

The Influence of Complexity on the Adoption of Tissue Culture Banana Seedlings in Tanzania

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ABSTRACT

Tissue culture seedlings have been used to improve production in agriculture. However, tissue culture suffers from low adoption. In this context, adoption studies in Tanzania of these types of seedlings are scarce and in general, do not jointly account for the judgment factors affecting the adoption decision among banana farmers. This study investigates the Influence of Complexity on Adoption. Farm-level data were collected through a questionnaire administered to 350 banana farmers in Kilimanjaro. Binary logistic was used to analyse the data and the results show the easier-to-grow significantly increased adoption. The findings of this study propose that; future information on seedlings technology must demonstrate an advantage over traditional seedlings and the investigation evidence supporting seedlings innovation must be clearly visible. We, therefore, concluded that the innovation adoption process has a social and complex element; it requires adequate extension of Information systems and negotiations with key stakeholders in the whole value chain.

Keywords: Banana;
Tissue; Seedlings;
Adoption; Tanzania.

INTRODUCTION

Banana is an important vegetatively propagated staple food, traditionally grown as a semi-perennial crop in Kilimanjaro, Kagera, Mbeya, Kigoma, Arusha, and other regions in Tanzania. Bananas feed up to 30% of the entire human population in Tanzania, and the highlands East African cooking banana (Mchare and Matooke) feeds up to 95% of the population FEWS., (2018); Meya et al., (2023). Banana contributes to around 70% of the household income through the sales of banana bunches (Baijukya, et al., (2005).

Bananas have become the main source of food in the world and their consumption increases along with the increase in the human population Evans et al., (2020). The global export data for bananas is almost 22.7 million tonnes, and this data represents nearly 20% of global production. To the best of my knowledge, the current banana trade is valued at USD 11 billion (FAO, 2020; Voora et al., 2020; Mulugo et al., 2022). The global consumption of bananas is estimated to grow by 1.21% for the forecast period of 2019–2024 and Ecuador in the year 2023 exports to the European Union, Russia, the Middle East, the United States of America, and the Far East reached 35 million boxes, which is about 8% increase. These figures position Ecuador as the largest exporter of bananas, accounting for about 25% of the global exports in total (Voora et al., 2023).

Despite the banana being an essential source of food in Tanzania, diseases and pests have affected the plant, causing yield reductions, thereby negatively affecting the livelihoods of banana producers. In Tanzania, the first disease to be reported was Banana Xanthomonas Wilt (BXW) and the disease was first reported in the Kagera region in the year 2005 (Carter et al., 2010). Another disease is the Banana Bunchy Top Virus (BBTV). The disease caused by this virus infection is termed a Banana Bunchy Top Disease (BBTD). The disease was reported in Kigoma, Kilimanjaro, and Dar es Salaam in the years 2021 and 2022, and the disease is spread by the

movement of banana suckers from one farm to another (Shimwela, et al., (2022); Gurbuz, et al., (2023). There is a need to reduce or restrict the movement of planting materials from one region to another and establish a functional banana seed system to control the spread of BBTD (Shimwela, et al., 2022).

Declining banana productivity is a major problem constraining banana (*Musa* spp.) production in Tanzania Meya., (2023). Banana fruit yield consequently reaches only 15% of the potential, primarily due to inadequate technology. Therefore, it is necessary to explore alternative innovative technologies to increase yield such as Banana tissue culture, which offers disease-free banana tissue culture seedlings that grow vigorously, uniformly, and offer high yields. These banana cultivars are produced in large quantities by using Plant Tissue Culture technology and can be cultivated easily all year Navik et al., (2023). On the other hand, the raw materials for banana tissue culture seedlings production are mostly from the tissue culture process of growing an entire plant from an explant and this aspect of plant biotechnology depends on the phenomenon known as cell totipotency, which describes any single cell's capacity to produce full disease free planting seedlings (Hemanthakumar., and Preetha, . (2023); Ozyigit, et al., (2023).

