribute to its health-promoting properties (Bhowmik *et al.*, 2022). These attributes of plant in preservation of food enhances the economic value of such foods (Irokanula *et al.*, 2015). Tomato weight loss percentage, deterioration percentage, total soluble solid, lycopene and β-carotene content increased with the storage period at room temperature as compared to the evaporative coolers (Esa *et al.*, 2015). Postharvest losses (PHL) threaten food, nutrition and income security (Affognon *et al.*, 2015). The surface washing of tomatoes with aqueous extract of *Psidium guajava* and *Jatropha curcas* leaves at different concentration has enhanced shelf life and decreases



deterioration of tomato varieties (Ahmad *et al.*, 2020). Therefore, there is need to determine the effect of powdered *Jatropha* leaves and most appropriate storage medium suitable for optimum tomato quality and shelf life extension.

Materials and Methods

The experiment conducted was 2 X 3 factorial laid out in a Completely Randomized Design and replicated 3 times in the laboratory of the Department of Horticulture, Federal University of Agriculture Abeokuta. The factors were variety (Cobra F1 and kerewa) harvested at breaker stage stored with powdered *Jatropha* leaves and stored in three media (Evaporative Coolant Structure; Charcoal Cooling Chamber and Open shelf). Data were collected on colour change by scoring on a scale of 1- 4 (4-green, 3-breaker, 2-turning, 1- full ripe); firmness with the use of penetrometer, shelflife and proximate content. Proximate analysis was carried out to evaluate percentages of moisture, lycopene, vitamins A and C content as described by AOAC, 2023. Data were subjected to analysis of variance (ANOVA) using SAS package. Standard error ($SE_{\pm}$) $P \leq 5\%$ was used to separate means. The initial and final means of the data obtained from the proximate analysis were compared using standard error.

Results

There was no significant difference on effect of tomato fruits freshness when stored with botanicals till day 49 (Table 1). Tomato fruits freshness was influenced by different media from day 21 to day 42 (Table 1). The freshness of tomato fruits stored in ECS were more maintained followed those stored in CCC while those stored in OS were less maintained. Firmness of tomato fruits stored with botanicals were significantly different (Table 2). The initial and final values of tomato fruits stored with powdered *Jatropha* leaves had a minimum percentage decrease in firmness when compared with those stored without botanicals. The firmness of tomato fruits stored in different media were significantly different after storage (Table 2). Lowest percentage decrease in firmness was observed in tomato fruits stored in CCC followed by ECS while those stored in OS had the highest percentage decrease. Tomato fruits stored with powdered *Jatropha* leaves significantly extend its shelf life till 39 days while those without botanicals till 31 days (Table 2). Storage of tomato fruits in different media significantly differed (Table 2). It was observed that tomato fruits stored in ECS extended the shelf life of tomato fruits (44days) followed by CCC (42days) compared with those stored in OS which had the least shelf life (32 days). There was a significant difference on total soluble solid (g/100g) present in tomato fruits stored with botanicals (Table 3). Tomato fruits stored powdered *jatropha* leaves had the higher percentage increase compared to those without botanical. The impact of storage media on total soluble solid differs (Table 3). Tomato fruits stored in CCC had the highest total soluble solid followed by ECS and OS had the lowest total soluble solid. There was significant difference on effect of lycopene content on tomato fruits stored with powdered *Jatropha* leaves (Table 3). The initial and final values of tomato fruits stored with powdered *Jatropha* leaves had minimal percentage increase (0.46%) compared with those without botanical (0.05%). The lycopene content of tomato fruits stored in different media were significantly different after storage (Table 3). Highest percentage increase in lycopene content was in tomato fruits stored in CCC, followed



by ECS compared those stored in OS had the lowest percentage increase. Vitamin A content observed in tomato fruits stored with botanical was significantly different (Table 4). Powdered jatropha leaves helps to enhance vitamin A content in tomato fruits compared to those not stored with botanical (Table 4). Storage media influence the vitamin A content. ECS enhance vitamin A content than CCC and OS. There was significant difference on effect of vitamin C content (g/100g) on tomato fruits stored with botanicals (Table 4). Tomato fruits stored with powdered jatropha leaves enhance vitamin C content than those stored without botanical. Tomato fruits vitamin C content was influenced by different media (Table 4). Tomato fruits stored in ECS had the highest percentage increase, followed by those stored in CCC and OS had the lowest percentage increase.

Table 1: Effect of botanical on fruit freshness of tomato fruits stored in different media

Treatment		Fruit freshness (Days after storage)							
Botanical		0	7	14	21	28	35	42	49
Powdered jatropha leaves		1.73	1.73	1.73	1.41	1.41	1.31	1.21	1.00
Control		1.73	1.73	1.73	1.41	1.32	1.19	1.05	0.99
SE ($\pm$)0.05		NS	NS	NS	NS	0.01	0.01	0.20	NS
<u>Storage Media</u>									
Evaporative structure	coolant	1.73	1.73	1.73	1.41	1.38	1.30	1.13	1.00
Charcoal chamber	cooling	1.73	1.73	1.73	1.41	1.37	1.21	1.08	1.00
Open shelf		1.73	1.73	1.73	1.41	1.35	1.18	1.06	1.00
SE ($\pm$)0.05		NS	NS	NS	NS	0.01	0.01	0.20	NS

Table 2: Effect of botanical on fruit firmness and shelflife on tomato fruits stored in different media

Media				
Treatment	Fruit firmness			Shelflife
Botanical	Initial	Final	% Decrease	Days
Powdered jatropha leaves	8.62	8.14	5.57	39
Control	8.48	8.00	5.66	31
SE (+)0.05	0.16			0.14
<u>Storage Media</u>				
Evaporative coolant structure	9.74	9.27	4.83	44
Charcoal cooling chamber	9.58	9.12	4.8	42
Open shelf	6.31	5.83	7.61	32
SE (+)0.05	0.16			0.36

Table 3: Effect of botanical on total soluble solid and lycopene content of tomato fruits stored in different media

Treatment	Total Soluble Solid			Lycopene content		
	Initial	Final	% Increase	Initial	Final	% Increase



	e					
Powdered jatropha leaves	19.93	17.48	12.29	11.91	12.12	1.72
Control	19.93	18.42	7.78	11.91	11.82	0.75
SE (±) 0.05	0.22			0.54		
<u>Storage Media</u>						
Evaporative coolant structure	19.93	17.48	12.29	11.91	12.12	1.72
Charcoal cooling chamber	19.93	17.1	14.2	11.91	12.45	4.34
Open shelf	19.93	18.42	7.58	11.91	11.82	0.75
SE (±) 0.05	0.22			0.54		

Table 4: Effect of botanical on vitamin A and C content of tomato fruits stored in different media

Treatment	Vitamin A content			Vitamin C content		
			%			%
Botanical	Initial	Final	Increase	Initial	Final	Increase
Powdered jatrophaleaves	99.42	102.2	2.68	19.44	19.35	0.46
Control	99.42	100.6	1.19	19.44	19.45	0.05
SE (±) 0.05	0.85			0.13		
<u>Storage Media</u>						
Evaporative coolant structure	99.42	102.2	2.68	19.44	19.35	0.46
Charcoal cooling chamber	99.42	99.58	0.16	19.44	19.55	0.46
Open shelf	99.42	100.6	1.19	19.44	19.45	0.05
SE (+) 0.05	0.85			0.13		

Discussion

Botanical preservatives help to improve the flavour and sugar contents of the tomato and also effective in extending the storage life of fruits while inhibiting the growth of pathogens and increasing the physical quality of fruits. This is in agreement with Irokanulo *et al.*, (2015) who confirmed the use of botanicals in lieu of chemicals as preservatives of fruits that is efficacious and less toxic to human.

The effect of storage media on proximate content of tomato fruits revealed that there was percentage increase in total soluble solid, lycopene, vitamin A and C content in storage media. The increase experienced in vitamin A was in accordance with the work reported by Toor *et al.*, (2006).

Conclusion

The study concluded that tomato fruits harvested at breaker stage stored with powdered jatropha leaves and those in ECS and CCC increased its nutritional quality as compared to



control that had greater compositional changes with maximum quality loss during storage in other storage media.

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Proximate Composition of Fresh and Dried *Gymnarchus niloticus* from Mbiama, Ndoni and Omoku Markets, Rivers State

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Abstract

This study assessed the proximate composition of fresh and dried *Gymnarchus niloticus* obtained from Mbiama, Ndoni, and Omoku markets in Rivers State, Nigeria. Proximate analysis was conducted following AOAC (2000) methods, and data were analyzed using one-way ANOVA with Duncan's Multiple Range Test. Significant differences ($p < 0.05$) were observed between fresh and dried samples: moisture content was higher in fresh fish, while dried samples showed increased protein and ash levels, indicating enhanced nutrient density due to moisture reduction. Crude fat decreased slightly after drying, and carbohydrate levels declined across locations, particularly in Ndoni and Omoku. Overall, drying improved storage stability and nutritional quality, underscoring its value as an effective post-harvest preservation method.

Keywords: Fat content, *Gymnarchus niloticus*, Mbiama, Moisture content, Protein,

Introduction

Globally, fish remains one of the most affordable and accessible sources of high-quality animal protein, playing a central role in the diets of millions, especially in low- and middle-income countries (FAO, 2018; Jamabo, 2025). The proximate composition of fish, which includes moisture, crude protein, lipid, ash, and fibre content, is crucial in evaluating their nutritional quality and economic value (Davies *et al.*, 2017). Moisture is a significant component of fish flesh, generally comprising 60–84% of the total weight (Jamabo and Nwaekpe, 2017). Moisture content influences the shelf life and textural properties of fish and varies inversely with lipid content. High moisture content is commonly observed in lean fish, while fatty species display lower moisture levels (Jamabo and Nwaekpe, 2017). For instance, freshwater species like *Gymnarchus niloticus*, commonly known as the African knifefish, typically show moisture levels within this range, although precise data may vary depending on environmental and physiological factors. The fish is a freshwater fish species native to African river systems, including the Nile and Niger Rivers, as well as their tributaries. This species is known for its elongated body, electric-sensing abilities, and its high commercial value as a food fish. In Nigeria, *G. niloticus* is a prized species due to its taste and market demand, making it an attractive candidate for aquaculture development. The aim of the study is to determine the proximate composition of the fresh and dried *G. niloticus* collected from Omoku, Ndoni and Mbiama markets in Rivers State.



Materials and Methods

Sample collection: Fresh and dried fish samples were bought from farmers at three different locations in Rivers State, Omoku, Ndoni and Mbiama markets (Figure 1). After collection, the fish samples were quickly taken to the lab for chemical analysis. The facilities of the Food Analysis Laboratory, Rivers State University, Department of Food Science and Technology was used for the study.

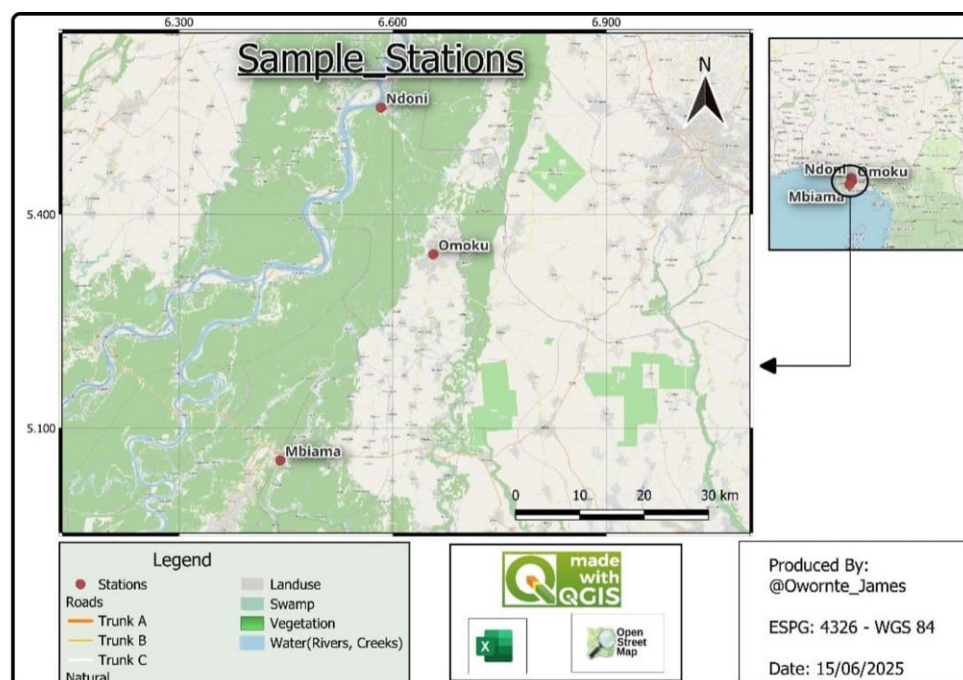


Figure 1: Map of the study area

Equipment used: The facilities of the Food Analysis Laboratory, Department of Food Science and Technology, Rivers State University, Port Harcourt, Rivers State were used for the work.

Procedure for Proximate Analysis: The proximate composition of the fish samples, including moisture, crude protein, crude fat, ash, crude fibre, and carbohydrate contents, was determined following the methods of the Association of Official Analytical Chemists (AOAC, 2000). Moisture Content: Determined by oven-drying the samples to constant weight. The difference between the fresh and dry weight was expressed as percentage moisture. Crude Protein: Estimated using the Kjeldahl method, where the nitrogen content of the sample was determined and converted to protein using the appropriate nitrogen-to-protein conversion factor. Crude Fat: Analyzed by Soxhlet extraction, in which lipids were extracted using an organic solvent and quantified as a percentage of the dry weight of the sample. Ash Content: Measured by incinerating the sample at 550 °C in a muffle furnace until all organic matter was burnt off, leaving the inorganic mineral residue expressed as percentage ash.



Crude Fibre: Determined by sequential acid and alkali digestion of the sample, with the residue weighed and expressed as a percentage of the original sample weight. Carbohydrate Content: Calculated by difference, subtracting the sum of moisture, crude protein, crude fat, and ash from 100% of the dry weight.

Statistical Analysis: The data were analyzed using a one-way ANOVA and Duncan's Multiple Range Tests to compare the mean values of the samples and to avoid error inherent in performing multiple *t*-tests. Results were tested for statistically significant differences at the 0.05 level.

Results

The results of the proximate composition show notable changes in the proximate composition of samples from Mbiama, Ndoni, and Omoku due to the drying process, with significant differences ($p < 0.05$) observed across most proximate parameters. Table 1 indicated that fresh samples from all locations exhibited significantly higher moisture content compared to the dried samples. Dried samples show a marked increase in protein content across all locations which suggests that drying is effective in enhancing protein concentration by reducing dilution from moisture. Percentages of ash composition, which represent the mineral content, the samples were significantly ($p < 0.05$) higher in dried samples than fresh samples. Crude fat levels decreased slightly post-drying in most locations, although the difference remained significant. Carbohydrate levels generally decreased in dried samples, particularly in Ndoni and Omoku.

Table 1: Proximate Composition of the fresh and dried *Gymnarchus niloticus* samples

Location	Sample	Moisture (%)	Ash (%)	Protein (%)	Crude fat (%)	Crude fibre (%)	Carb (%)
Mbiama	Fresh	65.89 ± 0.15*	2.4±0.007*	18.83±0.021*	9.79±0.296*	0.365±0.021*	2.725
	Dried	18.26±0.014*	6.86±0.057*	65.08±0.042*	7.16±0.028*	1.00±0.141	1.64±
Ndoni	Fresh	68.2 ± 0.014*	1.935±0.007*	14.98±0.028*	10.515±0.007*	0.25±0.014*	4.12±
	Dried	13.99±0.042*	5.43±0.014*	72.40±0.050*	4.765±0.021*	0.425±0.007*	2.99±
Omoku	Fresh	70.53±0.014*	1.89±0.00*	16.52±0.021*	7.24±0.028*	1.345±0.021*	2.48±
	Dried	15.03±0.021*	6.15±0.07*	69.31±0.035*	6.645±0.007*	1.31±0.014*	1.555

NB: Asterisks (*) indicate statistically significant differences ($p < 0.05$) mean

Discussion

Post-harvest processing and environmental conditions play a crucial role in shaping the nutritional and safety profiles of fish consumed in the Niger Delta region of Nigeria. Environmental factors such as water quality, temperature, and available feed have been



shown to influence fish composition, supporting earlier reports that the nutritional quality of fish varies with ecological conditions (Byrd *et al.*, 2020). Physiological and dietary variations among fish populations across locations may also contribute to differences in proximate composition (Ajibare *et al.*, 2023).

Drying, one of the most common preservation methods, substantially alters the proximate composition of fish. Moisture loss through drying is a well-established process that results in concentration of the dry matter (da Silva *et al.*, 2008). Previous studies have consistently reported significant reductions in moisture content of dried fish species, including mullet, carp, catfish, tilapia, Bonga shad, tongue sole, and barracuda (Adeyeye *et al.*, 2015; Tenyang *et al.*, 2020). However, disparities in moisture levels are often linked to variations in the drying method, intensity of heat, smoking duration, and type of kiln employed (Ajibare *et al.*, 2023). Safe moisture content levels for dried fish are generally recommended to be within 6–8% (Olayemi *et al.*, 2011). The reduction in moisture has direct implications on other proximate parameters. As water is lost, protein, fat, and ash content become relatively more concentrated in dried samples. Protein enrichment in dried fish has been widely documented, underscoring the role of drying in improving the protein density of fish as a dietary source (Tenyang *et al.*, 2020; Ajibare *et al.*, 2023). Factors such as fish size, stage of maturity, feeding practices, and environmental conditions also influence protein content (Jamabo and Nwaekpe, 2017). Similarly, increases in ash content after drying reflect the concentration of minerals following moisture loss, a pattern confirmed in multiple studies (da Silva *et al.*, 2008).

Fat, carbohydrate, and crude fibre contents tend to show less predictable patterns following drying. While some studies reported increases in lipid concentration with smoking and drying, others observe reductions, likely due to oxidative or thermal degradation of fats during processing (Ajibare *et al.*, 2023). Carbohydrates, though minor constituents in fish, often decrease due to degradation at high temperatures, despite their relatively small contribution compared to proteins, carbohydrates remain relevant as part of dietary intake (Anthony *et al.*, 2000).

Conclusion

This study provides valuable insights into the proximate composition of fresh and dried *Gymnarchus niloticus*, a freshwater species of nutritional and economic importance in Nigeria and sub-Saharan Africa. The analyses revealed that fresh samples were characterized by high moisture content and relatively lower concentrations of protein, ash, and other nutrients, while traditional drying significantly reduced moisture and concentrated protein, ash, and other proximate parameters. These compositional shifts confirm the role of drying not only as a preservation method but also as a means of enhancing the nutritional density of fish. The higher crude protein and mineral contents observed in dried samples demonstrated their potential as a superior dietary source in combating protein-energy malnutrition, particularly in regions where fish constitutes a major component of food security and livelihood.



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Leveraging Black Soldier Fly Larvae Production for Sustainable Entrepreneurship: Implications for the Green Economy in Nigeria

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Abstract

The increasing pressures of food insecurity, youth unemployment, environmental degradation, and inefficient organic waste management systems in Nigeria demand innovative and sustainable solutions. Black Soldier Fly Larvae (BSFL) production has emerged as a transformative strategy to address these challenges by converting organic waste into high-value protein for animal feed and nutrient-rich frass for soil fertility enhancement. This review synthesizes scholarly evidence on the biology, production systems, and value chain opportunities associated with BSFL, highlighting its integration into Nigeria's green economy framework. The paper explores the economic viability of BSFL production, emphasizing its potential to reduce livestock feed costs, generate green jobs, and foster circular economy principles. It also identifies key barriers—including social acceptability, infrastructural limitations, regulatory gaps, and safety concerns—that constrain BSFL adoption. Policy recommendations and research priorities are proposed to scale production and mainstream BSFL as a viable tool for sustainable entrepreneurship. The study highlights the critical role of BSFL in promoting environmental sustainability, economic diversification, and inclusive development in Nigeria.

Keywords: Bioconversion, BSFL, Circular economy, Insects, Organic waste

1. Introduction

Nigeria's expanding population presents several development issues, including food insecurity, high rates of youth unemployment, inflation, environmental degradation, and unsustainable waste disposal systems (Efenakpo *et al.*, 2025). Food insecurity particularly, has been made worse in many African nations by the "triple threat" of population increase, climate change, and economic downturns (Ssemukaaya *et al.*, 2024). On the other hand, the continuous increase in organic wastes generated worldwide is becoming an emerging threat to human health, biodiversity and the ecosystem (Siddiqui *et al.*, 2022). These multiple threats have consequently spurred the interest in alternative locally sourced and resilient solutions that will provide alternative protein sources, sustainable waste management, and eco-friendly agricultural inputs and production (Efenakpo *et al.*, 2016; Agbgounleri *et al.*, 2023). There is no doubt that the solutions to addressing these issues needs to be a robust innovative, long-term solutions that combine economic growth and environmental preservation.



Black Soldier Fly Larvae (BSFL) production, which has gained global popularity in recent years as a sustainable and alternative protein source for animal feed production, organic fertilizer, and waste management, is one of these alternatives (Ewusie *et al.*, 2019; Dortmans *et al.*, 2021). Like many other nations around the world, Nigeria has the potential to take advantage of the countless opportunities presented by the production of black soldier fly larvae for long-term, sustainable economic growth. The BSFL (*Hermetia illucens*), is an insect species that has garnered global recognition recently for its efficiency in converting organic waste into high-value protein and biofertilizer (Dortmans *et al.*, 2017; Siddiqui *et al.*, 2022). Its cultivation and utilization present a promising avenue for green entrepreneurship (Dortmans *et al.*, 2017).

