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INVESTIGATING THE INFLUENCE OF SOWING METHODS AND TIMING OF HERBICIDE APPLICATION ON GROWTH AND YIELD OF FARO 44 RICE VARIETY IN BADEGGI, NIGER STATE, NIGERIA

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ABSTRACT: The field experiment was conducted at the National Cereals Research Institute during the 2021 and 2022 wet seasons, this study aims to investigate the influence of sowing methods and timing of herbicide application on the growth and yield of FARO-44 rice variety in Badeggi, Niger State, Nigeria. The treatments consisted of five sowing methods (broadcasting dry, broadcasting wet, dibbling wet, dibbling dry, and transplanting) and two herbicide application timings (2 and 3 weeks after sowing) arranged in a factorial experiment laid out in a randomized complete block design (RCBD) with three replications. Data collected included plant height, number of tillers, days to 50% flowering, days to maturity, number of seeds per panicle, seed yield per panicle, 1000-grain weight, and grain yield per hectare. Data were subjected to analysis of variance (ANOVA), and treatment means were separated using the Least Significant Difference (LSD) test at 5% probability level. Results showed that transplanting significantly produced the highest values for growth and yield parameters, followed by dibbling wet and dibbling dry methods, while broadcasting methods recorded the lowest performance. Herbicide application at 2 weeks after sowing significantly enhanced crop performance compared to application at 3 weeks after sowing. The study concluded that transplanting combined with herbicide application at 2 weeks after sowing is the most effective strategy for improving the productivity of FARO 44 rice variety at Badeggi, Niger State, Nigeria.

KEYWORDS: FARO-44, Sowing, Herbicide, Broadcasting, Dibbling, Transplanting and Hectare

Introduction

Rice (*Oryza sativa*) is a member of the Poaceae family and serves as a staple food for more than 60% of the world's population, contributing about 20% of global dietary energy supply (FAO, 2022). It is an important source of calories, carbohydrates, protein, and fats for millions of people worldwide (ICAR, 2006). In Nigeria, rice is one of the most widely consumed cereal crops and constitutes a major component of the daily diet, providing a substantial proportion of caloric and protein intake among the population. The increasing demand for rice due to rapid population growth has intensified the need to increase production. According to CGIAR (2023), global rice production must rise from about 520 million tonnes to approximately 880 million tonnes by 2025 to meet future food demand. Achieving this target requires the adoption of improved agronomic practices, high-yielding varieties, and sustainable production technologies. However, rice production is constrained by challenges such as water scarcity, increasing fertilizer costs, labor shortages, and weed infestation, which necessitate efficient crop management strategies for sustainable productivity.

Africa, despite accounting for only 2.6% of global rice cultivation area and 4.6% of the population, produces an average of 14.6 million tonnes of rice annually on 7.3 million hectares, as reported by AfricaRice (2022). West Africa dominates the continent's rice production, covering 56.5% of the land area, approximately 3.7 million hectares. In Nigeria, rice has become a staple food across all social classes, with demand surpassing other staples. The country's annual rice consumption is 5.4 million metric tons, worth over \$9.2 billion. However, domestic production only reaches 2.3 million metric tons, resulting in a significant import deficit of 3.1 million metric tons (Federal Ministry of Agriculture and Rural Development) FMARD. (2021). Nigerian farmers face substantial challenges in boosting productivity, including optimizing establishment methods, effective weed control, and fertilizer application, all of which significantly impact rice yields, as noted by Arouna *et al.* (2017).

Faro 44, has lately become one of the most widely spread rice varieties. In comparison to most local cultivars, Faro 44 rice paddy is one of the most desirable cultivars available to farmers since it is of higher quality, with much higher productivity and production success (National Bureau of Statistics and Presidential Initiative on Rice) NSPI. (2024).

It has a reasonable amount of starch and has a good malting quality and germination capacity. Faro 44 can be cultivated twice or more in a year under irrigation farming, depending on the temperature and soil fertility. Under ideal conditions, the production of Faro 44 can vary from 7 to 10 tonnes per hectare NSPI (2024).

It is known for its superior milling qualities, which promote a better end product during milling. It has a minimal chance of breaking during processing due to its mild water absorption and rupturing tendency around 60-65°C NSPI (2024).

Table 1: Nigerian Seed Portal Initiative on FARO-44 (SIPI-692033)

FARO-44 (SIPI-692033)	
Crop Name	Rice
National Code	NGOS-91-44
Variety Name	FARO-44
Original Name	SIPI-692033
Outstanding Characteristics	Long grain, optimum production under low management.
Agroecological Zones	Forest Transition/Derived Savanna, Humid Forest
Origin/Source	Taiwan
Developing Institute	WARDA/ IITA/ NCRI
Breeder(s)/Collaborators	T.M. Masajo, B.N. Singh, O.A. Oladimeji
Potential Yield (t/ha)	6-8 (t/ha)
Year of Release:	1990
Year of Registration	1991

Source: Nigerian Seed Portal Initiative (2024)

Rice production faces numerous challenges, with weed growth being the most significant obstacle. Weeds can reduce rice yields by 75-100% due to competition for resources like water, nutrients, and light. (Akobundu, 2011; Imeokparia, 2011; Lavabre, 2011). No-tillage rice is more vulnerable to weed competition than transplanted rice, especially when using dwarf varieties and fertilizers. Poor weed control can lead to 40% production losses. Early weed control is crucial in direct sowing, where rice seeds and weeds germinate simultaneously. Farmers have various weed control methods, including chemical treatments, traditional practices, and manual weeding (Street and Lanham, 2016). Effective weed management requires precise timing and method selection, with herbicide efficacy being critical. Researchers have identified effective herbicides for different growth stages, including pre-plant, burn-down, pre-emergence, and post-emergence treatments. (Mahajan and Chauhan, 2022; Allen, 2012). Specific herbicides like thiobencarb, pendimethalin, and ethoxysulfuron have proven effective in controlling weeds in direct-seeded rice systems (Kumar *et al.*, 2018; Mahajan and Chauhan, 2022).

In Nigeria, rice farmers employ various planting techniques, including broadcasting, dibbling on ridges, and random or row transplanting (Fukagawa and Ziska, 2019). While row transplanting is touted as a means to increase rice yields in lowland areas, it demands substantial water and labor resources. To address these challenges, direct seeding is now being advocated as a more efficient and labor-saving approach that conserves water (Kamai *et al.*, 2020). Manual weeding is the traditional method, but it's no longer viable due to labor shortages and increasing costs. Moreover, distinguishing between rice seedlings and weeds, particularly grasses, is difficult during the early growth stage,

making manual weeding ineffective. (Kamai *et al.*, 2020). Therefore, herbicides are considered the most effective solution for weed control in direct-seeded rice (DSR) (Sanjoy *et al.*, 2019). Pre-emergence herbicide application is crucial for efficient weed management in DSR. However, selecting the right herbicide is essential for cost-effective weed suppression. Environmental factors, such as soil moisture, can impact herbicide efficacy and crop safety by affecting absorption, translocation, or metabolism. To boost rice production and meet the growing population's demands, it's essential to optimize rice planting methods, nitrogen rates, and herbicide application timing based on prevailing conditions (Sanjoy *et al.*, 2019).

Despite the importance of optimizing rice production, there is a lack of knowledge on the best planting method and herbicide application timing for achieving high yields in this agro-ecological zone (Adeosun *et al.*, 2019; Kamara *et al.*, 2021). This study aims to fill this knowledge gap by investigating the effects of different planting methods and herbicide application timings on rice productivity, with the goal of identifying the most effective practices for improving yields.

Problem Statement

Rice (*Oryza sativa*) is one of the most important staple food crops consumed in Nigeria and across the world. Despite increased demand for rice due to rapid population growth, rice productivity in Nigeria remains relatively low compared to its production potential. One of the major constraints to rice production is poor crop establishment resulting from inappropriate sowing methods and ineffective weed management practices. Different sowing methods influence plant population, nutrient utilization, weed competition, and ultimately grain yield.

Weed infestation is another major factor limiting rice productivity in Nigeria. Weeds compete with rice plants for nutrients, water, light, and space, especially during the critical growth stages. Herbicides are commonly used for weed control; however, improper timing of herbicide application may reduce weed control efficiency and negatively affect crop growth and yield. Although several studies have been conducted on rice production, limited information exists on the combined effects of sowing methods and timing of herbicide application on the performance of FARO-44 rice variety under the ecological conditions of Badeggi, Niger State. Therefore, there is a need to determine the most suitable sowing method and optimum herbicide application timing for improved growth and yield of FARO-44 rice variety.

Aim of the Study

This study aims to investigate the influence of sowing methods and timing of herbicide application on the growth and yield of FARO-44 rice variety in Badeggi, Niger State, Nigeria.

Specific Objectives

The specific objectives of the study are to:

1. evaluate the effect of different sowing methods on the growth and yield of FARO-44 rice variety;
2. determine the influence of herbicide application timing on the growth and yield of FARO-44 rice variety;
3. assess the interaction effects of sowing methods and herbicide application timing on yield components and grain yield of FARO-44 rice variety;
4. identify the most effective sowing method and herbicide application timing combination for optimum rice productivity in Badeggi, Niger State.

Materials and Method

Description of the Experimental Site

The experiment was conducted at the research field of National Cereals Research Institute headquarters, Badeggi, Niger state. National Cereals Research Institutes Badeggi experimental field is located at (latitude 9°04'10.05''N and longitude 0°01'13.31''E), in the southern Guinea Savannah Agro Ecological Zone of Nigeria. The experiment was carried out during the wet season of 2021 and 2022.

Treatments and Experimental Design: The trials were carried out in two years in the raining season. The experiment consisted of factorial combinations of five planting methods (dry-seeding broadcasting, wet-seeding broadcasting, dry-seeding dibbling, wet-seeding dibbling and row transplanting methods) and two levels of timing of herbicides application (2 and 3 weeks after sowing). The (15) treatments combinations with three replications were laid down factorial in a split-plot design with timing of herbicide application and NPK fertilizer rate allocated to the main plot while sowing methods were designated to the sub-plot. The gross plot size was 9m² (3m x 3m) and net plot size was 4m² (2m x 2m).

Agronomic Practices

Land Preparation: The experimental field was prepared according to standard procedures, involving ploughing, harrowing, leveling, and manual bounding. In both locations, nursery beds were created for sowing seeds and raising seedlings, which were later transplanted to the field.

Seed/Seedling: Direct seeding and broadcasting were done using both dry and pre-germinated seeds. A nursery was established for the seedlings, which were later transplanted at 14 days after establishment at a rate of 2 seedlings per hole. Both transplanting and direct seeding were done with a spacing of 20 x 20 cm. The FARO 44 rice seed variety was used, with the following seeding rates: 25 kg/ha for transplanting, 50 kg/ha for direct seeding, and 60 kg/ha for broadcasting.

Fertilizer Application: A basal application of NPK 15:15:15 fertilizer was applied on the day of sowing or transplanting, prior to sowing or transplanting. The first topdressing with Urea was applied 3-4 weeks after sowing or transplanting, followed by a second topdressing with Urea 6-8 weeks after sowing or transplanting, according to the specified fertilizer rates for each treatment.

Disease and Pest control: Throughout the experimental period, there were no occurrences of pest or disease outbreaks. As a result, no pesticides were applied during the experiment.

Harvesting: The rice field was harvested when 80-85% of the panicles had turned yellow or brown, which occurred around 14-16 weeks after sowing (WAS). Harvesting was done using a rice sickle.

Threshing and Winnowing: Threshing was done manually using a drum on a tarpaulin. The seeds were then separated from the chaff through winnowing, a process that uses air to blow away the lighter chaff, leaving the heavier seeds behind.

Growth and Yield Parameters

In each plot, five hills were randomly selected and tagged for data collection throughout the experimental period. The following growth and yield parameters were recorded:

Growth Parameters

Plant Height (cm)

Plant height was measured at 10 weeks after sowing (WAS) and at harvest using a meter rule. Measurements were taken from ground level to the apical bud of the tagged plants, and the mean height was recorded.

Number of Tillers

The number of tillers was counted from the tagged plants at 10 WAS, and the average number of tillers per plant was recorded.

Days to 50% Flowering

Days to 50% flowering were determined by counting the number of days from sowing to the stage when approximately 50% of the plants in each plot had flowered.

Days to Maturity

Days to maturity were recorded as the number of days from sowing to the harvesting date for each treatment.

Yield Parameters

Number of Seeds per Panicle

The number of seeds per panicle were determined by threshing the selected tagged panicles, counting the seeds obtained, and recording the average value.

Seed Yield per Panicle (g)

Seeds obtained from the selected panicles after threshing were weighed using a sensitive weighing balance, and the mean seed weight per panicle was recorded.

Grain Yield (t ha⁻¹)

Total grain yield at harvest was determined by weighing grains obtained from each net plot using a Mettler Scale Model 1210. The values obtained were converted to tonnes per hectare (t ha⁻¹).

Statistical Analysis

Data collected from the experiment were subjected to Analysis of Variance (ANOVA) using the General Linear Model (GLM) procedure in GENSTAT statistical software (2008 edition). The experiment consisted of a factorial combination of five sowing methods and two herbicide application timings arranged in a Randomized Complete Block Design (RCBD) with three replications.

The statistical model adopted for the analysis was:

$$Y_{ijk} = \mu + B_i + S_j + H_k + (SH)_{jk} + \sum_{ijk}$$

Where:

- Y_{ijk} = observed value of the dependent variable;
- μ = overall experimental mean;
- B_i = effect of the i^{th} block (replication);
- S_j = effect of the j^{th} sowing method;
- H_k = effect of the k^{th} herbicide application timing;
- $(SH)_{jk}$ = interaction effect between sowing method and herbicide application timing; and
- $\sum_{ijk}$ = random experimental error associated with each observation.

Whenever significant differences were detected among treatment means, separation of means was carried out using the Least Significant Difference (LSD) test at the 5% probability level ($P \leq 0.05$).

Result and discussions

Assessment of the Physical and Chemical Properties of the Experimental Soil at Badeggi During the 2021 and 2022 Wet Seasons

Table 2 presents the physical and chemical properties of the soil at the experimental site in Badeggi, Niger State during the 2021 and 2022 wet seasons. The result showed that the soil texture was predominantly sandy clay, with a slightly acidic pH range of 5.16 to 5.4 across both years. The soils had a moderate organic carbon content of 2.5-2.8%, relatively low total nitrogen levels, moderate available phosphorus, and low exchangeable cation levels, consistent with the soil characteristics described by Peter *et al.* (2006)

Table 2: Physical and Chemical Properties of Soil at the Experimental Site in Badeggi, Niger State During the 2021 and 2022 Wet Seasons

Properties	Badeggi (2021)	Badeggi (2022)	Combined
PH	7.3	6.9	7.1
O.C.%	1.82	1.80	1.81
O.M.%	3.12	3.09	3.11
N%	0.35	0.28	0.32
Avail P (ppm)	12.35	8.43	10.39
K	0.34	0.30	0.32
Na	0.21	0.19	0.20
Ca	3.56	3.21	3.39
Mg	2.86	2.15	2.51
EA	0.50	0.67	0.59
TEB	6.97	5.85	6.41
CEC	7.47	6.52	7.00
B.S.%	93%	89%	91%
Particle size analysis			
Sand %	78.6	74.6	76.6
Silt %	5.4	5.4	5.4
Clay %	16	20	18
Texture	Sandy loam	Sandy loam	Sandy loam

Source: Laboratory analysis by the Soil Science Department, National Cereals Research Institute, during the 2021 and 2022 cropping seasons.

Effect of Sowing Methods and Herbicide Application Timing on the Growth and Yield of FARO-44 Rice Variety in Badeggi During the 2021 and 2022 Wet Seasons

Table 3 shows the effects of sowing methods and timing of herbicide application on plant height, number of tillers, days to 50% flowering, days to maturity, number of seeds per panicle, seed yield per panicle, 1000-grain weight, and grain yield per hectare of FARO-44 rice variety at Badeggi, Niger State, during the 2021 and 2022 wet seasons.

Plant Height

The result showed that transplanting significantly produced the tallest plants (86.59 and 128.01 cm) in 2021 and 2022, respectively, compared with the other sowing methods. The increased plant height observed under transplanting may be attributed to better plant establishment, reduced competition, and improved nutrient utilization. Herbicide application at 2 weeks after sowing (WAS) significantly resulted in taller plants (85.19 and 104.75 cm) compared with herbicide application at 3 WAS in both years. This may be due to early weed suppression, which reduced crop-weed competition during the critical growth stage of rice. There was no significant interaction between sowing methods and herbicide application timing on plant height, indicating that both factors acted independently. The findings agree with the reports of Adeosun *et al.* (2019), who observed improved rice growth under transplanting methods and early weed control practices.

Number of Tillers

Transplanting significantly produced the highest number of tillers (17.55 and 20.33) in both years compared with other sowing methods. Early herbicide application at 2 WAS also significantly increased the number of tillers compared with application at 3 WAS. The higher tiller production recorded under transplanting could be associated with reduced plant competition and enhanced root establishment. Early weed control possibly improved nutrient availability and moisture utilization, thereby encouraging tiller formation. This finding is consistent with the observations of Kamara *et al.* (2021), who reported that effective weed management and proper crop establishment improved tillering ability in rice.

Days to 50% Flowering

The transplanting method significantly delayed flowering, recording 69.94 and 70.33 days in 2021 and 2022, respectively, compared with other sowing methods. Broadcasting methods attained 50% flowering earlier than transplanting and dibbling methods. However, herbicide application timing had no significant effect on days to 50% flowering. The delayed flowering observed under transplanting may be attributed to prolonged vegetative growth due to better nutrient uptake and crop vigor.

Days to Maturity

The results indicated that transplanting significantly delayed maturity compared with broadcasting and dibbling methods. Although all treatments showed relatively similar maturity periods ranging from 115.94 to 116.50 days, herbicide application at 2 WAS significantly resulted in earlier maturity than application at 3 WAS. The earlier maturity observed under early herbicide application may be

associated with reduced weed competition, which enhanced efficient utilization of growth resources by rice plants.

Number of Seeds per Panicle

Transplanting significantly produced the highest number of seeds per panicle in both years compared with the other sowing methods. Similarly, herbicide application at 2 WAS significantly increased the number of seeds per panicle compared with application at 3 WAS. The superior performance of transplanting may be due to improved crop establishment and reduced intra-specific competition, which enhanced assimilate production and grain formation.

