MODELLING WILLINGNESS TO PAY FOR GENETICALLY MODIFIED TELA® BT MAIZE SEED TECHNOLOGY IN MPUMALANGA PROVINCE, SOUTH AFRICA

BY

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DECLARATION

I declare that the mini dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (Agricultural Economics) has not previously been submitted by me for the degree at this or any other university; that it is my own work in design and execution, and all material contained therein, has been duly acknowledged.

16 August 2022

Mr Phetoe P

Date

DEDICATION

I dedicate my dissertation work to my family and friends. I am grateful to my mom Gloria Phetoe and my 4 siblings (Khomotso, Noko, Sello and Phenyo Phetoe). Special dedication to my late father Chris Khomotso Phaka, and Pastor Abia Oupa Nkgoeng who equally played a fatherly role in my life. To my all-time friends Nkgoeng Kingsley and Kutu Pule, thank you for being there for me always. May the Lord bless you all and make his face shine upon you.

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ABSTRACT

Maize (*zea maize*) is the most important crop in South African grain production, providing nutrients to both humans and animals. It is a basic raw material for producing fuel, starch, oil and alcoholic beverages, as well as other economic benefits such as high yields and high income. Smallholder households have great reliance on agriculture that has shown little productivity improvement over a long period of time. This slow agricultural progression is largely attributed to a relatively low adoption and use of improved technologies, including hybrid seeds and fertilizers. The GM technology has been identified as one of the solutions to prevalent issues of food inadequacy brought about by population growth and dissatisfactory food production by people living in less developed countries.

This study aimed at modelling willingness to pay (WTP) for genetically modified TELA® Bt maize seed technology in Mpumalanga Province, South Africa. The objectives of the study were to: profile socio-economic characteristics of smallholder maize farmers in Mpumalanga Province, assess farmers' knowledge, attitudes, perceptions, and practices (KAPP) towards the TELA® Bt maize seed technology in Mpumalanga Province, South Africa, determine smallholder maize farmers' WTP for the TELA® Bt maize seed technology in Mpumalanga Province, South Africa and analyse the determinant factors influencing smallholder maize farmers' WTP for TELA® Bt maize seed technology in Mpumalanga Province. Data was collected from 289 farmers using purposive and multistage sampling techniques for the TELA® Bt maize, and snowball sampling techniques for the non-TELA® Bt maize farmers

The descriptive statistics, which included cross tabulations and frequency distributions were used to describe socioeconomic characteristics of smallholder maize farmers and their typology, which addressed the first objective of the study. To address the second objective of the study, the Likert-scale and descriptive statistics were used to assess farmers' knowledge, attitudes, perceptions, and practice (KAPP) towards the TELA® Bt maize seed technology in the study area concerned. A discrete choice experiment was deployed to solicit and compute the mean willingness to pay (MWTP) from the farmers, and finally, the Logistic regression model was used to identify determinant factors significant towards WTP for TELA® Bt maize seed technology.

The results from the Logit scale for parameter estimates used to compute the mean willingness to pay (MWTP) showed that the additional amount farmers were willing to pay for a 1 kg bag of the TELA Bt maize seed technology was R6.59. The Logistic regression model empirical results showed that among farmers who were willing to pay for the TELA® Bt maize technology, household size, access to extension services, health perception, trust in government and benefits perception had a significant impact in their WTP.

In light of the research findings, several policy suggestions were made that there should be a concerted effort from the side of the government to ensure frequent exposure of farmers to extension services. It also calls for the private institutions and NGOs responsible for the introduction of GM technology to work cohesively with the members of the public and the media to help facilitate the dissemination of relevant information about GM crops.

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LIST OF ABBREVIATIONS

AATF	African Agricultural Technology Foundation
ARC	Agricultural Research Council
CIMMYT	International Maize and Wheat Improvement Center
CVM	Contingent Valuation Method
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture Land Reform and Rural Development
DCE	Discreet Choice Experiment
GC	Grain Crops
GE	Genetic engineering
GM	Genetically Modified
GMOs	Genetically Modified Organisms
R&D	Research and Development
SADC	Southern African Development Community
SAGL	The Southern African Grain Laboratories
SSA	sub-Saharan Africa
WEMA	Water Efficient Maize for Africa
WTP	Willingness to Pay

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Maize (*zea maize*) is the most important crop in South African grain production, contributing 83% of the national grain production (Diko & Wang, 2020). Apart from providing nutrients to both humans and animals, it is a basic raw material for producing fuel, starch, oil, and alcoholic beverages, as well as other economic benefits such as high yields and high income (Azadi *et al*., 2013; Zilberman *et al*., 2018). This commodity is produced across South Africa with the Northwest, Free State and Mpumalanga Provinces accounting for the major maize producing areas (Diko & Wang, 2020). Mpumalanga contributes more to the total maize production, with approximately 25% of the annual South African maize output coming from the province under just about 24.74% worth of production land (Sechube *et al*., 2020).

The introduction of Genetically Modified (GM) maize varieties in South Africa, first came in 1997 after the authorisation of the Genetically Modified Organism Act, and since its inception over 80% of maize produced in the country is GM (Van der Walt, 2010). South Africa has been participating in biotechnology research and development through governmental parastatal and academic institutions for more than a decade (Gouse *et al*., 2016). Maize is one of the crops that more research developments have been centred around, and about 2.5 to 2.75 million hectares of hybrid maize on average, is assumed to be planted throughout the country each year (Sihlobo, 2016). By the end of 2017, commercialised crops comprising GM technology were reported to have been planted globally to the value of 190 million hectares, with developing countries accounting to 53% of the total output (Carzoli *et al*., 2018). Studies have substantially proven that in the agricultural sector, GM technology is one of the fastest growing technologies in modern history and this is primarily driven by the considerable incentives for farmers resulting from the incorporation of GM technology into their farming practices (Kamthan *et al*., 2016; Levidow & Carr, 2007).

For over two decades, GM technologies have been applied successfully and broadly to protect maize against insect pests that are damaging to the crop. One of the opportunities that come with the adoption of Bt embedded crops is that they have proven to be effective at controlling crop damaging pests, specifically those that are of economic importance to developing countries like South Africa (Kunert, 2011).The insecticidal Crystalline (Cry) protein in the Bt (*Bacillus thuringiensis*) maize produce is essential for providing resistance to popular African maize stem borer (*Busseola Fusca*) and Chilo borer (*Chilo Partellus*), both of which could cause yield losses in the Sub-Saharan smallholder structure (Fisher *et al*., 2015).

Moreover, gene biotechnology in maize crops comes highly recommended, in that it comprises more benefits from desired characteristics such as taste, appearance, texture and size (Chagwena *et al*., 2019). In Africa, debates around the establishment of Genetically Modified Organisms (GMOs) to address macro-economic goals such as food security have not seen much fruition, owing to uncertainties on their impact on human health and the environment (Carzoli *et al.*, 2018; Qui, 2014). Negative rumours and reports that are widespread regarding GM technologies often bring about negative attitudes, and this comes as farmers grow more concerned about their safety (Deng *et al*., 2019). These reports come because of controversies concerning the use of GM foods that had been prevalent over the years on whether they are a sustainable solution to food insecurity. To these claims, it was highlighted that the hostile attitude can be pinpointed to knowledge deficiency about the benefits and advantages of GM technology, which affects consumer purchasing decisions (Todua & Gogitidze, 2017).

