The Influence of Observability on The Adoption of Tissue Culture Banana Seedlings in Tanzania

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Abstract:

In seedling technology, Banana seedlings are undergoing a profound transformation with the integration of advanced innovation, referred to as tissue culture banana seedling. The study delves into the science of seedling technology and innovation adoption within the banana farming sector. We explore the dynamic interactions between tissue culture innovation and farmer adoption. The study adopted a positivism philosophy, cross-sectional survey design, and purposive sampling techniques. A sample size of 350 banana farmers in Kilimanjaro was drawn from the population of the study using the Yamen formula for sample size determination. Since the outcome variable was dichotomous the binary logistic regression model was employed. The result indicates that the highest mean was for the statement banana tissue culture seedling grow faster compared to local sucker (M=3.75), indicating the speed of growth is seen as a clear observable benefit. Standard deviations were relatively low, ranging from 0.826 to 0.872, indicating less variation in responses. These results suggest smallholder farmers perceive tissue culture banana seedlings as having moderately high observability, especially related to the visible benefits of faster planting growth and income generation compared to using local banana seedlings. We shed light on the adoption of tissue culture banana seedlings. Adoption is reshaping traditional seedling suckers practices, enhancing productivity and business opportunity. Farmers' adoption will lead to economic development and job creation. Farmers markets provide opportunities for small farmers and businesses to sell their products, and support to meet the growing demand for locally produced food.

Keywords: Seedlings, Technology, Banana, Observability, Kilimanjaro

Introduction

The banana is a widely consumed food item that is farmed extensively in several countries like India, China, Indonesia, Brazil, Ecuador, Philippines, Angola, Tanzania, Kenya, Uganda, and Costa Rica. It is considered the largest fruit crop globally (Aurore et al ., 2009). The crop is often regarded as a crucial energy source in the diets of individuals residing in tropical wet environments. The banana industry plays a substantial role in the worldwide food trade. The agriculture industry has experienced significant expansion in banana production, with global production reaching over 125 million tonnes per year (Filipenco, 2023).

Currently, there are more than 1,000 different types of bananas cultivated in around 150 countries. The most commercially successful variety is the Cavendish, which makes up around 47% of the world's banana production. Tanzania ranks ninth among the largest banana-producing countries, with an annual production of approximately 3.5 million tonnes (Statistics, 2024). Banana production is a significant agricultural activity in the Tanzanian economy, ranking third in importance behind rice and maize, it employs more than 900,000 farming households. More than 60% of the bananas in Tanzania are cultivated in the areas surrounding Kilimanjaro. The preferred types of bananas in this region are green cooking bananas, specifically Nshale, Matooke, and Tariban. In the Kagera and Mbeya regions, they grow Plantain bananas, locally known as Mzuzu, Cavendish, and Nshakala, which are used for cooking (Tumaini et al ., 2024).

The increasing population expansion and urbanisation in Tanzania have led to food insecurity due to insufficient food availability (Bedasa & Deksisa, 2024). Emerging issues pose a danger to the productivity and sustainability of banana production. The banana business has faced several obstacles that have hindered the ability of both small-scale farmers and traders to fulfill the increasing demand and the stringent quality requirements of export markets in major trading regions (Tumaini et al., 2024 & Shimwela et al., 2022). The banana industry has also expressed concerns regarding plant diseases that have a substantial influence on food security. The diseases in question are black sigatoka disease (BSD), Banana Fusarium Wilt Tropical Race 4, and Banana Bunchy Top Virus (BBTV). Notably, prominent producers have issued warnings regarding the potential breakout of these diseases (Mbo et al., 2024 & Hamed et al., 2024).

Hence, the banana tissue culture technique must be prioritised as the most auspicious field for implementing biotechnological methods to enhance the yield of numerous genetically identical plantlets (Erick et al., 2024). This approach demonstrates numerous advantages compared to traditional propagation strategies. It offers disease-free bananas of excellent quality and ensures consistent planting. Hence, it is imperative to implement strategies aimed at minimising the expenses associated with production (Akala et al., 2021).