Seed Yield per Panicle

The transplanting method significantly produced the highest seed yield per panicle compared with the other sowing methods. Herbicide application at 2 WAS also significantly enhanced seed yield per panicle relative to herbicide application at 3 WAS. This result suggests that early weed control improved photosynthetic efficiency and assimilate partitioning towards grain development.

1000-Grain Weight

Transplanting significantly recorded the highest 1000-grain weight compared with the other sowing methods. Herbicide application at 2 WAS significantly improved 1000-grain weight relative to herbicide application at 3 WAS. The increased grain weight may be attributed to better nutrient availability and lower weed interference during grain filling stages.

Grain Yield per Hectare

The result revealed that transplanting significantly produced the highest grain yield per hectare (4882.5 and 6073 kg ha⁻¹) in 2021 and 2022, respectively, compared with the other sowing methods. Herbicide application at 2 WAS significantly enhanced grain yield compared with application at 3 WAS. Significant interaction effects between sowing methods and herbicide application timing were observed on grain yield per hectare. The superior grain yield obtained under transplanting combined with early herbicide application may be attributed to better crop establishment, reduced weed competition, and efficient utilization of nutrients and moisture. This finding agrees with the reports of Chikoye *et al.* (2020), who observed higher rice yield under proper planting methods and timely weed management practices.

Table 3: Effect of Sowing Methods and Timing of Herbicide Application on Plant Height, Number of Tillers, Days to 50% Flowering, Days to Maturity, Number of Seeds per Panicle, Seed Yield per Panicle, 1000-Grain Weight and Grain Yield per Hectare at Badeggi, 2021 and 2022 Wet Seasons

Treatments	Plant Height (cm)		Number of tillers		Days to 50% Flowering		Days to Maturity		Number of seeds per panicle		Seed Yield per Panicle (Kg)		1000-Grain Weight (g)		Grain Yield per Hectare (tons)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Sowing Methods (S)																
Broadcast dry	82.82d	89.84b	11.54e	15.17d	67.11c	67.17d	116.00c	116.17b	176.24d	118.83e	84.53d	83.66d	22.79bc	23.87d	2977.54c	3833.33d
Broadcast wet	82.21e	85.33d	11.69d	13.83e	67.28c	67.00e	115.94d	116.17b	177.49c	134.50d	8777.56c	82.50e	22.87bc	24.17c	2638.47d	3930.56cd
Dibbling dry	84.49c	88.38c	13.99b	18.17b	68.39b	68.00b	115.56e	115.67c	179.41b	142.50e	89.38c	86.82c	23.56b	24.11b	3152.50c	4333.33c
Dibbling wet	85.67b	89.12b	12.78c	16.50c	68.33b	67.83c	116.06b	116.11b	179.39b	157.50	92.57b	96.16b	23.92b	24.44a	3495.69b	5277.78b
Transplanting	86.59a	128.01a	17.55a	20.33a	69.94a	70.33a	116.44a	116.50a	182.18a	149.50	105.13a	107.83a	24.71a	24.48a	4882.50a	6073.19a
SE±	0.03	18.82	0.04	0.00	0.29	0.00	0.25	0.02	0.06	0.01	0.07	0.00	0.05	0.05	110.10	83.08
Timing of Herbicide Application (H)																
2 WAS	85.19a	104.75a	13.93a	17.26a	68.47	68.06	116.24a	116.38a	179.65a	142.47a	95.54a	92.39a	23.76a	24.22b	3576.91a	4883.33a
3 WAS	83.52b	87.53b	13.09b	16.33b	68.37	68.06	115.76b	115.87b	178.65b	139.66b	90.92b	90.40b	22.73b	24.16b	3201.78b	4495.94b
SE±	0.02	11.90	0.03	0.00	0.19	0.00	0.16	0.02	0.04	0.00	0.04	0.00	0.03	0.03	69.64	52.54
Interactions																
S x H	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**

Source: Field experiment and laboratory analysis conducted at the National Cereals Research Institute during the 2021 and 2022 wet seasons.

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. ¹Weeks after sowing; ²not significant difference at 5% level of probability

Interaction Effects of Sowing Methods and Herbicide Application Timing on Grain Yield of FARO-44 Rice Variety

Table 4 shows the interaction effects of sowing methods and herbicide application timing on grain yield per hectare of FARO-44 rice variety during the 2021 and 2022 wet seasons at Badeggi, Niger State.

The result indicated that transplanting combined with herbicide application at 2 WAS significantly produced the highest grain yield compared with the other treatment combinations. In 2022, transplanting combined with herbicide application at both 2 WAS and 3 WAS produced statistically similar grain yields per hectare.

The enhanced yield performance under transplanting and early herbicide application may be attributed to efficient weed suppression during the critical growth period, improved plant

establishment, and increased nutrient uptake. The interaction effect suggests that the effectiveness of herbicide timing depended on the sowing method adopted.

These findings are consistent with previous studies which reported that appropriate crop establishment methods combined with timely weed management significantly improve rice productivity under lowland conditions.

Table 4: Interaction Effect of Sowing Methods (S) x Timing of Herbicide (H) Application on Rice Grain Yield per Hectare at Badeggi in 2021 and 2022

		Timing of Herbicide Application			
		Badeggi 2021		Badeggi 2022	
Sowing Methods	2WAS		3WAS	2WAS	3WAS
Broadcast dry	2506.19h		2662.78	3444.44h	4222.22e
Broadcast wet	3144.44e		2132.50i	3722.22g	4138.89f
dibbling dry	3221.39d		3083.61f	4333.33d	4333.33d
Dibbling wet	4328.61c		3048.89f	4888.89c	5666.67b
Transplanting	5081.11a		4683.89b	6090.83a	6055.56a
SE (±)		64.6		65.4	

Source: Computed from field experimental data obtained from trials conducted at the National Cereals Research Institute during the 2021 and 2022 wet seasons.

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. ¹Weeks after sowing; ²not significant difference at 5% level of probability.

Discussions

Transplanting method of sowing produced significantly better plant growth performance and increased in grain parameters and grain yield compared to other methods of sowing. This could be as a result of taller plants, increased tiller count, higher biomass and dry matter accumulation, more panicles, higher seed yield per hill, and greater photosynthetic capacity. These was consistent with findings by Kawure *et al.* (2023), emphasizing that transplanting and direct seed dibbling methods generally resulted in higher yields compared to seed drilling and broadcasting methods.

Application of herbicide at 2WAS produced significantly increased grain yield per hectare compared to 3WAS of herbicide application in both years.

Table 4 result in 2021 indicated the interaction on the grain yield revealed that, the transplanting method of sowing with herbicide application at 2weeks after sowing (2WAS) produced significantly higher grain yields compared to other sowing methods and herbicide application timings. In 2022 however, transplanting method of sowing with herbicide application at 2WAS produced significantly higher grain yield per hectare but statistically at par with transplanting method of sowing with herbicide application at 3WAS.

This indicates that the superiority of transplanting sowing method for increasing rice grain yield per hectare in the study area. Herbicide application at 2WAS is the most effective timing for enhancing grain yield when using the transplanting method.

Conclusion

The results of this study demonstrated that both sowing methods and timing of herbicide application significantly influenced the growth and yield performance of FARO-44 rice variety at Badeggi during the 2021 and 2022 wet seasons. Among the sowing methods evaluated, transplanting consistently produced superior agronomic performance in terms of plant height, number of tillers, yield components, and grain yield per hectare compared with broadcasting and dibbling methods. This indicates that transplanting provides better crop establishment, improved resource utilization, and reduced early weed competition.

Similarly, herbicide application at 2 weeks after sowing (WAS) was more effective than application at 3 WAS, resulting in improved growth parameters and higher grain yield. Early herbicide application enhanced weed control during the critical growth stages of rice, thereby reducing competition for nutrients, water, and light.

The interaction effects revealed that the combination of transplanting and herbicide application at 2 WAS produced the highest grain yield across both years, although interaction was significant only for grain yield per hectare. This suggests that optimal rice productivity is achieved when appropriate planting methods are integrated with timely weed management practices.

Overall, the study concludes that transplanting combined with herbicide application at 2 WAS is the most effective agronomic practice for maximizing growth and grain yield of FARO-44 rice variety under the conditions of Badeggi, Niger State, Nigeria.

Recommendations

Based on the study's findings, the following recommendations are made:

1. Transplanting is the recommended planting method for improved rice productivity in the study area.
2. Applying herbicides at 2 weeks after sowing (2 WAS) is recommended to enhance rice production.
3. For optimal results, combine transplanting with herbicide application at 2 WAS to boost rice growth, development, and yield, and maximize profits.

4. As a suitable alternative to transplanting, dibbling wet sowing with 2 WAS herbicide application is recommended for the study area.

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RESPONSE OF BAMBARA GROUNDNUT (*VIGNA SUBTERRANEA* [L.] VERDC.) TO A SINGLE SUPER PHOSPHATE APPLICATION IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT: The trial was conducted in the Institute of Agricultural Research (IAR) farm, located at Samaru, Nigeria, in two-year field trial (2019-2020) to identify the reaction and performance of Bambara groundnut landraces to single super phosphate (SSP) fertilization under Northern Guinea Savannah conditions. The experiment was tested on three landraces (Burkina, Nav-4, and Black) and three SSP rates (0, 45, and 90 kg P₂O₅ ha⁻¹) in a three-replication Randomized Complete Block Design. The findings demonstrated that 90 kg P₂O₅ ha⁻¹ had a significant positive effect in terms of nodulation, biomass production, pod yield, seed yield, shelling percentage and hundred-seed weight. Nav-4 landrace was confirmed as superior vegetative performance (plant height, canopy spread, leaf area index, and growth rate) with a maximum seed yield, shelling percentage, and biomass weight. The black landrace produced the largest number of pods and seeds. Correlation analysis showed that there was a strong positive correlation between seed yield and pod weight ($r = 0.96$), shelling percentage ($r = 0.50-0.56$), and biomass weight ($r = 0.72$). Path analysis found a pod weight as the key yield determinant, which explained 78-86% of the seed production variation. It was economically shown that the most profitable rates of net returns in 2020 were 90 kg P₂O₅ ha⁻¹: N315,468 (Burkina), N327,834 (Nav-4), N334,037 (Black). The study concludes that the use of SSP at 90 kg P₂O₅ ha⁻¹ in combination with Nav-4 landrace is the best option to achieve maximum Bambara groundnut production in Northern Guinea savannah of Nigeria.

KEYWORDS: Northern Guinea Savanna, Bambara groundnut, Single super phosphate, Landraces, and Response.

Introduction

Bambara groundnut (*Vigna subterranea* [L]) Bambara groundnut ranks as the third most significant pulse crop in Africa, after groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata*) (Shiyam *et al.*, 2016). The nutritional value of the crop is high, with a protein content of 9.6-40% (Nwidi *et al.*, 2020), which makes the crop a significant source of protein to the people who cannot afford animal protein. Bambara groundnut grains are rich in carbohydrates (55.5–70.0%), proteins (17–24%), lipids (4–12%), fibre (3–12%), and ash (3–5%), and provide 362–414 kcal/100 g of metabolizable energy, contributing to their value as a complete food (Halimi *et al.*, 2019). Through symbiosis with nitrogen-fixing rhizobia, Bambara groundnut (BGN) can contribute approximately 4–200 kg N ha⁻¹ to the soil (Puozaa *et al.*, 2017).

Although these are the advantages, the production of Bambara groundnuts is still at low levels of production with low yields. The most prominent world producer is Nigeria with over 100,000 tonnes in 2017 (FAOSTAT, 2017) but agricultural production in the field of small holder farmers is far less than the genetic potential of the crop (Hillocks *et al.*, 2021). Despite its nutritional and agronomic importance, Bambara groundnut generally produces low yields ranging from 300 to 850 kg ha⁻¹, largely due to phosphorus (P) deficiency, particularly in acidic soils (Mayes *et al.*, 2019; Temegne *et al.*, 2019). This low productivity is attributed to the crop's high sensitivity to P deficiency, as phosphorus plays a critical role in nodulation and biological nitrogen fixation (Nziguheba *et al.*, 2016).

Single Super Phosphate (SSP) is a compound of 16 percent P⁻³-₂O⁻⁴-₅ ha⁻¹, which has a formula, Ca (H₂PO₄)₂H₂O, and includes sulfur and calcium (Prakash, 2023). It has been reported that P fertilization promotes crop growth through solubilization and P uptake in Bambara groundnut (Nweke and Emeh, 2013; Temegne *et al.*, 2018).

The planting materials used mostly are local landraces that have different seed morphology (Mohammed *et al.*, 2016), thus are genetically different. Very little research has been done on the interaction between phosphorus fertilization and landrace selection in Nigeria. This study, therefore aimed to:

1. Evaluate the growth and yield potential of Bambara groundnut landraces in response to a single super phosphate application.
2. Determine the optimum level of single super phosphate for good growth and yield of Bambara groundnut landraces.

Materials and Method

These tests were done in the 2019 and 2020 wet seasons at the Institute of Agricultural Research Farm, (IAR), Ahmadu Bello University (ABU), Samaru -Zaria (Latitude 11° 11'N and Longitude 7° 38'15"E) located in the Northern Guinea Savannah of the agro- ecological zone of Nigeria. The treatments included three Bambara groundnut landraces (Burkina, Nav-4 and Black) and three levels of phosphorus using single super phosphate (0, 45 and 90 kg P₂O₅ ha⁻¹). The experiments had been planned in a three replication, Randomized Complete Block Design. The plot size was 11.25 m² (2.5 m x 4.50 m) and had 6 ridges, with the net plot of 2 ridges (3.75m x 2).

Glyphosate was sprayed at 4 litres ha⁻¹ before undertaking land preparation. The soil was plowed and plowed using harrows with 75cm spacing and plots and replications were made based on experiment design. On 28 June 2019 and 26 June 2020, inter- and intra-row spacing of 75 and 30 cm was used to plant respectively. At 3 WAS two seeds were put in each hole and thinned to one plant per stand. Side placement was used with SSP at 5 cm against plants at sowing depending on treatments (0, 45 and 90 kg P₂O₅ ha⁻¹) and paraquat and metolachlor were applied at sowing (4 litres ha⁻¹ each) and three additional hoe weedings at 3, 6 and 9 WAS. Aphid control was done by the application of Profenofos 40% + cypermethrin 4% EC twice at 500 ml ha⁻¹ at 6 and 8 WAS. They were harvested when physiological maturity occurred where the leaves were yellowish brown and pods brown. Stand count, plant height (cm), canopy spread (cm), number of branches, biomass weight, number of nodules at 30 and 60 days, leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), number of pods per plant, weight of the pod per plant, pod yield (kg ha⁻¹), seed yield (kg ha⁻¹), haulm yield (kg ha⁻¹), harvest index, shelling percentage, and hundred-seed weight (g) data were taken.

Data collected was analyzed and compared in terms of ANOVA using the General Linear Model (GLM) procedure in (statistical analysis software) SAS software (version 9.4). Treatments means were separated using DMRT at 5% probability level (Duncan, 1955) to determine significant effects of the treatment. Correlation analysis (Little and Hills, 1978), and path analysis (Singh & Chaudhary, 2019), were done. Farm net income: FNI = TR - TC was used to undertake economic analysis.

Results and discussion

Soil Properties

Both years had the soil that was sandy loam. The soil pH was moderately acidic (4.98 in 2019 and 5.03 in 2020). The level of phosphorus was low, 9.65 mg kg⁻¹ less than 12.15 mg kg⁻¹. The organic

carbon (12.05-13.60 g kg⁻¹) and the total nitrogen (1.48-1.65 g kg⁻¹) were also low, which proved the low soil fertility (Chude *et al.*, 2011).

Table 1: Physical and chemical properties of soils of experimental fields at Samaru during the 2019 and 2020 wet seasons

Years	2019	2020
Soil depth (cm)	0-30	0-30
Soil characteristics		
Physical composition (g kg⁻¹)		
Sand	620	580
Silt	220	240
Clay	160	180
Textural class	Sandy Loam	Sandy Loam
Chemical composition		
P ^H in H ₂ O (1:2.5)	5.85	6.01
P ^H in 0.01m CaCl ₂ (1:2.5)	4.89	5.03
Organic carbon (g kg ⁻¹)	12.05	13.60
Available phosphorus (mg kg ⁻¹)	9.65	12.15
Total nitrogen (g kg ⁻¹)	1.49	1.65
Exchangeable bases (cmolk g⁻¹)		
Ca	2.98	3.05
Mg	0.49	0.56
K	0.15	0.16
Na	0.21	0.24
CEC	3.83	4.01

Soil samples as analyzed in the Agronomy Department, Ahmadu Bello University, Samaru, Zaria.

Effect of SSP on Growth Parameters

In 2019, the power of SSP in 45 kg P₂O₅ ha⁻¹ generated taller (18.29 cm) plants at 3 WAS than the control (14.64 cm) (Table 2). In 2019, SSP at 45 kg P₂O₅ ha⁻¹ at 9 and 12 WAS resulted in plants with a height of 22.00 cm and 27.44 cm at 9 and 12 WAS, respectively. In 2019, SSP of 90 kg P₂O₅ ha⁻¹ was least (26.21 cm) at 3 WAS, and SSP of 45 kg P₂O₅ ha⁻¹ was widest (38.48 cm) at 6 WAS than the control (30.96 cm) (Table 2). At 6 WAS, 90 kg P₂O₅ ha⁻¹ generated SSP at 90 kg P₂O₅ ha⁻¹ created wider canopy (32.33 cm) compared to the control (28.67 cm). In 2019, the mean of branches was higher at 45 and 90 kg P₂O₅ ha⁻¹ than at the control (11.77) at 6 WAS (Table 2). The splendid outcome of SSP at 90 kg P₂O₅ ha⁻¹ was that fresh and dry haulm weight was the most prolific at the majority of all sampling periods in 2019.

Table 2: Effect of SSP levels and landrace on crop vigour, canopy spread, number of branches and plant height of Bambara groundnut at Samaru during 2019 and 2020 wet seasons

Treatment	Rate	Canopy Spread (cm)		Number of Branches		Plant Height (cm)	
	kg P ₂ O ₅ ha ⁻¹	2019	2020	2019	2020	2019	2020
		6WAS	6WAS	9WAS	9WAS	12WAS	12WAS
Landrace (L)							
Burkina		31.83b	29.33	11.86b	12.13b	15.25	26.46b
Nav-4		37.56a	31.00	13.40a	13.60a	16.84	29.06a
Black		34.77ab	30.73	12.93ab	13.40a	16.77	28.26a
SE±		1.135	0.765	0.425	0.452	0.763	0.502
Phosphorus (P)							
Control	0	30.96c	28.67b	11.77b	12.11b	14.64b	26.78b
SSP	45	38.48a	29.89ab	13.56a	13.89ab	18.29a	27.44ab
SSP	90	32.99bc	32.33a	12.22ab	13.78ab	18.27a	28.11ab
SE±		1.466	0.988	0.549	0.584	0.985	0.648
Interaction							
L x P		NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are statistically similar at 5% level using DMRT. WAS = Weeks After Sowing, NS = Not significant.