This review examines the potential of BSFL production as a green entrepreneurship model that supports the principles of sustainability, inclusive economic growth, and ecological integrity. Also, the biology and ecology of the Black Soldier Fly, production technologies, economic and environmental benefits, and the policy environment in Nigeria. The paper further elucidates the implications for the circular economy and green job creation while identifying barriers and recommendations for mainstreaming BSFL production into national development strategies.

2. Biology and Ecology of the Black Soldier Fly

Black Soldier Fly (*Hermetia illucens*) is a non-pest and invasive, beneficial insect species belonging to the dipteran family Stratiomyidae (Ewusie *et al.*, 2019). Its native throughout the Americas, however are now found in every continent due to transfer during shipping (Pazmiño-Palomino *et al.*, 2022). The adult flies which measures about 16 millimeters are harmless and do not transmit diseases, making them safe for use in controlled environments (van Huis *et al.*, 2013; Mithun *et al.*, 2020; Ahmad *et al.*, 2021; Tumpa *et al.*, 2021). While their larvae are voracious feeders, capable of consuming and converting organic waste (agricultural, food, and animal waste) into protein and fatty acid rich biomass and residue rich in nutrients (Diener *et al.*, 2009; Banks *et al.*, 2014).

Like all insects, the BSF undergoes metamorphosis with the different life stages as shown in Figure 1. The egg is the starting stage of a BSF life cycle and it also marks the end of the previous life stage where a female BSF laying a cluster of eggs known as ovipositing (Dortmans *et al.*, 2021). The female BSF can deposit 400–800 eggs in tiny, dry, protected holes near organic waste that is degrading after which the female dies (Ahmad *et al.*, 2021; Dortmans *et al.*, 2021; Tumpa *et al.*, 2021). The eggs' proximity to the decomposing organic matter ensures that the newly hatched larvae will have their initial food source close by once they emerge. In addition, the organic matter also shields the eggs from predators, and the sheltered cavities keep the egg packets from drying out in the sun.

The eggs laid by BSF hatch after four days and the emerged cream-like colour larvae, which are barely visible, starts feeding voraciously on the decomposing organic matter and grow from less than one millimeter to around 2.5 cm length and 0.5 cm width (Dortmans *et al.*, 2021). The BSFL requires a period of 14 - 16 days to pupate (Dortmans *et al.*, 2017; Agbgounleri *et al.*, 2023). The larval stage is the only stage during which the BSF feeds and, therefore, it is during this time of larval development that enough fat reserves and protein are stored that allow the larvae to undergo pupation, emerge as flies, find mates, copulate and (as a female) lay eggs before dying (Dortmans *et al.*, 2021).

After having gone through five larval stages, the larvae reach the final larval stage: the prepupa. When transforming into a prepupa, the larva replaces its mouthpart with a hook-shaped structure and becomes dark brown to charcoal grey in colour. It uses this hook to easily move out and away from the food source towards a nearby dry, humus-like, shaded and protected environment that it deems safe from predators and this is where the imago emerge from the pupa and fly off without significant hindrance.

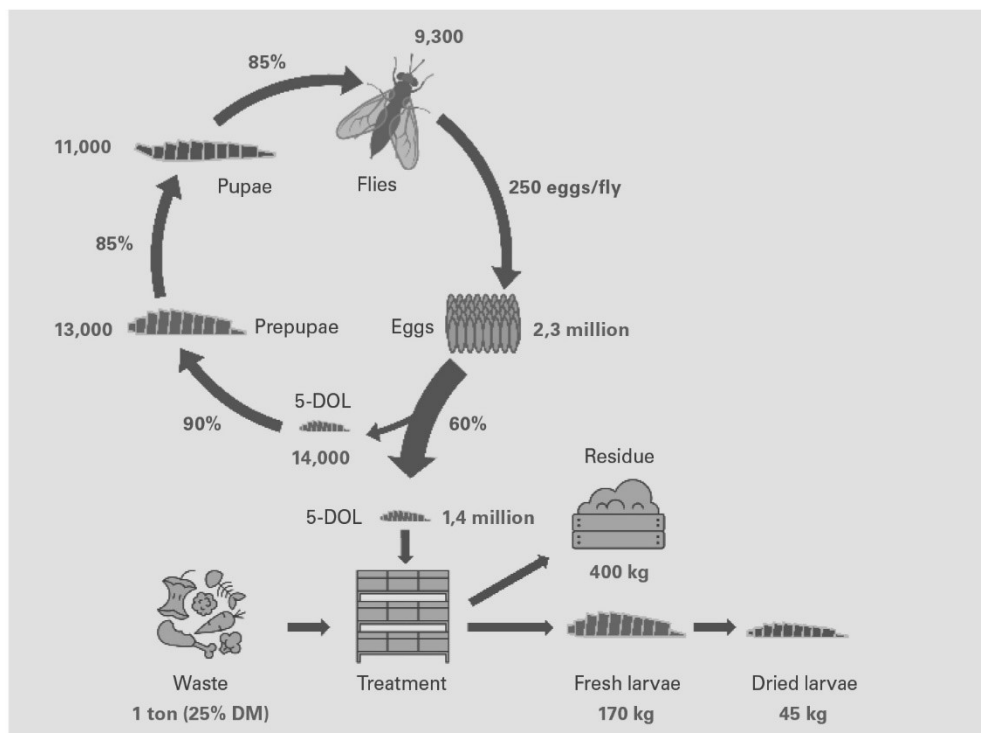


Figure 1: The metamorphic stages of BSFL with its Performance indicators
 Source: Dortmans *et al.* (2021)

Table 1: Key biological attributes of the BSFL

S/N	Attributes	Description	Authors
1	Rapid growth cycle	Larvae mature in about 14–18 days.	Dortmans <i>et al.</i> , 2021
2	High feed conversion efficiency	BSFL can convert up to 75% of organic waste into larval and residue biomass.	Dortmans <i>et al.</i> , 2017; Siddiqui <i>et al.</i> , 2022
3	Environmental adaptability	Thrives in tropical and subtropical climates like Nigeria.	Dortmans <i>et al.</i> , 2021
4	Nutritional composition	Larvae contain 35–45% protein and 30–40% fat, suitable for animal feed and aquaculture.	Dortmans <i>et al.</i> , 2017



3. Production Systems and Value Chain Opportunities for BSFL Production

The global demand for sustainable protein sources and effective waste management solutions has spotlighted the BSFL as a promising candidate (Ewusie *et al.*, 2019; Dortmans *et al.*, 2021). BSFL's ability to convert organic waste into high-protein biomass and nutrient-rich frass positions it as a key player in circular bioeconomy models (Siddiqui *et al.*, 2022). This review critically examines recent scholarly literature on BSFL production systems and explores value chain opportunities, emphasizing technological advancements, economic viability, and socio-environmental impacts.

3.1 BSFL Production Systems

BSFL production systems have evolved from rudimentary small-scale backyard setups to sophisticated commercial operations integrating automation and smart technologies (Dortmans *et al.*, 2021). The basic BSFL production systems involve the collection of organic waste, larval inoculation, growth in a bioconversion unit, harvesting, and processing. However, several models have been introduced in the production system over time to optimize the process. Avila *et al.* (2022) introduced a "smart bin" system equipped with sensors and automated aeration, optimizing larval growth conditions and reducing manual labor. Such innovations enhance scalability and consistency in larval production.

The BSFL production inputs and infrastructure system include—organic waste such as fruit peels, food waste, and livestock manure, BSF eggs or breeding colonies which could be purchased or trapped from the wild (Ewusie *et al.*, 2019), bioconversion units such as containers, trays, or reactors and harvesting and drying equipment. Substrate selection critically influences larval development and protein content. A systematic review by Hopkins *et al.* (2021) revealed that BSFL reared on fish waste exhibited the highest protein content (78.8%), while those fed on fruit and vegetable waste had the lowest (12.9%). This underscores the importance of substrate optimization in production systems.

3.2 Value Chain Components and Opportunities

BSFL production present an immerse value chain components and opportunities. The *upstream* value component, which involves the insect breeders, egg producers, input suppliers, the *midstream* value component which include the waste collectors, BSFL growers, and processors and the *downstream* value component which involves the animal feed manufacturers, farmers, aquaculture firms, organic fertilizer retailers. On the other hand, the opportunities can be categorized into the following; animal feed and fertilizer, bio-based products and economic viability

a) *Animal Feed and Fertilizer*

BSFL-derived products have garnered attention as sustainable alternatives in animal nutrition and agriculture. The larvae's high protein and lipid content make them suitable for poultry, aquaculture, and pet feeds (Salahuddin *et al.*, 2024). Simultaneously, BSFL frass (larval residue) serves as an organic fertilizer, enriching soils with essential nutrients and beneficial microorganisms (Siddiqui *et al.*, 2024a).

b) *Bio-based Products*

Beyond feed and fertilizer, BSFL biomass and extracted fats offers avenues for bioplastic production, biodiesel, and chitosan extraction. These applications align with circular



economy principles, promoting waste valorization and reducing reliance on fossil-based resources (Siddiqui *et al.*, 2024b).

c) *Economic Viability*

The BSFL industry has witnessed significant growth, with the global market valued at \$128 million in 2019 and projected to reach \$3.4 billion by 2030 (Wan and Zain, 2023). This expansion is driven by increasing demand for sustainable protein sources and waste management solutions.

3.3 Socio-Environmental Impacts of BSFL Production

BSFL production contributes to environmental sustainability by mitigating greenhouse gas emissions associated with organic waste decomposition. Moreover, it offers socioeconomic benefits, particularly in developing regions. Barragán-Fonseca *et al.* (2023) highlighted the potential of small-scale BSFL-fish farming models to enhance food security and provide income-generating opportunities for local communities.

Consumer acceptance is pivotal for market penetration. A study involving 4,412 participants across Ghana, Mali, and Niger revealed that 88% were willing to consume vegetables grown with BSFL frass, and 87% were open to meat from animals fed with BSFL (Traore *et al.*, 2024). This acceptance is indicative of a broader trend in sub-Saharan Africa towards embracing innovative and sustainable agricultural practices. The willingness to consume such products is likely influenced by various factors, including the need for sustainable food sources, economic considerations, and evolving dietary preferences in the region.

BSFL production systems present multifaceted opportunities across various sectors, from agriculture to bio-based industries. Advancements in technology and growing consumer acceptance underscore its viability as a sustainable solution for protein production and waste management. Thus, addressing existing challenges in BSFL production through targeted research and supportive policies will be instrumental in realizing the full potential of BSFL in the global value chain.

4. BSFL Production and the Green Economy in Nigeria

Nigeria is actively exploring sustainable solutions to address pressing challenges in waste management, food security, and economic development. The green economy emphasizes resource efficiency, low-carbon growth, and social inclusion. BSFL production aligns with these principles in multiple ways. Hence, BSFL production has emerged as a promising avenue, aligning with the principles of the green economy by promoting resource efficiency, reducing environmental impact, and fostering inclusive growth.

4.1 Waste Management and Environmental Sustainability

Nigeria generates approximately 32 million tons of food waste annually, contributing significantly to greenhouse gas emissions and environmental degradation (Nnoli *et al.*, 2024). BSFL production offers a circular solution to organic waste challenges in urban and rural areas by reducing landfill reliance and greenhouse gas emissions while transforming waste into productive inputs. Consequently, its farming offers an innovative approach to mitigate these wastes and enhance environmental sustainability.



The larvae efficiently convert organic waste, including food scraps and agricultural residues, into high-protein biomass and nutrient-rich frass. This process not only reduces the volume of waste but also minimizes methane emissions associated with traditional waste decomposition methods. For instance, the Lagos State Waste Management Authority (LAWMA) has initiated projects utilizing BSFL to manage organic waste in markets and households, aiming to improve sanitation and reduce waste accumulation in the city (Adesina, 2024).

4.2 Economic Opportunities and Livelihood Enhancement

BSFL production presents significant economic opportunities, particularly in the agricultural sector. The larvae serve as a cost-effective alternative to traditional animal feed ingredients like fishmeal and soybean meal, which are often expensive and imported (Raman *et al.*, 2022). By reducing reliance on these conventional feeds, BSFL farming can lower production costs for livestock and aquaculture farmers. BSFL farming can also create diverse employment opportunities, from waste collection to larvae processing and product marketing. Youth and women, particularly in rural areas, can benefit from low-capital entry into the insect farming sector.

In Ibadan, Oyo State, a startup named Athair Farms has successfully established a BSFL farm, producing affordable and nutritious feed for poultry and fish farmers (Adesina, 2024). This initiative has led to significant cost savings and improved productivity for local farmers. Moreover, according to Essiet (2024), the Agricultural Social Entrepreneurship Foundation (ASEF) has partnered with international organizations to train 100,000 Africans, including 40,000 Nigerians, in insect farming. This program aims to empower individuals with income-generating skills in the BSFL value chain, contributing to poverty reduction and economic diversification.

4.3 Contribution to Sustainable Agriculture Production

BSFL-based feed and fertilizer improve livestock productivity and soil health, contributing to resilient food systems. The frass produced by BSFL is a nutrient-rich organic fertilizer that enhances soil fertility and promotes sustainable agriculture. Utilizing BSFL frass can reduce dependence on chemical fertilizers, leading to improved crop yields and environmental conservation. Field experiments have demonstrated that maize crops treated with BSFL frass yielded 29–44% higher net income compared to those using commercial organic fertilizers (Beesigamukama *et al.*, 2022).

This highlights the potential of BSFL by-products to contribute to food security and sustainable farming practices in Nigeria (Agbgounleri *et al.*, 2023). The substitution of fishmeal with BSFL can reduce overfishing and supports biodiversity conservation. BSFL production aligns with Nigeria's green economy objectives by offering sustainable solutions for waste management, enhancing agricultural productivity, and creating economic opportunities. With strategic investments and policy support, BSFL farming can play a pivotal role in Nigeria's transition towards a more sustainable and inclusive economy.

4.4 Climate Change Mitigation

BSFL production also contributes to climate mitigation efforts by offsetting emissions from waste decomposition and reducing demand for fishmeal and soybean (Agbai, 2024). Greenhouse gas emissions from BSFL production and processing are lower compared to those from conventional waste breakdown and composting. BSFL effectively breaks down



waste without producing a lot of gas emissions, in contrast to ruminant animal husbandry, which produces methane that contribute to greenhouse gases.

5. Market Potential and Economic Viability of BSFL

The market for insect protein was projected to value at USD 1.05 billion in 2024 and is expected to reach USD 6.16 billion by 2032 (DBMR, 2025). Environmental concerns and a drive to lower carbon footprints in food production are the main causes of this growth, which is ascribed to growing awareness of sustainable and eco-friendly protein substitutes. Nigeria's growing demand for affordable and sustainable livestock feed, presents a lucrative opportunity for BSFL production (Agbgounleri *et al.*, 2023). The country's burgeoning population which exceeds 200 million and growing at approximately 3% annually, generates an estimated 50 million tonnes of organic waste each year (Agbai, 2024). This abundant waste stream provides a substantial resource for BSF larvae production. The larvae thrive in Nigeria's favorable climate, with optimal temperatures between 24–30°C, facilitating year-round cultivation.

According to Cherdthong (2025), the global market for BSF larvae is projected to reach \$3.96 billion by 2033, reflecting a compound annual growth rate driven by the demand for sustainable protein sources. Nigeria, with its significant livestock and aquaculture sectors, stands to capture a substantial share of this market. The country's feed industry, which accounts for 5–10% of Africa's total demand, is poised for transformation through the integration of BSF larvae into feed formulations.

5.1 Economic Viability

BSF larvae production presents a cost-effective alternative to traditional feed ingredients and protein sources—fishmeal, soybean—enhancing profitability for livestock producers. Farmers have reported that rearing up to two tonnes of BSF larvae can yield a return on investment of approximately ₦1,000,000 monthly (Meenakshisundaram *et al.*, 2024). This profitability is attributed to the larvae's high protein content, ranging from 28% to over 48%, and lipid levels between 12% and 42%, comparable to fishmeal.

The decentralized nature of BSF farming allows for localized production, reducing transportation costs and ensuring fresh supply to nearby markets. In Kaduna, for instance, BSF larvae are sold at approximately ₦600 per kilogram, compared to ₦800–₦900 per kilogram in Lagos, highlighting the economic advantages of regional production networks (Ohabughiro, 2025).

Moreover, the integration of BSF larvae into animal feed can significantly reduce feed costs, which constitute up to 70% of livestock production expenses in Nigeria. By substituting imported protein sources with locally produced BSF larvae, farmers can enhance profitability and resilience against market fluctuations.

5.2 Consumer Acceptance and Willingness to Pay

Consumer acceptance is pivotal for the successful commercialization of BSF-based products. Traore *et al.*, (2023) noted that consumers across Ghana, Mali, and Niger were willing to consume vegetables grown with BSF frass fertilizer, and meat from animals fed with BSF larvae. While willingness to pay a premium was moderate, the findings indicate a favorable



perception of BSF-derived products, suggesting potential for market growth with appropriate education and marketing strategies.

The production of BSFL presents a viable pathway toward sustainable entrepreneurship and economic diversification in Nigeria. By leveraging the country's abundant organic waste and favourable climatic conditions, BSF farming can contribute to food security, environmental sustainability, and income generation. Strategic investments, policy support, and consumer education are critical to realizing the market potential and economic benefits of this innovative sector.

6. Challenges and Barriers of BSFL Production in Nigeria

The production of Black Soldier Fly Larvae (BSFL) in Nigeria faces several challenges and barriers, despite its potential as a sustainable protein source for poultry feed. These challenges are multifaceted, encompassing social, economic, environmental, and safety concerns. Understanding these barriers is crucial for developing strategies to enhance BSFL production in Nigeria.

6.1 Social and Cultural Barriers

Cultural resistance which often spurred from poor perceptions of insects due to knowledge gap often make people perceive insects as dirty or unsafe and hinder BSFL acceptance.

- a) **Consumer Acceptance:** While there is a high level of acceptability among poultry farmers in Oyo State, Nigeria, broader consumer acceptance remains a challenge. This is partly due to limited awareness and cultural perceptions about using insects as feed ingredients (Olutegbe and Ojuoluwa, 2022).
- b) **Knowledge and Education:** Although knowledge levels among farmers are relatively high, there is still a need for widespread education and awareness campaigns to increase acceptance and understanding of BSFL benefits (Olutegbe and Ojuoluwa, 2022).

6.2 Economic and Resource Challenges

- a) **Cost and Investment:** The initial investment and operational costs for setting up BSFL production facilities can be prohibitive. There is a need for cost-effective solutions and government support to make BSFL production economically viable (Purnamasari *et al.*, 2022).
- b) **Land and Space Availability:** The unavailability of land and space for BSFL production is a significant constraint, particularly in urban areas where land is scarce and expensive (Olutegbe and Ojuoluwa, 2022).
- c) **Market awareness:** Lower consumer and farmer knowledge gap about BSFL benefits of hinders its growth in Nigeria.
- d) **Infrastructure and funding:** Inadequate access to capital, processing facilities, and market linkages is also a major challenge to BSFL production in Nigeria.

6.3 Environmental and Safety Concerns

- a) **Safety Issues:** The safety of BSFL as a feed ingredient is a major concern due to potential microbiological, chemical, and physical contaminants. Ensuring the safety of



the entire value chain, from rearing substrates to processing methods, is critical (Purnamasari and Khasanahb).

- b) **Pathogen and Contaminant Risks:** There are concerns about the presence of pathogens and contaminants in BSFL, which require effective mitigation strategies to ensure safe production (Raman *et al.*, 2022; Mufungwe *et al.*, 2024).

6.4 Technological and Operational Barriers

Technical knowledge gaps which include limited expertise in BSFL biology and production systems often hinders BSFL production.

- a) **Manual Labor and Automation:** The reliance on manual labor for rearing BSFL can be a barrier to scaling up production. Innovations such as automated rearing systems can help reduce labor costs and improve efficiency.
- b) **Regulatory Uncertainty and Institutional Support:** Lack of clear policies on insect farming, feed safety, and organic fertilizer use. There is a need for better coordination between regulatory authorities and the establishment of clear guidelines and standards for BSFL production (Purnamasari *et al.*, 2022).

While these challenges are significant, they also present opportunities for innovation and development. Addressing these barriers through targeted interventions, such as policy support, technological advancements, and public education, can enhance the viability of BSFL production in Nigeria. Additionally, exploring alternative substrates and improving safety protocols can further support the growth of this industry. Future research should focus on optimizing rearing substrates, enhancing automation technologies, and conducting comprehensive life cycle assessments to quantify environmental benefits. Collaborative efforts between stakeholders, including policymakers, researchers, and industry players, are essential to unlock the full potential of BSFL in sustainable development.

7. Policy and Institutional Framework for the integration of BSFL into Nigeria's national development and environmental strategies

The integration of Black Soldier Fly Larvae (BSFL) into Nigeria's national development and environmental strategies necessitates a comprehensive policy and institutional framework that addresses their potential in waste management, sustainable agriculture, and food security. The larvae's ability to convert organic waste into valuable biomass positions them as a promising tool for tackling waste management challenges and providing an alternative protein source for animal feed. However, the lack of clear legislation and institutional support in Nigeria hinders the full realization of these benefits. Hence, to establish a solid legislative framework, specific legislation is needed to guide the rearing, consumption, and commercialization of BSFL in Nigeria, which would help harness their potential for environmental sustainability and food security (Vadivelu and Asaithambi, 2024). Additionally, establishing regulatory standards for BSFL production and processing is crucial to ensure safety and quality, addressing concerns about microbial and chemical safety (Usman and Yusuf, 2020).

