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Assessing the Adoption of Biotechnology for Sustainable Crop Production among Smallholder Cowpea Farmers in Abuja, Nigeria

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Abstract

This study assessed the adoption of biotechnology for sustainable cowpea production among smallholder farmers in Abuja, Nigeria. A multi-stage sampling technique was employed to select 200 respondents across four Area Councils. Findings revealed that 62% of the respondents were male, with an average age of 44.2 years. Most farmers (71%) were married, and 76% had formal education. The mean farm size was 1.7 hectares, and farming experience averaged 11.8 years. Despite 56.5% belonging to cooperatives, only 48% had access to extension services and 40.5% to credit. On awareness, 77% of respondents had heard about biotechnology, 64.5% understood Bt cowpea as pest-resistant, and 68.5% believed it enhances yield. However, only 32% were confident explaining biotechnology, and 45.5% admitted lacking sufficient knowledge to make informed decisions. Logit regression analysis identified education ($p = 0.008$), farm size ($p = 0.011$), cooperative membership ($p = 0.006$), access to credit ($p = 0.007$), and pest pressure ($p = 0.046$) as significant predictors of adoption. Marital status and soil fertility constraints were not significant. Farmers perceived Bt cowpea as beneficial, with high mean scores for pest control (3.23), reduced pesticide use (3.15), and yield improvement (3.13). Concerns about health effects (2.71) and institutional trust (2.66) were moderate. Challenges ranked highest included lack of seed access (mean rank = 6.82), limited training (6.35), and input cost (6.01). Kendall's $W = 0.72$ indicated strong agreement on constraints. The study concludes that smallholder adoption of biotechnology is influenced by socio-economic, institutional, informational, and perceptual factors.

Keyword: Bt cowpea, Biotechnology, adoption, production, Smallholder farmers, Abuja

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Introduction

Agricultural biotechnology has become increasingly central to debates around food security, sustainable development, and climate change adaptation, particularly in sub-Saharan Africa where food systems face mounting ecological and demographic pressures. For countries like Nigeria, where agriculture employs over 70% of the labour force and provides livelihoods for millions of smallholder farmers, the strategic application of biotechnology has been positioned as a vital instrument in achieving food self-sufficiency, reducing rural poverty, and combating malnutrition [19, 3]. Among the various crops cultivated in Nigeria, cowpea (*Vigna unguiculata*) stands out as a critical legume not only for its protein-rich composition but also for its socio-economic and agroecological importance in the semi-arid regions of the country. Cowpea serves as both a dietary staple and a cash crop, particularly for smallholder farmers in northern Nigeria, where traditional farming systems are often marked by low external input use, land degradation, and vulnerability to climatic shocks [27, 9]. However, despite its importance, cowpea yields have historically remained low due to a range of abiotic and biotic stressors—such as drought, poor soils, and insect pest infestations, especially the devastating *Maruca vitrata*, which can lead to over 80% yield loss in untreated conditions [14, 22].

Recent scientific and institutional efforts have led to the development and release of genetically modified (GM) cowpea varieties designed specifically to combat the persistent challenges faced by small-scale producers [24, 17]. Chief among these innovations is the genetically engineered Bt cowpea, developed under the auspices of the African Agricultural Technology Foundation's Pod Borer Resistant (PBR) Cowpea Project. This variety incorporates the *Bacillus thuringiensis* (Bt) gene, which enables the plant to express a protein toxic to the *Maruca vitrata* pest, significantly reducing the need for synthetic pesticide applications and potentially improving both yield and environmental health [18, 14]. Across different regions of Nigeria, biotechnology adoption has shown a highly variable pattern, influenced by an array of interlinked socio-economic, cultural, political, and ecological factors. Issues such as access to formal education, extension services, credit facilities, land tenure security, and gender-based disparities all play crucial roles in shaping how, when, and why farmers engage with new agricultural technologies (10, 23, 30].

The adoption of agricultural biotechnology—particularly among small-scale cowpea farmers in Nigeria—is thus deeply embedded in broader questions about power, access, and inclusion in knowledge production and technology dissemination [4, 7]. Many of the prevailing narratives in biotechnology promotion tend to view farmers as passive beneficiaries of scientific advancement, rather than active participants in the co-creation, adaptation, and contextualization of innovations. Yet empirical evidence shows that technology adoption is far from a linear process; it is a complex, iterative negotiation between technological attributes, farmer perceptions, local knowledge systems, and institutional environments [25, 26].

