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Levels of adoption of good agronomic practices on improved Cassava varieties in Anambra State, Nigeria

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ABSTRACT

This study examined the levels of adoption of improved cassava varieties and good agronomic practices (GAP) among cassava farmers in Anambra State, Nigeria. The specific objectives were to; identify the extent of adoption of cassava varieties released in the years, estimate the levels of adoption of good agronomic practices, ascertain the determinants of adoption of good agronomic practices and identify constraints militating against adoption of good agronomic practices (GAP) in the study area. Using a multistage sampling technique, data were collected from 120 respondents across eight farming communities through structured questionnaires and analyzed with descriptive statistics and regression analysis. Findings revealed that majority of the farmers were female (51.7%), with an average age of 33 years, household size of six, farm size of 2 hectares, and farming experience of 20 years. Adoption rates of improved cassava varieties were high, particularly TME-419, which had the highest adoption index due to its disease resistance and high yield. Among GAP, adoption rates varied - ridge making (43.1%), use of improved cuttings (54.1%), and pest/disease control (67.9%) had relatively high adoption, while planting distance (16.0%) and fertilizer application (2.2%) had low uptake. Key determinants of adoption included education, income, cooperative membership, access to cuttings, and extension contact. However, high cost of cuttings, limited access to credit, inadequate knowledge of weather problems, pest pressure, and poor extension services constrained adoption. The study concludes that while adoption of improved cassava varieties is high, uptake of agronomic practices remains uneven and these necessitating targeted interventions.

KEY WORDS: *Cassava adoption*; *Improved varieties*; *Smallholder farmers*; *Anambra state*; *Nigeria*

1. Introduction

Cassava is the most widely and popularly cultivated root crop as regards to area allocation and the number of growers in Nigeria (Tesfamicheal *et al*, 2017). The importance of cassava is increasing as it is almost replacing yam and other traditional staple foods as a famine reserve and insurance crop against hunger (Wossen *et al.*, 2017). The crop is important not only as a food but also as a major source of income for rural households. As a cash crop, cassava generates income for the group number of households compared to other staples (Wossen *et al.*, 2017), and justifies people's focus on the crop. Improving agricultural productivity, particularly,

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cassava productivity through efficient dissemination of improved varieties is therefore essential for poverty reduction efforts in Nigeria.

Cassava crop is a very versatile commodity with numerous uses and by products; the crop is planted all year round depending on the availability of moisture. Each component of the plant can be valuable to its cultivator, about 16 percent of cassava root production was used as industrial raw material in 2001 in Nigeria, 10 percent was also used as chips in animal feeds, 5 percent was processed into a syrup concentrate for soft drinks and less than 1 percent was processed into high quality cassava flour used in biscuits and confectioneries (Udemezue and Onwuneme, 2017).

According to Tesfamicheal *et al* (2017), it is generally known that improved agricultural technologies play a critical role in agricultural transformation and economic growth in developing countries. Correctly, adoption of improved agricultural technologies should, all things being equal, boost overall productivity and increase additional income for farmers. In doing so, technology adoption can accelerate economic growth, create marketing opportunities and help millions of farmers to be out of poverty traps (Wossen *et al.*, 2017). In this regard, the dissemination and diffusion of improved crop varieties has been seen as the primary pathway through which technological change in the agricultural sector can bring about productivity gains (Tesfamicheal *et al.*, 2017).

Intensification of better agricultural production system is one of the ways of increasing the welfare of farmers. This can be achieved if farmers take advantage of improved crop variety such as cassava. Some direct impacts of agricultural technologies (such as changes in agricultural productivity and farm income) are relatively easy to measure quantitatively, which is probably why they have been the focus of most impact research. It is however difficult to establish the causal effect of farming technology on welfare, but at the same time this is necessary if we want to know the extent of agricultural enhancement of the poor (Afolami *et al.*, 2015).

To increase productivity, technology must be adopted in the production process and the rate of adoption of a new technology is subject to its profitability, degree of risk associated with it, capital requirements, agricultural policies and socioeconomic characteristics of farmers (Udemezue and Agwu, 2018). Therefore, adoption of innovation is the last step in a decision process to make full use of an innovation having considered that such will impact positively on the livelihood of the adopter. Adoption is regarded as a decision to make full use of an innovation or technology as the best course of action available.

Understanding the levels of adoption of agricultural technologies is essential in planning and executing technology related programs for meeting the challenges of food production in developing countries (Udemezue and Agwu, 2018). In view of this, the International Institute of Tropical Agriculture (IITA) initiated cassava research in the early 1970s with a focus on developing varieties with resistance to major diseases such as cassava mosaic virus disease (CMD) and cassava bacterial blight (CBB). Consequently, International Institute of Tropical Agriculture (IITA) in conjunction with National Root Crops Research (NRCRI) Umudike has developed and released more than 46 cassava varieties with multiple disease resistance and high yield potentials. In addition, they developed good agronomic practices and biological control and integrated pest management options to reduce losses due to insect pests. Despite these major efforts made by IITA and partners to develop and disseminate a growing number of improved cassava varieties and good agronomic practices, there is still a lack of comprehensive and rigorous evidence of adoption and impacts of these varieties and agronomic practices on poverty reduction. Against this backdrop, this research is designed to investigate adoption analyses of good agronomic practices on recent improved cassava varieties in Anambra State, Nigeria. The specific objectives were to; identify the extent of adoption of cassava varieties released in the years, estimate the levels of adoption of good agronomic practices, ascertain the determinants of adoption of good agronomic practices and identify constraints militating against adoption of good agronomic practices (GAP).

2. Material and Methods

The study area for this research is Anambra State. The State is located in the South East of Nigeria. It is bounded by Delta State to the West, Imo State to the South, Enugu State to the East and Kogi State to the North. The State lies on the longitude 6° 35'E and 7'E and latitude of 5° 38'N and 6° 47'E (Udemezue *et al*., 2024). The target population for this study was cassava seed farmers in the State. Multistage sampling techniques were used for this study. Four local governments out of 21 local governments in Anambra State were selected due to their popularity in cassava seed marketing. Ayamelum, Anambra East, Anambra west and Ogbaru local government were selected. In the second stage, two communities each from a local government were selected. Here Omor and Umumbo in Ayamelum Local Government, Igbariam and Umuoba Anam in Anambra East, Nzam and Iyi Ora Anam in Anambra west, Atani and Osamala in Ogbaru Local Government were purposely selected. These gave a total of eight (8) communities. Third stage, 15 farmers were selected from each community using simple random techniques and this gave a total sample size of 120 respondents. Data were collected through structured questionnaires**.** Data collected for the research were analyzed using statistical tools such as, descriptive statistics and regression analysis.

3. Results and Discussion

Findings of the study indicated that majorities (51.7%) of the farmers were female while 48.3% of them were male (Table 1). This finding contrasts with the general expectation that cassava farming is typically male-dominated, as reported by Tesfamicheal *et al.* (2017). The higher female participation observed in this study may be attributed to the role of cassava in household food security and its compatibility with domestic traditionally undertaken by women. Moreover, 40% of the cassava farmers were married and 20.3% were single. This implies that the respondents were dominated by married men and women who invariably contributed to increase in household size farm labour (Tesfamicheal *et al.*, 2017). However, 45% of them completed primary school education while 25% of the farmers completed secondary school education respectively. This implies on the aggregate that the majority of the farmers had one form of education or the other, and thus had the advantage of adopting innovation, since education helps in adopting improved agricultural technologies as observed by Tesfamicheal *et al.* (2017).

Table 1: Socio-economic characteristics of cassava farmers in Anambra State

Variables	Frequency	Percentage	Mean
Sex			
Male	58	48.3	
Female	62	51.7	
Age			
18-25	25	20.3	
26-35	56	46.7	33 years
36-45	20	16.7	
46-55	19	15.8	
Marital status			
Married	48	40.0	
Single	25	20.3	
Separated/divorced	30	25.0	
Widowed	17	14.2	
Farm size			
Less than 1 ha	20	16.7	
1-2 ha	58	48.3	
3-4 ha	32	26.7	2 ha
5 and above	10	8.3	
Farming experience			
Less than 10 yrs	51	42.5	
10-20 yrs	43	35.8	
21-30 yrs	15	12.5	14 years
31-40 yrs	11	9.2	
Educational level			
Non formal education	25	20.3	
Primary school	54	45.0	
Secondary school	30	25.0	
Tertiary institution	11	9.2	
Family size			
1-5	49	40.8	
6-7	35	29.2	
8-9	28	23.3	6 persons
10-11	8	6.7	
Extension visit			
Yes	35	29.2	
No	85	70.8	
Membership of organization			
Yes	75	62.5	
No	45	37.5	

Source: field work, 2024

Also, this buttresses the reason why most of the farmers adopted at least one of the improved cassava varieties. The average mean age, household size, farm size and farming experience of the farmers were 33 years, 6 persons, 2ha and 20 years therein. The average age of the farmers implies that the farmers are in their active years, with an advantage of transferring innovations that enhance farm productivity. It is expected that improved varieties of cassava will be adopted at a faster rate in this area, which is in line with the observation of (Uchemba *et al*., 2021). However, the average hecterage of the farmers indicates a predominance of smallholder farming, which is typical in cassava production systems in Nigeria. This finding corresponds with Esheya (2019) and Oshioriamhe *et al*. (2025), who observed that most cassava farmers operate on relatively small plots of land, possibly due to land constraints or resource limitations.

As regards to farming experience, farmers had an average year of 20 and Such levels of experience suggest that most cassava farmers have been in the sector long enough to gain practical knowledge, which can enhance their adaptability and risk management. According to Aboajah *et al*. (2018) and Oshioriamhe *et al*. (2025), this depth of experience positively influences the adoption of improved practices and technologies.

In terms of the extent of adoption of cassava varieties released to farmers, TME-419, TMS-98/0581, TMS-98/0505, TMS, 30572, TMS-3055 and TMS-98/0510 were adopted by the farmers according to their order of preference respectively (Table 2). TME-419 variety has a high level of adoption, seconded by TMS-98/0581 and TMS-980505.

Table 2: The extent of adoption of cassava varieties released to farmers

Improved cassava varieties	Mean
TME-4I9	4.9
TMS-98/0581	4.6
TMS-98/0505	4.4
TMS-30572	4.2
TMS-3055	2.9
TMS-98/0510	2.3
Ground mean	3.9
Adoption index (%)	0.78

Source: field work, 2024.

Note: adoption index was calculated by dividing the ground mean (M) adoption scores by 5 (that is, 5-stages of adoption). The adoption index between 0.5-1 was regarded as high level of adoption.

This result is in agreement with Afolami *et al.* (2015) that majority (60.2 %) of the farmers adopted TME 419 variety among the introduced improved cassava varieties in the states because of its thin stem and larger yield compared to other varieties introduced while 39.8 % did not. This result is similar to the findings of Ojo and Ogunyemi' (2014) in Ekiti State where 60.6 % farmers were found to have adopted TME 419 among improved cassava varieties introduced to them in the State. This finding was also not in line with the result of Uchemba *et al*. (2021) which showed that improved cassava production technologies has not been fully adopted by all the farmers in their study. This could be that majority of their respondents were still at the evaluation stage of adoption in the study areas. The farmers also established the fact that TME 419 was the best technology introduced to them due to its disease resistance and low water moisture content compared to other varieties. Therefore, the improve cassava varieties disseminated to farmers in the study were adopted with an adoption index of 0.78(78%) indicating high adoption level.

On the extent of levels of adoption of improved cassava agronomic practices by the farmers (Table 3), 43.1% of the farmers adopted ridge making disseminated to them while 3.2% of the farmers rejected it. However, 54.1% of the farmers adopted the use of improved cassava cuttings disseminated against 1.4% of them who rejected

Table 3: Levels of adoption (%) of improved cassava agronomic practices by the farmers

Agronomic practices	Not aware	Aware	Interest	Evaluation	Trail	Adoption	Rejection
	0	1	2	3	4	5	6
Ridge making using tractor	-	40.3	10.4	1.7	1.3	43.1	3.2
Use of improved cuttings	13.3	2.3	20.9	3.7	4.3	54.1	1.4
Planting period (April-October)	1.8	5.5	14.3	8.9	7.2	20.8	41.5
Planting distance (1m ×1m @ angle 45°)	30.9	3.3	10.5	21.5	15.5	16.0	2.3
Fertilizer application (NPK 15:15:15 @ 8-12 weeks)	10.6	11.2	13.5	14.3	16.2	2.2	32.0
Diseases and pests control measures	2.9	3.3	10.5	6.1	9.3	67.9	-

Source: Field survey, 2021

the technology. Moreso, 20.8% of the farmers adopted planting period of cassava production disseminated while 41.5% of them rejected the technology. As regards to planting distance, fertilizer application and disease/pest control; 16.0%, 2.2% and 67.9% of the farmers adopted the technologies while 2.3%, 32.0% and 0% of the farmers rejected the technologies disseminated to them.

The decision to adopt agronomic practices by the farmers was significantly influenced by some socioeconomic factors (Table 4). Among these were: educational level, membership of cooperative, access to cassava cuttings, income and extension contact. These variables were found to be statistically related to the factors influencing the levels of adoption of improved cassava agronomic practices by the farmers in study area. Educational level, income, extension contact, and cooperative membership are significant determinants of improved agronomic practices in cassava production, with higher education, increased income, frequent extension contact, and active participation in cooperatives generally leading to greater adoption of best practices (Nwaobiala, 2018). These factors provide farmers with the knowledge, resources, and social support needed to adopt new technologies and improve their production systems. The finding agrees with Afolami *et al.* (2015) that availability of improved cassava cutting within the village determines the adoption of improved cassava agronomic practices by the farmers in study area. Also, the study is in agreement with Fidelis *et al.* (2023) that access to extension services and cooperative membership significantly influenced adoption of cassava farmers' agronomic practices in the study area. According to Wossen *et al.* (2017), access to extension services can boost the adoption of new farm technology by removing barriers caused by information inefficiencies. Extension access, in particular, supports adoption by exposing farmers to new technology and teaching them about appropriate agricultural and management practices (Fidelis *et al.*, 2023).

In addition to directly impacting adoption, access to extension services has a positive impact on welfare by assisting farmers in closing the yield gap between expected and actual harvests (Fidelis *et al.*, 2023). Cooperatives are often considered an essential institutional innovation that might assist farmers to overcome the stumbling blocks to their access to farm inputs (Verhofstadt & Maertens, 2014; Ma & Abdulai, 2016). Cooperatives can provide scale advantages and hence enhance agricultural technology adoption by pooling

Table 4: Determinants of adoption of good agronomic practices of improved cassava varieties disseminated to farmers

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	Beta	Std. Error	Beta		
(Constant)	1378.467	24.135		57.114	.000
Educational level	392.988	25.881	-3.376	-19.364	.000
Membership of cooperative	-465.421	48.743	-2.473	-12.342	.000
Access to cassava cuttings	130.666	3.984	2.394	31.073	.000
Income	432.240	11.540	.423	6.840	.000
Extension contact	-484.709	39.071	-3.582	-12.891	.000

Source: Field work, 2024. R^2 = 0.873, Adjusted R^2 = 0.780

multiple resources such as credit, knowledge, and labour among members.

On the other hand, the constraints to adoption of good agronomic practices (GAP) among cassava farmers**;** high cost of cassava cuttings, limited access to credit, lack of knowledge of weather related problems, damage by livestock such as cattle, pests and diseases pressure and limited extension service respectively (Table 5). This result is in line with Fidelis *et al*. (2023) that high cost of improved cassava materials and inadequate information of the improved variety were the constraints working against agronomic practices in their study, also the finding is in line with where they said that inadequate funds were the major constraint facing adoption of cassava agronomic practices in their study.

Table 5: Constraints militating against adoption of Good Agronomic Practices (GAP) among cassava farmers

Constraints	Mean
High cost of cassava cuttings	3.23
Limited access to credit	3.12
Inadequate knowledge of weather related problems	2.20
Damage by livestock such as cattle	2.13
Pests and diseases pressure	2.10
Limited extension service	2.00

Source: Field work, 2024. Cut off point, 2 and above.

4. Conclusion

The research established that cassava remains a crucial livelihood crop in Anambra State, especially for women and smallholder farmers. Improved cassava varieties such as TME-419 have been widely adopted, showing significant potential for increasing yield and resilience against diseases. However, adoption of good agronomic practices is relatively low, constrained by socioeconomic and institutional challenges. Factors such as education, access to extension services, and cooperative participation significantly enhance adoption levels. Addressing these barriers is essential to maximize the benefits of improved technologies, close yield gaps, and enhance food security and income for rural households.

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Effect of different phosphorus dose application on nutrient composition of Soybean (*Glycine max* L.)

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ABSTRACT

The type and amount of nutrient applied to the soil are key factors in crop production. An experiment was conducted in 2022 at research station of the institute of Agricultural Research and Training (IAR&T) Ikenne, Ogun State to examine the effect of different phosphorus concentrations on nutrient composition of soybean. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replicates. Each replicate measured 11.2 × 2 m^2 was divided into four plots of 2 × 2.4 m^2 separated by 0.5 m. The treatments were different rates of phosphorus fertilizer at 0 kg ha^{-1}, 20 kg ha^{-1}, 40 kg ha^{-1} and 60 kg ha^{-1}. Soybean variety used was TGX 1440 – IE. Cultural practices were carried out and data taken. At maturity soybean grains were harvested, threshed and weighed in kg/ha. The grains were analyzed for proximate and mineral composition. The result showed that application of 60 kg P ha^{-1} significantly ($p<0.05$) gave the highest grain yield of 190.76 kg ha^{-1} than other treatments. Proximate analysis result showed that soybean treated with 60 kg/ha of phosphorus had the highest protein content (39.50%). While crude fat, was not affected by application of phosphorus. Phosphorus at zero levels gave high values of iron and calcium content (18.01 mg kg^{-1} and 324.02 Cmol kg^{-1} respectively) while 20 kg ha^{-1} level of phosphorus gave highest value for magnesium content (338.74 Cmol kg^{-1}). Application of Phosphorus at the rate of 60 kg ha^{-1} for optimum soybean grain yield with high protein content is therefore recommended.

KEY WORDS: *Soybean*; *Phosphorus*; *Grain*; *Yield*; *Proximate*

1. Introduction

Soybean (*Glycine max* L.) is a widely consumed agricultural commodity around the world in many forms, such as the whole soybean, soy oil and soy meal (Fearnside, 2001). Soybean as described is known as "miracle bean" or the "golden bean" because it is a cheap, protein rich grain with a high protein content of about 40% which is superior to all other plant foods and it has a good balance of the essential Amino acids (Omotayo *et al.*, 2007 and Zarei *et al.*, 2012)

Soybean contains approximately 37-41% protein, 18-21% oil, 30-40% carbohydrate and 4-5 Ash research has shown that (Morrison *et al.*, 2000). Generally, soybean is regarded as a highly versatile and multipurpose agricultural product

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that has about three hundred and sixty-five (365) application in the formulation of both human, animal foods and other industrial uses; soybean has the highest protein content of all field crops and is the second only to groundnut in terms of oil content among the food legumes. (Hungria *et al*., 2015). Soybean has therefore been recognized as one of the premier agricultural crops today, thus it is the best source of protein and oil, and now been recognized as potential supplementary source of nutritious food (Wilcox & Shibbles, 2001).

A major constraint for Soybean production on disturbed soil is Phosphorus (Ferguson *et al.*, 2006). Phosphorus nutrition has strong impact on photosynthesis and yield quality of Soybean (Singh *et al.*, 2014).

Soybean quality and protein content is influenced by nutrient availability and phosphorus has a positive effect upon its protein content. Phosphorus application is necessary for high protein and yield of soybean grains (Shah *et al.*, 2001) and yield components like the straw (Chieizey, 2001).

Phosphorus has significant implications on growth and yield of soybean attributes (Kumaga and Ofori, 2004). Small quantity of phosphorus in the soil is a key obstacle to the growth as well as yield of soybean. Soybeans thrives well on a relatively well – drained loamy soil rich in phosphorus with a pH range of 4.5 to 8.5, but performs badly on drought stressed soils and water soaked soils and soil lack of phosphorus (MOFA, 2006).

Phosphorus is the main nutrient contributing protein in soybean, phosphorus from the soil is imperceptible, it is the most nutritive nutrients that soybean productivity comes from; phosphorus deficiency in soybean can limit the nodule formation while the Phosphorus fertilization does not only overcome the deficiency but also promote nutrient uptake and eventual yield of the crop (Carsky *et al.*, 2001).

Phosphorus application is also necessary for high protein and oil yield from Soybean grains (Shah *et al.*, 2001). Damodar *et al*. (2000) and Manna *et al*. (2007) reported that manure application along with Phosphorus inorganic fertilizer is an effective strategy to help improve soybean nutrient like iron, calcium and magnesium also phosphorus in the soil. It has been reported that, Phosphorus application through Single Super Phosphate significantly increased the grain yield and oil content in the crop (Tanwar & Shaktawat, 2003).

Nutrient availability inflrences the quality of soybean with phosphorus having a positive impact on Soybean nutrient composition (Borges & Mallarino, 2000). Several researchers have pointed out that the use of Phosphorus significantly improves the content of Soybean nutrient composition (Brennan & Bolland, 2004). It becomes imperative therefore to determine the quantity of phosphorus level that should be applied to soybean to obtain optimum nutrient quality in soybean; hence, this study.

2. Material and Methods

2.1 Experimental site

The experiment was carried out at the out-station of the Institute of Agricultural Research and Training (IAR&T) Ikenne, Ogun State. (Latitude 6º 51' 21.11", Longitude 3º 42' 20.23"), altitude 228.0 m above the sea level). Ikenne is in the rain forest Agro ecology of Nigeria with mean annual temperature range 27-35 ºC and mean annual rainfall ranging from 1500 – 2000 mm. It has distinct wet and dry seasons. The wet season has double rainfall peaks during June and September with short break in between called August break. The experimental plot measuring 11.1 m × 8 m was prepared by ploughing and harrowing and laid out into 12 plots of 2.4 m × 2 m.

2.2 Experimental design and treatment application

The experiment was laid out in the randomized complete Block Design (RCBD) with three replicates. Each replicate measures 11.1 × 2 m^2 separated by 1m apart and each replicate was divided into 4 plots of 2 × 2.4 m^2 separated by 0.5 m. Phosphorus (SSP) fertilizers (P) at different rates were incorporated into the soil a week before planting. The different rate of phosphorus fertilizer is 0 kg ha^{-1}, 20 kg ha^{-1}, 40 kg ha^{-1}, 60 kg ha^{-1}.

2.3 Planting material and procedures

The soybean (*Glycine max* L.) seed used was early maturing TGX 1440 - IE which was obtained from the seed store of the Institute of Agricultural Research and Training (IAR&T) Moor Plantation, Ibadan.

Soybean seeds were sown in the month of June of the cropping season at the rate of two seeds per stand, agronomic practices such as weed control was carried out. Weeds were controlled by using metaphox pre-emergence herbicide with glyphosate as an active ingredient at the rate of 3 litres ha^{-1} immediately after sowing and manually, using traditional hoe at six (6) and nine (9) weeks after emergence.

2.4 Data collection and analysis

Data were collected on growth and yield parameters. At maturity, when the soybean pods were dried (in November of the same year), soybean seeds were harvested, threshed and weighed and weight recorded in kg ha^{-1}. Then the seeds were taken to the laboratory for proximate analysis and mineral composition analysis. The data collected were subjected to statistical analysis using ANOVA to test the level of significance of treatment on the measured parameters and the significant means were compared and separated using least significant difference (LSD) at 5% levels of probability.

3. Results and Discussion

The result of physical and chemical properties of the pre cropping soil is presented in Table 1. It showed that the soil was slightly acidic with a pH of 6.14. Total nitrogen was very low (0.083%), compared to the standard value of (1-1.5), available phosphorus (7.63 mg kg^{-1}) compared to the standard value of (7 - 7.20) and organic carbon (0.83%) compared to the standard value of (1.0 - 1.4) were low. Exchangeable base: potassium, calcium, magnesium and sodium of the soil range from 0.29–1.10 and 0.40 cmol kg^{-1}, the texture of the soil was sandy loamy soil with sand, silt and clay content of 861, 79 and 60 g kg^{-1} respectively.

3.1 Effect of phosphorus concentration on soybean yield (kg ha^{-1})

The effect of treatment on the yield of soybean is presented in Table 2, The yield of soybean was significantly ($p<0.05$) higher with the application of 60 kg P ha^{-1} than other levels of P with a yield difference of 52.56% for zero application, 21.24 and 36.6 % for 40 and 20 P respectively. This study buttresses the fact that phosphorus, an essential mineral nutrient is required in relatively large amount to maintain growth and play a vital role in improving soybean yield and quality (Jack & Sara, 2001) and that it has strong impact on photosynthesis and yield quality of soybean grains (Singh *et al.*, 2014).

Table 1: Physical and chemical characteristics of experimental soil

Parameters	Value
pH	6.14
Total Nitrogen	0.08
Organic carbon (g kg^{-1})	0.83
Available phosphorus (g kg^{-1})	7.63
Exchangeable Cations (cmol kg^{-1})	
Ca^{2+}	0.59
Mg^{2+}	1.10
Na^{+}	0.40
K^{+}	1.01
H^{+}	1.01
ECEC	3.39
Particle size distribution (g kg^{-1})	
Sand	861
Clay	60
Silt	79
Textural class	Sandy loam

3.2 Effect of phosphorus concentration on proximate analysis of soybean seeds

The result of proximate analysis of soybean is also presented in Table 2. It was observed that treatment effect was not significant on moisture content of soybean; while it was significant for crude protein. Soybean treated with 60kg of phosphorus had the highest value of protein content 39.50% which was significantly higher than other treatments. This result corroborates the work of Tanwar & Shaktawat (2003) who also opined that phosphorus application significantly increased the seed protein content (SPC) of soybean. Bilal *et al*. (2020) also discovered that 60 kg P ha^{-1} produced high protein content of (42%) in soybean. Treatment effect was not significant on crude fat. This is in contrast to the work of Brennan & Bolland (2004) who submitted that, phosphorus significantly improves the oil content of many oil seed crops also in contrast with Bilal *et al.* (2020) who discovered that increase in phosphorus increased the oil content in soybean.

The study however support the findings of Rogerio *et al.* (2013) who stated that different levels of phosphorus in oil seed crops (Crambe) does not significantly increased oil content of the crop. Considering the crude fiber content, the control (0 P) was significantly higher than other treatments except that of 20 P. Meanwhile, there was no significant difference between the crude fibre content of soybean at 20 P and 60 P application. This indicates that enough crude fibre content can still be derived with the application of 60 kg P ha^{-1} which also supports optimum yield

Table 2: Effect of phosphorus concentration on yield and proximate **a**nalysis of soybean

Treatment (kg P ha^{-1})	Yield (kg ha^{-1})	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	Total Ash (%)	NFE (%)
0 (Control)	90.50b	9.58	34.57b	24.22	6.69a	5.49	19.44a
20	120.92ab	9.68	35.75b	23.46	6.22a	5.29	19.50a
40	150.25ab	9.35	37.19b	22.82	5.38b	4.88	20.38a
60	190.76a	9.69	39.50a	23.91	5.97b	5.04	15.89b
LSD (P= 0.05)	80.52	NS	1.50	NS	0.58	NS	3.45

Note: NS – Not Significant, Significant means were separated by LSD P<0.05

and protein content in soybean for total ash there was no significant difference among the treatments.

Significant difference was observed among the treatments for nitrogen free extract in which soybean treated with 40 P was significantly higher than those treated with 60 P but was comparable to those of 0 phosphorus and 20 phosphorus statistically. This is also an indication that application of phosphorus for soybean supports the availability of free nitrogen extract. This is consistent with the findings of Malik *et al.* (2006) who also discovered that nitrogen is one of the main yield related characters in soybean which of course is made more available with application of phosphorus.

