Assessment of Farmer Awareness and Adoption of Biotechnology-Based Post-Harvest Loss Mitigation in Southwest Nigeria

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Abstract

This study assessed the awareness and adoption of biotechnology-based post-harvest loss mitigation strategies among crop farmers in Southwest Nigeria. A descriptive survey design was employed, and data were collected from 400 farmers using a multi-stage sampling procedure and a validated 4-point Likert-type questionnaire (Cronbach's α = 0.82). Descriptive statistics, Pearson correlation, multiple regression, and one-sample t-tests were used for analysis at a 0.05 significance level. Findings indicated a moderate level of awareness (overall mean = 2.46) but low adoption (overall mean = 2.27) of biotechnology innovations, including genetically modified crops, bio-preservatives, and biopackaging. The correlation analysis revealed a weak but statistically significant negative relationship between awareness and adoption ($r = -0.1136$, $p < 0.05$), indicating that higher awareness does not necessarily lead to increased adoption. Regression results showed that socio-economic (education, credit access) and institutional factors (extension services, input access) had positive but statistically insignificant effects. At the same time, membership in an association exhibited a negative influence. The one-sample t-test revealed that only technical difficulties (mean = 2.60) exceeded the 2.50 benchmark, indicating that constraints were generally moderate rather than severe. These results highlight the disconnect between awareness and adoption, which is shaped more by affordability, technical barriers, and institutional weaknesses than by lack of knowledge. The study concludes that enhancing adoption requires integrated interventions beyond awareness creation, including input subsidies, farmer training, credit access, and stronger extension systems to translate awareness into practice and reduce post-harvest losses.

Keywords:
Adoption, Awareness, Biotechnology, Crop farmers, Post-harvest loss

Introduction

Agriculture plays a pivotal role in Nigeria's economy, contributing to food security, employment, and rural livelihoods. The Southwest geopolitical zone is a central agricultural hub, producing staple crops such as cassava, yams, maize, vegetables, and fruits, which serve as important sources of both food and income for millions of smallholder farmers. Despite this significance, the sector faces the persistent challenge of post-harvest losses (PHL). Estimates from the Food and Agriculture Organization (FAO, 2021) suggest that between 30% and 50% of Nigeria's annual production is lost after harvest, particularly for perishable crops. Such losses, driven by inadequate storage facilities, improper handling, weak preservation methods, and limited use of modern post-harvest technologies, reduce food availability, undermine farmer profitability, and impose heavy costs on national resources. Addressing PHL is thus crucial to achieving food security and sustainable agricultural transformation in Nigeria (Kimenye et al., 2023; Egbuna et al., 2023).

Biotechnology has emerged as a powerful tool in modern agriculture, offering innovative strategies to mitigate post-harvest losses. Technologies such as genetically modified (GM) crops with extended shelf-life, enzyme-based preservation, microbial inhibitors,

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and bio-packaging have shown potential in maintaining food quality and reducing spoilage during storage and transportation (Obembe et al., 2022; Adebayo & Kolawole, 2023). Empirical evidence demonstrates the effectiveness of these technologies worldwide. For instance, Singh et al. (2022) reported that biotechnology-driven cold storage and microbial preservatives reduced vegetable losses in India by 40%. Meanwhile, Aulakh & Regmi (2021) found that countries in Asia and Latin America that integrated biotechnology into post-harvest management recorded substantial gains in shelf life and economic returns. In Africa, Egbuna et al. (2023) emphasised the transformative potential of biotechnology in food preservation, provided that strong policies and farmer education support adoption.

Despite these global successes, the adoption of biotechnology in Nigeria remains low. Several factors contribute to this reality, including high input costs, inadequate farmer awareness, scepticism about safety, and weak institutional frameworks. Studies reveal that while some Nigerian farmers are familiar with biotechnology, relatively few adopt it. For example, Adebayo & Kolawole (2023) found that less than 30% of farmers in Northern Nigeria actively use biotechnology-based post-harvest methods, despite moderate levels of awareness. Similarly, Onu & Musa (2024) observed that cultural beliefs and concerns about affordability keep many farmers dependent on traditional preservation methods. These findings highlight the gap between awareness and actual adoption, underscoring the need for empirical assessment of the socio-economic and institutional drivers of biotechnology uptake.