Adoption decisions are rarely made in isolation; they are embedded within broader livelihood strategies, community norms, and risk management practices that reflect historical experiences and expectations of both technology and governance. Moreover, agricultural innovations in Nigeria often occur within fragile systems of input supply chains, market access, and public extension, all of which may affect the reliability, affordability, and appeal of adopting biotechnological seeds [28, 15]. The interplay between these institutional safeguards and local trust in public institutions significantly influences adoption behaviour, especially where farmers lack consistent access to reliable information about the science, safety, and efficacy of biotech crops [13, 24].

Within this evolving landscape of agricultural transformation in Nigeria, the case of cowpea biotechnology presents a particularly rich empirical and policy terrain for investigating the real-world challenges and possibilities of innovation adoption among smallholders [16, 25]. Cowpea's dual role as a subsistence and cash crop means that any technological intervention in its production system has the potential to generate both agronomic and socio-economic ripple effects. However, because small-scale farmers are not a monolithic group, understanding adoption dynamics requires disaggregated, context-sensitive research that accounts for regional variation, gender roles, household asset levels, and institutional proximity [20, 22].

While biotechnology may promise increased yields and reduced chemical inputs, the decision to adopt such technologies is mediated by practical concerns such as seed availability, affordability, compatibility with existing practices and more abstract considerations related to trust, identity, and perceived control over agricultural decision-making [13, 23]. Rather than assume biotechnology will be universally welcomed or resisted, a more grounded analysis must seek to understand the multiplicity of factors that shape farmers' agency in contexts of structural inequality, information asymmetry, and changing agro-economic conditions. Addressing this knowledge gap is not only essential for evaluating the effectiveness of past investments in biotechnology research and extension but also for informing future policies and programs that aim to foster inclusive and sustainable agricultural innovation systems in Nigeria and across Africa.

Theoretical Framework

Rogers' Diffusion of Innovations (DoI) Theory)

This study adopts Rogers' Diffusion of Innovations (DoI) Theory as its primary theoretical foundation to examine the adoption of biotechnology—specifically Bt cowpea—among small-scale farmers in Nigeria. [26] defines diffusion as the process by which an innovation is communicated over time through specific channels within a social system. Adoption, in this context, occurs through five sequential stages: knowledge, persuasion, decision, implementation, and confirmation. This progression allows researchers to trace how farmers become aware of biotechnology, evaluate its relevance, and ultimately decide whether or not to integrate it into their production systems.

A core aspect of DoI theory is the perceived attributes of an innovation, which influence its adoption. These include relative advantage (perceived benefit over existing practices), compatibility (fit with existing values and practices), complexity (ease of understanding), trialability (the ability to experiment with it on a limited basis), and observability (visibility of results). In the case of Bt cowpea, farmers may be more inclined to adopt if they perceive significant yield advantages, see clear demonstrations from neighbours, and can experiment on a small plot before full-scale adoption.

Rogers also identifies adopter categories—innovators, early adopters, early majority, late majority, and laggards—which describe the differing willingness among farmers to adopt new technologies. Early adopters, often with better access to resources and information, can influence others in the community, making their experiences critical to broader adoption. The DoI framework also highlights the importance of communication channels and social systems in shaping adoption patterns. In rural Nigeria, where trust, tradition, and interpersonal networks are vital, local extension services and farmer cooperatives play a key role in facilitating the spread of innovations.

Conceptual Framework

The conceptual framework for this study, exploring the relationship

between the independent variables and the dependent variable (adoption of biotechnology) being mediated by the intervening variables. The independent variables (socio-economic characteristics) in this study are factors presumed to directly influence the likelihood of biotechnology adoption. The intervening variables are contextual factors that can mediate or moderate the relationship between independent and dependent variables. They include access to information, risk perception and attitudes, cultural and religious beliefs, and regulatory and policy environment.

Therefore, this study aims to assess the adoption of biotechnology for sustainable crop production among small-scale cowpea farmers in Nigeria. To accomplish this, the following objectives are put forward to:

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

ii. examine the level of awareness and understanding of biotechnology among smallholder cowpea farmers.

iii. identify the socio-economic, institutional, and agronomic factors influencing adoption decisions.

iv. evaluate farmers' perceptions of the risks and benefits associated with biotechnological innovations, particularly Bt cowpea.

v. investigate the challenges limiting biotechnology adoption in the study area

Materials and Methods

Study Area

Abuja, the Federal Capital Territory (FCT) of Nigeria, is located in the central region of the country and covers approximately 7,315 square kilometers. While known for its urban and administrative functions, Abuja also includes vast rural areas across six Area Councils: Abuja Municipal, Bwari, Gwagwalada, Kuje, Abaji, and Kwali. These rural districts are predominantly agrarian, with smallholder farmers cultivating staple crops such as maize, yam, cassava, and millet using traditional, rain-fed practices.