The highest LAI was 1.22 at 6 WAS in 2020, which was obtained at SSP at 90 kg P₂O₅ ha⁻¹ (Table 3). In 2019, there were many more nodules at 60 days produced by SSP at 90 kg P₂O₅ ha⁻¹ than the control (9.33 and 7.78, respectively) (Table 3). When SSP was applied at 90 kg P₂O₅ ha⁻¹ (5196 kg ha⁻¹) yielded a higher biomass weight in 2019 (3024.9 kg ha⁻¹) and 2020 (2923.4 kg ha⁻¹) than the control (1990.7 and 2261.7 kg ha⁻¹), respectively (Table 3).

Table 3: Effect of SSP levels and landrace on leaf area index, number of nodules and biomass weight of Bambara groundnut at Samaru during 2019 and 2020 wet seasons

Treatment	Rate	Leaf Area Index		Number of Nodules		Biomass Weight (kg ha ⁻¹)	
	Kg P ₂ O ₅ ha ⁻¹	2019	2020	2019	2020	2019	2020
		3 WAS	6 WAS	60 days	60 days		
Landrace (L)							
Burkina		0.65b	0.92	7.93b	17.67	2635.0b	2660.6
Nav-4		0.99a	0.93	9.26a	13.67	3493.4a	2785.1
Black		0.83ab	1.06	8.67ab	14.60	2838.9b	2740.8
SE±		0.116	0.062	0.418	1.763	184.6	117.6
Phosphorus (P)							
Control	0	0.84	0.83b	7.78b	14.22	1990.7c	2261.7c
SSP	45	0.81	0.93b	7.89b	15.00	2300.9c	2563.0b
SSP	90	0.69	1.22a	9.33ab	14.89	3024.9b	2923.4ab
SE±		0.150	0.080	0.506	2.276	238.7	151.9
Interaction							
L X P		NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are statistically similar at 5% level using DMRT. WAS = Weeks After Sowing, NS = Not significant.

Impact of SSP on Yield Components

The mean pods per plant (27.89 in 2019 and 29.89 in 2020) and the fresh and dry pod weight (30.89 g in 2019 and 26.33 g in 2020) were the highest in SSP at 90 kg P₂O₅ ha⁻¹ in 2019 and 2020, respectively, as compared to the control (Table 4). There was a high yield of pods when SSP was applied. In 2020, the control yielded 0.78 tonnes ha⁻¹, SSP at 45kg P₂O₅ ha⁻¹ yielded 1.00 tonnes ha⁻¹, and SSP at 90kg P₂O₅ ha⁻¹ yielded 1.11 tonnes ha (Table 4).

SSP with 90 kg P₂O₅ ha⁻¹ resulted in the greatest number of seeds per plant (37.89 in 2019 and 41.11 in 2020) and yield of seeds (1.00 tonnes ha⁻¹ in 2019 and 1.11 tonnes ha⁻¹ in 2020) than the control (0.33 tonnes ha⁻¹ in both years). In 2019 and 2020, SSP at 90 kg P₂O₅ ha⁻¹ had greater shelling percentage (88.00 and 86.89, respectively) and hundred seed weight (62.33 g and 62.67 g, respectively) than the control (Table 4).

Effect of Landrace

The plants of Nav-4 and Black grew taller and broadened their canopy spread as compared to Burkina in most of the sampling times (Table 4). At 3 WAS in 2019 (0.99), and 9 and 12 WAS in 2020 (2.15), Nav-4 has significantly higher LAI than Burkina (Table 4). In 2019, Nav-4 had more biomass weight (3493.4 kg ha⁻¹) compared to Burkina (2635.0 kg ha⁻¹) and Black (2838.9 kg ha⁻¹) (Table 4). In 2020, the number of pods (25.60) and seeds per plant (31.87) were the highest in the black landrace (Table 4). In 2019, Nav-4 gave more seed yield (1.07 tonnes ha), shelling percentage (86.46%), and hundred seed weight (68.96 g) than other landraces (Table 4).

Table 4: Effect of SSP levels and landrace on pod yield, seed yield, shelling percentage and 100-seed weight of Bambara groundnut at Samaru during 2019 and 2020 wet seasons

Treatment	Rate	Number of Pods Plant ⁻¹		Pod Yield (t ha ⁻¹)		Seed Yield (t ha ⁻¹)		Shelling %		100-Seed Weight (g)	
	kg P ₂ O ₅ ha ⁻¹	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Landrace (L)											
Burkina		24.86	24.80ab	1.27a	1.27	0.93ab	1.07	80.60b	82.60	59.38b	60.53
Nav-4		23.20	22.53b	1.20ab	1.20	1.07a	1.07	86.46a	82.27	68.96a	66.67
Black		24.60	25.60a	0.93b	1.13	0.73b	0.93	80.60b	84.20	65.18ab	66.53
SE±		1.258	0.965	0.102	0.067	0.086		1.818	2.426	2.464	2.442
Phosphorus (P)											
Control	0	14.33c	12.00e	0.67c	0.78c	0.33c	0.33c	70.00b	76.11b	52.33c	50.89c
SSP	45	17.11c	18.44d	0.89bc	1.00b	0.89b	1.00b	84.56ab	83.78ab	64.56b	63.22b
SSP	90	27.89b	29.89b	1.00bc	1.11b	1.00ab	1.11b	88.00a	86.89a	62.33b	62.67ab
SE±		1.625	1.246	0.131	0.083	0.111	0.111	2.348	3.132	3.181	3.153
Interaction											
L x P		*	NS	NS	NS	NS	NS	NS	NS	NS	*

Means followed by the same letter(s) within a treatment group are statistically similar at 5% level using DMRT. * = significant at 5%, NS = Not significant.

Correlation

Correlation analysis in 2019 (Table 5) revealed that pod weight, canopy spread, and biomass weight were strongly and positively correlated with seed yield under SSP application. This indicates that phosphorus from SSP enhanced reproductive growth, particularly pod development. Conversely, dry haulm showed a negative correlation with seed yield, suggesting that excessive vegetative growth did not translate into higher productivity. These findings are consistent with Yaroson *et al.* (2019), who reported that SSP significantly improved pod weight and seed yield in Bambara groundnut, while excessive haulm growth reduced harvest efficiency.

Table 5: Pearson correlation coefficient between the growth and yield parameters of bambara groundnut landraces at Samaru, 2019

	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	0.960**	1									
3	0.503**	0.476**	1								
4	0.071	0.007	0.120	1							
5	0.091	0.017	0.112	0.118	1						
6	0.044	-0.059	0.241	0.006	0.317*	1					
7	-0.011	0.002	0.316*	0.317*	0.230	0.121	1				
8	0.367*	0.369*	-0.090	0.066	0.079	0.211	0.071	1			
9	0.403**	0.396**	0.347*	0.041	0.218	0.066	0.377**	0.023	1		
10	0.255	0.242	0.158	0.211**	0.028	0.524**	0.033	0.023	0.057	1	
11	0.211	0.193	0.398**	0.151	0.378**	0.070	0.191	0.019	0.319*	0.213	1

DF = (n-2) = 44, r = 0.291 (5%) and 0.376 (1%) * = significance at 0.05 and ** = significance at 0.01 level of probability. 1 = seed weight per hectare, 2 = pod weight per hectare, 3 = shelling percentage, 4 = biomass weight per hectare, 5 = hundred seed weight, 6 = leaf area index, 7 = dry haulm, 8 = relative growth rate, 9 = number of branches, 10 = canopy spread and 11 = Plant height.

In 2020 (Table 6), correlation analysis again showed that pod weight was the dominant trait positively associated with seed yield under SSP. Canopy spread and number of branches also correlated positively but contributed indirectly. Negative correlation with dry haulm persisted, reinforcing the idea that reproductive growth is more important than vegetative expansion for yield. These results align with Whitehead *et al.* (2004), who emphasized phosphorus as a limiting nutrient for pod development in legumes, including Bambara groundnut.

Table 6: Pearson correlation coefficient between the growth and yield parameters of Bambara groundnut landraces at Samaru, 2020

	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	0.962**	1									
3	0.561**	0.521**	1								
4	0.723**	0.770**	0.314	1							
5	0.736**	0.753**	0.359*	0.775**	1						
6	0.140	0.084	0.147	0.189	0.206	1					
7	-0.085	-0.035	0.090	0.055	0.297	0.189	1				
8	0.105	0.094	0.127	0.096	0.156	0.100	-0.165	1			
9	0.425**	0.443**	0.450**	0.271	0.468**	0.140	0.043	0.228	1		
10	0.388**	0.411**	0.275	0.412**	0.582**	0.227	-0.079	0.188	0.396**	1	
11	0.037	0.026	0.349*	0.003	0.104	0.054	0.272	0.351*	0.164	0.375*	1

DF = (n-2) = 44, $r = 0.291$ (5%) and 0.376 (1%) * = significance at 0.05 and ** = significance at 0.01 level of probability. 1 = seed weight per hectare, 2 = pod weight per hectare, 3 = shelling percentage, 4 = biomass weight per hectare, 5 = hundred seed weight, 6 = leaf area index, 7 = dry haulm, 8 = relative growth rate, 9 = number of branches, 10 = canopy spread and 11 = Plant height.

Path Analysis

Path analysis in Table 7 confirmed that pod weight had the highest direct effect on seed yield, while canopy spread and branch number contributed indirectly through pod weight. This highlights pod weight as the most critical yield determinant under SSP fertilization. Similar conclusions were drawn by Ibrahim *et al.* (2019), who found pod weight to be the strongest direct contributor to Bambara groundnut yield under phosphorus fertilization.

Table 7: 2019 Direct and indirect contribution

Pod weight	0.928328	0.027317	0.001311	0.002361	0.005951	-0.00527	0.96
Number of seeds plant ⁻¹	0.441884	0.057389	0.008638	0.002069	0.003886	-0.01087	0.503
Seed weight ha ⁻¹	0.015782	0.006428	0.077122	0.0013	0.000689	-0.01032	0.091
Number of branches	0.367618	0.019914	0.016813	0.005963	0.001402	-0.00871	0.403
Canopy spread	0.224655	0.009067	0.002159	0.00034	0.024593	-0.00582	0.255
Plant height	0.179167	0.022841	0.029152	0.001902	0.005238	-0.0273	0.211

Path analysis in 2020 (Table 8) demonstrated that pod weight exerted the strongest direct contribution to yield, while canopy spread and branch number acted indirectly. This confirms the consistency of

SSP's effect across seasons. The findings agree with Vanlauwe *et al.* (2002), who reported that phosphorus fertilization enhances pod filling and seed weight in African legumes.

Table 8: 2020 Direct and indirect contribution

Pod weight	0.885509	0.053641	0.045997	-0.01377	-0.00899	-0.00039	0.962
Number of Seeds plant ⁻¹	0.46135	0.102958	0.02193	-0.01398	-0.00602	-0.00524	0.561
Seed weight ha ⁻¹	0.666788	0.036962	0.061085	-0.01454	-0.01273	-0.00156	0.736
Number of branches	0.39228	0.046331	0.028588	-0.03108	-0.00866	-0.00246	0.425
Canopy spread	0.363944	0.028313	0.035552	-0.01231	-0.02188	-0.00563	0.388
Plant height	0.023023	0.035932	0.006353	-0.0051	-0.0082	-0.01501	0.037

Conclusion and Recommendations

Based on the results of the current research, it can be concluded that using SSP at a rate of 90 kg P₂O₅ ha⁻¹ has a significant positive impact on the growth and yield of Bambara groundnut, achieving the highest pod yield (1.00-1.11 tonnes ha⁻¹), seed yield (1.00-1.11 tonnes ha⁻¹), number of pods (27.89-29.89), shelling percentage (86.89-88.00%), and the Nav-4 landrace showed better performance. It is suitable for most of the Northern Guinea Savanna. Based on the findings of the study, the following recommendations were made:

1. In the case of farmers in the Northern Guinea Savanna of Nigeria, Nav-4 landrace and the use of SSP at 90 kg P₂O₅ ha⁻¹ production are suggested as the combination that would bring farmers the most seed and profitability of Bambara groundnut production.
2. In the case of resource-constrained farmers, application of a minimum of 45 kg P₂O₅ ha⁻¹ should be used to gain reasonable yield increments.
3. Extension services need to change the level of educating farmers about the necessity of phosphorus fertilization and the importance of selecting the landraces, so that demonstration plots should be created to reveal the economic advantage.

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DETERMINANTS OF AWARENESS AND UTILIZATION OF THE NIGERIAN INSTITUTE FOR OIL PALM RESEARCH'S INNOVATION: CASE STUDY OF OIL PALM PRODUCERS IN SOUTH-SOUTH NIGERIA

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ABSTRACT: Despite the significant potential of agricultural research innovations to improve oil palm productivity, a good number of oil palm producers in South-South Nigeria may be lacking the awareness of existing agricultural research innovations developed by NIFOR which could hinder their ability to optimize yields, reduce costs and enhance their livelihoods. Against this backdrop, this study becomes expedient. A multi-stage sampling technique was used to select 360 respondents. Primary data were collected using a structured questionnaire while descriptive and inferential statistics were used to analyze the data. The result on socioeconomic profile indicates that the oil palm producers had a mean age of 59 years with a predominant male composition of 97.50% while the females represented 2.50%. Majority of the respondents (97.50%) were married, while 2.50% were widowed, and an average household size of six persons. Educational attainment was moderately distributed with 35% having primary education, 35.80% secondary education and 29.20% tertiary education which correspond to an average of approximately 11 years of schooling. Awareness of NIFOR's technological innovations was observed in 57.20% of the respondents and was significantly influenced by some of the respondents' socioeconomic characteristics. Key constraints to the utilization of NIFOR technologies as indicated by likert scale ratings, include; inadequate finance, high transportation cost, limited information on NIFOR innovation, lack of government intervention/subsidy, high cost of NIFOR innovations and limited contacts with extension agents. It was suggested that NIFOR, ADP and other agencies should strengthen extension services through targeted awareness campaigns on improved planting and processing materials available at NIFOR. Additionally, government should subsidize agricultural innovations such as planting and processing equipment while policy makers and financial institutions should promote inclusive agricultural financing by expanding access to low-interest loans with flexible repayment plans to enable the oil palm producers conveniently pay for improved planting and processing equipment.

KEYWORDS: Determinants, Oil palm producers, Awareness, Innovations, Utilization, and NIFOR.

Introduction

Agriculture has played a substantive role in the nation's gross domestic product generation, averaging around 24% over a seven year period between 2019 & 2023 (NBS, 2024). Nigeria (1,500,000 MT), currently produces more palm oil than any other African country and ranks number five in the world after Indonesia (46,500,000 MT), Malaysia (19,300,000 MT), Thailand (3,700,000 MT) and Colombia (1,900,000 MT) who are ranked first, second, third and fourth respectively (USDA, 2024). The oil palm industry supplies palm oil and palm kernel oil for both household and industrial uses and also supplies non-edible products including biodiesel (Abdul-Qadir and Abu, 2021). The industry provides income, employment and raw materials for other industries (Ojemade *et al*, 2020).

In achieving its mandate and by extension, finding solution to the unemployment situation in the country, the Nigerian Institute for Oil Palm Research, (NIFOR) has developed cutting-edge technologies that when utilized by the farmers, will create employment, increase income and also improve their general wellbeing (Abdul-Qadir and Abu, 2021)

Established in 1939, NIFOR is currently under the aegis of the Federal Ministry of Agriculture and Food Security (FMAFS) with a mandate to conduct research into the production and products of the Oil palm, Coconuts, Raphia, Shea, Jojoba as well as Date palm, while ensuring the effective transfer of its research outputs to farming households in order to enhance their productivity and living standards.

The Institute has developed numerous cutting-edge research technologies including the Extension Works Seeds (EWS) and the Plantation Establishment Technology (PET), amongst other technologies. The Plantation Establishment Technology (PET) is an important technology in plantation establishment that minimizes losses and plantation abandonment. The NIFOR *Tenera* hybrid seed technology can create employment opportunities for a large number of people in the oil palm value chain when commercialized. This hybrid popularly known as Extension Work Seeds (EWS), is the starting point of the oil palm value chain. Within the value chain, there are other value addition technologies developed by NIFOR, some of which includes; oil palm seedlings/ seedlets production, modern agronomic method of plantation establishment and Small Scale Processing Equipments (SSPE) (NIFOR, 2006). The *Tenera* hybrid or Extension Work Seeds (EWS) released by NIFOR to farmers, has the potential of producing up to 18-25Metric Tones of Fresh Fruit Bunches per hectare per year under good plantation management as against 1-3Metric Tones of Fresh Fruit Bunches/ha/year in the wild or unimproved variety (Okuy *et al.*, 2006).

The Institute also manufactures SSPE for sale to oil palm farmers and processors for milling efficiency and improved extraction rate. The NIFOR SSPE are of three types; (a) NIFOR large; whose capacity is 0.5-1.0 tone FFB/hour and capable of processing FFB from 50-100ha plantation; (b) NIFOR Medium: with a capacity of 0.25-0.50 tone FFB/hr designed for farmers with oil palm holdings of between 20-50ha and; (c) NIFOR Mini, which caters for farmers with less than 20 ha and it is appropriate for cottage palm oil production. Both the NIFOR mini and NIFOR medium are miniature SSPE with slight modification in design. The major difference between the two is that while the latter is automated, the former is fully manual. (NIFOR, 2006)

Although agricultural research innovations have the potential to improve oil palm productivity and sustainability, many oil palm producers in South-South Nigeria may be lacking awareness of these innovations which could hinder their ability to optimize yields, reduce costs and enhance livelihoods. Low awareness rate among the oil palm producers could limit use or adoption of a technology and also significantly impact on the yields and income of the farmers. Research has shown that farmers who have better access to information, training opportunities and institutional support, are more likely to adopt modern oil palm innovations than those who lack such privileges (Tey *et al.*, 2015). Research innovations in the oil palm industry have contributed significantly to improving productivity and sustainability. However, certain barriers can limit their use or adoption. Nonetheless, identifying and addressing these barriers remains critical. (Murphy *et al.*, 2021)

In view of the foregoing, the study specifically: (i) profiled the socio-economic characteristics of the oil palm producers in South-South, Nigeria, (ii) examined the oil palm producers awareness of NIFOR developed innovations (iii) examined the key factors influencing the oil palm producers awareness of NIFOR developed technologies (iv) identified the constraints faced by the farmers in utilizing NIFOR developed technologies

It is hoped that the information derived from this study will be useful to policy makers in making policies aimed at creating awareness and enhancing the use of NIFOR developed technologies among oil palm producers

Research Methodology

Study Area

The research was conducted in South-South Nigeria. The Atlantic Ocean borders the region on the south and Cameroon on the east. The South- South States occupy 85,303 Square Kilometers of land and are made up of six States that include Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers.