The success of the research and development of novelty usually occurs when farmers make active use of technology. The challenge with developing countries is low adoption rates of tissue culture technology, it is associated with factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, and inadequate incentives associated with farm tenure arrangements. Sánchez et al., (2018). Noted that, all institutions involved in the generation and the transfer of agricultural technology are advised to design and conduct research that clearly identifies the adoption rate and explains the motivations and determinant factors of farmers.

In Tanzania, the propagation system is characterised by both formal and informal plant material supply. Most small farmers who grow bananas (*Musa* spp) get seedlings from informal sources (Mulugo et al., 2022). Similarly, in Kilimanjaro, the production of bananas dropped from 968,060 tonnes during the 2018/2019 season to 852,682 tonnes in the 2019/20 season. Banana production declined further to 732,662 tonnes in 2021–2022 (Joseph, 2022). The consequences are, pests worsen the productivity of bananas and diseases, especially banana bunchy top disease (BBT) caused by the banana bunchy top virus and Banana Xanthomonas Wilt (BXW), and the diseases are transmitted through banana suckers.

The intervention against this challenge is the adoption of tissue culture biotechnology (Shimwela, et al. 2022; Joseph, 2022). Recently, the Tanzania Horticulture Association (TAHA) in collaboration with development partners, the Ministry of Agriculture, private tissue culture laboratory, has been involved in the development and dissemination of tissue-cultured banana seedlings to increase income and food security that will ultimately ensure the livelihood security of small-scale farming families. However, the banana seedlings uptake is marginal by farmers in Kilimanjaro.

The analysts have established that it is uncommon for farmers to adopt a particular technology without fully realising the benefits it offers (Muyanga, 2019; Birch, (2018). Some farmers may perceive tissue culture seedlings as not being beneficial, while others do perceive them as beneficial for several reasons that need to be known and resolved. The importance of tissue culture in the banana field depends on various

factors that have been discussed that influence the adoption of new technology by farmers. Some farmers were not interested in adopting banana tissue culture, as they preferred the use of local suckers. There were different reasons for not using Tissue Culture, especially by farmers with limited knowledge of the introduced technology (Kirimi et al., 2023).

Diffusion of innovation theories has established different attributes that relate to the adoption of new technology by smallholder farmers, and relate to compatibility, complexity, observability, trialability, and feasibility that influence farmers to adopt or not to adopt all new technologies (Rezaei-Moghaddam and Saleh., 2010).

Complex technologies were more likely to be adopted than less complex technologies (Miller and Mariola, 2019). Less complex technologies had a higher level of continuance. On the contrary, technologies that do not meet the needs of adopters or that can be easily replaced by others are more likely to be abandoned as out-of-date.

Science and technology stand at the center of many critical issues facing societal development. Agricultural technology adoption is founded on the important work of Rogers in his theory of diffusion of innovations Langat et al., (2013). It highlights different attributes that lead to technology acceptance and the complexity attribution highlighted in references with the effect it brings to farmers to understand and apply the introduced technology innovation (Rogers, 2004).

Thus, this work contributes to the previous literature on the adoption by assessing the complex effect of the tissue-culture banana seedlings. Studies consider farmer attitudes and complex perceptions as relevant factors in explaining the decision to adopt. In this regard, there are still some things we do not know about how tissue-culture banana seedlings in Kilimanjaro work, as the theory assumes there is enough research information available to the extension/change agent and does not tend to see knowledge as a combination of research outputs and the farmer's knowledge, experience, and interpretation of the problem.

Moreover, there is the suggestion that all farmers should adopt innovation. The action of innovating is considered positive whereas rejecting an innovation is reflected negatively (Rogers, 2004). To capture and simplify this complexity, Binary Logistic Regression was employed to infer the responses of the completely targeted population by determining the relationship between independent and dependent variables and their effect on the adoption of tissue culture bananas in the Kilimanjaro region.