The choice of Abuja as the study area is informed by its dual characteristics-a rapidly urbanizing center surrounded by predominantly agrarian communities. Within the rural fringes of Abuja, cowpea is widely cultivated, particularly in the Gwagwalada, Kwali, and Kuje Area Councils, which are known for their active agricultural zones. These areas provide a representative setting to examine biotechnology adoption among small-scale farmers because they reflect a microcosm of broader national trends: a mixture of traditional farming practices, growing exposure to agricultural extension services, and increasing interactions with urban markets and innovation platforms. Moreover, Abuja's proximity to key federal institutions such as the National Biotechnology Development Agency (NABDA), the National Agricultural Extension and Research Liaison Services (NAERLS) liaison offices, and the National Biosafety Management Agency (NBMA) creates a unique opportunity to study the intersection of policy, regulation, and grassroots adoption of biotechnological innovations.

Population of the Study and Research Design

The target population for this study comprises small-scale cowpea farmers residing in selected Area Councils within the Federal Capital Territory (FCT), Abuja, Nigeria.

The study will employ a cross-sectional design, collecting data at a single point in time from a sample drawn from the target population. This allows for the examination of relationships between variables such as education level, farm size, access to extension services, and adoption behavior. The design is supported by structured questionnaires, in-depth interviews, and focus group discussions to gather empirical evidence across multiple dimensions—demographic, behavioural, institutional, and attitudinal.

Sample Size and Sampling Techniques

This study employed a multistage sampling technique to select a total of 200 small-scale cowpea farmers from the Federal Capital Territory (FCT), Abuja. The multistage approach was adopted to ensure systematic, regionally representative, and practical selection of respondents from the diverse rural farming communities across Abuja's Area Councils, while maintaining cost and time efficiency in fieldwork.

In the first stage, four (4) out of the six (6) Area Councils in Abuja were purposively selected based on their recognized agricultural activity and prevalence of cowpea cultivation. These include: Gwagwalada, Kwali, Kuje, and Abaji. These councils represent Abuja's major cowpea-producing zones and offer significant variation in terms of extension access, farmer demographics, and proximity to biotechnology institutions.

In the second stage, within each of the selected Area Councils, two farming communities were randomly selected using simple random sampling. This yielded a total of eight (8) communities for the study. Community selection was guided by agricultural extension records and local knowledge of cowpea farming prevalence, ensuring that sampled communities are actively involved in cowpea production.

In the third stage, from each selected community, a proportional random sampling technique was used to select individual respondents. The sample size was proportionally distributed across the 8 communities, with 25 respondents selected from each community to achieve the total sample size of 200 respondents. Lists of registered or known farmers were obtained with the assistance of local agricultural extension officers, from which respondents were randomly drawn using a lottery method. This multistage approach ensures geographic diversity, representation of varied socio-economic groups, and reliable generalizability within the FCT's small-scale cowpea farming population.

Data Collection

For this study, the primary data collection instrument was a structured questionnaire designed to elicit comprehensive information from small-scale cowpea farmers across selected Area Councils in the Federal Capital Territory, Abuja. The questionnaire was administered to a sample of 200 respondents, with each session lasting approximately one hour to allow for thoughtful and accurate responses. To ensure validity and reliability, the instrument was subjected to a pilot test involving a small group of cowpea farmers outside the main study sample. This pre-test enabled the identification of ambiguous or unclear questions, leading to refinements that improved clarity, relevance, and alignment with the study's objectives. Adjustments were made to better capture farmers' perceptions, experiences, and constraints related to the adoption of biotechnology. To further enhance response accuracy, trained enumerators were engaged to assist participants in understanding and completing the questionnaire, especially where literacy levels were limited or clarification was needed during administration.

Data Analysis

The data collected for this study were analyzed using a combination of descriptive and inferential statistical methods, tailored to address each of the study's specific objectives. Descriptive statistics such as frequencies,

percentages, and means were employed to analyze Objective (i) and (ii). To assess Objective (iv), a 4-point Likert scale was used. Objective (iii) was analyzed using a Multiple Regression Model to determine the strength and significance of relationships between explanatory variables and biotechnology adoption. For Objective (v), Kendall's Coefficient of Concordance (W) was used to rank and assess the level of agreement among respondents regarding the severity of identified challenges. All statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences), Version 24, ensuring robust and systematic data handling.