3.3 Effect of phosphorus concentration on mineral composition of soybean

The result of treatment effect on mineral analysis of soybean is presented in Table 3. The result revealed that, there was significant differences in iron content among all the treatment, soybean with no treatment (Control) had the highest iron content of 18.01%, which was significantly higher than other treatments. This indicates internal inactivation of iron by the phosphorus this is because, phosphorus deficiency has been shown to result in increased iron concentration (Liao *et al.*, 2006). Likewise, for calcium content there were significant differences across the treatments. Soybean not treated with phosphorus (Control) had the highest calcium content of 324.02%, while the soybean treated with phosphorus were significantly lower in calcium content, with 40 kg P ha^{-1} having the least followed by 20 P then 60 P. These results showed that application of Phosphorus fertilizer to the soil in soybean field has nothing to do with the iron content and calcium content in soybean. These minerals can be gotten by soybean from other sources. Meanwhile, effect of treatment on magnesium content of soybean seed showed that there were significant differences among the treatments in which soybean treated with 20 kg of phosphorus had the highest magnesium content of 338.74% which is comparable statistically with those 40 and 60 level of phosphorus while the 0 level of phosphorus had the least value of magnesium content of 281.03% different from those of 40 and 60 level of phosphorus.

Table 3: Effect of phosphorus concentration on mineral composition analysis of soybean

Treatment (kg P ha^{-1})	Fe (Mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
0 (Control)	18.01a	324.02a	281.03c
20	10.78d	211.70c	338.74a
40	13.53c	201.56d	325.56b
60	14.68b	232.49b	325.56b
LSD (0.05)	0.03	0.79	0.53

Note: Significant means were separated by LSD $P<0.05$

4. Conclusion

Phosphorus concentration of 60 kg ha^{-1} gave the highest soybean yield of 190.76 kg ha^{-1} and high protein content (39.50%). Mineral content like magnesium also responds to application of phosphorus in soybean. However, crude fat does not response to phosphorus application in soybean. Also with zero phosphorus fertilizer application to soybean, enough minerals like iron and calcium which are beneficial to humans can be derived from the crop.

Selective phosphorus concentration can be used in precision soybean cultivation to improve target nutrients in soybean. This will encourage the production of soybean selectively rich in predetermined class of nutrients. Soybean production is targeted to make protein for man hence, the applications of 60 kg ha^{-1} of phosphorus is recommended to achieve optimum yield and high protein content in soybean which does not however affect the availability of oil in the crop adversely.

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Ergonomic risks of crop production activities among agricultural workers in Ekiti State, Nigeria

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ABSTRACT

The study shed lights on the significant ergonomic risks faced by agricultural workers during crop production activities in Ekiti State, Nigeria. It utilized data collected from 120 farm workers through questionnaires and interviews using a multi-stage sampling procedure. Descriptive statistics and a multivariate probit model were employed for data analysis. The study found that the majority (60.8%) of agricultural workers in Ekiti State, Nigeria, were male, with an average age of around 43 years. They reported various ergonomic hazards, including body pain (73.3%), cut from farm implements (73.3%), sprain (64.2%), eye problems (56.7%) and respiratory tract irritation (55%). Musculoskeletal injuries such as lower back pain (77.5%), upper back pain (74.2%), shoulder pain (67.5%), wrist/hand pain (65.8%) were prevalent among the workers. Factors such as sex, age, education, experience, farm size, credit access, safety training, work hours, spraying hours, and chemical exposure were significant in predisposing workers to ergonomic risks. Constraints to safe farm practices included inadequate finance for machinery (86.7%), poorly designed implements (83.3%), lack of safety training from extension agents (74.2%), inadequate knowledge of farm safety measures (59.2%) and constant mechanical hazards due to faulty or bad machineries or equipment (56.7%). Regular training on musculoskeletal disorders (MSDs) and safety, along with using improved agricultural equipment, safe work methods, and proper postures, can help mitigate ergonomic risks and improve the quality of life for agricultural workers in the study area.

KEY WORDS: *Agricultural workers*; *Crop production*; *Ergonomic risks*; *Musculoskeletal disorder*

1. Introduction

The agriculture sector plays a crucial role globally in meeting human needs by providing food, employment, and raw materials for industries. In Nigeria, agriculture is a vital sector, with approximately 75 percent of the population relying on it as their main source of livelihood (Anderson *et al.*, 2017). Crop production, in particular, drives the agricultural sector, accounting for a substantial portion of Nigeria's Gross Domestic Product (GDP) (Olowogbon *et al.*, 2021). In the second quarter of 2023, the agricultural sector contributed around 21 percent to Nigeria's GDP, with crop production alone covering nearly 19 percent (Statista, 2023). Crop production involves the intentional and continuous process of cultivating diverse plants with the

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primary goal of producing food for human consumption and feed for the livestock industry. Additionally, it serves other purposes such as providing medicinal resources, generating foreign exchange through exports, and supplying materials for commercial and industrial purposes (Mamai *et al.*, 2020).

The agriculture sector poses inherent risks to workers (Babu, 2016), with manual labour being a predominant feature due to the lack of mechanized farming in Nigeria. Human power accounts for approximately 90% of the energy sources in agricultural activities, leading to prolonged periods of working in awkward body positions (Abubakar *et al.*, 2023). This can result in static contraction of muscles, reduced blood flow, and ultimately, increased body pain and decreased productivity (Mulyati *et al.*, 2019). These extreme working conditions contribute to the development of Musculoskeletal Disorders (MSDs), which are recognized as the most prevalent safety issue in agriculture (Eguoaje *et al.*, 2019). The lack of proper equipment and poor knowledge of ergonomics exacerbate these problems, highlighting the need for ergonomics to play a significant role in addressing and reducing musculoskeletal injuries among agricultural workers (Prasad *et al.*, 2019).

Ergonomics, as a multidisciplinary science, focuses on creating a better match between the job and the worker to ensure their health and safety. It involves designing and arranging work environments and tools in a way that promotes ease of use and safety for workers (Naeini *et al.*, 2014; Vyas and Bajpal, 2016). The International Ergonomics Association defines ergonomics as the science of understanding the interaction between humans and various elements of a socio-technical system. In crop production, the use of herbicides, insecticides, fungicides, and other agrochemicals is essential for protecting crops from weeds, insects, and diseases (Richardson *et al.*, 2019). However, exposure to these chemicals poses significant ergonomic and occupational risks, leading to both acute and chronic health issues for agricultural workers (Vyas, 2020). Despite the importance of ergonomics in promoting a safe and healthy relationship between work, workers, and their environment (Vyas and Bajpal, 2016), deliberate efforts to reduce ergonomic-related injuries in Nigerian agricultural workplaces have been lacking (Olowogbon *et al.*, 2021). Therefore, this study aims to investigate the ergonomic risks associated with crop production activities among agricultural workers in Ekiti State, Nigeria. Specifically, the study assessed the prevalent ergonomic risk hazards among the agricultural workers, determined factors predisposing agricultural workers to ergonomic risk hazards, and identified the constraints to safe farm practices.

2. Material and Methods

The study was conducted in Ekiti State, Nigeria, which was formed from Ondo State on October 1, 1996, with its capital in Ado-Ekiti. Located at coordinates 7°40'N 5°15'E, Ekiti State is bordered by Kwara State to the north, Kogi State to the northeast, Ondo State to the south and southeast, and Osun State to the west. The state comprises 16 Local Government Areas (LGAs) and has a population of approximately 2,384,212 people, spread across an area of approximately 5,887.890 square kilometres. Agriculture serves as the backbone of the state’s economy, with crops such as yam, rice, cassava, cocoa, among others, cultivated both for subsistence and commercial purposes.

The study utilized a multi-stage sampling technique to choose both the communities and respondents. Firstly, two Local Government Areas (LGAs), Gbonyin and Oye, were purposively selected out of the 16 LGAs in Ekiti State due to their prevalence of farming activities. Secondly, four communities were randomly selected from each of the two LGAs, totalling eight communities. Finally, within each selected community, 15 farmers were randomly chosen using simple random sampling techniques, resulting in a total of 120 respondents for the study. Data were collected through well-structured questionnaires and interview schedules.

2.1 Method of data analysis

The data generated on ergonomic hazards and constraints to safe farm practices in the study area were analyzed using descriptive statistics tools such as frequency, percentages, means, and standard deviation. Additionally, a multivariate probit model was employed to determine the factors predisposing agricultural workers to ergonomic risk hazards. This statistical model allowed for the examination of the relationship between multiple factors simultaneously and their influence on the likelihood of experiencing ergonomic hazards.

2.2 Multivariate probit (MVP)

In a single-equation statistical model, information on one ergonomic risk hazard experienced by agricultural workers does not affect the likelihood of experiencing another ergonomic risk hazard. However, the MVP approach allows for the simultaneous modelling of the influence of explanatory variables on each different ergonomic risk hazard while considering potential correlations between unobserved disturbances and the relationship between the different hazards (Belderbos *et al.*, 2004). Complementarities (positive correlation) and substitutability (negative correlation) between different symptoms can contribute to this correlation. Failure to account for unobserved factors and interrelationships among ergonomic risk hazards may lead to biased and inefficient estimates (Greene, 2008). The observed outcome of ergonomic risk hazards can be modelled using a random utility formulation. For each agricultural worker (i=1,…., N) facing ergonomic risk hazard j (j = 1,…, j) of crop production activities. Let U0 represent the effects on the worker from traditional management practices, and letUk represent the effects of experiencing kth hazard: (k = PH, MH, CH, EH) denoting physiological hazards (PH). Mechanical hazard (MH), Chemical hazards (CH) and Environmental Hazards (EH) respectively.

The general multivariate probit model is specified as follows:

$$Y^*_{ijk} = X'_{ij}\beta_k + U_{ij} \; k = PH, MH, CH, EH) \text{ ------------- } (1)$$

Using the indicator function, the unobserved preferences in equation (1) translate into the observed binary outcome equation for each symptom as follow:

$$Y_k = \begin{Bmatrix} 1 \; if Y^*_{ijk} > 0 \\ 0 \; otherwise \end{Bmatrix} \qquad k = PH, MH, CH, EH) \text{----} (2)$$

In the multivariate model, where the experience of different hazards is possible, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity (for identification of the parameters) where;

(k =PH, MH, CH, EH) ~MVN (0, Ω) and the symmetric covariance matrix Ω is given by

$$\Omega = \begin{bmatrix} 1 & P_{PHMH} & P_{PHCH} & P_{PHEH} \\ P_{MHPH} & 1 & P_{MHCH} & P_{MHEH} \\ P_{CHPH} & P_{CHMH} & 1 & P_{CHEH} \\ P_{EHPH} & P_{EHMH} & P_{EHCH} & 1 \end{bmatrix} \text{------------------ (3)}$$

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic components of different types of hazards. In equation (3), this assumption means that the Multivariate Probit (MVP) model jointly represents the ability to experience a particular hazard. This specification, with non-zero off-diagonal elements, allows for correlation across the error terms of several latent equations, representing unobserved characteristics that affect the experience of alternative hazards. Essentially, it accounts for the fact that experiencing one type of hazard may be related to experiencing another type of hazard due to common underlying factors or mechanisms.

The model for this study is specified as:

$$Yij = \beta 0 + \beta Xji + \varepsilon \text{ --------------------------------- (4)}$$

Where:

Y_{ij} is a binary dependent variable that takes the value of 1 if the ith agricultural worker reports jth ergonomic risk hazard and 0 otherwise. Following Vyas (2020), the jth ergonomic risk hazards are as stated: Y_1 = Physiological hazards; Y_2 = Mechanical hazard; Y_3 = Chemical hazards; Y_4 = Environmental Hazards. X_{ji} is a vector of explanatory variables and is expressed as:X_1 = Age of farmer (years); X_2= Sex of farmer (dummy); X_3 = Educational level (years); X_4= household size (Number of people); X_5= Farm Size (hectare); X_6= Farm work experience (years); X_7= Chemical application experience (years); X_8= Previous safety training exposure (1 = yes, 0 = otherwise); X_9 = Daily working hours (1 – greater than or equal to 6 hours, 0 otherwise); X_{10}= Spraying hours (1 – greater than or equal to 6 hours, 0 otherwise); X_{11}= Credit access (Dummy); X_{12}= Extension contacts (Dummy).

3. Results and Discussion

Results of the socio-economic variables included in the model are presented in Table 1. The result reveal that majority (60.8%) of the sampled agricultural workers were male, 62.5% were aged between 41 and 50 years with an average age of about 43 years which indicates that the workers were relatively young and within their economically active years. The average years of schooling of about 9 years suggests that most respondents had secondary education. About 40% of the respondents had between 6 and 10 persons in their family. The mean family size was about 5 persons, indicating that the workers generally had small family sizes. Almost half (49.2%) of the workers had less than 10 years of experience as agricultural workers, while 40.8% had between 6 to 10 years of experience in chemical application. The mean years of experience were 14, indicating that workers had substantial experience in the agricultural sector, which could influence the adoption of safe farm practices. The average farm size was 3 hectares, suggesting that respondents were predominantly working on small-scale farms.

Only 37.5% of the workers had undergone safety training, potentially impacting safe farm practices. Approximately 47.5% of the respondents worked

Table 1: Summary of selected socio-economic characteristics of the respondents

Variable	Frequency	Percentage (%)	Mean
Sex			
Male	73	60.8	
Age			
31-50	75	62.5	42.95±11.33
Educational Qualification			
Secondary education	32	26.7	8.942±2.33
Household Size			
6-10	48	40.0	5.19±2.63
Farm Work Experience			
≤10	59	49.2	14.01±9.99
Application of Chemical Experience			
6-10	49	40.8	
Farm Size			
≤5	61	50.8	3.18±1.78
Safety Training			
Yes	45	37.5	
Working Hours			
>6	57	47.5	
Chemical Spraying Hours			
4-6	67	55.8	
Credit Access			
Yes	28	23.3	
Extension Contacts			
Yes	21	17.5	

n = 120

for less than 6 hours daily, while 55.8% applied chemicals for duration of 4 to 6 hours daily. Access to credit facilities and extension services was limited, with only a few (23.3% and 17.5%, respectively) having access. This could negatively impact the adoption of innovations and safe farm practices.

3.1 Agricultural workers self-reported ergonomic hazards in the study area

Work related ergonomic injuries have been identified to be prevalent among the workers. Following Vyas (2020), these injuries were classified in Table 2 and discussed below:

Physiological hazards

Physiological hazards typically arise from prolonged hours of vigorous work, repetitive movement, carrying heavy loads, exhaustion, and assuming awkward postures while working. The results in Table 2 indicate that the major physiological hazards experienced by workers in the study area include body pain (73.3%), sprains 64.2%), fatigue (59.2%), and headaches (55%). This finding is consistent with previous research by Ajay *et al*., (2021) which highlighted that farm labourers often experience musculoskeletal injuries due to activities such as repetitive bending, twisting, lifting heavy items, and continuous motions when working for long hours.

Mechanical hazards

Mechanical hazards in agriculture often stem from farm equipment and tools, leading to injuries such as cuts, falls, and burns. In the study area, the various mechanical hazards reported by agricultural workers include: Cuts from cutlass and hoes, resulting in injuries to 73.3% of the workers, burns from chemical application, causing injury to 33.3% of the workers, falls from ladders, silos, and rooftops, which were a source of injury for 22.5% of the workers and falls from motorcycles or bicycles during farming operations, affecting 21.7% of the workers. Ergonomic measures such as providing protective gear, ensuring equipment is in good working condition, and implementing safety guidelines can help reduce the incidence of mechanical hazards and promote a safer working environment for agricultural workers.

Chemical hazards

Chemical hazards in agriculture, such as contact dermatitis or eczema, are often caused by exposure to pesticides and other chemical products used for plant protection (Vyas, 2020). The results in Table 2 indicate the following reported chemical hazards among workers in the study area: Eye problems, including redness of eyes, watering, burning sensation and, irritation were reported by 56.7% of the workers; Skin problems, such as burning, inflammation, and irritation of the skin, were reported by 55.8% of the workers while handling chemicals. Breathing difficulties when spraying chemicals were reported by 49.2% of the workers and 44.2% of the workers reported experiencing giddiness when inhaling chemicals accidentally or when exposed to pungent smells. Ajay *et al.*, (2021) reported similar results for workers in India.

Environmental hazards

Environmental hazards in agriculture pose risks such as air and water pollution, respiratory irritants, and food poisoning. The self-reported ergonomic environmental hazards experienced by workers presented in Table 2, reveals that around 55% of the workers had respiratory problems such as irritation in respiratory tract, while 43.3% had chest tightness. Water pollution was a major hazard to 42.5% and food poisoning was experienced by 29.2% of the workers in the study area. These findings underscore the significant health risks posed by environmental hazards in

Table 2: Self-reported ergonomic hazards experienced by the workers

Physiological Hazards	Frequency	Percentage
Body pains	88	73.3
Fatigue	71	59.2
Sprain	77	64.2
Ligament pull	23	19.2
Headache	66	55.0
Excessive sweating	57	47.5
Fever	35	29.2
Mechanical hazards		
Cut from cutlass/hoes	88	73.3
Fall from ladders/silos/roof tops	27	22.5
Burns	40	33.3
Fall from motorbikes/bicycle	26	21.7
Chemical Hazards		
Eczema	33	27.5
Burn from pesticide application	35	29.2
Inflammation/irritation of skin	67	55.8
Eye problems	56	56.7
Breathing difficulty	59	49.2
Dizziness	29	44.2
Stomach cramp	15	12.5
Environmental hazards		
Irritation in respiratory tracts	66	55.0
Chest tightness	52	43.3
Food poisoning	35	29.2
Water pollution	51	42.5

*Multiple responses

agriculture, including respiratory issues, water pollution, and food borne illnesses. The findings are consistent with previous research by Vijay (2014); Andersson and Treich (2014) highlighting the elevated risk of respiratory conditions such as hypersensitivity pneumonitis, asthma, bronchitis, tuberculosis, pneumonia, influenza and death among farm workers. Implementing measures to mitigate environmental hazards, such as proper ventilation, water management practices, and food safety protocols, can help reduce the incidence of these ergonomic hazards and promote the health and safety of agricultural workers.

3.2 Musculoskeletal problems and body discomfort during crop production activities

Musculoskeletal problems and discomfort among agricultural workers are often attributed to the physical demands of agricultural production activities, including lifting handling of heavy loads; static positioning, squatting and continuous bending. These activities can lead to work-related musculoskeletal injuries, resulting in pain in various parts of the body such as the shoulders, neck, back, nerves and wrists. Additionally, the use of traditional tools and methods in agriculture may further increase the risk of musculoskeletal injury due to the high level of human energy required (Vyas, 2014). The results presented in Table 3 indicate that lower back pain, experienced by 77.5% of the respondents was the most prominent musculoskeletal injury reported by respondents in the study area. Other reported musculoskeletal injuries included upper back pain (74.2%), shoulder pain (67.5%), wrist/hand pain (65.8%), ankle/feet pain (59.2%), knee pain (58.3%), neck pain (54.2%), elbow pain (51.7%), and hip and thigh pain (50.8%). This suggests that respondents had experienced multiple musculoskeletal injuries during their farming operations.

These findings are consistent with previous research, such as the study by Abubakar *et al.*, (2023), which reported work-related musculoskeletal discomfort among farmers in North-Western Nigeria, particularly in the neck, wrist/hand, upper back, and lower back. Moreover, Vyas (2014) highlighted that disorders in the lower back are frequently associated with activities involving lifting and carrying heavy loads. The repetitive or prolonged exertion of static force during such activities can lead to strain and injury in the lower back region. Similarly, upper limb disorders, affecting areas such as the hands, wrists, fingers, arms, neck, elbows, and shoulders, may result from prolonged laborious or perceptible effort. Tasks requiring repetitive movements or sustained static postures can lead to strain and discomfort in these upper limb areas. Additionally, such activities can exacerbate existing musculoskeletal issues or contribute to the development of new ones.

Table 3: Musculoskeletal problems and body discomfort experienced by workers

Body Parts Affected	Frequency	Percentage
Neck	65	54.2
Shoulder	81	67.5
Elbow	62	51.7
Wrist/hand	79	65.8
Upper back	89	74.2
Lower back	93	77.5
Hip and thigh	61	50.8
Knees	70	58.3
Ankle/feet	71	59.2

*Multiple responses

3.3 Frequency (%) of musculoskeletal hazards experienced by farmers/week

The results presented in Table 4 indicate the frequency of ergonomic-related pains reported by the respondents on a weekly basis. The result reveals that 20% of the respondents reported neck pain twice in a week, 23.3% reported should pain thrice a week, elbow pain was reported once by 22.5% of the respondents, wrist/hand pain was reported thrice by 26.7% while 44%, 55.8% and 30% reported to always experience upper back, lower back and hip/thigh pains respectively. Furthermore, knee and ankle/feet pains were reported thrice a week by 24.2% and 30% respectively. These findings highlight the significant prevalence of ergonomic-related pains among agricultural workers on a weekly basis, which could have negative consequences on the health and productivity of the workers. Similar results were reported by Olowogbon *et al.*, (2021), indicating a consistent pattern of ergonomic-related issues among agricultural workers.

3.4 Factors predisposing agricultural workers to ergonomic risk hazards

The results of the multivariate probit model, which examined factors predisposing agricultural workers to ergonomic hazards in the study area, are presented in Table 5. The model was estimated jointly for four ergonomic hazards: physiological, mechanical, chemical, and environmental. The Wald test statistic for the overall significance of the model yielded a p-value of 0.000, indicating that the multivariate probit regression is highly significant overall. This suggests that the combined effect of the explanatory variables on the four ergonomic hazards is statistically significant. The results are presented below:

Physiological hazards

The coefficient of sex was positive and significant ($p<0.05$), indicating that being male increases the probability of experiencing physiological hazards. Male agricultural workers may be more susceptible to musculoskeletal disorders due to occupational exposures. Additionally, the coefficient of age was positive and significant ($p<0.01$), indicating that older workers are more likely to experience physiological hazards. This finding is consistent with those of Tonelli *et al.*, (2014) indicating that aging farmers are at higher risk of musculoskeletal disorders, possibly due to prolonged exposure to physical strain over their careers.

In the same vein, the coefficient of farm size was

Table 4: Frequency (%) of musculoskeletal hazards experienced by workers/week

Parts Affected	Once	Twice	Three times	Always
Neck	23(19.2)	24(20.0)	14(11.7)	23(19.2)
Shoulder	23(19.2)	26(21.7)	28(23.3)	19(15.8)
Elbow	27(22.5)	18(15.0)	22(18.3)	4(3.3)
Wrist/hand	14(11.7)	23(19.2)	32(26.7)	28(23.3)
Upper back	5(4.2)	23(19.2)	17(14.2)	54(45.0)
Lower back	11(9.2)	12(10)	10(8.3)	67(55.8)
Hip and thigh	12(10)	17(14.2)	14(11.7)	36(30.0)
Knees	10(8.3)	21(17.5)1	29(24.2)	26(21.7)
Ankle/feet	7(5.8)	17(14.2)	36(30.0)	30(25.0)

Source: Compiled from field survey, 2022 positive and significant ($p<0.05$), suggesting that workers on larger farms are more likely to experience physiological hazards. This may be attributed to the increased physical demands associated with managing larger agricultural operations.

Conversely, the coefficient of education was negative and significant ($p<0.01$), indicating that workers with higher levels of education are less likely to experience physiological hazards. This suggests that education may provide individuals with knowledge and skills to adopt safer work practices and reduce the risk of musculoskeletal disorders. The coefficient of credit access was negative and significant ($p<0.05$), suggesting that workers with access to credit are less likely to experience physiological hazards. Access to credit may enable farmers to invest in mechanization or other technologies that reduce physical strain and improve working conditions. Also, the coefficient of daily hours worked was negative and significant ($p<0.10$), indicating that working fewer hours per day reduces the likelihood of experiencing physiological hazards. This underscores the importance of managing workload and avoiding excessive physical exertion to prevent musculoskeletal injuries.

Mechanical hazards

The coefficient of farm size was negative and significant ($p<0.05$), indicating that larger farm size is associated with a lower probability of experiencing mechanical hazards. This suggests that workers on smaller farms may face higher risks of mechanical hazards, possibly due to limited access to mechanized equipment or higher reliance on manual labour. Additionally, the coefficient of the frequency of extension visits was negative and significant ($p<0.05$), indicating that regular visits from extension agents are associated with a lower probability of experiencing mechanical hazards. Extension agents play a crucial role in providing training, guidance, and support to farmers, including information on safety practices and equipment maintenance, which can help reduce the risk of mechanical injuries.

Chemical hazards

The coefficient of spraying hours was positive and significant at the 5% alpha level, indicating that longer hours of chemical application are associated with a higher probability of experiencing chemical hazards. This finding aligns with findings of Olowogbon *et al.,* (2021), suggesting that prolonged exposure to chemical spraying activities increases the risk of chemical-related health problems. On the other hand, the coefficient of credit access was negative and significant ($p<0.05$), suggesting that workers with access to credit are less likely to experience chemical hazards. Access to credit may enable farmers to invest in safer equipment, protective gear, and training, thereby reducing the risk of chemical-related health issues. Furthermore, the coefficient of safety training was negative and significant ($p<0.05$), indicating that workers who had undergone training in the safe use and application of farm chemicals are less likely to experience chemical hazards. In addition, the coefficient of chemical application experience was negative and significant at the 10% level, suggesting that workers with previous experience in chemical application are less likely to experience chemical hazards. This highlights the importance of hands-on experience and familiarity

Table 5: Factors predisposing crop farmers to ergonomic risk hazards

Variable	Physical hazard	Mechanical hazard	Chemical hazard	Environmental hazard
Sex	1.234** (0.037)	-0.123 (0.793)	-0.975** (0.026)	0.398 (0.363)
Age	0.83*** (0.005)	-0.012 (0.692)	0.026 (0.341)	0.009 (0.735)
Educational level	-0.75*** (0.003)	0.224 (0.233)	0.152 (0.381)	-0.275** (0.024)
Household size	-0.008 (0.947)	-0.095 (0.380)	-0.047 (0.657)	0.044 (0.667)
Farm work experience	0.085 (0.108)	0.028 (0.472)	0.007 (0.382)	-0.059* (0.080)
Farm size	1.004** (0.027)	-0.01**(0.452)	-0.004 (0.806)	0.005 (0.845)
Credit access	-1.636** (0.033)	1.092 (0.158)	-1.535** (0.030)	-0.057 (0.932)
Extension contact	0.879 (0.300)	-1.42** (0.026)	-0.553 (0.475)	0.541 (0.472)
Safety training	-0.727 (0.200)	0.177 (0.724)	-0.968** (0.028)	-0.568 (0.207)
Daily work hours	-0.425* (0.051)	-0.290 (0.578)	0.013 (0.979)	0.345 (0.471)
Spraying hours	-0.995 (0.253)	0.335 (0.703)	0.616** (0.022)	-0.375 (0.629)
Chemical experience	-0.072 (0.295)	-0.014 (0.815)	-0.101* (0.072)	0.054 (0.343)
Constant	-3.330 (0.075)	1.588 (0.259)	-0.392 (0.755)	-1.691 (0.189)

Note: N= 120; Log pseudo likelihood = -113.684; $chi^2(10) = 25.495$; Prob> chi2 = 0.0000.
***, ** and * indicate significance at 1% 5% and 10% levels respectively. Figures in parentheses are z-values

with chemical handling procedures in reducing the risk of chemical-related health problems.