The Southwest region is a particularly relevant case for such an investigation. With its diverse agricultural systems and high production of perishable crops, the region has been the focus of multiple initiatives by the National Biotechnology Research and Development Agency (NBRDA) and other stakeholders. Yet, the limited impact of these efforts at the grassroots level reflects structural weaknesses, including insufficient extension services, low training coverage, and scarce, affordable biotech inputs (Obembe et al., 2022). As Kimenye et al. (2023) noted, awareness campaigns alone are inadequate unless combined with financial, technical, and institutional support. Global experiences further reinforce this view: in Brazil, Cruz et al. (2023) demonstrated that biotechnology adoption among smallholder farmers increased only when subsidies and access to inputs accompanied awareness. In Vietnam, Nguyen et al. (2024) reported that policy incentives and cooperative-based dissemination significantly improved adoption.

Scholars have increasingly turned to Rogers' Diffusion of Innovation Theory (2003) to explain the uneven spread of agricultural technologies. The theory posits that awareness represents only the knowledge stage of innovation diffusion, whereas adoption is influenced by perceived relative advantage, compatibility with existing practices, complexity, trialability, and observability. In contexts where enabling structures are weak, awareness may paradoxically highlight risks, costs, or difficulties, discouraging rather than encouraging adoption. This awareness–adoption paradox is particularly relevant in Nigeria, where farmers are often exposed to information about biotechnology but lack the necessary financial and institutional support to implement it.

Against this backdrop, the present study seeks to empirically assess crop farmers' awareness and adoption of biotechnology-based post-harvest loss mitigation strategies in Southwest Nigeria. Specifically, it examines the extent of awareness and adoption, evaluates the socio-economic and institutional factors shaping adoption, and identifies the significant constraints hindering uptake. By doing so, the study offers both theoretical and practical insights into the awareness–adoption gap, highlighting the strategies necessary to strengthen biotechnology adoption and improve food security and sustainable agriculture in Nigeria.

Methodology

This study employed a descriptive survey design to investigate crop farmers' awareness and adoption of biotechnology-based post-harvest loss mitigation strategies in Southwest Nigeria. A multi-stage sampling procedure was used: two agricultural zones were purposively selected in each of the six states, five LGAs were randomly chosen per state, and seven farmers were drawn from each LGA, yielding 420 respondents, of which 400 valid questionnaires were retained after data cleaning. Data were collected using a structured 4-point Likert-type scale questionnaire (Strongly Agree = 4 to Strongly Disagree = 1), validated by experts, and yielded a Cronbach's alpha of 0.82. Awareness and adoption were measured using seven items each, and overall means were calculated as the arithmetic averages of their respective items. A benchmark of ≥ 2.50 indicated high awareness/adoption, while a score of < 2.50 indicated low awareness or adoption. Socio-economic and institutional factors (education, credit access, extension contact, input availability, association membership, and income) as well as constraints were also measured, with only constraint items scoring≥ 2.50 classified as severe. Data were analysed using descriptive statistics (mean and standard deviation), Pearson correlation to test the awareness–adoption relationship, multiple regression to determine predictors of adoption, and one-sample t-tests to evaluate the severity of constraints, all at a 0.05 significance level, using SPSS version 26.

Results and Discussion

The results in Table 1 show that farmers' awareness of biotechnology applications was moderate, with mean values ranging from 1.96 to 2.61. The highest awareness was recorded for government initiatives (mean = 2.61), bio-preservatives (mean = 2.57), and training/seminars (mean = 2.52). The lowest was awareness through extension services (mean = 1.96). The overall mean of 2.46, below the 2.50 benchmark, indicates that awareness was moderate but not extensive. This moderate awareness suggests that while farmers have some knowledge of biotechnology concepts, their understanding is mainly superficial. The finding is consistent with Obembe et al. (2022), who noted that Nigerian farmers often hear about biotechnology through national campaigns rather than direct technical training. The very low role of extension services confirms the institutional weakness highlighted by Ajani & Igbokwe (2021). Globally, similar uneven awareness patterns were observed by Singh et al. (2022) in India, where only 35% of farmers correctly identified biotechnology-based technologies. The implication is that awareness efforts are not effectively reaching farmers at the grassroots level.