Undeniably, the process of risk assessment prior any large-scale deployment of new technology is important to evaluate potential risks that could emerge post its implementation. In an identical manner, the Bt maize seed technology had to be assessed of any hazardous impacts it could pose on human health, to which it was established that there were no adverse effects likely to happen (Hellmich, 2012). Also, literature extensively attest to GM technology foods benefits far outweighing its risks (Shahzadi *et al*., 2015). Nonetheless, drawbacks in the adoption Bt maize seed technology are not exclusively so much about its safety or the controversies surrounding the crop, but they are largely about the biosafety frameworks that most developing countries are finding hard to put in place to address effects of climate change and population growth on its commercialisation (Raman, 2017; Rostok *et al*., 2019).

The Grain Crops (GC) campus of the Agricultural Research Council (ARC) undertakes research projects on maize, among other research programmes. One recent Research and Development (R&D) initiative includes the Water Efficient Maize for Africa (WEMA). This project is a public-private partnership that is coordinated by the African Agricultural Technology Foundation (AATF), with active involvement of other partners that include Monsanto and CIMMYT (Masuka *et al*., 2017). Such initiatives could play an immense role to the South African agricultural development since the market for GM foods like maize has marked a considerable presence in the food industry and is growing remarkably (Bhattarai, 2019).

1.2 Problem statement

Smallholder maize production is of strategic economic significance to rural livelihoods, especially in the sub-Saharan Africa (SSA), where it is mostly a staple food crop providing an average of 40–50% calories consumed by the poor (Agrimag, 2019). Consequently, the commodity has triggered academic and political interest accompanied by remarkable progress and successes in maize R&D focusing on new and well adapted varieties (Santpoort, 2020; Smale, 1995; Smale & Jayne, 2003).

There are number of efforts to advance the development of the germplasm with embedded drought tolerance (Lybbert & Bell, 2010). In 2016, five Bt maize varieties trademarked TELA® developed through the WEMA Project were approved for registration or commercial release royalty-free (i.e., without payment of technology fee) to smallholder farmers in South Africa (Beyene *et al*., 2016; 2017; Edge *et al*., 2018; Nang'ayo *et al*., 2014; Senyolo et al., 2021). The WEMA project made the varieties available to smallholder farmers' royalty free in cognisant that the majority of these farmers tend to struggle with affordability of new technologies (Senyolo et al., 2021). The varieties were initially bred conventionally, to be drought tolerant through the WEMA Project, but protected with the Bt gene (MON89034) against stem borer pests (Hellmich, 2012; Kunert, 2011).

Several smallholder farmers have accessed the varieties through local seed companies and have been growing the TELA® Bt maize varieties for the past few years (Fischer et al., 2015). On the other hand, consumer organizations and non-governmental organizations have expressed concerns regarding food safety, ethical, religious and environmental grounds brought about by the advancement to introduce and implement the use of GM foods (Kimenju *et al*., 2005; Simelane *et al*., 2016; Udomkun *et al*., 2018). Nevertheless, the perceived health, quality, economic, and food security benefits thus far outweigh the supposed negative impacts, which have not yet been scientifically proven, are the driving force behind consumers' acceptance of GM foods (Bocher *et al*., 2019; Makweya *et al*., 2019; Munthali, 2013; Onyango & Govindasamy, 2005). Therefore, in order to contribute to this ongoing discussion of socio-economic importance, this study sought to model preference and willingness to pay (WTP) for genetically modified Tela® Bt maize seed technology in Mpumalanga Province, South Africa.

1.3 Motivation of the study

The South African economy, just like most of Sub-Saharan African countries, is greatly dependent on agriculture as a significant provider of employment and a major earner of foreign exchange, with maize being the most important and second largest produced crop (DAFF, 2017; DALRRD, 2020). Smallholder households have great reliance on agriculture that has shown little productivity improvement over a long period of time (Shee *et al*., 2019). This slow agricultural progression is largely attributed to a relatively low adoption and use of improved technologies, including hybrid seeds and fertilizers (Barrett *et al*., 2017).

The GM technology has been identified as one of the solutions to prevalent issues of food inadequacy brought about by population growth and dissatisfactory food production by people living in less developed countries, particularly in Africa (Munthali, 2013; Simelane *et al*., 2016; Udomkun *et al*., 2018). Therefore, improving the genetics of planting materials of the most preferred crops, specifically those that are considered staple foods can greatly contribute to agricultural productivity (Opoku, 2017). Despite there being unfounded allegations on allergic reactions and long-term health effects of GM crops

(Hulela *et al*., 2020), it was discovered, from the economic perspective that consumers are inclined to purchase GM technology crops on condition that there are potential trade-off benefits like cheaper prices than alternative foods (Waite, 2017). Consumers have also shown higher willingness to pay for second generation GM technology traits that improve crop capacity to withstand droughts and diseases without tempering with the nutritional value of foods (Zilberman, 2018).

According to Muzhinji & Ntuli (2020), most countries in the SADC region have not been able to realise these promises that come with GMO crop varieties because very few of them have fully implemented the necessary biosafety framework to regulate modern biotechnology products. South Africa is one of the few countries with the likes of Egypt, Burkina-Faso, and Sudan to authorise the use of GM maize seed (Gouse *et al*., 2016). Another issue that stands out regarding consumer research is to establish what their preferences are, to inform producers so that they can align their development of new products with consumer preferences (Urrutia *et al*., 2012). Although several studies have been conducted in developed countries like United States of America and the Republic of China related to GM food products (Font, 2009; Toledano, 2017), there remains limited information about farmers' preferences and their WTP for GM maize seed in South Africa. Consequently, this study was necessitated by the need to determine farmers' WTP for the technology to inform adoption decisions.

1.4 Scope of the study

1.4.1 Aim of the study

This study aimed at modelling willingness to pay (WTP) for genetically modified TELA® Bt maize seed technology in Mpumalanga Province, South Africa.

1.4.2 Objectives of the study were:

(i) To profile socio-economic characteristics of smallholder maize farmers in Mpumalanga Province.

(ii) To assess farmers' knowledge, attitudes, perceptions, and practices (KAPP) towards the TELA® Bt maize seed technology in Mpumalanga Province, South Africa.

(iii) To determine smallholder maize farmers’ WTP for the TELA® Bt maize seed technology in Mpumalanga Province, South Africa.

(iv) To analyse the determinants influencing smallholder maize farmers’ WTP for TELA® Bt maize seed technology in Mpumalanga Province.

1.4.3 Hypothesis

(i) Farmers’ knowledge towards the TELA® Bt Maize seed Technology in Mpumalanga Province of South Africa, which influences different factors including perception and attitude do not influence their practices.

(ii) The TELA® Bt Maize seed Technology attributes preferences in Mpumalanga Province of South Africa, do not determine smallholder maize farmers’ WTP.

(iii) The determinants do not influence smallholder maize farmers’ WTP for TELA® Bt maize seed technology in Mpumalanga Province, South Africa.

1.5 Organisation of the study

The study is organised as follows: The first chapter introduced the study, stated the problem and motivation of carrying out such study. An outline of the research aims, objectives and hypotheses guiding this study were also presented in this chapter. The second chapter reviews the literature on similar and related empirical studies regarding the Knowledge, Attitude, Perception and Practices (KAPP) as well as the review on Willingness to pay (WTP) theory. Chapter 3 discusses the research methodology and describes the study area as well as the outline of different analytical procedures used to achieve the current study objectives. Chapter 4 present the results and discuss these against the given objectives. Finally, Chapter 5 provides the summary, conclusion drawn, and recommendations based on the findings.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers the review of literature in relation to the study. It starts with defining the key concepts and later reviews previous studies conducted both locally and internationally. This provided an easy understanding of what key words in the topic intended to address and provided deeper insights into studies previously conducted, ultimately giving an opportunity for identifying gaps, findings and recommendations by those studies.