The dependent variable of this study was measured on a dichotomous scale. This means 0-No (farmers not adopted tissue culture banana seedlings) and 1- Yes (farmers adopted tissue culture banana seedlings). Furthermore, the research is expected to provide the foundation for greater efficiency of agricultural policies as well as help generate and transfer technologies. Importantly, the findings of the current study will act as a catalyst for smallholder farmers' adoption of tissue-culture banana seedlings in the Kilimanjaro region. In addition, a better understanding of the underlying dynamics of the adoption may help improve strategies and accelerate adoption.

METHOD

The study adopted an explanatory where cross-section design was employed at different stages. The study used a population of Banana farmers in Kilimanjaro region from Rombo district, Hai district, Moshi Rural, and Moshi municipal. Structured questionnaires were used to collect data from 350 smallholder farmers who have been

in banana farming for at least 3 years. The study used a multistage sampling technique; farmers were purposively selected randomly and proportionally surveyed and interviewed from 36 villages. The descriptive analysis was used to analyse quantitative data and Binary Logistic Regression was employed to infer the responses of the targeted population by determining the influence of complexity on the adoption of tissue culture banana seedlings in the Kilimanjaro region.

RESULTS AND DISCUSSION

Table 1: The Cronbach Alpha Test

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.736	.890	29

Internal consistency was used to assess the reliability of the data whereby the split-half technique was employed. The technique involved separating the farmers into four equal halves responding to the same set of research tools. The score for each set was computed and the relationship between the two sets of score were examined to see whether the measure of reliability was used to evaluate the degree to the different respondent's data test that probe the same hypothesis.

The Cronbach Alpha test was used to find out the reliability of the data, that is, the internal consistency of the data. According to Greco et al., (2018). An Alpha Coefficient above .70 is an acceptable value. The results above summarise the results of the Cronbach Alpha Test. The consistency of results across items was measured with Cronbach's alpha of more than 0.736. Since Cronbach's alpha coefficient aimed to measure internal consistency reliability for a set of items. In this study, the items on a scale are interrelated and measure the same underlying construct. A Cronbach's alpha coefficient of 0.736 suggests a moderate level of internal consistency. This means the items are related and measure the adoption of banana tissue culture seedlings with the same construct, and the implication was internally consistent.

Table 2: Omnibus Tests of Model Coefficients

Step 1	Chi-square	df	Sig.
Step	11.071	6	.086
Block	11.071	6	.086
Model	11.071	6	.086

Source: Field Data, (2022)

The **Table 2** results signpost that, the Sig. value is .086 which is greater than .05 ($p < .0005$). The table results further indicate the chi-square value of 11.071 with 6 degrees of freedom (df). From these results, it is realised that the model did not perform well as expected.

Table 3: Hosmer and Lemeshow test

Chi-square	df	Sig.
26.561	7	.000

Source: Field Data, (2022)

The above model goodness of fit is not supported by the Table 3 results. The results specifically indicate that Sig. value of .000 which is less than .05 with the chi-square value of 26.561 with 7 degrees of freedom. These results support the model in the sense that the model used in the study had no goodness of fit like what the previous table indicated.

Furthermore, **Table 4.** Results describe the set of Complexity variables which explained the variability between .031 and .051. In other words, the explained variation in the dependent variable based on this study model ranged from 31% to 51%. Using the Nagelkerke R^2 value, the explained variation in the dependent variable is 51%.

Table 4: Model Summary

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
321.918	.031	.051

Source: Field Data, (2022)

Table 5. Results call attention to how well the model was able to predict the correct category of the dependent variable for each case. It is noted that the model correctly classified the 82.0 percent accuracy in classification.

Table 5: Classification Table

Observed	Predicted Adoption		% Correct
	Not Adopted TCBS	Adopted TCBS	
Not Adopted TCBS	285	1	99.7
Adopted TCBS	62	2	3.1
Overall Percentage			82.0

Source: Field Data, (2022)

Table 6 results show that complexity 27 ($p=.006$) was statistically significant while all the rest complexity items 26, 28, 29, 30, 31 ($p=.564$; $p=.405$; $p=.175$; $p=.694$; $p=.350$) were statistically insignificant. In other words, one item of complexity (easier to grow) added significantly to the model while the rest of the items (have easier names to refer to, easier to prepare for consumption, have easier technologies to use in growing, have easier technologies to use for consumption, easier to irrigate) did not add significantly to the model. This further means that only one item of complexity influenced the adoption of banana tissue culture seedlings.