The area lies between latitudes 4°45' and 6°2' North of the equator and longitudes 5°1' and 7°2' east of the Greenwich meridian (Tawan, 2006).

Sampling Technique

The researcher worked very closely with the Oil palm Growers Association of Nigeria (OPGAN) in each of the States, which provided the sampling frame of registered oil palm farmers in Edo (1,713), Delta (1,628), and Akwa-Ibom States (1,707) as at the time of this research. A multistage sampling technique was used at 95% confidence level from the oil palm producers' population of 5,048 to get the number of respondents that served as the sample size for the study using the following formula.

$$n = \frac{N}{1 + N * (e)^2}$$

Where:

n = sample size,

N = size of target population,

e = limit of tolerable error (level of significance = 0.05) and

1 = constant.

$$n = \frac{5,048}{1 + 5,048 * (0.05)^2}$$

$$n = 370.6 = 371$$

Data Collection

A multistage sampling technique was used for sampling. Data on socio-economic profile, awareness rate and constraints to the utilization of NIFOR developed technologies were obtained using a set of questionnaire structured in line with the specific objectives of this research. The researcher also engaged the services of the States' Agricultural Development Programme (ADPs) for trained resident enumerators that assisted in the administration of the questionnaire in the States selected.

In the first stage of sampling, three States were purposively selected from the six States in the South-south geopolitical zone of Nigeria for logistical reasons. They include Edo, Akwa-Ibom and Delta States. The second stage involved a purposive selection of all three agro-ecological zones per State, making it nine zones in all. The purposive selection of all three zones across the States was because the crop is cultivated across all the agro-ecological zones. The third stage involved a random selection of two local government areas across each of the agro-ecological zones of the three selected States which brought the LGAs selected to six per State and 18 in all across all three States.

Stage four involved a random selection of two towns/communities from each of the six selected LGAs per State bringing the total number to 12 towns/communities selected per State, and 36 towns/communities across all three States. The last stage was the selection of 371 respondents proportionately, based on the population or concentration of the oil palm farmers in each of the States with 124 oil palm farmers selected in Edo{ Ozalla(10), Udonmora(10), Ikpeshi(10), Igarra(10) , Uromi(10), Eguare(10) , Irrua(10), Ewu(10), Isiuwa(14), Okada(10), Ehor (10) and Eguomhe(10)}; 116 in Delta{ Agbor (10), Isele-uku(10), Onicha-ugbo(10), Ozoro(10), Otor-owhe(9), Akugbene(9), Asaba(10) ,Okoloba(9), Ugheli(10), Agbarho(10), Otumara(10) Edjeba(9), and 120 in Akwa-Ibom{ Afaha Ibesit(10), Ikot Edet(10), Ekpone Ibia(10), Nung Ita(10), Abak(10), Afaha Obong(10) , Ikot-Ekpene(10), Ikot- Obio Nso(10), Obot Inwang(10), Amamong(10), Oron town (10) and Akai Uko(10). However, 11 out of the 371 questionnaire retrieved were not useful, hence, 360 was the sample size for the study.

Data Analysis

Descriptive and inferential statistics were used for this study and they include means, percentages, standard probit regression and ratings from a 5-point likert scale. For the 5-point likert scale ratings, the corresponding values for the categories were 5, 4, 3, 2 & 1 (for very serious, serious, not serious, moderately serious and not a problem respectively). The mean score was calculated as follows: $\frac{5+4+3+2+1}{5} = 3$. This served as the cut-off point. Based on this, any score below 3 ($MS < 3$) was taken as a weak factor and was not considered serious while those with mean score of 3 and above ($MS \geq 3$) were taken as strong factors and considered serious.

Model Specification

The standard (binary) probit regression model specification for analyzing factors influencing awareness is given below, taking a binary value of 1 = aware, 0 = not aware. The model is specified as:

$$P(Y_i=1) = \Phi(B_0+B_1Z_1+B_2Z_2+B_3Z_3+B_4Z_4+B_5Z_5+B_6Z_6+B_7Z_7+B_8Z_8+B_9Z_9)$$

Where:

$Y_i = 1$ if respondent i , is aware, or 0 if otherwise

Φ is the cumulative distributive function of the standard normal distribution

Z_i is a vector of independent variables

B_i is a vector of coefficients to be estimated

Z_1 = Age of respondent (years)

Z_2 = Gender (1 if male, 0 if female)

Z_3 = Household Size (Number of people in the household)

Z_4 = Education (number of years spent in school)

Z_5 = Credit access (₦)

Z_6 = Farm Size (in hectares)

Z_7 = Extension visits (Number of extension visits in the past year)

Z_8 = Ln off-farm income (₦)

Z_9 = Cooperative Membership (1, if member of a cooperative, 0, if otherwise)

Results and Discussions

Socio-Economic Characteristics of the Respondents

The socio-economic characteristics were ascertained and presented in Table 1. The results showed that the mean age of the oil palm farmers was 59 years. This implies that the farmers were still within the productive age of farm production and could still be productive within the next one and a half decade with availability of the requisite farm inputs and other interventions. This result agrees with the findings of Omonfonwan, *et al.*, (2021) who found that oil palm producers in Edo and Delta States of Nigeria, had an average age above 50 years (53 yrs). The result on gender showed that men (97.50%) and women (2.50%) were actively involved in oil palm production but the percentage of men was higher. This agrees with the findings of Awotide *et al.*, (2015) who found that male-headed households dominates agricultural production in Nigeria

Table 1: Distribution of Respondents According to Socioeconomic Characteristics

Response option	Frequency	Percentage	Mean
Age of Farmers			
41-50	54	15.00	59
51-60	146	40.60	
61-70	116	32.20	
71-80 Years	44	12.20	
Gender			
Male	351	97.50	
Female	9	2.50	
Marital Status			
Single			11.1
Married	351	97.50	
Divorced	0	0.00	
Widowed	9	2.50	
Educational Level			
No formal Education	0	0.00	11.1
Primary education	126	35.00	
Secondary Education	129	35.80	
Tertiary Education	105	29.20	
Farming Experience			
11-20 years	180	50.00	20.13
21-30 years	176	48.90	
31-40 years	4	1.10	

Household Size			
1-5	192	53.33	6.33
6-10	160	44.44	
11-14	8	2.22	
Farm Size			
1-5 ha	0	0.00	12.7
6-10 ha	120	33.30	
11-15 ha	240	66.7	
Extension Visit			
None per month	178	49.4	1.33
Once per month	7	1.9	
Twice per month	98	27.2	
Three times and above	77	21.4	
Cooperative Membership			
Yes	171	47.5	
No	189	52.5	
Credit Access			
Yes	170	47.20	
No	190	52.80	
Off-Farm Income (₦) Per Annum			
101,000-200,000 P/A	23	6.39	329,400
201,000-300,000 P/A	26	7.22	
301,000-400,000 P/A	294	81.67	
401,000-500,000 P/A	17	4.72	
Total	360	100.00	

Source: Field survey, 2025

The result on marital status showed that 97.50% were married, while 2.50% were widowed, implying that married people were more. From the result, it can be said that the oil palm producers will most likely handle their farm businesses with a high level of commitment due to household demand.

On educational level, the mean number of years of schooling by the oil palm producers was approximately 11years. This suggests that there were more educated people engaged in oil palm production in the study areas. This agrees with Okere *et al.*, (2024) who found out that a greater proportion (66.7%) of oil palm processors in Agbor, Delta State, Nigeria, had formal education. With this high level of education, there is the tendency that the respondents will understand the need to embrace new innovations if they are aware of its existence.

The distribution of respondents according to farming experience suggests that average number of years of farming was 20 years. Farm experiences acquired over time could have an impact in embracing or adopting new farming methods.

The result on farm size indicates that majority (66.70%) of the farmers had farm holdings of between 11-15 hectares, while 33.30% had a farm size of between 6-10ha. Farm holding of a farmer refers to the piece of land cultivated by the farmer. It is often assumed that farmers who own large farms are richer and are very quick in taking risks of adopting new farming technologies as well as have better access to information on improved farming techniques than farmers with lesser acreages of farmland (Adakaren *et al.*, 2018).

Result on extension visits showed that the average number of extension contact was about once per year. The more extension contacts farmers have, the higher their chances of being aware of new agricultural innovations

On cooperative membership, majority of the respondents (52.50%) were not members while 47.20% were members. It is expected that social participation could facilitate a farmer's awareness and willingness to use agricultural research innovations. Cooperative membership as reported by Umunna *et al.*, (2012) plays a vital role in accessing information as it relates to agriculture.

Majority (52.80%) had no access to credit from either government or private credit agencies while 42.20% of them had access. Lack of credit access by farmers may hinder the use of modern farm method which is capable of increasing agricultural yields and according to Freeman *et al.*, (1998), when farmers are able to access credit, it can help them operate optimally, given fixed resources such as land.

Results on off-farm income showed that the average off-farm income was ₦329,400 per annum, an indication shows that respondents had other source of income aside income generated from farming.

Awareness rate of NIFOR Developed Technologies

Table 2 presents farmers' rate of awareness about NIFOR developed research innovations which includes the NIFOR Extension Works Seeds (EWS), and the Small Scale Processing Equipments (SSPE). Farmers' awareness rate is important for both the farmers and the agricultural sector as a whole. When a great portion of farmers are well-informed about the latest innovations and technologies, they can make informed decisions about adoption which can improve food security and their overall welfare. Results on the rate of awareness shows that 57.20% were aware of NIFOR developed technologies, while 42.80% were not aware.

This agrees with Mbamalu (2019) whose findings showed that knowledge and awareness of renewable energy and its characteristics were high in Lagos and Ogun states, but disagrees with the

findings of Kendall *et al.*, (2017) who observed low awareness of farmers and adoption of precision agriculture on family farms in China

Table 2: Awareness rate of NIFOR Developed Technologies

Category	Frequency	Percentage (%)
I am aware of NIFOR developed EWS and SSPE	206	57.20
I am not aware of NIFOR EWS and SSPE	154	42.80
Total	360	100.00

Source: Field survey, 2024

Factors influencing farmers awareness of NIFOR developed Technologies

Table 3 presents the standard probit analysis of factors influencing farmers' awareness of NIFOR developed technologies. Four variables significantly influenced the oil palm farmers' awareness of NIFOR developed technologies. The empirical results from the analysis revealed that the coefficients of household size, farm size, extension visits and cooperative membership were statistically significant.

Table 3: Probit Estimates for Factors Influencing Awareness of NIFOR Developed Technologies Among the Oil Palm Farmers

Variables	Coefficients	t-values	Marginal Effects
(Intercepts)	-12.115	6.067	-1.359
Age	0.007	0.016	0.001
Gender	0.253	1.302	0.028
Household size	0.506*	0.275	0.057*
Education	0.036	0.038	0.004
Farm size	0.149**	0.060	0.017**
Extension visit	2.006***	0.481	0.225***
Ln off farm income	0.440	0.400	0.049
Cooperative membership	1.102**	0.495	0.124**
Observations	360		
Pseudo R2	0.6986389		
Log Likelihood	-74.064		
Akaike Information Crit.	166.128		

Source: Field survey, 2024 *significant at 10% **significant at 5%, ***significant at 1%

The coefficient of household size (0.506), $P=0.1$, indicates a positive and significant relationship between household size and farmers' awareness. The marginal effect of 0.057 indicates that household size increases the probability of a farmer being aware of NIFOR developed technologies by 5.7% holding other factors constant. This is an indication that larger household sizes are associated with increased awareness of agricultural research innovations as members of a large household may have more opportunities for exposure to information about modern farming technologies because the larger the household size, the higher the chances of at least one or two members of the households, having access to the information.

The coefficient of farm size (0.149), $P=0.05$, indicates a positive and significant relationship between farm size and farmers' awareness about NIFOR developed technologies at 5% probability level. The marginal effect of farm size (0.017) represents the change in probability of a farmer being aware of NIFOR developed technologies when farm size increases by one unit (e.g. one more hectare). Specifically, the marginal effect of 0.017 suggests that a one-unit increase in farm size, increases the probability of an oil palm farmer being aware of NIFOR developed technologies by 1.7% holding other factors constant. This further suggests that larger farm sizes are associated with increased awareness of agricultural research innovations due to the fact that farmers with a large farm size, tend to have more financial resources or flexibility to invest in agricultural innovation compared to farmers with small holdings who may be constrained by finances as a result of reduced farm income. Cameron and Trivedi (2005) emphasized the importance of interpreting marginal effects in probit models to understand the impact of explanatory variables.

The coefficient of extension visits (2.006), $P=0.01$, showed a positive and significant relationship between awareness and extension visits. This indicates that oil palm producers who had access to extension services were more predisposed to information on research innovation or technologies developed by NIFOR thereby highlighting the crucial role of extension in creating awareness. This is in line with the findings of Oduniyi, Oluwaseun Samuel, Antwi Micheal, (2018) who revealed that extension services had a positive influence on climate change awareness. The marginal effect for extension visit (0.0225) suggests that extension visits increased the probability of awareness of NIFOR developed technologies by 22.5% holding other factors constant. Oparinde, Amos, Aturamu, & Daramola, (2018), also stated that extension education delivered by extension agents boosts farmers' awareness.

The coefficient of cooperative membership (1.102), $P=0.05$, was positive and significantly related to farmers awareness of NIFOR developed technologies at 5% level of probability which suggests that cooperative membership has a significant and positive impact on farmers awareness. The marginal effect of 0.124 indicates that, membership of a cooperative society, enhances the chances of a farmer being aware of NIFOR developed technologies by 12.4% holding other factors constant. This is indicative of the fact that cooperative membership improves farmers' chances of awareness through access to information, networking opportunities, and capacity building. This finding aligns with that of Rahman *et al.* (2018) who established that an increase in cooperative membership increases awareness of information communication technology.

Constraints in the Use of NIFOR Developed Technologies

Table 4 presents the results on the constraints faced by the oil palm farmers in using NIFOR developed technologies. It showed that inadequate finance, limited access to credit, high interest rates on loans, high transportation cost, limited information on NIFOR innovations, lack of government intervention/subsidy, high cost of NIFOR developed technologies and limited contacts with extension agents were the serious constraints faced by the farmers. Inadequate finance with a mean score of 4.96, was the most serious constraint militating against the oil palm farmers in adopting or using NIFOR developed technological innovations in the study area

Table 4: Constraints Faced by the Respondents in the Use of NIFOR Developed Technologies

Variables	Mean
Inadequate finance	4.96*
Limited access to credit	4.50*
High interest rates on loans	4.90*
Uncertainty about return on investment	2.44
Lack of technical know-how or skills	2.43
Limited access to maintenance or repairs services	2.07
High transportation cost	4.92*
Limited information on NIFOR innovation	3.21*
Risk aversion or skepticism	2.46
Seasonality in business	2.87
Price fluctuation	2.96
Insecurity	2.49
Lack of government intervention/ subsidy	4.93*
Limited access to Extension Agents	3.55*
High cost NIFOR research innovations	3.51*

Source: Field survey, 2024 (*Serious; mean score = 3.00)

On the other hand, uncertainty about returns on investment, lack of technical know-how, risk aversion, seasonality in business, price fluctuation and insecurity, had the least ratings with means scores of 2.44, 2.43, 2.07, 2.46, 2.87, 2.96, and 2.49 respectively and therefore not serious constraints.

Conclusion

The study examined the determinants of awareness and utilization of NIFOR developed technologies. Findings on awareness indicate that only a slight majority of the respondents (57.20%) had knowledge of NIFOR's technological innovations on oil palm. The study also revealed that household size, farm size, extension visits, and cooperative membership, significantly influenced the farmers' awareness, while inadequate finance, limited access to credit, high interest rates on loans, high transportation cost, limited information on NIFOR innovations, lack of government intervention/subsidy, high cost

of NIFOR developed technologies and limited contacts with extension agents were the serious constraints faced by the oil palm farmers in the use of NIFOR developed technologies in the study area.

Recommendations

1. For more oil palm farmers to be aware of NIFOR's developed technologies, the ministry of agriculture and food security, ADP and other relevant agencies of government saddled with the responsibility of creating awareness of improved agricultural innovations, should embark on an aggressive awareness campaigns on the availability of improved planting and processing materials developed by NIFOR, for farmers to adopt same, as a means of improving their livelihoods. Also, on its part, NIFOR should aggressively create awareness about its research technologies in order to effectively market them to the oil palm producers.
2. Extension visits were found to have significantly influenced farmers' awareness of NIFOR agricultural innovation at 1% probability level. The government should therefore deploy adequate extension officers in order to scale up extension visits to ensure prompt information dissemination through regular contacts with the farmers.
3. Cooperative membership also significantly influenced farmers' awareness. Therefore, it should be promoted. This will enhance the oil palm farmers' access to current information on agricultural research innovation through networking or knowledge sharing.
4. Policy makers and financial institutions can work to improve access to credit for the oil palm farmers to increase their ability to afford agricultural research innovations. This could be done by establishing credit facilities with favorable interest rates and repayment terms.
5. The Government at the State and federal levels should also subsidize the cost of acquiring agricultural research innovations (improved planting materials, processing equipments, etc) at affordable rates as this will encourage more oil palm farmers to use the developed technologies which is crucial for food security and their overall wellbeing.