Model Specification

Multiple Regression Model

To address Objective (iii identify the factors that influence the adoption of biotechnology—a Multiple Regression Model was utilized. The model captures the relationship between the dependent variable (biotechnology adoption) and several socio-economic, institutional, and agronomic predictors.

The model is specified as:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + ... + \beta nXn + \varepsilon$$

Where:

- Y = Level of biotechnology (Bt cowpea) adoption (dependent variable)
- β_0 = Intercept
- $\beta_1 \ldots \beta n$ = Regression coefficients
- $X_1 \ldots Xn$ = Independent variables (e.g., age, education, farm size, extension access, income, input access, farming experience)
- ε = Error term (captures unobserved influences)

Model for Likert Scale Rating

To assess respondents' perception of biotechnology, a 4-point Likert scale was employed. Respondents were presented with a series of items related to biotechnology adoption, and they were asked to rate their responses based on the degree of agreement or frequency of exposure. The Likert scale was structured as follows:

- Strongly Agree (SA) – 4
- Agree (A) – 3
- Disagree (D) – 2
- Strongly Disagree (SD) – 1

The decision benchmark was set at 2.5, which served as the cut-off point for determining whether the responses indicated a generally positive or negative disposition. A mean score ≥ 2.5 was interpreted as a high level of positive perception, while a score < 2.5 reflected limited negative view.

To calculate the mean Likert score for each item, the following formula was used:

Where:

- = Mean Likert score
- Σ = Summation symbol
- F = Frequency of each Likert response (4, 3, 2, 1)
- n = Assigned Likert value for each response category
- Nr = Total number of respondents

Kendall's Coefficient of Concordance (*W*)

To address Objective (v)—which seeks to identify and rank the major challenges limiting the adoption of biotechnology among small-scale cowpea farmers—this study employed Kendall's Coefficient of Concordance (*W*) as the appropriate statistical tool.

The formula for calculating Kendall's Coefficient of Concordance is:

Where:

W = Kendall's Coefficient of Concordance

= Sum of ranks for each challenge

= Mean of the ranks

m = Number of respondents

n = Number of ranked challenges

Results and Discussion

Socio-Economic Characteristics of Small-scale Cowpea Farmers

The study revealed that 62% of respondents were male and 38% were female. This reflects the gender imbalance often seen in Nigerian agriculture, where men typically control land and make production decisions. Gender dynamics may influence access to resources, decision-making autonomy, and exposure to biotechnology [11, 12].

The results in Table 1 revealed that the average age of respondents was 44.2 years, with most falling between 31 and 50 years. This age distribution suggests that cowpea farming is largely practiced by economically active adults. Age has been linked to risk perception and technology adoption, as younger farmers often adopt more rapidly when compared to older, more conservative counterparts [21].

The findings on marital status reveal that most farmers were married (71%). Married individuals are likely to have family labour support, which can influence production scale and decisions regarding adoption of new technologies [29].

Formal education was observed in 76% of respondents, with 31% attaining secondary and 18% tertiary education. Only 24% had no formal education. Higher educational attainment facilitates access to information and interaction with extension agents, thereby increasing the likelihood of adoption [12].

The mean farming experience among respondents was 11.8 years, with most having 6–10 years of experience. This suggests that the majority are well-established farmers familiar with local agronomic practices. Farmers with moderate experience may be more flexible and informed, while extremely long-term farmers could resist change due to entrenched habits [8].

Farm sizes averaged 1.7 hectares, with 44.5% cultivating between 1–2 hectares. This confirms the classification of respondents as small-scale farmers. Limited land size can affect economies of scale, reduce surplus production, and increase risk aversion, especially with unfamiliar technologies [6]. More than half (56.5%) of respondents were members of cooperatives. Membership can enhance collective bargaining power and facilitate exposure to agricultural innovations. Previous studies have identified cooperative membership as a significant predictor of innovation adoption in farming communities [2]. Only 48% of farmers reported access to extension services. Limited access can result in misinformation, poor adoption decisions, or complete exclusion from innovation programs [5].