In recent years, there has been a growing inclination in various nations, including Kenya, to transition from traditional banana suckers to tissue culture seedlings (Indimuli, 2013). Consequently, numerous researchers have proposed that substituting seedling transplanting with tissue culture seedlings will provide the chance to enhance banana production. The studies mentioned are "Modern Approaches to In vitro Clonal Banana Production" by Erol et al. (2023) and "Efficient Regeneration of Local Banana

Tissue Culture Using Floral Apices by Cytokinin Combination" by Makhsunah et al., (2023). The study conducted by Navik et al (2023) focuses on the application of tissue culture technology to improve the nutritional value of Red Dacca and Cavendish bananas in India, specifically in the context of organic farming. Within this particular framework, the utilisation of banana tissue culture seedlings is vital for the generation of a substantial quantity of plantlets that possess comparable genetic characteristics.

This technique offers multiple benefits in the agricultural sector to enhance the well-being of farmers in poor nations. According to Akech (2023), the newly produced plantlets and plants have a higher probability of being devoid of viruses and illnesses. Furthermore, Busogoro et al., (2023) showed that the use of banana tissue culture not only improves productivity but also leads to greater yield levels when combined with effective disease control. This integrated approach has effectively motivated farmers to adopt the package. Nevertheless, research conducted in Kenya by Kirimi et al., (2023) discovered that the majority of farmers showed little inclination toward embracing banana technologies. Instead, they favored conventional methods due to fluctuating market prices, the absence of subsidized inputs for banana production, limited access to technological resources, scarcity of extension experts, and insufficient demonstrations. Conversely, farmers often base their varietal preferences on presumed criteria, leading to the rejection or non-adoption of certain cultivars (Madalla et al., 2023).

Consequently, tissue culture methods have been developed to generate different culture techniques, wherein macro-propagated plantlets of tissue culture plants exhibit superior performance compared to suckers in terms of bunch weight, hands per bunch, fingers per bunch, and finger size (Manju & Pushpalatha, 2020). In addition, the utilisation of tissue culture technology has been shown to enhance food security and socio-economic factors in the adoption of tissue culture seedlings for banana production (Mulugo et al., 2020).

Nevertheless, the utilisation of the Tissue culture technique in East Africa is still comparatively limited. The adoption of Tissue Culture banana in Tanzania has been limited and inconsistent in Kenya, accounting for a mere 7% of the entire banana production in the country (Bandewar et al., 2017). Adoption rates in countries such as Uganda and Burundi are considerably lower (Kikulwe et al., 2007). Therefore, it is crucial to conduct a study on the adoption of Tissue Culture seedlings, and it is essential to implement observability measures to guide the study in Kilimanjaro.

The objective of this study was to delineate the adoption characteristics of tissue culture banana seedlings among farmers, as well as to identify the innovation traits that impact adoption in the Kilimanjaro region. For this study, Roger's theory is applied to incorporate observable factors that a farmer must consider when adopting and cultivating tissue culture banana seedlings. According to Roger's theory, the attitudes of observability include influential components that affect the adoption of agricultural technologies.

Menon and Sujatha (2021) did a case study in India to examine the application of Rogers' theory of innovation diffusion. The analysis results indicate that the compatibility and trialability of a product have a substantial impact on the intention to purchase solar panels. In Yemen, Zolait and Sulaiman (2008) conducted a study that utilised the Theory of Reasoned Action, incorporating the innovation attributes introduced by Rogers' theory. The findings corroborate the assertion that attitude, relative advantage/compatibility, observability, simplicity of use, and mass media engagement are the primary factors influencing the intention to utilise Internet banking.

In their study done in Bengkulu City, Muliadi and Usman (2024) aimed to investigate the impact of relative advantage, compatibility, complexity, triability, and observability on the adoption of e-wallet applications. The test results indicate that the factors of relative advantage and compatibility do not influence the decision to adopt, however, complexity, trialability, and observability have a favorable impact on the adoption decision.

These publications offer evidence that supports the adoption of technology, however, they do not thoroughly investigate the impact of technology on tissue culture banana seedlings in Kilimanjaro. In our current study, we aim to directly assess the impact of observability on the adoption of tissue culture banana seedlings in Kilimanjaro, even in the presence of illnesses like Banana Xanthomonas Wilt and Banana Bunchy top viral. Hence, research was carried out in Kilimanjaro to assess the impact of observability on the acceptance of tissue culture banana seedlings. The study sought to gain a deeper understanding of the factors that contribute to the adoption of tissue culture seedlings, specifically in terms of enhancing yield production and income. Additionally, the study aimed to provide suggestive evidence for the public, private, and non-governmental sectors to facilitate learning.