Institutional support is also vital, with investment in research and development being crucial to optimize BSFL rearing conditions and enhance waste conversion efficiency. This includes understanding the optimal environmental conditions for BSFL growth and waste management



(Salahuddin *et al.*, 2024). Furthermore, capacity-building initiatives such as training programs for farmers and waste managers can significantly improve the adoption of BSFL technologies, leading to better waste management practices and an increased protein supply for animal feed (Cifuentes, 2022).

From an environmental and economic perspective, BSFL can effectively treat organic waste, thereby reducing the burden on municipal waste systems and contributing to environmental sustainability (Purkayastha *et al.*, 2022). The economic viability of utilizing BSFL in waste management and as a protein source can also reduce costs and increase profitability for farmers, supporting economic development.

Moreover, social acceptance and market development are critical components of this integration. Building consumer confidence through awareness campaigns and marketing strategies can enhance the acceptance of BSFL products (Vadivelu and Asaithambi, 2024). Additionally, developing infrastructure for the production and distribution of BSFL products will facilitate market growth and integration into national development strategies (Purkayastha *et al.*, 2022).

While the potential of BSFL in Nigeria is significant, challenges such as social acceptance, market development, and regulatory barriers must be addressed. A holistic approach involving legislation, institutional support, and public engagement is essential for effectively integrating BSFL into Nigeria's development and environmental strategies. This integration can contribute to sustainable agriculture, improved waste management, and enhanced food security, aligning with both national and global sustainability goals.

8. Research and Innovation Priorities to scale BSFL production

Scaling Black Soldier Fly Larvae (BSFL) production requires addressing several research and innovation priorities to enhance efficiency, productivity, and sustainability. These priorities encompass the integration of technology, optimization of feed formulations, and addressing cultural and regulatory considerations. Each of these areas plays a crucial role in the successful expansion of BSFL production systems.

The integration of technology is vital for improving BSFL rearing efficiency. The use of semi-automated systems, such as IoT-based cabinets, can significantly enhance production by utilizing platforms like Raspberry Pi and Arduino to automate feeding and monitor environmental conditions, thereby reducing labor and time requirements (Suwannayod *et al.*, 2022). Additionally, smart digital technologies, including multi-sensor monitoring and AI-driven data analysis, can further optimize BSFL production by improving decision-making and intervention strategies (Siddiqui *et al.*, 2022).

Optimizing feed formulations is another essential priority for maximizing the nutrient content of BSFL. This involves experimenting with different organic waste compositions to identify optimal conditions for larvae growth and nutrient conversion (Danieli *et al.*, 2019). Efficient feed conversion not only enhances the nutritional value of BSFL, but also contributes to waste reduction, aligning with sustainable production goals (Siddiqui *et al.*, 2024).

Cultural and regulatory considerations are also critical for the successful scaling of BSFL production. Addressing cultural and religious concerns, such as the halal status of BSFL-fed



animals, is crucial for market acceptance. Ensuring that BSFL use complies with religious dietary laws can expand its use in diverse markets (Jamaludin *et al.*, 2024). Moreover, regulatory frameworks need to be developed to support the safe and sustainable scaling of BSFL production, ensuring compliance with environmental and health standards (Jamaludin *et al.*, 2024).

While these priorities focus on enhancing BSFL production, it is also important to consider the broader context of agricultural innovation. Similar to the challenges faced in other sectors, such as sustainable crop production and manufacturing, BSFL production can benefit from interdisciplinary research and collaboration. This approach can help bridge gaps in technology adoption and regulatory frameworks, ultimately supporting the sustainable intensification of BSFL systems.

9. Conclusion and Recommendation

The production of Black Soldier Fly Larvae (BSFL) presents a transformative opportunity for Nigeria, addressing critical challenges such as food insecurity, waste management, and economic diversification. As outlined in this review, BSFL farming not only provides a sustainable protein source for animal feed but also contributes to environmental sustainability through efficient organic waste conversion. The integration of BSFL into Nigeria's agricultural framework aligns with the principles of the green economy, fostering resource efficiency and inclusive growth which also supports multiple SDGs, particularly those on zero hunger, decent work, and climate action. Despite the promising potential of BSFL production, several barriers hinder its widespread adoption. These challenges include social acceptance, regulatory frameworks, and the need for technological advancements. To harness the full potential of BSFL, a multi-faceted approach is essential.

To harness the full potential of Black Soldier Fly Larvae (BSFL) production in Nigeria, a multi-faceted approach is essential. This includes establishing comprehensive legislation to support BSFL rearing and commercialization, alongside regulatory standards ensuring safety and quality. Investing in research initiatives focused on optimizing production systems and enhancing technological advancements is crucial. Additionally, implementing training programs will educate farmers and waste managers about BSFL benefits and techniques, while public awareness campaigns can address cultural perceptions to enhance consumer acceptance. Infrastructure development for production and processing, combined with fostering partnerships among government, NGOs, and the private sector, will create an enabling environment. Finally, encouraging market linkages for BSFL products can promote economic opportunities and job creation, positioning Nigeria as a leader in sustainable agricultural practices.



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Effect of Different Ashing Temperatures on Some Nutrient Content of Palm Kernel Shell Ash

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Abstract

The increasing generation of palm kernel shell (PKS), a by-product of palm oil processing, presents both an environmental challenge and an opportunity for resource recovery in developing economies. The experiment was conducted at John Ker Farms, Ikot Ekpene Local Government Area in Akwa Ibom State, Nigeria. This study investigated the effect of different ashing temperatures (200–1000°C) on the physical and chemical properties of palm kernel shell ash (PKSA), with particular focus on soil fertility as a major potential for soil amendment. Results revealed that PKSA pH ranged from slightly acidic (5.92) to weakly alkaline (9.37), indicating its potential as a liming material for acidic soils. Electrical conductivity values were low (0.23–3.34 ds/m), suggesting suitability for reducing salinity stress and supporting diverse soil microbial activity. Mineral analysis showed calcium content of 18–48 mg/kg, magnesium 60–96 mg/kg, phosphorus 30–165 mg/kg, potassium 6.6–16.1 mg/kg, sodium 1.4–2.2 mg/kg, and iron 9.1–11.8 mg/kg. Calcium, magnesium, and phosphorus contents were particularly enhanced with ashing, demonstrating improved potential for soil fertility management. Conversely, iron content decreased with higher ashing temperatures. Overall, the findings indicate that PKSA at 600 °C appear suitable for high yields of crops, this should be produced for sustainable crop production. The study revealed that the ash from palm kernel shell from different temperatures contains macro-nutrients and micro-nutrients which are essential for life development in both plant and animal. However, these elements vary in concentrations but are present in amount that can be utilized purposefully. It can thus be concluded that the Palm Kernel Shell Ash, which are good sources of these essential elements, therefore makes these agricultural waste materials suitable, cheap and ready for use.

Keywords: Palm kernel shell, Temperature, Ash, Nutrient

Introduction

The increasing global emphasis on sustainability, resource optimization, and environmental protection has led to a growing interest in the beneficial use of agricultural residues. One of the critical areas of focus is the valorization of biomass waste, particularly those that are underutilized or discarded as waste in developing countries. Among these residues, palm kernel shell (PKS), a by-product of palm oil processing, has emerged as a potential resource for several industrial applications (Ukonu *et al.*, 2021). In palm oil-producing countries such as Nigeria, Indonesia, and Malaysia, PKS is generated in large quantities, often without proper disposal or productive use, resulting in environmental degradation and resource



inefficiency. Palm kernel shells are hard endocarp waste obtained after the extraction of palm kernel oil. Traditionally, they have been used as fuel in boilers, but their full potential remains largely. When subjected to controlled thermal treatment (ash production), PKS transforms into Palm Kernel Shell Ash (PKSA) — a siliceous material with a high concentration of oxides such as silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3), which can impart pozzolanic properties (Mary *et al.*, 2019). The chemical composition and physical structure of PKSA are highly dependent on the ashing conditions, particularly temperature and duration. The ashing temperature significant

ly influences properties such as color, fineness and mineral content. To optimize the utility of PKSA in industrial applications, it is essential to understand how varying ashing temperatures affect its physical properties (such as pH, moisture content, electrical conductivity, and ash weight) and chemical composition Coxe-Interlambor *et al.* (2022). This knowledge will provide a scientific basis for determining ideal processing conditions for producing high-quality PKSA suitable for agricultural and environmental uses Inetianbor *et al.* (2024). Furthermore, existing studies have largely focused on the general properties of PKSA at a single or arbitrary temperature, without systematically analyzing how different temperature levels affect both the physical and chemical properties. Without such data, stakeholders in agriculture, construction, manufacturing, and environmental management cannot confidently adopt PKSA as a reliable material. Gap in the knowledge creates a critical barrier to the sustainable and scalable utilization of PKS waste. The Objectives of the study are to investigate the effect of different ashing temperatures on some nutrient content of palm kernel shell ash. To produce PKSA at selected temperatures (e.g. 200 °C, 400 °C, 600 °C, 800 °C and 1000 °C) under controlled conditions. To determine and compare some chemical properties of the ash at each temperature levels. To recommend the optimal temperature range for producing high-quality PKSA suitable for soil fertility management.

Materials and Methods

The experiment was conducted at John Ker Farms, Ikot Ekpene Local Government Area in Akwa Ibom State, Nigeria. This area is located between Latitude: 5° 09' 315" N and Longitude: 7° 42' 618" E in a humid tropical climate and rainforest vegetation characterized by high rainfall with distinct wet and dry seasons. The rainy season normally starts from March to Late October following the dry season from, Ikot Ekpene Local Government Area in Akwa Ibom State, Nigeria. Palm Kernel Shell (PKS) was sorted to remove unwanted materials such as stone, wood and so on. The PKS was washed and then sun-dried for 72 hours at ambient temperature to reduce the moisture content inherent in them. This was carried at the laboratory in the Department of Soil Science and Land Resources Management, Faculty of Agriculture, University of Uyo. The dried PKS were packed inside cellophane bags and sealed, before pulverization. The dried PKS were crushed into smaller particles using a mortar and pestle and sieved to a 30µm size. The crushed PKS were then burnt in a Nabertherm furnace at 200°C for 20 minutes to obtain palm kernel shell ash (PKSA). Some of the PKSA produced were further subjected to temperatures of 400°C, 600°C, 800°C and



1000°C for about 2 hours, respectively. The pH of the PKSA was measured a known weight of the PKSA was dissolved in a known volume of deionised water and stirred to obtain a homogenous mixture. The pH of the mixture was thereafter determined with the aid of a pH meter (Hanna Combo pH meter, model: HI 98 129). The moisture content of some of the PKS was determined using Nabertherm Furnace standard at 30-300°C in an oven (Nabertherm, Model number: LE6/11/B150) in the Animal Science Laboratory, University of Uyo, Nigeria. Other physical properties such as ash content, pH, and Electrical conductivity were determined by following the method as described by Ikubanni *et al.* (2020). A measured quantity (2 g) of the PKSA was put in a Kjeldahl flask; 20ml of concentrated nitric acid (HNO₃) was added and sample was digested by heating, clear digest was obtained, cold and filtered into a 50 ml volumetric flask through a Whatman (No. 42), 150mm diameter filter paper and was made up to mark with distilled water. The resultant solution was analysed for mineral elements using the Atomic Absorption Spectrophotometer. The Temperatures Levels are as follows; T0 – Control, T1 - 200°C, T2 - 400°C, T3 - 600°C, T4 - 800°C and T5 - 1000°C. This research adopted Completely Randomized Design (CRD) for statistical analysis. The experiment consisted of six treatment levels of which each were replicated three times. The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a package program, Statistics 10 software. The significant differences among the treatment means were compared using Duncan Multiple Range Tests to compare group means and interpret results.

Results and Discussion

Results of the mineral elements shows that palm kernel shell ash have these elements in varied concentration as presented in Figures 1– 8. Nutrient concentrations in plants vary with plant species (Ukonu *et al.*,2021) and also cultivation location. In palm kernel shell (control) and palm kernel shell ash subjected to different temperatures, pH ranged from 5.92 to 9.37 as presented on Figure 1, this indicates acidic conditions at 0 °C and 200 °C, while alkaline were recorded in the other temperatures, were significantly different from each other at $P < 0.05$. At 600 °C, the pH of the ash was slightly neutral to weakly alkaline at 1000 °C this indicates that the pH of ashed palm kernel is slightly alkaline, similar values were reported by Ukonu *et al.* (2021). The results show that where the palm kernel shell is not ashed. And it is added to the soil, the acidic condition of the soil will increase, but where it starts ashing at 600 °C – 1000 °C, the PKSA is a good source of liming materials, could be used for management of acidic soil conditions. Most nutrients are available in slightly acidic to neutral soils (pH 6.0 – 7.5), Sundalian *et al.* (2021).

Electrical conductivity of the palm kernel shell (control) and palm kernel shell ash from 0°C to 1000°C indicates Low Electrical conductivity (Ec) as shown in Figure 2. The Electrical conductivity values ranges from 0.23 - 3.34 ds/m. According to Dungani *et al.* (2018), low electrical conductivity in soil generally indicates lower levels of soluble salts, which helps to reduce salinity stress on plants, promoting healthier growth and reducing the risk of yield losses. Low EC can also lead to a more balanced nutrient uptake by plants, support a more diverse and healthy soil microbial community. Manoj *et al.* (2012) states that most crops



grow best in soil with low to moderate EC levels < 4 ds/m. This shows that the palm kernel shell (Control) and palm kernel shell ash at different temperatures are suitable for Halomorphic conditions according to Utford (2021).

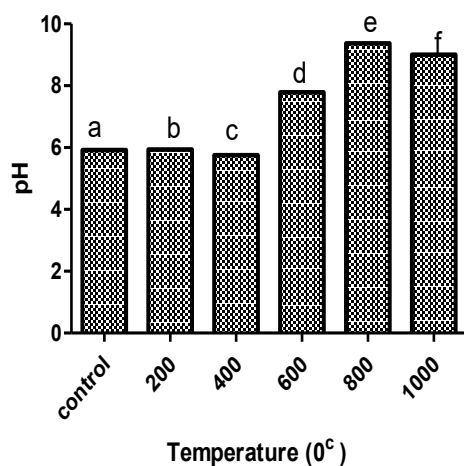


Figure 1; The effects of different temperatures on pH. Conductivity.

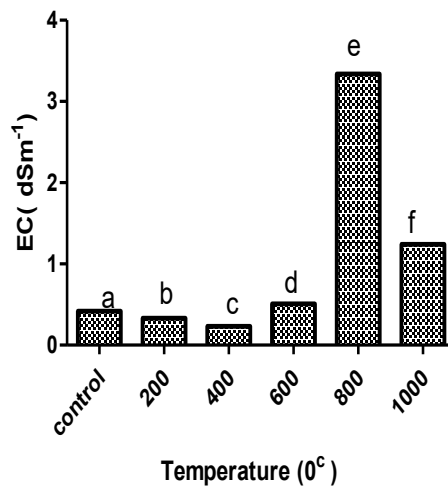


Figure 2; The effects of different temperatures on Electrical

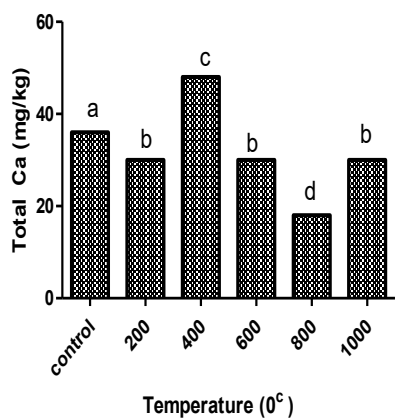


Figure 3; The effects of different temperatures on Ca content.

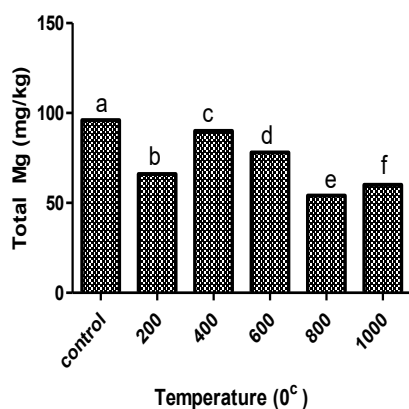


Figure 4; The effects of different temperatures on Mg



At the end of the ashing process, total calcium content ranges from 18 - 48 mg/kg. Palm kernel shells (control) and PKSA had different values. Temperature values at 200°C, 600°C and 1000°C were not significantly different from each other at $P < 0.05$, but 400°C and 800°C were significantly different from each other. This shows that PKSA at 400°C and 800°C will produce better results. Meanwhile, report from Ukonu *et al.* (2021) reported 33.14 mg/kg in palm kernel ash, while Inetianbor *et al.* (2024) reported 15.00mg/kg of calcium in palm kernel shells, and coconut shells had 24.00mg/kg. Results from Figure 3 show that the palm kernel shell and PKSA are good sources of liming materials that could be used to lime acidic soils, therefore improving conditions for plant growth, and essential nutrients for plants, improving soil structure and supporting microbial activity. Magnesium content, as shown on Figure 4; ranges from 60 – 96mg/kg. Palm kernel shell (control) had 96mg/kg. During the ashing process with different temperature 400°C had the highest value of 90mg/kg and was significantly different from other Temperatures at $P < 0.05$. This result is similar to the result reported by Inetianbor *et al.* (2024); indicating that magnesium plays a significant role in carbohydrate metabolism, nucleic acids and binding agents of cell walls in plants (Sunday *et al.*, 2016). Magnesium also supports photosynthesis, chlorophyll formation and enzyme activation in plants. Thus, adequate magnesium levels support balanced soil fertility and plant health. Thus, the PKSA also serves as a good source of liming materials that will help reduce acidity and improve crop yield, etc. Phosphorus content, as shown on Figure 5; were affected by different temperature readings; P in the PKS and PKSA ranged from 15.00 – 82.5 mg/kg. As the temperature increases from 200°C, the P content also increases and they were all statistically different at $P < 0.05$. According to Manoj *et al.* (2012). Higher temperatures can stimulate microbial activity, including those that produce phosphatase, enzyme that breaks down organic phosphorus (P) into inorganic forms available for plants; therefore, the results show that the higher the temperature, the higher the quantities of phosphorus present in the PKSA materials. Results shown on Figure 6; indicates that Potassium (mg/kg) ranged from 6.6 - 16.1 (mg/kg). PKS control had 73 mg/kg, while the value for the K increases as the temperature increases. There was no significant difference at $P < 0.05$ at 600 °C and 800 °C. According to Inetianbor *et al.* (2024). Ash, especially from PKS or wood, can be a good source of potassium. but the exact amount varies depending on the source material and burning conditions. Hardwood and PKS generally contain more K than softwood ashes. The result above shows that K when applied to the soil, will improve plant health, soil fertility, enhances water retention, strengthens plant tissues and aid in nutrient transport, leading to increased crop yields and disease resistance. It could also serve as a liming agent according to Obuika *et al.* (2018). The amount of Sodium (Na) present in the ash subjected to different temperature ranges is shown on Figure 7; Na ranges from 1.37 – 2.17 mg/kg. It is clearly shown that 400°C had the least content of Na present in the ash. The Na content was generally low. According to Inetianbor *et al.* (2024), if sodium is high, it may affect the soil structure, impact water quality, and cause soil salinity. All the temperature ranges show the PKS and PKSA are good sources of liming materials. Iron (Fe) values were shown on Figure 8; the values ranged from 9.09 – 11.82 mg/kg. As the PKS were subjected to different temperatures, the content of the Fe decreased; thus, the higher the temperature, the lower the



Fe content. According to Ukonu *et al.* (2021) 10.02mg/kg was reported this result is also similar to the values presented on Figure 8.

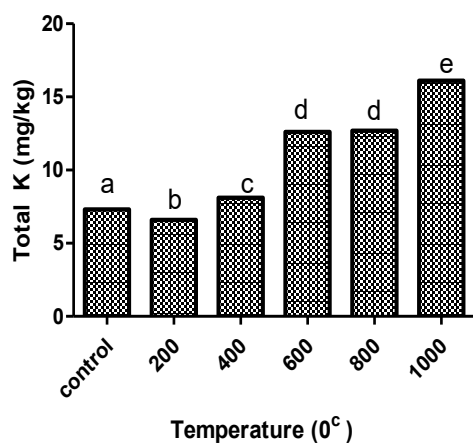
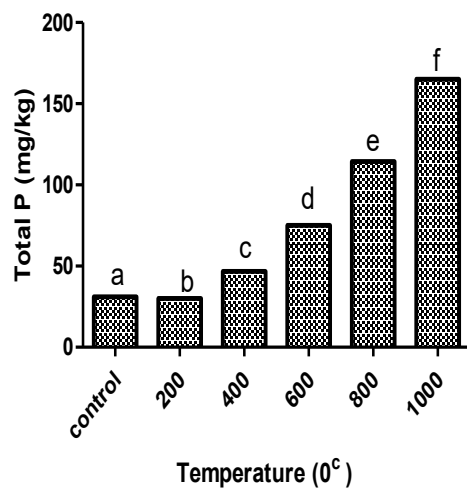


Figure 5: Showing effects of different temperatures on P

content

Figure 6: Showing effects of different temperatures on K content

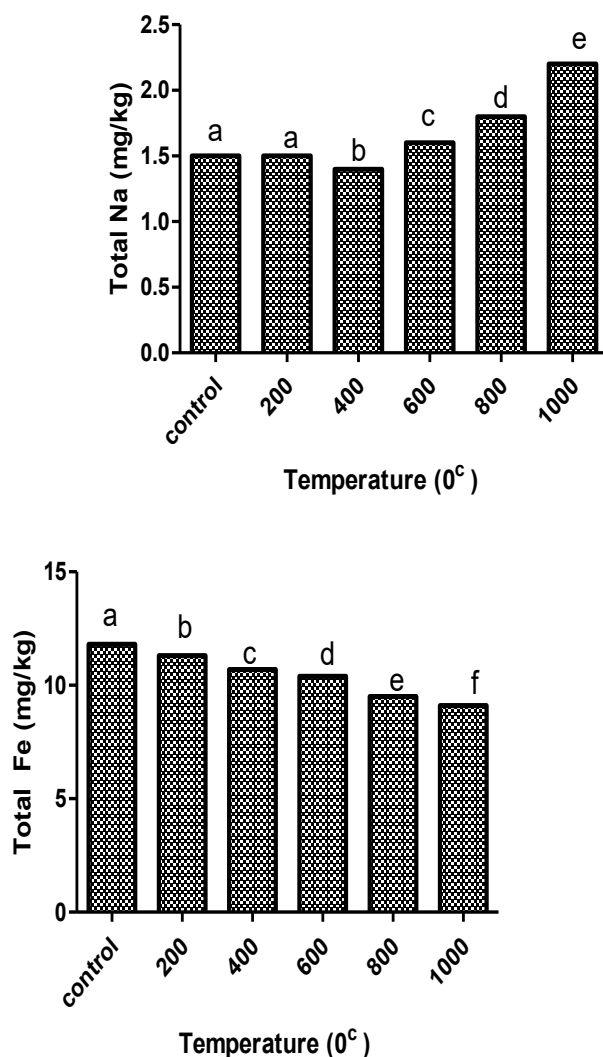


Figure 7: The effect of different temperatures on Na content. Figure 8: The effect of different temperatures on Fe content.