Variable	Freq (n = 200)	Percent
Gender		
Male	124	62.0
Female	76	38.0
Marital status		
Single	34	17.0
Married	142	71.0
Widowed/Divorced	24	12.0
Educational level		
No formal education	48	24.0
Primary school	54	27.0
Secondary school	62	31.0
Tertiary education	36	18.0
Age (Mean = 44.2 yrs)		
18 – 30 years	22	11.0
31 – 40 years	58	29.0
41 – 50 years	66	33.0
51 and above	54	27.0
Years of farming Experience (Mean = 11.8 yrs)		
1 – 5 years	41	20.5
6 – 10 years	72	36.0
11 – 20 years	54	27.0
21 years and above	33	16.5
Farm Size (Mean = 1.7 ha)		
Less than 1 hectare	61	30.5
1 – 2 hectares	89	44.5
2.1 – 5 hectares	50	25.0
Cooperative Membership		
Member	113	56.5
Non-member	87	43.5
Access to Extension Services		
Yes	96	48.0
No	104	52.0

Table 1: Socio-Economic Characteristics of Rural Farmers (n = 200).

Source: Field Survey, 2025.

Level of Awareness and Understanding of Biotechnology among Smallholder Cowpea Farmers

The majority of respondents (77%) reported having heard of biotechnology as a scientific method used in agriculture. This indicates a relatively high level of general awareness among smallholder farmers. Similar findings by [8] in Nigeria suggest that farmers' exposure to agricultural information - often through radio, cooperatives, or extension agents contributes to baseline awareness.

Around 68.5% of respondents believed that biotechnology could improve yields and reduce pesticide use. This aligns with findings by [14] who reported high expectations among Nigerian farmers regarding Bt cowpea's benefits. Approximately 64.5% of farmers indicated that they understood Bt cowpea to be genetically modified to resist pests such as *Maruca vitrata*. This level of understanding reflects increasing diffusion of biotechnology information within cowpea-producing areas. Studies have shown that understanding the specific traits of GM crops is a critical step in the innovation-decision process outlined in [26] Diffusion of Innovations theory.

Just 58% of respondents acknowledged that genetically modified crops are developed through laboratory-based DNA manipulation. This suggests a moderate understanding of the science underpinning biotechnology. While some farmers grasp the concept of genetic engineering, a gap remains in their deeper scientific comprehension [13]. A notable 45.5% of respondents felt they lacked sufficient knowledge to make informed decisions regarding biotechnology adoption. This finding highlights a common barrier noted by [5], who emphasized that knowledge constraints rather than outright resistance often limit innovation uptake. About 41% of respondents expressed the belief that genetically modified crops might pose health risks to humans or animals. Such concerns reflect ongoing skepticism and misinformation, which are common barriers to biotechnology adoption in developing countries [3].

Roughly 37% of farmers believed that GM crops could damage the soil or have adverse environmental effects. According to [12], risk perception among smallholder farmers can delay or prevent the adoption of beneficial innovations, regardless of the scientific evidence supporting safety and efficacy. Only 32% of farmers reported feeling confident enough to explain the differences between traditional breeding and biotechnology-based crop improvement. This suggests that while awareness may exist, deeper understanding and confidence in biotechnology concepts are limited [1].

Statement on Awareness and Understanding of Biotechnology	Frequency (f)	Percentage (%)
I have heard about biotechnology as a method used to improve agricultural productivity through scientific innovations.	154	77.0%
I understand that Bt cowpea is a genetically modified crop designed to resist major insect pests such as *Maruca vitrata*.	129	64.5%
I believe biotechnology can help farmers increase crop yields and reduce the use of harmful pesticides.	137	68.5%
I know that genetically modified crops are developed through DNA manipulation in laboratories by scientists.	116	58.0%
I think biotechnology is unsafe and may pose unknown health risks to humans and animals.	82	41.0%
I believe genetically modified crops like Bt cowpea can damage the soil or affect the environment negatively.	74	37.0%
I feel I do not have enough knowledge to make informed decisions about adopting biotechnology on my farm.	91	45.5%
I am confident in explaining to others the differences between traditional crop breeding and modern biotechnology techniques.	64	32.0%

Table 2: Level of Awareness and Understanding of Biotechnology among Smallholder Cowpea Farmers
Source: Field Survey, 2025

Multiple Responses Factors Influencing Adoption of Biotechnology among Smallholder Cowpea Farmers

The model statistics in Table 3 suggest that the model diagnostics confirmed the regression model's validity. Among the ten (10) factors tested, eight (8) factors had coefficients that were statistically meaningful: gender, age, educational level, farming experience, farm size, cooperative membership, contact with extension agents and perceived pest pressure, while marital status and soil fertility constraints was not statistically significant.