Environmental hazards

The probability of experiencing environmental hazards was significantly influenced by education, with a p-value less than 0.05. A year increase in years of schooling led to a 0.0275% decrease in the probability of experiencing environmental hazards. This suggests that higher levels of education are associated with a reduced likelihood of encountering environmental hazards in agricultural work settings. Education may equip individuals with knowledge and awareness of environmental risks and safety practices, enabling them to mitigate hazards effectively. The probability of experiencing environmental hazards was also influenced by working experience, with a p-value less than 0.10. A year increase in working experience led to a 0.056% decrease in the probability of experiencing environmental hazards. This indicates that individuals with more experience in agricultural work are less likely to encounter environmental hazards, possibly due to their familiarity with safety protocols and effective risk management strategies. This finding supports the submission of Olowogbon *et al.*, (2021) that years of agricultural engagement is expected to influence the acquisition of skills and capability to adopt technological innovation in crop production activities.

3.5 Constraints to safe farm practices in the study area

The results presented in Table 6 highlight the major constraints to safe farm practices identified by agricultural workers in the study area. These constraints include:

Table 6: Constraints to safe farm practices in the study area

Constraints	Frequency	Percentage
Poorly designed implements	100	83.3
inadequate finance for machinery purchase	104	86.7
lack of safety training from extension agents	89	74.2
Constant mechanical hazards due to faulty or bad machineries or equipment	68	56.7
Lack of technical knowhow on equipment use or application	53	44.2
Insufficient background information on safety practices	69	57.5
Illiteracy: cannot read the instructions on chemical labels	21	17.5
Inadequate knowledge/awareness of farm safety measures	71	59.2

1. *Inadequate finance for machinery purchase*: The majority (86.7%) of respondents reported inadequate finance as a significant constraint to safe farm practices. This suggests that limited financial resources hinder farmers' ability to invest in modern machinery and equipment, which are essential for improving efficiency and reducing ergonomic risks in agricultural operations.

2. *Poorly designed implements*: A large proportion (83.3%) of respondents identified poorly designed implements as a major constraint. This indicates that the design and functionality of agricultural tools and equipment may not adequately address ergonomic considerations, leading to increased risk of injuries and discomfort among workers.

3. *Inadequate extension agents to train workers on farm safety*: A substantial percentage (74.2%) of respondents reported a lack of extension agents as a significant constraint. Extension agents play a pivotal role in providing farmers with information, training, and support on safety practices and technologies. The shortage of extension agents may limit farmers' access to essential safety resources and knowledge.

4. *Inadequate knowledge/awareness of farm safety measures*: A considerable proportion (59.2%) of respondents indicated inadequate knowledge and awareness of farm safety measures as a constraint. This suggests that there is a need for improved education and training initiatives to enhance farmers' understanding of safety practices and promote a culture of safety in the agricultural sector.

5. *Constant mechanical hazards due to faulty or bad machineries or equipment*: More than half (56.7%) of the respondents reported constant mechanical hazards as a significant constraint. This highlights the prevalence of equipment malfunction or deterioration, which poses risks to worker safety and productivity.

These findings align with previous research by Olowogbon *et al.*, (2021), which also identified similar constraints to safe farm practices in North-central zone of Nigeria. By addressing these challenges, it will be possible to create safer and more sustainable working environments for agricultural workers, ultimately improving their well-being and productivity in the study area.

4. Conclusion

The study concluded that Working in the agricultural sector poses significant ergonomic risks, particularly in terms of musculoskeletal disorders (MSDs), which can impact the health and well-being of farm workers. The study identified multiple musculoskeletal injuries among agricultural workers, with lower and upper back pain, shoulder pain, wrist/hand pain, ankle/feet pain, and neck pain being prominent. Factors such as sex, age, education, experience, farm size, credit access, extension contacts, safety training, daily work hours, spraying hours, and chemical experience were found to predispose agricultural workers to various ergonomic risks, including physiological, mechanical, chemical, and environmental hazards. These findings emphasize the need for targeted interventions and strategies to mitigate ergonomic risks and improve the health and well-being of agricultural workers in the study area.

The following recommendations were proposed based on the study's findings:

1. *Regular training*: Agricultural workers should receive regular training to increase awareness of musculoskeletal disorders (MSDs) and safety measures. Training programs should focus on the proper use of improved agricultural equipment, personal protective equipment (PPE), safe work methods, and ergonomic postures to reduce the risk of injuries.

2. *Enhancement of extension services*: There is a need to reorient and train extension agents to better educate farm workers on safety practices, particularly regarding pesticide application. Extension services should emphasize the importance of reading and adhering to pesticide labels and manuals to minimize exposure to harmful chemicals.

3. *Promotion of sustainable farming practices*: Farmers should be encouraged to reduce or eliminate the use of synthetic pesticides by transitioning to bio-pesticides and organic farming methods. Governments can support this transition through incentives and legislation that prioritize environmental and worker safety.

4. *Hazard identification and prevention*: There is a crucial need to identify and prevent ergonomic hazards in agricultural work environments. This can be achieved through interventions such as equipment design improvements, enhanced work processes, and increased awareness of risk factors among workers.

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Awareness and utilization of digital tools for sourcing and sharing innovative agricultural production practices among urban dwellers in Rivers State, Nigeria

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ABSTRACT

The growing challenge of food insecurity in developing nations has stimulated new research into cultivating crops in non-traditional farming environments. Innovative agricultural practices such as aeroponics, vertical farming, hydroponics, and urban agriculture are increasingly gaining global attention. This study investigated the awareness and utilization of digital tools for sourcing and sharing innovative agricultural production practices among sub-urban dwellers in Rivers State, Nigeria. A multistage sampling procedure was employed to select 105 adult respondents, and data were collected through structured questionnaires. The data were analyzed using descriptive statistics - mean, percentage, ranking - and chi-square analysis. Results revealed that 88.6% and 99.8% of respondents were aware of bucket and bag farming, respectively, while less than 42% knew about other innovative production systems. Only about 9% had practiced aeroponics, hydroponics, aquaponics, or vertical farming. Approximately 29.6% of the respondents did not own Android phones. Among digital tools, WhatsApp was the most widely used (72.6%), followed by video calls (18.1%). Inadequate access to farm inputs, facilities, and materials ranked as the major constraint to effective use of digital tools. A significant difference was observed in favor of respondents not utilizing digital tools for information sourcing and sharing. The study recommends that Agricultural Extension Agents intensify awareness campaigns, link farmers to reliable sources of farm inputs, and train them on effective digital engagement. Furthermore, government policies should aim to reduce the costs of power, airtime, data, and agricultural inputs to enhance technology-driven innovation in food production.

KEY WORDS: *Agricultural extension*; *Digital tools*; *Utilization*; *Innovative Agricultural Production Practices*

1. Introduction

Among the seventeen Sustainable Development Goals (SDGs) put forward by the United Nations, ending poverty, achieving zero hunger and good health and well-being of all were prioritized as the first three (Sach *et al.*, 2022). The hope of achieving these goals by 2030 seems bleak, especially in many developing nations where advancement in agricultural production appears not to be keeping pace with unabated population growth. In most of those nations, farmers are conservative, ageing and operating at subsistence level of production. The major challenge is that in

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spite of the fact that youths are characterized by energy, intelligence, innovativeness and risk-taking, the teaming youths (constituting over 45% in some countries), are negatively disposed to and hardly get involvement in agricultural transformation process (Jibowo & Sotomi, 1996; Olatunji, 2017). Aside these, there exist unabated rural-urban migration (especially of youths) and unfavourable land use pattern that do not prioritize agriculture. The combined effects of these are widespread food shortages, hunger, poverty and low standard of leaving among the citizenry (Nwokolo *et al*., 2023; United Nations, 2017).

Consequently, increasing food insecurity is leading to opening of new frontier of research into how food can be grown even in urban metropolis and sub-urban centres. Hence, several innovative agricultural production practices without the usual traditional planting in the farm have emerged (Ojoma, 2023). These zero acreage farming practices include: Bucket farming, Sack farming, aeroponic, vertical farming, hydroponic, Aquaponic farming, *etc*. (Naqvi *et al*., 2022; AlShrouf, 2017). Aeroponic farming is a method of growing plants in the air without soil. Plant roots are suspended in the air misted with solution that is rich in nutrient. Hydroponic farming involves planting crops in containers with the roots submerged in water containing essential nutrients. Aquaponic farming that combines aquaculture and hydroponic farming. Vertical farming involves cultivating crops on inclined surfaces using vertically stacked layers indoors or in a controlled environment.

Focussing and provision of zero-acreage-farming-related agricultural advisory services to urban dwellers will certainly lead to increased food production, hunger reduction and increased standards of living among the citizenry (Ojoma, 2023).

In the last two to three decades, advancement in research has led to significant improvement in Information-Communication Technology. Several hardware and digital tools developed have brought phenomenal changes into the processes of sourcing and sharing information (Kotarba, 2018; Schallmo & William (2018). The traditional use of Town-Criers, radio, television, *etc* is fast giving way to better, faster and more efficient use of mobile Button-phones, Android phones, Laptops, Tablets, e-mail, WhatsApp, Video conferencing (*e.g*. Zoom, Google Meet, Skype), Video calls, LinkedIn, Facebook, Instagram, YouTube and others. These digital tools are veritable for urban dwellers to use for sourcing and sharing relevant innovative agricultural practices. Most dwellers in urban centres are literate and not as conservative as most rural farmers (Chapman, 2022). This makes the job of field Agricultural Extension Agents easy. All he has to do is to create awareness about available innovative agricultural extension practices, provide links to digital tools that clienteles may utilize for sourcing and sharing relevant production information. The Extension Agent may be required to present specimen and sometimes demonstrate some of those innovative agricultural extension practices before clienteles.

The primary objective of this study was to assess the awareness and utilization of digital tools for sourcing and sharing innovative agricultural production practices among urban dwellers in Rivers State, Nigeria. The study aimed to explore the extent to which urban residents are informed about and engaged with emerging agricultural innovations that can enhance productivity in non-traditional farming environments. Specifically, the objectives were to determine the level of awareness of selected innovative agricultural production practices among urban dwellers, identify the specific innovative practices that respondents have experimented with, and examine the types of Information and Communication Technology (ICT) devices owned by them. Furthermore, the study sought to identify the digital tools commonly utilized by respondents, as well as the frequency of their use for sourcing and sharing agricultural information. It also aimed to assess the major constraints limiting the effective utilization of digital tools in accessing and disseminating knowledge on innovative agricultural practices.

Two hypotheses were formulated to guide the study: (1) there is no significant difference between the frequencies of respondents who are aware and those who are not aware of selected digital tools; and (2) there is no significant difference between the frequencies of respondents who utilize and those who do not utilize selected digital tools. The findings of this research are expected to provide insight into the digital readiness of urban farmers and highlight the potential of digital platforms in promoting innovative agricultural practices for sustainable food production.

2. Material and Methods

Multistage sampling procedure was used to select 105 adult males and females the study. First, three sub-urban communities were purposely selected because of their proximity. The second stage involved systematic sampling of one house out of every ten houses. The third stage involved selection of any adult male or female who was ready to willingly participate in the study. Structured questionnaire was designed, validated and administered for data collection. Relevant data were analysed using descriptive statistics (mean, percentage and ranking) and chi-square analysis to test the null hypotheses at 5% level of significance.

3. Results and Discussion

3.1 Awareness of innovative agricultural production practices among households in port harcourt, Rivers state, Nigeria

As shown in Table 1, the results of data analysis reveal that majority of the respondents were aware of bag farming (99.8%) and bucket farming (88.6%) respectively. Next to these were aeroponic farming and hydroponic farming of which 41.9% and 40.9% of respondents were aware. Only 34.3% and 35.2% of the respondents are aware about vertical farming and aquaponic farming. It is commendable that majority of the respondents are aware about bag and bucket farming. However, increased extension awareness campaigns are needed to popularize vertical farming and aquaponic farming that most of the respondents. As noted by Rogers (2003) and Oladele (1999), Adoption of agricultural technologies or innovations will be impossible unless information about the innovations are effectively communicated through effective communication channels to potential adopters for awareness, which may engender innovation trial or adoption.

3.2 Selected innovative agricultural production practices that respondents have tried

Data on Table 2 reveal that it is only bucket farming and bag farming that majority off of the respondents have tried at one time or the other.

Table 1: Percentage distribution of respondents who were aware of selected innovative agricultural production practices

Sl. No.	Innovative agricultural production practices	Awareness (Frequency)	Percentage (%)	Rank
1	Bucket farming	93	88.6	2
2	Bag farming	95	99.8	1
3	Aeroponic farming	41	41.9	3
4	Hydroponic farming	43	40.9	4
5	Aquaponic farming	37	35.2	5
6	Vertical	35	34.3	6

Source: Field survey, 2025

Bucket farming and bag farming ranked first and second with 66.67% and 59.05% respectively in terms of trials. The percentage of respondents who have tried the other innovative practices ranged from 8.57% for vertical farming to the least 1.9% for aquaponic farming in spite of the fact that awareness percentages were above were above 34% for each of them. Constraints to utilization of the digital tools for sourcing and sharing information on innovative farming which respondents reported, may explain, in part, the reasons for abysmally low percentages recorded in terms of trials of these innovative practices. Further research may unveil real and remote reasons for non-trial of these large practices by very percentage of households in this study area.

Pingali, (2021) found that farmers who adopt agricultural innovations had increased productivity and income. Manos and Xydis (2019) explained that the rise in urbanization and the need to achieve food security and sustainability has made innovations in food production and processing imperative for most developing nations. It is important that urban dwellers engage in soil-less farming, especially for its advantages of reduction in pests and diseases, prevention of soil degradation, efficient water usage and increased production.

3.3 Basic information-communication tools that respondents possess

As shown in Table 3, about 67.6%, 70.4%, 42.86% and 8:57% of the respondents possess. Button phone, Android phone, Laptop and Tablets respectively. While it is commendable that 70.6% of respondents have android phones, 28.6% do not have this invaluable tool that is essential for sourcing and sharing internet-based information about innovative agricultural production practices, such as sack faming, Aeroponic farming,

Table 2: Percentage distribution of respondents who have tried selected innovative agricultural production practices

Sl. No.	Innovative agricultural production practices	Awareness (Frequency)	Percentage (%)	Rank
1	Bucket farming	70	66.67	2
2	Bag farming	62	59.05	1
3	Aeroponic farming	5	4.76	3
4	Hydroponic farming	8	7.08	4
5	Aquaponic farming	2	1.90	5
6	Vertical	9	8.57	6

Source: Field survey, 2025

aquaponic farming and the like. However, it is worth noting that increasing number of persons are possessing android phones (70.4%) more than button (manual) Phones (67.6%). Abubakar & Abdurahman (2018) found that, although some of their study sample possessed information-communication tools such as radio, television, internet-enabled phones, laptops, etc, they primarily source and share agricultural production information through friends, relatives or co-farmers.

3.4 Respondents' use of digital tools to source and share information on innovative agricultural production practices

As revealed in Table 4, the digital tools that most of the respondents utilized for sourcing and sharing innovative agricultural production practices is WhatsApp (76.20%). This is followed by Phone calls (2nd rank, 68.6%), YouTube (3rd rank, 65.7%) and e-mail (4th rank, 45.7%). Video call was utilized by 24.76% (5th rank) while the use of Facebook had only 18.1%. The following were the least used digital tools: Instagram (16.2%), Video conferencing (14.37%) and LinkedIn (5.7%). Nnadi, (2014) reported that informal source of information (through friends, neighbours, other farmers, etc and not the use of digital tools) formed the highest means of sourcing and sharing agricultural production information among urban vegetable farmers in Owerri, Imo State, Nigeria. It appears that many of urban dwellers/farmers still rely more on sourcing and sharing innovative agricultural production practices through informal sources.

It is commendable that as high as 65.7% are

Table 3: Percentage distribution of respondents on the basis of information-communication-tools that they possess.

Sl. No.	Innovative agricultural production practices	Number possessed	Percentage (%)	Rank
1	Button phone	71	67.6	2
2	Android phone	75	70.4	1
3	Laptop	45	42.86	3
4	Tablet	16	8.57	4

Source: Field survey, 2025

Table 4: Percentage distribution of respondents who were using various digital tools to source and share information on innovative agricultural production practices

Sl. No.	Digital tools	No. using digital tools (Frequency)	Percentage (%)	Rank
1	E-mail	48	45.71	4
2	WhatsApp	80	76.2	1
3	Video conferencing (e. g. Zoom, google meet, Skype, etc)	15	14.3	8
4	Phone call	72	68.6	2
5	Video call	25	24.76	5
6	LinkedIn	6	5.7	9
7	Instagram	17	16.2	7
8	Facebook	19	18.1	6
9	YouTube	69	65.7	3

Source: Field survey, 2025

utilizing YouTube. Agricultural Extension Agents can leverage on this to further promote the use of YouTube for sourcing and sharing innovative agricultural production practices among urban dwellers. YouTube offers excellent stock of videos of innovative agricultural production practices with "how-to-do-it" guidelines.

3.5 Constraints to utilization of digital tools for sourcing and sharing innovative agricultures production practices

Results of data analyses in Table 5 reveal that all the eleven constraint-related items have mean rating that ranged from the least $\overline{x}$=2.41 for item 11 (ranked 11th) to the highest $\overline{x}$=3.25 for item 10 (ranked 1st). The implication is that all the eleven items pose varying degrees of constraints to the respondents. The most serious constraints include: Inadequate facility and materials needed for innovative agricultural production practices (ranked 1st), Lack of land space for innovative agricultural production practices (ranked 2nd), High cost of airtime and data (ranked 3rd), Lack of technical Know-how (of using some digital tools (ranked 4th), Lack of time to source or share information on innovative agricultural production practices (ranked 5th), Lack of awareness of some digital tool (ranked 6th).

Rathra *et al*. (2020) had also found that high cost of construction of housing, animal feeds and lack of timely insemination facilities were major constraints faced by urban farmers in India.

Field extension agents should effectively refer farmers to where they can procure materials and guide them to improve where necessary. Farmers should also be educated on how to make maximum use of available land. For example, through adoption vertical farming. Government should implement policies that will reduce the cost of data and airtime. Since respondents

Table 5: Mean distribution of respondents' rating of constraints to utilization digital tools for source and share information on innovative agricultural production practices

Sl. No.	Digital tools	Sum of ratings	Mean rating ($\overline{x}$)	Rank
1	Lack of awareness of some digital tools	292	2.78	6
2	High cost of airtime and data	315	3.0	3
3	Lack of technical Know-how (of using some digital tools)	305	2.91	4
4	Inadequate time to search for innovative agricultural production practices	281	2.67	8
5	Lack of interest in agriculture	269	2.56	10
6	Lack of time for innovative agricultural production practices	289	2.75	7
7	Lack of land space for innovative agricultural production practices	339	3.22	2
8	Lack of time to source or share innovative agricultural production practices	295	2.81	5
9	Non-practicability of some innovative agricultural production practices	273	2.6	9
10	No adequate facility and materials needed for innovative agricultural production practices	341	3.24	1
11	Problem of authenticity of on-line information on innovative agricultural production practices	253	2.41	11

Source: Field survey, 2025 *Mean ($\overline{x}$) ≥ 2.5 implies constraint mentioned lack of technical know-how, Field Extension Agents should embark on effective seminars, demonstrations and use of specimen in teaching. Vigorous awareness campaign should be mounted in every community to bridge the gap in awareness which respondents noted as a serious constraint.

3.6 Significance of difference between the frequencies of respondents who are aware and those not aware of selected innovative agricultural production practices

The results of chi-square analysis on Table 6 showed that observed value was 78.73 while critical valve is 11.07. The null hypothesis was rejected. This implies that there is significant difference between the frequencies of respondents who are aware and those not aware of selected innovative agricultural production practices.

The difference was in favour of those who are not aware. Data on Table 2 showed that less than 42% are aware of aeroponic, hydroponic, aquaponic and vertical farming. Rigorous awareness campaigns are needed to bring these practices to the notice of urban-dwellers.

3.7 Significance of difference between the frequencies of respondents who utilize digital tools for sourcing and sharing information on selected innovative agricultural production practices

The results of chi-square analysis showed (Table 7) that observed value is 146.2 while critical valve is 15.51. The null hypothesis was rejected. This implies that there is a significance difference between the frequencies of respondents who utilize digital tools for sourcing and sharing information on selected innovative agricultural production practices and those who do not. The observed difference is in favour of those who did not utilize digital tools. It can be seen in Table 4 that the percentage of respondents who used those digital tools was above 50% only in 3 out of 9 items. As noted by Chapman (2022), most dwellers in urban centres are literate and not as conservative as most rural farmers. As such, digital tools would proof invaluable in the hands of urban dwellers to use for sourcing and sharing relevant innovative agricultural practices. Field Extension Agents should promote the use of digital tools that respondents were not utilizing for quick information sourcing and sharing.

Table 6: Chi-square analysis of frequencies of respondents who are aware of selected innovative agricultural production practices

Sl. No.	Innovative agricultural production practices	Observed (O)	Expected (E)	$\frac{(O-E)2}{E}$
1	Bucket farming	93	52.5	31.24
2	Bag farming	95	52.5	34.4
3	Aeroponic farming	41	52.5	2.52
4	Hydroponic farming	43	52.5	0.17
5	Aquaponic farming	37	52.5	4.57
6	Vertical	35	52.5	5.83
	Chi-Square Observed $\chi 2$ =			78.73
	Chi-Square Critical ($\chi 2$) =			11.07

Table 7: Chi-square analysis of frequencies of respondents who utilized digital tools for sourcing and sharing information on innovative agricultural production practices

Sl. No.	Innovative agricultural production practices	Observed (O)	Expected (E)	$\frac{(O-E)2}{E}$
1	E-mail	68	52.5	4.57
2	WhatsApp	80	52.5	14.4
3	Video conferencing (eg. Zoom, Google meet, Skype, *etc*)	15	52.5	26.8
4	Phone call	72	52.5	7.2
5	Video call	44	52.5	1.4
6	LinkedIn	6	52.5	41.2
7	Instagram	17	52.5	24.0
8	Facebook	19	52.5	21.4
9	YouTube	69	52.5	5.2
	Chi-Square Observed ($\chi 2$)			146.17
	Chi-Square Critical ($\chi 2$)			15.51

Source: Field survey, 2025

4. Conclusion

Urban dwellers are increasingly participating in agriculture as evidenced by majority of the sample for this study Majority of them are both ware and have been practicing bucket farming and bag farming. However, many of them are not aware about aeroponic, hydroponic, vertical farming and aquaponic farming. It is aquaponic that is the strangest to many of them. Many of them have android phones but it appears that majority only use it for entertainment and rarely for sourcing or sharing information related to innovative agricultural practices. Inadequate facility and materials needed for innovative agricultural production practices is the greatest problem they are facing. Others also pointed to lack of land space for innovative agricultural production practices and lack of technical know-how of using some digital tools. Awareness campaign, training and governments' intervention are paramount to overcome those challenges as the people move towards achieving the first 3 in the list of Sustainable Development Goals (SDGs).

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Mycological studies and pathogenicity of Tannia (*Xanthosomas agittifolium*) postharvest Tuber Rot

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ABSTRACT

Pathogenicity assays were conducted in 2021 and repeated in 2023 at the National Root Crops Research Institute (NRCRI), Umudike, Nigeria, to identify the primary aetiology of postharvest deterioration in decaying *Xanthosomas agittifolium* (tannia) tubers. Among the fungal isolates recovered, *Penicillium* spp**.** demonstrated the highest virulence, characterized by aggressive growth patterns and significant rot progression (27 mm). Rot initiation commenced upon mycelial contact of pathogens with tuber surface wounds, triggering a sequence of events. Upon contact, these fungi produced large quantities of oxalic acid and polygalacturonases, which acted synergistically. Oxalic acid sequestered calcium, lowering the pH to optimize endopolygalacturonase and cellulase activity. The advancing hyphae depleted pectic substances within tuber tissues, leading to peroxidase release via enzymatic activity. This sequential breakdown ultimately results in water-soaked, necrotic, and macerated tuber tissues.

KEY WORDS: *Enzyme*; *Fungi*; *Isolation*; *Pathogenicity*; *Postharvest rot*; *Xanthosoma tubers*

1. Introduction

Cocoyams, comprising taro (*Colocasia esculenta*) and tannia (*Xanthosomas agittifolium*), are major tuber crops cultivated and consumed as staple foods across Africa, Latin America, the Pacific Islands, and Asia (FAO, 1993). Globally, cocoyams serve as a primary energy source for over 400 million people (Ubalua, 2016). Noted for their shade tolerance, *Xanthosoma* is particularly prevalent in southeastern Nigeria. While *Colocasia* is primarily used for soup thickening, *Xanthosoma* is boiled, roasted, or fried. A significant constraint to profitable *Xanthosoma* production is the short postharvest shelf-life of corms and cormels (2-5 months), limiting market potential and economic returns for farmers. Consequently, production lags behind major root and tuber crops like cassava and yam, exacerbated by disease susceptibility and limited planting material availability.

Flowering is rare in cocoyams, necessitating vegetative propagation and limiting genetic recombination. Despite their nutritional value, profitable production and storage of *Xanthosoma* remain hampered by microbial attacks.

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Xanthosoma corms and cormels are highly susceptible to microbial deterioration within 2-5 months postharvest. Reported storage losses in Nigeria are substantial. Postharvest physiological deterioration (PPD) discourages commercial production, storage, and utilization, restricting economic benefits for farmers and limiting supply to agro-industries. Optimal *Xanthosoma* storage occurs in cool, dry, well-ventilated environments for 2-5 months. At low temperatures (7°C), *C. esculenta* and *X. sagittifolium* can store for up to 4 months, while at higher ambient temperatures (25-30°C), storage may extend to 4-6 months (FAO, 2004). Conventional methods - such as barn heaping under shade, covering with straw/plantain leaves, wood ash application, pit storage with soil/leaf cover, or storage on wooden platforms with dry grass and occasional sprinkling - have proven ineffective beyond 5-6 months due to high losses. Leaving corms unharvested until needed is an alternative, yet all these methods fail to provide significant storage improvement. Recent suggestions for pre-storage fungicide dips (*e.g.*, sodium hypochlorite within 24h postharvest) raises economic and health concerns, potentially limiting adoption by local farmers.

Cocoyam spoilage results from complex interactions between physical, physiological, and pathological factors. The disease was first reported in Ghana in 1945 (Posnette, 1945) and subsequently observed in various Nigerian states (Ishan Ekpoma, Etsako, Edo State in 1954; Bori, River State in 1955; Anambra, Imo, and Cross River in 1960), becoming epidemic in Nigeria by the late 1970s (Arene and Okwuowulu, 1997). Losses manifest as reduced quality and quantity. Storage deterioration typically initiates at wound sites incurred during harvesting and handling, providing entry points for pathogens. Initial infection by primary pathogens is often followed by secondary invasion by opportunistic pathogens and saprophytes colonizing necrotic tissues. Rotted corms/cormels exhibit blue/black or brown discoloration and foul odor within 2-5 months. Beyond microbial rots, physiological sprouting is another significant cause of storage loss, with reported losses of ~50% after 2 months and ~95% after 5 months (Paraquin and Miche, 1971). Conservative estimates indicate ~25% postharvest losses in the tropics (Coursey and Booth, 1972), though losses for *C. esculenta* in southeastern Nigeria can reach 76% during severe infections (Nwufo, 1980; Nwufo and Fajola, 1981).

Key pathogens implicated in on-farm and storage rots include *Fusarium solani*, *Botryodiplodia theobromae*, *Rhizopus stolonifera*, *Aspergillus niger*, *Sclerotium rolfsii*, *Fusarium oxysporum*, *Pythium myriotylium*, *Penicillium* spp., and *Phytophthora infestans*. Rot losses as high as 40-60% have been reported in Nigeria (Ubalua and Chukwu, 2008; Anele and Nwawuisi, 2008), underscoring the need for further research. Physiologically, cocoyam corms/cormels, like cassava and yam, are living structures experiencing endogenous respiratory and transpiratory water loss. These processes directly impact produce quality and susceptibility to microbial attack, leading to rapid tissue breakdown by pathogens within 2-5 months. Rot thus poses a major challenge to cocoyam cultivation, storage, and utilization due to inevitable harvest damage. Breeding programs, mutation breeding, and genetic engineering have yielded limited success in enhancing storability. This study aimed to isolate and identify fungal pathogens from rotten *Xanthosoma* corms and determine their relative roles and degrees of virulence in postharvest rot.