Literature Review

Banana production and trade have been affected; by the economic, technological, and climate challenges tied to its production as well as the emergence of pests and diseases that are threatening banana production to smallholder farmers (Pelkmans & Nikolopoulou, 2024). The fast-changing environment, the emerging pests and diseases, and the forthcoming need to feed the increasing global population that is predicted to increase from nine billion to ten billion people by the year 2050 (Imam et al.,2024). The researchers, laboratories, and plant breeders are facing the challenges of exploring more competent and quality seeds to improve crop production Imam et al., (2024). Moreover, with the forthcoming need to feed the increasing global population the inadequate supply, access to quality banana seedlings adoption of available introduced seed crops are major constraints to banana production (Kalyebara et al., 2007).

Banana actors and smallholder farmers in a given region are predominantly dependent on banana suckers obtained from their farmers or the nearest family neighbors' orchards (Ocimati et al., 2013). The over-dependence on locally sourced banana suckers has thus led, over time, to increase pests and diseases on smallholder farms. Access to clean seeds is partly been hampered by the low investment in micropropagation facilities (Abdallah, et al., 2022). The production of micro-propagated plants in plant-tissue-culture technology is the most important method for the propagation of free disease plantlets micro propagation-based (Tinzaara, 2018).

The adoption literature has been very insightful and informative in defining the initial stages and application of technology. Agricultural diversification is required to meet future seed needs and demands for the adoption of new technologies in agriculture. Application and practice of the best cultural practices, fertilisation, and pest control measures will not give the necessary results without the usage of the best planting material (Kirimi et al., 2021). Currently, tissue culture has adopted a viable solution in the horticultural propagation method that has revolutionised the horticultural industry. However, the challenges to adoption vary from one farmer to another and the challenges include; lack of financial resources, low education level, lack of credit, limited access to information, insufficient human capital, inadequate farm size, inappropriate transportation infrastructure, and market access (Suman, 2017 & Tumaini et al., 2024).

Madzar, (2022) conducted a study in Serbia on the motives for the introduction of agricultural innovations, and the method applied for analysis was logistic regression because all observed variables were categorical, exploring the motives of Serbian farmers for introducing innovations from the aspect of Rogers' main attributes of innovations. The outcomes of the applied method of binary logistic regression show that agricultural producers are not so much driven by personal motives in introducing agriculture innovations, especially not by their observability and compatibility with farmers' adopted values. The results also show that Serbian farmers want and need to try new things, but that the market is still not a good place for them to do so (Tumaini et al., 2024).

However, such studies have added to our knowledge about the factors that determine the initial uptake of innovation. The knowledge from the post-adoption process might explain discontinuance with the innovation distinctiveness facilitated its adoption and contributed to its continued use.

This study is based on Rogers' Diffusion theory, with a particular focus on the observability of knowledge components as a crucial factor for the adopters (Rogers, 2003). To the best of our knowledge, most empirical studies are derived from the diffusion of technology theory. As the theory framework includes observability, it becomes better able to explain factors influencing the adoption of the innovation; therefore, we consider Roger's theory to guide this study. Rogers asserts that innovativeness plays a crucial role in comprehending and influencing behavior during the process of making decisions about innovation. It also serves as a motivating factor in the adoption and spread of technology (Sahin, 2006; Parisot, 1997). Although these studies provide insights into technology adoption, they do not address the influence of observability on tissue culture banana seedling adoption in Kilimanjaro. Based on these findings' explanations, the following hypothesis was derived.

H_5. There is a relationship between observability and adoption of tissue culture banana seedlings

Methods

Field surveys were carried out in Kilimanjaro, a region with a land area of 13,209 square kilometers. It is situated at coordinates 4°8′1.32″S 37°48′31.68″E. The designated region for banana cultivation includes Moshi Rural, Moshi District Council, Hai District, and Rombo District. Kilimanjaro benefits from the movement of the Intertropical Convergence Zone, which results in the primary rainy seasons. A quantitative approach was utilized, which involved conducting a cross-sectional survey among 350 smallholder farmers. The selection of participants was done using a multi-stage random sampling process. A closed questionnaire was employed to get data from farmers.