2.2 Definition of key concepts

2.2.1 Willingness to pay (WTP)

An economic measure of what the maximum amount in monetary terms an individual is willing to forego in other goods and services to obtain a good, in this case the TELA® Bt maize seed technology (Asmamaw *et al*., 2016).

2.2.2 Genetically Modified Organism (GMO)

A term used for crops with genetic material (DNA) altered through genetic engineering techniques, which leads to a change in its physical traits in a way that would not occur naturally to tolerate pests and herbicides, drought and also to improve the growth of the plant (Azadi *et al*., 2015; Mahlase, 2016).

2.3 Review of previous studies

2.3.1 The socio-economic characteristics

The literature on farmers' viewpoint and stance about GMOs is not definitive, considering their diverse spatial endowments, these variations are inevitably integral part of their WTP. Notably, the majority of studies on the socio-economic variables' influence on WTP differ to a greater extend in their context. As a result, Song *et al*. (2021) submitted that each study's discoveries ought to be viewed within the perimeters of its own context.

Findings by Bass *et al*. (2021) on gender variable, hinted that both males and females are distinctively driven by different social and personal objectives in their WTP. With that being said, a high proportion of females were discovered to have higher WTP for products that comprised an element of environmental protection when purchasing a new product (Dardanoni & Guerriero, 2019). Some studies have found that men get comfortable with the resources they had always been having at their disposal and that they do not like trying new things, which reduces their chances of WTP for GMOs (for example, see Kalantari *et al*., 2021).

Regarding age, Kucher *et al*. (2019) proved in their study on factors forming consumer WTP that the variable age negatively relates with WTP. It was further demonstrated that relatively young farmers are more responsive to new innovations, as compared to older and matured farmers who are reluctant to change (Harun *et al*., 2015). In another study, a conflicting opinion was brought to surface claiming that with mature and working-age members having higher opportunities of earning substantial income, their WTP can correspondingly improve with age (Omotayo *et al*., 2021). To support both these claims, Desteur *et al*. (2019) added that the findings on the relationship between age and WTP have shown that the outcomes can go either way. In another study by Evans *et al*. (2017), age was found to be statistically significant and having a negative sign. The implication was that younger farmers may be more eager to try GM crops, simply because of their long-term effects of gaining experience. Nevertheless, Slaba (2019) maintains that age remains a significant factor, as it is tightly connected with consumer life cycle that influences their buying patterns.

Age and experience are the two non-mutual exclusive variables that depend on each other as far as their effects on WTP are concerned. Yet, as much as age influences WTP with the growing number of years, the same is not true for experience where the driving force is largely based on different factors to be discussed below. It is not about whether the new GM technology could bring about positive results to their farming, but rather past experiences with different maize crops those farmers have been exposed to that explains their differences in WTP (Liu *et al*., 2015). As a result, farmers who have had a satisfactory previous experience with the crop in question, rely on their expertise to make purchasing decisions (Berges *et al*., 2015).

The trade-offs between the new GM maize seed and what the farmers had been accustomed to regarding maize seeds varieties are the determinant factors in WTP (Chini & Spers, 2020). Okoffo *et al*. (2016) explained that experience gathered through farming years is what triggers farmers to stick to primitive methods of production, and not necessarily embrace new GM technology, regardless of its benefits. Consequently, as much as older household heads are generally experienced in farming, their WTP declines with age (Martey *et al*., 2014). According to Dwivedi *et al*. (2018), the only exception where farmers feel the desire to buy new technology could be when they have been using GM maize seed technology brand and they perceive it credible (even when it involves new technological innovations).

Education is also one of the factors that significantly influences WTP, more especially when it is related to the improvement of environmental products and services for conservation of resources (Xiong *et al*., 2018). It influences WTP positively, such that the more educated farmers are, the more they become open for paying for newer products than those they have been exposed to over the years (Song *et al*., 2021). Thus, WTP is expected to improve with educational intervention, as farmers have a slight edge of understanding interventions and weigh the trade-offs accordingly (Ali *et al*., 2019).

The importance of education cannot be overemphasized enough as it expands also to important policy implications suggesting governments' intensification in education (Bakar *et al*., 2021). In a study by Jin & LI (2020) on the impact of education on pro-environmental WTP, it was revealed that higher educational attainment stimulates WTP incentive by households. Interestingly, the low levels of education by farmers suggest that for them to learn new and better ways to improve their livelihoods, the whole process implies increased learning costs, which explains why they would rather pass (Ma *et al*., 2020).

Contrary to these arguments, Harun *et al*. (2015) argued that farmers' education levels have a negative correlation with WTP and further claimed that the variable bears no significant effect.

Just like with education, household income has in many studies been found to positively influence WTP, whereby an increase in farm income leads to a sharp increase in WTP for GM crops (Bhat & Sinha, 2016). In another study by Kokoye *et al*. (2018) farmers' income level was also discovered to be a strong predictor of their WTP, that is, it showed a positive direct response proportionate to income. In essence, every marginal increase in the household's per-capita income has an effect on WTP (McFadden & Huffman, 2017), and this is often the case with elderly farmers that reasonably get high income (Chen & Gao, 2016).

From a social point of view, as farmers' education levels increase, their chances of earning non-farm income are multiplied, thus improving their WTP probabilities (Martey *et al*., 2014). Age, together with farming experience and education level are the fundamental social and economic variables that dictate the means to pay in order to lead sustained livelihoods (Aydoğdu *et al*., 2020). Giving a different perspective, Mu *et al*. (2019) pointed out that farmers who strictly depend on crop farming for their livelihoods have a higher WTP for maximised utility than those with diverse alternatives. This conveys a message that farmers with limited financial resources, will mostly likely not be able to afford the cost of newly introduced GM technology (Ghazanfar *et al*., 2015).

To address limited financial challenges, farmers would in most cases engage in multiple economic activities such as participating in the informal economy to supplement their inadequate incomes (Rapsomanikis, 2015). Shausi *et al*. (2019) reiterated that such activities that farmers engage themselves in signifies the crucial role played by income on WTP. However, it was also discovered that when farmers are satisfied with the income derived from agriculture, it becomes fairly easy for them to want to pay more and continue their pursuit for growth and expansion (Dogan *et al*., 2020).

In its broader sense, extension service is defined as a process that assists farmers in becoming conscious of improved technologies and adopt them to improve their efficiency, income and welfare (Sebaggala & Matovu, 2020). Extension service workers are the key personnel crucial in the dissemination of information amongst smallholder farmers, for a successful and rapid adoption of new technologies (Biswas *et al*., 2021; Kotey *et al*., 2017). As recognised by Antwi-Agyei & Stringer (2021) the role of extension agents goes beyond just disseminating information, but also includes the transfer of appropriate technologies and new farming methods that cater for specific needs of farmers. This comes after farmers showed their dissatisfaction with how extension service providers turned out somewhat inadequate in delivering their services to them, in that they don't address their problems at hand (Balloch & Thapa, 2016). The challenges around the agricultural extension service's inability to deliver excellent performance are due to historical setup of public agricultural extension services, wherein it has been subjected to poor financial support systems (Somanje *et al*., 2021). Others range from but not limited to farmers not having accessibility to dependable, practical, and understandable information provided them through extensions services (Brookes & Dinh, 2021*).*

The available agricultural research on the effect of extension services on WTP has revealed that farmers who are frequently exposed to and have experience with new knowledge and technologies through extension service networks appear more willing to pay for GM technologies (Schnurr & Addison, 2017). Aydogdu (2017) observed that more efficient extension and training services contribute positively to farmers probability of using GM technology and their WTP. Cawley *et al*. (2015) reiterated the aforementioned facts that interaction with extension services positively affects farmers' technology adoption decisions. This implies, along the same line of reasoning, that the agricultural extension service mechanism for ensuring a maximised adoption and use of GM crops could prove an effective tool to improve productivity in South Africa (Pan *et al*., 2018). Overall, the extension services' work is very significant given that farmers' capacity building to adopt new farming technological innovations has to a great extent, direct link to their concerted effort to change their attitude vis-à-vis GMOs (Elias *et al*., 2015). Nevertheless, the results are in contrasts to the much-alluded proposition that the male counterparts are mostly in the forefront when it comes to adoption of new GM technology, as they are still accustomed to taking all the major responsibilities on farming issues (Zhang *et al*., 2020).