Summary, Conclusion and Recommendation

Soil fertility management enhances and ensures sustainable agriculture production and guarantees healthy living. Supplying the soil with essential plant nutrients, creating conducive environment for soil organisms and conserving the soil for continuous use are important indices of soil fertility management. Palm kernel shell charcoal offers a range of benefits when applied to agricultural soil. From improving soil structure to enhancing nutrient retention, its impact on agriculture is multifaceted and far-reaching. The porous nature of palm kernel shell charcoal contributes to improved soil structure. When incorporated into the soil, it enhances aeration by creating channels for the movement of air, water, and nutrients. Additionally, the charcoal's porous structure aids in water retention, preventing excessive drainage and promoting optimal moisture levels for plant growth. Palm



kernel shell charcoal act as a natural fertilizer, enriching the soil with essential nutrients. Its carbon-rich composition promotes the growth of beneficial microorganisms, which play a vital role in nutrient cycling and availability. The study revealed that the ash from palm kernel shell from different temperature contains macro-nutrients and micro-nutrients which are essential for life development in both plants and man. However, these elements vary in concentration, but are present in amount that can be utilized purposefully. It can thus be concluded that the Palm Kernel Shell Ash which are good source of these essential elements, makes these agricultural waste materials suitable, cheap and ready for use. Organic wastes such as ash from Palm Kernel Shell should be recycled and processed into valuable products for soil fertility management. Palm Kernel Shell Ash (PKSA) at 600 °C produces better nutrient composition than other temperatures. Organic wastes from Palm Kernel Shell Ash (PKSA) therefore, are a good source of liming materials for acidic soils, which will help improve soil fertility and crop yield.

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Effect of Powdered Sections of *Ocimum gratissimum* (Scent Leaf) in the Management of *Meloidogyne incognita*-infected Okra

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Abstract

Meloidogyne species contribute to poor growth and yield of okra. *Ocimum gratissimum* (OG) has been reported effective in their management. There is paucity of information on the contribution of each section of the plant to its nematicidal efficacy. A potted experiment laid out in a completely randomized design was carried out to determine the nematicidal efficacy of sections of OG (flower, leaf, stem and roots) in the management of *Meloidogyne incognita* (MI)-infected okra. Two-weeks old okra were inoculated with 5000 eggs of MI each, except uninoculated treatments. Powdered sections of OG and carbofuran were applied at one week after inoculation (WAI) to okra as treatments, except uninoculated control okra. Data were collected on growth parameters such as fresh shoot weight, gall index (GI), nematode population and reproductive factor. Data were analyzed using analysis of variance and means separated using least significant difference. Sections of OG significantly ($P \leq 0.05$) improved the growth of infected-treated okra. In fresh shoot weight, OGstem, OGleaf, OGroot, OGflower, carbofuran and uninoculated improved growth by 58%, 56.7%, 42.5%, 47%, 51% and 50%, respectively compared to inoculated-untreated. Treated okra with *Ocimum* sections and carbofuran significantly reduced GI by *M. incognita* and the lowest gall index of 2 was recorded in both OG leaf and carbofuran. *Ocimum gratissimum* leaf, OGstem and carbofuran reduced nematode population significantly by 84.1%, 77.5% and 84.1%, respectively compared to inoculated-untreated. Sections of *Ocimum gratissimum*, especially leaf and stem compared effectively with carbofuran in the management of *Meloidogyne incognita* on okra.

Keywords: Carbofuran, Management, *Ocimum gratissimum*, Okra, Root-knot nematodes

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is one of the most important vegetable crops in the world belonging to the Malvaceae and commonly grown in the tropics and warmer temperate regions of the world (Ayto and John, 2002; Oppong-Sekyere *et al.*, 2011; Patil *et al.*, 2015). Okra is a multipurpose and economic crop for farmers and marketers in Nigeria with many health benefits (Mihretu *et al.*, 2014). It is rich in dietary fibre, minerals (Sodium, Calcium, Sodium, Potassium, Zinc, and Iron), vitamins (A, B, and C), antioxidants, and folate. Okra seed is rich in proteins (15–26%), the seed oil is edible (20–40%), and rich in



unsaturated fatty acids like the linoleic acid essential for human nutrition (Moyin, 2007). The mature fruit and stems are used in the paper industry, and okra mucilage can be used as food additives (NRCNAs, 2006; Benchasri, 2012; Kumar *et al.*, 2013; Gemedé *et al.*, 2015; Dubey and Mishra, 2017).

Some notable pests and pathogens such as insects and plant-parasitic nematodes constitute challenges to okra production worldwide (Berkerlaar, 2001; Alhassan, 2023). Plant-parasitic nematodes can cause yield losses of 10-50% in severely infested fields (Berkerlaar, 2001). Root-knot nematodes (*Meloidogyne* species) are considered among the top five major pathogens and the first among 10 most important genera of plant-parasitic nematodes in the world infecting diverse plants including okra (Mukhtar *et al.* 2013a). *Meloidogyne incognita* attacks different crops including vegetables, causing severe growth retardation evident in the formation of galls (Adesiyan *et al.*, 1990). It is the most dominant species on okra and implicated in yield losses of 27% (Sikora and Fernandez, 2005; Mukhtar *et al.*, 2013b). A number of strategies have been developed for the management of root-knot nematodes, but their adoption is restricted due to some limitations (Johnson *et al.*, 1992; Maleeva *et al.*, 2000). These strategies include chemical control, fallowing, cover cropping, crop rotation, biological control, flooding, host resistance and use of organic amendments (Berkerlaar, 2001; Noling, 2002).

Chemical control is expensive and is only economically viable for high value crops, and could create a potential hazard to the environment and human health when not judiciously adopted (Asimea *et al.*, 2015). Synthetic nematicides' non-availability due to prohibitive cost and toxicity has led to the use of botanicals, a form of organic amendment in the management of nematode pests in an eco-friendly way (Tanimola and Papadopoulos, 2014)

Organic amendments have a suppressive effect on plant-parasitic nematodes through stimulation of antagonistic microbes or by releasing toxic by-products upon decomposition (Sayre and Starr, 1988; McSorley, 1998). The soil amendments also greatly contribute to soil fertility and increased water holding capacity resulting in improved plant growth and hence tolerance to nematodes (Sikora, 1992). The amendments supply nutrients after decomposition and also increase the level of biological activity and diversity in the soil (Berkerlaar, 2001). *Ocimum gratissimum* has been reported to be an organic amendment used in managing *M. incognita* and quite relevant in organic farming promoting little or minimum use of synthetic nematicides (Asimea *et al.*, 2015; Tanimola *et al.*, 2015). However, the most effective part of *Ocimum gratissimum* is yet to be determined in managing okra plants on *M. incognita* with a view to promoting sustainable utilisation. This study was carried out to investigate the effects of different parts of *Ocimum gratissimum* in the mitigation of adverse effects of *M. incognita* on okra.

Materials and Methods

Experimental Site

This study was conducted out at the raised platform of the Screen-house section of the Department of Crop and Soil Science, University of Port Harcourt, Nigeria, between August and December, 2023. The experimental site was located between latitude 4° 31'N and 5°



00N and longitude 6° 45''E and 70°E with an average temperature of 27°C, relative humidity of 78% and average rainfall that ranges from 2500-4000 mm.

Experimental Design

The pot experiment was laid out in a Completely Randomized Design (CRD) with seven (7) treatments which was replicated five (5) times to give a total number of thirty-five (35) pots. The experiment was carried out in two trials. The treatments are, Uninoculated (UnIno), Inoculated (Ino), Inoculated + powdered *Ocimum* leaf (InOcL), Inoculated + powdered *Ocimum* stem (InOcS), Inoculated + powdered *Ocimum* root (InOcR), Inoculated + powdered *Ocimum* flower (InOcF) and Inoculated + Carbofuran (InoCar). Pots were filled with steam-sterilized top soil. Sectioning of *Ocimum* into flower, leaf, stem and roots were carried out and the sections were air-dried for six weeks on the laboratory bench. Milling was done to convert the dried sections of the *Ocimum gratissimum* into powder with Kenwood® blender. Arrangement and assignment of treatments to units was done after sowing the seeds into the polypots. Okra seeds were sown 2 per pots, which was later thinned to 1 plant per pot after 1 week. Inoculation with 5000 *Meloidogyne incognita* eggs per plant stand was done two weeks after sowing (WAS).

Data Collection

Data were collected at appropriate time of crop development. Growth data such as number of leaves was visually counted, plant height (cm) was determined using rulers, stem diameter (cm) was determined using Vernier caliper and fresh shoot and root weight (g) were determined using electronic sensitive weighing scale. The growth data were collected every week.

Nematode Data

Galls on okra roots were rated using scale of Taylor and Sasser (1978). Eggs were extracted from roots using the hypochlorite method (Hussey and Baker, 1973) and the population determined. Second-stage juveniles (J2) were extracted from soil (Whitehead and Hemming, 1965) and the population was determined. Final nematode population (Pf) and reproductive factor (Pf/Pi), where Pf= Final nematode population; Pi= Initial nematode population were calculated.

Data Analysis

Data were analyzed using analysis of variance with statistical analysis system [SAS] (2009) package and means were partitioned (separated) using Fisher's least significant difference (LSD) at 5% of level significance.

Results

Effect of *Ocimum gratissimum* Sections on the Growth of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation (First Trial)

Table 1 showed the effect of *Ocimum gratissimum* sections on the growth of *Meloidogyne incognita*-infected Okra at eight weeks after Inoculation (8 WAI) [First Trial]. The infected okra plant treated with powdered *Ocimum gratissimum* leaf had the highest mean plant height



of 25.28 cm, but this was not significantly ($P \leq 0.5$) higher than plant height of carbofuran-treated okra (24.1 cm). All treated okra with sections of *Ocimum gratissimum*, carbofuran and uninoculated control had significantly ($P \leq 0.5$) higher mean plant height than inoculated-untreated okra.

All treatments with exception of inoculated-untreated okra (9) had significantly more number of leaves ($P \leq 0.5$) (Table 4.1). Carbofuran-treated okra (15.4) had the highest number of leaves which was not significantly higher than uninoculated okra (14.8) and *O. gratissimum*-treated okra (14.6). Inoculated-untreated okra had the least mean number of leaves (9). The highest mean stem girth of 3.7 cm was obtained in treated okra with *O. gratissimum* leaf, but not significantly higher ($P \leq 0.5$) than mean stem girth of uninoculated control. All treated okra had significantly higher mean stem girth than inoculated untreated okra in the first trial (Table 1).

Table 2 showed the effect of *Ocimum gratissimum* sections on the growth of *Meloidogyne incognita*-infected Okra at eight weeks after inoculation (8WAI) (second trial). The highest mean plant of 26.6 cm was recorded in *O. gratissimum* leaf treated okra and this was significantly higher than mean plant height of other okra. However, all treated okra had

Table 1: Effect of *Ocimum gratissimum* Sections on the Growth of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation (First Trial)

Treatments	Plant height (cm)	Number of leaves	Stem girth (cm)
UnInoculated control	22.48	14.8	3.36
Inoculated control	15.32	9	1.42
Inoc + <i>O. gratissimum</i> leaf	25.28	14.6	3.7
Inoc + <i>O. gratissimum</i> stem	19.96	12.8	2.84
Inoc + <i>O. gratissimum</i> flower	19.6	12.4	2.72
Inoc + <i>O. gratissimum</i> root	18.86	13.4	2.84
Carbofuran @ 3 kg.a.i./ha	24.1	15.4	3.3
LSD ($P \leq 0.05$)	1.46	1.25	0.36

Inoc= inoculated; kg. a.i./ha= kilogramme active ingredient per hectare

Table 2: Effect of *Ocimum gratissimum* Sections on the Growth of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation (Second Trial)

Treatments	Plant height(cm)	Number of leaves	Stem girth (cm)
UnInoculated control	24.02	15.4	3.66
Inoculated control	15.1	9.4	1.4
Inoc + <i>o. gratissimum</i> leaf	26.6	15	3.7
Inoc + <i>O. gratissimum</i> stem	20.26	15.2	3.02
Inoc + <i>O. gratissimum</i> flower	20.68	11.8	2.84
Inoc + <i>O. gratissimum</i> root	18.92	13.6	2.7
Carbofuran @ 3 kg.a.i./ha	22.98	15.2	3.76
LSD ($P \leq 0.05$)	2.17	1.83	0.40

Inoc= inoculated; kg. a.i./ha= kilogramme active ingredient per hectare



significantly higher ($P \leq 0.5$) mean plant height than inoculated untreated okra in the second trial. The trend observed in the second trial was similar to that of the first trial. In the number of leaves of infected okra, okra plants treated with *O. gratissimum* leaf, stem, root, uninoculated and carbofuran had significantly ($P \leq 0.5$) more number of leaves than inoculated untreated and *O. gratissimum* flower treated okra. All treated okra had significantly more number of leaves than inoculated untreated okra. Carbofuran-treated okra had the highest mean stem girth of 3.76 cm, but this was not significantly higher ($P \leq 0.5$) than *O. gratissimum* leaf-treated okra (3.7 cm) and uninoculated okra (3.66 cm). The lowest mean stem girth of 1.4 cm was obtained in inoculated-untreated okra and this was significantly lower ($P \leq 0.5$) than mean stem girths of other treatments in second trial (Table 2).

Effect of *Ocimum gratissimum* Sections on the Fresh Shoot and Root Weights (g) of *Meloidogyne incognita*-infected Okra at Eight Weeks after Inoculation (Trial 1)

The highest fresh shoot mean weight was obtained in *Ocimum gratissimum* stem-treated okra with 7.38 g, but this did not differ significantly ($P \leq 0.5$) from okra treated with *Ocimum gratissimum* leaf, Carbofuran and uninoculated (Table 3). Inoculated-untreated okra had the lowest mean fresh shoot weight of 3.1 g in the first trial. However, all treated okra had significantly ($P \leq 0.5$) higher mean fresh shoot weight than inoculated-untreated okra in the first trial. The trend observed in the second trial was similar to that in the first trial (Table 4.3). Inoculated-untreated okra had the highest mean fresh root weight of 6.6 g, which was significantly higher ($P \leq 0.5$) than root weights from all other treated okra. Okra treated with *Ocimum gratissimum* root had the least mean root weight of 2.62 g and this was not significantly ($P \leq 0.5$) different from okra treated with Carbofuran (3.07 g) and *Ocimum gratissimum* stem (3.23 g) for the first trial. All treated okra had significantly ($P \leq 0.5$) lower mean fresh root weight than inoculated untreated okra in the first trial. The trend observed in the second trial is similar to that on the first trial (Table 3).

Table 3: Effect of *Ocimum gratissimum* Sections on the Fresh Shoot and Root Weights (g) of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation (First trial and Second trials) (8WAI).

Treatments	Fresh shoot weight (g)		Fresh root weight (g)	
	Trial 1	Trial 2	Trial 1	Trial 2
Uninoculated control	6.20	6.50	3.43	3.24
Inoculated control	3.10	3.03	6.6	6.93
Inoc + <i>O. gratissimum</i> leaf	7.16	6.67	3.51	3.43
Inoc + <i>O. gratissimum</i> stem	7.38	6.67	3.23	3.71
Inoc + <i>O. gratissimum</i> flower	5.85	5.77	5.66	5.28
Inoc + <i>O. gratissimum</i> root	5.39	5.33	2.62	1.58
Carbofuran @ 3 kg.a.i./ha	6.33	6.28	3.07	2.91
LSD ($P \leq 0.05$)	1.25	1.43	0.71	1.43

Inoc= inoculated; kg. a.i./ha= Kilogramme active ingredient per hectare



Effect of *Ocimum gratissimum* Sections on Gall Index of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation

Table 4 showed the effect of *Ocimum gratissimum* sections on the gall index of *Meloidogyne incognita*-infected Okra at eight weeks after inoculation. Uninoculated untreated okra had 0 gall index since it was uninfected. The lowest mean gall index of 2 was obtained in *Ocimum gratissimum* leaf and carbofuran treated okra, but this did not differ significantly ($P \leq 0.5$) from *Ocimum gratissimum* stem treated okra (2.2). The highest mean gall index of 4.2 was obtained in inoculated-untreated okra and this was significantly ($P \leq 0.5$) higher than mean gall indices from other treated okra in the first trial. In the second trial, *Ocimum gratissimum* leaf treated okra had the lowest mean gall index of 1.4, but this was significantly lower ($P \leq 0.5$) than mean gall index from carbofuran treated okra (1.8). However, the highest mean gall index of 4.6 was obtained in inoculated untreated okra and this was significantly higher than indices from other treated okra (Table 4). All treated okra had significantly lower ($P \leq 0.5$) gall indices than inoculated untreated okra in both trials (Table 4).

Effect of *Ocimum gratissimum* Sections on the Nematode Population of *Meloidogyne incognita*-infected Okra at Eight Weeks after Inoculation (First and second trials)

Table 5 showed the effect of *Ocimum gratissimum* sections on the nematode population of *Meloidogyne incognita*-infected Okra at eight weeks after inoculation in the first trial. Inoculated okra had the highest mean nematode egg population and this was significantly higher than the egg population of other treated okra. There was no significant difference between *Ocimum gratissimum* leaf and carbofuran treated okra with the same population of 48,000 and they were the lowest among the treated okra. For the second-stage juvenile population (J2), the trend observed in the egg population of *M. incognita* was the same where the inoculated untreated okra had the highest J2 population and *O. gratissimum* leaf and carbofuran treated okra had the lowest population. The observation made in the final nematode.

Table 4: Effect of *Ocimum gratissimum* Sections on the Gall Index of *Meloidogyne incognita*-infected Okra at Eight Weeks after Inoculation (First and second trials).

Treatments	Gall Index	
	First Trial	Second Trial
Uninoculated control	0.0	0
Inoculated control	4.2	4.6
Inoc + <i>O. gratissimum</i> leaf	2	1.4
Inoc + <i>O. gratissimum</i> stem	2.2	2.2
Inoc + <i>O. gratissimum</i> flower	3.4	2.8
Inoc + <i>O. gratissimum</i> root	2.6	2.6
Carbofuran @ 3 kg.a.i./ha	2	1.8
LSD ($P \leq 0.05$)	0.53	0.59

Inoc= inoculated; kg. a.i./ha= Kilogramme active ingredient per hectare



Table 5: Effect of *Ocimum gratissimum* Sections on the Nematode Population of *Meloidogyne incognita*-Infected Okra at Eight Weeks after Inoculation (First Trial).

Treatments	Egg population	J2 population	Pf
Uninoculated control	0	0	0e
Inoculated control	308000(5.48)	12400(4.09)	320400(5.50)
Inoc + <i>O. gratissimum</i> leaf	48000(4.67)	2800 (3.42)	50800(4.69)
Inoc + <i>O. gratissimum</i> stem	72000(4.81)	3200(3.48)	75200(4.83)
Inoc + <i>O. gratissimum</i> flower	152000(5.17)	6000(3.77)	158000(5.19)
Inoc + <i>O. gratissimum</i> root	120000(5.07)	4000(3.57)	124000(5.08)
Carbofuran @ 3 kg.a.i./ha	48000(4.67)	2800(3.42)	50800(4.69)
LSD (P≤0.05)	29379.7(0.13)	1419.1(0.16)	29266.9(0.13)

Inoc= inoculated; kg. a.i./ha= kilogramme active ingredient per hectare; ()= values in parenthesis are logarithmic transformed; Pf= Final nematode population

population in the first trial did not differ from the trend observed for egg and J2 population (Table 4.5)

Table 4.6 showed the effect of *Ocimum gratissimum* sections on the nematode population of *Meloidogyne incognita*-infected Okra at eight weeks after inoculation in the second trial. Inoculated-untreated okra had the highest mean egg population (376, 000) which was significantly higher ($P \leq 0.5$) than the mean egg populations of other treated okra. The lowest egg population of 32,000 was recorded in *O. gratissimum* leaf treated okra, but this did not differ significantly ($P \leq 0.5$) from carbofuran treated okra (36,000) (Table 6). All treated okra had significantly ($P \leq 0.5$) lower egg population than inoculated-untreated okra. In terms of second-stage juvenile and final nematode population, their trends in population is similar to that of egg population in the second trial.

Effect of *Ocimum gratissimum* Sections on the Reproductive Factor(Rf) of *Meloidogyne incognita*-infected Okra at Eight Weeks After Inoculation.