A total of 350 banana farmers in Kilimanjaro were selected as the sample size for this study, utilizing the Yamane formula for determining sample size (n = N/(1+N(e)2 (Yamane, 1967; Umar, & Wachiko, 2021). This study aimed to identify farmers who cultivate bananas using tissue culture and non-tissue culture methods, as specified in the research questions. Given that the dependent variable was binary, the binary logistic regression model was utilised. The classification was established as Y=0 (non-adopter) or Y=1 (adopter of tissue culture). X represents the vector of independent variables or predictors. The independent variable is the perceived attribute of innovation, specifically observability. The binary logistic regression model is expressed in terms of the conditional probability of Y being equal to 1, given X: (Askar et al., 2006).

Results

The profile has been constructed based on the districts, wards, age, gender, education level, agricultural experience, and the type of banana seedlings for which data was collected in the Kilimanjaro region. The data were gathered by a structured questionnaire and evaluated using descriptive and inferential statistical methods, for the study's purpose. The data was examined using both descriptive and inferential statistics. The quantitative data was classified, and a first descriptive analysis was used to summarise the data. This entailed calculating statistics such as frequency, percentage, mean, and standard deviation to describe the distribution of data derived from participant replies. Furthermore, inferential statistics, specifically Binary Logistic Regression, were employed to make conclusions about the entire intended population.

Demographic characteristics of the respondent

The farmers were instructed to specify their age within the specified ranges: 18-35, 36-45, 46-55, and 55-100, using brackets. In addition, the study evaluated participants based on their gender, marital status, educational attainment, and occupation. Table 1 contains a concise presentation of the study findings.

Table 1. Demographic Information of the Respondents (n=350)

District	**Frequency**	**Percentage**
Hai	94	26.86
Rombo	100	28.57
Moshi DC	87	24.86
Moshi MC	69	19.71
Age (Years)		
18 and 35	55	15.71
36 and 45	55	15.71
46 and 55	100	28.57
55 and 100	140	40
Gender		
Female	217	62
Male	133	38
Education level		

No-formal education	13	3.71
Primary education	212	60.57
Secondary education	80	22.86
Diploma	18	5.14
1st Degree	22	6.29
MA and above	5	1.43
Farming experience (Years)		
1 and 5	59	16.86
Above 5	291	83.14

Source: Field Data, (2022)