The last variable that is equally important to be discussed under this section is household size and its effect on willingness to pay. The average household size bears witness to the potential likelihood of household's ability to supply labour and further contribute to improved economic livelihood in rural areas (Omotayo *et al*., 2021). Furthermore, the household members can also help with the cultivation of maize crops in the farms in order to curb food insecurity that most rural people continually find themselves having to battle with (Baloch & Thapa, 2016). Moreover, Elias *et al*. (2020) stated that households with better availability of farm labour stand a good chance of having an increased agricultural productivity, and other farm related benefits owing to the divisibility of the labour force.

Whilst Shausi *et al*. (2019) discovered that household size is not significant to WTP, on the contrary, Antwi-Agyei *et al*. (2021) argued that households with high number of people available tend to have a higher WTP. These authors suggests that the higher the family size, the less likely it is that they would be willing to pay for new technological innovation for crop varieties (Temesgen & Tola, 2015).

2.3.2 KAPP literature review

Studies have revealed that there is very little information pertaining to GM technology (Hernandez *et al*., 2017), which raises lots of concerns and uncertainties around the farming communities, especially concerning the benefits and risks of GMOs (Kumar *et al*., 2018). Flachs (2018) asserted that lack of complete knowledge from the side of the farmers had serious implications on how decisions are made concerning the use of GM technology, versus conventional methods farming. The use of GMOs is perceived particularly by interest groups and opponents of GM technology as means to replace indigenous farming practices to serve agri-business interests (Autade *et al*., 2015). The spill over effects of such perceptions is such that farmers are put in a position where they are undecided about what farming practices to follow and persist with (Zakaria *et al*., 214). Oparinde *et al*. (2017) highlighted that due to lack of knowledge and varying perceptions from the side of the farmers on what they presume would be the impact of adopting GMOs, research on farmers attitutudes towards the GM technologies has not been given duly fitting attention to find out what the overall feeling is. The study attempted to put into perspective what the general status quo is regarding smallholder farmers' position is concerning their knowledge, perceptions and attitudes towards GMO technology as well as how they impact their decision making as far as their farming practices are concerned.

Knowledge

It is on record that due to the current flaws in how information on Bt maize is disseminated to smallholder farmers, most of which are farming with Bt maize, are not fully knowledgeable of what makes it different than other hybrid maize varieties (Tianyu & Meng, 2020). In most cases, knowledge about what GM technology is and how it could be deployed, including vast opportunities it brings to the farming sector has not been disseminated well to smallholder farmers particularly (Kwade et al.,2019). Consequently, there is a need to intensify investments into agricultural Research and development

(R&D) directed at increasing farmers' knowledge about Bt maize technology, as well as other crops that farmers are not familiar with (Panzarini *et al.,* 2015). When there are more educational resources directed at farmers improvement in knowledge and awareness, it benefits them to make the correct decisions when presented with new GM innovations (Kotey *et al*., 2016).

Farmers' knowledge on agriculture is obligatory for the sustainability of resources used in the environment and the ecosystem (Azadi *et al*., 2015). This knowledge is important in understanding and familiarizing oneself with ways in which farmers carry out activities using the limited resources at their disposal, incorporating that to make efficient usage of GM technology (Hameed & Sawicka, 2019). Those with substantial knowledge about GM crops are well aware of the importance of reduced and more efficient use of pesticides through environmentally friendly chemicals, which biotechnology provides (Bakar *et al*., 2021; Cui & Shoemaker, 2018). Farmers' level of knowledge about GM technology dictates their views about benefits and risk perceptions, thus the attitude they hold (Amin *et al*., 2014). Consequently, whether farmers remain more adamant to either farming conventionally and refraining from any form of practices to suggest acknowledgement of GM crops being the ultimate key to their farming struggles (Méda *et al*., 2018) or using GM technology in their farming practices relies on their attitude upon receiving knowledge on the technology (Ghasemi *et al*., 2013).

According to Todua *et al*. (2017), farmers who are open to expanding production in diversified manner tend to open up easily to new ideas that could help in that regard. Extension workers ought to be entrusted with satisfying this dire need of knowledge dissemination to farmers. One of the crucial roles of extension workers to farmers is to promote farmer led innovation and guide them through provision of information on programs in modern agriculture (Kumar *et al*., 2018). The cultivation of GM crops requires the adoption of new and improved management practices to ensure that farmers obtain full benefits of such management practices. Therefore, information dissemination and demonstration through extension services becomes mandatory (Kotey *et al*., 2017).

Perception

The perceptions regarding the use of GM technology crops are largely driven by the plausible loss accompanied by the adoption and implementation of GM technology into farming systems (Hernandez et al., 2017). This clouds farmers judgement in that they become sceptical about the possible unintended consequences, whether they would be beneficial or contrary to what they would have expected (Azadi *et al*., 2015; Kwade *et al*.,2019). Along the same lines of reasoning, it has been highlighted that attribute of innovations may influence their perceptions, more especially risk perceptions (Schnurr & Dowd-Uribe, 2021).

In most developed and some parts of developing countries, public perception on GM foods and technology is divided, with the majority of people believing that GM technology might put the environment, health and socioeconomic climate at risk (Mnaranara *et al*., 2017). Public perception is important when it comes to GM varieties in understanding modern biotechnology and agricultural development, and this is also crucial in influencing government regulations and farmers' use of agricultural technology (Rzymski & Krolezyk, 2016).

Another challenge that comes with the use of GM technology crops, as far as its adoption is concerned is the lack of farmer inclusive engagement as major stakeholders on what approach should be taken to ensure impactful outcomes and show regard for farmers perspective (Schnurr & Mujabi-Mujuzi, 2014; Sanou *et al*., 2018). Smallholder position with respect to GMOs is emphatically of great importance, as they are directly affected and partly responsible for the future of agricultural technology in all aspects of its promotion (Almeida *et al*., 2015). Considering that farmers are affected by the spread of GM crops also drives their decision making for future endeavours as to what technology seems plausibly appropriate for their growth (Kikulwe & Asind, 2020). With that being said, the silencing of farmers in the formulation of public policies on GMOs is considered regrettable as it denies them active participation to help in adapting to new technology (Zakaria *et al*., 2014; Almeida *et al*., 2015).

The disproportionate attention given the farmers on their views on the technology, their absence from the discussions and the limited interest amounts to an important missing element, further fuelling their scepticism (Kikulwe & Asind, 2020). From this, it could be justifiably presumed that the coalition between the government role and the public opinions on GM technology plays a pivotal role in defining farmers' stance on GM technology as far as their perception is concerned (Mnaranara *et al*., 2017).