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PROFIT ANALYSIS AND MARKET STRUCTURE OF FRESH TOMATO MARKETING IN ANAMBRA STATE, NIGERIA

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ABSTRACT: The study examined profit analysis and market structure of fresh tomato marketing in Anambra State, Nigeria. Specifically, it described the market structure, market conduct, cost and returns and constraints to fresh tomato marketing in the study area. Multistage sampling procedure was used to select 180 marketers (45 wholesalers and 135 retailers). Data were collected from primary source using structured questionnaire. Collected data were analyzed by means of descriptive analysis, Enterprise budgeting, Shepherd-Futrel, Gini coefficient and Relative Importance Index (RII). From the result, market structure using Gini coefficient gave an index of 0.7565 and 0.7139 for wholesalers and retailers respectively. These values indicate a high level of income inequality in terms of sales margin distribution among marketers and a concentration of sales in the hands of a few individuals where certain marketers may have the ability to influence product prices. The result of marketing efficiency gave coefficients of 63% and 78% for wholesalers and retailers respectively. The level of inefficiency was higher (78.8%) among the retailers than the wholesalers (63%) implying that the wholesalers were more efficient in the marketing of fresh tomato than the retailers. The result of profitability of fresh tomato marketing showed that cost of stock was the important cost of marketing having represented 89.47% and 91.56% of the total cost of marketing for the wholesalers and retailers respectively. Net marketing income was ₦77,560,714.30 for wholesalers and ₦12,409,249.00 for retailers, proving that fresh tomato marketing is a profitable enterprise. The study recommended that government of all tiers should improve the road network in order to facilitate the movement of agricultural produce to diverse locations and fluctuation of prices of fresh tomato should be addressed by establishing a market board that regulates food prices.

KEYWORDS: Profit, market structure, conduct, and fresh tomato.

Introduction

Tomato is the one of the widely grown vegetables in the world, accounting for more than one fifth of the world production (Abdurrahman *et al.*, 2022). According to Nkamigbo *et al.* (2019), tomato (*Lycopersicon esculenta*) is a major vegetable crop that achieve tremendous popularity over the century and aside from being tasty, it promotes healthy nutritional balance as it an excellent source of lycopene (a very powerful antioxidant) that help to fight many forms of cancer development. It is one of the most important crops both in scale of production and level of consumption. It has high economic value and high nutritional potentials in our diet. Nwigwe *et al.* (2020) stated that tomatoes are very important in the daily meal preparation since it can be eaten raw or cooked. Large quantities are used to produce soups, juices, sauces, ketchups, purees and paste. It can be used in canning industries. Katanga *et al.* (2018) viewed tomato as cultivated for its fleshy fruits, known as a protective food because of its special nutritive value and its wide spread production. It is one of the richest sources of nutrients, dietary fibers, antioxidant like lycopene and beta-carotene, which are the compounds that protect cells from cancer. Odemero and Gbigbi (2019) opined that tomato is important in the daily meal of households in most parts of the world. It is an essential ingredient in soups or sometimes consumed raw as juice and sauces, and an important raw material in the canning industries. The unripe tomato is used for pickles. Odemero and Gbigbi (2019) further stated that tomato marketing in domestic markets is a source of livelihood to those who engaged in it and can generate foreign exchange earnings to exporting nations. Aliyu *et al.* (2020) stated that tomato is an important vegetable which supplies vitamins, minerals and fibres to its consumers and is of high nutritional values. They further opined that it is widely accepted and commonly used in a variety of dishes as raw, cooked or processed products more than any other vegetable. It provides 3-4 % total sugar, 15-30mg/100g ascorbic acid, 7.5-10mg/100ml treatable acidity and 20-50mg/100g fruit weight of lycopene-antioxidants for cancer prevention especially those of the prostate gland, lungs and stomach.

Materials and Method

The study was carried out in Anambra State, Nigeria. Anambra State is an agrarian State with several raw materials and agro products being produced in various parts of the State. Some of the crops grown in the State include oil palm, maize, rice, groundnut, cassava, cucumber, tomato, watermelon, greenbean, soyabean, livestock such as goats, sheep, poultry and cattle are also raised. Anambra State is an agrarian State. The State occupies an area of 4,844 KM², geographically and lies within longitude 5°55¹ and 6°42¹N. The population of the State is 4, 182,232 with population density of 863 persons per km² (NPC, 2006). The state has several daily markets both in the rural and urban areas

where agricultural goods are sold especially fresh tomato known as *Ogbo-tomato* market. Fresh tomato is a thriving business in the State due to its nutritional and medicinal value. The study population was made up of all fresh tomato marketers in the State. Multi-stage sampling procedure was used to select 9 Local Government Areas, 9 daily fresh tomato markets and 180 intermediaries (45 wholesalers and 135 retailers) for the study. The respondents were selected based on the size of the markets; details of the process were given as: In stage one, three agricultural zones were randomly selected from the four agricultural zones of the State. In stage two, three LGAs were randomly selected from each of the three selected agricultural zones making it a total of 9 LGAs. Stage three involved a purposive selection of one daily market with large number of consumers from each of the selected LGAs. A total of nine markets were selected for the study. In stage iv, twenty fresh tomato marketers (five wholesalers and fifteen retailers) were selected from each of the selected nine markets in stage iii making it a total of 180 respondents for the study.

Results and Discussion

Market structure of fresh tomato marketing

Agada and Ocholi (2021) stated that market structure is the nature and degree of competition in the market for goods and services. Thus, the structure of market for both food (goods) and services (factor) market are determined by nature of competition prevailing in a particular market. Result of the analysis of market structure using Gini coefficient is shown in Table 1 and Table 2 respectively. The results revealed a Gini coefficient of 0.7565 and 0.7139 for wholesalers and retailers respectively. The implication is that there is a high level of income inequalities (sales margin) in the distribution of income among the marketers and high concentration of sales in the hand of few marketers thus the existence of imperfect competition in the market. The variation is quite more among the wholesalers because of time and place utilities advantages. Isibor and Nkamigbo (2023) in their study of turmeric market stated that Gini coefficient of 0.6866 for wholesalers and 0.7495 for retailers were indication of high level of income inequality in terms of sales margin distribution among the marketers and a concentration of sales in the hands of a few individuals. It further revealed the existence of imperfect competition in the turmeric market where certain marketers may have the ability to influence product prices. This agrees with Ugwumba *et al.* (2019), Osundare *et al.* (2020), Jonathan and Zanding-Fibi (2023) and Isibor *et al.* (2023) who reported a Gini coefficients of 0.6278, 0.83, 0.68 and 0.7026 for watermelon, tomato, vegetables and fresh pepper marketing in their study areas.

Table 1: Estimated Gini Coefficient of the marketing agents (wholesalers)

Monthly sales (₦)	F	Proportion of WT _s (X ₁)	Cum. of WT _s (₦)	TMS (₦)	Cum. Pro of TMS Y _i	X ₁ Y _i
220,000-420,000	17	0.3777	55,348,982.10	0.3777	0.2570	0.0970
421,000-621,000	12	0.2666	50,425,412.56	0.6443	0.2341	0.0624
622,000-822,000	10	0.2222	39,069,059.00	0.8665	0.1814	0.0403
823,000-1,023,000	6	0.1333	70,501,842.54	0.9998	0.3273	0.0436
Total	45		215,345,296.00			0.2436
GC = $1 - \sum X_1 Y_i$		= 1 - 0.2436 =	0.7565			

Note: WT_s = Wholesalers, Pro = Proportion, Cum = Cumulative, TMS Total monthly sales.

Source: Field survey, 2025.

Table 2: Estimated Gini Coefficient of the marketing agents (retailers)

Monthly sales (₦)	F	Proportion of WT _s (X ₁)	Cum. of WT _s (₦)	TMS (₦)	Cum. Pro of TMS Y _i	X ₁ Y _i
90,000-120,000	29	0.2148	8,186,182.00	0.2148	0.1393	0.0299
121,000-151,000	38	0.2814	15,745,061.00	0.4962	0.2679	0.0753
152,000-182,000	23	0.1703	5,965,621.00	0.6665	0.1015	0.0172
183,000-213,000	45	0.3333	28,864,647.00	0.9998	0.4912	0.1637
Total	135	0.9998	58,761,511.00			0.2861
GC = $1 - \sum X_1 Y_i$		= 1 - 0.2861	= 0.7139			

Note: RT_s = Retailers, Pro = Proportion, Cum. = Cumulative, TMS =Total Monthly Sales.

Source: Field survey, 2025.

Market Conduct of Fresh Tomato Marketers

This describes the pattern of behavior of fresh tomato marketers in adapting to the market situation. It involves criteria for purchase, strategies for fixing selling price (price determination), membership of market union, entry mode, free entry and exit, sources of market information, and marketing strategies adopted. The result of the analyses carried out on market conduct for fresh tomato are discussed and further presented in Table 3. The table presents the distribution of respondents according to indicators of market conduct for fresh tomato in the study area. On criteria used for purchase, the result showed that wholesalers (42.22%) and retailers (60.00%) considered degree of freshness as major criteria for purchase. Also, wholesalers (33.33%) considered absence of harvest cuts and breakage while retailers (32.59%) considered degree of freshness as another criterion, while degree of freshness and absence of harvest cuts and breakages on the fruits were the least considered criteria by both wholesalers and retailers with indications at 24.44% and 7.40% respectively.

On strategies for fixing selling price, the findings revealed that majority of the wholesalers (46.6%) and retailers (74.07%) used common pricing techniques of fixing price after considering expenses

incurred. This is in consonance with the findings of Nkamigbo et al, (2019), who reported consideration of expenses incurred as a tool for fixing price among watermelon marketers. Fresh tomato market price in the study area was also determined through bargaining as indicated by 33.33% of wholesalers and 22.22% of retailers. This agrees with Ocholi and Gege (2023), who reported bargaining as a tool for price determination among ginger marketers in Benue State. Demand and supply push as a determinant of price was indicated by 18.8% and 25.6% for wholesalers and retailers respectively. The result on Table 3 indicated that majority (86.66% and 96.29%) of wholesalers and retailers respectively were members of market union. On sources of market information, the result indicated that majority (64.44%) and 89.62%) of wholesalers and retailers respectively, obtained their market information from fellow marketers. The result also revealed that 26.66% and 10.37% of wholesalers and retailers respectively sourced information from market unions. On marketing strategy adopted, the results showed that majority 37.77% and 74.81% for wholesalers and retailers respectively applied the strategy of creating customer friendly attitudes in selling their products. Cleaning the seed of tomato was another strategy for the wholesalers (42.22%) and retailers (17.03%).

Table 3: Market conduct of fresh tomato marketing

Variables		Wholesalers		Retailers	
Criteria for purchase		F	%	F	%
Degree of freshness		11	24.44	44	32.59
Size of basket		19	42.22	81	60.00
Absence of harvest cuts and breakages		15	33.33	10	7.40
Total		45	100	135	100
Strategies for fixing selling prices					
Fix price after consideration of purchase price and other expenses		21	46.66	100	74.07
Fix price through bargaining		15	33.33	30	22.22
Demand and supply push		9	20.00	5	3.70
Fix prices by tomato marketers union		-			
Total		45	100	135	100
Membership of market union					
Yes		39	86.66	130	96.29
No		6	13.33	5	3.71
Total		45	100	135	100
Entry mode					
By registration		45	100.00	135	100.00
By chance		-			
Total		45	100	135	100
Free entry and exit					
Yes		45	100	135	100
No		-			
Total		10	100	135	100

Sources of market information				
Fellow marketers	29	64.44	121	89.62
Middlemen	4	8.88	-	
Market union	12	26.66	14	10.37
Total	45	100	135	100
Marketing strategy adopted				
Customer friendly attitude	17	37.77	101	74.81
Selling at strategic point	9	20.00	-	
Selling clean and neat fresh	19	42.22	23	17.03
Selling below prevailing market prices	-		10	7.40
Total	45	100	135	100

Source: Field Survey, 2025

Profitability of fresh tomato marketing among the intermediaries

Enterprise budgeting analysis was used to estimate the monthly profitability of fresh tomato marketing among the intermediaries as shown in Table 4. Result of the analysis indicating total cost (TC), total revenue (TR), total variable cost (TVC), total fixed cost (TFC), gross margin (GM), net marketing income (NMI), mean net marketing income (MNMI) and net return on investment (NROI) is presented in Table 4. The Table of analysis revealed that out of the total cost of ₦137,784,581.7 spent by the wholesalers, purchases constituted 89.47 % while the least of the expenditure was on Ego ani and Job (0.34). In the other hand, the retailers spent 91.56% of the total cost on purchases and 1.0% on ego ani as the least expenses. For the intermediaries, product cost constituted 89.98% of the total cost of marketing while least expenditure was loading (0.55%). From the analysis, the result is in agreement with Nkamigbo *et al.* (2019), Sodeeq *et al.* (2021) and Osunmakinde *et al.* (2024) who reported in their studies of tomato marketing in their area that cost of stock purchase account for 88.3 and 92.1% of the total cost of marketing of fresh tomato to become the most important cost to consider in starting the marketing business. On enterprise profitability, the wholesalers realized ₦215,345,296.00 after spending a total variable cost of ₦136,249,810.80 and a total cost ₦137,784,581.7. This transaction generated a gross margin of ₦79,095,485.20, net marketing income of ₦77,560,714.30, mean net marketing income of ₦1,723,571.4. the retailers also generated gross margin of ₦14,502,986.00, net marketing income of ₦12, 409,249.1 and net return on investment of 0.267. The implication of the net return on investment figures is that the wholesalers and retailers respectively return 56 kobo and 26 kobo for every 1 Naira invested in the enterprise. Overall the profitability indicators (gross margin, net marketing income, mean net marketing income and net return on investment values) showed that fresh tomato marketing was profitable both at the wholesale and retail levels marketing. Nkamigbo *et al.* (2019) and Sodeeq *et al.* (2021) attested to the profitability of fresh tomato marketing Nnewi metropolis and Oyo State.

Table 4: Estimated Monthly Profitability of Fresh Tomato Marketing by the Intermediaries

Variable	WHs	% of TC	RTs	% of TC	WH & RT	% of TC
Total Revenue TR	215,345,296.00		58,761,511.00		274,106,807.00	
Variable Cost (VC)						
Purchases	121,905,383.20	89.47	40,525,180.00	91.56	162,430,563.20	89.98
Ego ani and Job	463,872.00	0.34	732,000.00	1.65	1,195,872.00	0.66
Transportation	11,657,897.60	8.55	1,944,000.00	4.39	13,601,897.60	7.53
Loading	1,010,543.00	0.74	-		1,010,543.00	0.55
Miscellaneous cost	1,212,115.00	0.88	1,057,345.00	2.38	2,269,460.00	1.25
Total Variable Cost (TVC)	136,249,810.80	100	44,258,525.00	100	180,508,335.80	100
Fixed Cost (FC)						
Monthly shop rent/display stand	981,348.00	63.94	1,487,268.00	71.03	2, 468, 616.00	68.03
Depreciation on equipment	432,985.00	28.21	601,456.00	28.72	1,034, 441.00	28.50
Interest on loan	120,437.90	7.84	5,012.90	0.23	125,450.80	3.45
Total Fixed Cost (TFC)	1,534,770.90	100	2,093,736.90	100	3,628,507.80	
Total Cost (TC)	137,784,581.7		46,352,261.90			
Gross margin	79,095,485.20		14,502,986.00			
Net Marketing Income	77,560,714.30		12, 409,249.1			
NMI Mean	1,723,571.4		91,920.36			
Return on Investment	1.56		1.267			
Net Return on Investment	0.56		0.26			
Gross Ratio	0.63		0.788			
Marketing Efficiency	63		78.8			

Source: Field Survey, 2025

Marketing Efficiency of Fresh Tomato Marketing

The Sherpherd-Futrel technique was employed to determine the co-efficient of marketing efficiency. The technique expresses marketing efficiency as the ratio of the total cost to total revenue expressed as percentages. The lower percentage, the better the marketing efficiency since less proportion of the revenue will be expanded on the total cost of marketing.

The model is slated as:

$$ME = \frac{TC}{TR} \times \frac{100}{1}$$

$$\text{For wholesalers } ME = \frac{137,784,581.7}{215,345,296.00} \times \frac{100}{1} = 0.639$$

$$\text{For retailers } ME = \frac{46,352,261.90}{58,761,511.00} \times \frac{100}{1} = 0.788$$

The result of the analyses revealed that none of the intermediaries attained efficiency of 100% in the marketing of fresh tomato implying the existence of good level of inefficiencies among the intermediaries (wholesalers and retailers). The level of inefficiency was higher (78.8%) among the

retailers than the wholesalers (63%) implying the wholesalers were more efficient in the marketing of fresh tomato than the retailers. This can be explained that the wholesalers have economic of sales, they buy in bulk from producers and sale to retailers and sometimes the end users. The finding is at variance with the report of Abdurrahman et al. (2022) who reported a marketing efficiency 273.34% and 168.24% for retailers and wholesalers of fresh tomato marketing in their study area which is greater than unity which implies that the operation involved in the marketing of fresh tomato is efficient.

Constraints to fresh tomato marketing

The constraints militating against fresh tomato marketing in the study area were shown in Table 5 for both the wholesale and retailers respectively. From the Table both the wholesalers and retailers had similar constraints but some were more pronounced in the wholesale than retail marketing and vice versa. For the wholesalers, the problem of perishability nature (M=3.50) of the product was perceived as the most serious constraints of fresh tomato marketing in the study area. The product doesn't last for a long time after harvesting without storage and in the course of transportation if there is delay on the road the produce begins to rot which reduces the value and invariably affects the selling price. Another constraint of great importance is high market fees (M=3.30) collection by government agencies and market union. This has adversely affected the profit margin of the produce as most of them complain that the tax is becoming unbearable from day to day. Transportation of fresh tomato (M=3.15) fruits from the point of production to the market constitutes among the highest marketing cost incurred by the marketers and sometimes the produce do damage on the cost of transportation thus increasing the marketing cost of the marketers. Sit at home palaver (M=3.05) is a very great sabotage of the economy which hinders free flow of marketing on the said days although government is doing everything to stop it but no minimal effect has been recorded. Other constraints that affect fresh tomato marketing at the wholesale level but not of great importance were poor storage facilities (M=3.01), breakage on transit (M=2.49), irregularity of supply (M=2.40) and high cost of product (M=2.35).

For the retailers, the most serious perceived constraint was perishability of the product (M=3.50). This particular constraint affects the retailers most as they are the one that deals with the end users mostly. If the produce remains for day without been sold, it starts deteriorating thus affecting the marketing cost and profit margin. Sit at home (M=3.05) has become a major economic set back to most of the perishable goods in the study area. This has affected the retailers so much that some of them do come out in the evening to a market called *Uwa Mgbede* (evening market) to make sure that their products are sold in order to minimize losses and maximize profit. High market fees (M=3.30)

collection by agents of government is becoming a threat to marketers most especially the retailers. In order to avert this some of them have damage their tomato in the bid to run away thus affecting their profit margin. Poor storage facilities (M=3.05) is becoming worrisome to both farmers and marketers of perishable product as no well-known preservation tool is available to preserve their produce. Marketers sometimes sell below cost price when they notice that the fruit may rot if not sold immediately thus reducing the profit. Other constraints to fresh tomato marketing in the study area were high cost of product (M=2.45), irregularity in supply (M=2.30), high cost of transportation (M=2.25) and breakage on transit (M=2.20).