Table 7 showed the effect of *Ocimum gratissimum* sections on the reproductive factor (Rf) of *Meloidogyne incognita*-infected Okra at eight weeks after inoculation. In the first trial, inoculated untreated okra had the highest mean reproductive factor of 64.08 which was significantly higher than reproductive factors of other treatments. *Ocimum gratissimum* leaf and carbofuran treated okra both had the lowest Rf of 10.16 and this was significantly lower ($P \leq 0.5$)

Table 6: Effect of *Ocimum gratissimum* Sections on the Nematode Population of *Meloidogyne incognita*-Infected Okra at Eight Weeks After Inoculation (second trial)



Treatments	Egg population	J2 population	Pf
Uninoculated control	0	0	0
Inoculated control	376000(5.57)	14400(4.15)	390400(5.59)
Inoc + <i>O. gratissimum</i> leaf	32000(4.48)	2000(3.30)	34000(4.51)
Inoc + <i>O. gratissimum</i> stem	48000(4.67)	3200(3.48)	51200(4.70)
Inoc + <i>O. gratissimum</i> flower	88000(4.92)	5600(3.73)	93600(4.95)
Inoc + <i>O. gratissimum</i> root	108000(5.02)	4800(3.67)	112800(5.03)
Carbofuran @ 3 kg.a.i./ha	36000(4.54)	2400(3.36)	38400(4.57)
LSD ($P \leq 0.05$)	38055.35(0.16)	1609.20(0.13)	38886.76(0.15)

Inoc= inoculated; kg. a.i./ha= kilogramme active ingredient per hectare; ()= values in parenthesis are logarithmic transformed; Pf= Final nematode population

Table 7: Effect of *Ocimum gratissimum* Sections on the Reproductive Factor (Rf) of *Meloidogyne incognita*-infected Okra at Eight Weeks after Inoculation.

Treatments	Rf	
	First Trial	Second Trial
Uninoculated control	0	0
Inoculated control	64.08	78.08
Inoc + <i>O. gratissimum</i> leaf	10.16	6.8
Inoc + <i>O. gratissimum</i> stem	15.04	10.24
Inoc + <i>O. gratissimum</i> flower	31.6	18.72
Inoc + <i>O. gratissimum</i> root	24.8	22.56
Carbofuran @ 3 kg.a.i./ha	10.16	7.68
LSD ($P \leq 0.05$)	5.85	7.78

Inoc= inoculated; kg. a.i./ha= kilogramme active ingredient per hectare



than for the rest of the treated okra. All treated okra had significantly lower ($P \leq 0.5$) Rf than inoculated untreated okra (Table 7). In the second trial, inoculated untreated okra had the highest mean Rf (78.08) and this was significantly ($P \leq 0.5$) higher than for the rest of the treated okra. *Ocimum gratissimum* leaf (6.8) had the lowest mean Rf, but this did not differ significantly ($P \leq 0.5$) from carbofuran treated okra (7.68).

Discussion

This research work evaluated the efficacy of different sections of *Ocimum gratissimum* in the mitigation of the adverse effects of *Meloidogyne incognita* on okra. The use of various parts of indigenous plants as botanical extracts has become important in pest management in recent years following the environmental hazard caused by chemical control measures (Olowe 1992, Mangala and Mauria, 2006). Recent study on the efficacy of *Ocimum gratissimum* in the management of *Meloidogyne incognita* on okra indicates that *O. gratissimum* extracts compare favourably with commercial nematicide, Carbofuran, (Asimiea *et al.*, 2015). Similarly, powdered potions of *Vernonia amygdalina* leaf have been reported as successful in the Management of *Meloidogyne incognita* on okra. Other studies include the efficacy of aqueous extracts of *Rhizophora mangle* l. bark in the management of *Meloidogyne incognita* on Okra (Tanimola and Asimiea, 2018a and 2018b). Botanicals, especially the leaf section have been reported to contain a lot of bioactive secondary metabolites (phytochemicals) such as alkaloids, saponins, tannins, flavonoids and glycosides which play important role in pathogen defense (Ikram *et al.*, 2023). These phytochemicals which have been reported toxic to plant-parasitic nematodes help in reducing their population, i.e. their management (Chitwood, 2002). *Ocimum gratissimum* has the phytochemicals: oleanolic acid, caffeic acid, ellagic acid, epicatechin, sinapic acid, rosmarinic acid, chlorogenic acid, luteolin, apigenin, nepetoidin, xanthomicrol, nevadensin, salvigenin, gallic acid, catechin, quercetin, rutin, and kaempferol. Others are the essential oils: camphene, β -caryophyllene, α - and β -pinene, α -humulene, sabinene, β -myrcene, limonene, 1,8-cineole, trans- β -ocimene, linalool, α - and δ -terpineol, eugenol, α -copaene, β -elemene, p-cymene, thymol, and carvacrol (Ositadinma *et al.*, 2021). It is suggested that these phytochemicals are responsible for the nematicidal effect of *O. gratissimum*.

Ocimum gratissimum, effectively reduced the number of nematode population and reproduction in infected okra than infected untreated okra. *Ocimum gratissimum* sections especially the leaf compared effectively with carbofuran in the management of *M. incognita* on okra. Botanicals, especially the leaf section have been reported to contain a lot of bioactive secondary metabolites (phytochemicals) such as alkaloids, saponins, tannins, flavonoids and glycosides which play important role in pathogen defense (Ikram *et al.*, 2023). The botanicals upon decomposition release multiple secondary metabolites and several other organic acids into the soil (Ntalli and Caboni, 2017). These metabolites may be toxic, hinder the normal physiological process of nematodes and causes their death. These chemical compounds inhibit hatching of eggs and enhance juvenile mortality. These phytochemicals



which have been reported toxic to plant-parasitic nematodes help in reducing their population, i.e. their management (Chitwood, 2002). Most workers have reported that the leaves in most plants are more active in the management of pests (Tanimola and Fawole, 2019). They opined that the leaf is more active for most physiological processes such as photosynthesis than other parts as various synthesis of diverse compounds like sugars and phytochemicals take place in the leaf (Fatoki and Fawole, 1999; Satish and Joshi, 2011; Tiwari *et al.*, 2011). In this study, the leaves of *O. gratissimum* were most active, followed by the stem, then roots and flowers. The effectiveness of the powdered leaf in promoting growth could be due to the concentration of the reported phytochemical in the leaves than in any other parts of the plant.

It is apparent from the result of this investigation that *Meloidogyne incognita* infected okra treated with *O. gratissimum* sections experienced better growth than infected untreated okra. The plant extract effectively reduced the number of nematode population. Also, the results on gall index and reproductive factor indicates that *O. gratissimum* inhibited nematode reproduction in infected okra. *Ocimum gratissimum* sections, especially the leaf, compared effectively with carbofuran in the management of *M. incognita* on okra, this observation conforms to earlier report on the efficacy of *O. gratissimum*.

Conclusion

The use of *Ocimum gratissimum* provides efficient, environmentally safe and cheaper method of nematode management of okra. *Ocimum gratissimum* leaf was most effective in the control of *Meloidogyne incognita* infected okra. Other researchers (Perri, 1999; Oka *et al.*, 2000; Afouda, 2008) have reported successes in using various plants extracts in nematode management. It is suggested that the active ingredients that provide nematicidal functions in *O. gratissimum* are concentrated in the leaves of the plant. It is therefore more economical to extract active ingredients from the leaves of the plant. Further study should be conducted to determine the proportion of each phytochemical in various parts of *O. gratissimum* plant.

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Effect of Bio-fertilisers on Okra (*Abelmoschus esculentus*) Production

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Abstract

Pursuing sustainable agricultural practices necessitates alternatives to chemical inputs, such as bio-fertilisers. This study evaluated the effects of different application rates of a locally produced bio-fertiliser on the growth and yield of okra (*Abelmoschus esculentus*). The bio-fertiliser was prepared from a blend of poultry manure and *Moringa oleifera* leaf biomass (4:1 ratio). The experiment was laid out in a Completely Randomised Design (CRD) with three replications. Treatments consisted of three application rates: T1 (control: 0g/plant), T2 (5g/plant), and T3 (10g/plant), applied every 10 days. Growth parameters (germination rate, plant height, leaf number) and yield indices (flower number per plant, fruit number per week per plant) were monitored over 120 days. Results indicated that bio-fertiliser application positively influenced okra performance. The intermediate application rate (T2: 5g/plant) resulted in the highest germination rate (86%), outperforming the control (82%) and the high application rate (T3: 84%). However, the highest application rate (T3: 10g/plant) produced the most significant improvement in vegetative growth, yielding the tallest plants and the highest number of leaves. Yield parameters were significantly enhanced in both bio-fertiliser treatments compared to the control. The study concludes that the poultry-moringa bio-fertiliser effectively enhances the growth and productivity of okra. While the highest rate (10 g/plant) promoted superior vegetative growth, the intermediate rate (5g/plant) is the optimal application rate for achieving a balance between excellent germination and high yield, mitigating potential negative effects associated with higher dosage.

Keywords: *Moringa oleifera*, Organic amendment, Plant growth, Soil health, Sustainable agriculture, Yield parameters

Introduction

The global quest to improve environmental health through the green energy revolution is gaining momentum. Environmental pollution, significantly exacerbated by greenhouse gas emissions and soil-degrading chemicals, necessitates changing attitudes and practices across all sectors of the environmental economy. A pivotal strategy for mitigating current environmental degradation is adopting eco-friendly agricultural practices, among which bio-fertilisers are prominent.

Bio-fertilisers contain living microorganisms that promote growth when applied to seeds, plant surfaces, or soil by increasing the supply or availability of primary nutrients to the host plant (Eze et al., 2023). Unlike chemical fertilisers, bio-fertilisers provide nutrients, improve



soil structure, stimulate beneficial microbial activity, and enhance plant tolerance to abiotic stresses. They are vital in maintaining long-term soil fertility and sustainability (Mohapatra et al., 2013). This study evaluated the effect of a poultry-moringa-based bio-fertiliser on the growth and productivity of okra (*Abelmoschus esculentus*).

Materials and Methods

The experiment was conducted at the Teaching and Research Farm of the Department of Agricultural Technology, Federal Polytechnic Oko, during the 2024 planting season (April to June). Okra seeds were procured from the Agricultural Development Program (ADP) office in Awka. The study consisted of three treatments based on the rate of bio-fertiliser application per plant: T1 (Control): 0g, T2: 5g, and T3: 10g. The bio-fertiliser was applied every 10 days. It was prepared in the Soil Science Laboratory of Federal Polytechnic Oko by combining four parts of poultry manure with 1 part of *Moringa oleifera* leaf biomass. A seed viability test was conducted prior to planting.

The experimental design was a Completely Randomised Design (CRD) with three replications. Each treatment was replicated three times, with each replicate consisting of 15 potted plants, resulting in 45 plants per treatment. The bio-fertiliser was applied every 10 days. All other agronomic practices (watering, weeding, etc.) were done judiciously as needed. Data on plant height, leaf number, germination rate, flower number per plant, and fruit number per week per plant were collected at 10-day intervals using a meter rule and a weighing scale. The collected data were analysed using descriptive statistics in SPSS software.

Results and Discussion

Applying the bio-fertiliser influenced the okra's growth and yield parameters. The highest germination rate (86%) was observed in treatment T2 (5g bio-fertiliser), followed by T3 (10g bio-fertiliser) at 84%, and the control T1 (0g) with the lowest rate of 82% (Figure 1). The slightly lower germination in T3 compared to T2 may be attributed to a potential initial microbial imbalance or a slight phytotoxic effect at the highest application rate, which could have temporarily altered soil conditions.

Figure 1 shows the mean values of the growth parameters of okra (*Abelmoschus esculentus*) planted with different levels of bio-fertilizers.

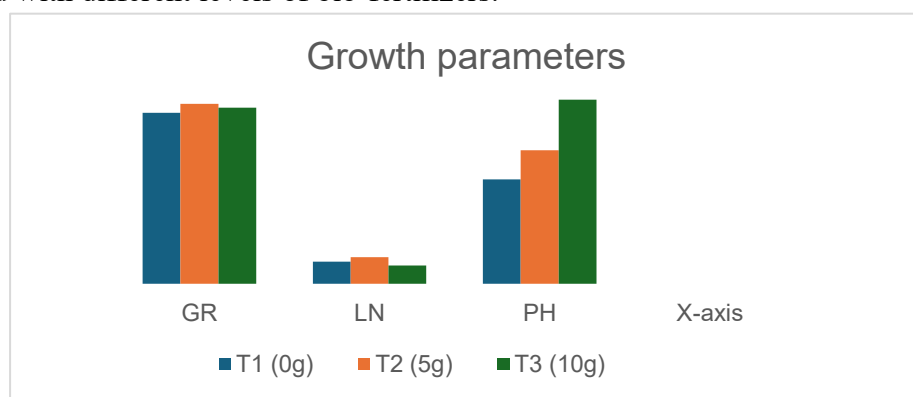




Figure 1: Mean value of growth parameter (plant height (PH), leaf number (LN), and germination rate (GR) of *A. esculentus*

The treatment group that received the highest bio-fertiliser application (T3) demonstrated the best plant height and leaf number performance throughout the growth period. This finding supports the results of Okpasi & Edim (2024), who reported that bio-fertilisers can significantly improve plant growth.

The yield parameters (flower number per plant and fruit number per week per plant) were significantly improved by adding the bio-fertiliser. This confirms previous reports by Akubuenyi et al. (2025) on okra. The results indicate that the microorganisms in the bio-fertiliser enhanced nutrient availability, leading to increased productivity. However, considering both germination and sustained yield, the optimal rate for the best overall results appears to be 5g per plant (T2), as the highest rate (T3) showed a slight inhibition at the germination stage.

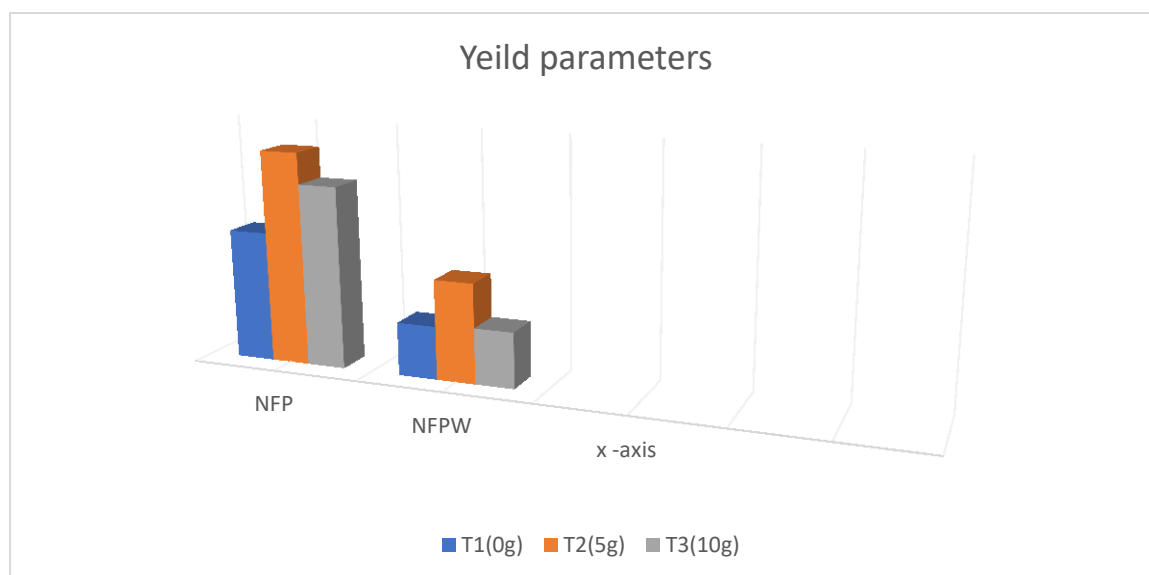


Figure 2: Mean values of yield parameters (number of flowers per plant (NFP) and number of fruits per week per plant (NFPW)) of *A. esculentus*.

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Assessing the Threat of Industrial Trace Metal Contamination to Agricultural Food Security: A Case Study of *Penaeus monodon* from Degema, Nigeria.

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Abstract

This study investigated the spatial bioaccumulation of trace metals (Cd, Pb, Cr, As, Zn, Cu, Ni) in the Giant Tiger Prawn (*Penaeus monodon*) from Bille Creek, Degema LGA, Rivers State, Nigeria, over six months (December 2024 to May 2025). Monthly samples of prawns and sediments were collected and analyzed using Atomic Absorption Spectrophotometry (AAS). The trace metal concentrations in prawn tissues followed a consistent order: Zn > Cu > Pb > Ni > Cr > Cd > As. Spatially, metal concentrations were homogeneous across stations ($p > 0.05$), indicating uniform contamination despite proximity to oil facilities. Spatially, Zn, Pb, and Cd showed significant peaks in the early wet season, with the highest concentrations observed in December. Arsenic exhibited the highest Bioaccumulation Factor (BAF) of 1.222 in April, indicating high bioavailability. The Pearson correlation analysis revealed strong positive correlations between Cd, Pb, Cr, As, and Zn ($r > 0.90$), suggesting shared anthropogenic sources, likely linked to oil operations and seasonal hydrological inputs. Cu showed distinct bioaccumulation behaviour with negative correlations to other metals. The study concludes that *P. monodon* consistently bioaccumulates metals across the creek, with seasonal variation in contamination levels, which highlights the need for targeted pollution control and seasonal consumption advisories to mitigate public health risks.

Keywords: *Penaeus monodon*, Trace metals, Bioaccumulation, Degema, Creek, SDG 12 (Responsible Consumption and Production), SDG 14 (Life Below Water).

Introduction

Aquatic environments are increasingly impacted by trace metal contamination, primarily due to both natural geochemical processes and growing human activities such as industrial runoff, mining, and agrochemical use (Rainbow, 2007; Wu *et al.*, 2016). Metals like cadmium (Cd), lead (Pb), arsenic (As), and copper (Cu) persist in sediments and accumulate over time, posing serious ecological and public health risks, particularly through bioaccumulation in marine organisms. In areas like the Nigerian Rivers State, where urban and industrial activities are prevalent, it is critical to monitor trace metal buildup to assess the ecological health of water bodies and the safety of seafood for human consumption (Iwegbue *et al.*, 2021; Egesi *et al.*, 2023).



The Giant Tiger Prawn (*Penaeus monodon*), a significant species in the Niger Delta's estuarine environment, serves both as an important food source and as a bioindicator for environmental pollution (Bellante *et al.*, 2012). Found in coastal fisheries and aquaculture, *P. monodon* accumulates trace metals from its surroundings, making tissue-metal analysis an effective way to monitor ecosystem health (Chris *et al.*, 2024; Jolaosho *et al.*, 2024a). Seasonal factors like rainfall, tides, and sediment composition, along with biological cycles and water flow, influence how trace metals are transported and accumulated across space and time, leading to varying levels of exposure among prawn populations in the region (Adesogan *et al.*, 2021; Adetutu *et al.*, 2023).

Given the seasonal and spatial variability of trace metal accumulation, detailed monitoring frameworks are essential to fully understand the dynamics of contamination in the Niger Delta (Jolaosho *et al.*, 2024b; Umoren *et al.*, 2025;). This study aims to improve knowledge by collecting seasonal samples from various locations within the Degema Local Government Area, covering both short- and long-term exposure scenarios. Furthermore, health risk assessments using indices such as the Hazard Quotient (HQ), Hazard Index (HI), and Estimated Daily Intake (EDI) are necessary to translate metal concentrations into actionable data regarding consumer safety (FAO/WHO, 2011; USEPA, 2023;). By addressing these factors, the research aims to enhance ecological risk frameworks, food safety guidelines, and resource management, contributing to the sustainable development of fisheries and the protection of public health in the region.

Materials and Methods

Study area

The Degema Local Government Area in Rivers State is home to Bille Creek, which connects Bille village to the Sombrero River. Known for its fishing industry, the region experiences a tropical climate with high temperatures and humidity. It is also rich in oil and gas, with companies like Shell operating there, despite ongoing legal disputes over oil spills and environmental damage.

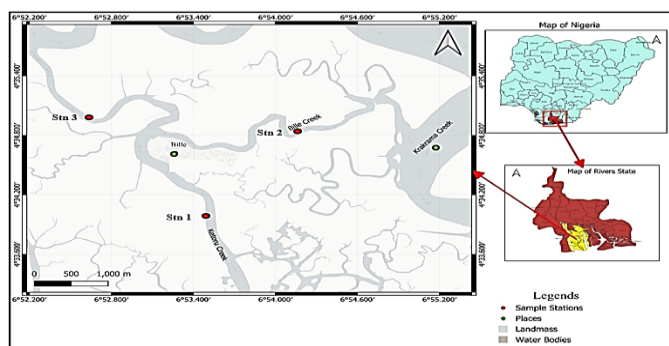


Figure 1: Map Showing the Sample Sites from the Bille Creeks



Sample and Sampling Techniques

Global Positioning System (GPS) coordinates identified sampling sites in Bille, Ketoru, and Krakraama. Twelve triplicate samples were collected randomly from December 2024 to May 2025, with control samples taken 2 km away from the oil and gas sites. Sampling occurred during both rainy and dry seasons. A portable Milwaukee pH600 multimeter analyzed pH, conductivity, temperature, dissolved oxygen, BOD, salinity; HACH DR/890 measured nitrate levels. Sixty live prawn samples from three stations were obtained from local fishermen, preserved with ice, and transferred to the lab.

Sediment Samples Collection

Over six months (Dec 2024-May 2025), nine sediment samples were collected monthly from three sites, preserved, and analyzed using Atomic Absorption Spectrophotometry.