Attitude

Attitudes towards GM crops in many countries are still mixed due to conflicting opinions, despite the fact that GM technology is one of the most broadly practiced technology in agricultural GM products (Todua *et al*., 2017). People tend to fear what they don't have full comprehension of and the same is true with biotechnology, hence, the mixed feelings (Autade *et al*., 2015).

Literature demonstrated that with time, farmers in developing countries tend to have a negative attitude towards GM technology crops (Mahlase, 2014; Almeida *et al*., 2015). To farmers, continued use of GM technology crops lead to high dependence on agents and loss of their identity. On the other hand, farmers feel like there is no transparency to make them think otherwise on the potentials and risks of GMOs as information is not easily accessible to them (Almeida *et al*., 2015). To make matters worse, NGO's and social movements that are given the latitude to advocate their displeasure with the use of

GM technology are managing well in their attempts to convince producers that the promised benefits are nothing but illusory (Kikulwe & Asind, 2020).

The success rate of GM technology is also indirectly affected by consumer resistance as a result of negative sentiments, which bring about negative change in the attitudes of farmers towards genetically engineered crops (De Steur *et al*., 2019). Fears around the safety of transgenic procedures and their undefined long-term effects on the environment and human health stimulates rejection of GM foods (Rzymski & Krolezyk, 2016). Conversely, the acceptance of GM foods by farmers can be improved, provided the breeding technology used directly benefit them rather than just having traits outside agronomic domain like increased yield, pest resistance and herbicides tolerance (Muringai, 2018).

Practices

Millions of people in Sub-Saharan countries are presumed to be suffering chronic undernourishment with only maize, cassava and a handful of other crops providing much needed calories (Oparinde *et al*., 2017). Due to unfavourable climatic conditions (Patidar & Patidar, 2015), the farming sector is left vulnerably exposed to crop failures, reduced crop yields and quality loss (Biswas *et al*., 2021). Tonne's worth of food produced in farming are lost due to the infestation of pests, globally on an annual basis (Donatelli *et al*., 2017) . On the economic side, the use of pesticides has proven itself valuable to the agricultural sector by increasing productivity, protecting plants and reducing insect-borne and endemic diseases (Barrows *et al*., 2014). The challenges on the control of pests that farmers have been struggling with over the years makes pesticide-free cultivation not so much an appealing move for farmers (Nguyen *et al*., 2018).

On the flip side, the increased use and misuse of pesticides, which could have negative effects on human health and agro-ecosystem, create pesticide resistance of insects and diseases and are of concern to role players in agricultural industry (Nguyen *et al*., 2018; Rocha-Munive *et al*., 2018).The wide variety of pesticides application to crops in Sub-Saharan countries is necessitated by high temperatures and humid conditions that often lead to a rapid multiplication of insects and diseases, thereby consequently resulting in decreased output yields (Nguyen *et al*., 2018).

Conversely, the application of biotechnology in developing countries provides farmers with great opportunities and potentials to improve their living standards and expand on production (Azadi *et al.*, 2015). GM technology is introduced to farmers usually when crops they farm with are faced with considerable problems relating to pest damages and drought challenges, worsened by global warming impact (Sanou *et al*., 2018). The use of GM technology in agricultural practices and development has been faced with polarised opinions between vigorous opposition and enthusiastic acceptance (Paul, 2018). Behind the heated debate lies a more low-resolution challenge of finding a common ground to coming up with measures to combat hunger, malnutrition, and abject poverty (Azadi *et al*., 2015).

The opponents of GM crops argue that the introduction of agricultural biotechnology could pose a threat to the survival of indigenous crops, and thus, negatively affecting biodiversity (Flachs, 2015). They also argue that lack of farmers' knowledge concerning the correct use of Genetic Engineering (GE) technology is one of the underlying factors why farmers are reluctant to use it (Sanou *et al*., 2018). The concerns surrounding GM technology are also directed at questioning the alteration effects on the nutritional quality of foods as well as the potential antibiotic resistance and allergic reactions likely to result from their consumption (Ghasemi *et al*., 2013). The unending debates about the adoption of GM crop technologies are primarily centred on the benefits and safety of crops and foods made from this cutting-edge technology (Klumper & Qaim, 2014). In light of the unprecedented growing number of populations in Africa and around the world at large, coupled with the growing concern of food insecurity, the prospects of GE agriculture being a solution to such burning issues should be given considerations (Kwade *et al*., 2019).

On the positive side, there is a strong correlation between the adoption of Bt technology and income gains (Oparinde *et al*., 2017). Part of the reasons why this is true is because the application of the technology reduces chemical pesticides use and increases yield substantially (Azadi *et al*., 2015). Nevertheless, the contribution of GE technology has not been given enough attention it deserves, except to be looked at as a negative contributor to development (Mahlase, 2016). As a result, the importance of accelerating the adoption of this technology has not been overly emphasised enough. Above all, the stagnation could also be ascribed to how technology is perceived by the public and the farmers in particular, which has a direct impact on its acceptance and adoption rate (Ali *et al*., 2019).

2.3.3 Willingness to pay theory review

Environmental valuation has been considered for non-market valuation to obtain monetary measures of the benefits to individuals' welfare of products improvements and interventions (Guijaro & Tsinaslanidis, 2020). The approaches for assessing WTP can be categorised in to two classifications- revealed and stated preferences (Carson & Czajkowski, 2021; Okoffo *et al*., 2016). The revealed preference approach involves participants who bid real money for actual products; hence, it comes highly recommended to provide unbiased estimates of WTP (Fezzi *et al.,* 2014). However, such crucial market data are barely accessible for research purposes (Guijaro & Tsinaslanidis, 2020). With the stated preference approach, WTP is obtained through a hypothetical market. Unlike the revealed preference, methods under this approach are susceptible to hypothetical bias (Pecharat *et al*., 2020). To solve the hypothetical bias problem of the stated preference technique, an alternative approach was designed by Cummins and Taylor known as cheap talk script (Lemons *et al*., 2022). Another approach that most studies use to minimise the embedding effect of the stated preference technique is by using responses based on marketable goods (Danso *et al*., 2017), and such is the case with the current study.

The three primary evaluation techniques most literatures are found to use in modelling WTP are Contingent Valuation (CV), Discreet Choice Experiment(DCE) and Experimental Auction (Bhattarai, 2019; Sekyere, 2014; Shee *et al*., 2019). The basic methods used to elicit WTP using the three techniques includes: personal interviews, written surveys, and experimental auctions (Corte *et al*., 2021). In recent years, DCE and the contingent valuation method (CVM) have become the state of the art in analysing consumers' WTP (Zander & Feucht, 2018).

The number one principle of the DCE and CVM is to create a hypothetical market where respondents are asked about their preference for a product or changes to its attributes and WTP respectively (Ahmed *et al*., 2015; Zhang *et al*., 2020). Both methods are used primarily because they comprise using an indirect survey that involves rating and ranking procedures for different product attributes to estimate preference structure from which WTP can be derived (Lusk, 2011). The stated preference techniques used by the DCE and CV methods are assumed to be more reliable than the revealed preference techniques used by the experimental auction (Omotayo *et al.,* 2021).

The DCE method is used for market goods with ethical properties such as environmental impacts, whereas the CVM is widely used in environmental economics in the analysis for public goods and very rarely for private goods (Zander & Feucht, 2018). Many academic studies have traditionally used CVM in environmental related research fields including outdoor recreation and tourism (Yi, 2019). The noticeable difference between the two is that the CVM provides the value of total environmental changes while the DCE method is able to value multifaceted environmental changes at once (Pecharat *et al*., 2020). For a CVM study design, a payment card is used to elicit WTP, and it employs either a single bounded or a dichotomous choice format (Janko & Zemedu, 2015). In both formats, participants are asked to state the amount of money they would spend for consumption of a certain good to a question on paying a previously determined amount referred to as the bid price (Gebrezgabher, 2015).