Table 5: Constraints to fresh tomato marketing

Constraints	Wholesalers mean score	Rank	Retailers mean score	Rank
Sit-at-home palaver	4th	3.05	2nd	3.02
Poor storage facilities	5th	3.01	4th	2.50
Perishability nature	1st	3.50	1st	3.10
High market fees by government	2nd	3.30	3rd	2.80
High cost of transportation	3rd	3.15	7th	2.25
Irregularity in supply (seasonality)	7th	2.40	6th	2.30
High cost of product	8th	2.35	5th	2.45
breakage on transit	6th	2.49	8th	2.20

Source: Field survey, 2025

Conclusion

The study examined profit analysis and market structure of fresh tomato marketing in Anambra State, Nigeria. The study specifically described market structure, market conduct, cost and returns and constraints to fresh tomato marketing in the study area. The findings showed that perishability, high market fees by government and high cost of transportation were perceived as the most serious constraints of the wholesaler's while perishability, sit at home palaver were perceived as serious on the retailers. Fresh tomato marketing in Anambra, Nigeria is a profitable enterprise both at the wholesale and retail levels given the positive values of gross margin, net marketing income, mean net marketing income and return on investment. The marketers were efficient in the business although inefficiencies still existed among their activities due to marketing constraints. The study recommended that the level of profitability would improve if adequate measures are taken by government and marketers to address marketing constraints.

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NIGERIA'S AGRICULTURAL EXPORT TRADE WITH SELECTED AFRICAN PARTNER COUNTRIES: TRADE INTENSITY, EXPORT POTENTIALS AND GRAVITY MODEL ANALYSIS

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ABSTRACT: This study analyzed Nigeria's agricultural export trade with selected African partner countries, focusing on trade intensity, unrealized export potential, and the economic and geographical factors influencing bilateral exports. The study covered nine African countries: Côte d'Ivoire, Ghana and Togo in West Africa; South Africa, Angola and Zimbabwe in Southern Africa; and Egypt, Morocco and Algeria in North Africa. Secondary annual data covering 2020–2024 were obtained from the International Trade Centre (Trade Map), UN Comtrade, CEPII and the World Bank. Agricultural products classified under Harmonized System (HS) Chapters 01–24 were examined, with particular attention to cocoa beans, sesame, cashew nuts and ginger. Descriptive and trend analyses, Trade Intensity Index and International Trade Centre Export Potential Map were employed, while pooled Ordinary Least Squares, Fixed Effects, Random Effects and robust estimators were used to estimate the gravity model. The results indicated substantial fluctuations and relatively limited export flows for several agricultural commodities across the selected African markets. The Export Potential Map revealed unrealized opportunities in several destinations, particularly Morocco, Egypt, Algeria and South Africa, although the magnitude varied by commodity. The Hausman specification test supported the Fixed Effects model. Nigeria's GDP had a negative and significant effect on agricultural exports, while destination-country GDP had a positive and significant effect in the Fixed Effects specification. Destination population exhibited a negative and significant coefficient, although its interpretation was constrained by substantial multicollinearity with destination GDP. Geographical distance negatively influenced exports in the pooled, Random Effects and robust specifications. The study recommends strengthening trade facilitation, transport infrastructure, export logistics, product quality compliance, and market-specific export promotion to improve Nigeria's utilization of identified African agricultural export opportunities. These measures could enhance market access and support sustained expansion of agricultural exports within the African regional market.

KEYWORDS: Agricultural exports, Trade intensity, Export potential, Gravity model, African trade, Nigeria.

Introduction

International trade promotes economic growth by enabling countries to specialize, access larger markets, earn foreign exchange and improve resource allocation. Agricultural trade is particularly important for developing economies because of its contribution to employment, income generation, economic diversification and non-oil export earnings. In Nigeria, agricultural products such as cocoa, sesame, cashew, ginger and other commodities remain important components of the non-oil export base. Empirical evidence indicates that expanding agricultural and agri-food exports could contribute to Nigeria's economic diversification and strengthen its participation in international markets (Abdullahi *et al.*, 2021; Busari & Kehinde, 2021).

Nigeria's agricultural export opportunities are particularly important within the African market. As a major West African economy and member of ECOWAS, Nigeria has established trade relationships with several African countries, while the African Continental Free Trade Area (AfCFTA) provides a broader framework for expanding intra-African trade. However, regional market access does not automatically translate into increased agricultural exports, as trade flows are influenced by economic size, market demand, geographical distance, transportation costs and other bilateral characteristics. Evidence from African trade studies suggests that regional trade arrangements can improve market integration and create opportunities for agricultural export expansion (Edeme *et al.*, 2022).

Despite these opportunities, Nigeria's agricultural exports remain constrained by inadequate infrastructure, high logistics costs, limited value addition and difficulties in meeting market and quality requirements. Using a gravity-model framework, Abdullahi *et al.* (2021) found that economic size, importer population, ECOWAS membership and contiguity influenced Nigeria's agri-food exports, while geographical distance negatively affected trade. Similarly, Busari and Kehinde (2021) reported that Nigeria's GDP positively influenced agricultural trade, whereas distance reduced trade flows. These findings demonstrate that Nigeria's agricultural export performance depends not only on domestic production capacity but also on the economic and geographical characteristics of destination markets.

Nevertheless, existing studies have largely examined Nigeria's agricultural trade over longer periods and across broad international markets. Less attention has been given to the recent pattern of Nigeria's agricultural exports specifically within African markets during the period 2020–2024,

including differences between actual and potential trade across destinations. Recent evidence from Nigeria's commodity-specific export studies also indicates that some trading partners may record unrealized export opportunities (Olaere *et al.*, 2025). This creates a need for a contemporary assessment of Nigeria's agricultural export destinations and the factors shaping bilateral export flows within Africa. Against this background, this study investigates Nigeria's agricultural exports within the African region, identifies destination markets with unrealized export potential, and examines the economic and geographical factors influencing Nigeria's bilateral agricultural exports using the gravity-model framework.

Despite Nigeria's substantial agricultural production capacity and strategic position in the African regional economy, its agricultural export potential within African markets remains underutilized. Agricultural products are important to the country's non-oil export base, but exports continue to face constraints such as inadequate infrastructure, high transportation and logistics costs, limited value addition, quality requirements, and difficulties in accessing regional markets. These challenges may limit Nigeria's ability to benefit fully from expanding intra-African trade opportunities. The issue is particularly relevant given Nigeria's participation in ECOWAS and the African Continental Free Trade Area (AfCFTA). However, regional trade agreements alone do not guarantee increased bilateral agricultural exports, as trade flows also depend on economic size, market demand, geographical distance, transportation costs, and other country-specific factors. Understanding these determinants is therefore important for assessing Nigeria's agricultural export performance within African markets.

Previous studies provided useful evidence but left important gaps. Abdullahi *et al.* (2021), using a gravity model for Nigeria's agri-food exports to 70 major trading countries from 1995 to 2019, found that economic and geographical factors influenced export performance and identified unrealized export potential in some markets. Similarly, Busari and Kehinde (2021) reported significant effects of Nigeria's GDP and geographical distance on agricultural trade flows over 1970–2019. However, these studies covered broader international markets and longer historical periods, providing limited evidence on the recent pattern of Nigeria's agricultural exports within Africa. Furthermore, limited attention has been given to identifying African markets where Nigeria may have unrealized export potential alongside examining the factors influencing bilateral export flows. This creates an empirical gap regarding the contemporary structure and determinants of

Nigeria's agricultural exports during 2020–2024, a period of increasing emphasis on intra-African trade and continental market integration. Addressing this gap can provide evidence for improving market targeting, trade facilitation, logistics, export promotion, and regional agricultural trade strategies. Accordingly, this study examines Nigeria's agricultural exports within the African region, identifies destination markets with unrealised export potential, and determines the economic and geographical factors influencing bilateral agricultural exports using the gravity-model framework.

Objectives of the Study

The broad objective of this study is to examine Nigeria's agricultural export performance and trade potential within selected African markets from 2020 to 2024.

The specific objectives are to:

1. Examine the export growth performance of selected Nigerian agricultural commodities, particularly cocoa, sesame, ginger, and cashew, in selected African markets from 2020 to 2024.
2. Assess the unrealised export potential of selected Nigerian agricultural commodities in selected African destination markets.
3. Estimate the determinants of Nigeria's agricultural exports to selected African countries using the gravity model of international trade.

Methodology

This study focused on selected Nigerian partner countries across the broader African region to analyse Nigeria's agricultural export trade. Africa comprises 55 countries, as recognised by the United Nations, and spans approximately 29.65 million km² of land, with a population exceeding 1.5 billion people as of 2024 (United Nations, 2024a). Within this vast continental context, agricultural production systems and trade flows are significantly influenced by prevailing climatic conditions, which determine distinct agroecological and geographic zones. These zones affect crop suitability, production potentials, and the patterns of intra-continental agricultural trade that form the foundation of this research (United Nations, 2024a). For this study, nine major African partner countries were selected, representing three key geographic regions, West Africa, Southern Africa, and North Africa, each with distinct agro-ecological characteristics and socio-economic contexts:

West African Zone: This zone typically comprises tropical and subtropical climates, ranging from humid coastal zones to semi-arid interiors, conducive to a variety of staple and tree-crop

cultivation. The selected countries in this zone are Côte d'Ivoire, Ghana, and Togo. West Africa covers an area of approximately 6.06 million km². It has an estimated population of around 466.5 million people in 2025, making it one of the most densely populated and agriculturally active regions on the continent (United Nations, 2024b; Worldometer, 2025). The climatic diversity supports diversified agricultural systems, from cocoa and oil palm in the humid south to cereals and legumes in savanna areas, contributing to both domestic food security and regional trade.

Southern African Zone: Southern Africa is characterised by semi-arid to sub-tropical climates, with significant variation between coastal zones and highland plateaus that influence agricultural production. In this region, South Africa, Angola, and Zimbabwe are considered key partners in Nigeria's agricultural exports. The Southern African region covers about 2.65 million km² and had a population of approximately 74 million in 2025, making it the least densely populated African subregion yet critical to trade dynamics due to its unique climatic zones and export-oriented agriculture (United Nations, 2024c; Worldometer, 2025). Agriculture in this zone includes maize, livestock, horticultural products, and irrigated high-value crops, with climatic variability increasingly affecting production patterns.

North African Zone: North Africa includes predominantly arid and Mediterranean climatic regimes, where irrigated agriculture along river basins and coastal plains forms the basis of production. The selected North African partners are Egypt, Morocco, and Algeria. The North African subregion covers approximately 7.77 million km² of land and had an estimated population of about 276.3 million in 2025 (United Nations, 2024d; Worldometer, 2025). Egypt's Nile irrigated systems, Morocco's diversified agricultural sector, and Algeria's extensive arid lands with pockets of productive irrigated agriculture reflect the region's agro-ecological diversity and its influence on trade in cereals, horticultural produce, and processed agricultural products.

Classifying these partner countries within their respective geographic and agro-ecological zones underscores how climatic conditions and regional demographic and land-use patterns shape agricultural production capabilities and trade relations with Nigeria. This regional segmentation provides the analytical framework for assessing Nigeria's export performance and comparative advantage across diversified African agricultural markets.

The African region comprises 55 nations as recognized by the United Nations, with the return of Morocco, which has an estimated population of over 1.2 billion people. The region covers a total

area of approximately 30million km² (Pannhausen and Untied, 2010). The region can be divided into three agro-ecological production zones, which are mainly determined by prevailing climatic conditions. These zones are important factors in existing agricultural production systems and intra-regional agricultural trade flows.

Secondary data on yearly time series of bilateral merchandise export values for all categories of agricultural commodities (HS Codes 01-24) at 2-digit levels were obtained from the Trademap (ITC-International Trade Centre Database) for the period 2020-2024. The choice of this period was to examine the impact of Nigeria's current administration and regional strategies on export trade in agricultural and food products. All product values were measured in US Dollars, in thousands. The revised 2002 edition of the Harmonised System (HS) of product classification was adopted. Other data sources included the UNCOMTRADE database and weighted distance data from the website <http://www.cepii.fr>. The data on population and national GDP series were from the World Bank Data Bank.

Data Analysis

The trade intensity index (TII) was pioneered by Brown (1947) and developed and popularized by Kojima (1964) as applied by Drysdale and Garnaut (1982). The model was later modified and used by Mothana (2005) and Reuben and Arene (2013), was used to address objective (i). TII is expressed in two forms: the export intensity index (XII) and the import intensity index (MII), which was specified as follows:

$$TII_{ij} = \frac{X_{ij}/X_i}{X_{wj}/X_w} \quad (1)$$

Where:

TII_{ij} = Trade Intensity Index of exports from country i to country j

X_{ij} = exports from country i to country j

X_i = total exports of country i

X_{wj} = total world exports to country j

X_w = total world exports

The trade intensity index assumes that trade regionalization occurs when there is a high concentration of trade flows biased to a certain geographical region. Thus, the index indicates the intensity of trade within a sub-region. For instance, a value greater than one shows that a region's trade is not only biased to but also gives more importance to a particular region than it does to the world market. To achieve objective(ii), the study used the International Trade Centre's (ITC) Export Potential Map (EPM) to identify African markets where Nigeria has room to expand its

agricultural exports. The analysis examined Nigeria's current export levels relative to the estimated export potential of the specific agricultural products under study across different African markets. The difference between the estimated potential and actual exports shows the export potential gap. A positive gap suggests scope for Nigeria to increase its exports to that market. The markets with the largest potential gaps were therefore identified as the destinations with the greatest opportunities for expanding Nigeria's agricultural exports.

Export Potential Analysis

To address objective (ii), the study used the International Trade Centre's (ITC) Export Potential Map (EPM) to identify African markets where Nigeria has opportunities to expand exports of the selected agricultural commodities. The analysis compared estimated export potential with actual export values for each commodity and destination market. The export potential gap was calculated as follows:

$$EPG_{\{ij\}} = EP_{\{ij\}} - AX_{\{ij\}} \quad (2)$$

Where:

- ($EPG_{\{ij\}}$) = export potential gap for commodity (i) in destination country (j);
- ($EP_{\{ij\}}$) = estimated export potential for commodity (i) in destination country (j);
- ($AX_{\{ij\}}$) = actual exports of commodity (i) to destination country (j).

A positive gap indicates estimated room for additional exports, whereas a zero or negative gap indicates that actual exports have reached or exceeded the estimated potential. Markets with the largest positive gaps were identified as priority destinations for further consideration. These estimates represent model-based opportunities and should not be interpreted as guaranteed export outcomes.

Gravity model analytical framework was used to address objective (iii), has been used in several fields of study, such as human migration and investment flows across countries; its application in international trade seems to dominate its overall use. The gravity trade model borrows from Isaac Newton's (1687) "Law of Universal Gravitation", which postulates that the force of attraction, F_{ij} , between two separate entities i and j is a positive function of the entities' respective masses, m_i and m_j , and inversely related to the squared distance, d_{ij} , between the objects. This law is formalized as seen in equation 3:

$$F_{ij} = G \frac{M_i M_j}{D_{ij}^2} \quad (3)$$

Where notation is defined as follows

F_{ij} = the attractive force.

M_i and M_j = are the respective two countries' masses.
 D_{ij}^2 = the distance between the two objects.
 G = a gravitational constant depending on the units of measurement for mass and force.

In analyzing trade, the basic gravity trade model, which has been used in empirical work over the years, was originally specified by Tinbergen (1962) and Poyhonem (1963) as seen in equation 4 as follows:

$$Trade_{ij} = \alpha \frac{GDP_i^{\beta_1} GDP_j^{\beta_2}}{D_{ij}^{\beta_3}} \quad (4)$$

Where $Trade_{ij}$ represents bilateral trade between country i and j , while GDP_i and GDP_j denote country i and j 's respective gross domestic products. D_{ij} is used as a proxy of bilateral distance between the two trading countries. In the formula above, α and β_s are parameters and the sign of β_1 and β_2 are expected to be positive, while that for β_3 will have *a priori* negative signs. Thus, comparing equations (3) and (4), it can be seen that in analyzing trade using the same gravity principle, the entities in equation (3) are replaced by a pair of countries in equation (4), while the countries' masses in equation (3) are proxied by the respective gross domestic product (GDP) in equation (4) with distance replaced by a variable representing resistance (which in most cases is the actual distance between the pair of trading countries).

Representing equation (4) in logarithmic format, a linear version of the model can be represented as seen in equation 5 as follows (Batra, 2004; and Ghosh and Yamarik, 2004):

$$\ln(Trade_{ij}) = \alpha + \beta_1 \ln GDP_i + \beta_2 \ln GDP_j - \beta_3 \ln(D_{ij}) + \mu_{ij} \quad (5)$$

Where α , β_1 , β_2 and β_3 are coefficients to be estimated. The disturbance error term (μ_{ij}) captures random events that which may have an impact on bilateral trade between the two trading countries and is assumed to be stationary, with a mean of zero and a constant variance. Thus equation (5) is the core gravity equation which has been used in all empirical studies, though with added right-hand side (RHS) variables (with each RHS variable added depending on the particular facet of trade being analyzed, the objectives to be achieved and availability of data). In this basic gravity, a positive correlation is expected between trade and GDPs, while a negative relationship will be expected between trade and distance.

Results and Discussion

Table 1: Annual Growth Rate of Nigeria's Cocoa Exports to Selected African Countries, 2020–2024

Destination	2020	2021	2022	2023	2024
Ghana	Nil	-99.9	-100.0	0.0	N/C
Togo	0.0	0.0	0.0	0.0	0.0
Angola	Nil	0.0	0.0	0.0	0.0
Algeria	Nil	0.0	0.0	0.0	0.0
South Africa	Nil	N/C	0.0	0.0	0.0
Egypt	Nil	-99.9	-100.0	0.0	N/C
Morocco	Nil	0.0	0.0	0.0	0.0
Zimbabwe	Nil	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nil	0.0	0.0	0.0	0.0

Source: Author's computation from trade data, 2026

Annual Growth Rate of Nigeria's Cocoa Exports

The result in Table 1 shows that Nigeria's cocoa exports to the selected African destinations were generally very low and irregular during 2020–2024. Ghana recorded a decline of 99.9% in 2021 and 100% in 2022, while Egypt similarly recorded declines of 99.9% and 100% over the same period. The zero or nil growth recorded for several destinations should not necessarily be interpreted as evidence of stable export performance because, in many cases, the underlying export value was either extremely small or zero. Similarly, the “not computable” observations arise because percentage growth cannot be calculated where the preceding year's export value was zero.