2. Material and Methods

2.1 Isolation, purification, and identification of pathogens

Fifty-three (53) decaying *Xanthosomas agittifolium* corms were sourced from the NRCRI, Umudike cocoyam barn. Corms were surface-sterilized with 70% ethanol and rinsed twice with sterile distilled water. Samples were dried on sterile paper towels in a laminar airflow hood for 10 minutes. Approximately 2 mm^3 tissue sections were excised from the advancing margin of lesions (junction of healthy and decayed tissue) using a sterile scalpel. Sections were plated onto Potato Dextrose Agar (PDA) and incubated at 27°C for four days. Plates were examined daily for fungal growth.

2.2 Purification and identification

Hyphal tips from the margins of developing mixed cultures were subcultured onto fresh PDA plates using flame-sterilized scalpels and incubated at 27°C until pure cultures were obtained. Pure cultures were identified microscopically and morphologically based on growth rate, colony color, mycelial morphology, and characteristics of sporulating structures and conidia, using standard taxonomic keys (Booth, 1971; Barnett and Hunter, 2000).

2.3 Estimation of pathogen frequency

The frequency of occurrence of isolated fungal pathogens was determined using thirty (30) additional decaying corms from the same source. Isolates were cultured separately on PDA. The presence of each isolate type in the 30 samples was recorded. Percentage occurrence was calculated as:

Percentage Occurrence = (Number of samples yielding a specific isolate / Total number of samples) × 100

2.4 Pathogenicity test

Healthy *Xanthosomas agittifolium* corms were washed with tap water and surface-sterilized with 70% ethanol. Corms were dried on sterile paper towels in a laminar airflow hood for 12 minutes. A sterile 5 mm diameter cork borer was used to create wells in the corms. Excised tissue plugs were retained in sterile Petri dishes. A 4 mm × 4 mm agar block from the actively growing margin of each pure test isolate was aseptically placed into a well. The well was sealed with sterile Vaseline to prevent contamination and labeled. Controls received sterile PDA plugs. The experiment was replicated five times per isolate. Inoculated corms were incubated in a polyethylene bucket at ambient conditions. After nine days, corms were cut transversely through the inoculation point. Rot diameter (mm) and lesion characteristics were recorded and compared to naturally diseased corms. Pathogens were re-isolated from lesion margins onto PDA. Pathogenicity was confirmed if the re-isolated pathogens exhibited identical microscopic, cultural, and morphological characteristics to the original inoculum.

3. Results and Discussion

3.1 Pathogen isolation and identification

Four fungal isolates were consistently recovered from the rotten *Xanthosoma* corms in both 2021 and 2023: *Fusarium oxysporum*, *Penicillium* spp., *Botryodiplodia theobromae*, and *Aspergillus niger*. Their morphological characteristics on PDA at 28°C were distinct:

- *B. theobromae*: Exhibited rapid growth, covering the plate in 48 hours. Mycelia were initially grey but turned black after 5 days, with spores transitioning from hyaline and aseptate to dark-brown.

- *F. oxysporium*: Colonies were whitish to pale pink, characterized by septate hyphae and elongated, curved macroconidia.

- *Penicillium* spp.: Colonial growth was moderate within 7 days. Conidiophores were dense and blue-green due to spore production, with flask-shaped phialides.

- *A. niger*: Displayed rapid growth, with a slightly brownish culture surface and a contrasting yellow reverse side. The conidiophores were upright and simple, terminating in a swelling bearing phialides.

3.2 Pathogen frequency and virulence

Penicillium spp. exhibited the lowest frequency of occurrence in the sampled rotten corms in both 2021 and 2023 (Table 1A & 1B). However, pathogenicity tests revealed that the *Penicillium* spp. were the most virulent pathogens, inducing the largest rot lesions (27 mm in 2021, 29 mm in 2023) (Table 2A & 2B), suggesting that the *Penicillium* spp. may be the primary causal agent of *Xanthosoma* postharvest tuber rot. In contrast, *A. niger*, while more frequently isolated (21.7% in 2021, 21.3% in 2023), caused significantly smaller lesions (10 mm in 2021, 11.7 mm in 2023) (Tables 1A & 1B**,** 2A & 2B). *F. oxysporum* also demonstrated high virulence (25 mm lesion diameter in 2021), while *B. theobromae* was the least virulent (8 mm lesion diameter) (Table 2A).

3.3 Disease development mechanism

The ability of these isolates to induce rot on wholesome *Xanthosomas agittifolium* corms were investigated. Fig. 1 and 2 are typical representations of inoculation, incubation, and disease induction and progression in wholesome *Xanthosoma* corms after nine days of incubation.

Postharvest rot in cocoyams results from physical damage, physiological processes, and pathological factors, with pathogen attack being the most significant cause. Initial infection by primary pathogens (e.g., *Penicillium* spp.) facilitates subsequent colonization by secondary opportunists and saprophytes on necrotic tissues. The complex deterioration process involves enzymatic responses to wounding, originating from harvest/handling damage and spreading into storage parenchyma.

The growth rate varied from 3rd day to the 5th day while beyond the 6th day they attained their maximum growth rate covering the entire petri dishes. The mean radial diameter (Fig. 3-4) of the isolates differed significantly suggesting differences in the virulence of the isolates. While *F. oxysporium* and *Penicillium* spp. were more aggressive with an average diameter rot of 25 and 27 mm (Fig. 3 and 4) respectively, *B. theobromae* (Fig. 5) and *Aspergillus niger* (Fig. 6) recorded the least mean diameter of 8 mm and 10 mm respectively (Table 2A).

Table 1A: Percentage occurrence of the isolated fungal pathogens from the rotten *Xanthosomas agittifolium* corms (2021)

Isolated fungal pathogens	Occurrence			
	1st (5) sets of plates	2nd (5) sets of plates	3rd (5) sets of plates	Total average (%)
B. theobromae	15	16	13	14.7
Aspergillus niger	23	20	22	21.7
Penicillium spp.	10	7	8	8.3
Fusarium oxysporium	20	18	19	19

Table 1B: Percentage occurrence of the isolated fungal pathogens from the rotten *Xanthosomas agittifolium* corms (2023)

Isolated fungal pathogens	Occurrence			
	1st (5) sets of plates	2nd (5) sets of plates	3rd (5) sets of plates	Total average (%)
B. theobromae	17	14	11	14
Aspergillus niger	19	21	24	21.3
Penicillium spp.	14	9	11	11.3
Fusarium oxysporium	18	23	17	19.3

Table 2A: Induced infection on *Xanthosomas agittifolium* corms using the isolated fungal pathogens (2021)

Isolated pathogens	1st (5) sets of corms (mm)	2nd (5) sets of corm (mm)	3rd (5) sets of corm (mm)	Total average (mm)
A. niger	9	12	9	10
B. theobromae	6	8	10	8
Penicillium spp.	25	26	29	27
Fusarium oxysporium	23	25	26	25

Table 2B: Induced infection on *Xanthosomas agittifolium* corms using the isolated fungal pathogens (2023)

Isolated pathogens	1st (5) sets of corms (mm)	2nd (5) sets of corm (mm)	3rd (5) sets of corm (mm)	Total average (mm)
A. niger	12	10	13	11.7
B. theobromae	7	9	12	9.3
Penicillium spp	27	29	31	29
Fusarium oxysporium	24	19	28	23.7

Fig. 1: Inoculated *Xanthosoma* corms to determine the degrees of pathogenicity of the isolates

Fig. 2: Plastic bucket as an incubator

Fig. 3: *Fusarium oxypsorium*

Fig. 4: *Penicillium* spp.

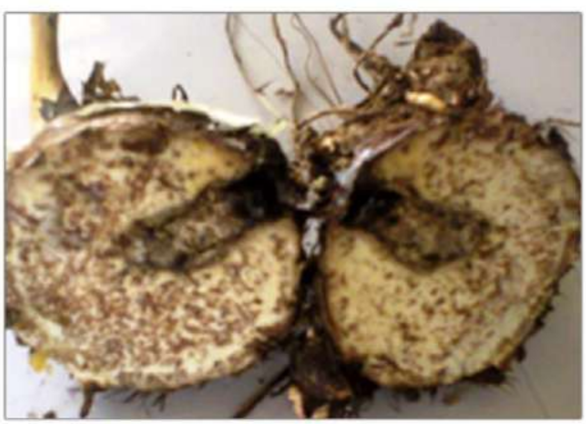

Fig. 5: *Botryodiplodia theobromae*

Fig. 6: *Aspergillus niger*

Fig. 7: Control

Pathogen penetration occurs intercellularly and intracellularly within the cortical parenchyma. Disease induction involves a sequence of events initiated by mycelial contact with the corm surface (Smith *et al*., 1984; Punja *et al*., 1985). The sequence of events leading to tissue maceration involves a synergistic biochemical attack:

1. The fungi produce large quantities of oxalic acid and polygalacturonases upon contact with the corms.

2. The oxalic acid serves to sequester calcium oxalate and lower the pH, creating the optimal acidic conditions for the maximum activity of key cell wall-degrading enzymes, endopolygalacturonases and cellulases.

3. The advancing hyphae invade the tissue, depleting the pectic substances and stimulating the release of peroxidase via enzymatic activity.

4. This degradation results in the characteristic water-soaked, necrotic, and macerated condition of the corm tissue.

3.4 Comparison with previous studies

The pathogens profile (*B. theobromae*, *F. oxysporum*, *Penicillium* spp. and *A. niger*) aligns with previous reports on *Colocasia esculenta* (taro) and cassava rots in southern Nigeria (Ugwuanyi and Obeta, 1996; Ugwuanyi and Obeta, 1999; Agu *et al*., 2014; Agu *et al*., 2016; Ubalua *et al*., 2020). While Ugwuanyi and Obeta (1996, 1999) also recovered *Corticium rolfsii* and *Geotrichum candidum*, differences in pathogen prevalence may be attributable to geographical location. The identification of these pathogens is crucial for understanding disease development patterns in *Xanthosoma* tubers.

4. Conclusion

This study identified *Penicillium* spp. as the primary causal agent of postharvest rot in *Xanthosomas agittifolium* tubers, despite its lower frequency of isolation compared to other fungi like *A. niger*. Its high virulence, demonstrated by the largest rot lesions (27-29 mm), underscores its significant role in postharvest deterioration. The disease mechanism involves synergistic production of oxalic acid and polygalacturonases by pathogens upon contact with wounded tuber surfaces, leading to pH reduction, optimal enzyme activity, pectin degradation, and ultimately tissue maceration.

Variations in pathogen prevalence and virulence observed between 2021 and 2023, and compared to other regions, highlight the influence of geographical and environmental factors. These findings provide a foundation for developing targeted management strategies against *Penicillium* spp. to mitigate postharvest losses in *Xanthosoma*.

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Antibiotic sensitivity and resistance profile of Coliform from irrigation water in some selected area of Sokoto State, Nigeria

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ABSTRACT

Human activities such as agriculture, domestic sewage disposal, industrial effluent release, urbanization, and poor healthcare waste management significantly contaminate irrigation water. The aim of this study is to detect coliform bacteria, sand their sensitivity profile isolated from irrigation water, the physicochemical analysis of the water samples was studied and recorded neutral across all the sample sites, with 7.18 from Wamakko followed by Tambuwal which recorded 7.17 and the least was from kware with 7.04 which fall within WHO (6.5–8.5) permissible limits. Electrical conductivity was highest in Wamakko (310 µS cm^{-1}) and lowest in Kware (180 µS cm^{-1}). Dissolved oxygen peaked in Tambuwal (6.2 mg L^{-1}), while BOD was highest in Wamakko (5.8 mg L^{-1}). Total dissolved solids and chloride concentrations were also within WHO and SON standards. Heavy metal analysis showed iron levels highest in Wamakko (10.5 mg L^{-1}), copper in Tambuwal (6.4 mg L^{-1}), and zinc in Tambuwal (13.4 mg L^{-1}), with lead detected in all samples (0.4–0.9 mg L^{-1}), exceeding WHO limits of 0.01 mg L^{-1}. Chromium ranged from 2.3 mg L^{-1} in Wamakko to 4.3 mg L^{-1} in Kware. Calcium and magnesium concentrations were moderate across all sites. Microbiological analysis revealed presumptive and confirmed coliforms with strong gas production in lactose broth. EMB agar confirmed the presence of *Escherichia coli*, while MacConkey agar indicated *Klebsiella* spp. and *Enterobacter* spp., *Salmonella* spp. was also isolated from Tambuwal samples. Biochemical tests supported these identifications. Antibiotic susceptibility profiling showed multidrug resistance among isolates: *E. coli* from Wamakko resisted tetracycline and ampicillin but was sensitive to gentamicin, while *Enterobacter* spp. from Tambuwal resisted ciprofloxacin and tetracycline. *Salmonella* spp. exhibited resistance to ampicillin but remained sensitive to ciprofloxacin and gentamicin. These findings indicate contamination of irrigation water with heavy metals and pathogenic coliforms that exceeded WHO standards, posing public health risks and highlighting the need for improved water treatment and monitoring.

KEY WORDS: *Water*; *Irrigation*; *Coliforms*; *Sensitivity*; *Multidrug*

1. Introduction

Water serve as an important resources for agricultural production and in Nigeria, irrigation farming is crucial for ensuring food security and sustaining the lively hoods of a vast population. A large portion of this irrigation water is sourced from surface waters such as rivers, streams, lakes and ponds which are highly susceptible to contamination from various man activity and

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anthropogenic activities (Akinbile *et al*., 2015). These activities include the discharge of untreated domestic sewage, agricultural runoff containing animal waste fertilizers and effluents from small-scale industries. Consequently, these water sources often become reservoirs for a plethora of pathogenic microorganisms.

The microbiological quality of irrigation water is a critical determinant of food safety. Fecal contamination introduces enteric pathogens, including bacteria, viruses, and parasites which can survive in water and soil and subsequently colonize crops. To assess this risk, microbiological indicators are used with coliform bacteria particularly *Escherichia coli* (*E. coli*), serving as the gold standard for indicating recent fecal contamination and the potential presence of more harmful pathogens (Edberg *et al*., 2000). The detection of high levels of these indicator organisms in water signifies a breach in sanitation and a direct threat to public health.

Studies conducted across Nigeria's geopolitical zones have consistently reported alarming levels of coliform contamination in water sources used for irrigation. For instance, research in South-western Nigeria found coliform counts far exceeding the limits recommended by the World Health Organization for agricultural use (Adeyemi *et al*., 2024). Similarly, studies in the Northern parts of the country have documented the pervasive presence of fecal coliforms in irrigation canals and reservoirs (Oluwasemire *et al*., 2020). This wide spread contamination is largely attributed to inadequate sanitation infrastructure, poor waste management systems, and the lack of regulatory enforcement for waste water discharge.

A more worrisome dimension of this public health threat is the emergence and dissemination of antimicrobial resistance (AMR). The misuse and overuse of antibiotics in human medicine, veterinary care and agriculture have exerted selective pressure leading to the proliferation of antibiotic-resistant bacteria in the environment. Irrigation water contaminated with fecal matter from humans and animals acts as a major conduit for these resistant organisms and their genetic determinants (Chigor *et al*., 2012). Recent investigations have identified multidrug-resistant *E.coli* and even extended-spectrum beta-lactamase (ESBL)-producing strains in Nigerian irrigation water sources (Odetokun *et al*., 2019). This presents a grave scenario where commonly available antibiotics may fail to treat infections acquired through the consumption of contaminated fresh produce.

When perishable crops like vegetables and fruits crops are irrigated with such contaminated water, they can become contaminated with these resistant bacteria. Consumption of raw or inadequately washed produce then becomes a direct route of transmission for resistant pathogens into the human gut. This can lead to difficult-to-treat infections; longer hospital stays higher health care costs and increased mortality (Okeke *et al*., 2021). Therefore, the issue transcends mere agricultural practice and sits at the intersection of environmental health, food safety and clinical medicine.

Despite the growing body of evidence, there remains a need for comprehensive and concurrent assessment of both the quantitative microbial load and the antibiotic susceptibility patterns of isolates from irrigation water across diverse agricultural regions in Nigeria. Such a study is vital to fully appreciate the scope of the problem, identify prevalent resistance patterns, and provide a scientific basis for targeted interventions. This research is designed to address this gap providing critical data that can inform policy, guide regulatory standards and ultimately contribute to safe guarding public health and ensuring the safety of the Nigerian food supply.

2. Material and Methods

2.1 Study area

Sokoto State is situated in north-western Nigeria within the Sudan Savannah ecological zone, between latitude 12°00′N–13°58′N and longitude 4°08′E–6°54′E. It shares an international boundary with the Republic of Niger to the north, Kebbi State to the west and south-west, and Zamfara State to the east and south-east. The state experiences a semi-arid climate with average rainfall of 500–750 mm annually and a prolonged dry season from October to May. Its economy is mainly agrarian, relying on irrigation farming, livestock rearing, and trading.

Kware, Wamakko, and Tambuwal LGAs were selected for this study due to their heavy reliance on irrigation farming (Fig. 1). Kware LGA located at approximately 13°12′N latitude and 5°16′E longitude, had a population of 133,899 in 2006, projected above 280,000 by 2025, with the Hausa-Fulani as the dominant tribe. Its people are mainly farmers and traders, cultivating rice, onions, tomatoes, and vegetables. Wamakko LGA lying at coordinates 13°03′N latitude and 5°07′E longitude, with a population of 179,619 in 2006 and estimated above 340,000 in 2025, is semi-urban and hosts Usmanu Danfodiyo University. Its people engage in farming, livestock rearing, trading, and petty businesses, with crops like millet, sorghum, and rice cultivated. Tambuwal LGA is located at coordinates 12°24′N latitude and 4°39′E longitude, had 224,931 people in 2006, and projected above 360,000 in 2025, dominated by Hausa-Fulani. The people practice irrigation and rain-fed farming, livestock trading, and small-scale businesses, with rice, pepper, and okra as common crops, and a major weekly market serving as a hub for trade.

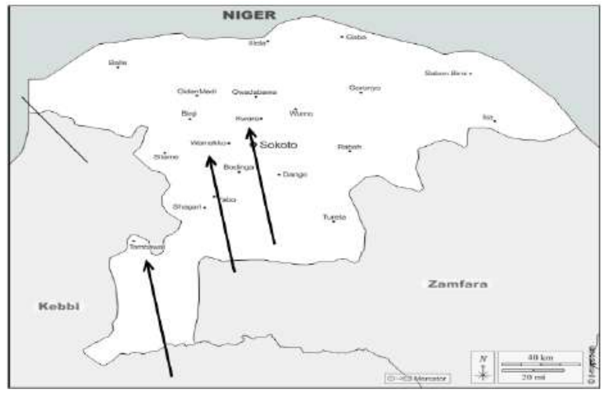

Fig. 1: Map of Sokoto State showing the study areas

2.2 Sample collection

A total of three water samples were collected, one from each of Kware, Wamakko, and Tambuwal LGAs of Sokoto State. The samples were collected from irrigation sources commonly used by farmers, such as rivers, lakes and streams. Collection was done using sterile 500 ml glass bottles that had been autoclaved at 121°C for 15 minutes. During sampling, bottles were rinsed with the water source before being filled at a depth of 15–30 cm to avoid surface contaminants. The bottles were tightly capped, labelled with the location and date, and placed in an ice-packed cooler. Samples were transported under cold conditions (4–8°C) to the Microbiology Laboratory of Sokoto State University, Sokoto, where they were processed within six hours for coliform detection and antibiotic sensitivity analysis.

2.3 Physicochemical analysis of the water samples

The physicochemical parameters of the water samples were analyzed following the procedures outlined by Greenberg *et al*. (1995). Parameters such as Electrical conductivity, TDS, TSS, BOD, COD, calcium, magnesium, dissolved oxygen, and various forms of alkalinity (carbonate, bicarbonate, and chloride) were determined using standard titrimetric and colorimetric techniques as described by (APHA *et al*., 2023).

2.4 Heavy metal analysis

The concentrations of selected heavy metals, namely zinc (Zn), iron (Fe), chromium (Cr), lead (Pb), and copper (Cu), was determined using Atomic Absorption Spectroscopy (AAS), in accordance with the methods described by James *et al*. (2023).

2.5 Coliforms detection

Presumptive test

The presumptive test was carried out by inoculating 10 mL, 1 mL and 0.1 mL of the water samples into test tubes containing 10 mL of MacConkey broth with inverted Durham tubes, incubated at 35–37 °C for 24–48 hours. Gas production and color change indicated possible coliform presence (APHA, 2017).

Confirmed test

Colonies from the positive presumptive tubes, a loopful was streaked onto Eosin Methylene Blue (EMB) agar plates and incubated at 35–37 °C for 24 hours. Colonies showing green metallic sheen (indicative of *E. coli*) or dark-centered colonies (other coliforms) were considered positive.

Completed test

A colony from EMB agar was inoculated into lactose broth with Durham tubes and on nutrient agar slants. Gas production in lactose broth and Gram staining of nutrient agar cultures were performed. Gram-negative, non-spore forming rods confirmed coliform identity (APHA, 2017).

2.6 Biochemical characterization of the bacterial isolates

Following gram staining as described by Cheesebrough (2006), biochemical tests were conducted to characterize the different bacteria; isolates the following test were carried out indole, methyl Red-Voges Proskauer (MRVP) and citrate utilization.

2.7 Antibiotic susceptibility testing

The antibiotic sensitivity of bacterial isolates was determined using the Kirby–Bauer disc diffusion method on Mueller–Hinton agar, following Clinical and Laboratory Standards Institute (CLSI, 2023) guidelines. Pure colonies of the isolates were suspended in sterile saline and adjusted to 0.5 McFarland turbidity standards. Sterile swabs were used to evenly spread the suspension across the surface of the agar plates.

Commercial antibiotic discs representing commonly used classes, including ciprofloxacin (5 µg), gentamicin (10 µg), ampicillin (10 µg), tetracycline (30 µg), ceftriaxone (5 µg), and chloramphenicol (30 µg), were aseptically placed on the agar surface using sterile forceps. Plates were incubated at 37°C for 18–24 hours, after which zones of inhibition around each disc were measured in millimeters. The results were interpreted as sensitive, intermediate, or resistant according to CLSI breakpoints.

3. Results and Discussion

The physicochemical parameters (Table 1) studied showed that the pH values of irrigation water samples from Tambuwal (7.15), Kware (7.04), and Wamakko (7.18) fall within the permissible range of 6.5–8.5 recommended by WHO and SON, indicating that the water is suitable for agricultural use in terms of acidity and alkalinity. Electrical conductivity (EC) values, however, were high (1882 µS cm^{-1} in Tambuwal, 1685 µS cm^{-1} in Kware, and 1587 µS cm^{-1} in Wamakko), exceeding the WHO and FAO recommended limits of ≤1000 µS cm^{-1} and 750 µS cm^{-1}, respectively. Elevated EC reflects high salinity, which could pose a risk to soil structure and crop productivity, this is in agreement with reports by Oladipo *et al*. (2022) that high conductivity levels in irrigation water reduce soil permeability and affect crop yield.

Dissolved oxygen (DO) ranged between 8.0–9.1 mg L^{-1}, above the minimum guideline of 5 mg L^{-1}, suggesting adequate aeration to support microbial and biochemical activities in the aquatic environment. However, biochemical oxygen demand (BOD) values were exceptionally high (22.1–23.2 mg L^{-1}), far above the <3 mg L^{-1} permissible limit. High BOD implies heavy organic pollution, possibly from agricultural runoff, sewage, or animal wastes. Similar findings were reported by Abubakar and Musa (2021), who linked high BOD in irrigation sources in northern Nigeria to poor waste management. Calcium and magnesium concentrations (Ca: 30–84 mg L^{-1}, Mg: 32.4–40.8 mg L^{-1}) were within acceptable ranges for irrigation water, while TDS values (80–120 mg L^{-1}) were lower than the 1000 mg L^{-1} limit, suggesting minimal dissolved solids content. Chloride, sulphate, and phosphate levels were all below WHO and FAO thresholds, making them less problematic for irrigation.

Table 1: Physicochemical characteristics of irrigation water samples

Parameters	Tambuwa	Kware	Wamakko
pH	7.15	7.04	7.18
EC (µS cm^{-1})	1882	1685	1587
DO (mg L^{-1})	8.2	8.0	9.1
BOD (mg L^{-1})	22.1	23.2	22.9
Ca^{2+} (mg L^{-1})	68.0	30.0	84.0
Mg^{2+} (mg L^{-1})	36.0	40.8	32.4
TDS (mg L^{-1})	110.0	80.0	120.0
Cl^{-} (mg L^{-1})	1.4	1.5	1.8
SO_4^{2-} (mg L^{-1})	0.07	0.06	0.9
PO_4^{3-} (mg L^{-1})	0.06	0.04	0.05
NO_3^{-} (mg L^{-1})	1.8	1.4	1.2

The heavy metal concentration (Table 2) showed that the concentrations of iron, copper, lead, zinc, and chromium in all samples were far above WHO and SON permissible limits, indicating serious contamination. Iron ranged from 5.1–10.5 mg L^{-1} against the 0.3 mg L^{-1} limit, which is consistent with the findings of Lawal *et al*. (2020), who reported elevated iron in irrigation water from Sokoto metropolis due to effluents from automobile workshops and open dumping. Copper levels (4.3–6.4 mg L^{-1}) also exceeded the 2.0 mg L^{-1} standard, in agreement with the same study, where high copper concentrations were linked to indiscriminate disposal of metallic wastes.

Lead concentrations (0.4–0.9 mg L^{-1}) were particularly alarming, being several times higher than the 0.01 mg L^{-1} safe limit, suggesting potential risks of bioaccumulation in crops irrigated with such water. A similar observation was made by Abubakar and Garba (2021) in Wurno and Goronyo LGAs of Sokoto, where lead contamination in irrigation water and vegetables was also above WHO limits. Chromium levels (2.3–4.3 mg L^{-1}) were higher than the 0.05 mg L^{-1} permissible limit, raising concern over carcinogenic exposure. This is comparable to the findings of Sharma *et al*. (2023) in Punjab, India, who associated elevated chromium in irrigation water with industrial effluents.

Zinc concentrations (8.1–13.4 mg L^{-1}) also exceeded the WHO permissible level of 3 mg L^{-1}, though SON allows up to 5 mg L^{-1}. This observation aligns with Oko *et al*. (2022), who reported elevated zinc levels in irrigation water from Enugu State due to mining activities. Magnesium (2.6–4.6 mg L^{-1}) and calcium (5.2–8.5 mg L^{-1}) concentrations in this study were within acceptable thresholds, which is in line with FAO guidelines for irrigation water. These patterns demonstrate that heavy metal contamination is not peculiar to Sokoto but a recurring issue in agricultural water sources across developing regions.

Table 2: Heavy metals concentrations in irrigation water (mg L^{-1})

Elements (mg ml^{-1})	Kware	Wamakko	Tambuwal
Iron (Fe)	5.1	10.5	9.4
Copper (Cu)	4.3	5.5	6.4
Lead (Pb)	0.9	0.8	0.4
Magnesium (Mg)	4.6	2.6	3.4
Zinc (Zn)	10.3	8.1	13.4
Calcium (Ca)	8.5	7.6	5.2
Chromium (Cr)	4.3	2.3	3.1

Microbiological Analysis of the water sample showed that the presumptive test (Table 3 - 8) confirmed the presence of coliform bacteria across the three study sites, with gas production observed in Durham tubes. The Most Probable Number (MPN) values, which ranged from 0.11 to >4.2, exceeded acceptable microbial safety thresholds, this showed faecal contamination and poor water quality for irrigation. This observation agrees with the findings of Lawal and Musa (2022) in Sokoto metropolis, which also detected high coliform counts in irrigation water samples and linked them to direct discharge of sewage and animal waste into open water bodies.