The findings revealed that gender was significant at the 10% level, indicating that male farmers were more likely to adopt biotechnology than their female counterparts. This is consistent with earlier studies showing that men often have greater access to resources, information, and decision-making power, which facilitates adoption [10].

Age negatively influenced adoption and was statistically significant at the 5% level. This suggests that younger farmers are more likely to adopt biotechnology than older ones. Older farmers may be more conservative, relying on traditional practices or skeptical of unfamiliar technologies [31].

Marital status was not statistically significant, indicating no substantial difference in biotechnology adoption between married and unmarried farmers. While some literature suggests that marital status can affect household labour availability and stability [29], it did not emerge as a critical factor in this study.

Education was highly significant at the 1% level. Farmers with higher educational attainment were more likely to adopt biotechnology. This finding aligns with [30] who emphasized the role of cognitive capacity in enabling informed decisions regarding modern agricultural technologies.

Farming experience showed a positive and significant effect at the 5% level. Similar findings have been reported in studies linking experience to greater exposure to formal and informal knowledge-sharing systems [24, 28].

Farm size was statistically significant at the 5% level, with larger farms more likely to adopt biotechnology. This is in line with existing studies showing that farmers with more land have greater capacity to experiment and absorb risk [1].

Cooperative membership was highly significant at the 1% level, indicating that belonging to a cooperative increased the likelihood of adoption. This supports the idea that social capital and institutional linkages are critical enablers of agricultural technology uptake, particularly in rural smallholder contexts [20]. Contact with extension agents was significant at the 10% level. Farmers who interacted with extension services were more likely to adopt biotechnology [2]. Perceived pest pressure was significant at the 5% level, suggesting that farmers who experienced higher pest infestation were more likely to adopt Bt cowpea. Perceived need or problem severity is a well-documented trigger for innovation adoption [26].

Soil fertility constraint was not statistically significant in influencing biotechnology adoption. This may indicate that farmers do not associate biotechnology particularly genetically modified cowpea with solving fertility issues [8].

Variable	Unstandardized Coeff. (B)	Standard error	t-value	Sig. (p-value)
Gender	0.642	0.329	1.951	0.051*
Age (Years)	-0.025	0.012	-2.070	0.038**
Marital Status	0.284	0.361	0.787	0.431
Educational Level	0.119	0.045	2.641	0.008***
Farming Experience (Years)	0.047	0.020	2.312	0.021**
Farm Size (Hectares)	0.312	0.122	2.557	0.011**
Cooperative Membership	0.788	0.285	2.761	0.006***
Contact with Extension Agents	0.519	0.269	1.929	0.054*
Perceived Pest Pressure	0.381	0.191	1.957	0.046**
Soil Fertility Constraints	0.210	0.195	1.075	0.282
Number of Observation	200			
Model Chi-square (χ^2)	48.912			
Nagelkerke R^2	0.427			
-2 Log Likelihood	182.134			
Sig. (F)	0.000			

Table 3: Multiple Regression Analysis on Factors Influencing Adoption of Biotechnology among Smallholder Cowpea Farmers
Note: ***, ** and * indicate significance at 1%, 5% and 10% probability level respectively
Source: Field Survey, 2025.

Farmers' Perceptions of the Risks and Benefits Associated with Biotechnological Innovations, Particularly Bt Cowpea

Most farmers perceived Bt cowpea as beneficial in reducing pesticide use, reflected in a mean score of 3.15. This indicates widespread agreement that biotechnology enhances environmental and health outcomes. [25] emphasized the reduced chemical dependency of Bt cowpea, which aligns with these perceptions. Farmers agreed that Bt cowpea increases yield, with a mean score of 3.13. [18] Report yield gains from Bt cowpea across northern Nigeria. [26] Theory highlights perceived "relative advantage" as key to adoption. Yield is a fundamental consideration for smallholder farmers, making this a powerful driver of positive perception.

Concerns about long-term health risks of GM crops were moderately expressed (mean = 2.71). A portion of farmers expressed uncertainty or worry about consuming biotechnology products. [25] attributes this to limited public awareness and biosafety education in Nigeria. The belief that biotechnology is intended for large-scale or foreign farmers was modestly affirmed (mean = 2.57). This indicates a perception of exclusion or limited relevance to smallholder needs. [15] suggests that lack of farmer participation in innovation processes contributes to mistrust. A mean score of 2.99 indicated that most farmers agreed the benefits of Bt cowpea outweigh its risks. This aligns with studies by [8], showing that perceived utility often overrides vague concerns.