As much as the CVM has gained enormous traction as one of the choicest methods in eliciting consumers' valuation of GM products, the sailing has not been just as smooth. Critics argue that the method is not incentive-compatible because households' decision-making strategies are not explicitly revealed as to how their preference for a good is determined (Danso *et al*., 2017). Furthermore, the shortcoming around the CVM is in its inability to provide full information relating to individuals' WTP, requiring extremely large samples to give accurate estimations of WTP (Shee *et al*., 2019). Respondents are also likely to overstate the amount they would be willing to pay for a product, compared to what they would actually pay for it under normal circumstances (Corte *et al.,* 2021).

Compared with other evaluation techniques, studies have proven beyond reasonable doubt that DCE provides more robust estimates of the value of non-market goods and services, especially when estimating improvements regarding quality of the good in question. The choice experiment technique employs a survey tool to represent goods and services as a set of attributes wherein the levels of the attributes differ across the choice set designed, allowing the valuation on how individuals react to different attribute levels (Khan *et al*., 2019). The DCE approach is mostly preferred despite its biases because the purchasing decisions of consumers tend to relate to observed market purchasing decisions, where a rational consumer has to select a product from a set of options (Danso *et al*., 2017). The trustworthiness of the DCE is based on a long-standing, well-established theory of choice behaviour that considers interlinked consumer behaviours (Berges *et al*., 2015).

2.4 Chapter summary

This chapter covered literature review on empirical studies in relation to the study. It started with defining the key concepts, those being Willingness to pay (WTP) and Genetically Modified Organism (GMOs) and later reviewed previous studies conducted both locally and internationally. Studies reviewed where those that provided an in-depth revelation on the status-quo around farmers' social and economic characteristics and how they related with knowledge, perceptions, attitudes, and practices around GM technologies, ultimately their WTP for such technologies. It further gave an overview on the approaches and techniques used to illicit WTP in relation to their strengths and weaknesses as well as their appropriateness to different studies and objectives under which they could be deployed. Most studies are giving opposing opinions on what factors are of paramount importance in influencing WTP and their direction of influence, a gap that this study looks to close. Furthermore, this study will also look at how such factors could be of effect within the South African context.

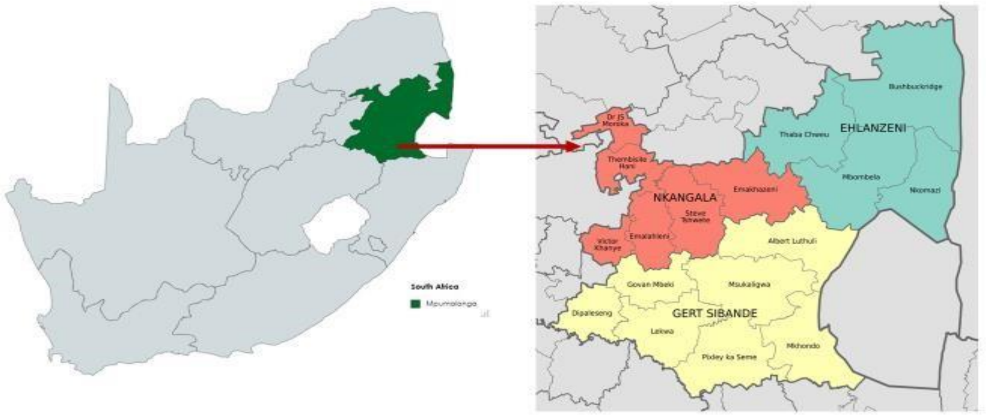
CHAPTER THREE: RESEARCH METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Introduction

This chapter discusses the study area, the research design employed to address the research objectives and the layout for the collection, measurement, and analysis of data for the study. The analytical techniques for addressing the objective on the sociodemographic as well as the framework towards conducting the KAPP evaluation is also provided. This chapter also provides a detailed account of the application of the DCE to WTP as well as the empirical model used to analyse factors influencing WTP. The chapter further goes on to describe some of the variables used in formulating questionnaires used in collecting data from smallholder maize farmers.

3.2 Study area

The current study was conducted in Mpumalanga Province, South Africa, which is one of the 9 provinces of the country. The geographical area comprises 3 districts, namely: Gert Sibande, Nkangala, and Ehlanzeni and it comprises 6.5% of South Africa's land area (DARDLA, 2015). Figure 3.2 below shows the map of South Africa and the location of Mpumalanga Province. Also shown in the map are the districts where the study was carried out.



Source: (Stats SA, 2016)

Figure 3.2: Map of South Africa and the Mpumalanga Province

The province is characterised by summer-rainfalls divided by the slope into the Highveld region with cold frosty winters, and the Lowveld region with mild winters and a subtropical climate. Agriculture forms part of the two leading sectors in the province, constituting 60% of the total land area (Khwidzhili & Worth, 2020). More than 30% of maize produced in South Africa comes from Mpumalanga, as it is one of the two leading provinces that produces tons of maize annually (DAFF, 2017). It was probably for this reason that in 2001, Mpumalanga was one of the provinces to have been identified by Monsato, owners of the Bt maize seed technology, as suitable for the GM maize crop production (Gouse *et al*., 2016). Farmers in the province are known to produce maize both conventionally and with the use of GM technology. Collectively, a total of approximately 5.5 t/ha of white maize yield is produced annually on dry and irrigated land, as compared to the 5.85 t/ha production yield of yellow maize (SAGL, 2019). The promotion of TELA® Bt maize seed technology was noted as important to mitigate the overall climate risk, and subsequently increasing resilience as well as enhancing food security (Greyling, 2019). The geographical co-ordinates of Mpumalanga province are $25.5653^{\circ}S, 30.5279^{\circ}$ covering a total surface area of 76.495 Km^2 of SA.

3.3 Research design

Research design refers to an overall strategy that one chooses to integrate the different components of the study in a coherent and logical way, thereby, ensuring one effectively addresses the research objectives and constitutes the blueprint for the collection, measurement, and analysis of data (De Vaus, 2006). The current study employed a cross-sectional research design, using both the qualitative and quantitative methodological approaches. The quantitative data was complemented by qualitative information, which helped to give underlying meanings regarding the perceived impacts of the TELA® Bt maize varieties on the welfare of the farmers.

3.3.1 Sampling procedure

The study used a combination of probability and non-probability sampling methods, depending on the sampling stage. According to Teddlie and Yu (2007), purposive sampling techniques are used to select units based on specific purposes associated with answering a research study's questions. Hence, a multi-stage sampling approach was utilised. Here, the target population, which is 289 was divided into districts (clusters), districts were further divided into municipalities (strata) and the units of strata were further divided into Villages/local towns (Taherdoost, 2016). Two out of three District Municipalities; Ehlanzeni and Nkangala District Municipalities were selected, as well as corresponding Local Municipalities (LMs) and villages where TELA® Bt maize seed technology has been deployed. These two municipalities were selected because they are amongst the major growing regions of TELA® Bt maize. This study was purposively conducted in Mpumalanga Province based on its dominant maize farmers, as well as the deployment of the TELA® Bt maize seed technology.