Table 6: Variables in The Equation: Complexity on Adoption of BTCS

Items/Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95%CI
BTCS have easier names to refer to compared to BLSu	0.11	0.191	0.332	1	0.564	1.116	0.768 - 1.622
BTCS is easier to grow compared to BLSu	-0.584	0.211	7.623	1	0.006*	0.558	0.369 - 0.844
BTCS is easier to prepare for consumption compared to BLSu	0.183	0.22	0.694	1	0.405	1.201	0.781 - 1.848
BTCS have easier technologies to use	0.292	0.215	1.844	1	0.175	1.338	0.879 - 2.039

Items/Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95%CI
to grow compared to BLSu							
BTCS have easier technologies to use for consumption compared to BLSu	-0.086	0.22	0.154	1	0.694	0.917	0.596 - 1.411
BTCS are easier to irrigate compared to BLSu	-0.192	0.205	0.872	1	0.35	0.826	0.552 - 1.235
Constant	-0.62	0.704	0.776	1	0.378	0.538	-

Source: Field Data, (2022);

Key: BTCS=Banana Tissue Culture Seedlings; BLSu=Banana local suckers*statistically significant

DISCUSSION

The variable “**complexity**” had six factors that were all together expected to affect the adoption of the tissue culture banana seedlings. These factors are easier to grow, have easier names to refer to, easier to prepare for consumption, easier technologies to use in growing, have easier technologies to use for consumption, and easier to irrigate. Among the six only one (i.e. **easier to grow**) was statistically significant while five factors (have easier names to refer to, easier to prepare for consumption, have easier technologies to use in growing, have easier technologies to use for consumption, and easier to irrigate) were not statistically significant.

These findings imply that the adoption of tissue culture banana seedlings is affected by complexity only in terms of easier to grow compared to banana local suckers. In other words, some farmers adopted tissue culture banana seedlings as they are easier to grow compared to banana local suckers. These findings further imply that the more the tissue culture banana seedlings are easier to grow compared to banana local suckers, the more the banana farmers adopt. These results are in contrast with those provided by Miller and Mariola, (2019); complex technologies were more likely to be adopted than less complex technologies if add value to farmers. However, less complex technologies had a higher level of continuance. On the contrary, technologies that do not meet the needs of adopters or that can be easily replaced by others are more likely to be abandoned as out-of-date.

On the other hand, the adoption of tissue culture banana seedlings is not affected by complexity in terms of easier names to refer to, easier to prepare for consumption, easier technologies to use for consumption, and easier to irrigate compared to banana local suckers. Some farmers did not adopt tissue culture banana seedlings because the seedlings do not have easier names to refer to, not easier to prepare for consumption, do not have easier technologies to use in growing, do not have easier technologies to use for consumption, and they are not easier to irrigate compared to banana local suckers.

These findings align with Rogers, he hypothesis that, some technologies are easy to understand, while others are not. Since not all technologies are that simple, for adopters to understand and learn from them. According to Rogers (2004), the diffusion of a technology that is too complex to communicate and apply is often slow. This implies that farmers who perceive technologies as complex are likely to discontinue them.

These findings are contradictory to what was found by Thorne, et al. (2022) in Australia. The perception of tissue culture technology was principally positive and significant as it was useful and relatively easy to use, given suitable extension services (Thorne, et al., 2022). The barriers to adoption were about the cost, access to the quantity, quality, and type of avocado trees (Thorne, et al., 2022).