The perception that biotechnology harms local ecosystems was rejected (mean = 2.44). Most farmers disagreed or strongly disagreed with this statement. [12] suggests farmers may compare Bt cowpea favourably against traditional chemical inputs, perceiving the technology as more environmentally friendly or less disruptive to local farming ecosystems. Farmers strongly perceived Bt cowpea as effective for pest control, as shown by a mean score of 3.23. This reflects practical awareness of the crop's resistance to *Maruca vitrata*. [14] confirm Bt cowpea's success in reducing pest damage. [26] "observability" and "compatibility" factors explain why farmers embrace visible and relevant benefits from biotechnology solutions.

Distrust in government and scientists to regulate GM crops scored a mean of 2.66, indicating moderate concern. While not dominant, this perception reflects regulatory skepticism. [15] attributes such attitudes to weak biosafety communication and limited stakeholder engagement in Nigeria.

Statements	Strongly Agree (4)	Agree (3)	Disagree (2)	Strongly Disagree (1)	Mean Score (Xs)	Decision
Bt cowpea helps to reduce the use of chemical pesticides, which is good for health and the environment.	82 (41.0%)	79 (39.5%)	25 (12.5%)	14 (7.0%)	3.15	ACCEPTED
I believe Bt cowpea increases yield compared to traditional cowpea varieties.	76 (38.0%)	88 (44.0%)	22 (11.0%)	14 (7.0%)	3.13	ACCEPTED
I am concerned that consuming genetically modified crops like Bt cowpea may have long-term health effects.	61 (30.5%)	54 (27.0%)	50 (25.0%)	35 (17.5%)	2.71	ACCEPTED
I feel that biotechnology is primarily developed for large-scale or foreign farmers, not for smallholders like me.	45 (22.5%)	58 (29.0%)	62 (31.0%)	35 (17.5%)	2.57	ACCEPTED
The benefits of using Bt cowpea outweigh any potential risks involved.	69 (34.5%)	81 (40.5%)	28 (14.0%)	22 (11.0%)	2.99	ACCEPTED
I think biotechnology could harm the natural balance of local ecosystems.	40 (20.0%)	53 (26.5%)	61 (30.5%)	46 (23.0%)	2.44	REJECTED
I believe Bt cowpea should be promoted because it addresses major pest problems faced by cowpea farmers.	91 (45.5%)	75 (37.5%)	22 (11.0%)	12 (6.0%)	3.23	ACCEPTED
I do not fully trust the government and scientists to ensure that genetically modified crops are safe and regulated properly.	64 (32.0%)	60 (30.0%)	41 (20.5%)	35 (17.5%)	2.66	ACCEPTED

Table 4: Farmers' Perceptions of the Risks and Benefits Associated with Biotechnological Innovations, Particularly Bt Cowpea
Source: Field Survey, 2025

Challenges Faced by Farmers Limiting Biotechnology Adoption Using Kendall's Coefficient of Concordance

The results of the Kendall's Coefficient of Concordance (*W*) analysis reveal a high level of agreement among respondents regarding the challenges limiting the adoption of biotechnology, with a Kendall's W value of 0.72 and a significance level of $p < 0.001$. The most critical challenge, ranked first with a mean score of 6.82, was the inadequate access to improved biotechnology seeds, particularly Bt cowpea. This reflects structural constraints in seed distribution systems and the limited presence of certified biotech seed suppliers in rural areas, which hinders farmers' ability to adopt new technologies even when they are willing.

The second-ranked challenge, with a mean rank of 6.35, was the lack of accurate information and formal training on biotechnology, reinforcing earlier findings that knowledge gaps impede adoption. Farmers need practical understanding of how Bt cowpea works and how to integrate it into their production systems. The high cost of biotech inputs, ranked third (6.01), also emerged as a significant economic barrier, as many smallholders operate with limited capital and cannot afford commercial biotech seeds or accompanying inputs.

Poor extension access (mean rank = 5.44), low awareness (mean rank = 5.02), and lack of credit (mean rank = 4.57) represent interconnected institutional challenges, consistent with previous research highlighting weak rural infrastructure and service delivery [5]. Interestingly, skepticism about health and environmental risks and cultural/religious resistance ranked seventh and eighth, respectively, suggesting that while socio-cultural concerns exist, farmers are more constrained by structural and economic factors than ideological opposition. These findings point to system-level limitations shaping adoption behaviour.