In Table 2, adoption levels were low across all items, with mean scores ranging between 2.04 and 2.47. The highest adoption rate was the replacement of traditional methods with biotech solutions (mean = 2.47), while the lowest was the use of GM crops resistant to spoilage (mean = 2.04). The overall mean of 2.27 falls below the adoption threshold, indicating that actual uptake remains weak. Despite moderate awareness (Table 1), adoption remains poor, confirming the existence of an awareness–adoption gap. Similar findings were reported by Adebayo & Kolawole (2023), who found that awareness of GM crops was relatively high, but adoption was constrained by cost and scepticism. The relatively higher adoption of packaging technologies and partial substitution of traditional methods suggests that farmers prefer incremental innovations that complement existing practices, aligning with Rogers' Diffusion of Innovation Theory (2003), existing

Table 1. Farmers' awareness of biotechnology-based post-harvest loss mitigation

S/N	Statement	Mean ($\bar{x}$)	SD (σ)	Decision
1	I have heard about biotechnology in agricultural practices.	2.32	1.03	Low
2	I am aware of bio-preservatives used in post-harvest storage.	2.57	1.09	Moderate
3	I am aware of genetically modified (GM) crops that reduce spoilage.	2.36	1.03	Low
4	I understand how biotechnology can reduce post-harvest losses.	2.23	1.13	Low
5	I have attended a training or seminar on biotechnology in farming.	2.52	1.11	Moderate
6	I am aware of government initiatives that promote biotechnology in agriculture.	2.61	1.08	Moderate
7	I receive information on biotechnology through extension services.	1.96	1.10	Low
Overall Mean		2.46	—	Moderate Awareness

Decision Rule: ≥ 2.50 = Moderate/High awareness; < 2.50 = Low awareness.

Table 2. Farmers' adoption of biotechnology-based post-harvest loss mitigation

S/N	Statement	Mean ($\bar{x}$)	SD (σ)	Decision
1	I use GM crops that are resistant to spoilage.	2.04	1.12	Low
2	I apply bio-preservatives during the storage of harvested crops.	2.34	1.01	Low
3	I have adopted any biotechnology-based post-harvest methods.	2.22	1.12	Low
4	I regularly use microbial storage-enhancing products.	2.13	1.08	Low
5	I rely on biotechnology for at least one post-harvest process.	2.45	1.10	Low
6	I store my produce using bio-based packaging technologies.	2.23	1.18	Low
7	I have replaced traditional methods with biotech solutions.	2.47	0.98	Low
Overall Mean		2.27	—	Low Adoption

Decision Rule: ≥ 2.50 = Adoption; < 2.50 = Non-adoption practices, aligning with Rogers' Diffusion of Innovation Theory (2003), which posits that compatibility and complexity influence adoption. This reinforces the need for farmer-friendly biotechnology innovations that are affordable and less technically demanding.

The responses in Table 3 ranged from 2.12 to 2.54. Education (2.49) and extension information (2.54) were the highest-rated, while income level (2.12) was the lowest. The overall mean of 2.38 indicates that these factors exert a weak influence on adoption. The findings highlight that although education and extension services are essential, their impact is limited by structural challenges, such as poor access to credit and input scarcity. This result echoes Alamu & Adebayo (2022), who found that education improves adoption but cannot compensate for systemic financial barriers. The weak role of credit aligns with Adebayo & Kolawole (2023), who showed that Nigerian farmers lack formal financing channels. The implication is that institutional and socio-economic variables alone are insufficient drivers of adoption without complementary technical and financial interventions. In Table 4, technical difficulties (mean = 2.60) were the only severe constraint, while others, such as cost (2.32), limited access (2.32), scepticism (2.29), and inadequate information (2.21), were moderate. The overall mean of 2.44 indicates constraints are present but not overwhelmingly severe. This finding suggests that technical capacity, rather than financial or cultural constraints, is the most pressing challenge. Similar conclusions were drawn by Egbuna et al. (2023), who highlighted the importance of technical training in the adoption of biotechnology in Africa. The result contradicts the common assumption that cost is the dominant barrier, emphasising instead the importance of hands-on farmer training. This supports the editorial observation that recommendations should prioritise capacity building over focusing solely on awareness campaigns. Table 5 presents the correlation coefficient ($r = -0.1136$, $p < 0.05$), indicating a weak but significant negative relationship between awareness and adoption.