The result indicates that Nigeria did not maintain a strong and continuous cocoa-export presence in most of the selected African markets during the period. This finding is important because Nigeria remains a significant cocoa-producing country, yet its cocoa export performance does not appear to have translated into sustained trade expansion across the selected African destinations. The finding is partly consistent with Aluko *et al.* (2021), who observed that although Nigerian cocoa exports remained internationally competitive, the industry experienced declining stages in its export performance.

The finding also contrasts with the positive long-run export drivers reported by Ogbanje and Ihemezie (2023), who found that cocoa output and cocoa export earnings were positively associated with Nigeria's long-run cocoa export performance. The difference may arise because

the present analysis is specifically concerned with African destination markets over 2020–2024, whereas the earlier study examined Nigeria's aggregate cocoa export performance over a much longer period. Thus, an increase in Nigeria's overall cocoa export capacity does not necessarily imply proportional growth in exports to every African destination.

Table 2: Annual Growth Rate of Nigeria's Sesame Exports to Selected African Countries, 2020–2024

Destination	2020	2021	2022	2023	2024
Ghana	Nil	-100.0	0.0	0.0	0.0
Togo	Nil	0.0	0.0	0.0	0.0
Angola	Nil	N/C	-100.0	0.0	0.0
Algeria	Nil	62.13	134.58	79.61	-90.10
South Africa	Nil	-69,100.0	N/C	316.20	281.80
Egypt	Nil	-96.54	-12.50	1,852.70	32.29
Morocco	Nil	0.0	0.0	0.0	0.0
Zimbabwe	Nil	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nil	0.0	0.0	0.0	0.0

Source: Author's computation from trade data, 2026.

Annual Growth Rate of Sesame Exports

The result in Table 2 indicates considerable volatility in Nigeria's sesame exports to the selected African countries. Algeria recorded positive growth of 62.13% in 2021, 134.58% in 2022 and 79.61% in 2023 before declining by 90.10% in 2024. Egypt also experienced substantial fluctuations, including a remarkable 1,852.70% increase in 2023 followed by a 32.29% increase in 2024. South Africa recorded an extremely large negative growth rate in 2021 and substantial positive growth in subsequent years. The very high growth rates should, however, be interpreted cautiously because they can result from small initial export values. For example, the reported Nigerian sesame export value to Egypt was only about US\$31,490 in 2021 and US\$35,750 in 2022. Consequently, a relatively small absolute change can produce a very large percentage growth rate. The result therefore demonstrates volatility rather than necessarily indicating a large expansion in the absolute volume of trade.

The finding is consistent with Okoronkwo, Njoku and Agwu (2024), who found that sesame export performance in Nigeria was significantly influenced by factors such as exchange rate and sesame production, both in the long and short run. This supports the view that changes in production and

macroeconomic conditions can produce substantial changes in export performance. However, the present result differs from a simple expectation of continuous export expansion, because some African markets experienced sharp declines despite Nigeria's continued sesame-export activity. This may reflect differences in destination demand, competing suppliers, transaction costs and the concentration of Nigeria's sesame exports in non-African markets.

Table 3: Annual Growth Rate of Nigeria's Ginger Exports to Selected African Countries, 2020-2024

Destination	2020	2021	2022	2023	2024
Ghana	Nil	N/C	N/C	N/C	N/C
Togo	Nil	N/C	N/C	N/C	N/C
Angola	Nil	N/C	N/C	N/C	N/C
Algeria	Nil	N/C	-100.0	N/C	N/C
South Africa	Nil	-27.65	118.57	-41.22	-89.05
Egypt	Nil	75.39	-1.17	44.90	-91.32
Morocco	Nil	98.36	246.53	130.83	-99.53
Zimbabwe	Nil	N/C	N/C	N/C	N/C
Côte d'Ivoire	Nil	N/C	N/C	N/C	N/C

Source: Author's computation from trade data, 2026.

Annual Growth Rate of Ginger Exports

The result in Table 3 shows that Nigeria's ginger exports to the selected African markets were highly unstable during 2020–2024. Morocco recorded strong positive growth between 2021 and 2023, with growth rates of 98.36%, 246.53% and 130.83%, respectively, before recording a sharp decline of 99.53% in 2024. Egypt recorded positive growth in 2021 and 2023 but experienced a 91.32% decline in 2024. South Africa also experienced alternating increases and decreases.

The result indicates that Nigeria's ginger export performance differed substantially across African destinations and years. The sharp decline recorded in 2024 may be associated with supply-side and market disruptions affecting the Nigerian ginger industry during the period. However, because the table represents growth rates rather than production or causal estimates, such explanations should be regarded as possible contributing factors rather than direct causal conclusions. The finding agrees broadly with Okoronkwo *et al.* (2024), who found that Nigerian ginger export performance was significantly influenced by ginger export price, export volume, interest rate, exchange rate and ginger production in both the long and short run. It also corresponds with the earlier evidence

of Alabi *et al.* (2021/2022) that ginger export performance in Nigeria is influenced by export quantity, exchange rate, interest rate and price-related variables. Importantly, the decline in selected African destinations does not necessarily mean that Nigeria's total ginger exports declined by the same magnitude. WITS data, for example, show that Nigeria exported ginger to several international markets, including the United Arab Emirates, Sudan, India, Germany and Vietnam. Thus, the result primarily demonstrates destination-specific instability.

Table 4: Nigeria's Export Potential for Cocoa Beans in Selected African Markets

Destination	Potential (US\$)	Actual (US\$)	Unrealised Potential (US\$)
Ghana	0	0	0
Togo	0	0	0
Côte d'Ivoire	0	0	0
South Africa	27,000	0	27,000
Angola	868	0	868
Zimbabwe	0	0	0
Egypt	0	0	0
Morocco	6,700	0	6,700
Algeria	137,000	0	137,000

Source: ITC Export Potential Map data, 2026.

Export Potential for Cocoa

The result in Table 4 shows that Algeria recorded the largest estimated unrealised export potential for Nigerian cocoa beans, valued at US\$137,000, followed by South Africa at US\$27,000 and Morocco at US\$6,700. Angola recorded a relatively small estimated opportunity of US\$868. The result suggests that selected African markets may provide additional opportunities for Nigeria's cocoa exports, particularly where estimated potential exists but actual exports were recorded as zero. However, the estimated potential should be interpreted as a model-based trade opportunity rather than a guaranteed export value.

The finding is particularly relevant when considered alongside evidence that Nigerian cocoa remains internationally competitive. Aluko *et al.* (2021) found that Nigeria's cocoa industry remained competitive in international markets despite weaknesses in export performance. Therefore, the existence of unrealised opportunities in African markets may reflect destination-specific market access, demand, trade relationships and transaction costs rather than an absence of Nigerian cocoa competitiveness.

Table 5: Nigeria's Export Potential for Sesame in Selected African Markets

Destination	Potential (US\$)	Actual (US\$)	Unrealised Potential (US\$)
Ghana	72,000	1,300	71,000
Togo	105	0	105
Côte d'Ivoire	12,000	0	12,000
South Africa	245,000	410,000	0
Angola	14,000	0	14,000
Egypt	4,400,000	536,000	3,900,000
Morocco	11,000,000	2,300	11,000,000
Algeria	2,700,000	1,400,000	1,400,000

Source: ITC Export Potential Map data, 2026.

Export Potential for Sesame

The result in Table 5 indicates that Morocco represents the largest estimated unrealised sesame export opportunity, with approximately US\$11 million, followed by Egypt with US\$3.9 million and Algeria with US\$1.4 million. Ghana, Côte d'Ivoire and Angola also recorded smaller unrealised opportunities. On the other hand, South Africa recorded actual exports of US\$410,000 against estimated potential of US\$245,000. This indicates that the model's estimated potential should not be interpreted as a maximum permissible export value. Rather, it represents an estimated opportunity under the conditions incorporated in the Export Potential Map methodology.

The result is relevant to the findings of Okoronkwo *et al.* (2024), who established that sesame production and exchange-rate conditions significantly influence Nigerian sesame export performance. Hence, exploiting identified market opportunities would also depend on Nigeria's capacity to maintain production, quality, competitiveness and favourable trade conditions.

Table 6: Nigeria's Export Potential for Cashew Nuts in Selected African Markets

Destination	Potential (US\$)	Actual (US\$)	Unrealised Potential (US\$)
Ghana	276,000	181,000	95,000
Togo	485	0	485
Côte d'Ivoire	—	—	—
South Africa	569,000	414,000	155,000
Angola	55,000	44,000	11,000
Zimbabwe	—	—	—
Egypt	214,000	23,000	191,000
Morocco	86,000	102,000	760,000*
Algeria	163,000	40,000	123,000

Source: ITC Export Potential Map data, 2026.

Export Potential for Cashew Nuts

The result in Table 6 shows unrealised cashew export opportunities in Ghana, South Africa, Angola, Egypt and Algeria. Egypt recorded an estimated unrealised opportunity of US\$191,000, while South Africa and Algeria recorded US\$155,000 and US\$123,000, respectively. The result is consistent with the broader evidence that Nigerian cashew export performance has been unstable. Ogunwolu *et al.* (2024) found that Nigeria's cashew export value experienced substantial fluctuations and that production and exchange-rate conditions were important determinants of export value.

Table 7: Nigeria's Export Potential for Ginger in Selected African Markets

Destination	Potential (US\$)	Actual (US\$)	Unrealised Potential (US\$)
Ghana	410,000	429,000	409,000*
Togo	87,000	0	87,000
Côte d'Ivoire	20,000	867	19,000
South Africa	557,000	1,200,000	0
Angola	19,000	0	19,000
Zimbabwe	140	—	140
Egypt	446,000	1,200,000	0
Morocco	2,300,000	1,200,000	1,100,000
Algeria	44,000	0	44,000

Source: ITC Export Potential Map data, 2026.

Export Potential for Ginger

The result in Table 7 shows that Morocco has the largest clearly reported unrealised ginger export potential among the selected African destinations, estimated at US\$1.1 million. Togo, Algeria, Côte d'Ivoire and Angola also have smaller estimated opportunities. Conversely, actual exports to South Africa and Egypt exceeded the reported potential estimates.

The result demonstrates that Nigeria's ginger export opportunities are not evenly distributed across African markets. This finding agrees with Okoronkwo *et al.* (2024), who established that ginger export performance is influenced by production, prices, exchange rates and other macroeconomic variables. The result also agrees with Alabi *et al.* (2021/2022), who identified exchange rate, interest rate, export price and domestic producer-price conditions among the factors influencing Nigerian ginger export performance. The implication is that identified market potential can only

be translated into actual exports where production and market conditions allow Nigerian exporters to compete effectively.

Table 8: Estimates of the Gravity Model of Nigeria's Agricultural Exports to Selected African Countries

Variables	Pooled OLS	Fixed Effects	Random Effects	Robust OLS
ln Nigeria GDP	-0.4146	-1.1968***	-0.7412***	-0.6718*
ln Destination GDP	0.3491	0.2824**	0.1514	0.1968
ln Destination Population	-0.1651	-6.4213***	-0.5948	0.0395
ln Distance	-1.7616***	Omitted	-1.1879*	-1.6986***
Year effects	No	Yes	Yes	Yes
Observations	45	45	45	45
Countries	—	9	9	—
R ²	0.6689	0.9567 within	0.5265	0.6925
F/Wald statistic	20.20***	110.39***	384.75***	12.48***

Note: *, ** and *** significance at 10%, 5% and 1%, respectively.

Gravity Model of Nigeria's Agricultural Exports

The result in Table 8 shows that the fixed-effects model provides the preferred specification based on the Hausman test reported below. The coefficient of Nigeria's GDP is negative and statistically significant at the 1% level under the fixed-effects specification ($\beta = -1.1968$; $p < 0.01$). This indicates that, holding the other variables constant within the model, increases in Nigeria's GDP were associated with lower agricultural exports to the selected African destinations during the study period.

This finding disagrees with Busari and Kehinde (2021), who reported a positive influence of Nigeria's GDP on agricultural trade flows. It also differs from Abdullahi *et al.* (2021), who found economic size, including Nigeria's GDP, to stimulate Nigeria's agri-food exports. The divergence may be associated with the shorter 2020–2024 period, the restriction of the present study to nine African destinations and the unusual economic and trade conditions during the period.

The coefficient of destination-country GDP is positive and statistically significant at the 5% level in the fixed-effects model ($\beta = 0.2824$; $p = 0.013$). This means that larger destination economies were associated with higher Nigerian agricultural exports. This finding agrees with Abdullahi *et al.* (2021), who found that economic size of Nigeria and its trading partners stimulates Nigerian agri-food exports. It is also consistent with the theoretical expectation of the gravity model that

larger economies generate greater trade flows. Destination population has a negative and statistically significant coefficient in the fixed-effects model ($\beta = -6.4213$; $p < 0.01$). This finding disagrees with Abdullahi *et al.* (2021), who reported that the importer population positively stimulated Nigeria's agri-food exports. Nevertheless, negative population effects are not impossible in gravity models. Previous IMF gravity evidence indicates that population can have a negative coefficient where larger populations are associated with greater domestic self-sufficiency or lower income per person for a given GDP level.

Finally, distance has a negative and statistically significant coefficient in the pooled OLS and robust OLS models, with coefficients of -1.7616 and -1.6986 , respectively. The random-effects coefficient is also negative and weakly significant (-1.1879 ; $p = 0.078$). This finding agrees with Busari and Kehinde (2021) and Abdullahi *et al.* (2021), both of whom identified distance as a negative determinant of Nigeria's agricultural/agri-food trade. It is also consistent with broader evidence that geographical distance constitutes a significant impediment to intra-African trade.

Conclusion

The study examined Nigeria's agricultural export performance and export opportunities in selected African markets, focusing on cocoa, sesame, ginger and cashew. The results show that exports to the selected African destinations were generally low, irregular and highly volatile between 2020 and 2024. The export-potential analysis, however, revealed unrealized opportunities for expanding Nigeria's agricultural exports, particularly for sesame in Morocco, Egypt and Algeria, cocoa in Algeria and South Africa, cashew in Egypt and South Africa, and ginger in Morocco. The gravity-model results further show that destination-country GDP had a positive and significant effect on Nigeria's agricultural exports, while Nigeria's GDP and destination population recorded negative coefficients in the fixed-effects model. Distance was negatively associated with exports in the pooled, random-effects and robust models. The Hausman test supported the fixed-effects specification, while the Wooldridge test indicated serial correlation and the VIF results revealed substantial multicollinearity between destination GDP and population. Overall, the findings indicate that Nigeria has opportunities to expand agricultural exports within Africa, but greater market access, production capacity, trade facilitation and efficient logistics are required to translate these opportunities into actual exports.

Recommendations

Based on the findings, the study recommends that:

1. Nigeria should target identified African markets with unrealized export potential, particularly for sesame, cocoa, cashew and ginger.
2. Production and product quality should be improved through better inputs, extension services, processing, packaging and compliance with export standards.
3. Trade and transport infrastructure should be strengthened to reduce the cost and difficulty of moving agricultural products to African markets, given the negative effect of distance on exports.
4. Export market information and financing should be improved to enable producers and exporters to respond effectively to demand and market opportunities.
5. Commodity-specific export strategies should be developed, since the level of export potential differs considerably across commodities and destination countries.

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**EFFECTIVENESS OF AGRICULTURAL EXTENSION SERVICES IN PROMOTING
AGRICULTURAL DIVERSIFICATION AND SUSTAINABLE RURAL DEVELOPMENT
IN ARDO-KOLA AND ZING LGAs, TARABA STATE, NIGERIA**

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ABSTRACT: This study assessed the effectiveness of agricultural extension services in promoting agricultural diversification and sustainable rural development among smallholder farmers in Ardo-Kola and Zing Local Government Areas of Taraba State, Nigeria. Specifically, the study described the socio-economic characteristics of farmers, examined farmers' perceptions regarding the effectiveness of extension services in promoting agricultural diversification, assessed their contribution to sustainable rural development and identified constraints affecting access to extension services. A multi-stage sampling procedure was used to select respondents. Although 168 questionnaires were targeted, 161 properly completed questionnaires were retrieved and used for analysis. Descriptive statistics were used to analyze the data. A five-point Likert scale with a mean decision threshold of 3.0 was used to assess farmers' perceptions. The findings showed that respondents were predominantly male (55%), with a mean age of 45 years, mean educational attainment of eight years, mean household size of seven persons, mean farming experience of 17 years and mean farm size of 2.96 hectares. Extension services were perceived as timely (mean = 4.025), relevant (mean = 4.081), accessible (mean = 3.988), useful for improving productivity through training (mean = 4.093), and effective in promoting agricultural diversification (mean = 3.988). Extension services were also perceived to contribute to food security (mean = 4.143), rural infrastructure (mean = 4.099), rural livelihoods (mean = 3.932) and community cooperation (mean = 3.919). Major constraints were poor access to extension agents, inadequate funding, lack of training programmes and distance to extension centres. The study concludes that extension services constitute an important institutional mechanism for supporting agricultural diversification and rural development, although institutional and operational constraints need to be addressed to improve their effectiveness.

KEYWORDS: Agricultural extension, agricultural diversification, rural development, smallholder farmers, food security, Taraba State.

Introduction

Agricultural diversification is increasingly recognized as an important strategy for strengthening the resilience of smallholder farming households and improving rural livelihood outcomes. It involves the combination of different agricultural enterprises and livelihood activities, including crop production, livestock production, aquaculture, agroforestry, processing and other income-generating activities. Evidence from sub-Saharan Africa indicates that multiple livelihood activities constitute an important component of rural household strategies, particularly where households face production and income risks associated with dependence on agriculture (De la O Campos *et al.*, 2023; FAO, 2023). For smallholder farmers in developing economies, diversification is particularly important because agricultural households are exposed to climatic variability, pest and disease outbreaks, market fluctuations and changes in input prices. Evidence from Nigeria indicates that changes in temperature and precipitation can adversely affect agricultural productivity and household income sources, while farmers may respond by modifying crop combinations and input-use decisions (Amare *et al.*, 2023). Diversification can therefore provide households with an opportunity to spread production risks and strengthen their capacity to cope with agricultural and economic shocks.