Challenges Limiting Biotechnology Adoption	Mean Rank	Rank Position
Farmers face major difficulty accessing improved biotechnology seeds such as Bt cowpea.	6.82	1st
There is limited access to accurate, timely information and formal training on biotechnology among smallholder farmers.	6.35	2nd
The high cost of biotech inputs, including seeds and complementary inputs, discourages farmers from adopting the technology.	6.01	3rd
Poor access to agricultural extension services affects farmers' exposure to biotechnology-related innovations and practices.	5.44	4th
Many farmers have low awareness and weak understanding of biotechnology concepts and their applications.	5.02	5th
Lack of access to affordable credit or financing limits the ability of farmers to invest in biotech-based production systems.	4.57	6th
Some farmers remain skeptical or fearful of potential health and environmental risks associated with GM crops like Bt cowpea.	4.11	7th
Cultural or religious beliefs discourage the acceptance and use of genetically modified crops among certain groups of farmers.	3.68	8th
Kendall's Coefficient of Concordance (W) Summary		
Number of challenges (n) = 8 Number of respondents (m) = 200 Kendall's W (calculated) = 0.72 Significance level = $p < 0.001$		

Table 5: Challenges Faced by Farmers Limiting Biotechnology Adoption Using Kendall's Coefficient of Concordance

Conclusion and Recomendations

This study assessed the adoption of biotechnology for sustainable cowpea production among smallholder farmers in Abuja, Nigeria, focusing on socio-economic characteristics, awareness and understanding of biotechnology, adoption drivers, farmers' perceptions, and adoption constraints.

Findings from the socio-economic profile revealed that 62% of respondents were male, with a mean age of 44.2 years and an average farm size of 1.7 hectares. Most farmers (71%) were married, 76% had formal education, and 56.5% belonged to cooperatives. Despite these institutional linkages, only 48% had access to extension services underscoring persistent limitations in agricultural support structures.

In terms of awareness and understanding, 77% of farmers reported having heard about biotechnology, while 64.5% understood that Bt cowpea is genetically modified to resist pests such as *Maruca vitrata*. Furthermore, 68.5% believed biotechnology can enhance yield and reduce pesticide use, yet only 32% were confident explaining biotechnology concepts, and 45.5% acknowledged they lacked sufficient knowledge to make informed decisions.

Binary logistic regression identified key factors influencing adoption. Significant predictors included education ($p = 0.008$), farm size ($p = 0.011$), cooperative membership ($p = 0.006$), contact with extension agents ($p = 0.054$), pest pressure ($p = 0.046$), gender ($p = 0.051$), and farming experience ($p = 0.021$). Marital status and soil fertility constraints were statistically non-significant, indicating that resource access and institutional participation had more predictive power than demographic characteristics alone. Farmers expressed generally positive perceptions of Bt cowpea. They agreed it reduces pesticide use (mean = 3.15), increases yield (3.13), and addresses pest problems (3.23). Nevertheless, concerns remained regarding health effects (mean = 2.71), environmental risks (2.44), and regulatory trust (2.66), reflecting cautious optimism and partial skepticism about biotechnology safety and governance.

Kendall's Coefficient of Concordance ($W = 0.72$, $p < 0.001$) showed strong consensus on the key challenges limiting adoption. These included lack of access to biotech seeds (mean rank = 6.82), limited training and information (6.35), and high input costs (6.01). Socio-cultural resistance and environmental skepticism ranked lower, suggesting that adoption is constrained more by systemic factors than by ideological opposition.

Based on the findings of the study, here are recommendations, derived from the data and analysis:

1. Targeted training programs and field demonstrations should be intensified to improve farmers' understanding of biotechnology. With only 32.0% of farmers able to differentiate biotechnology from traditional breeding, tailored learning materials in local languages would help bridge this knowledge gap.
2. Extension agents should be trained and equipped to disseminate biotechnology-related information effectively. Only 48% of farmers had access to extension services, indicating a need to expand outreach and ensure that biotechnology is included in extension curricula and practice.
3. Since 56.5% of respondents belonged to cooperatives, these groups should be used as entry points for biotech dissemination, training, and input supply. Strengthening cooperative capacity will facilitate peer learning and collective bargaining for inputs and services.
4. Educational campaigns should address lingering fears about health and environmental risks (mean = 2.71 and 2.44 respectively), as well as mistrust in government and scientists (mean = 2.66). Transparent biosafety communication and participatory regulatory processes can help build trust.
5. Considering the high cost of biotech inputs ranked third among challenges (mean rank = 6.01), government subsidies or public-private partnerships should be developed to make biotech seeds and complementary inputs affordable for smallholder farmers.

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