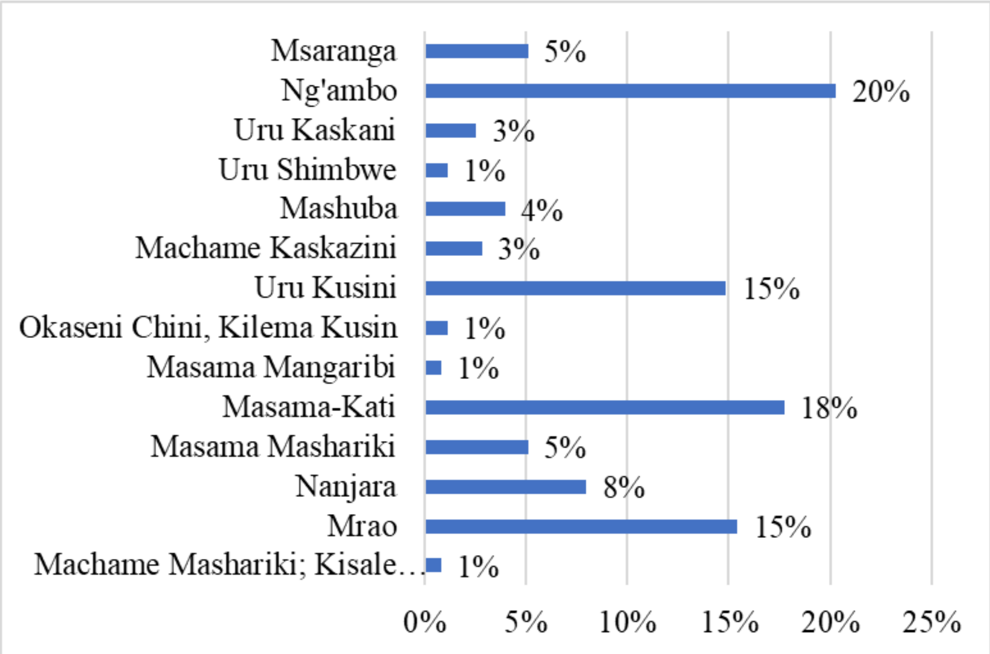

Figure 1. Survey Ward and Percentage of Farmers Interviewed

Table 1 indicates that the data was gathered from the four districts, with the majority of respondents (28.57%) coming from Rombo 100. Out of the 17 wards, the majority of the responders (20.29%) came from Ng'ambo, specifically 71 individuals. The majority of the participants were 140 years old, accounting for 40% of the total. There were 217 females, making up 62% of the respondents. 212 individuals, or 60.57%, had completed primary education. Additionally, 291 participants, equivalent to 83.14%, had more than 5 years of farming experience. A majority of the respondents, specifically 140 individuals, which accounts for 40% of the total, were within the age range of 55 to 100 years. Conversely, a smaller proportion of respondents, namely 55 individuals, which represents 15% of the total, were between the ages of 18 and 45 years.

The low number of individuals under the age of 35 can be attributed to various factors such as limited land ownership among youngsters, their pursuit of education, and their migration from rural to urban regions in search of work and economic opportunities. In terms of gender, 217 individuals, or 62%, were female, while 133 individuals, or 38%, were male. The higher proportion of females can be attributed to their position within the family, as well as their particular interests and ability to manage the farm and family.

Development practitioners must address the societal role of women while formulating strategies for the economic empowerment of women, while also taking into account the broader social, political, and economic context in which women reside.

The Influence of Observability on The Adoption of Tissue Culture Banana Seedlings in Kilimanjaro

Descriptive statistics were computed to assess the respondents' experiences in terms of the visibility of tissue culture banana seedlings compared to traditional banana seedlings. The variability of the responses was assessed by measuring the mean score and standard deviation (Field, 2009). A step-by-step regression analysis was performed using Binary Logistics Regression to examine three properties of the elements: observability of the dependent variable (whether it was planted or not). The findings in Table 2 demonstrate that the statement "Banana tissue culture seedlings grow faster compared to local suckers" received the highest mean score of 3.75, suggesting that the speed of growth is widely perceived as a distinct and measurable advantage. The statement on the acceleration of revenue generation also received a favorable mean (M = 3.62). The food security assertion had the lowest mean score (M = 3.42), indicating a good perception overall. The standard deviations had a comparatively low magnitude, ranging from 0.826 to 0.872, suggesting a reduced level of variability in the answers. The findings indicate that smallholder farmers consider tissue culture banana seedlings to have a relatively high level of visibility, particularly in terms of the noticeable advantages of faster plant growth and income generation compared to employing local banana seedlings.

Table 2. Mean Score for Observability Responses (n=350)

Item	**Mean**	**SD**
Banana tissue culture seedlings lead to more food security faster compared to Banana local suckers	3.42	0.872
Banana tissue culture seedlings lead to more income generation faster compared to Banana local suckers	3.62	0.826
Banana tissue culture seedlings grow faster compared to Banana local suckers	3.75	0.86

Source: Field Data, (2022)

Binary Logistics Regression Analysis

This section showcases the outcomes of Binary Logistic Regression, illustrating the parameters that influence the acceptance of tissue culture banana seedlings. A binary logistic regression analysis was performed on the observability scale, with the dependent variable being adoption or non-adoption. The variables in the equation represent observability. This methodology relies on the assumption that mistakes are independent, outliers are absent, and there is no multicollinearity. These assumptions are necessary to accurately evaluate the importance of the impact size and model variance (Paul et al., 2013).

Multicollinearity Test

The test for multicollinearity suggests that all the independent variables exhibit Variance Inflation Factors (VIF) below 10 and tolerance values exceeding 0.1, satisfying typical threshold standards. The VIF spans from 1.335 for Observability and 0.749 tolerance range for Observability as indicated in Table 3.

Table 3. Test of Multicollinearity

Variable	Tolerance	VIF
Observability	0.749	1.335

Source: Field Data, (2022)

Test of outliers

The outliers gave valuable insights into the methodology. An outlier can arise from a change in either the mean (location) or the variability (scale) of the process. While a specific observation in a given sample may appear to be an outlier, the underlying mechanism may have changed. Bootstrap percentiles were employed to evaluate potential anomalies. The descriptive statistics indicate that the 95% confidence intervals for the means vary between approximately 0.09 points (for Adoption). The Adoption variable has the tightest confidence interval, which spans from 0.14 to 0.23, with a range of 0.09 points (Walfish, 2006).