At Kware (Table 3 & 6), MPN values reached >4.2 in some samples, indicating heavy contamination. A similar report was made by Yahaya *et al.* (2020) in Birnin Kebbi, where high coliform loads were observed in irrigation canals receiving untreated effluents. In Wamakko (Table 4 & **7**), MPN values of up to 1.6 were recorded, consistent with the results of Suleiman *et al*. (2022), who reported that irrigation water from local streams contained unsafe levels of faecal coliforms due to nearby livestock rearing. Tambuwal samples (Table 5 & 8) also showed MPN indices ranging from 0.11 to 1.6, comparable to observations by Singh *et al.* (2021) in India, where faecal contamination in irrigation water was linked to poor sanitation and open defecation practices.

The presence of coliforms in all three locations indicates a high risk of contamination of irrigated vegetables, thereby posing health threats to consumers. This aligns with the general conclusion of Abubakar and Garba (2021), who emphasized that untreated irrigation water is a

Table 3: Presumptive coliform test results for Kware

Sample ID	Ratio			MPN Values		
	Positive tubes (Gas formation)			*(Index per gram)*		
	10:10	1:10	0.1:10	Ratio	Upper Limit	Lower Limit
A	2	2	1	0.28	0.94	0.087
B	2	2	2	0.35	0.087	0.94
C	3	3	3	>4.2	—	—

Table 4: Presumptive coliform test results for Wamakko

Sample ID	Ratio			MPN Values		
	Positive tubes (Gas formation)			*(Index per gram)*		
	10:10	1:10	0.1:10	Ratio	Upper Limit	Lower Limit
A	2	1	2	0.27	0.94	0.087
B	2	2	2	0.35	0.087	0.94
C	3	1	3	1.6	4.2	0.40

Table 5: Presumptive coliform test results for Tambuwal

Sample ID	Ratio			MPN Values		
	Positive tubes (Gas formation)			*(Index per gram)*		
	10:10	1:10	0.1:10	Ratio	Upper Limit	Lower Limit
A	1	0	2	0.11	0.38	0.036
B	2	2	1	0.28	0.94	0.087
C	3	1	3	1.6	4.2	0.40

Table 6: Presumptive coliform test results for Kware

Sample ID	BLG	EMB	Green Sheen	Probable identification
A	+	+	+	*E. coli*
E	+	+	–	*Klebsiella* spp.
B	+	+	+	*Enterobacter* spp.

Note: EMB= Eosin Methylene Blue Agar, BLG = Brilliant Green Lactose Galle, += Positive, **-** = Negative

Table 7: Presumptive coliform test results for Wamakko

Sample ID	BLG	EMB	Green Sheen	Probable identification
D	+	+	+	*E. coli*
G	+	+	–	*Klebsiella* spp.
B	+	+	+	*Enterobacter* spp.
I	-	-	-	Non coliform

Note: EMB= Eosin Methylene Blue Agar, BLG = Brilliant Green Lactose Galle, += Positive, **-** = Negative major pathway for pathogen transfer to food crops in Sokoto and other parts of Nigeria.

The confirmed test results on Eosin Methylene Blue (EMB) and MacConkey agar revealed the presence of *Escherichia coli*, *Klebsiella* spp., and *Enterobacter* spp. across Kware, Wamakko, and Tambuwal LGAs. Colonies showing a green metallic sheen on EMB, characteristic of *E. coli*, were consistently observed, and this finding corresponds with Lawal and Musa (2022), who also reported frequent *E. coli* isolation from irrigation water in Sokoto metropolis, attributing contamination to faecal seepage and poor sanitation. The presence of *Klebsiella* spp. was confirmed by pink colonies on MacConkey agar, a result similar to Abubakar and Garba (2021), who detected *Klebsiella* in irrigation water and vegetables from Wurno LGA, suggesting the persistence of this bacterium in agricultural environments. *Enterobacter* spp. were also isolated across the three LGAs, consistent with observations by Oko *et al*. (2022) in Enugu State, where *Enterobacter* was a recurrent contaminant of irrigation canals due to sewage discharge. The occurrence of non-coliforms in some Wamakko samples further indicates diverse microbial pollution, which Sharma *et al*. (2023) also described in Punjab, India, where irrigation water was contaminated with both coliforms and opportunistic pathogens from industrial effluents.

Gram staining confirmed that the isolates were predominantly Gram-negative rods, appearing pink under the microscope, which corresponds to the characteristics of coliforms. The observation of *E. coli*, *Klebsiella*, and *Enterobacter* spp. as Gram-negative bacilli agrees with Lawal *et al*. (2020), who similarly found Gram-negative enteric rods dominating irrigation water samples in Sokoto. The variations in arrangement, with some bacteria occurring in chains, pairs, or clusters, further reflect the normal morphological diversity of coliforms, which Abubakar and Garba (2021) also reported in their microscopic characterization of irrigation water isolates from Sokoto. The absence of Gram-positive bacteria in this study highlights that contamination was primarily of enteric origin, a finding consistent with Oko *et al*. (2022), who reported that Gram-negative enteric rods were the dominant contaminants of irrigation waters in southeastern Nigeria. Likewise, Sharma *et al*. (2023) in India observed similar Gram-negative predominance in irrigation canals, linking it to faecal and industrial effluent pollution.

The Gram staining results from Wamakko samples showed that all isolates were Gram-negative rods, appearing pink under the microscope and arranged mostly in pairs, clusters, and chains. This finding is typical of coliform bacteria and corresponds with earlier reports by Lawal and Musa (2022), who also documented Gram-negative rod predominance in irrigation water isolates from Sokoto metropolis, linking

Table 8: Presumptive coliform test results for Tambuwal

Sample ID	BLG	EMB	Green Sheen	Probable identification
B	+	+	+	*E. coli*
A	+	+	–	*Klebsiella* spp.
E	+	+	+	*Enterobacter* spp.

Note: EMB= Eosin Methylene Blue Agar, BLG = Brilliant Green Lactose Galle, += Positive, **-** = Negative them to faecal contamination. The presence of rod-shaped organisms with diverse arrangements further reflects the morphological diversity of enteric bacteria, a pattern that Abubakar and Garba (2021) similarly observed in water and vegetable samples from Wurno LGA.

In Tambuwal samples, most isolates were Gram-negative rods arranged in chains, pairs, and clusters, although Gram-positive cocci were also detected. The presence of cocci suggests possible contamination from skin flora or other environmental sources, which aligns with the findings of Oko *et al*. (2022) in Enugu State, where both enteric Gram-negative rods and Gram-positive cocci were recovered from irrigation canals. Additionally, the occurrence of both Gram-positive and Gram-negative rods in this study agrees with Sharma *et al*. (2023), who reported that irrigation water in Punjab, India, harboured mixed microbial populations due to inputs from sewage and agricultural runoff.

The biochemical characterisation of isolates from Kware, Wamakko, and Tambuwal confirmed the presence of *Escherichia coli*, *Klebsiella* spp., *Enterobacter* spp., *Staphylococcus* spp., and *Streptococcus* spp. The detection of *E. coli* through positive indole, citrate, and motility tests corresponds with the Gram staining and culture results, reinforcing its role as a faecal indicator organism. Similar biochemical profiles of *E. coli* have been reported in irrigation waters in Sokoto and neighbouring states (Lawal *et al*., 2020). The isolation of *Klebsiella* spp. and *Enterobacter* spp., both positive for citrate utilisation and urease, is consistent with the work of Abubakar and Garba (2021), who recovered these organisms from irrigation water and vegetables in Sokoto, suggesting widespread environmental persistence of coliforms in the region.

The identification of *Staphylococcus* and *Streptococcus* sp., characterised by catalase and coagulase reactions, indicates contamination from non-enteric sources such as human handling or animal activities near irrigation sites. This agrees with Oko *et al*. (2022), who reported similar findings in southeastern Nigeria, where both enteric and non-enteric organisms were recovered from water used for vegetable farming. The detection of mixed coliforms and non-coliforms in this study mirrors observations by Sharma *et al*. (2023) in India, where biochemical tests revealed diverse bacterial populations in irrigation canals contaminated by both sewage and agricultural effluents. Overall, the biochemical results complement the Gram staining and culture outcomes, demonstrating that irrigation waters in Kware, Wamakko, and Tambuwal are reservoirs of potentially pathogenic bacteria with both faecal and environmental origins. These might be due to attributed to poor hygiene and sanitation such as defecation, washing, bathing around the river which are common practices in the study area.

The antibiotic susceptibility test results revealed that isolates from sachet water across Kware, Wamakko, and Tambuwal exhibited varying levels of resistance and sensitivity to the antibiotics tested (Tables 9 – 11). In Kware (Table 9), *E. coli* showed resistance to ampicillin (12 mm) and tetracycline (10 mm), but was sensitive to ciprofloxacin (25 mm) and gentamicin (20 mm), while displaying an intermediate response to chloramphenicol (18 mm). This trend of resistance to ampicillin and tetracycline by *E. coli* has been widely reported in Nigeria, with Okeke *et al*. (2021) noting similar patterns in

Table 9: Antibiotic sensitivity pattern of Bacteria spp. from Kware (Zone of inhibition in mm)

Bacteria spp.	AMP (10 µg)	CIP (5 µg)	GEN (10 µg)	TET (30 µg)	CHL (30 µg)
E. coli	12 (R)	25 (S)	20 (S)	10 (R)	18 (I)
Staphylococcus sp.	15 (I)	23 (S)	22 (S)	14 (R)	19 (S)
Salmonella sp.	10 (R)	26 (S)	21 (S)	12 (R)	17 (I)

Interpretation: R = Resistant, S = Sensitive, I = Intermediate

Table 10: Antibiotic sensitivity pattern of Bacteria spp. from Wamakko (Zone of inhibition in mm)

Bacteria spp.	AMP (10 µg)	CIP (5 µg)	GEN (10 µg)	TET (30 µg)	CHL (30 µg)
Streptococcus sp.	12 (R)	25 (S)	20 (S)	10 (R)	18 (I)
Staphylococcus sp.	15 (I)	23 (S)	22 (S)	14 (R)	19 (S)
E. coli	12 (R)	25 (S)	20 (S)	10 (R)	18 (I)
Enterobacter spp.	18 (S)	16 (R)	10 (I)	12 (R)	7 (I)
Salmonella sp.	10 (R)	26 (S)	21 (S)	12 (R)	17 (I)

Interpretation: R = Resistant, S = Sensitive, I = Intermediate

Table 11: Antibiotic sensitivity pattern of Bacteria spp. from Tambuwal (Zone of inhibition in mm)

Bacteria spp.	AMP (10 µg)	CIP (5 µg)	GEN (10 µg)	TET (30 µg)	CHL (30 µg)
Klebsiella sp.	19 (R)	20 (S)	10 (S)	15 (R)	18 (I)
Staphylococcus sp.	15 (I)	23 (S)	21 (S)	17 (R)	19 (S)
E. coli	19 (R)	25 (S)	20 (S)	10 (R)	18 (I)
Enterobacter spp.	17 (S)	16 (R)	20 (I)	12 (R)	9 (I)
Salmonella sp.	10 (R)	26 (S)	21 (S)	18 (R)	16 (I)

Interpretation: R = Resistant, S = Sensitive, I = Intermediate

environmental isolates, attributing the resistance to the overuse of these antibiotics in both human and veterinary medicine. The sensitivity to ciprofloxacin and gentamicin is in agreement with findings by Yusuf *et al*. (2023), who reported these antibiotics as the most effective against *E. coli* from drinking water sources.

Staphylococcus spp. from Kware demonstrated intermediate resistance to ampicillin (15 mm), sensitivity to ciprofloxacin (23 mm), gentamicin (22 mm), and chloramphenicol (19 mm), but resistance to tetracycline (14 mm). A comparable observation was made by Olanrewaju *et al*. (2022), who found that *Staphylococcus* spp. isolated from sachet water were consistently resistant to tetracycline but susceptible to ciprofloxacin and gentamicin, reinforcing the persistence of these resistance trends in local water supplies. Similarly, *Salmonella* spp. in Kware was resistant to ampicillin and tetracycline yet sensitive to ciprofloxacin (26 mm) and gentamicin (21 mm), reflecting findings by Adeyemi *et al*. (2022), who documented resistance to first-line antibiotics in *Salmonella* isolates from food and water in southwestern Nigeria.

In Wamakko (Table 10), *Streptococcus* spp. isolates showed resistance to ampicillin (12 mm) and tetracycline (10 mm), but sensitivity to ciprofloxacin (25 mm) and gentamicin (20 mm), with intermediate resistance to chloramphenicol (18 mm). This agrees with the findings of Shittu and Bello (2020), who observed a similar sensitivity profile of *Streptococcus* spp. in contaminated wells, where ciprofloxacin remained the most effective drug. *Staphylococcus* spp. in Wamakko followed the same trend as in Kware, being resistant to tetracycline but sensitive to ciprofloxacin and gentamicin, a trend echoed by Adeyemo *et al*. (2021) in their study of sachet water in Lagos.

Interestingly, *Enterobacter* spp. in Wamakko displayed sensitivity to ampicillin (18 mm) but resistance to ciprofloxacin (16 mm), alongside intermediate resistance to gentamicin (10 mm) and chloramphenicol (7 mm). This pattern indicates emerging multidrug resistance, a finding consistent with Olanrewaju *et al*. (2022), who also reported ciprofloxacin-resistant *Enterobacter* spp. in sachet water samples from Sokoto, suggesting possible horizontal gene transfer of resistance traits in environmental settings. *E. coli* and *Salmonella* spp. in Wamakko mirrored the resistance profiles observed in Kware, strengthening the evidence of widespread resistance to older antibiotics across the region.

Tambuwal (Table 11) isolates revealed similar resistance dynamics. *Klebsiella* spp. was resistant to ampicillin (19 mm) and tetracycline (15 mm), but sensitive to ciprofloxacin (20 mm) and gentamicin (10 mm), with intermediate sensitivity to chloramphenicol (18 mm). These results are in line with the findings of Nworie *et al*. (2021), who observed multidrug resistance in *Klebsiella* spp. isolated from drinking water, where ciprofloxacin remained one of the few effective drugs. *Staphylococcus* spp. and *E. coli* isolates from Tambuwal also exhibited resistance to ampicillin and tetracycline, but sensitivity to ciprofloxacin and gentamicin, a pattern consistent with national surveillance reports on antimicrobial resistance in environmental samples (Yusuf *et al*., 2023). Moreover, *Enterobacter* spp. from Tambuwal showed resistance to ciprofloxacin (16 mm) and tetracycline (12 mm), while expressing intermediate resistance to gentamicin (20 mm) and chloramphenicol (9 mm).

This multidrug resistance reflects the trends seen in Wamakko and corresponds with global concerns highlighted by WHO (2022), which noted that *Enterobacter* spp. is increasingly recognised as an emerging multidrug-resistant pathogen in low-resource settings. *Salmonella* spp. from Tambuwal was also resistant to ampicillin and tetracycline, but sensitive to ciprofloxacin (26 mm) and gentamicin (21 mm), echoing reports by Adeyemi *et al*. (2022) that ciprofloxacin remains effective against *Salmonella* spp. despite the widespread resistance to other drugs.

4. Conclusion

Water sources for irrigation farming in this study contained high level of bacterial pathogens which are indicators of feacal contamination mostly *E. coli* and *Klebsiella* which indicate serious health threat, unsuitable for agricultural use. Government should conduct surveillance and regular monitoring of these water bodies in order to provide good quality and microbiologically safe water for this purpose, farmers and riverine communities should be encourage to practice sanitation mostly open defecation to ensure human health and protect against widespread of waterborne illnesses.

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From joblessness to Agribusiness: Youth awareness and participation in grass-cutter (*Thryonomys swinderianus*) farming in Ondo State, Nigeria

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ABSTRACT

This study assessed the awareness and participation of young people in grasscutter (*Thryonomys swinderianus*) farming as a means of addressing unemployment in Ondo State, Nigeria. The specific objectives included: determining awareness levels, identifying factors influencing participation, and analyzing employment challenges. A multistage sampling technique was used to select 206 respondents; data were analyzed with descriptive statistics and logistic regression. Results showed that, although 69.9% had heard of grasscutter farming, only 26.7% had received formal training, indicating a large awareness-practice gap. Major challenges reported included lack of capital (53.9%) and inadequate skills (25.7%). Remarkably, only 0.5% cited limited access to loans as a constraint, while 19.9% identified lack of opportunities. Logistic regression analysis revealed that youths earning over ₦50,000 monthly were 3.12 times more likely to participate in grasscutter farming than those earning below ₦20,000 ($p < 0.05$). Also, respondents aged 18–30 were significantly more likely to partake than older counterparts (Odds Ratio = 2.78, $p < 0.05$). Surprisingly, respondents without farmland were twice likely to engage in grasscutter farming than those with access to land (Odds Ratio = 2.04, $p < 0.05$), signifying flexibility in rearing systems .These findings emphasize the need for specific solutions, particularly access to capital, vocational training, and awareness, to promote youth engagement in alternative agribusiness ventures and reduce unemployment.

KEY WORDS: *Joblessness*; *Agribusiness*; *Grass-cutter*; *Youth*; *Awareness*

1. Introduction

The youth population is universally recognized as the strength for nation growth, development, and socio-economic change (Omarova *et al*., 2024). Young people are known by their energy, originality, flexibility, and potential for innovation, all of which are essential for productivity and economic advancement (Khan *et al*., 2024). Globally, over 1.2 billion people, or 16% of the world's population, are between the ages of 15 and 24 (Herrmann, 2022). In Sub-Saharan Africa, the youth sector is noticeable, with projections estimating that by 2030, 42% of the world's youth will reside in Africa (Cieslik *et al*., 2022). This youth bulge, if well harnessed, can offer a distinctive demographic dividend capable of forcing continuous economic growth and

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poverty decrease. In Nigeria, the youth population is not simply large but growing fast. According to the National Population Commission (NPC, 2019**)**, over 60% of the Nation's population is below 30**,** with persons aged 15–35 constituting almost 35% of the populace, amounting to well over 70 million people. This statistics sets youth at the center of Nigeria's present and future development agenda. However, getting to achieve this prospect is reliant on the nation's ability to provide suitable chances for education, skills development, and gainful employment.

In spite of Nigeria's abundant human and natural resources, the country continues to struggle with high levels of youth unemployment and underemployment, which impend its socio-economic progress, intensifying poverty, insecurity, rural-urban migration, and societal lack of expectations. Mishi *et al*. (2022) point out that youth unemployment was as high as 42.5%, with an additional 21% of young people underemployed, showing a dire need for workable and comprehensive livelihood possibilities. This problem is more prominent in rural and semi-urban areas, where restricted access to formal employment, poor infrastructure, and declining public sector job availability have left many young people economically vulnerable.

In recent years, the scope of agricultural enterprise has extended beyond traditional crop farming to include more advanced and scalable agribusinesses (Kansiime *et al.*, 2025). These include aquaculture, poultry farming, rabbit rearing, and increasingly, grass-cutter (*Thryonomys swinderianus*) farming, also known as cane rat production. Grass-cutter farming, specifically, has gained attention for its low start-up costs, fast reproductive cycle, minimal space requirements, and high market demand for its meat, which is thought of as a delicacy in many parts of West Africa (Ayariga, 2022). Grass-cutter meat, is mostly cherished for its high protein content, usually between 19% and 22%, making it an exceptional source of essential amino acids desirable for body growth, tissue repair, and immune function. Besides its protein richness, grass-cutter meat is low in fat and cholesterol, which makes it a healthier substitute to red meats such as beef and pork, mainly for individuals worried about heart condition (Asuquo *et al.*, 2024). Additionally, grass-cutter meat is rich in vital micronutrients such as iron, zinc, phosphorus, and B vitamins (especially B12 and niacin), which are needed for metabolic processes, red blood cell formation, and energy production. Its fine muscle fiber configuration also makes it easily digestible, suitable for all age groups including children and the elderly. Unlike pork or beef, grass-cutter meat faces no major religious or cultural restrictions, making it widely acceptable and marketable across different communities in Nigeria. These nutritional benefits place grass-cutter meat as not only a healthful food source but also a strategic element in addressing undernourishment and encouraging food security, especially in low-income and rural populations.

Historic records trace the domestication and commercialization of grass-cutters in West Africa to the 1980s, when research institutions such as the Centre Suisse de Recherches Scientifiques (CSRS) in Côte d'Ivoireand Nigeria's Institute of Agricultural Research and Training (IAR&T), Ibadan, began developing breeding methods and promoting grass-cutter farming as a source of income and protein (Obaniyi, 2022). In Nigeria, the potential for grass-cutter farming as a tool for youth empowerment is significant yet underutilized. Over 80% of meat consumption in sub-Saharan Africa is derived from small livestock and bush meat, with grass-cutters accounting for a growing share due to their perceived health benefits and taste (Kumar *et al.*, 2023). However, youth participation in this sub-sector remains low, often due to reasons such as lack of awareness, cultural perceptions, limited access to finance and training, and weak policy support.

This calls for direct research into the drivers and obstacles of youth engagement in grass-cutter farming. By evaluating the awareness levels, attitudes, and participation of young people toward grass-cutter production, governments, development organizations, and agricultural investors can support the interests and realities of the youth population group, to this end the following specific objectives were assessed in this study, to access the level of awareness among youth; to determine the factors influencing youth participation in grass cutter farming; and to identify the challenges faced by youth in their efforts to become employed.

2. Material and Methods

2.1 Study population and sampling techniques

The population of this study is comprised of youths in Ondo State, Nigeria. A multi-stage sampling technique was used for this study, giving rise to a total sampling size of two hundred and six (206) respondents.

2.2 Source of data

Data for this study was collected through the use of a well-structured questionnaire.

2.3 Data analytical techniques

The technique used for data analysis include: Descriptive statistics such as frequency counts, percentages, mean, inferential statistical tool such as Logistic Regression.

3. Results and Discussion

3.1 Respondents' level of awareness of Grass-cutter farming in the study area

The findings reveal a multi-dimensional understanding of youth awareness of grasscutter farming in the study area. As shown in Fig. 1, 69.9% of respondents specified they had heard about grass cutter farming, suggesting a relatively high level of general awareness. This general recognition shows that grasscutter farming is not an unfamiliar concept among youth, aligning with Akinbile *et al*. (2022) who noted growing public knowledge of non-conventional livestock enterprises in Nigeria. However, awareness alone does not equate to detailed understanding or active participation.

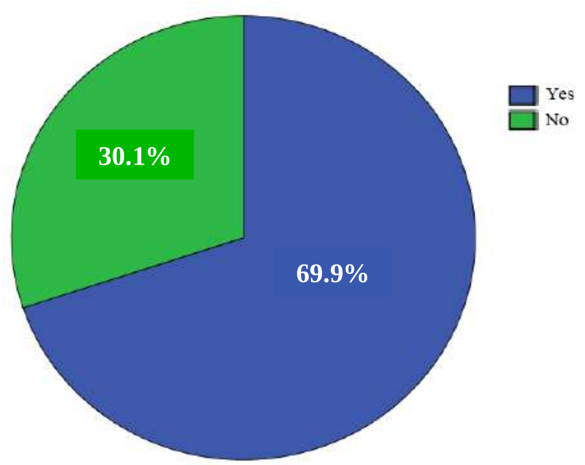

Fig. 1: Proportion of youth that have heard about grasscutter farming

As Fig. 2 illustrates, only 14.6% of respondents stated being very familiar with the practice, while 46.6% were somewhat familiar and 38.8% not familiar at all. This point to a critical gap between nominal awareness and experiential or technical familiarity. The effect is that although the enterprise is known, many young people lack sufficient exposure, training, or mentorship to confidently engage in it. This observation supports the findings of Olagunju *et al.*, (2021) who underscored the need for youth-focused agricultural extension services to extend familiarity with non-traditional livestock practices. Likewise, awareness of grasscutter farming as a viable livelihood option appears to be cautiously optimistic.

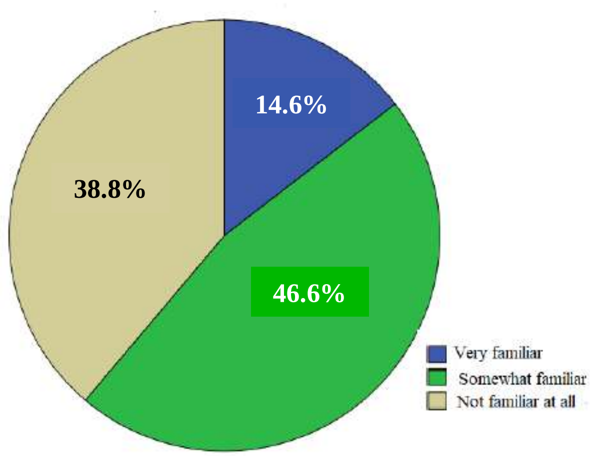

Fig. 2: Proportion of youth that are familiar with grasscutter farming

As presented in Fig. 3, 55.5% of respondents view grasscutter farming as a potential source of self-employment, while 29.0% are uncertain and 15.5% disagree with its viability. The inference here is twofold: even though majority recognizes its employment potential, a major proportion remains uncertain, likely due to poor visibility of successful models, lack of peer engagement, or perceived socio-cultural shame. This inconsistency is in line with Boye *et al.* (2024), who stated that youth awareness of agricultural ventures are often shaped by insufficient role models and inadequate policy support. The limited exposure to capacity-building opportunities further strengthens this indecision.

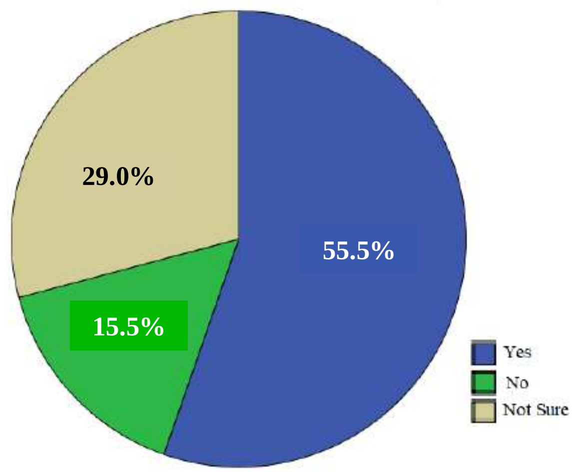

Fig. 3: Proportion of youth that view grasscutter farming as a potential source of employment

As shown in Fig. 4, only 26.7% of respondents had received any form of training in grasscutter farming, revealing a substantial gap in practical and technical knowledge. This lack of training directly hinders youths' ability to shift from passive awareness to active engagement. It authenticates the conclusions of Nwachukwu *et al*. (2020), who argued that agripreneurship uptake among youth is conditional on targeted training programmes, especially in niche areas like small livestock farming.

When asked about the profitability of grasscutter farming, 52.9% of respondents admitted its economic potential (Fig. 5). This hopefulness, despite low participation and training levels, mirrors a dormant entrepreneurial interest that can be harnessed through tactical planning. The implication is that youths may be willing to explore grasscutter farming if given adequate incentives, mentorship, and infrastructural support. These findings corroborate the work of Giwu and Mdoda, (2024), who identified profitability perception as a strong motivational factor in youth agribusiness decisions.