Determination of Trace Metals

Trace metal concentrations (Cu, Zn, Pb, Cd) were evaluated using Atomic Absorption Spectrophotometry (Varian AA 240 AAS) (APHA, 1992).

The Bioaccumulation Factor (BAF)

The Bioaccumulation Factor (BAF) was calculated by dividing the chemical concentration in the organism by that in the sediment, using mean values from the tables.

The formula for BAF is: $BAF = \text{Concentration in Fish} / \text{Concentration in Sediment}$.

Statistical Analysis

SPSS version 16 was used for descriptive statistics and ANOVA, with Duncan Multiple Range Test at the 0.05 significance level was conducted. Mean values determined concentrations in water, silt, and shellfish tissue. Data analysis was performed using Microsoft Excel, and statistical measurements included mean, standard deviation, and standard error of the mean.

Quality Assurance/Quality Control

Quantitative analysis followed ideal conditions with an internal standard (Shi *et al.*, 2018). Quality assurance was ensured by altering procedures throughout. Sample vials were cleaned with hydrochloric acid and deionised water. A Perkin-Elmer AAS and Flame Photometer (FP Model 140) tested shellfish, water, and sediments. Mussels were kept on ice before testing.

Results and Discussion

Table 1 shows the spatial trend of trace metals in [Zinc (Zn), Copper (Cu), Lead (Pb), Nickel (Ni), Chromium (Cr), Cadmium (Cd) and Arsenic (As)] *Penaeus monodon* tissue across three sampling sites revealed a consistent pattern: $Zn > Cu > Pb > Ni > Cr > Cd > As$. Cu and Zn showed no significant bioaccumulation, with concentrations exceeding 9 mg/kg at all stations. These findings align with Baki *et al.* (2018), who observed similar trends in



Malaysian coastal crustaceans. While the concentrations of cadmium (Cd) and arsenic (As) were low (0.066 mg/kg and 0.011 mg/kg, respectively), consistent with Otitoloju *et al.* (2009), the presence of lead (Pb) and nickel (Ni) raised concerns. The uniformity of metal distribution across stations suggests similar environmental conditions, underscoring the importance of basin-wide pollution mitigation efforts.

Table 1: Spatial Distribution of Trace Metals in *Penaeus monodon* Tissue

Metals (mg/kg)	Station 1	Station 2	Station 3	Codex (FAO/WHO)
Cadmium (Cd)	0.066±0.007 ^a	0.066±0.007 ^a	0.066±0.007 ^a	0.05
Lead (Pb)	0.184±0.029 ^a	0.184±0.029 ^a	0.184±0.029 ^a	0.2
Arsenic (As)	0.061±0.004 ^a	0.062±0.004 ^a	0.062±0.004 ^a	-
Chromium (Cr)	0.011±0.001 ^a	0.011±0.001 ^a	0.011±0.001 ^a	-
Zinc (Zn)	9.264±0.389 ^a	9.284±0.389 ^a	9.286±0.389 ^a	30
Copper (Cu)	9.213±0.534 ^a	9.209±0.534 ^a	9.242±0.534 ^a	-
Nickel (Ni)	4.515±0.264 ^a	4.536±0.264 ^a	4.514±0.264 ^a	-

Note: Values are mean ± standard deviation. Superscripts with the same alphabet indicate no significant difference (p < 0.05).

Spatial Distribution of Trace Metals in Sediment

Table 2 shows the trace metal concentration profile in sediment samples from three stations followed the order Cu > Zn > Ni > Pb > Cr > Cd > As. Copper (Cu) had the highest mean concentration (27.225–27.227 mg/kg), followed by zinc (Zn) and nickel (Ni), with concentrations of 18.27 mg/kg and 12.511–12.513 mg/kg, respectively. These results mirror Ekeanyanwu and Ogbuinyi (2018), who reported similar Cu and Zn levels in Imo River sediments, attributed to industrial effluents and urban runoff. Lower concentrations of Cd and As (0.307–0.309 mg/kg and 0.011–0.013 mg/kg) suggest minimal contamination, consistent with Adeniyi *et al.* (2024). The statistical uniformity across stations (p > 0.05) indicates consistent input and dispersion of metals, possibly due to stable sedimentary and hydrodynamic conditions, similar to findings by Farkas *et al.* (2007). However, elevated Cu and Zn concentrations may pose ecotoxicological risks to benthic organisms, affecting reproduction and enzyme activity (Bryan & Langston, 1992).

Table 2: Spatial Distribution of Trace Metals in Sediment at the Bille Creeks

Parameter	Station 1	Station 2	Station 3
Cd (mg/kg)	0.307±0.023 ^a	0.308±0.023 ^a	0.309±0.023 ^a
Pb (mg/kg)	1.072±0.126 ^a	1.073±0.126 ^a	1.074±0.126 ^a
Cr (mg/kg)	0.185±0.005 ^a	0.186±0.005 ^a	0.187±0.005 ^a
As (mg/kg)	0.011±0.001 ^a	0.012±0.001 ^a	0.013±0.002 ^a



Zn (mg/kg)	18.27±0.681 ^a	18.271±0.681 ^a	18.272±0.681 ^a
Cu (mg/kg)	27.225±0.315 ^a	27.226±0.315 ^a	27.227±0.315 ^a
Ni (mg/kg)	12.511±0.342 ^a	12.512±0.342 ^a	12.513±0.342 ^a

Note: Values are mean ± standard deviation. Superscripts with the same alphabet indicate no significant difference ($p < 0.05$).

Trace Metal Bioaccumulation in *Penaeus monodon*

The Bioaccumulation Factor (BAF) values in *Penaeus monodon* tissues across three Degema estuarine stations reveal key insights into trace metal accumulation (Table 3). Arsenic (As) exhibited the highest BAFs, peaking at 1.000 at Station 1, demonstrating significant bioavailability and tissue affinity, likely due to its speciation and ability to cross biological membranes (Bellante *et al.*, 2016). Zinc (Zn) and nickel (Ni) also showed moderately elevated BAFs, indicating their bioavailability, though below the bioaccumulation threshold, highlighting the need for long-term monitoring due to their toxicity potential (Pan & Wang, 2012). Copper (Cu) and chromium (Cr) had consistent, moderate BAFs, emphasizing stable environmental availability and potential toxic effects, particularly in gill and hepatopancreatic tissues (Rainbow, 2002; Pawlaczyk *et al.*, 2018). Cadmium (Cd) and lead (Pb) had the lowest BAFs, reflecting restricted bioavailability and biological exclusion mechanisms, but their toxicological risks remain high (Wang & Rainbow, 2008; Waqas *et al.*, 2024). The uniformity of BAF values across stations suggests consistent environmental conditions, supporting the use of *P. monodon* as a reliable bioindicator for estuarine contamination.

Table 3: Bioaccumulation Factor for Metals in *Penaeus monodon* based on stations

Element	Station 1	Station 2	Station 3
Cd	0.215	0.214	0.214
Pb	0.172	0.171	0.171
Cr	0.330	0.333	0.332
As	1.000	0.917	0.846
Zn	0.507	0.508	0.508
Cu	0.339	0.338	0.340
Ni	0.361	0.362	0.361

Spatial Variation of Physicochemical Parameters

Table 4 presents the spatial distribution of key physicochemical parameters in the Degema aquatic system, influencing trace metal behavior and bioavailability (Chapman *et al.*, 1996; Förstner & Wittmann, 2012). pH ranged from 6.234 ± 0.036 to 6.253 ± 0.036 , indicating a slightly acidic environment that enhances metal desorption (Luoma & Rainbow, 2008). Electrical conductivity showed minimal variation, suggesting consistent ionic mixing across the estuary (Rajeshkumar & Li, 2018). Temperature increased gradually from $24.494 \pm 0.108^\circ\text{C}$ to $24.647 \pm 0.112^\circ\text{C}$, influencing metabolic rates and metal uptake (Boyd, 2000). Dissolved oxygen remained stable, supporting aerobic life and promoting metal precipitation (Jiang *et al.*, 2014). Biological oxygen demand (BOD) values were consistent, reflecting



moderate organic load, while salinity showed a slight gradient, potentially affecting metal speciation (Bryan & Langston, 1992).

Table 4: Spatial Distribution of Physicochemical Properties

Parameters	Station 1	Station 2	Station 3
pH	6.234±0.036 ^a	6.244±0.036 ^a	6.253±0.036 ^a
Electrical Conductivity	16.552±0.08 ^a	16.554±0.08 ^a	16.556±0.08 ^a
Temperature	24.494±0.108 ^b	24.586±0.109 ^{ab}	24.647±0.112 ^a
Dissolved Oxygen	4.681±0.023 ^a	4.688±0.022 ^a	4.697±0.022 ^a
Biological Oxygen Demand	3.321±0.021 ^a	3.33±0.021 ^a	3.337±0.02 ^a
Salinity	0.888±0.008 ^b	0.896±0.008 ^{ab}	0.903±0.007 ^a

Note: Values are mean ± standard deviation. Superscripts with the same alphabet indicate no significant difference ($p < 0.05$).

Conclusion

This research emphasizes the critical need for continuous monitoring of trace metal contamination and bioaccumulation in *Penaeus monodon* in the Niger Delta. Elevated metal levels, particularly arsenic during the wet season, pose risks to aquatic life and human health. The findings highlight the importance of region-specific pollution control, consumption advisories, and long-term ecological risk assessments. These measures will help ensure sustainable fisheries, food safety, and align with global efforts to preserve marine life and promote responsible consumption as per SDGs 12 and 14. multi-metal approaches are essential for understanding heavy metal dynamics in tropical estuarine ecosystems.

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Barriers to Sustainable Agricultural Technologies and Practices Adoption Among Cassava Farmers in Rivers State

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Abstract

The study examined barriers to sustainable agricultural technologies adoption among cassava farmers in Rivers State, Nigeria. Structured questionnaire was used to collect data from 220 farmers who were sampled using a multi-stage random sampling procedure in a cross sectional survey. The data were subjected to descriptive (frequency, percentage and mean) analysis. The result revealed that more women (67.3%) than men (32.7%) were involved in cassava production. Most of the farmers were married (62.7%). Less than half of the respondents were aware of agroforestry (22.3%) as sustainable practices in cassava cultivation. Technologies maintenance cost ($\bar{X} = 2.9$) and limited and inefficient extension system ($\bar{X} = 2.8$) were identified barriers to the farmers' adoption of sustainable agricultural technologies for cassava production. Farmers in the study area should be adequately empowered by local leaders and other stakeholders in Rivers State to overcome the identified and other barriers to sustainable agricultural technologies adoption.

Keywords: Barriers, Sustainable agricultural technologies, Sustainable agriculture and adoption, Technologies adoption.

Introduction

Agriculture has remained the main source of livelihood for many household across the globe especially in developing countries (Eze & Abe, 2024). The sector plays important, active and significant role in the social and economic advancement of developing countries (Ahmed, Oyetoki & Salako, 2021). In Nigeria, agriculture is the main economic activity undertaken by majority of rural households who constitutes larger number of the nation's population (Bello *et al.*, 2022). A notable agricultural enterprise that promises great potential to improve the Nigeria economy and welfare of the the rural farmers is cassava production (Ojeleye, 2018).

Cassava (*Manihot esculenta*) is among the most important food crop that is widely cultivated by rural, peri-urban and urban dwellers in Africa (Banmeke *et al.*, 2021). According Ojeleye (2018), as a regional asset, cassava serves as one of the most vital basic food sources for over 200 million people living in Sub-Sahara African. In West African, cassava is the mostly grown food crop due to its value in the sub-regional economy (Acheampong *et al.*, 2018). In Nigeria cassava is recognized as essential commodity that have the potential to create the needed economic transformation, address the twin problems of food insecurity and mal-nutrition, reduce poverty and generate foreign exchange.

The demand for cassava products in Nigeria is steadily on the increase due to rapid population growth, better feeding habit and relative peaceful coexistence across tribal and national boundaries (Udoh *et al.*, 2005), thereby forcing farmers to produce more food that will meet the quantity of cassava needed to satisfy all. Springer et al. (2020) had reminded



that there is growing awareness that the farming system needs to intensify efforts and be transformed if the quality and quantity of cassava demanded by consumers must be reached. To increase cassava yield, the OECD-FAO (2016) had pointed that there must be either a significant increase in farm input resources or adjustment in the present cassava production operations. Noticeable investment in farm inputs includes higher amount of seeds, fertilisers, herbicides and the expansion of cassava cultivating land area. Research has shown that Nigeria have achieved increased agricultural output through the expansion of cultivated land area instead of through yield increase per hectare (Ojeleye, 2018). While increasing farm inputs might increase yield, it only provides short-term increments, which are unsustainable (Zeng *et al.*, 2018). In contrast, by carrying out changes to cassava production operations through the use of sustainable technologies, farm yield and production per hectare can be sustainably increased by the use of sustainable agricultural practices (Wambugu *et al.*, 2018).

The concept of sustainable agricultural practice is described as ability of farmers to indefinitely produce food without consequential damage to the ecological life. Sustainable agricultural technologies have widely been recognized as important farming operation and practices that improves production, increases farmers' income, savings and encourages better rural living conditions and overall national transformation in while maintaining environmental sanity (Sapbamrer & Thammachai, 2021). According to Bello *et al.* (2022), sustainable agricultural technologies plays pivotal role in reducing environmental degradation and addressing the challenges of low agricultural output through the application of eco-friendly recommendations in farming systems. Traditionally, cassava production in Nigeria which are predominantly carried out by rural farmers are largely unsustainable. This age long practices poses significant threat to both food security and environment. This is because the practices involve the use of non-sustainable methods.

Despite the importance of sustainable agricultural technologies, farmers in Rivers State have not adopted them in cassava production owing to various barriers. It is on this premise that the study seeks to investigate the the barriers to farmers' adoption of sustainable agricultural technologies in cassava production in Rivers State, Nigeria. Specifically, the study: described the socio-economic characteristics of cassava farmers in Rivers State, examine farmers' awareness of sustainable agricultural technologies in cassava production, and identified the barriers to farmers' adoption of sustainable agricultural technologies in cassava production in Rivers State

Methodology

The study was conducted in Rivers State, Nigeria. The state is located in the oil rich Niger-Delta, with lots of economic activities. The agricultural activities in the area are mainly fishing, livestock rearing and crop production. Major crops cultivated in Rivers State include oil palm, yam, cocoyam, pepper and cassava. The study population comprised of all cassava farmers in the state. Multistage sampling procedure was used to select the study sample. First, 2 out of the 3 Agricultural zones in the state were selected based on the preponderance of cassava production in these areas. Second, 7 Local Government Areas (LGAs) randomly selected. Third, 18 communities were selected and 220 registered cassava farmers obtained from the state Agricultural Development Program (ADP) were randomly selected for the study. Structured questionnaires were used to collect data. The data were analyzed using descriptive statistics.



Results

Socio-economic Characteristics

Table 1: Socio-economic characteristics of the respondents

	Variable	Frequency	Percentage	Mean
Age	21-30	27	12.2	47
	31-40	52	23.7	
	41- above	141	64.1	
Sex	Male	78	32.7	
	Female	142	67.3	
Marital status	Single	33	15.0	
	Married	138	62.7	
	Widowed/divorced/separated	49	22.3	
Highest Education	Non-formal	29	13.2	
	Primary	67	30.5	
	Secondary	96	43.6	
	Tertiary	15	6.8	
	Vocational	13	5.9	
Farming experience	1-10 years	26	11.8	22 years
	11-20 years	85	38.6	
	21 years and above	106	48.2	
Household size	1-5 persons	66	29.5	7 persons
	6-10persons	146	66.4	
	11 persons and above	9	4.4	
Sources of fund	Personal savings	144	65.5	
	Family and friends	50	22.7	
	Corporative societies	21	9.5	
	Donor agencies/NGO	5	2.3	
Size of farmland	1-5plots	207	94.1	2.9 plots
	6 plots and above	13	5.9	
Farmland ownership	Not owned land	122	55.4	
	Owned land	98	44.6	

Source: Field survey, 2024



From table 1, it shows that among the farmers, 64.1% were aged above 40 years, 23.7% 31-40 years and 12.2% 21-30 years. The average age of respondents was 44 years. This result corroborates the findings of Tijani (2022), that most farmers in rural communities in Nigeria are in their age of active engagement and this could positively improve agricultural production. Most of the farmers (67.3%) were female and 32.7% were male, suggesting that female are predominant cassava farmers in Rivers State. This is an indication that women have broadened their level of participation in agricultural practices (Tijani, 2022). Most of the farmers (62.7%) were married, 15.0% single, 22.3% widowed/separated/divorced. This suggested a farming population with more married people which could encourage one another to venture into the use and adoption of farming technologies to increase farm output. Hanson, Ferguson, Olofsson and Rantamäki-Lahtinen (2013), found that family members encourages farmers to venture in to the use and adoption of farming technologies. The highest education for 43.6% of the farmers was secondary school, 30.5% primary, 13.2% no formal, 6.8% tertiary and 5.9% vocational. Among the farmers, 48.2% had more than 20 years farming experience, 38.6%, 11-20 years and 11.8% 1-10 years. The average farming experience of the respondents was 22 years. More than half of the farmers (66.4%) belong to household size of 6-10 persons, 29.5% 1-5 and 4.4% 11 persons and above. The farmers' average household size was 7 persons. Majority of the farmers (65.5%) had personal savings as their main sources of fund for cassava production, 22.7% family and friends, 9.5% corporative societies and 2.3% donor agencies/NGOs. 94.1% the farmers cultivated cassava on 1-5 plots of land and 5.9% on above 5 plots of land. The average size of farmland cultivated by the farmers was 3 plots and 55.4% of the farmers cultivated on owned land and 44.6% not owned land.

Awareness of Sustainable Agricultural Technologies in Cassava Production

Table 2: Respondents' Distribution based on Awareness of Sustainable Cassava Production Technologies

Sustainable Cassava Production Technologies and Practices	Frequency (N=220)	Percentage (%)
Conservation Agriculture	34	15.4
Intercropping	220	100
Mulching	73	33.2
Water management	54	24.5
Agroforestry	49	22.3
Improved Cassava Varieties	185	84.1

Source: field survey, 2024

From Table 2, all of the farmers (100.0%) were aware of intercropping technology, 84.1% improved cassava varieties, 33.2% mulching, 24.5% water management, 22.3% agroforestry and 15.4% conservation agriculture. This suggests poor awareness of sustainable agricultural practices excluding inter-cropping and the use of improved cassava varieties which are age long traditional practices. And this condition could adversely affect their adoption by the farmers. This is so because according to Atala and Issa (2022), awareness of technologies proceeds their adoption.



Table 3: Barriers to farmers' adoption of sustainable agricultural technologies in cassava cultivation

Barriers to Sustainable Agricultural Technologies Adoption	Mean (X)	Remark
Lack of technologies awareness	2.1	Not a barrier
High cost of technologies	2.8	Barrier
Limited Access	2.8	Barrier
Lack of experience	2.9	Barrier
Infrastructural limitations	2.8	Barrier
Change resistance	2.7	Barrier
Technologies maintenance cost	2.9	Barrier
Lack of electricity	2.9	Barrier
Lack of access road	2.6	Barrier
Lack of water supply	2.0	Not a barrier
Inefficient extension system	2.8	Barrier
Poor technology performance	1.9	Not a barrier
Grand mean	2.6	Barrier

Source: field survey, 2024. $\bar{X} \geq 2.5$ is a barrier; $\bar{X} < 2.5$ is not a barrier.

The farmers identified the following as barriers to the adoption of sustainable agricultural technologies in cassava cultivation: lack of experience in sustainable agricultural technologies use ($\bar{X}=2.9$), high cost of sustainable agricultural technologies maintenance ($\bar{X} = 2.9$), lack of electricity ($\bar{X}= 2.9$), limited access to sustainable agricultural technologies ($\bar{X} = 2.8$), infrastructural limitations in the use of sustainable agricultural technologies ($\bar{X}= 2.8$), cost of sustainable agricultural technologies ($\bar{X}= 2.8$), inefficient agricultural extension systems ($\bar{X} = 2.8$), farmers' change resistance nature in the use of sustainable agricultural technologies in cassava cultivation ($\bar{X}= 2.7$), lack of access road ($\bar{X}= 2.6$). On the other hand, lack of technologies awareness ($\bar{X}= 2.1$), lack of water supply ($\bar{X}= 2.0$) and poor technologies performance ($\bar{X}= 1.9$). The overall mean of 2.6 suggested that the farmers faced a number of barriers to adoption of sustainable agricultural technologies in their cassava cultivation business. The sustainable agricultural technologies and practices are not adequately put to use and adopted among cassava farmers in Rivers State owing to various barriers including high cost of sustainable agricultural technologies, limited access to sustainable agricultural technologies, lack of experience in sustainable agricultural technologies use, infrastructural limitations in the use of sustainable agricultural technologies, farmers' change resistance nature in the use of sustainable agricultural technologies in cassava cultivation, sustainable agricultural technologies maintenance cost, lack of electricity for effective and efficient use of sustainable agricultural technologies in cassava cultivation, lack of access road in transportation of sustainable agricultural technologies to farmers and inefficient agricultural extension system that promote the use and adoption of sustainable agricultural technologies in cassava production. In line with this findings, Eze and Abe (2024), reported that farmers' adoption of sustainable agricultural technologies are faced with several barriers. This condition maybe responsible for the continuous use of unsustainable measures by farmers in the study area for cassava production which have had adverse effects on the ecosystem with poor yield and income (Eze & Abe, 2024).