This indicates a scarcity of exceptional data points that are causing the distributions to be distorted. In addition, the standard deviations across variables are relatively minor, ranging from 0.63592 to 0.79357. The low standard deviations, coupled with the tight confidence intervals, indicate the absence of any noteworthy outliers among these metric variables. The data exhibit a symmetrical distribution with no significant skewness, as evidenced by the findings presented in Table 4.

Table 4. Bootstrap Percentile Results for Outliers Test (n=350)

Variable			Bias	Std. Error	95% CI	
					Lower	Upper
Observability	Mean	3.5962	-0.0001	0.0387	3.5181	3.6714
	SD	0.7191	-0.0016	0.0398	0.6359	0.7936
Adoption	Mean	0.18	0	0.02	0.14	0.23
	SD	0.387	-0.001	0.017	0.35	0.419

Source: Field Data, (2022); CI= **Confidence Interval**

Logistic Regression Analysis

The technique of binary logistic regression was utilised to categorise and forecast the values of the element and the characteristic outcome. Before including variables into the equation, the baseline model was evaluated, as depicted in Table 5. The Wald test yielded a statistically significant result ($p < .000$), suggesting that incorporating the constant improves the fit of the model. The exponentiated coefficient for the constant was .224, indicating that the estimated baseline probability of the event occurring when all predictor values are zero. The number is 224.

Table 5. Baseline Model Summary

	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-1.497	0.138	117.215	1	0	0.224

Source: Field Data, (2022)

Omnibus test

The omnibus test was utilised to ascertain the presence of a substantial correlation between the predictor factors and the outcome variable in the study. The omnibus test was utilised to ascertain the presence of a substantial correlation between the predictor factors and the outcome variable in the study. The exercise conducted a comparison between the independent variables and the model that incorporated all the present predictors. The null hypothesis posits that the coefficients for all predictors are precisely zero, indicating that none of them hold any utility for prediction purposes. Nevertheless, the chi-square test for model X (104, 350) = 169,887 yielded a remarkably significant result, with p <.000. This presents compelling evidence to refute the null hypothesis. The Step, Block, and Model chi-square tests all yield the same conclusion, indicating that including the complete set of variables considerably improves the logistic model's capacity to explain the outcome compared to the baseline, as shown in Table 6.

Table 6. Omnibus Tests of Model Coefficients

Step 1	Chi-square	df	Sig.
Step	169.887	104	.000
Block	169.887	104	.000
Model	169.887	104	.000

Source: Field Data, (2022)

Logistic model summary

Table 7 presents indicators that assess the goodness-of-fit and explanatory power of the logistic regression model. More precisely, it provides the -2 Log Likelihood value as well as two pseudo-R-squared metrics: Cox & Snell R Square and Nagelkerke R Square. The Cox & Snell value is 0.385, whereas the Nagelkerke value is 0.626. The Nagelkerke value indicates that the model accounts for about 62.6% of the variance in the outcome variable. The model summary reveals that the whole model explains 62.6% of the variance in the adoption of banana tissue culture. This indicates that the independent variables, namely Observability, account for more than half of the impact on adoption.

Table 7. Model Summary

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
163.102	0.385	0.626

Source: Field Data, (2022)

Hosmer and Lemeshow Test

The Hosmer-Lemeshow goodness-of-fit test assesses the predictive accuracy of the logistic regression model about the observed outcomes in the data on the adoption of tissue culture banana seedlings. The test resulted in a chi-square value of X (350,8) = 5.123, with a p-value of .744. Given that the p-value is greater than the threshold of

0.05, we cannot reject the null hypothesis, which states that there is no difference between the expected and observed adoption outcomes. This suggests that the probabilities generated by the model closely align with the observed distribution of events in the banana seedling data. There is a strong correlation and accurate alignment between the anticipated adoptions and the actual decisions made by farmers on the adoption of tissue culture seedlings. Assuming the model performs well, we can confidently say that the logistic model, using the current predictors, accurately represents the observed results of tissue culture banana seedling adoption, as shown in Table 8.