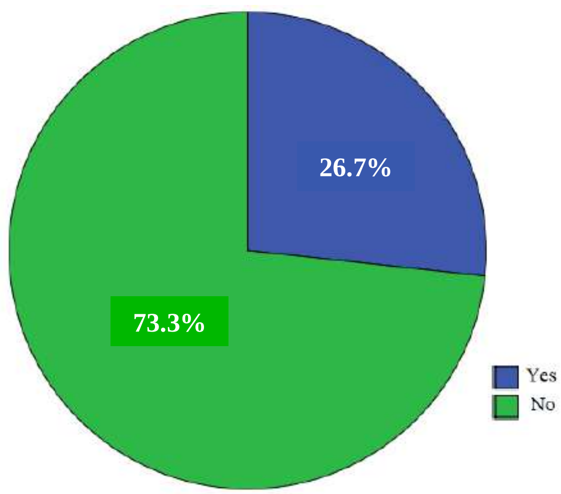

Fig. 4: Proportion of youths who received training on grasscutter farming

3.2 Factors influencing respondents' participation in grass-cutter farming

Table 1 presents the results of a binary logistic regression model employed to examine the socio-economic determinants of youth participation in grasscutter farming. The dependent variable, youth participation (Yes = 1, No = 0), was regressed on a range of predictors including sex, marital status, age group, education level, employment status, income level, household size, source of income, access to farmland, access to loans, and current agricultural involvement.

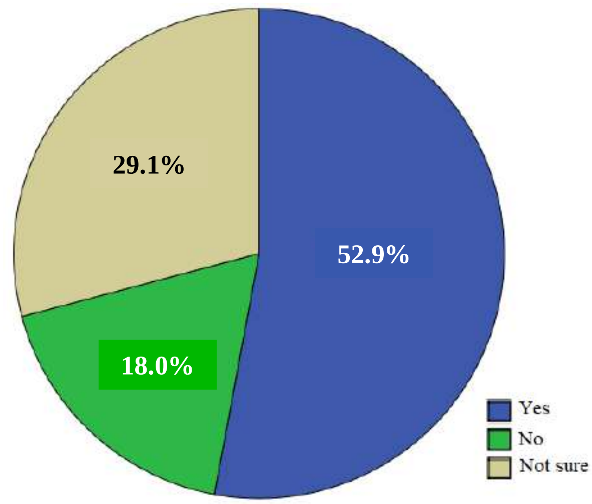

Fig. 5: Youths level of awareness regarding profitability of grasscutter faming

The results reveal that age is a statistically significant factor influencing youth engagement in grasscutter farming. Youths aged 18-25 years (B = 1.245, Exp(B) = 3.472, p = 0.022) and 26–30 years (B = 2.241, Exp(B) = 9.400, p = 0.005) are considered more likely to participate in grasscutter farming related to those above 40 years. This suggests that younger individuals are more willing to discover innovative agricultural ventures, possibly due to higher adaptability and fewer socio-economic commitments. These outcomes are consistent with Mensah *et al.*, (2024), who found that younger folks reveal better ingenuousness to small-scale livestock production, including grasscutter rearing, due to its low startup capital and quicker returns.

Income level also significantly impacts participation. Respondents grossing less than ₦20,000 monthly (B = -1.241, Exp (B) = 0.289, p = 0.030) were considerably less likely to engage in grasscutter farming compared to those earning above ₦100,000. This indicates that very low-

Table 1: Binary logistics model for association between various characteristics and youth participation

Characteristics	B	S.E.	Sig. (P-Value)	Exp (B)
Age group				
18-25 Years	1.245	0.543	0.022*	3.472
26-30 Years	2.241	.799	0.005*	9.400
Income				
Below ₦20,000	-1.241	0.573	0.030*	0.289
Access to Farmland				
No	0.738	0.458	0.007*	2.091
Access to Loan				
No	0.548	0.475	0.042*	1.730

*Significant at the 5% level ($p < 0.05$)

Source: Field Survey, (2025)

income youths may perceive even small-scale ventures like grasscutter farming as economically unsafe or unfeasible. This aligns with Nwachukwu *et al.* (2020), who stressed that monetary limitations are a major constraint to agribusiness entry among rural youth. Although income categories between ₦20,000 - ₦100,000 were not statistically significant, the negative direction of the coefficients suggests a steady pattern where increasing income supports a greater probability of participation.

Interestingly, access to farmland was positively and significantly associated with participation (B = 0.738, Exp (B) = 2.091, p = 0.007), demonstrating that youths without farmland access are twice as likely to involve in grasscutter farming matched to those with farmland. This is reasonable because grasscutter farming requires fairly less space and can be accompanied in backyard setups, making it more attractive to land-constrained individuals. This finding supports the study by Abdulai *et al*., (2023), who highlighted the suitability of micro-livestock farming for urban and peri-urban youth with limited land resources.

Similarly, access to loans demonstrated a statistically significant influence (B = 0.548, Exp (B) = 1.730, p = 0.042), with youths without access to loans being more likely to participate. This counter intuitive result may suggest that some youth adopt grasscutter farming precisely because it is one of the few agricultural enterprises that can be started with little or no external financing. This partially supports the assertion of Kadzamira *et al*., (2024) that youth often engage in low-capital agribusinesses due to the inaccessibility of formal credit systems. Overall, the model emphasizes that younger age, moderate income, lack of access to farmland, and absence of formal credit are important predictors of youth engagement in grasscutter farming.

3.3 Challenges faced by respondents in their efforts to become employed

Fig. 6 presents the main difficulties faced by youth in the study area to secure employment. The most commonly cited challenge was lack of capital, reported by 111 out of 206 respondents (53.9%). This highlights the critical role of financial constraints as a principal barrier to youth employment and self-employment. The consequence is that many young people are unable to start businesses or pursue income-generating activities due to insufficient funds. This is consistent with findings by Omolawal and Adeniyi (2024), who described that limited access to credit and start-up capital significantly impedes youth entrepreneurship in Nigeria. Without adequate financial resources, many viable business ideas remain unrealized, and the transition from unemployment to self-employment becomes highly constrained. The second most reported challenge was lack of skills, mentioned by 53 respondents (25.7%). This implies that a significant portion of the youth lacks the technical expertise, vocational training, and entrepreneurial competencies needed to thrive in today's labour market. This supports the study by Pater *et al*. (2022), which point to a mismatch between the skills youth possess and the demands of the labour market. It also underlines the need for more directed, practical, and youth-accessible training programme to close this gap.

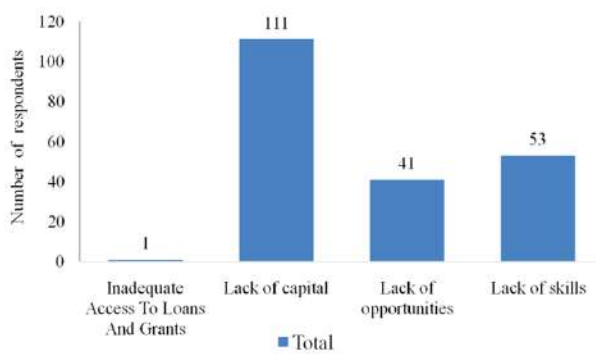

Fig. 6: Challenges faced by respondents in becoming employed

In addition, lack of opportunities was reported by 41 respondents (19.9%), replicating a bigger fundamental problem in the labour market. This discovery suggests that even when youth have the motivation and in some cases the skills, they often find it difficult to access job openings or entrepreneurial paths due to limited formal employment, poor infrastructure, or inadequate support systems. This observation is supported by Olubusoye *et al*. (2023), who note that structural unemployment, caused by a scarcity of suitable employment options, is a persistent issue affecting Nigerian youth. Remarkably, inadequate access to loans and grants was identified by only 1 respondent (0.5%). This may seem counterintuitive, considering the prominence of financial barriers. However, this finding could specify that many youth are either unaware of such opportunities, perceive them as inaccessible due to complex application procedures, or doubt formal financial institutions. It may also reveal low exposure to formal funding schemes, particularly in rural areas. Badejo *et al*. (2024) similarly found that many Nigerian youths prefer informal financing options or rely on family networks due to perceived inefficiencies in formal support systems.

4. Conclusion

This study offers vital understandings into the factors influencing youth awareness and participation in grasscutter farming. The findings are in line with and, in some cases, deviate from existing literature, presenting both confirmations of accepted information and fresh viewpoints specific to the Ondo State, Nigeria. One of the most significant findings is the dominance of financial constraints, particularly lack of capital, as the leading barrier to youth employment, cited by over half of the respondents (53.9%). In contrast, inadequate access to loans and grants, which received minimal acknowledgment (0.5%)

in this study, appears to deviate from earlier findings of Abudu *et al*. (2023) who reported that difficulty accessing credit facilities was a key hindrance for youth farmers in Edo State, Nigeria. This discrepancy could reflect regional differences in the availability or awareness of institutional financial programs, or it may suggest a preference among youths for informal funding mechanisms such as personal savings or family support, rather than formal loans.

Another prominent challenge identified was the lack of relevant skills, reported by 25.7% of respondents. With regard to awareness of grass cutter farming, the study revealed that while 69.9% of youth had heard of it, many lacked sufficient technical knowledge or exposure. This pattern reflects earlier findings by Ibrahim *et al*. (2021), who noted that while awareness of agricultural innovations may be relatively high, actual adoption and practice remain low due to inadequate training and support. Furthermore, the finding that younger respondents were more likely to be aware of grasscutter farming supports Mount's, (2021) conclusion that younger demographics are generally more open to non-traditional and emerging agribusiness opportunities.

The logistic regression analysis further strengthens the evidence by identifying age, income, land access, and access to loans as significant predictors of youth participation in economic ventures. Specifically, respondents aged 18 - 30 were significantly more likely to participate than those above 40, highlighting the potential of young adults as a key target group for agribusiness interventions. The influence of income level was particularly striking: those earning below ₦20,000 monthly were significantly less likely to participate, a finding consistent with Oyekale (2019), who found that financial stability strongly predicts youth engagement in productive enterprises.

Interestingly, the study found that youths without access to farmland were more than twice likely to participate in economic activity than those with land, which contradicts traditional assumptions. This finding diverges from studies like Wegerif and Guerena (2020), who emphasized land access as a critical driver of agricultural involvement. One possible explanation could be the emergence of alternative models such as urban farming, cooperative land sharing, or cage-based systems that reduce reliance on large physical spaces, allowing motivated youth to engage in farming activities even without land ownership.

In light of the study's findings, the following recommendations are proposed to address the key challenges identified and enhance youth participation in agribusiness initiatives such as grass cutter farming: Government agencies and non-governmental organizations should design and implement low-interest loan schemes and grant programmes specifically targeted at youth. These financial interventions will help to bridge the capital gap that has been identified as a major barrier to youth employment. Microfinance institutions should develop youth-focused loan products that support entry into small-scale agricultural enterprises, including grass cutter farming. These products should be accessible, flexible, and tailored to the realities of young entrepreneurs.

Agricultural extension services should be strengthened and expanded to deliver practical, field-based training on modern livestock rearing techniques, with a specific focus on small livestock enterprises such as grass cutter farming. Vocational training centers, polytechnics, and youth empowerment programmes should incorporate modules on non-conventional agribusiness ventures into their curricula, ensuring that young people are equipped with both the knowledge and the confidence to pursue these paths.

Strategic awareness campaigns should be organized through public-private partnerships to inform youths about the economic potential and sustainability of grass cutter farming and similar ventures. Media outreach, community workshops, and digital platforms can be used to expand reach and engagement. Peer learning and mentorship programmes should be established, highlighting successful youth entrepreneurs in the sector as ambassadors. These role models can serve to demystify the enterprise and inspire others to follow suit.

The Ondo State Ministry of Agriculture and other relevant agencies should formally integrate grass cutter farming into their youth development and agricultural empowerment policies. This will institutionalize support and provide a framework for program delivery. Policy incentives should be introduced to encourage private sector investment in youth agribusiness training and financial support. Such incentives could include tax breaks, public recognition, or access to government-backed credit facilities.

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Adoption of Cassava processing technologies among rural women of Kogi State, Nigeria

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ABSTRACT

This study explores the adoption of cassava processing technologies among rural women in Kogi State, Nigeria, a region recognized as one of the country's leading cassava producers. It addresses critical challenges including low productivity, post-harvest losses, and gender-based disparities in technology access. Primary data were collected from 140 respondents across four agricultural zones to examine their socio-economic characteristics, adoption levels, perceived benefits, influencing factors, and constraints to adoption. Findings indicate that 90% of respondents possess formal education, while 66.4% access credit primarily through informal sources such as family and friends. High adoption rates were recorded for technologies such as mechanical peelers, automatic fryers, and starch extractors (100%), whereas the adoption of bagging machines was the lowest (51.4%). The most influential factors driving adoption included observability (mean = 3.34), cost-effectiveness (mean = 3.33), and relative advantage (mean = 3.17). Perceived benefits of these technologies include improved energy efficiency, enhanced product quality, and opportunities for product diversification. However, adoption is hindered by constraints such as inadequate training, high labour requirements, limited institutional support, and insufficient storage infrastructure. The study concludes that although the adoption level is relatively high, addressing these challenges is essential for sustained technology use. It recommends targeted training programs, expanded extension services, improved access to financing, investment in storage facilities, and the establishment of cooperative support networks to enhance the adoption and long-term sustainability of cassava processing technologies among rural women.

KEY WORDS: *Cassava*; *Women*; *Processing*; *Technologies*; *Rural*; *Kogi state*

1. Introduction

The main objective of using technology in agriculture is to boost yield, achieve higher efficacy and increase profitability. As a result, to reduce food and nutritional insecurity, a problem within our society at this time, smallholder farmers have to embrace advanced agricultural technologies to raise productivity of food crops (Sennuga *et al*., 2022). The creation of agriculture comes from the fusion of technological progress into the domains of agricultural production, storage, and processing, to increase efficiency. Cassava production and processing have benefited from upgraded technologies that include using improved varieties along with fertilizers, new

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tillage procedures, mechanization, herbicides and pesticides as well as proper spacing, motorized graters, motorized flakers and mechanical sifters. Enhancing farm productivity, which intrinsically raises farmers' income and alleviates poverty, is possible only through the adoption of these advanced technologies (Jegede *et al*., 2021).

Cassava (*Manihot esculenta*), a South American plant grown predominantly for its roots and is an important carbohydrate source for several Nigerian and developing country households (Osuafor *et al*., 2020; Amadi and Solomon, 2020). Research indicates that Nigeria stands as the top producer of cassava in West Africa. About 63 million tons of cassava (FAO, 2023) makes Nigeria the world's top producer (26% of the total global output). The volume of this item is greater than yam, sorghum, and rice, while more than 75 percent of the world's poor live in countryside areas, yet both resources and policies prioritize urban growth. A great deal of the rural community is dependent, both directly and indirectly, on small-scale food production and processing. (World Bank, 2020). The various methods for changing cassava roots into varied products are directed by local cultural and personal preferences. The poor storage qualities of cassava and the requirement to minimize or eliminate the toxic compound that render it unconsumable have made processing an important part of its use. Because of the losses incurred during processing, along with the high labor requirements, traditional methods of cassava processing are not very efficient. The problems remain primarily because there are inadequate post-harvest facilities. It has had a longstanding tendency to demonstrate that the process toward embracing new technology practices happens gradually.

Nigerian women play a pivotal role in addressing several bottlenecks within smallholder farming systems, particularly in activities such as weeding, harvesting, processing, and storage (Awoyemi *et al*., 2020). In the case of cassava, rural women are responsible for nearly all processing operations, and the introduction of improved processing technologies has significantly enhanced their efficiency. These evolved technologies not only streamline the processing stages but also reduce energy demands and improve sanitary conditions, thereby contributing to better-quality outputs. Against this background, the present study was designed to achieve several specific objectives: to describe the socio-economic characteristics influencing the adoption of cassava processing technologies among rural women in the study area; to determine the level of adoption of these technologies; to examine the factors affecting their adoption; to assess the perceived effects of technology adoption on cassava processing; and to identify the constraints limiting the effective utilization of cassava processing technologies among rural women.

2. Material and Methods

The study was carried out in Kogi State, which is in Nigeria. This state occupies a geographical size of 2774,747 sq km and has a population of 3,595,789 according to the NPC census in 2006 but is projected at 5,685,864 million as at 2022 according to the NBS. About 172000 farm families are indicated within the state, with 70% of this population in the rural areas and involved more or less in crop farming and animal husbandry (Kogi State Government, 2023). Kogi State lies in the north-central part of Nigeria, on geographical coordinates of 7° 49' N latitude and 6° 45' E longitude. Most areas of Nigeria are a young sedimentary zone of Pleistocene to Recent and alluvial fan plain of the River Niger offer excellent soil for agricultural activities. Among the climatic factors there is average maximum temperature that makes 33.2 °C and the average minimum temperature is 22.8 °C.

This research adopted the multistage sampling method because Kogi State has four agricultural zones, namely zones A, B, C and D. The first phase (Phase I) consisted of an exploratory, non-probability sampling technique that entails the selection of one Local Government Area (LGA) per agricultural zone. Three towns/villages at random from each of the four LGAs, to give the study a total sample of 12 towns/villages. In detail, these areas were Jege village and Aiyede village, and Ife-Olukotun village from Yagba East LGA; Anyigba town and Abocho village, and Achigili village from Dekina LGA; Sarkin-Noma town and Agbaja village, and Lokon-goma from Lokoja LGA; and Ochadamu town, Ejule town, and Alloma village. A total of 140 rural women were selected as respondents for the study. Data were collected from primary sources using a well-structured questionnaire. Data were analyzed using descriptive statistics such as frequencies, percentages, mean scores, probit regression model and Kendall's coefficient of concordance.

3. Results and Discussion

3.1 Socio-economic characteristics

Age of the respondents: The results in Table 1 show that the majority (47.9%) of rural women were within the age bracket of 31–40 years, with an average age of 35 years. This implies that the rural women were in their middle and productive years, actively contributing to the processing and production of cassava products. At this age, they can still understand, adopt and use new technologies for all aspects of processing and production. This supports the findings of Ogonna *et al*., (2020), which stated that processors within this age range can still adopt new innovative technology in the cassava processing industry.

Marital status of the respondents: The marital status data in Table 1 shows that the majority (67.9%) of the women were married. This implies that most of the cassava processors were responsible for managing a household and meeting the needs of their families. As a result, they may be more inclined to adopt new technologies to generate additional revenue and increase productivity to meet household demands. This supports the findings of Falola *et al*. (2022), which noted that 73.3% of women involved in cassava processing were married, as married women typically prioritize the well-being of their families.

Processing experience: Table 1 reveals that the majority of the women (63.6%) had between 6 to 10 years of cassava processing experience, with an average of 7 years. This suggests that most respondents had a relatively solid level of experience. However, this finding contrasts with the results of Falola *et al*. (2022), which reported that most cassava processors (52.5%) had between 10 and 20 years of experience.

Access to credit facility: Access to credit helps rural women acquire new and improved tools and equipment for cassava processing. Table 1 shows that 66.4% of respondents had access to credit facilities, with an average sum of ₦18,107.14, while the remaining 33.6% did not, relying on personal savings to fund their activities. This finding contradicts Ibitunde *et al*. (2021), which reported that the majority (71.7%) had no access to credit, limiting their ability to afford new technologies and potentially hindering their adoption of these innovations.

Table 1: Socio-economic characteristics of the rural women

Variables	Frequency (140)	Percentage (%)	Mean
Age (years)			
<20 years	15	10.7	35 years
21- 30 years	27	19.3	
31 - 40 years	67	47.9	
41 - 50 years	28	20.0	
50 years and below	16	7.2	
Marital status			
Married	95	67.9	
Single	25	17.9	
Divorced	8	5.7	
Widowed	12	8.6	
Cassava processing experience			
1 -5 years	34	24.3	7 years
6 - 10 years	89	63.6	
11 - 15 years	17	12.1	
Amount received			
No credit	47	33.6	18,107.14
1 – 20,000	3	3.6	
20,001–40,000	85	60.7	
Above 40,000	3	2.1	

Source: field survey, 2024

3.2 Level of adoption of cassava processing technologies

The respondents were asked to indicate their use of various cassava processing technologies by checking the appropriate boxes. The data revealed (Table 2) that mechanical peelers (100%), automatic fryers (100%), and starch extraction equipment recorded the highest adoption rates among rural women. These findings indicate a widespread integration of these technologies into cassava processing activities. Notably, this contrasts with the findings of Awoyemi *et al.* (2020), who reported minimal adoption of similar technologies at the usage level, highlighting possible regional differences, recent improvements in access, or evolving perceptions of technology usefulness among women processors.

However, flash dryers followed closely, with 98.6% of respondents adopting this technology. This indicates that flash dryers also have significant impact and relevance due to their advantages, including rapid drying, energy efficiency, and improved product quality (Ogbonna *et al*., 2022). This study contradicts the research by Jegede *et al*. (2021), which claimed that the usage and adoption of flash dryer technology were low. The bagging machine is another cassava processing technology among rural women. However, the findings from this research revealed that this technology had a lower level of adoption and usage (51.4%). The low adoption level could be attributed to poor extension education, lack of awareness, and the high cost of the technology. This aligns with the findings of Awoyemi *et al*. (2022), which also reported a very low adoption level of this technology.

3.3 The factors influencing the level of adoption of cassava processing technologies among rural women

The probit regression model was used to analyze the factors affecting the adoption of cassava processing technologies among rural women in the study area. Table 3, shows a Pseudo R^2 value

Table 2: Adopted technologies of cassava processing

Processing technologies	Frequency (140)	percentage	Rank
Mechanical peelers	140	100.0	1st
Automatic garri fryers	140	100.0	1st
Starch extraction machines	140	100.0	1sts
Flash dryers	138	98.6	4th
Hammer mills (for flour)	136	97.1	5th
Cassava washing machine	135	96.4	6th
Mechanical sifters	128	91.4	7th
Cassava slicers	121	86.4	8th
Drying racks	119	85.0	9th
Fermentation tanks	108	77.1	10th
Batch mixers	106	75.7	11th
Hydraulic pressers (for dewatering)	102	72.9	12th
Sorting machines (stalk remover)	96	68.6	13th
Mechanical graters (motorized)	93	66.4	14th
Fermentation racks	91	65.0	15th
Bagging machines	72	51.4	16th

Source: Field work, 2024

of 0.4640, indicating that 46% of the variation in technology adoption (the dependent variable) was explained by the independent variables. The LR chi² value of 88.13, significant at the 1% level (p = 0.0000), suggests that the model accurately predicts the relationship between the dependent variable and its influencing factors.

Eleven variables were proposed to influence the adoption of improved cassava processing technologies. Of these, six were found to be statistically significant: processing experience, level of education, cost of technology, income, complexity of technology, and extension contact.

Processing experience had a positive coefficient (0.0515) and was significant at the 1% level. This means that the more experience women had in cassava processing, the more likely they were to adopt new technologies. This finding aligns with Vihi *et al*., (2022), who also found a positive relationship between processing experience and adoption. Level of education also had a positive coefficient (0.7947973) and was significant at the 5% level. This suggests that higher levels of education increase the likelihood of adopting improved technologies, as education enhances literacy and exposure. This finding is supported by Uchemba *et al.* (2021), who similarly observed a positive impact of education on technology adoption.

Cost of technology had a negative coefficient (-1.0169) and was significant at the 1% level. This indicates that the high cost of the technology discourages adoption. Awoyemi *et al*. (2022) also found that high costs were a major barrier to the adoption of improved processing tools. Annual income had a negative coefficient (-0.2941721) and was significant at the 1% level, indicating that women with lower income were less likely to adopt the technologies. This finding contradicts

Table 3: The factors influencing the level of adoption of cassava processing technologies

Variables	Coefficient	Std error	Z-value	P-value
Age	0.0515183	1.522033	0.03	0.973
Processing experience	0.5737073	0.1286726	4.46***	0.000
Compatibility	-0.3153063	0.5253846	-0.60	0.548
Level of education	0.7947973	0.4080829	1.95**	0.051
Triability of the technology	0-.2996967	0.3551987	-0.84	0.399
Relative advantage of the technology	0.6029463	0.5186993	1.16	0.245
Cost of the technology	-1.016922	0.2721163	-3.74***	0.000
Annual income	-0.2941721	0.0749174	-3.93***	0.000
Complexity of the technology	-0.1163602	0.0369332	-3.15***	0.002
Processing for family consumption	-0.4178169	0.2989091	-1.40	0.162
Extension contact	0.0957691	0.0425498	2.25**	0.024
Constant	3.684319	1.4089	2.62***	0.009
Number	140			
LR chi^2 (11)	88.13***			
Prob > chi^2	0.0000			
Pseudo R^2	0.4640			
Log likelihood	-50.910219			

Source: Field survey, 2024. Note: **, *** are Significance at 5% and 1% respectively.

Vihi *et al*. (2022), who found a positive relationship, suggesting that women with higher incomes were more likely to adopt innovations. Extension contact had a positive coefficient (0.0957691) and was significant at the 5% level, showing that rural women who had regular visits from extension agents were more likely to adopt new processing technologies. This contrasts with the findings of Uchemba *et al*. (2021), who reported no influence of extension visits on adoption rates among cassava processors. In summary, factors such as experience, education, and access to extension services positively influenced the adoption of cassava processing technologies, while high costs and lower income levels acted as barriers.

3.4 Constraints associated with the adoption of cassava processing technologies

The constraints limiting the adoption of improved cassava processing technologies are presented in Table 4. The findings indicate that the most critical barriers include lack of training on the use of new technologies (mean = 7.85), high labor demands involved in cassava processing (mean = 6.79), limited technical and financial support (mean = 6.46), absence of processor networks (mean = 6.34), and lack of adequate storage facilities (mean = 6.33). Conversely, poor extension services (mean = 4.81) and environmental barriers to using new technologies (mean = 4.33) were ranked as the least significant constraints.

The findings highlight that human capacity gap, particularly inadequate trainings which are the most significant barriers to the adoption of improved cassava processing technologies among rural women. Without the necessary knowledge

Table 4: Constraints associated with the adoption of cassava processing technologies

Constraints	M	Rank
Lack of training of how to use new technologies	7.85	1st
High labor demand in cassava processing	6.79	2nd
Limited technical and financial support for cassava processors	6.46	3rd
Lack of cassava processors network	6.34	4th
Lack storage facilities for cassava products	6.33	5th
Poor local market for processed products	6.25	6th
Difficulty in integrating new technologies into their existing practices	6.00	7th
Opaque value chain in cassava processing enterprise	5.51	8th
Fewer forums for relationship building (such workshops and seminar) among cassava processors	5.34	9th
Poor extension services	4.81	10th
Environmental barriers against using new technology	4.33	11th
N	140	
Kendalls W[a]	0,118	
Chi-square	165.136	
Df	10	
Asymo.sig	.000	

Source: Field survey, 2024

and skills to operate these technologies effectively, even the most beneficial innovations remain underutilized. Similarly, the high labour demands associated with cassava processing further discourage adoption, especially among women who often juggle multiple responsibilities. Limited access to both technical guidance and financial resources compounds these challenges, creating a cycle of low investment and minimal technological advancement. The lack of structured networks among cassava processors also hinders knowledge sharing, collective bargaining, and access to group-based support systems.

The relatively lower rankings of poor extension services and environmental barriers suggest that while these factors are present, they may not be the primary deterrents in the study area. However, their continued neglect could hinder future interventions if left unaddressed. Overall, the results underscore the importance of a multi-dimensional approach to technology adoption - one that goes beyond just availability, and addresses knowledge dissemination, financial accessibility, labour efficiency, and infrastructural development. Addressing these constraints holistically is essential for promoting inclusive and sustainable cassava processing among rural women in Kogi State.

4. Conclusion

The study concludes that the adoption of improved cassava processing technologies among rural women in Kogi State is moderately high. These technologies have significantly enhanced cassava processing by increasing production rates, reducing physical drudgery, and improving overall efficiency. Their use has enabled rural women to optimize processing activities, diversify products, and improve the quality of outputs. However, several barriers continue to impede full adoption. Chief among these are the lack of technical training, high labor demands, limited access to technical and financial support, absence of organized processors' networks, and inadequate storage facilities. Addressing these challenges is essential for sustaining and scaling up the benefits of cassava processing technologies. Therefore, it was recommended that continuous, hands-on training programme should be designed and implemented by the government to equip rural women with the necessary technical skills to effectively operate and maintain cassava processing technologies. These programs should be context-specific and delivered in local languages where necessary.