Agricultural extension services occupy a strategic position in supporting agricultural diversification and rural livelihood development. Extension systems provide a link between farmers, agricultural research institutions, technology providers, markets and other development actors. Through advisory services, demonstrations, training and dissemination of agricultural information, extension personnel can improve farmers' knowledge and technical capacity and facilitate the use of improved agricultural practices. The Federal Government of Nigeria has also emphasized the importance of demand-driven and market-oriented extension and advisory services for improving access to agricultural technologies and strengthening linkages among farmers, research institutions, input suppliers and markets (Federal Ministry of Information and National Orientation, 2023). Despite this potential, agricultural extension delivery in Nigeria continues to face constraints. A recent study of extension agents in North-Central Nigeria found that insufficient numbers of extension workers, inadequate transportation and inadequate training programmes were among the major constraints affecting the dissemination of climate-smart agricultural practices (Ojo *et al.*, 2024). Similarly, recent evidence from Nigeria identifies inadequate funding,

poor infrastructure, transportation and communication limitations as continuing challenges to effective extension delivery (Nwauba, 2024). Improving the frequency, accessibility and practical usefulness of extension services is important for translating agricultural information into improved farm and livelihood outcomes.

Although agricultural extension has been widely discussed as an instrument for improving agricultural productivity and technology use, there remains a need for location-specific evidence on how farmers perceive the effectiveness of extension services in promoting agricultural diversification and broader rural development outcomes. In particular, limited attention has been given to the combined contribution of extension services to food security, rural infrastructure, livelihood improvement and community cooperation among smallholder farmers in Ardo-Kola and Zing LGAs. This study therefore examines the effectiveness of agricultural extension services in promoting agricultural diversification and sustainable rural development among smallholder farmers in the two Local Government Areas of Taraba State, Nigeria.

Despite the agricultural potential of Taraba State, rural households continue to face challenges associated with low productivity, limited income, food insecurity and livelihood vulnerability. Agricultural diversification provides an opportunity to address some of these challenges by enabling households to combine different enterprises and income sources. However, diversification requires knowledge, technical skills, access to information, improved inputs and institutional support. Although previous studies have examined agricultural extension, technology adoption and agricultural productivity, relatively limited empirical attention has been given to the effectiveness of extension services in simultaneously promoting agricultural diversification and broader rural development outcomes in the two LGAs. The study therefore examined farmers' experiences and perceptions of extension services and their perceived contributions to food security, infrastructure, livelihoods and community cooperation.

The broad objective was to assess the effectiveness of agricultural extension services in promoting agricultural diversification and sustainable rural development among smallholder farmers in Ardo-Kola and Zing LGAs of Taraba State. The specific objectives were to:

- i. describe the socio-economic characteristics of smallholder farmers in the study area;

- ii. examine farmers' perceptions regarding the effectiveness of extension services in promoting agricultural diversification and
- iii. identify the major constraints affecting farmers' access to and utilization of agricultural extension services for diversification.

Methodology

The study was conducted in Ardo-Kola and Zing LGAs of Taraba State, Nigeria. Both LGAs are agricultural areas characterized by Guinea Savannah vegetation and seasonal rainfall. Crop production and livestock rearing constitute important economic activities. The areas were selected because of their agricultural intensity and participation in extension programmes implemented through the Taraba State Agricultural Development Programme and complementary development projects. A multi-stage sampling technique was employed to select the respondents for this study. This method was chosen to ensure that the sample was representative of the diverse farming populations in the study area and to minimize selection bias. The selection process followed three distinct stages.

- **Stage 1:** Purposive Selection of Local Government Areas (LGAs) Ardo-Kola and Zing Local Government Areas were purposively selected due to their high concentration of smallholder farmers and their strategic roles in the agricultural production zones of Taraba State. These LGAs represent distinct agro-ecological variations that are conducive to both crop and livestock diversification.
- **Stage 2:** Selection of Wards From the ten (10) administrative wards in each Local Government Area, four (4) wards were selected from each LGA, making a total of eight (8) wards for the study. The selection was done using a Simple Random Sampling technique (balloting method) to ensure that every ward had an equal and independent chance of being included in the research.
- **Stage 3:** Selection of communities/villages Within each of the eight selected wards, prominent farming communities were purposively identified based on their active involvement in extension-led programs and agricultural activities.

The total sample size was determined using the Taro Yamane (1967) formula. To ensure a balanced geographical representation and to facilitate a comparative analysis across the study area, an Equal

Allocation method was adopted. Consequently, the target sample was set at 168 respondents, divided equally among the eight (8) selected wards. However, out of the 168 copies distributed 161 were successfully retrieved and found usable.

Table 1: Distribution of Respondents by Local Government Area and Wards

Local Government	Selected Wards	No. of Respondents
Ardo-Kola	Alin Gora	21
	Sunkani	21
	Mayo Ranewo	21
	Iware	21
Zing	Monkin	21
	Zing	21
	Bitako	21
	Lamma	14
Total	8 Wards	161

Source: Field Survey (2025)

Primary data were collected using structured questionnaires. Frequencies and percentages were used to describe socio-economic characteristics, while means and standard deviations were used to assess farmers' perceptions. A five-point Likert scale was used, ranging from 1 = strongly disagree to 5 = strongly agree. A mean score of 3.0 was adopted as the decision threshold; values of 3.0 and above indicated agreement/effectiveness.

Results and Discussion

Socioeconomic Characteristics of Respondents

The socioeconomic characteristics of the respondents presented in Table 1 provide important insights into the demographic, institutional, and production attributes of farmers in Ardo-Kola and Zing Local Government Areas of Taraba State. These characteristics are important because they influence farmers' access to extension services, adoption of agricultural innovations, participation in diversification activities, and overall rural livelihood outcomes. The result revealed that male respondents constituted 55% of the sampled farmers, while females accounted for 45%. This indicates that although males dominated farming activities in the study area, female participation in agriculture was also substantial. The high involvement of women suggests that agricultural diversification and extension programmes are increasingly becoming gender inclusive within the study area. Women's participation is particularly important because they contribute significantly

to household food production, processing, and marketing activities. This finding agrees with Okonkwo (2024), who reported that women farmers play critical roles in agricultural production and are increasingly benefiting from agricultural extension programmes in rural Nigeria.

The age distribution showed that 26% of the respondents were between 31 and 40 years, 24% were between 41 and 50 years, while 24% fell within the 51–60 years category. The mean age was 45 years, indicating that most respondents were within their economically active and productive years. Farmers within this age bracket are generally energetic, experienced, and more capable of adopting improved agricultural technologies and diversification strategies promoted by extension agents. Younger and middle-aged farmers are often more receptive to innovation and willing to take production risks compared to older farmers. This finding is consistent with Amusan and Adeleke (2023), who found that economically active farmers were more willing to adopt improved agricultural technologies and diversified farming systems when exposed to extension services.

Educational attainment among respondents revealed that 39% attained secondary education, 26% had primary education, 24% attained tertiary education, while only 12% had no formal education. The mean years of schooling was eight years, suggesting moderate literacy among the respondents. Education plays a vital role in enhancing farmers' ability to access, understand, and utilize extension information effectively. Literate farmers are generally better positioned to interpret technical recommendations, adopt improved farming practices, and participate in diversified agricultural enterprises. This finding supports the report of Sulaiman *et al.* (2024), who established that educational attainment significantly influenced farmers' understanding and utilization of extension services in Nigeria.

The household size distribution indicated that 53.4% of the respondents had household sizes ranging from 6–10 persons, while 35% had between 1–5 persons. The mean household size was seven persons. Large household sizes may provide family labour necessary for diversified farming activities such as mixed cropping, livestock management, processing, and marketing. However, larger households may also increase pressure on household resources, thereby making livelihood diversification an important strategy for improving food security and household welfare. This finding agrees with Bello *et al.* (2022), who reported that household labour availability

significantly influences agricultural diversification among rural farming households in Northern Nigeria.

The findings further showed that respondents possessed substantial farming experience. About 24% had farming experience ranging between 16–20 years, 21% had between 11–15 years, while 19% had between 21–25 years. The mean farming experience was 17 years, indicating that the respondents had acquired considerable practical farming knowledge over time. Farmers with long years of farming experience are more likely to understand environmental and market uncertainties and therefore adopt diversified farming systems to minimize production risks and stabilize household income. This finding is in line with Jimoh *et al.* (2023), who observed that farming experience positively influences farmers' willingness to diversify agricultural enterprises in Nigeria.

The farm size distribution revealed that 45% of respondents cultivated between 2.1 and 4.0 hectares, while 34% cultivated between 0.1 and 2.0 hectares. The mean farm size was 2.96 hectares, indicating that the majority of respondents were smallholder farmers. Smallholder farmers often adopt diversification strategies to reduce production risk, improve household food security, and increase income sources. The predominance of small-scale farming in the study area suggests the need for effective extension support to enhance productivity and diversification opportunities. This finding corroborates the report of FAO (2023), which emphasized that smallholder farmers in developing countries increasingly rely on diversification strategies for livelihood sustainability and resilience.

The study also revealed that 61% of respondents belonged to cooperative societies, while 39% did not belong to any cooperative organization. Cooperative membership is important because it facilitates farmers' access to agricultural information, credit facilities, extension programmes, inputs, and market opportunities. Farmers who belong to cooperatives are often more exposed to innovations and collective learning opportunities that enhance agricultural diversification. This finding agrees with Bello *et al.* (2022), who found that cooperative participation significantly improved farmers' access to extension services and agricultural innovations in Northern Nigeria.

Access to credit was relatively moderate, as 55% of respondents reported having access to credit facilities, while 45% lacked access to formal or informal credit sources. Credit access is an important factor in agricultural diversification because it enables farmers to purchase improved inputs, invest in livestock enterprises, acquire farm equipment, and expand production activities. Farmers with access to credit are generally more capable of adopting innovations and participating in income-generating agricultural activities. This finding supports the study of Adegbite and Machethe (2023), who reported that access to credit positively influenced farmers' adoption of improved agricultural technologies and livelihood diversification strategies.

Furthermore, the findings showed that 67% of respondents had contact with extension agents, while 33% had no extension contact. The relatively high proportion of farmers with extension contact suggests that extension services were fairly active within the study area. Regular interaction with extension personnel exposes farmers to improved agricultural technologies, diversification opportunities, production management practices, and livelihood improvement strategies. Extension contact is therefore expected to enhance farmers' adoption of diversified farming systems and contribute positively to rural development outcomes. This finding aligns with Nwankwo *et al.* (2024), who found that frequent extension contact significantly improved productivity, diversification, and livelihood outcomes among rural farmers in Nigeria.

Table 2: Socio-Economic Characteristics of Respondents

Variables	Frequency	Percentage (%)	Mean
Sex			
Male (1)	88	55	
Female (0)	73	45	
Age (Years)			45
21–30	26	16	
31–40	42	26	
41–50	39	24	
51–60	38	24	
61 and above	16	10	
Educational Level			8
No Formal Education (0)	19	12	
Primary Education (1–6 yrs)	41	26	
Secondary Education (7–12 yrs)	63	39	
Tertiary Education (13–15 yrs)	38	24	
Household Size			7
1–5	57	35	
6–10	86	53	
11–15	18	11	
Farming Experience (Years)			17
1–5	16	10	
6–10	23	14	
11–15	34	21	
16–20	38	24	
21–25	31	19	
26–30	19	12	
Farm Size (Ha)			2.96
0.1–2.0	54	34	
2.1–4.0	73	45	
Above 4.0	34	21	
Cooperative Membership			
Yes	98	61	
No	63	39	
Access to Credit			
Yes	89	55	
No	72	45	
Extension Contact			
Yes	107	67	
No	54	34	

Source: Field Survey Data, 2026.

Farmers' Perceptions and Experiences Regarding the Effectiveness of Extension Services in Promoting Agricultural Diversification

The findings presented in Table 2 reveal that farmers generally held positive perceptions regarding the effectiveness of extension services in promoting agricultural diversification in Ardo-Kola and Zing Local Government Areas of Taraba State. All the measured indicators recorded mean scores above 3.0, indicating agreement that extension services were functional and beneficial in the study area. The result shows that respondents agreed that extension services are timely, with a mean score of 4.0248. This implies that extension agents provide information at appropriate periods of the farming calendar, which is critical for decision-making in agricultural production. Timely extension delivery enhances farmers' ability to adopt recommended practices such as improved cropping systems, livestock management, and input application. This finding is consistent with Sulaiman *et al.* (2024), who reported that timeliness of extension delivery significantly influences farmers' adoption of agricultural innovations and diversification practices in Nigeria.

Similarly, respondents strongly agreed that the information provided by extension agents is relevant, with a mean score of 4.0807. This indicates that extension messages are aligned with farmers' needs and local production realities. Relevant information increases farmers' trust in extension systems and enhances their willingness to adopt recommended technologies. This finding agrees with Adebayo *et al.* (2023), who found that relevance of extension information significantly determines farmers' adoption behaviour and engagement in diversified farming systems. The study also revealed that farmers agreed that extension agents are accessible, with a mean score of 3.9876. This suggests that extension personnel are relatively available and can be contacted by farmers when needed. Accessibility of extension agents is a key factor in effective agricultural advisory services because it facilitates continuous interaction, problem-solving, and technical support. This finding supports Nwankwo *et al.* (2024), who reported that accessibility of extension officers enhances farmers' productivity and livelihood outcomes through improved communication and technical assistance.

Furthermore, respondents agreed that training provided by extension agents improves productivity, with the highest mean score of 4.0932. This indicates that extension-led training programmes have a strong positive impact on farmers' production capacity and diversification efforts. Training

exposes farmers to improved technologies, best agronomic practices, livestock management skills, and agribusiness opportunities. This finding is consistent with FAO (2023), which emphasized that farmer training is a key driver of agricultural productivity growth and rural livelihood diversification in developing economies.

Finally, respondents agreed that extension services promote agricultural diversification, with a mean score of 3.9876. This implies that extension programmes encourage farmers to engage in multiple agricultural enterprises such as crop diversification, livestock integration, and mixed farming systems. Diversification reduces production risks and enhances income stability among rural households. This finding aligns with Jimoh *et al.* (2023), who reported that agricultural extension services significantly contribute to farmers' adoption of diversified farming systems and improved livelihood resilience.

Table 3: Perceptions and experiences of farmers regarding the effectiveness of extension services in promoting agricultural diversification

Farmers' Perception	SA	A	N	Mean	Std. Dev
Extension services are timely	53 (32.9)	59 (36.6)	49 (30.4)	4.0248	0.79805
Information provided is relevant	61 (39.1)	52 (32.3)	48 (29.8)	4.0807	0.82139
Extension agents are accessible	48 (29.8)	63 (39.1)	50 (31.1)	3.9876	0.78252
Training provided improves productivity	66 (41.0)	44 (27.3)	51 (31.7)	4.0932	0.85001
Extension promotes diversification	47 (29.2)	65 (40.4)	49 (30.4)	3.9876	0.77450

Source: Field Survey (2026)

Constraints Faced by Farmers in Accessing and Utilizing Extension Services for Agricultural Diversification

The results presented in Table 3 reveal several constraints limiting farmers' access to and effective utilization of extension services for agricultural diversification in Ardo-Kola and Zing Local Government Areas. The identified challenges range from institutional and infrastructural limitations to communication and capacity-related issues. The most severe constraint reported by respondents was poor access to extension agents, with a mean score of 4.0248. A large proportion of farmers indicated that extension personnel are either insufficient or not frequently available in their communities. This limitation reduces farmers' exposure to technical guidance, improved farming practices, and diversification opportunities. This finding agrees with Auta *et al.* (2023),

who reported that inadequate extension coverage and low extension-to-farmer ratios significantly constrain agricultural development in rural Nigeria.

Inadequate funding was also identified as a major constraint, with a mean score of 3.9006. Respondents indicated that insufficient financial support limits the ability of extension services to organize training programmes, demonstrations, and field visits. Financial constraints also affect the mobility of extension agents and the availability of teaching materials. This finding is consistent with FAO (2023), which noted that underfunding of agricultural extension systems remains a major barrier to effective service delivery in developing countries. Lack of training programmes recorded a mean score of 3.5342, indicating that farmers experience limited access to structured capacity-building activities. Training is essential for equipping farmers with skills required for adopting diversified farming systems, improving productivity, and managing agricultural enterprises effectively. The absence of regular training reduces farmers' ability to respond to modern agricultural challenges. This finding supports Nwankwo *et al.* (2024), who observed that limited extension training reduces farmers' adoption of improved agricultural technologies and livelihood diversification strategies.

Poor communication was also identified as a constraint, with a mean score of 2.9503. This suggests moderate severity, but it still represents a significant barrier to effective extension service delivery. Communication gaps may arise from language barriers, low literacy levels, inadequate ICT infrastructure, or poor interaction between extension agents and farmers. This finding agrees with Sulaiman *et al.* (2024), who reported that weak communication channels reduce the effectiveness of extension services and limit farmers' understanding of agricultural innovations. Distance to extension centers recorded a mean score of 3.0062, indicating that physical access to extension offices remains a challenge for many farmers. Long distances discourage frequent visits, reduce participation in extension activities, and limit access to timely agricultural information. This finding aligns with Bello *et al.* (2022), who found that rural farmers often face accessibility challenges due to poor infrastructure and the uneven distribution of extension facilities.

Table 4: Constraints faced by farmers in accessing and utilizing extension services for agricultural diversification

Constraint	Moderate (%)	Severe (%)	Very Severe (%)	Mean
Poor access to extension agents	51 (31.7)	55 (34.2)	55 (34.2)	4.0248
Inadequate funding	59 (36.6)	59 (36.6)	43 (26.7)	3.9006
Lack of training programs	46 (28.6)	36 (22.4)	43 (26.7)	3.5342
Poor communication	63 (39.1)	45 (28.0)	-	2.9503
Distance to extension centers	56 (34.8)	53 (32.9)	-	3.0062

Source: Field Survey, 2026

Conclusion

The study demonstrates that agricultural extension services are perceived by farmers in Ardo-Kola and Zing LGAs as important for promoting agricultural diversification and rural development. Farmers reported positive experiences regarding the timeliness and relevance of extension information, accessibility of extension agents, usefulness of training and the contribution of extension to diversification. Extension services were also perceived to contribute to food security, rural infrastructure, household livelihoods and community cooperation. Nevertheless, poor access to extension agents, inadequate funding, insufficient training programmes and physical distance from extension centres remain important challenges. The evidence therefore indicates that strengthening the institutional capacity and coverage of agricultural extension services can improve their contribution to diversified agricultural production and rural development in the study area.

Recommendations

Based on the findings, the following recommendations are proposed:

1. Government and agricultural development agencies should increase the number and geographical coverage of trained extension personnel.
2. Adequate funding should be provided for field visits, demonstrations, training and mobility of extension personnel.
3. Regular training programmes should focus on agricultural diversification, improved production practices and enterprise management.

4. Cooperative organizations should be used more extensively as platforms for extension delivery, collective learning, access to inputs and agricultural information.

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