Table 8. Hosmer and Lemeshow Test

Chi-square	**df**	**Sig.**
5.123	8	0.744

Source: Field Data, (2022)

Classification between farmers adopted tissue culture seedlings and non-adopters.

The classification table assesses the logistic regression model's performance by comparing its projected results of adopting banana tissue culture seedlings to the actual observed outcomes in the dataset. Table 9 shows that the model achieved a high level of accuracy in predicting non-adopters, correctly identifying 98.6% of them. It also had a moderate level of accuracy in predicting adopters, with a correct prediction rate of 59.4%. Overall, the model's predictive accuracy rate was 91.4%. Nevertheless, the main focus is to differentiate individuals who adopt from those who do not adopt, and the comparatively lower sensitivity of 59.4% for those who adopt tissue culture suggests a deficiency in accurately identifying the adoption of banana seedlings. Significantly, out of a total of 64 adapters, 26 were mistakenly categorized as non-adopters, which reveals a noteworthy constraint.

Table 9. Classification Table

Observed	**Predicted: Adoption**		**% Correct**
	Non- Adopters	Adopters	
Non- Adopters	282	4	98.6
Adopters	26	38	59.4
Overall Percentage			91.4

Source: Field Data, (2022)

Logistic coefficients' Results

The evaluation of the contribution of each predictor in the model was computed as depicted in Table 10. The adoption of banana tissue culture was significantly influenced by Observability ($B = 44.668$, $p < .001$). These findings highlight the complex and diverse elements that influence adoption decisions, highlighting the significance of taking observability into account while promoting the adoption of banana tissue culture.

Table 10. Logistic Regression Coefficients' Summary

Variable	B	Sig.	Exp(B)	95% C.I. for EXP(B)
Observability	44.668	0.000	2.507	(2.471, 2.544)
Constant	-188.7	0.000	0	(0.000, 0.000)

Discussion

The findings revealed significant insights into how observability affects the adoption of tissue culture banana seedlings. Upon examining the distinct impacts of each variable, we observe the significant contribution of each. Especially regarding their accelerated growth and ability to generate income in comparison to local individuals who are easily deceived. The mean scores, which range from 3.42 to 3.75, suggest fairly positive perceptions. The highest mean score is linked to the observable advantage of faster growth.

This can be attributed to the need to consider observability, as Muliadi and Usman (2024) also reported comparable findings. These writers assert that there is a direct and positive correlation between observability and adoption decisions. This means that any increase in observability will result in a corresponding rise in adoption. Erick and other individuals assert that the adoption of banana tissue culture is substantially influenced by the presence of extension services, the cost of seedlings, access to funding, educational attainment, and the availability of agricultural inputs. The socio-economic variables should be considered to support various stakeholders in increasing banana production and improving food security (Erick et al., 2024).

These findings support the assertion made by Rogers and Williams (1983) that farmers are more inclined to accept agricultural innovations when they can easily observe the results. Tristiyanti (2017) supports the notion that observability has a beneficial impact on the acceptance of technology. Similarly, Al-Jabri and Sohail (2012) argue that the visibility of technology adoption has a beneficial impact. In contrast to Krismawan's findings in 2013, Denies argues that observability does not have a detrimental impact on attitudes towards and adoption of innovation. Conversely, the latest research findings indicate that observability has a beneficial impact on the adoption of banana tissue culture. Thus, these hypotheses could provide a rationale for the observed results regarding the adoption of banana tissue culture seedlings. Ultimately, it is worth noting that the decision to use tissue culture seedlings takes into account the factor of observability. Thus, the researcher substantiates the following theory.

H_1: observability influences the decision to adopt banana tissue culture seedlings.

The research model results

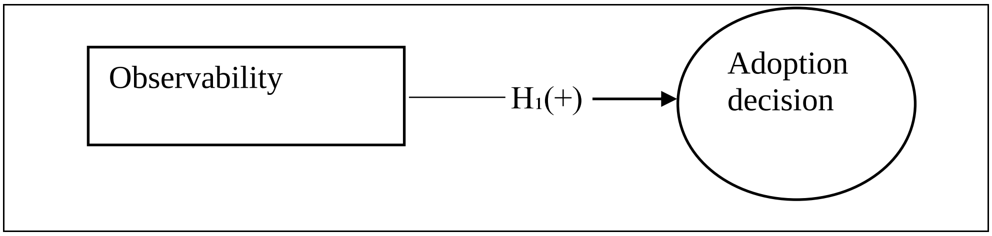

Figure 2. The Research Model Results

Therefore, the enhancement of the agricultural system has played a crucial role in providing sustenance for the growing population. Banana tissue culture seedlings technology is employed to facilitate agricultural development. Given Kilimanjaro's extensive history in banana and other food production, the implementation of tissue culture in banana agriculture would ensure that the region remains a substantial contributor to Tanzania's food security.