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Determination of optimum maturity of “Mabrouka” mango (*Mangifera indica* L.) fruits based on biochemical and sensory properties

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ABSTRACT

An experiment to determine optimum maturity of Mabrouka mango fruits on the basis of biochemical and sensory parameters was conducted in Benue State in 2018. Selected mango orchards from three Local Government Areas (LGAs) of the state - Gboko, Konshisha, Otukpo - were used for the study. Fruit maturity stages were defined based on weeks after flowering (WAF). Thus the 6 stages were 21, 22, 23, 24, 25 and 26 WAF. The experiment was a 3 × 6 factorial arranged in completely randomized design (CRD). Factors were location (3) and maturity stage of fruit (6). Biochemical and sensory attributes were evaluated. Results indicated significant influence of location on TSS and pH with fruits from Gboko recording significantly higher values of these parameters. TSS and pH also increased with increase in number of weeks after flowering. Crude protein, crude fibre and carbohydrate decreased with advance in fruit maturity from 21 to 26 WAF. Conversely, ash and moisture contents increased with increase in weeks after flowering. Sensory properties evaluated did not respond significantly to location except peel colour. Most of the sensory traits responded to fruit ripening stage, increasing with increase in number of weeks after flowering, although not to the same extent. Fruits harvested 25 WAF had the highest overall acceptability scores. Sensory traits also improved when fruits were stored. It is conclusive that for best sensory traits and TSS, fruits should be harvested 25 to 26 WAF although there may be less carbohydrate and protein contents.

KEY WORDS: *Mabrouka mango*; *Biochemical*; *Sensory*; *Optimum maturity*

1. Introduction

Mango (*Mangifera indica* L.) is one of the most popular fruits consumed world-wide (Evans and Ballen, 2012) with over 1000 known varieties and commercial production in 87 countries (Tharanathan *et al.*, 2006). Mango is the fifth largest fruit crop produced worldwide after banana, grapes, apples and oranges (Bally *et al.*, 2009; Okoth *et al.*, 2013a). It is one of the most extensively exploited fruits for food, juice, flavour, fragrance and colour and a common ingredient in new functional foods often called super fruits (Kittiphoom, 2012). Mango fruit contains almost all the known vitamins. It is an excellent source of pro-vitamin A, necessary for sustenance of a healthy skin. Mango contains high concentrations of phytochemicals, including gallic

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acid, mono galloyl glucosides, gallotannins, flavonol glycosides and benzophenone derivatives (Schieber *et al.*, 2000); some of which are unique to the plant and have been proposed for use in creating phytochemical rich dietary supplements (Barreto *et al.*, 2008). Ripe mangoes are processed into frozen mango products, canned products, dehydrated products, and ready-to-serve beverages (Ramteke and Eipeson, 1997; Kittiphoom, 2012).

In spite of the importance of mango, huge losses are experienced yearly due to wrong time of harvesting, poor harvesting, poor handling and poor storage techniques. Lack of proper knowledge of fruit maturity is considered to be one of the major problems contributing to post-harvest losses in mango (Gitonga *et al.*, 2010).

The post-harvest behaviour of mango is generally influenced by the maturity of the fruit at harvest. In most fruits, quality is maximized when the fruits are harvested more mature or ripe, whereas shelf and storage life are extended if they are harvested less mature or unripe (Toivonen, 2007; Ambuko *et al.*, 2014). Fruits harvested prematurely especially those targeting distant markets fail to attain optimal sensory attributes which affects consumer acceptance. Also, their shelf life is very short because they are highly susceptible to mechanical damage (Yahia, 2011). The quality and consistency of processed products such as juices, pulps, jams and dehydrated or dried products is affected by quality of fruits which is in turn affected by harvest maturity amongst other factors. As the fruits change from mature green stage to tree ripe stage and during storage, various physical and physiological changes occur and this may affect the quality of both fresh and processed mango products (Brecht *et al.*, 2009). Farmers often use subjective maturity indices based on visual judgement of size, peel and flesh colour, peel gloss etc but maturity determination based on visual observation is unreliable and also prone to errors because the subjective indices are affected by factors such as production location, variety and cultural practices.

Harvesting at the right maturity stage is critical for all mango value chain actors to ensure high quality of fresh fruits and processed mango products which is critical for market access and consumer acceptance. For the farmers, knowledge of maturity indices will guide them to harvest at the right stage for the target market and/or use, thereby minimizing rejections at the market stage and reducing losses. Amongst the mango varieties cultivated in Benue State, Mabrouka is one of the most sought after variety due to its unique sweetness, richness, flavour, considerable shelf life and high market value. Nevertheless, high losses have been experienced along the supply chain due to wrong harvesting stage amongst other factors. It is important that maturity indices be established for cultivars, growing regions and purpose of harvest (immediate consumption, local or export markets, storage, *etc*). It is both necessary and very common that several indices be used together in a complimentary manner to make a better decision. Information on the appropriate maturity stage of Mabrouka in Benue State and Nigeria at large is scarce if not lacking. Considering the position of Benue state in mango production in Nigeria, there is a pressing and urgent need to determine the appropriate harvesting stage of Mabrouka so as to improve its sensory and nutritional quality, extend its storage life and facilitate marketing. This study was therefore carried out to determine the most appropriate harvesting stage for Mabrouka fruit on the basis of biochemical and sensory attributes.

2. Material and Methods

Mango orchards were selected in three Local Government Areas of Benue State in Southern Guinea Savannah of Nigeria. The Local Government Areas are Konshisha (Latitude 7º 01′47.75″ N, Longitude 8º 39'37.33" E) Otukpo (Latitude 7º 16′ 1.06″ N, Longitude 8º 04'3.50"E) and Gboko (Latitude 7º 18′ 58.18″ N, Longitude 8º 54'6.01" E). From each of the farms in each location, five mango trees of similar vigour and age were selected and tagged at 50% flowering. The number of days from 50% flowering to physiological maturity (mature green stage), based on flesh colour defined by yellowing of the flesh around the seed was established as stage one (1) [21 weeks after flowering (147 days after flowering)]. Subsequent stages were stage two (2)[22 weeks after flowering (154 days after flowering)], stage three (3)[23 weeks after flowering (161 days after flowering)], stage four(4)[24 weeks after flowering (168 days after flowering)], stage five (5)[25 weeks after flowering (175 days after flowering)] and stage six(6)[26 weeks after flowering (182 days after flowering)] were take seven (7) days apart. At each harvest date, 10 fruits were harvested from each sampled tree using a cloth bag attached to a long pole. The fruits were immediately washed in water containing 1% acetic acid for disinfection. Only uniform fruits were selected. Selected fruits from each mango tree in the same location were combined and divided into two lots of 25 fruits each for biochemical analyses immediately after harvest as well as after storage. Determinations of biochemical attributes were done in the Chemistry and Biological Sciences laboratories of Benue State University Makurdi.

The experiment was a factorial combination of location and fruit ripening stage laid out in Completely Randomized Design (CRD) and replicated three times. The three locations were Konshisha, Gboko and Otukpo. The six fruit maturity stages were 21, 22, 23, 24, 25 and 26 weeks after flowering (WAF).

2.1 Biochemical analysis

Relevant biochemical parameters were evaluated. Total Soluble Solids (TSS) content of the juice extracted from the fruits (from each location and maturity stage) was determined using a hand refractometer. The mean TSS level was expressed as % brix.

Total Titratable Acidity (TTA) of mango fruits was estimated by titrating a known volume of juice obtained from the fruits of all the treatments against standard sodium hydroxide solution (0.1 N) using phenolphthalein as an indicator. The acidity of fruits so obtained was expressed as grams of anhydrous citric acid per 100 g of pulp. The TTA was expressed as % citric acid equivalent using the formula;

Acidity Percentage = Sample reading (ml) × Dilution factor (0.0064) × 100 ÷ sample weight (ml).

pH value in fruit juice were measured directly using a pH meter.

Proximate analysis (crude protein, crude fibre, crude fat, moisture and ash contents) were done according to AOAC (1995) methods while carbohydrate percentage was evaluated as follows;

Carbohydrate (%) = 100 – (% Moisture + % Protein + % Crude fibre + % Crude fat + % Ash content).

2.2 Sensory analysis

Sensory evaluation of fruits was done using 20 panellists of different gender and age. The observations were recorded when the fruits were just harvested and when 75% of the fruit was ripened. Mango was compared from different locations and maturity stages for texture, colour, flavour, taste and overall acceptability. Sensory evaluation was done using a nine point hedonic scale where 9 = like extremely; 8 = like very much; 7 = like moderately; 6 = like slightly; 5 = neither like nor dislike; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike very much; 1 = dislike extremely. The ratings for the sensory attributes were as described by Ihekoronye and Ngoddy (1985).

2.3 Statistical analysis

Data obtained from the study was subjected to analysis of variance (ANOVA) using GENSTAT statistical package. Means were separated using Fisher‘s Least Significance Difference (F-LSD) at 5% level of probability.

3. Results and Discussion

A summary of main and interaction effects of location and maturity stage on some biochemical properties of Mabrouka fruit in Benue State is presented in Table 1 and 2 respectively. Location exerted significant effect on TSS and pH with the Gboko location giving significantly higher values of the two parameters. The least of the values were from the Konshisha fruits. On the other hand, fruit maturity stage showed significant influence on all the three parameters evaluated viz: TSS, TA and pH. While TSS and pH showed increasing values with advance in maturity, that is weeks after flowering, TA adopted the opposite trend. Generally, interaction of location and maturity stage showed that TSS and pH values increased with maturity level of fruits while for TA, the reverse was the case. However, the magnitude of the variation in values of the traits was not the same across locations.

Table 1: Main effect of location and ripening stage on some biochemical properties of Mabrouka mango fruits in Benue State, Nigeria

Treatment	Total Soluble Solids (TSS) (Brix %)	Titratable acidity	pH
Location			
Gboko	12.3	1.53	4.57
Konshisha	10.9	1.68	3.65
Otukpo	11.6	1.61	4.11
LSD $_{(0.05)}$	0.34	NS	0.12
Ripening Stage			
21WAF	7.4	2.71	2.28
22 WAF	8.2	2.50	3.05
23 WAF	9.1	2.01	3.88
24 WAF	14.8	1.13	5.00
25 WAF	14.1	0.81	5.15
26 WAF	16.3	0.49	5.30
LSD $_{(0.05)}$	0.48	0.19	0.31

Note: WAF - Weeks after Flowering; NS – Not significant at 5% level of significance

Data gotten from proximate analysis of Mabrouka showed that crude fibre decreased with increase in maturity stage. Fruits harvested at 21weeks after flowering gave the highest crude fibre. Fruits harvested in Konshisha at 21 weeks after flowering gave the highest crude fibre. The lowest crude fibre was obtained from fruits harvested in Konshisha at 26 weeks after flowering (Fig. 1).

Crude protein on the other hand decreased with increase in maturity stage. Fruits harvested from

Konshisha gave the highest crude protein of Mabrouka and the difference was significantly higher than that produced by Otukpo and Gboko respectively. Fruits harvested in Konshisha at 21 weeks after flowering and Gboko at 26 weeks after flowering gave the highest and the lowest crude protein of Mabrouka, respectively (Fig. 2).

In terms of ash content, a steady increase in values was observed as maturity stage increased. Fruits harvested at 26 weeks after flowering gave the highest ash content among the maturity stages evaluated. Fruits harvested from Konshisha at 26 weeks after flowering gave the highest ash content while those harvested in Otukpo at 21 weeks after flowering gave the lowest ash content (Fig. 3). Crude fat followed similar pattern with respect to maturity stages. With respect to location, fruits harvested in Gboko at 26 weeks after flowering produced the highest crude fat compared to other locations (Fig. 4).

Carbohydrate content of Mabrouka decreased with increase in maturity. Fruits harvested at 21 weeks after flowering produced the highest carbohydrate

Table 2: Interaction effect of location and ripening stage on dry matter and biochemical properties of Mabrouka mango fruits in Benue State, Nigeria

Location	Ripening Stage	Total Soluble Solids (TSS) (Brix %)	Titratable acidity	pH
Gboko	21WAF	7.6	2.39	2.20
	22 WAF	8.7	2.13	3.60
	23 WAF	9.8	1.81	4.30
	24 WAF	14.8	1.39	5.64
	25 WAF	15.6	0.88	5.76
	26 WAF	17.5	0.57	5.94
Konshisha	21WAF	7.3	3.03	2.36
	22 WAF	7.8	2.76	2.50
	23 WAF	8.4	2.31	3.46
	24 WAF	14.8	0.88	4.36
	25 WAF	12.6	0.73	4.55
	26 WAF	15.0	0.50	4.66
Otukpo	21WAF	7.4	2.71	2.28
	22 WAF	8.2	2.61	3.05
	23 WAF	9.1	1.90	3.88
	24 WAF	14.8	1.13	5.00
	25 WAF	14.1	0.84	5.15
	26 WAF	16.3	0.50	5.30
LSD $_{(0.05)}$		0.83	0.32	0.31

Note: WAF - Weeks after Flowering; NS – Not significant at 5% level of significance

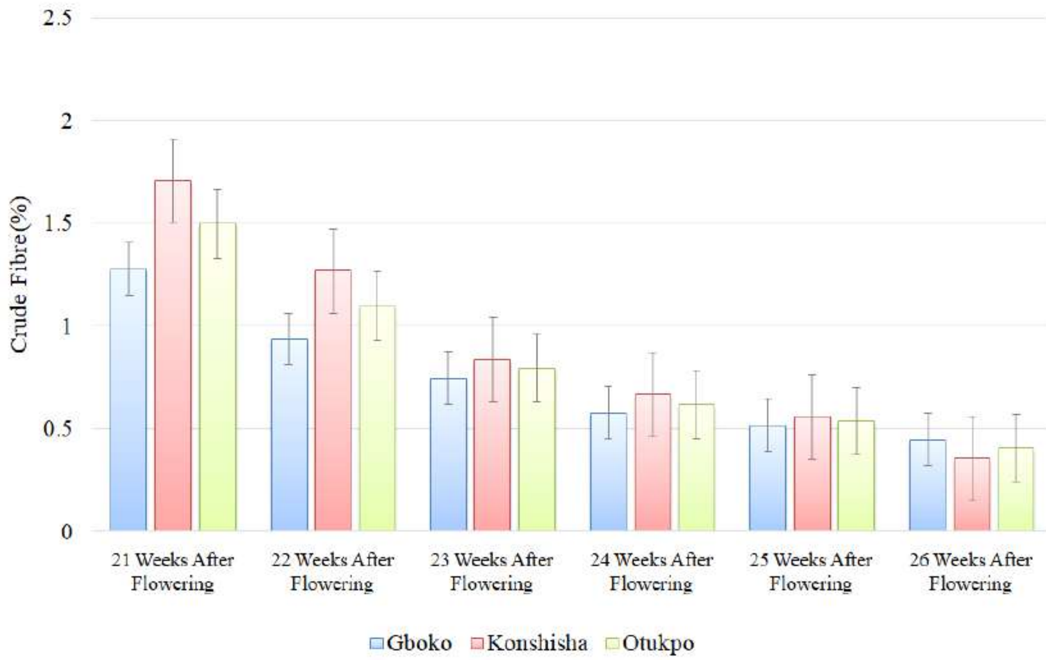

Fig. 1: Effect of location and maturity stage on the crude fibre composition of Mabrouka obtained from proximate analysis in 2018

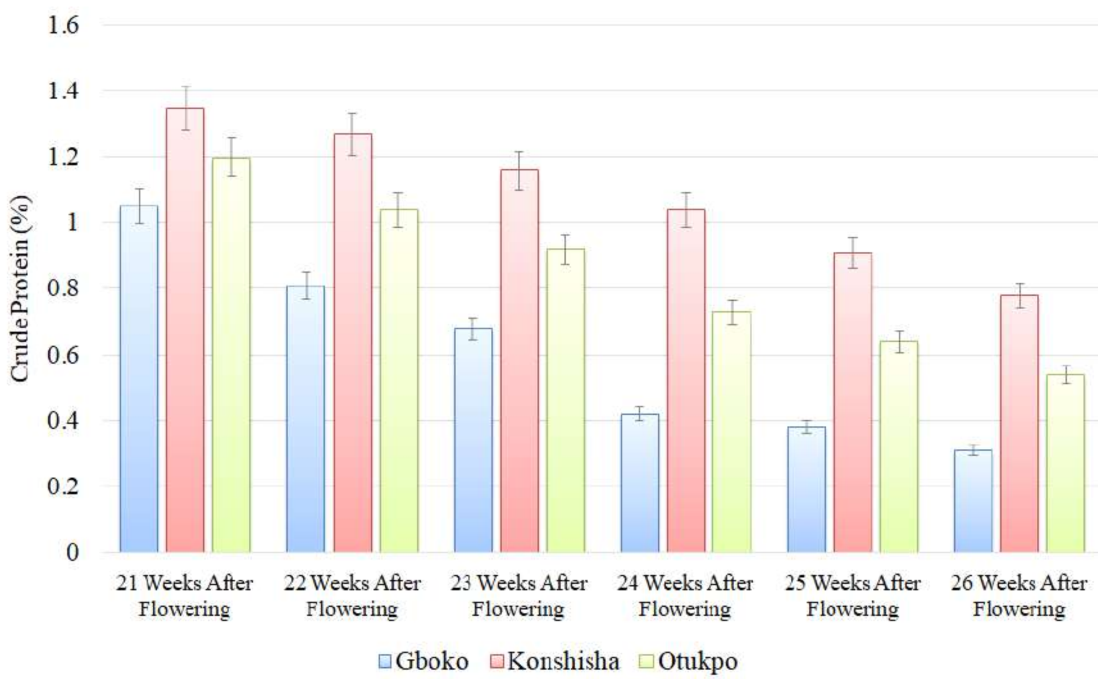

Fig. 2: Effect of location and maturity stage on the crude protein composition of Mabrouka obtained from proximate analysis in 2018

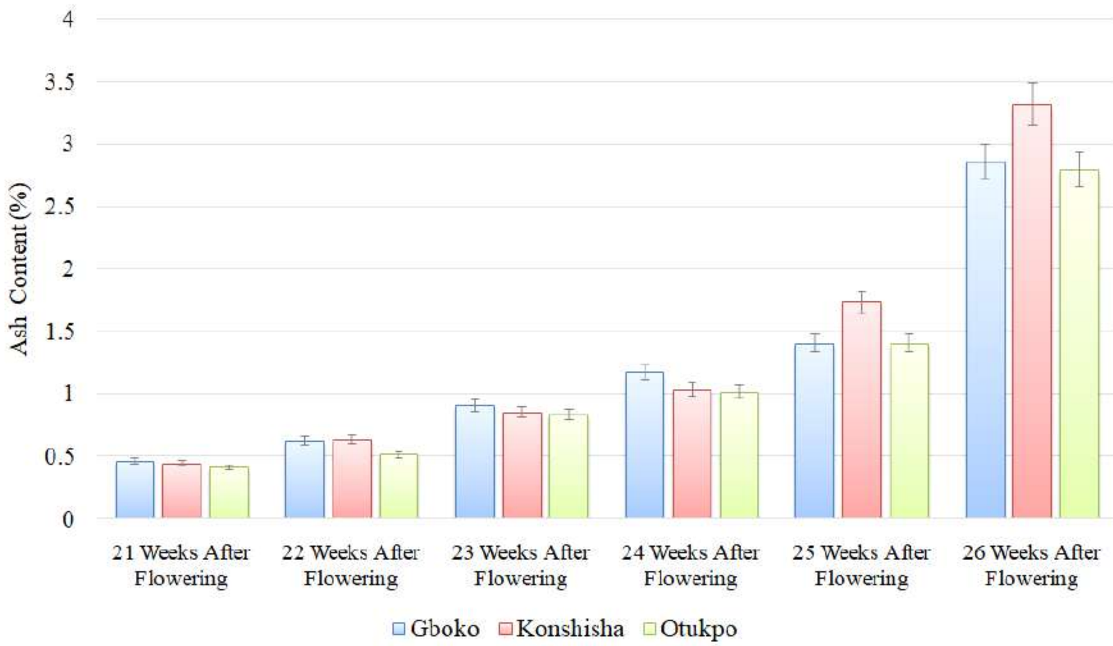

Fig. 3: Effect of location and maturity stage on the ash content of Mabrouka obtained from proximate analysis in 2018

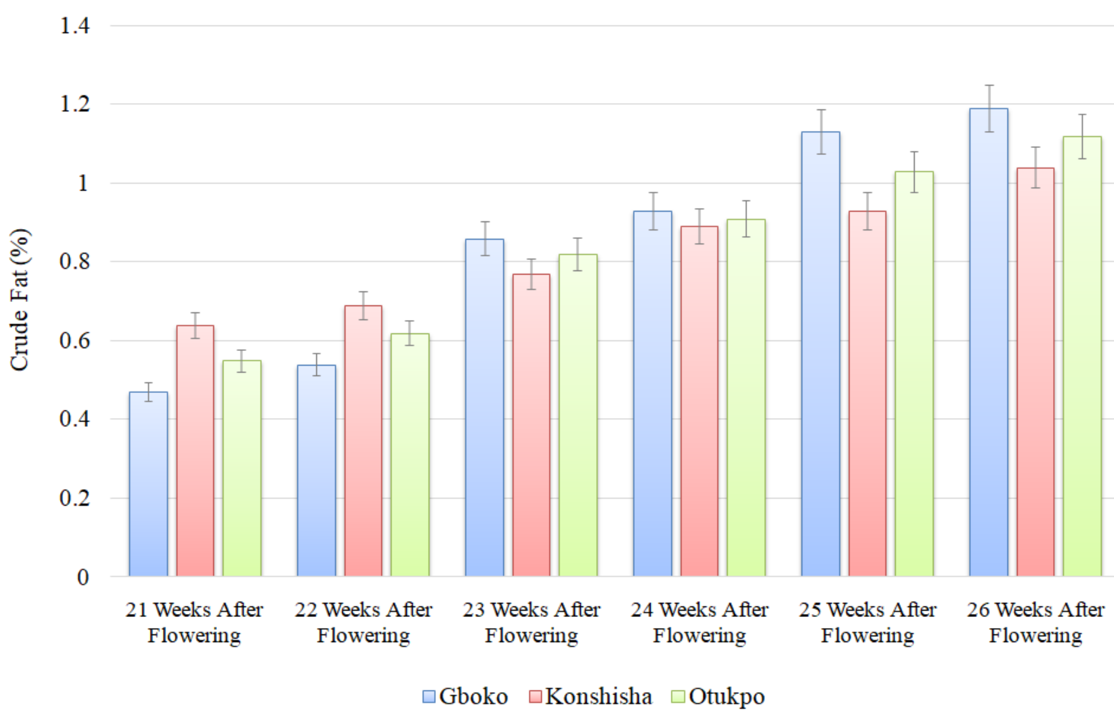

Fig. 4: Effect of location and maturity stage on the crude fat composition of Mabrouka obtained from proximate analysis in 2018

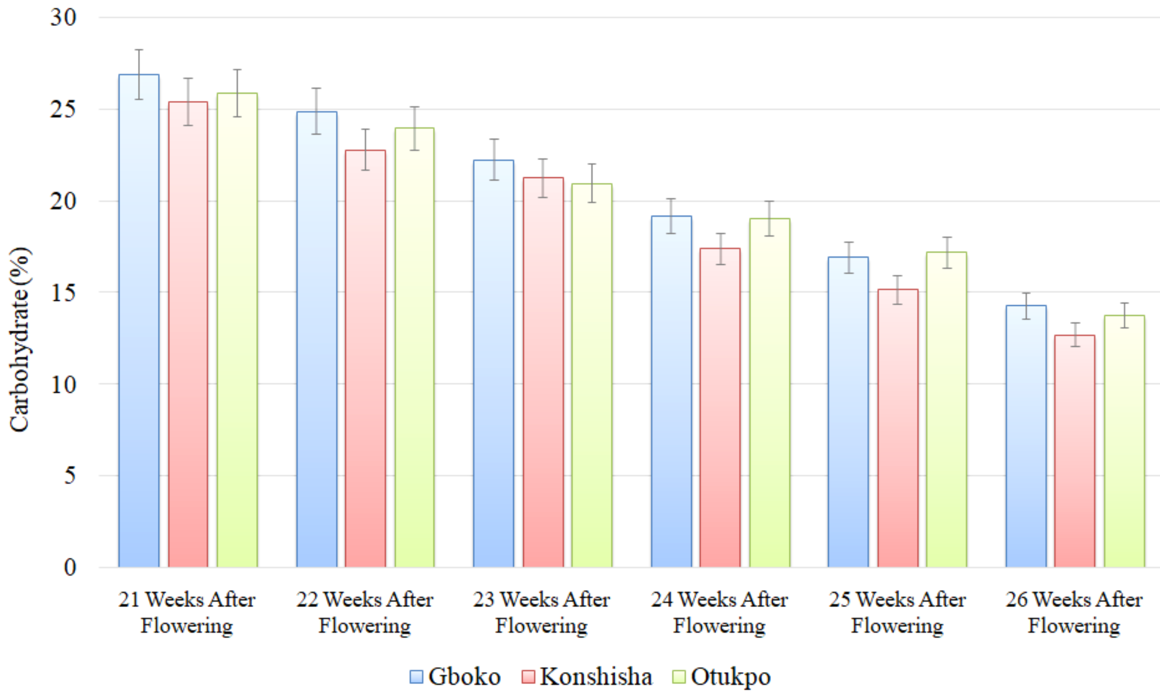

Fig. 5: Effect of location and maturity stage on the Carbohydrate content of Mabrouka obtained from proximate analysis in 2018

content of Mabrouka among the maturity stages evaluated. The lowest carbohydrate content was obtained at 26 weeks after flowering. Fruits harvested in Gboko at 21 weeks after flowering and fruits harvested in Konshisha at 26 weeks after flowering gave the highest and lowest carbohydrate content respectively (Fig. 5).

Table 3 shows the effects of location and maturity stage on sensory attributes of Mabrouka mango fruits. The sensory attributes generally did not respond markedly to location except peel colour before storage. In this case, the peel colour of the Konshisha fruits appeared more attractive immediately after fruit harvest compared to the other locations. Fruit maturity stage however, gave a significant influence on most of the sensory attributes evaluated. Generally, sensory traits improved with delay in harvesting of fruits from 21 to 26 WAF, although there were slight variations with respect to individual traits. For instance, the texture of fruits harvested 24 WAF was the best, comparatively. Peel colour of fruits harvested 26 WAF was preferred by panellists. Flavour and taste were best when fruits were harvested 25WAF. In terms of overall acceptability, fruits harvested 25WAF got the highest score. It was evident that all the sensory traits were better when fruits were stored than immediately after harvest, judging from their scores.