The next stage involved identification and selection of the farmers who had been planting the TELA® Bt maize seed, as well as those who had not yet adopted the technology. Due to the low numbers of farmers who are sowing the TELA® Bt maize seed (based on reconnaissance visits), a census method was then deployed with the intention to collect data from all the farmers who were identified to have planted TELA® Bt maize. The records available showed that there were approximately 183 TELA® Bt maize farmers across the study area and consequently all these farmers were considered for the study. In addition, snowball sampling was used to purposively contact the non-TELA® Bt maize farmers until 106 farmers were reached. The sampling for the latter group of farmers also ensured that only the farmers who had not adopted the TELA® Bt maize were exclusively selected for this category. This process was done with the help of the extension officers working in the study area.

3.3.2 Data collection methods

Interviews were conducted to collect primary data, using structured questionnaires containing a combination of open and closed ended questions. The questionnaires were structured to cover the socio-economic and demographic information, major attributes that elicit WTP for genetically modified TELA® Bt maize seed technology among smallholder maize farmers. Consequently, questionnaires were administered to 289 smallholder farmers that were actively engaged in maize farming in Mpumalanga Province, South Africa. To ensure that the data collected conforms to validity and reliability, the questionnaire were subjected to pre-testing, through a pilot survey.

3.4 Research Methods/Analytical techniques

3.4.1 Descriptive statistics

The Descriptive statistics was employed to address the first objective of the study, which was to profile the socio-economic characteristics of smallholder maize farmers in Mpumalanga Province. This included cross tabulations and frequency distributions to describe socio-economic characteristics of smallholder maize farmers in the study area and their typology.

3.4.2 Likert Scale and Descriptive statistics

The Likert scale and Descriptive statistics were used to address objective two of the study. These were used to assess farmers' knowledge, attitudes, perceptions and Practice (KAPP) towards the TELA® Bt maize seed technology in the study area following procedures used by Kimenju *et al*. (2005) and Font (2009).

Table 1: Framework towards conducting the KAPP evaluation

Component	Definition	Attributes	Unit of measure	Sources
Knowledge	Farmers' awareness about the TELA® Bt maize technology.	-Farmers' knowledge about the use and importance of TELA® Bt maize technology on human nutrition and economy, the traits of the seeds.	**Binary response** Scaling: 1 if the farmer had knowledge, 0 otherwise. Farmers with knowledge provided sources of information for analysis purposes.	(Kimenju *et al*., 2005; Munthali, 2013)
Perceptions	The farmers' viewpoint about the benefits of TELA® Bt maize technology given their knowledge about the technology.	-TELA® Bt maize seed technology increases productivity and offers solution to world food problem. - TELA® Bt maize seed technology can create foods with enhanced nutritional value. -TELA® Bt maize seed technology can reduce pesticides on food. - TELA® Bt maize seed technology has potential of reducing pesticide residues in the environment.	**Three-point Likert scale** Scaling range: Agree, Neutral and Disagree. Farmers who agreed to the statements were regarded as having a positive perception and those who did not agree will be regarded as having a negative perception.	(Kimenju *et al*., 2005; Font, 2009).
Attitudes	A weighted some of perceptions towards it and its corresponding process (Ongachi *et al*., 2018)	- TELA® Bt maize seed technology increases productivity and offers solution to world food problem. - TELA® Bt maize seed technology threatens the environment. - Consuming TELA® Bt maize seed technology foods can damage one's health. - TELA® Bt maize seed technology makers are playing god.	**Three-point Likert scale** Scaling range: Agree, Neutral and Disagree. Farmers who agreed to the statements were regarded as having a positive attitude and those who do not agree were regarded as having a negative attitude.	Kimenju *et al*., 2005; Font, 2009).

Practices	Practices refers to what farmers are currently doing as informed and influenced by their knowledge, perceptions and attitudes related to maize production, management of droughts (erratic rainfall) and excessive heat	- Whether farmers plant conventional maize as compared to TELA. - Drought and heat control measures.	**Binary response** Scaling: 1 if the farmer preferred conventional methods, 0 otherwise.	(Ntawuruhunga, 2016; Ehn & Fox, 2019).

3.4.3 Determination of WTP

3.4.3.1 Empirical framework of the discrete choice experiment

Of the three implicitly discussed evaluation techniques, the study adopted the Discreet Choice experiment (DCE). The experimental auction and the CVM were considered not to be suitable for this study. With the experimental auction, the product needs to already be existent in the market (Louviere *et al*., 2010), this could have been a challenge as the TELA® Bt maize seed is not yet established in the markets. The disadvantage with the CVM method is that it provides little information concerning WTP and does not consider the individual attributes, requiring extremely large samples for accurate estimations of WTP (Shee *et al*., 2019) , which is not feasible for this study.

The DCE is one of the trusted approaches to analyse preference due to its proven economic theory (Toledano, 2017). The normal discrete choice analysis estimates the underlying utility components either holistically or partially concerning the levels of attributes for a product or service. The utility structure is estimated according to a choice set, which can be determined completely in terms of attributes (Asrat *et al*., 2010). In the discrete choice analysis, the respondents choose between alternative product profiles where they are decomposed into attributes levels and estimate scores for these levels and their importance, respectively.

The initial step was to identify key attributes that determine farmers' choice when selecting seeds for maize crops, as guided by the framework in the study by Obadha *et al*. (2019). Empirical results showed that the attributes that farmers consider primarily when selecting a new variety are the grain colour, tolerance to excessive rain, resistance to diseases, tolerance of drought (Kassie *et al*., 2015), resistance to pests (Kassie *et al*., 2012), yield (Asrat *et al*., 2010), and early maturity, but this is not to suggest that the list is exclusive to the selected traits. The price (Lee *et al*., 2013) of a product is also another crucial extrinsic trait that has an effect on purchasing decision. The price attribute is important as it allows one to measure trade-offs between levels and monetary units, thus, the measure of WTP as a division of level coefficient by the price attribute coefficient (Perez-Troncoso, 2020).

The second step was to establish discussion group comprising researchers (Troncoso, 2020) in an attempt to shorten the primary information, as guided by literature, so that it could be to a manageable proportion. In collaboration with local extension service worker, researchers from the University of Limpopo (UL) and the Agricultural Research Council (ARC) and through focus group discussions, the final attributes were selected. Given that there is no standard way to identify the exact attributes that drive WTP, the discussion group allowed for the evaluation and the verification on the fitness of the attributes through a pilot questionnaire. The final list consisted of attributes from four categories: yield, pest resistance, drought tolerance and seed price. Regarding the additional information on cost attribute and levels, the price of maize seed was calculated from the average price for a bag of 1kg of seed, provided by local partners. Additionally, the three levels of price reflected the low-end and high-end prices that could be observed in actual seed market in the study area (Rowen *et al*., 2018). Table 2 below shows a framework of the DCE and how attributes were designed with their corresponding levels.

Table 2: TELA® Bt maize seed attributes and levels

Attributes	Attribute labels	Levels
Price (Lee *et al*., 2013)	TELA® Bt maize seed in R/Kg.	22.5, 41.25, 52.5
Drought Tolerance (Kassie *et al*., 2015)	Ability of TELA® Bt maize to yield more than other maize varieties under water deficient conditions.	10%, 20%, 50%
Yield (Asrat *et al*., 2010)	Grain yield measured in (tha^{-1}).	0.5, 2.0, 3.5
Pest resistance (Kassie *et al*., 2012)	Ability of TELA® Bt maize seed to withstand pests.	10%, 20%, 50%

Lastly, in order to reduce the exhaustion that the respondents are likely undergo, it was necessary to reduce the number of product profiles to a manageable number for the respondents. A full factorial design (Sen, 2016) of $(3 \times 3 \times 3 \times 3 = 81)$ was generated using SPSS that yielded 81 choice sets. These choice sets were randomly allocated to

81 questionnaires. Within each choice set, the responded had to make a choice between 3 alternatives.