Conclusion

The paper emphasizes that the adoption of tissue culture banana seedlings by farmers is greatly impacted by the observability of factors such as food security, income generation, and rapid growth. Hence, the enhancement of the banana tissue culture seedlings technology is one of the techniques employed to promote agricultural development. In summary, the analysis of the study's findings indicated that smallholder farmers usually acknowledge the favorable characteristics of tissue-cultured banana seedlings in comparison to indigenous banana suckers.

The tissue culture seedlings technique holds great potential in addressing a wide range of farmer needs, including yield, food security, and revenue prospects. To enhance the adoption of tissue culture banana and increase banana production, it is crucial to involve farmers and other stakeholders. This can be achieved by investing in local tissue culture banana laboratories and establishing a strong seed system that specifically caters to the needs of farmers.

Recommendation for Theory

In the high-rainfall areas of Tanzania, Bananas and plantains are the main food source. The study provided evidence of a notable correlation between observability and the acceptance of tissue culture banana seedlings in farmers' decision-making processes. The observability characteristics of innovations serve to reduce ambiguity regarding the novelty of the seedling's innovation. The results of the study provide evidence that aligns with Rogers' theory of innovation. The observable outcomes seen by Kilimanjaro farmers will probably lead to a higher rate of adoption of banana tissue culture. The study findings demonstrated the farmers' ability to observe the growth and income generation of banana tissue culture seedlings, as opposed to local suckers, by providing evidence. The participation of farmers in seedling technology is a modern and effective approach that influences their decision to embrace it.

Recommendations for Policymakers, private sectors, and Practice

In Tanzania, the cultivation of bananas ranks as the fourth most significant crop in terms of both food production and revenue generation, benefiting over 30 percent of the population. Remarkably, Tanzania holds the highest consumption rate of bananas globally, with each individual consuming between 280-500 kg annually (Lucas & Jomanga, 2021). More than 80% of Tanzania's population resides in rural regions, and the agricultural industry accounts for over 25% of the country's economy while employing more than 65% of the nation's workforce (Mukasa, 2018). The research findings aligned with the objectives outlined in The Tanzania Development Vision 2025, which aims to eradicate poverty and elevate Tanzania from the category of least developed countries (Tandari, 2004).

Hence, the Tanzanian government must provide subsidies for the cost of tissue culture banana plantlets. In addition, private entities such as banks, cooperatives, Tanzania Agricultural Research Institute (TARI), Tanzania Horticulture Association (TAHA), Southern Agricultural Growth Corridor of Tanzania (SAGCOT), and other stakeholders must increase their investment in extension services. This will enhance the linkage between farmers and researchers. This initiative aims to stimulate the development of sustainable food systems throughout Tanzania by exerting influence and leveraging partnerships to establish a strong and supportive agricultural environment. The goal is to create an environment where farmers, private sector entities, and government organizations can flourish, and where smallholder farmers have the resources and empowerment to produce an ample supply of food.

To facilitate the acquisition of tissue culture plantlets by farmers, the government should establish a banana tissue culture nursery and demonstration plot in each of the banana production regions, namely Kilimanjaro, Arusha, Kagera, and Mbeya. This will enable the dissemination of knowledge regarding tissue culture technologies to neighboring farming communities and potential buyers.

Recommendation for Further Research

Further research is required to explore the extent to which we can accurately measure the effects and results of tissue culture seedlings in banana production, specifically in other regions of Tanzania such as Kagera and Mbeya. This research should also involve examining additional variables related to Rogers' adoption theory. Additionally, it would be beneficial to systematically document the subjective experiences and viewpoints of farmers who have encountered both positive and negative information on tissue culture banana seedlings. Additionally, future research should investigate the comparatively advantageous experiences of banana tissue culture seedlings that are assigned to and occasionally heard by farmer groups participating in the survey.

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