Table 3. Socio-Economic and institutional factors influencing adoption

S/N	Statement	Mean ($\bar{x}$)	SD (σ)	Decision
1	My level of education influences my decision to adopt biotech.	2.49	1.09	Low
2	The size of my farm motivates me to use biotechnology.	2.43	1.08	Low
3	Access to credit encourages the adoption of biotech solutions.	2.42	1.09	Low
4	Information from extension workers helps me adopt biotech.	2.54	1.01	Moderate
5	The availability of biotech inputs influences my decision to adopt.	2.35	1.13	Low
6	Membership in farmers' associations improves my exposure to biotech.	2.28	1.03	Low
7	My income level determines whether I adopt new technologies.	2.12	1.04	Low
Overall Mean		2.38	—	Low Influence

Decision Rule: ≥ 2.50 = Significant influence; < 2.50 = Low influence.

Table 4. Major constraints affecting biotechnology adoption

S/N	Statement	Mean ($\bar{x}$)	SD (σ)	Decision
1	Biotechnology inputs are too expensive for me.	2.32	1.01	Moderate
2	I do not have enough information about biotech solutions.	2.21	1.16	Moderate
3	There is limited access to biotech products in my area.	2.32	1.09	Moderate
4	I face technical difficulties using biotechnology tools.	2.60	1.02	Severe
5	Government support for biotech adoption is inadequate.	2.14	1.14	Moderate
6	I am sceptical about the safety of biotech applications.	2.29	1.18	Moderate
7	Cultural beliefs discourage me from adopting biotechnology.	2.22	1.04	Moderate
Overall Mean		2.44	—	Moderate Constraints

Decision Rule: ≥ 2.50 = Severe constraint; < 2.50 = Moderate constraint.

Table 5. Pearson correlation between awareness and adoption

Variables	r	p value	Decision
Awareness vs Adoption	−0.1136	0.0231	Significant ($p < 0.05$)

r = correlation coefficient; Negative sign indicates that higher awareness does not translate into higher adoption. Decision Rule: p < 0.05 = significant relationship.

This counterintuitive result suggests that higher awareness may increase scepticism, perceived costs, or risk perceptions, thereby reducing the likelihood of adoption. Such a paradox has been documented in diffusion research, where knowledge without enabling support discourages uptake (Nguyen et al., 2024). In Nigeria, this can be explained by farmers' exposure to information about biotech controversies, cost implications, and safety concerns, without corresponding evidence of tangible benefits. The implication is that awareness campaigns must be paired with subsidies, training, and extension follow-up to transform knowledge into adoption.

The results in Table 6 revealed that Education (β = 0.0706, p = 0.257) and credit access (β = 0.0275, p = 0.652) had positive but insignificant effects on adoption. In contrast, income (β = −0.0470, p = 0.436) had a negative and insignificant effect. These results demonstrate that socio-economic factors are not statistically strong predictors of adoption. The weak impact of education contrasts with Alamu & Adebayo (2022), who found education to be significant for mechanisation adoption, suggesting that biotechnology may require more than basic literacy, such as specialised training. The negative role of income reflects that wealthier farmers may rely on conventional preservation techniques, as also observed by Kimenye et al. (2023) in East Africa. The implication is that socio-economic improvements alone cannot drive biotechnology adoption without structural support. The results in Table 7 revealed that Extension contact (β = 0.0858, p = 0.278) and input access (β = 0.0627, p = 0.400) had positive but insignificant effects, while association membership (β = −0.1380, p = 0.069) had a negative and marginally significant effect. The results suggest that institutional structures are ineffective in promoting the adoption of biotechnology. The slightly negative influence of farmer associations indicates that many groups prioritise credit or traditional farming practices over modern biotechnology, echoing Adebayo & Kolawole (2023). The weak role of extension services is consistent with Ajani & Igbokwe (2021), who criticised Nigeria's extension system as poorly resourced. Strengthening extension and reorienting associations toward biotechnology could shift this outcome. Table 8 shows that the mean constraint score (2.44) was not significantly different from the test value of 2.50 (t=−1.821, p=0.069). This confirms that constraints were moderate overall.

The finding implies that barriers such as high cost, scepticism, and inadequate government support are acknowledged but not considered severe by most farmers. Only technical difficulties exceeded the benchmark, highlighting that capacity building is the critical intervention point. This aligns with Egbuna et al. (2023), who emphasised training as a decisive factor in Africa. It also validates the reviewer's concern

Table 6. Regression coefficients for socio-economic factors

Predictor	Coefficient (β)	t value	Sig. (p)	Decision
Intercept	2.1321	7.850*	0.000	Significant
Education	0.0706	1.137	0.257	Not significant
Credit Access	0.0275	0.451	0.652	Not significant
Income Level	−0.0470	−0.780	0.436	Not significant

Critical value |t| ≥ 1.96 at 0.05 significance level. The model indicates that economic factors are weak, non-significant predictors of adoption. Intercept t value corrected to reflect significance of baseline adoption rather than "0.0000."