Conclusion and Recommendations

Not much number of cassava farmers were aware of conservation agriculture, mulching, water management and agroforestry, while all the farmers were aware of intercropping and majority of them were aware of improved cassava varieties. High cost of sustainable agricultural technologies, limited access to sustainable agricultural technologies, lack of experience in sustainable agricultural technologies use, infrastructural limitations in the use of sustainable agricultural technologies, farmers' change resistance nature in the use of sustainable agricultural technologies in cassava cultivation, sustainable agricultural technologies maintenance cost, lack of electricity for effective and efficient use of sustainable agricultural technologies in cassava cultivation, lack of access road in transportation of sustainable agricultural technologies to farmers and inefficient agricultural extension system that promote the use and adoption of sustainable agricultural technologies and practices in cassava production were identified as barriers to cassava farmers' adoption of sustainable agricultural technologies and practices in Rivers State. Local leaders and other important stakeholders should partner with farmers to pool resource together to overcome the barriers to sustainable agricultural technologies and practices adoption among cassava farmers in the study area.

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Dietary Effect of a Microbial Carbohydrase (Xylanase and Glucanase mix) on Feed Intake, Nutrient Retention and Biometric Indices of Nile tilapia (*Oreochromis niloticus*)

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Abstract

High levels dietary non starch polysaccharide (NSP), a non-digestible fibre, in plant by-products such as wheat bran (WB) have hampered their use as cheap energy sources in fish diet in place of maize (MZ). This study aimed to evaluate the dietary effect of xylanase and glucanase mixture (XyG mix) addition to WB on nutrient retention of Nile tilapia (*O. niloticus*). Six diets (30% crude protein) consisting of two basal controls with no enzyme (MZ₀ and WB₀) and four basal diets with WB pretreated with 0.1g (WB_{0.1}), 0.2g (WB_{0.2}), 0.3g (WB_{0.3}) and 0.4g (WB_{0.4}) of XyG mix were formulated and randomly assigned to triplicate fish (mean initial weight 8.41 ± 0.01 g; 20 fish per tank). The fish were fed the diets to satiation twice daily for 56 days. The fish fed WB₀ displayed significantly reduced final body weight (FBW), hepatosomatic index (HSI) and viscerosomatic index (VSI), which were improved by X+G mix compared to WB₀ ($P > 0.05$). Protein production value (PPV), lipid production value (LPV) and energy retention (ER) decreased significantly in the MZ₀ and WB₀ group compared to other fish ($P < 0.05$). These indices were significantly ($P < 0.05$) enhanced in the WB_{0.1}, and WB_{0.2}, compared to the WB₀ and MZ₀. LPV and ER were similar statistically between the MZ₀ and WB_{0.2} groups ($P > 0.05$). Relative to MZ₀ group the WB_{0.1} and WB_{0.2} showed highest net profits/ return on investment and the lowest cost per unit production than other diets. In conclusion, addition of XyG (0.1-0.2g) to WB by pretreatment can completely substitute MZ without affecting nutrient utilization of Nile tilapia.

Keywords: Xylanase and Glucanase, Non-starch polysaccharides, Nutrient utilization, Growth performance, Nile tilapia

Sub-Theme: Innovations in Organic Agriculture, Poultry and Livestock Production

1. Introduction

Fish meal (FM) and fish oil as well as soya bean and corn are the major sources of protein and energy in diets for monogastric animals including fish (Gallardo *et al.*, 2017); however, these valuable feedstuffs account for roughly 49% of the 67 metric tonnes of feed stuff used in fed aquaculture, which also makes significant contribution to human food feed competition, providing opportunities to substitute these feedstuffs with less food feed competitiveness like plant by-products in order to reduce global dependence on arable land and promote efficient resource use (Chary *et al.*, 2024). However, many studies have shown that cereals and cereal by-products, such as wheat bran (WB) contain non starch polysaccharide



(NSP) components like arabinoxylan (AX), β -glucan and mix linked glucan (Dalsgaard *et al.*, 2016), which decrease endogenous enzyme interaction with chyme and reduce nutrient digestion due to the viscous nature these indigestible fibre components digestibility (Castillo and Gatlin, 2015).

Dietary NSP degrading enzymes such as microbial xylanase can enhance fish digestive enzyme activities (Hassaan *et al.*, 2019) by decreasing decrease chyme viscosity, which improved digestive enzyme and stimulate feed intake (Sinha *et al.*, 2011), enhance nutrient deposition and growth performance (Nakamura *et al.*, 2022). Additionally, supplementing diet with β -glucanase can hydrolyse other plant cell wall components such as glucan, improving protein and lipid utilization (Nakamura *et al.*, 2022). Most plants including soyabean meal (SBM), and cereal by-products like wheat bran (WB) are rich in AX and β -glucan (Sinha *et al.*, 2011; Maas *et al.*, 2019), which can be hydrolysed by dietary xylanase and glucanase mixture (XyG mix) (de Brito *et al.*, 2021), increasing growth and enhancing nutrient deposition in animals than diet with low NSP content (Cowieson *et al.*, 2010; Maas *et al.*, 2025). However, due to the type and component of NSP (de Macedo *et al.*, 2023), variable responses reported in several fish species (Magalhães *et al.*, 2016). It is probable that pre-treating NSP-rich ingredient with carbohydrase could significantly depolymerise WB AX fraction (Sinha *et al.*, 2011), resulting in the reduction of viscosity-induced faecal loss and enhancement of feed efficiency (Magalhães *et al.*, 2016). There are no reports of studies that evaluated fish growth performance and nutrient deposition and retention due to XyG pretreatment of NSP-rich ingredient like WB, which contain much higher insoluble NSP than SBM, and maize (Sinha *et al.*, 2011). This study therefore evaluated the effect of pretreatment of WB with carbohydrase (XyG) on the growth performance, feed utilization, and biometric indices of Nile tilapia

2. Materials and Methods

2.1 Experimental design and diet formulation

Two iso nitrogenous (30 crude protein) and isocalorific (18.7-19 kJ/g gross energy) diets based on wheat bran (WB₀) and maize (MZ₀) as basal energy sources, with analysed crude fibre of 3.64% and 6.9%, and calculated total NSP of 12.79% and 22.47% for the low (LFD) and high fibre diets (HFD), respectively based on Sinha *et al.* (2011), were formulated to meet the dietary requirement for Nile tilapia (de Brito *et al.*, 2021), respectively. The WB in each of four similar WB diets (WB_{0.1}, WB_{0.2}, WB_{0.3}, and WB_{0.4}) was pretreated with XyG at 0.1, 0.2, 0.3 and 0.4g/kg (Natugrain TS[®], 5600 xylanase and 2500 glucanase, BASF SE, Ludwigshafen, Germany). The enzyme was produced by submerged fermentation with *Aspergillus niger*. All the six diets were randomly assigned to triplicate groups of Nile tilapia (*O. niloticus*) in a completely randomised design. The pretreated WB (subjected to dry incubation at 45⁰C and with 15-25% moisture, for 1-2 hrs) was mixed homogenously with the other major ingredient (FM, soy oil, SBM, groundnut cake and feed additives). All ingredients were previously ground with a Hammar mill and screened through a 1.5mm mesh, clean water was added to the compound mixture after pretreated WB was added to the entire feed that was mixed with soy oil to obtain a wet feed with 10% moisture. Feed extrusion was done using a single screw extruder with a 3mm die at a conditioning at 85⁰ C, resulting in a floating feed of 3mm. The diets were oven dried at 105⁰ C for 2 hrs and stored



at -20 prior to experimental feeding. The ingredient composition of the diets is shown in Table 1.

2.2 Experimental Fish and feeding trial

A total of 360 fish (mean weigh $8.41 \pm 0.01\text{g}$) were sourced from the University of Port Harcourt Demonstration Farm and were acclimated to laboratory conditions for seven days. The fish were fed a commercial diet during this period with water sourced from an overhead tank that supplied the holding tanks. Water parameters that were determined during this period were dissolved oxygen, pH, ammonia, nitrites and temperature, maintained optimally at $>5\text{ mg/L}$, 6.5-8, 0.02mg/L, 0.001mg/L and 27°C , respectively. After acclimation, 20 fish were randomly assigned to each tank (of 70 L per tank) in replicate and fed the diets to apparent satiation twice daily for 56 days. Water was renewed daily by draining though a tap fitted at the end of each tank and faecal samples removed to manage ammonia levels. Fish growth performance was monitored and measured every two weeks with final body weight (FBW) and feed utilization parameters calculated at the end of the trial.

Table 1: Ingredient (as fed basis) composition of the experimental diets

Ingredients	LFD	HFD				
	MZ ₀	WB ₀	WB _{0.1}	WB _{0.2}	WB _{0.3}	WB _{0.4}
Fish maeal (72%CP)	80	50	50	50	50	50
Yellow Maize	300					
Wheat bran		300	300	300	300	300
Groundnut cake	50	50	50	50	50	50
Soybean	400	465	465	465	465	465
Soy oil	80	50	50	50	50	50
Dicalcium phosphate	15	15	15	15	15	15
Bone meal	10	10	10	10	10	10
Table Salt	5	5	4.9	4.85	4.8	4.6
Vit-Min mix	20	20	20	20	20	20
Methionine	15	11	11	11	11	11
Lysine	12	12	12	12	12	12
Cassava starch	13	12	12	12	12	12
XylanaseGlucanase	0	0	0.10	0.15	0.20	0.40
Total (g)	1000	1000	1000	1000	1000	1000



2.3 Nutrition Utilization and Retention Efficiency

At the end of the feeding trial, the following zootechnical indices were measured and calculated from the fish biomass at the end of the trial

Feed intake (FI) = Amount of feed consumed per tank/number of fish

Feed efficiency (FE, %)= weight gain/ feed intake X 100

Protein production value (PPV, %)= protein gain(g) /Protein intake(g)X 100

Lipid production value (LPV, %)= Lipid gain/Lipid intake X100

Energy retention efficiency (ER) = Energy gain/Energy intake X 100

Hepatosomatic index (HSI, %) = wet liver weight/final body weight X100

Viscero-somatic index (VSI, %) = wet viscera mass (g)/final body weight (FBW, g) X100

2.4 Chemical analysis

Triplicate samples of diet was analysed for proximate composition (AOAC, 2000). Briefly, moisture contents of the sample were determined after oven drying at 105⁰ C for 4 hrs to a constant weight. The estimation of Crude protein (NX 6.25) was based on acid hydrolysis using kjedahl distillation apparatus. The Lipid content in the samples was determined using solvent extraction with petroleum ether (DW-SXT-02, Shanghai Drawell Scientific Instrument, China). Crude fibre (CF) was determined by measured after hydrolysis with sulphuric acid (H₂SO₄) and sodium hydroxide (NaOH), followed by degradation of dry matter at 600⁰C for 4hrs. (Jiang *et al.*, 2022). Dietary crude ash content was determined after incineration in a muffle furnace at 550C for 16hrs.

2.5 Economic assessment of the diets and fish production

All diets were assessed for economy of production based on the previous methods described by Akpoilih *et al.* (2023). Specifically, the cost of feed was determined based on the prevailing market price of individual ingredients, while the cost of XyG mix and wet weight of fish were determined from the market price of \$8/kg and \$2.168kg, respectively. The economic conversion ratio (ECR) was estimated by using the expression= Feed cost (\$/kg) x feed conversion ratio (FCR). The economic indices Nile tilapia fed the diets were calculated based on mean values per diet.

2.6 Statistical analysis

All data were subjected to one-way ANOVA using the GLM of SPSS (IBM Version 20, USA). The data were first checked for normality and equality of variance by Shapiro-Wilk test and Levene tests, respectively. When significant differences were detected among the treatments, means were separated by Duncan multiple range test. Significant differences among means were reported at P<0.05. All data were reported as means± standard error (S.E)



3. Results

3.1 Growth response and biometric indices

The growth and biometric indices of Nile tilapia are presented in Table 2. No significant differences were observed in for the initial body weight ($P>0.05$). The least FBW, HSI and VSI were recorded in the fish group that fed on WB_0 , which was much lower than MZ_0 fish ($P<0.05$). The supplementation of XyG significantly improved ($P<0.05$) the growth of Nile tilapia, with $WB_{0.10}$ showing best FBW as compared to $WB_{0.2}$, $WB_{0.3}$ and $WB_{0.4}$, which were statistically similar to MZ_0 fish ($P>0.05$)

3.2 Feed utilization and nutrient retention

The feed intake and nutrient retention in Nile tilapia fed the experimental diets is presented in Table 2. The fish that fed on WB_0 exhibited significantly lower FI than the MZ_0 group ($P<0.05$). XyG increased the FI of the $WB_{0.1}$, $WB_{0.2}$ and $WB_{0.4}$ compared to WB_0 , with no significant difference among them ($P>0.05$). FE, PPV, LPV and ER were significantly reduced in the WB_0 group compared to other fish ($P<0.05$). These indices were significantly enhanced ($P<0.05$) in the $WB_{0.1}$, $WB_{0.2}$, and $WB_{0.3}$ and $WB_{0.4}$ groups to a greater extent than the WB_0 and MZ_0 . The LPV and ER showed no significant difference between the MZ_0 and $WB_{0.2}$ groups ($P>0.05$). Similarly, fish fed MZ_0 , $WB_{0.2}$ and $WB_{0.4}$ were not statistically-similar for FE and ER values ($P>0.05$).

Tables 2. Final body weight, nutrient conversion efficiencies and production value and biometric indices of Nile tilapia fed the diets for 56 days

Parameter s	Final weight (g)	Feed Intake (g/fish)	Feed Efficiency (%)	PPV (%)	LPV(%))	Energy Efficienc y (%)	HSI (%)	VSI (%)
MZ_0	32.5 ^a	35.70 ^a	67.48 ^c	39.43 ^c	24.08 ^a	28.35 ^{bc}	1.56 ^b	3.50 ^b
WB_0	27.4 ^c	30.2 ^c	62.8 ^a	15.79 ^c	4.44 ^c	15.70 ^d	1.25 ^d	2.49 ^d
$WB_{0.1}$	30.5 ^b	34.6 ^b	63.84 ^b	75.21 ^a	27.80 ^a	45.44 ^a	1.69 ^a	3.55 ^b
$WB_{0.2}$	33.7 ^a	38.9 ^{ab}	65.01 ^b	61.56 ^b	23.64 ^a b	38.74 ^b	1.49 ^c	4.89 ^a
$WB_{0.3}$	34.7 ^a	41.1 ^a	63.97 ^b	27.08 ^d	24.09 ^a	26.95 ^c	1.48 ^c	3.12 ^c
$WB_{0.4}$	34.2 ^a	40.2 ^a	64.15 ^b	48.43 ^c	18.54 ^b	32.92 ^{bc}	1.71 ^a	3.64 ^b
Pooled SE	0.776	0.001	0.307	0.926	0.441	0.405	0.009	0.013

Means of three replicate fish ($\pm$ S.E) with different superscripts in the same column are significant ($P<0.05$)



Discussion

In this study, Nile tilapia fed the WB_{0.1}-WB_{0.2} exhibited higher FI accompanied with enhanced retention of lipid and protein when compared MZ₀ (Table 2). This finding was corroborated by Maas *et al.* (2020) who showed that high fibre diet with WB significantly decreased protein, carbohydrate and NSP digestibility, reducing growth performance. Previous studies revealed that the efficiency of utilization was higher in the low energy diet, indicating better utilization in energy deficient diet (Maas *et al.*, 2025). This study showed that XyG significantly improved ERE and PPV and ameliorated the decreased energetic contribution of the HFD to fish growth. This aligns with previous findings which depicts an enhancement in ERE with 0.2g XyG in Nile tilapia (de Macedo *et al.*, 2023). In this study, increased nutrient retention by XyG (0.10-0.2g) could be explained by increased hydrolysis of NSP leading to improved energy utilization and growth performance (de Brito *et al.*, 2021). This improvement indicated better utilization of protein for growth than energy expenditure, demonstrating the protein sparing effect of XyG, resulting in decreased nutrient loss in faeces (Magalhaes *et al.*, 2016). Moreover, in contrast to the results obtained by de Brito *et al.* (2021) who reported reduced energy utilization in XyG supplemented WB-SBM diet relative to MZ-SBM diet without XyG, this study demonstrated better energy utilization, reflected in higher feed and energy efficiency, than the MZ₀ fish. The outcome of this study suggests the potential of pretreatment to degrade AX with greater efficiency than supplementation, resulting in higher xylooligosaccharide production in the gut, which support host energy, utilization, and growth enhancement (Wang *et al.*, 2022).

Economic evaluation of XyG inclusion in the diet showed that relative to MZ₀ and WB₀, the WB_{0.1} and WB_{0.2} fish had the least ECR (lowest cost per uniproduction) and highest net profit and return on investment (Table 3) than other treatments, indicating reduced cost of production and enhanced cost savings. This aligned with the findings previous studies that showed improved economic indices of Nile tilapia and African catfish fed with XyG and/ phytase compared to control diet without enzymes (Maas *et al.*, 2019; Akpoilih *et al.*, 2023).

Table 3: Economic evaluation of Nile tilapia fed the diets for 56 days

Ingredients	MZ ₀	WB ₀	WB _{0.1}	WB _{0.2}	WB _{0.3}	WB _{0.4}
1) Feed cost (\$/kg feed) ^a	1.074	0.7926	0.7924	0.7926	0.7923	0.7921
Cost of XYG (\$/kg feed) ^b	-	-	0.0008	0.0012	0.0016	0.0032
Cost savings (\$/kg feed) ^c	-	0.2814	0.2816	0.2814	0.2817	0.2819
Net Savings (\$/kg feed) ^d	-	-	0.2808	0.2802	0.2801	0.2787
2) Economic Efficiency (feed cost/unit WG)						
Cost savings (\$/kg feed fed)*	0.148	-	0.261[#]	0.149	0.146	0.138
	-	-	0.113[#]	0.0103	0.0069	
Net profit (\$/kg feed fed) [#]	0.148	-	0.260	0.148	0.144	0.135
	-	-	0.1122	0.0091	0.0053	
Return on Investment (ROI) ⁱ	-	-	325.49	123.33	90.0	42.19
			140.25	7.58	3.313	-
Economic conversion ratio (feed cost x FCR)	2.48	1.990	1.690	1.769	1.817	1.846



^a Feed cost per kg diet was calculated based on the current exchange rate of 1\$= 1538.46 Nigerian naira; Based on a market price of \$8 per kg; ^cCost savings was calculated based on difference in feed cost between XYG and control diets; ^d Based on the difference between the cost savings and XYG price per kg; ¹ Expressed as a ratio of net profit to XYG price per kg; *, # Upper and lower values are relative to the WB₀ and MZ₀ diet, respectively

In conclusion, this study has demonstrated the potential of xylanase and glucanase mixture in decreasing the fibre component in practical diet without affecting the growth performance and nutrient retention efficiency of Nile tilapia. Additionally, the findings indicated that low inclusion of the enzyme mixture (0,1-0.2g) improved the economic variables (low feed cost per unit production) of Nile tilapia, highlighting the benefits of enzyme pretreatment in improving fish farmers' productivity and profitability.

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Effect of Compaction on Soil Properties and Hydraulic Functions Under Different Land Use Types in Choba

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Abstract

This study evaluated the effect of soil compaction on soil properties and hydraulic functions across grassland, cassava, and tree land use types at the University of Port Harcourt Research Farm. The objectives were to assess the influence of compaction on soil properties, determine critical threshold that can affect the use of the soil, and understand its effect on hydraulic functions. Soil samples from various depths were analyzed under two compaction levels (561.40 kJ/m³ and 935.67 kJ/m³). Results revealed that maximum bulk density increased significantly with the level of compaction averaging 2.03 g/cm³ at 561.40 kJ/m³ and 2.13 g/cm³ at 935.67 kJ/m³. Total porosity decreased from 44.48 % in uncompacted soils to 23.59 % and 19.90 % respectively, for 561.4 and 935.67 kJ/m³ compaction levels, while moisture retention at field capacity declined from 31.00 % in uncompacted soils to 17.35 % and 15.97 % for the two compaction levels, respectively. The results further indicated that compaction decreased total porosity and moisture retention while increasing the soil bulk density, with grassland and cassava areas exhibiting compaction at depth that limits water movement and root growth, while tree areas showed higher resilience at the surface due to higher organic matter content but experienced deeper compaction. The results of this study confirmed that compaction negatively affect soil properties and hydraulic function, therefore practices that encourages compaction should be avoided. However, addition of organic materials to improve the organic matter content of the soil, improve soil structure and maintain soil health for crop productivity should be encouraged.

Keywords: Bulk density, Compaction, Hydraulic properties, Moisture content, Porosity

Introduction

The capacity of land to enhance and maintain agricultural productivity is closely linked to effective soil management practices. Achieving sustainable agriculture requires soils with optimal structure, characterized by adequate aeration, efficient water infiltration, and favorable water retention (Seifu *et al.*, 2018). These factors are essential for reducing soil degradation through runoff and erosion. Additionally, well-structured soils offer essential mechanical support to crops, minimize root penetration resistance, and reduce the energy needed for tillage as they are key attributes for farmers to maximize crop yields and



efficiency in agricultural operations. Soil compaction affects soil fertility through increasing bulk density and soil strength. It also decreases infiltration rate, total porosity and amount of water stored in the root zone for crop use (Udom & Ehilegbu, 2018). Compacted soils tend to have reduced water infiltration and root penetration, leading to poor crop yields. Soil compaction, if not properly managed, could undermine efforts to achieve food security in line with the United Nations Sustainable Development Goal (SDG) 2, which aims to end hunger and ensure access to nutritious and sufficient food for all (Gonzalez, 2022). Soil bulk density is a critical measure of soil compaction, influencing key properties such as porosity and hydraulic conductivity. These soil characteristics directly affect soil's ability to transport air and water, essential for plant growth and overall soil health. The relationships between bulk density, porosity, and hydraulic conductivity are dynamic and influenced by moisture content, with tropical soils, such as those in Nigeria, being particularly sensitive due to their unique structure, land use, and environmental conditions.