Results obtained from the study revealed that location, maturity stage and their interaction affected changes in the fruits biochemical parameters during ripening. TSS was observed to

Table 3: Main effect of location and maturity stage on sensory attributes of Mabrouka mango fruit before and after storage in Benue State, Nigeria

Treatment	Texture		Peel Colour		Pulp Colour		Flavour		Taste		Overall acceptability	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Location												
Gboko	5.2	7.8	5.5	8.0	5.8	8.1	5.6	8.2	5.2	8.5	5.4	8.2
Konshisha	5.5	7.9	6.1	8.3	6.3	8.4	6.3	8.5	5.5	8.6	6.0	8.4
Otukpo	5.3	7.8	5.8	8.1	6.1	8.2	5.9	8.4	5.3	8.5	5.7	8.3
Mean	5.33	7.83	5.80	8.13	6.07	8.23	5.93	8.37	5.33	8.53	5.70	8.30
$LSD_{(0.05)}$	NS	NS	0.51	NS	NS	NS	NS	NS	NS	NS	NS	NS
t-value	-8.00*		0.00		0.00		0.00		0.00		-7.00*	
Maturity Stage												
21 WAF	3.5	7.4	4.7	7.7	5.3	8.1	5.2	8.2	3.8	8.3	4.5	8.2
22 WAF	4.6	7.8	5.4	8.0	5.8	8.1	5.3	8.4	4.5	8.4	5.0	8.2
23 WAF	4.8	7.8	5.5	8.2	5.6	8.2	5.4	8.3	4.7	8.6	5.1	8.4
24 WAF	7.0	8.0	5.7	8.3	5.6	8.4	5.6	8.3	5.5	8.6	6.8	8.3
25 WAF	6.6	7.6	6.4	8.5	6.8	8.5	6.9	8.2	7.0	8.7	7.3	8.5
26 WAF	5.5	8.3	7.1	8.1	7.3	8.3	7.2	8.7	6.6	8.7	5.4	8.2
Mean	5.33	7.82	5.80	8.13	6.07	8.27	5.93	8.35	5.35	8.55	5.68	8.30
$LSD_{(0.05)}$	0.92	0.46	0.7	NS	0.62	NS	0.98	NS	0.92	NS	0.93	NS
t-value	-5.39*		-7.05*		-5.97*		-7.00*		-7.89*		-5.00*	

Note: WAF - Weeks after Flowering; NS – Not significant at 5% level of significance increase with increase in maturity stage. This result is in agreement with the findings of Absar *et al.* (1993) who also reported that TSS was increased with maturity of mango fruits. TSS is an important factor in the determination of quality in many fruits. A TSS of 13.8% to 17.0% indicates the highest quality of fruits to attain the optimum harvesting stage (Morton, 1987; Kamol *et al.*, 2014). The highest TSS was observed in fully matured fruit (26 weeks after flowering) while it was lowest at the least maturity stage (21 weeks after flowering) evaluated. Normally, as fruit maturity progresses and sugar content increases, total soluble solids will also increase (Rahman *et al.*, 2016; Salamat *et al.*, 2013). The increase in soluble solid contents may be due to hydrolysis of sucrose to invert sugars as reported by Bhatti (1975) and Ullah (1990). The significantly higher TSS value produced in Gboko among the locations evaluated may be due to differences in the soil and climatic conditions of the locations. Lotze and Bergh (2005) reported that maturity indices like TSS are greatly influenced by prevailing climatic conditions and vary from season to season.

Titratable acidity of Mabrouka ranged from 0.49 to 2.71 and abated with the advancement of maturity. Ambuko *et al.*, (2017) also reported reduced levels of acidity as fruits ripened. Kosiyachinda *et al.* (1984) stated that titratable acidity decreases with the onset of maturation, however no common value for the maximum titratable acidity exists that could be used to determine the earliest acceptable picking time. In most climacteric fruits, acidity declines as ripening advances (Wills *et al*., 1989). The reduction in acidity may be due to the degradation of citric acid which could be attributed to its conversion to respiratory substrates required by the cells (Abbasi *et al.*, 2009; Ambuko *et al.*, 2017). Fuchs *et al.* (1980) stated that the decline in acidity during ripening is as a result of starch hydrolysis leading to an increase in total sugars and a decrease in acidity.

Analysis of variance showed that pH of Mabrouka was significantly affected by maturity stage, location and their interaction. The pH of Mabrouka increased with increase in maturity. This result conforms to the findings of Tridjaja and Mahendra (2000) who reported that the pH of fruit flesh significantly increased with the onset of fruit maturation. Soares *et al.* (2007) similarly observed that the pH of guava increased during the different maturity stages (Wongmetha *et al.*, 2015). This phenomenon might be possible due to oxidation of acid during maturation resulting in higher pH. In general, young fruits contain more acids that decline throughout maturation until ripening due to their conversion to sugars (gluconeogenesis) (Wongmetha *et al.*, 2015). Gboko produced higher pH values than Otukpo and Konshisha respectively. This could be ascribed to differences in environmental factors.

Results obtained from proximate analysis of Mabrouka showed that the moisture content of Mabrouka was not significantly affected by location and location × maturity stage interaction but maturity stage had significant effect on the moisture content of Mabrouka. As maturity advances, the moisture content of mango also increases. Therefore, the observed increase in moisture content of mango pulp with advancement in maturity was expected. During ripening, carbohydrates are hydrolysed into sugars increasing osmotic transfer of moisture from peel to pulp (Kays, 1991). Crude fibre composition reduced as fruits advanced in maturity. This result is consistent with the finding of Okoth *et al.* (2013b) who reported a slight decreasing trend with ripening. The decrease in fibre could be attributed to a decrease in insoluble pectin associated with an increase in soluble pectin during the course of ripening (Mathooko, 2000; Mamiro, *et al.*, 2007; Okoth *et al.*, 2013b). The crude protein content of Mabrouka decreased steadily from 21 weeks after flowering to 26 weeks after flowering. Appiah *et al.* (2011) also observed a decrease in crude protein of mango with advancement in maturity stage. The decrease in crude protein could be attributed to dramatic decrease in the enzymes required for ripening. The crude fat of Mabrouka increased as maturity advanced. This concurs to the findings of Mamiro (2007). The change in fat content on extended maturity could be due to decreased citrate level, which is believed to be the immediate source of acetyl coenzyme A required for biosynthesis of fatty acid and triglyceride (Gomez-Lim, 1997; Okoth *et al.*, 2013b). The increase in ash content of Mabrouka and the decrease in carbohydrate with progression in maturity agree with the findings of Appiah *et al.* (2011). The increase in ash might be due to differential absorption capacity of different minerals at different stages of development. Decrease in carbohydrate can be ascribed to low levels of sugar, starch and dietary fibres with advancement of maturity. The variation in crude fibre, crude protein and carbohydrate with location could be due to variables like soil composition and climate condition of the area of mango growth.

For fruits evaluated at harvest, sensory panellists preferred Mabrouka fruit texture/firmness at 24 weeks after flowering irrespective of the location. This was reflected in the higher hedonic scale scores obtained at 24 weeks after flowering. For fruits evaluated after ripening, panellist preferred fruits harvested at 26 weeks after flowering. Generally, consumers have preference for firm but ripe mango fruits. As fruits mature, the firmness of the fruit reduces and further declines with ripening. Textural characteristics such as fruit firmness in fruits like mango are more perceived by consumers than other aromatic properties (Johnson, 2000). However, for fruits evaluated at harvest, the preference of sensory panellist with respect to peel and pulp colour and flavour, increased with advancement in maturity. Colour of the skin and flesh is an important quality aspect, which creates the first impression of the fruit on sight to the consumer; it greatly influences degree to which it is purchased for either fresh consumption and/or for processing purposes (Okoth *et al.*, 2013a). Flavour involves the combined effect of acidity, soluble solids and aroma volatiles (Harker *et al.*, 2002). Production of aroma volatiles in mango fruits is linked with metabolism at the later stages of maturity (Fellman *et al*., 2003) and hence, fruits picked at a more mature stage have relatively high production of aroma volatiles and hence better flavour quality, which is a consumption quality important to consumer acceptability of mangoes (Malundo *et al*., 1996).

The overall flavor is described as a result of perception by the taste buds in the mouth and the aromatic compounds detected by the epithelium in the olfactory organ in the nose (Rathore *et al.*, 2007; Saeed *et al.*, 2009). Taste preference of Mabrouka increased with increase in maturity up to 25 weeks after flowering then a slight decrease was observed at 26 weeks after flowering but no significant difference was observed between 25 and 26 weeks after flowering. Baloch and Bibi (2012) made a similar observation and opined that fruit taste was developed during the ripening process. As the taste is a combination of sugar and acids present in the fruit, it was expected that the sugar contents were increased and the acid value was decreased with the passage of time (Kays, 1991; Malundo *et al.*, 2001; Baloch and Bibi, 2012). Scores obtained for overall acceptability of Mabrouka showed that people had preference for Mabrouka fruits harvested at 25 weeks after flowering.

4. Conclusion

From results of the study, it is conclusive that for best sensory traits and TSS, fruits should be harvested 25 to 26 WAF especially when intended for immediate consumption or short distant markets. Fruits intended for long distant markets could be harvested earlier to strike a compromise between quality/acceptability and shelf life.

5. Conflict of interest

The authors have not declared any conflict of interests

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Effects of subsidized inputs on rice production under value chain development programme in Benue and Niger States, Nigeria

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ABSTRACT

This study examines the effects of subsidized agricultural inputs on rice farmers' productivity and livelihood outcomes under Value Chain Development Programme (VCDP) in Benue and Niger States, Nigeria. A multistage sampling technique was used to select programme beneficiaries, and data were analysed using descriptive statistics, logit regression, t-test, and propensity score matching. The results obtained shows that rice farmers in the study area were mostly males (85.4%) and (57.5%) and formally educated (70.8% and 85.6%) with an average age of 42 years among rice farmers in Benue and Niger states respectively. Findings show that subsidized inputs such as improved seeds (92.0% and 95.0%), fertilizers (89.0% and 93.0%), herbicides and mechanization support (71.0% and 81.1%) significantly increased rice yield from pre-VCDP average of 2.9 t ha^{-1} to 5.1 t ha^{-1} among rice farmers in Benue and Niger states respectively. Farmers' income, food security, and livelihood assets improved, consistent with VCDP's programme theory. Determinants of subsidy access included cooperative membership, extension contact, education, and farm size. The study concludes that subsidies under VCDP enhanced rice productivity and household welfare. Recommendations include timely input delivery, expansion of mechanization services, youth inclusion strategies, and digitalized subsidy management.

KEY WORDS: *Input subsidy*; *Rice production*; *VCDP*; *Productivity*; *Smallholder farmers*

1. Introduction

Rice production is central to Nigeria's agricultural transformation agenda, contributing to food security, rural employment, and household income (IFAD, 2022). Despite rising domestic demand, national supply remains insufficient due to low productivity, limited access to modern inputs, climate-related risks, and institutional inefficiencies (World Bank, 2019). To address these challenges, the Federal Government and IFAD introduced the Value Chain Development Programme (VCDP), targeting rice and cassava farmers in selected states including Benue and Niger. VCDP supports farmers through input subsidies such as improved seeds, fertilizers, herbicides, land development services, and mechanization delivered through cooperatives using matching grant modalities (IFAD, 2022). Subsidies are designed to stimulate the adoption of improved technologies, enhance productivity, reduce production costs, and strengthen market

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participation (FMARD, 2021). However, empirical evidence of how these subsidized inputs translate into measurable productivity gains and livelihood improvements at the farmer level remains limited, particularly within structured value chain programmes.

Rice occupies a crucial space in household food expenditure. Importantly, it is a staple food with rich cultural identity. In Thailand, rice is described as the essence of life. In China, it is referred to 'life' and generally the root of Asian civilization. In addition, rice has a rich nutritive value that provides more than 15 essential vitamins and minerals including folic acid, B vitamins, potassium, magnesium, selenium, fiber, iron and zinc (Onwuka, 2021). Considering the nutritional value of rice in the body, there is hardly any country in the world where it is not utilized in one form or the other. In Nigeria, rice is one of the few food items whose consumption has no cultural, religious, ethnic or geographical boundary (Ibitoye *et al.*, 2017).

According to Fosu (2017), Nigeria's enormous agricultural potentials are yet to be fully exploited. FAO (2018) opined that utilization of production knowledge and use of technology makes the real value of productivity that boost Nigeria's' economy. Thus, if well managed, the sector has potential to contribute substantially to GDP, employment and revenue generations. It is in this regard, that the Nigerian government positions agricultural sector as one of the driving forces for the anticipated economic growth that is required to reduce poverty (World Bank, 2019).

Prior programme assessments noted increases in farmers' adoption of improved seeds, access to extension, and participation in market linkages (VCDP, 2021). Yet, the magnitude of productivity gains and livelihood outcomes attributable to subsidized inputs is not well documented in peer-reviewed studies. Understanding these dynamics is vital for sustaining and scaling agricultural subsidy interventions. This study contributes to knowledge by empirically analysing the effects of subsidized inputs on rice farmers' productivity, income, and livelihood outcomes in Benue and Niger States. It also identifies socio-economic predictors of subsidy access among programme beneficiaries. Findings will guide policymakers, development partners, and practitioners in designing and sustaining inclusive agricultural input support programmes.

2. Material and Methods

This study was conducted in Benue and Niger States, Nigeria. Niger State was created out of the former Northwestern State and became a fully autonomous State on 3rd February 1976, with headquarter at Minna. Niger State is in the North-central part of Nigeria and lies in between longitude 3° 30' and 7° 20' East of the Greenwich Meridian and latitude 8° 20' and 11° 30' North of the equator. The State presently comprises of 25 Local Government Areas (LGAs) and it is made up of three major ethnic groups which are the Nupe, Gbagyi and Hausa. However, the total inhabitants in the State are over 3,954,772 people during the 2006 population census. But, going by the annual population growth rate of 2.5% in Nigeria, the population of Niger State was projected to be 5,556,200 in the year 2016 (National Bureau of Statistics, 2020). However, Benue State falls within Longitude 7°47′ E to 10°0′ E and Latitude 6°25′ N, 8°8′ N. It is borded in the North by Nasarawa state and in the East by Taraba and Cross- River States. The State covers an estimated land area of 34,059 km^2 and the total inhabitants in the State was 4,219,244 people during the 2006 population census. However, going by the annual population growth rate of 3.4% in Nigeria, the population of Benue State was projected to be 6,514,513 people in the year 2022 (NBS, 2020).

A multistage sampling technique was used. VCDP-implementing LGAs were purposively selected, followed by random selection of Farmer Organisations (FOs). Rice farmers participating in VCDP were then randomly sampled using Yamane's formula to select sample size from sampling frame as obtained from Value Chain Development Programme data base. Thus, a total of 331 rice farmers formed the sample size for the study. Structured questionnaires were used to collect primary data analysis was conducted using descriptive statistics (mean, frequency distribution, and percentage) and inferential statistics (Ordered Logit regression model) was used to examine the determinant of rice farmers access to inputs subsidies under VCDP was specified as follows:

Ordered Logit Regression model - involves the relationship between a dependent variable and a collection of independent variables. The value of dependent variable is defined as a combination of independent variables plus error term.

$Y = f(X_1, X_2, X_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_n, e_i)$

The implicit form of the ordered logit regression model is given as:

$$Y = f(X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{13}+e) \text{--} (1)$$

The explicit form is specified as follows:

$$Y = \beta_0+ \beta_1X_1+ \beta_2X_2+ \beta_3X_3+ \beta_4X_4+ \beta_5X_5+ \beta_6X_6+ \beta_7X_7+ \beta_8X_8+ \beta_9X_9+ e \text{-----------------------------} (2)$$

Y = Level of access to inputs subsidies (high=3, moderate=2, low=1).
X_1 = Age (Age of farmers)
X_2 = Household size (numbers of people in the household)
X_3 = Educational status of farmers (Years of schooling)
X_4 = Farming experience (Number of years involved in farming)
X_5 = Marital status (married =1, otherwise = 0)
X_7 = Farm size (Hectares)
X_8 = Extension contact (number of visit)
X_9 = Access to credit (amount of credit received)
X_{10} = Major occupation (farming= 1, otherwise = 0)
X_{11} = Income (in Naira)
X_{12} = distance to redemption centre (km)
X_{13} = Cooperative membership (yes=1, no=0)
ß0 = Intercept
$ß_1 – ß_{13}$ = Regression coefficients
ei = error term.

3. Results and Discussion

3.1 Socio-economic characteristics of the respondents

Age of the respondents: Entries in Table 1 revealed that majority (70.6%) of the respondents Benue state and (87.5%) of the respondents in Niger state were between the age bracket of 31-50 years with average age of 42 years respectively. This implies that, farmers in the study area were still within their active and productive age, *i.e* strong, energetic and full of innovative ideas that could be advantageous in efficient use of inputs subsidies given for rice production. At this age, farmers should be able to withstand the pressure and rigours involved in rice production from pre-planting operation till harvesting and post-harvesting operation respectively. This finding agreed with Okunola *et al*. (2018) who stated that majority of the farmers were within the youthful age group regarded as economically active age, innovative and productive age to carry out farming activities efficiently.

Table 1: Distribution of respondents according to socio-economic characteristics

Variables	Niger State (n=185) Freq (%)	Benue State (n=146) Freq (%)
Age (years)		
30 years and below	7 (3.8)	18 (12.3)
31-40 years	80 (43.2)	55 (37.7)
41-50 years	82 (44.3)	48 (32.9)
Above 50 years	16 (8.6)	25 (17.1)
Mean	42 years	42 years
Sex		
Male	158 (85.4)	84 (57.5)
Female	27 (14.6)	62 (42.5)
Marital status		
Married	159 (85.9)	129 (88.4)
Single	18 (9.7)	8 (5.5)
Divorce	2 (1.1)	1 (0.7)
Widow(er)	6 (3.2)	8 (5.5)
Formal education		
Yes	131 (70.8)	125 (85.6)
No	54 (29.2)	21 (14.4
Level of education		
Non-formal education	54 (29.2)	21 (14.4
Primary education	7 (3.8)	4 (2.7)
Secondary education	36 (19.5)	38 (26.0)
Tertiary education	88 (47.6)	83 (56.8)
Mean of years in schooling	11 years	12 years

Source: Field Survey, 2025

Sex of the respondents: Results in Table 1 showed that majority (57.5%) and (85.4%) of the respondents in Benue and Niger States were male respectively. This finding revealed that there are more male respondents than female respondents in the study area. This also might be due to the tedious, labourious and strenuous activities involved in rice production that could only be handled by men and restrict women to only domestic chores or as farm labourer in the study area. This is similar to the findings of Osanyinlusi and Adenegan, (2017) who found that men were dominant in rice production compared to female farmers.

Marital status of the respondents: Table 1 showed that the majority (88.4%) of the respondents in Benue State and (85.9%) of the respondents in Niger State were married. This implies that farmers in the study area had the motivation to cater for their family needs such as provision of nutrition while also using family members as source of cheap labour for rice production activities. The result is in line with Okpe *et al*. (2019) who pointed out that, married persons were more involved in crop production due to higher food demand in the household.

Educational level of the respondents: The results in Table 1 showed that majority of the respondents (85.6%) in Benue State and (70.8%) of the respondents in Niger State had one form of formal education or other involving attending primary, secondary and tertiary institutions with an average school year of 11 years and 12 years in Niger and Benue States respectively. Indicating a high literacy level, with high percentage of the rice farmers at tertiary level of formal education. Given that there is high level of literacy, it is expected that extension agents may disseminate information on good agronomic practices with ease among farmers in the study area. This result is in line with that of Bello *et al*. (2016) who reported that farmers in rural Northern Nigeria had formal education with average of 6 years in school thus, influencing the adoption of rice production technology among the farmers.

3.2 Access to subsidized inputs

The result in Fig. 1 shows that subsidies rice seed (92.0%), subsidies fertilizer (89.0%) and subsidies herbicides (75.0 %) were the major input subsidies benefited among the respondents in Benue state. The high percentage of beneficiaries accessing subsidized rice seed (92.0 %) under the VCDP indicates that most rice farmers in Benue State received improved seed varieties. Access to quality seed likely enhanced germination rates, crop uniformity, and resistance to pests and diseases, thereby contributing to higher yields.

The high percentage of rice farmers benefiting from subsidized fertilizer (89.0 %) under the VCDP reflects strong support for soil fertility management in Benue State. Fertilizer provision at reduced cost enabled farmers to apply adequate nutrients particularly nitrogen, phosphorus, and potassium at recommended rates and timings. This likely improved plant vigour, enhanced tillering, promoted uniform grain development, and increased overall yields. The substantial percentage of beneficiaries accessing subsidized herbicides and mechanization support (71.0 %) indicates that weed management was effectively supported under the VCDP. This reduced the labour required for manual weeding, ensured timely weed control, and minimized competition for water and nutrients between rice plants and weeds. This assertion agrees with Okpe *et al.*

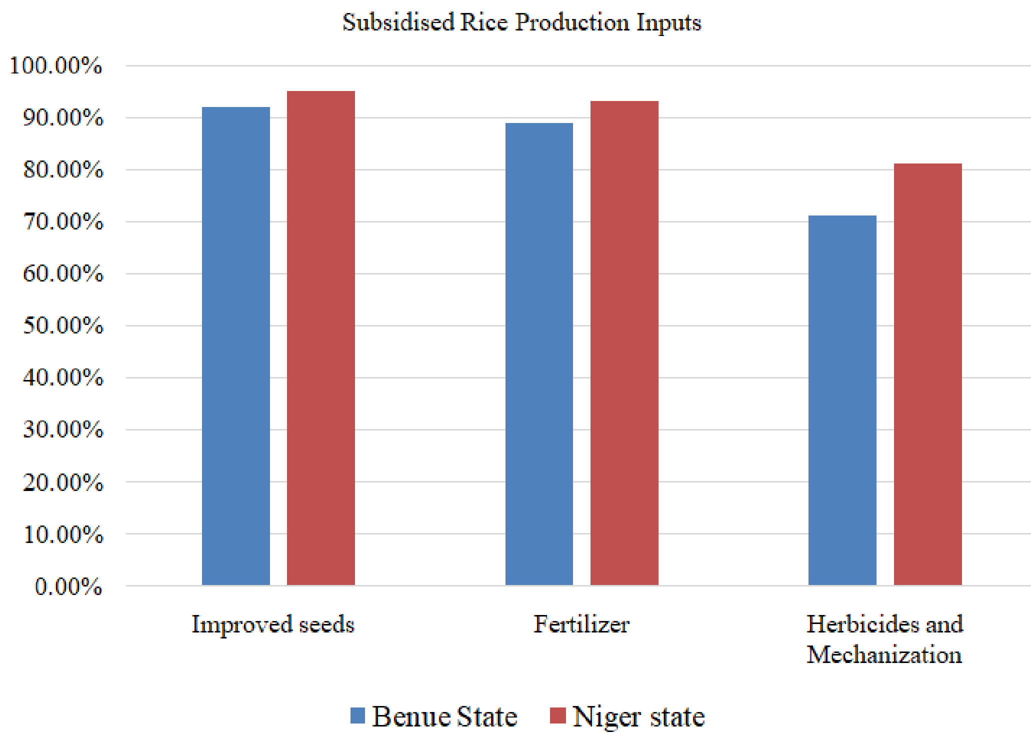

Fig. 1. Subsidized rice production inputs benefited by rice farmers

(2022), who found that access to seed, fertilizer and agrochemicals were the farm subsidies benefited by the crop farmers in Southern Nigeria.

Furthermore, subsidies seed (95.0 %), subsidies fertilizer (93.0 %) and subsidies herbicides and mechanization (81.1 %) were the major input subsidies benefited among the respondents in Niger State. Similarly, to Benue State, the high uptake in Niger state reflects the programme's strong focus on providing essential production inputs that directly enhance yield potential. Access to improved seed varieties likely improved germination rates, crop uniformity, and resistance to pests and diseases, enabling farmers to achieve higher and more stable yields. In addition, subsidized fertilizer provision allowed farmers to meet the nutrient requirements of their rice crop at reduced cost, promoting vigorous growth, better tillering, and improved grain filling. Subsidized herbicides and mechanization reduced the labour and time demands of manual weeding, ensured timely weed control, and minimized yield losses caused by weed competition. Similar to the findings of Ibitoye *et al*. (2017) who showed that access to fertilizer subsidies reduced the financial burden on farmers while ensuring that essential nutrients were applied in sufficient quantities, which has been shown to boost tiller production and grain filling.

3.3 Determinants of rice farmers access to inputs subsidies

Ordered logit regression model was used to examine the determinant of rice farmers access to subsidized inputs under VCDP in the study area. Thus, the result in Table 2 shows the R^2value of (0.7921 and 0.6334) for Benue and Niger states respectively. Implying that about (79 % and 63 %) respectively of Benue and Niger States variations that occurred in the determinants of rice farmers access to inputs subsidies were explained by the independent variables included in the models. while the remaining 21 % and 37 % respectively for Benue and Niger States rice farmers might be due to the non-inclusion of some important variables or measurement error. The Prob>chi^2 is

Table 2. Determinants of rice farmers access to subsidized inputs

Variables	Benue state		Niger state	
	Coefficient	Z-value	Coefficient	Z-value
Household size	0.0648	0.99	0.0589	1.45
Level of education	0.3495	3.49***	1.1529	2.22**
Farming experience	-0.1100	-1.49	0.0527	2.37**
Farm size	0.3459	3.29***	0.9048	3.38***
Extension contacts	0.5243	3.07***	-0.6639	-0.92
Cooperative membership	0.7110	3.09***	2.7747	7.29***
Constant	0.7129	0.86	0.6698	1.49
Number of observations	146		185	
LR chi^2 (12)	69.40		134.70	
Prob>chi^2	0.0000***		0.0000***	
Pseudo R^2	0. 7921		0.6334	

Source: Field survey, 2025

Note: *, **, *** implies significant at 10%, 5% and 1% level of probability significant at 1 % level of probability. This implies the model is fit for the objectives.

The result shows that cooperative membership ($p < 0.01$), extension contact ($p < 0.05$), educational level ($p < 0.01$) and farm size ($p < 0.05$) were positively significant among the rice farmers in Benue and Niger states respectively. This implies that an increase in any of these variables leads to likelihood increase in rice farmers access to subsidized inputs provided by Value Chain Development Programme in both Benue and Niger states. This finding concurs with that of Ayoola *et al.* (2017), who reported that access to extension service increase the farmers' level of awareness on various production inputs needed for farming practices. This also agrees with the findings of Wekesah *et al.* (2019), who posits that most farmers in sub-Saharan Africa have access to subsidized production inputs.

3.4 Effects of subsidized inputs on productivity and livelihood outcomes

Based on the yield performance on average rice output increased from 2.9 t ha^{-1} before VCDP subsidy to 5.1 t ha^{-1} with the subsidized inputs programmed from VCDP. This is consistent with IFAD (2022), which reported yield increases of 3–5 t ha^{-1} among supported farmers. Improved seed adoption and balanced fertilization contributed significantly to yield gains. However, Farmers experienced:

- Improved food security
- Higher savings
- Increased access to social services
- Better decision-making autonomy
- Enhanced productive assets

These outcomes reflect the programme's Theory of Change, which emphasises livelihood strengthening through market-driven productivity interventions (IFAD, 2022).

4. Conclusion

The study establishes that subsidized inputs under VCDP significantly enhanced rice productivity, income, and livelihood outcomes among farmers in Benue and Niger States. Determinants of access highlight the importance of cooperatives and extension services in reaching targeted beneficiaries. It is recommended that VCDP should ensure timely delivery of subsidized inputs to align with planting periods and also scale up mechanization support to reduce drudgery and expand cultivated areas. Rice farmers should also strengthen cooperative management capacities for efficient input distribution.

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Tables and figures: All Tables and figures must have a title and a legend to make them self- explanatory and they should be given numbers.

References (APA Style, 7th Edition):

For Journal article: Kammar, S. C. (2023). Studies on the influence of different organic manures on soil microbial activity, growth and yield performance of blackgram (*Vigna mungo* L.). *Current Innovation in Agriculture Science, 1*(1), 1–7.

For Books: Lombard, P. B., & Waetwood, M. N. (1987). *Rootstocks of fruit crops* (pp. 145–183). In R. C. Room & R. F. Carlson (Eds.), A Wiley-Interscience Publication.

For Book Chapter: Lombard, P. B., & Waetwood, M. N. (1987). Pear rootstocks. In R. C. Room & R. F. Carlson (Eds.), *Rootstocks of fruit crops* (pp. 145–183). A Wiley-Interscience Publication.

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