Based on the findings of this study, it seems fair to suggest that; easier-to-grow results add knowledge to the findings of Indimuli, (2013), whose studies found that discontinuance decision is pegged on several factors. Namely: technical and socio-economic factors. On the one hand, technical factors include factors such as pests and diseases, labour requirements of the cultivation of Tissue Culture bananas, and costs of plantlets. In this context, previous studies have mentioned that the technical and socio-economic factors may affect the adoption of agricultural technologies, especially in developing countries where precision agriculture is underdeveloped. Additionally, Thorne et al., (2022) emphasised that perceptions of tissue culture technology adoption were generally positive when introduced simultaneously with appropriate extension services.

CONCLUSION

This study focused on the Influence of Complexity on the Adoption of Tissue Culture Banana Seedlings in Kilimanjaro (Tanzania). Using the binary logistic analysis model. The dependent variable adopts, nor non-adopters is represented by (1) adopters and (0) non-adopters. The independent categorical variable was complexity, which was measured in a five-point Likert scale. Results of the binary logit regression model revealed that, the adoption of tissue culture banana seedlings affected with easier to grow. Therefore, Binary Logistic Regressions found some factors were not statistically significant to the adoption of the tissue culture banana seedlings in Kilimanjaro.

Therefore, agricultural development strategies should address the complex of tissue culture seedlings to farmers and promote tissue culture banana seedlings adoption in the various locations of Tanzania. These results provide the basis for better-informed policy and private-sector interventions in rural areas where an increase in the productivity of bananas is required. Given the importance of the banana in Kilimanjaro and other areas in Tanzania, there is considerable interest in understanding the influence of complex factors on the adoption of the banana tissue culture seedlings.

The current study confirmed that the adoption of the tissue culture banana seedlings is affected by the easiness of growing seedlings. It is interesting because if tissue culture benefits information reach farmers, many smallholder farmers could adopt the banana tissue culture seedlings and farmers will be protected against the banana disease effects. However relatively small percentage of the household heads surveyed were found to plant banana tissue culture seedlings, probably because of the high cost, limited information, disease, and other various challenges.

Our results also revealed not all the items in the study did affect the adoption of the tissue culture banana seedlings. However, the specific items in complexity positively influenced the adoption of banana tissue culture seedlings. Besides, not all the items of complexity affected the adoption of the tissue culture banana seedlings in the Kilimanjaro region. Considering the above, the position of the government and

private sectors in supporting tissue culture seedlings propagation, and dissemination process may play an important role in increasing the adoption by smallholder farmers.

Regional Agricultural reforms must-have features that incorporate new programs for the transfer of financial resources, especially those focused on smallholder farmers. Taking this into consideration, the Ministry of Agriculture, Tanzania Horticulture Association, and other development partners in agriculture should address the various available tissue culture seedlings suitable for farmers and efficiently promote the adoption of precision innovation technology to various stakeholders in the value chain. Additionally, Colleges and Universities should invest in strengthening, the capacity of graduates with knowledge of tissue culture seedlings. Similarly, the existing extension officers should receive regular courses focussing on various topics on agriculture innovation from qualified consultants to increase their knowledge, and later transfer the knowledge to farmers to accelerate the likelihood of changes towards the adoption of tissue culture banana seedlings locality.

An understanding of the technology dynamics for the seedlings sector may help improve strategies to promote adoption. Tanzania's rural extension should aim to improve the quality of life of the smallholder farmers in a justifiable way. We appreciate the Tanzania and private sector extension service for playing an important role but could be strengthened further to provide objective and timely training when new technology emerges. Inadequate research institutes and tissue culture laboratories lead to less technological multiplicity and higher seed prices, which would have negative implications for Banana seedling's availability and the agricultural sector development at large. To achieve the above, it is necessary to create joint actions among all the actors involved in the sector.

Therefore, the current study contributes to the development of new knowledge in the adoption of tissue culture technologies literature. The adoption of improved seeds together with technological complexity innovations can increase the productivity of bananas in Tanzania. This will allow for increased adoption, therefore, increasing yield and contributing to the sustainability of the Tanzania local economy.

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