Materials and Methods

Study Site: The study was carried at the University of Port Harcourt, Teaching and Research Farm, a rainforest zone of Southern Nigeria. The area is located within latitude 4°54'31" N and longitude 6°55'22"E, covering a total perimeter of 901.14 m and area of 48,243.35 m² with an elevation of 12.76 m height above sea level,

Field Methods and Sample Preparation: The study site was categorized based on three different land uses viz: Teaching and Research Farm Unit (TRFU 1) grassland area, Teaching and Research Farm Unit (TRFU 2) cassava cultivated area and Teaching and Research Farm Unit (TRFU 3) tree crop area. A soil profile pit was sunk on each of the identified mapping units, and was analyzed for some pedological features. Disturbed and undisturbed bulk soil samples were collected from the different soil horizons at a depth of 0-15 cm apart and 15 kg. Disturbed samples were collected using soil auger. The horizons were sampled from bottom to top to avoid contamination. The soil samples for some physicochemical analysis were air-dried and passed through a 2 mm sieve for laboratory analysis. Particle size distribution was carried out by Gee and Bauder (1986) method, bulk density by Grossman & Reinsch (2002), total porosity by Flint and Flint (2002), and moisture content by the Blake (1965) method

Laboratory Compaction Procedure: The soil samples collected were air dried and passed through a 19 mm sieve and pulverized. 5 kg of the samples were weighed into the compaction pan for the compaction test. A minimum of five different moisture contents was used in developing the laboratory soil compaction curves. The initial moisture content which vary from 2-3 % of the oven dried samples were increased by five units at each level of compaction. Thorough mixing of the soil and minimum moisture losses by evaporation was ensured during the test. A manual hand soil compactor was used for the test. The soil samples collected from the field were moistened in the compaction pan and compacted in a metal rings of 10 cm diameter and 12.73 cm height in three layer each receiving 25 blows of a 2.5 kg rammer drop from a height of 30.5 cm. The number of blows was reduced by 10 to give a second compaction level of 15 blows. After application of the blows, a specimen sample



was removed to determine soil moisture, dry bulk density, wet density and the Compaction Efforts (CE) under which the soil was compacted and calculated as described by Head (1992).

Results

The results of the physiochemical and hydraulic properties of the soil of the studied area are presented in Table 1. The TRFU 1 had yellowish brown colour in the various soil horizon and a sandy texture with a moderately rapid permeability class. TRFU 2 had dark brown colour soil in the various horizon with a sandy loam texture and a moderately rapid conductivity class (Table 1).

Table 1: Some morphological and physical properties of the research and teaching farm in relation to the mapping units and corresponding horizon depths

Land Use	Depth (cm)	Color	Particle size			Textural class	Permeability code
			% Sand	% Silt	% Clay		
TRFU 3	0 – 15	Dark Brown (10YR 3/3)	43.8	17.4	38.8	Clay loam	4
	15 – 30	Dark Brown (10YR 3/4)	42	18	40	Clay	5
	30 – 45	Dark Brown (10YR 3/4)	41	18.5	40.5	Clay	5
	45 – 60	Dark Brown (10YR 3/4)	40	19	41	Clay	5
TRFU 2	0 – 15	Light Brown (10YR 5/6)	53.2	16	30.8	Sandy Clay loam	3
	15 – 30	Light Brown (10YR 5/5)	52	16.5	31.5	Sandy clay loam	3
	30 – 45	Light Brown (10YR 5/4)	51	17	32	Sandy clay loam	3
	45 – 60	Light Brown (10YR 5/3)	50	17.5	32.5	Sandy clay loam	3
TRFU 1	0 – 15	Yellowish-Brown (10YR 5/6)	57.2	24.6	18.2	Sandy loam	2
	15 – 30	Yellowish-Brown (10YR 5/5)	56	25	19	Sandy loam	2
	30 – 45	Yellowish-Brown (10YR 6/5)	55	25.5	19.5	Sandy loam	2
	45 – 60	Yellowish-Brown (10YR 6/4)	54	26	20	Sandy loam	2

The lowest and highest bulk density of 1.36 gcm³ and 1.63 at 0 – 15 cm and 15 – 30 cm was recorded in the TRFU 3 and TRFU 1, respectively. Also the lowest and highest particle density of 2.38 gcm³ and 2.84 at 15 – 30 cm and 45 – 60 cm depth was recorded in the TRFU 3 and 2 respectively. While, the lowest and highest porosity value of 36.40 and 43.98% at the TRFU 1 was recorded in the 15 – 30 cm and 30 - 45 cm depth respectively. The lowest and highest moisture content of 0.22 and 0.31 at 15 – 30 cm and 0 – 15 cm depth was recorded in



the TRFU1 and 3 respectively. Furthermore, field capacity had lowest and highest values of 24.00 and 35.44% at the TRFU 1 and 2, respectively. While, permanent wilting points of 17.74 and 30.22 were recorded as the lowest and highest values at the depth of 0 – 15 and 45 – 60 cm depth in the TRFU1 and 3, respectively. In the same vein, the lowest and highest available water capacity of 2.76 and 7.84 at the 30 – 45 cm and 45 – 60 cm depth were recorded in the TRFU1 and 3, respectively. While, the lowest and highest saturated hydraulic conductivity of values of 1.1 cm/hr and 3.0 cm/hr at the 45 – 60 cm and 0 – 15 cm were also recorded at the TRFU 2 and TRFU 1. A slow and moderate conductivity class was recorded for TRFU 1 and TRFU 3, respectively (Table 2).

Table 2: Some physical properties and soil moisture characteristics of the soil at the Teaching and Research Farm

Land Use	Depth (cm)	BD (g/cm ³)	PD (g/cm ³)	Porosity	Moisture content (Dry basis)	Percentage Content at		Moisture		Conductivity class
						FC	PWP	AWC	Ksat (cm/h)	
TRFU 3	0 – 15	1.36	2.39	42.97	0.31	35.44	28.31	7.12	2.5	Moderate
	15 – 30	1.48	2.38	37.91	0.26	34.48	29.38	5.09	2.2	Moderate
	30 – 45	1.62	2.58	37.41	0.23	32.86	30.10	2.76	1.8	Slow
	45 – 60	1.54	2.55	39.43	0.26	34.39	30.22	4.17	1.5	Slow
TRFU 2	0 – 15	1.51	2.71	44.48	0.30	28.98	23.97	5.00	1.6	Slow
	15 – 30	1.54	2.48	37.91	0.25	29.03	24.51	4.52	1.5	Slow
	30 – 45	1.49	2.46	39.43	0.26	30.13	24.71	5.42	1.2	Slow
	45 – 60	1.6	2.74	41.45	0.26	28.95	25.35	3.60	1.1	Slow
TRFU1	0 – 15	1.55	2.61	40.44	0.26	24.64	17.74	6.90	3.0	Moderate
	15 – 30	1.63	2.57	36.40	0.22	24.00	18.46	5.54	2.6	Moderate
	30 – 45	1.53	2.73	43.98	0.29	25.82	18.53	7.29	2.3	Moderate
	45 – 60	1.50	2.53	40.95	0.27	26.63	18.79	7.84	2.0	moderate

The pH value of 4.4 and 5.4 at a depth of 45 – 60 and 0 -15 cm representing the highest and lowest values were recorded for TRFU 3 and 1, respectively. Also the lowest and highest electrical conductivity values of 0.18 and 0.44 ds/m at 30 – 45 and 15 – 30 cm depth were recorded in the TRFU 2 and 3, respectively. Furthermore, 0.70 and 1.18 as lowest and highest values for total organic matter were recorded at the 45 – 60 and 0 – 15 cm depth for TRFU 1 and 3, respectively. In the same vein, the lowest and highest organic matter of 1.21 and 2.04 at the 45 – 60 and 0 -15 cm depth were also recorded in the TRFU1 and 3, respectively (Table 3).



Table 3: Some chemical properties of soil in the Teaching and Research Farm

Land use	Depth (cm)	pH	EC (dS/m)	TOC	TOM
TRFU3	0 – 15	4.7	0.40	1.18	2.04
	15 – 30	4.7	0.44	1.02	1.76
	30 – 45	4.5	0.38	0.88	1.52
	45 – 60	4.4	0.36	0.78	1.35
TRFU2	0 – 15	5.1	0.21	0.94	1.62
	15 – 30	5.1	0.20	0.88	1.52
	30 – 45	4.9	0.18	0.84	1.45
	45 – 60	4.9	0.18	0.78	1.35
TRFU1	0 – 15	5.4	0.34	0.88	1.52
	15 – 30	5.2	0.33	0.84	1.45
	30 – 45	5.1	0.20	0.78	1.35
	45 – 60	5.0	0.23	0.70	1.21

Discussion

Effect of compaction on some soil physical, moisture related and chemical properties of the different mapping units

Sandy loam textural class dominated the entire soil horizons of the TRFU 1 with yellowish brown colour which may be attributed to the presence of organic matter in the soil, while TRFU 2 and 3 are dominated with sandy clay loam and clay with light brown and dark brown colour respectively. The permeability class for the TRFU 1, TRFU 2 and TRFU 3 were moderately rapid, slow and moderately slow, respectively. Bulk density across the different land use types is within the critical threshold limit, but increases with depth from 1.55 to 1.63 g/cm³ reducing porosity (40.44% to 36.40%). This is in agreement with the work of Shaheb *et al.* (2021). Field capacity increased with increased in depths which support deep-root water access, though compaction may restrict root expansion. Permanent wilting points are within the threshold limit value required for crop production, while available water content obtained was moderate for most tropical crops. The pH was found to decrease with depth, especially in trees areas which may be due to acidification. Electrical conductivity (EC) was higher in compacted soils. Total organic carbon (TOC) and organic matter (OM) declined with depth which may be due to reduced biological activity in compacted layers. Furthermore, the tree area was found to retain more water which may be due to higher organic matter, while cassava and grass area exhibited better drainage, but reduced retention. Soil texture and organic matter influenced hydraulic responses differently under compaction.

Summary and Conclusion



The research examined the influence of soil compaction on different land-use types, including tree area, cassava cultivated and grassland area. The study found that compaction led to increased bulk density and decreased porosity, with moisture at field capacity varying inconsistently, indicating that soil properties are depth- and location-dependent. The impact of compaction varied across different land-use types, with the tree area showing some resilience due to higher organic matter content, while the grassland and cassava areas experienced more severe compaction. The findings underscore the importance of sustainable land management practices to minimize soil compaction and maintain soil health and productivity

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Effect of Moringa Plant Parts Extracts at Various Concentrations on the Germination of Maize, Okra and Soybeans seeds

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Abstract

Allelochemicals compounds in plants play important role in the determination of plant diversity, dominance, succession, and climax of natural vegetation, and in the productivity of plants in agro-ecosystems. *Moringa oleifera* has been reported to be allelopathic in nature, though with many agronomic importance. Crops which are allelopathic have been observed to affect seed germination. There is little information as regards the effects of Moringa parts on some selected crops in Nigeria. This study aimed at evaluating the allelopathic effects of Moringa parts on the germination of maize, okra and soybean. The experiment was carried out in the laboratory of the Department of Agronomy, University of Ibadan, Nigeria. Treatments involved varying concentrations (0%, 25%, 50%, 75%, 100%) of aqueous extracts of leaf, bark, root and twig of Moringa fitted in a 4 x 5 x 3 factorial experiment laid out in a completely randomized design. The treatments were replicated three times and test crops used were, maize seeds (variety DMR-ESR-Y), soybean seed (variety TGX 1987 -62F) and okra seed (variety LD88/1). Percentage germinations were recorded for the experiment. Data were subjected to analysis of variance (ANOVA) and means were separate with LSD. Results showed that germination of maize, okra and soybean seeds decreased with increase in concentrations of all the aqueous extracts, irrespective of plant parts used. Germination was found to decrease most when treated with 100% and 75% extracts. The inhibitory effect of leaf, bark, twig and root aqueous extracts of Moringa were similar. The study revealed that extracts from different Moringa parts impeded seed germination of maize, okra and soybean at concentrations of 25%, 50%, 75%, 100%, but effectively at concentrations of 75% and 100% under laboratory conditions.

Keywords: Allelopathy, Aqueous extract, Moringa plant parts, Seed germination

Introduction

Seed germination is an important stage in crop establishment and productivity, as it determines plant vigor, uniformity, and subsequent yield. *Moringa oleifera* (commonly known as the drumstick tree) has been identified as a “miracle tree” due to its rich phytochemical composition and wide range of agricultural, nutritional, and medicinal applications. Different parts of the Moringa plant (leaves, seeds, pods, and bark) contain bioactive compounds such as cytokinins, antioxidants, vitamins, and minerals, which has been reported to stimulate physiological and biochemical processes in seeds and plants.



allelochemicals, are mostly secondary metabolites, which are produced as byproducts during different physiological processes in plants (Bhadoria, 2011; Farooq *et al.*, 2011a). Moringa leaf extract (MLE), in particular, has been used as a natural growth enhancer due to its high content of zeatin (a type of cytokinin), which promotes cell division and elongation, thus improving germination and seedling vigor.

The effect of Moringa extracts, however, may vary depending on the part of the plant used and the concentration applied. At optimal levels, moringa extracts have been shown to promote germination, seedling growth, and stress tolerance, while excessively high concentrations may inhibit germination due to allelopathic effects or osmotic stress. Maize (*Zea mays*), okra (*Abelmoschus esculentus*), and soybean (*Glycine max*) are among the most important food and cash crops worldwide. Their successful establishment from seed is critical for agricultural productivity and food security.

Materials and Methods

The study was conducted to evaluate the efficacy of *Moringa oleifera* leaves, bark, twig and root aqueous extracts on germination of maize, okra and soybeans. The experiments were conducted at laboratory of the Department of Agronomy, Faculty of Agriculture and Forestry, University of Ibadan (7° 24'N, 3° 54'E). For preparation of leave, bark, twig and root extracts, the plant parts were ground to fine powder and extracted by soaking 100 gram of the powder in 1litre of distilled water for 24 hours and then filtered. This stock solution was diluted at different concentrations (0%, 25%, 50%, 75%, and 100%) using distilled water.

Distilled water was used as a control treatment. 10 ml of extracts solution were added to each Petri dishes. All Petri dishes were placed in a carton box representing a dark room. Germination was determined by counting the number of germinated seeds at 24-h intervals. Germination was deemed to occur only after the radicle had protruded beyond the seed coat by at least 1 mm.

Source of Moringa Plant Parts

Young Moringa leaves not less than 40 days old and bark, twig and root were harvested from grown trees located at the screenhouse area of the Department of Agronomy.

Materials Used

Oven-dried plant parts of Moringa, petri dish, cotton wool, distilled water, carton boxes, maize seeds (of variety DMR-ESR-Y, from Institute of Agricultural Research and Training(IAR and T), soybean seed (of variety TGX 1987 -62F from International Institute of Tropical Agriculture, IITA) and okra seed (variety LD88/1 from National Horticultural Research Institute, (-NIHORT).



Experimental Design

There were three experimental factors (i) four different parts of moringa plant (ii) five different concentrations (iii) three crop seeds. There were 60 treatment combinations, replicated three times in a Completely Randomized Design.

Data Collection and Statistical Analysis

Data were collected on the germination count of the crops. The data collected were subjected to analysis of variance (ANOVA) using GenStat software (4.0 edition). Significance different treatment means were separated using LSD at 5% level of probability.

Results and Discussion

Table 1 shows germination of the maize seed was significantly influenced ($p < 0.05$) by the concentration of moringa plant parts at 2, 3 and 4 days after sowing. Highest germination was recorded in seeds not treated with extract (control) while the lowest germination was recorded in seeds treated with 100% concentration of the extracts at the 2 and 3 days after sowing but at the 4 days after sowing, was significantly higher than those recorded for 75% concentration and 100% concentrations but comparable to those obtained from 25% and 50% concentrations.

The parts of moringa from where the extracts were obtained had significant influence on the germination of the maize seeds only at day 3 after sowing. The leaf extract significantly reduced the germination of maize seeds compared to the extract from the bark of the plant. There was however no significant influence in the effects of root and twig extracts compared to that of leaf as well as that of bark extract.

Effect of Moringa Plant Parts Extract at Various Concentrations on the Germination of Okra seed

Table 2 shows the effects of the sources and concentrations of moringa extracts on the germination of seeds of okra. It could be seen that the seeds did not record 100% germination at the early day of treatment of the seeds with germination increasing from 27.5 to 34% from the 2nd to the 4th day after treatment. Sources of the extract significantly affected the germination of okra seeds. Although, 25% extract treatment resulted in higher germination percentage compared other concentrations across the period of observations, these were significantly lower than those recorded for the control. The extracts from the leaves and bark of moringa significantly reduced the germination of okra seeds compared to those obtained from the other parts of the plant (Table 2).

Effect of Moringa Plant Parts Extract at Various Concentrations on the Germination of Soybean Seed

Table 3 shows that the concentration of extracts had significant influence on the germination of soybean. At the period of observation, the control of zero extract concentration resulted in significantly higher percentage germination of soybean seeds than all other concentrations. At



2 and 3 days after treatment (DAT), the seeds treated with 25% extract concentration across the various plant parts as sources of extract had significantly higher percentage germination than those treated with other concentrations. The percentage seeds germination at 4 DAT was also higher from the seeds treated with 25% concentration of the extract, but this was not significantly higher than those treated with 50 and 75% extract concentrations. At all the points of observation, 50, 75 and 100% extract concentrations caused similar effects on the germination soybean seeds.

The plant parts of moringa from where the extracts were obtained had significant effects on the germination of soybean seeds at 2 and 3 DAT but the effects were not significant at the 4th DAT. The moringa plant leaves as a source of the extract resulted in a significantly lower germination percentage than all other sources at 2 and 3 DAT except that from the bark. The extract from the various plant parts at 2 DAT resulted in the following significant order of germination of soybean seeds: bark < root < twig whereas, at 3 DAT the order was bark < root = twig. The interactions of both concentration and sources of the extract were significant all points of observation.

Table 1: Effect of Moringa plant parts extract at various concentrations on germination of maize seed

	Germination (%)		
	Days after sowing		
	2	3	4
Concentration (A)			
0	81.7	99.2	100
25	77.5	95.8	98.3
50	69.2	93.3	92.5
75	65.0	92.5	90.8
100	59.2	89.2	90.0
LSD _(0.05)	12.9	8.4	8.7
Plant Parts (B)			
Bark	68.0	98.0	93.3
Leaf	66.0	90.7	93.3
Root	72.7	92.0	92.7
Twig	75.3	95.3	97.3
LSD _(0.05)	ns	7.5	ns
Interaction AxB	*	ns	ns

ns= non - significant, *= significant



Table 2: Effect of Moringa plant parts extract at various concentrations on the germination of okra seed

	Germination (%)		
	Day after sowing		
	2	3	4
Concentration (A)			
0	27.5	33.3	34.0
25	23.3	28.3	28.6
50	7.0	8.2	8.5
75	5.0	5.0	5.8
100	5.8	7.5	7.9
LSD _(0.05)	1.9	3.0	1.3
Plant Parts (B)			
Bark	6.7	10.0	10.3
Leaf	2.7	4.0	5.3
Root	20.0	23.3	92.7
Twig	28.0	29.3	30.3
LSD _(0.05)	7.50	8.08	8.4
Interaction A x B	***	***	***

***= significant (p= 0.001)

Table 3: Effect of Moringa plant parts extract at various concentrations on the germination of Soybean seed

	Germination (%)		
	Days after sowing		
	2	3	4
Concentration (A)			
0	27.5	33.3	80.0
25	23.3	28.3	54.2
50	7.0	8.2	47.5
75	5.0	5.0	43.3
100	5.8	7.5	31.7
LSD _(0.05)	1.9	3.6	12.3
Plant Parts (B)			
Bark	6.7	10.0	64.7
Leaf	2.7	4.0	54.2
Root	20.0	23.3	50.0
Twig	28.0	29.3	56.0
LSD _(0.05)	7.5	8.1	Ns
INTERACTION AXB	***	*	*

*= significant (p= 0.05)

Failure of the seeds to germinate at higher concentrations (75% and 100%) of *Moringa oleifera* plant extract suggests there was inhibition. Randhawa *et al.* (2002) reported that root



length of *Trianthema portulacastrum* was affected by sorghum water extract and significantly inhibited by high concentration of 75% and 100% sorghum water extract.

Extract from different parts of *M. oleifera* affected seed germination in similar manner. Hossain *et al.*, (2012) revealed that allelochemicals released by different plant parts of *M. oleifera* impeded the rate of germination in similar manner. In this study the leaf had higher effect on germination on the seeds than the other plant parts these was also reported by Copping (1996) that leaves are the most potent source of allelochems, however, the toxic metabolites are also distributed in all other plant parts in various concentrations, also previous study by Vrchotová *et al.*, (2011) reported that the leaves of *I. glandulifera* inhibited germination of *Leucosinapis alba* and *Brassica napus* seeds.

Root and twig extract had higher effect on germination of the maize and soybean seeds. okra seeds recorded higher inhibition than soybean and maize this may be due to the size of okra seeds compared to maize and soybeans seeds size or their ability to also absorb matters, according to Zakaria and Razak (1990) they reported that the differences in the germination percentage of crops could be attributed to differences in the selective permeability of the seed coat to inhibitory substances. There was no influence of the plant parts on both shoot and root dry matter production, this could mean allelopathy is not active in non-growing plant.

Conclusion

All plant parts have allelopathic effect, but the leaf had more. Lower concentration promote growth than higher concentration which inhibit growth. Fresh moringa leaf extracts has higher allelopathic effect than dry leaf extract. Seeds size also can determine effectiveness of allelopathy of the plant parts used. Allelopathic plant part effect is more pronounce at early stage of growth.

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