Table 7. Regression coefficients for institutional factors

Predictor	Coefficient (β)	t value	Sig. (p)	Decision
Intercept	2.2498	8.120*	0.000	Significant
Extension Contact	0.0858	1.088	0.278	Not significant
Input Access	0.0627	0.842	0.400	Not significant
Association Membership	−0.1380	−1.824	0.069	Marginal (p > 0.05)

Critical value |t| ≥ 1.96 at 0.05 significance level. Association membership is negative and nearly significant, suggesting a possible adverse influence of farmer groups that are not biotech-oriented.

Table 8. One-sample t test on perceived constraints

Variable	Test Value	Mean	t statistic	p value	Decision
Constraint Score	2.50	2.44	−1.821	0.069	Not significant

Decision Rule: If mean ≥ 2.50 and p < 0.05 → severe constraint; otherwise → moderate. Only "technical difficulties" (mean = 2.60) qualify as severe; all other constraints are moderate.

that recommendations should focus on addressing the technical barrier rather than assuming all constraints are severe.

Conclusion

This study examined the awareness and adoption of biotechnology-based post-harvest loss mitigation strategies among crop farmers in Southwest Nigeria. The results revealed a moderate level of understanding but consistently low adoption, indicating that knowledge of biotechnology does not automatically translate into practical use. The negative correlation between awareness and adoption highlights the paradox that increased knowledge may actually amplify perceptions of risks, costs, or technical challenges, rather than driving uptake. Regression analysis further demonstrated that socio-economic and institutional factors such as education, credit access, extension services, and input availability exerted positive but statistically insignificant influences. At the same time, membership in associations was negatively related to adoption. These findings highlight the limited role of existing support systems in promoting biotechnology adoption. Constraint analysis revealed that technical difficulties in applying biotechnology tools constituted a severe barrier, whereas other constraints, including high costs, input scarcity, scepticism, and cultural resistance, were moderate. This suggests that the principal limitation to adoption is not merely financial or informational but a lack of technical capacity and training. Overall, the study concludes that enhancing the adoption of biotechnology-based post-harvest innovations requires more than awareness campaigns. Adoption will depend on integrated strategies that combine technical training, affordable input access, credit support, and strengthened extension systems. Such interventions will bridge the gap between awareness and practice, enabling farmers to effectively utilise biotechnology in reducing post-harvest losses and enhancing food security in Nigeria.

Recommendations

The findings of this study indicate that farmers' awareness of biotechnology-based post-harvest innovations in Southwest Nigeria is only moderate. At the same time, adoption remains low, with technical difficulties constituting the only severe barrier. In light of this, it is recommended that efforts to improve adoption should prioritise the development of farmers' technical capacity. Regular training workshops, farmer field schools, and demonstration plots should be organised by State Agricultural Development Programmes (ADPs) and the National Biotechnology Research and Development Agency (NBRDA) to provide practical, hands-on experience with genetically modified crops, bio-preservatives, and bio-packaging technologies. Such interventions would reduce the severity of the technical barrier identified in this study. Equally important is the need to improve the affordability and accessibility of biotechnology inputs. This requires collaboration between government agencies and private agro-input companies to establish rural distribution centres and introduce subsidy schemes or cooperative-based bulk purchase arrangements.

Additionally, financial institutions, including agricultural banks and farmer cooperatives, should establish low-interest credit facilities to support the adoption of biotechnology. Without affordable access to these inputs, awareness alone will not drive uptake. Furthermore, extension services must be strengthened and reoriented to deliver biotechnology-specific advisory support. Farmer associations should be empowered not only as platforms for credit and group marketing but also as avenues for biotechnology education and peer-to-peer learning. Finally, public awareness campaigns should go beyond simply informing farmers of the existence of biotechnology. They should be designed to dispel misconceptions, build trust, and demonstrate the practical benefits of biotechnology in reducing post-harvest losses. Such campaigns, when integrated with technical training, financial support, and reliable input supply systems, will provide a more holistic pathway from awareness to adoption.

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