For the purpose of this particular study, a “status quo” alternative, which addresses the decision problem in terms of changes to the existing state, which was from conventional maize seed to GM seed was not included. The inclusion of “status quo”, is important to present farmers with options and offer the opportunity for them to either delay or refuse to make a choice, provided the options given are not welfare enhancing. The opt-out alternative, as is usually called in some literatures like Weldvijk *et al*. (2013), is necessary in cases where the research seeks to predict the likely adoption of a new intervention or service (Campbell & Erden, 2018). However, there were no indications in the piloting that suggested any impressions that farmers would prefer to refuse all the choices in a choice set, hence, the opt out option was not included in that regard. An example of a choice set is provided in table 3 below.

Table 3: TELA® Bt maize seed choice set

13. Assuming that the following TELA® Bt maize seed technology were your ONLY options, which one would you prefer to plant?

Attributes	**Choice 1**	**Choice 2**	**Choice 3**
Price (R/Kg)	41.25	22.5	52.5
Drought Tolerance (%)	10	50	20
Yield (tha^{-1}).	0.5	2.0	3.5
Pest resistance (%)	50	20	10

I would prefer to plant maize variety under **choice 1**..............**choice 2**............**choice 3**.............

(Please tick one option)

3.4.3.2 Economic framework

According to Asrat *et al*. (2010) on random utility theory, the utility that an individual i assigns to some attributes associated with TELA® Bt maize seed technology can be described as: $U_i = V_i + E_i$. Furthermore, an individual, i, is more likely to choose attributes that provide a utility that offers more satisfaction than any other alternative available in a specific choice set for utility maximisation. Among some of the modelling techniques that analyse choice data, the Generalised Multinomial Logit (GMNL) was chosen to be the most appropriate to estimate the scale parameter (Toledano, 2017). Based on the GMNL model, $prob\ (y_i - j) = \frac{e^{x_i \beta_j}}{\sum_{k=1}^{4} e^{x_i \beta_k}}$ j=1, 2, 3, 4 (1)

Then the supposed utility of an individual farmer, i, for selecting alternative, j, provided in a set of choice, t, can be given in the following formula: $U_{njt} = [\sigma_n \beta + YN_n + (1 - Y)\, \sigma_n N_n] + E_{njt}$. Where Y is a mixing parameter between 0 and 1, whose value represents the level of independence between the scale term σ_n and the heterogeneity of the estimates of attributes (N_n). Attribute-based method used for evaluating preferences allows respondents to choose between, rank and rate two or more options at a time (Sekyere, 2014). Additionally, the decision by farmers to adopt improved maize variety was largely governed by their WTP for different attributes on choice sets (Kassie *et al*., 2015). Therefore, price was entered intrinsically for different choice sets to attributes levels, and using the results from the GMNL model coefficients, the effects of price as an attribute was entered indirectly in an argument called an index function given as: $\Delta\, V_j = \alpha - \beta b_t$ (Aryal *et al*., 2009). The index was then used to measure the WTP of the most preferred attribute by farmers given as $MWTP_j = \frac{-\beta_j}{U}$, which denotes the ratio of coefficients related to the marginal rate of substitution between cost and the marginal utility of the product attribute (Petcharat, 2020).

3.4.4 Determinants of WTP for TELA® Bt maize seed technology.

The Logistic regression model was used to address the fourth objective of the study, which sought to analyse determinants of WTP for TELA® Bt maize seed technology in the study area. The value attributed to the respondent’s WTP is marked as 1 whereas the value for the respondents who are not willing to pay is marked as 0 (Wooldridge, 2013). The interest is predominantly to predict the probability of WTP for the TELA® Bt maize seed technology (Willing/not willing). Then the Logistic regression model was presented as:

$$WTP_\iota = ln\left(\frac{p}{1-p}\right) = B_0 + B_1X_1 + B_2X_2 + \ldots \ldots + B_nX_n + U_i \qquad (2)$$

WTP_ι is a dummy variable where 1 denotes positive WTP and, 0 denotes negative WTP. P represents a probability dependent variable of the value 1. X_ι is a vector of independent variables. β denotes a magnitude of parameters that can be predicted, and while applying this model, the assumption is that there exists an indirect random variable equal to y*, which was considered provided it gave positive outcome. Maximum likelihood method, as observed in most non-linear probability models was the one used to estimate the parameters. U_i is the error term capturing unobservable constituents to the researcher and were treated as having an indirect effect. The general Logistic regression model for the relationship between WTP and the factors that affect the decision was formulated in the following way:

$$Y_i = B_0 + B_1X_1 + \ldots\ldots. B_nX_n + U_i \qquad (3)$$

Model specification

$$Y_i = B_0 + B_1 Gender + B_2 Age + B_3 Education\ level + B_4 Household\ income +$$

$$B_5 Household\ size + B_6 Farming\ experience + B_7 Access\ to\ extension\ services$$

$$B_8 Knowledge\ of\ Bt\ maize\ technology + B_9 Trust\ in\ government +$$

$$B_{10} Benefits\ perception + B_{11} Health\ perception + B_{12} Ethical\ concerns +$$

$$B_{13} Environmental\ concerns + B_{14} Equity\ concerns + U_i$$

Table 4: Table of variables

Variables			Description	Unit of measure	Expected sign
Dependent					
Y			WTP Willingness to pay household is Dummy pay, 0 otherwise	1 if the willing to	
Independent					
X1	GND	Gender	1 male, 0 otherwise.	Dummy	+
X2	AGE	Age	Years in number	Years	+/-
X3	LOF	Level of education	Number of years in schooling	Years	+
X4	HHI	Household income	Monthly income	Rand	+
X5	HHS	Household size	Number of people within the house	Number	-
X6	FEP	Farming experience	Number of years farming	Years	+
X7	AES	Access to extension services	1 if yes, 0 otherwise	Dummy	+
X8	KNW	Knowledge of TELA® Bt maize technology	1 if yes, 0 otherwise	Dummy	+
X9	TIG	Trust in government	1 if yes, 0 otherwise	Dummy	-

X10	BNP	Benefits perception	1 if yes, 0 otherwise	Dummy	+
X11	HLP	Health perception	1=strongly disagree, 2= disagree, 3=neutral, 4=agree, 5=strongly agree	Categorical	-
X12	ECC	Ethical concerns	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree	Categorical	-
X13	EVC	Environmental concerns	1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree	Categorical	-

3.5 Ethical consideration

3.5.1 Ethical clearance

Permission to conduct this research was obtained from Turfloop Research Ethics Committee (TREC) to ensure conformity with ethical principles of the University of Limpopo, preceding its commencement.

3.5.2 Anonymity and confidentiality

Confidentiality and anonymity of the respondents are the focal point to ethical research practice. In this WTP study, personal information and anonymity of the respondents (maize farmers) were given a duly fitting attention. All the names of farmers taking part, which are a part of their identity, were not revealed under any circumstances in the study and the data they gave to the enumerators was only used for research objectives. As such, the privacy and confidentiality of the respondents was guaranteed and respected. The nature and purpose of this study was explained to the respondents prior to commencement and voluntary participation by farmers with option to withdraw was also ensured.

3.5.3 Request for permission

The objective behind the ethics clearance was to make sure that the nature of this study did not bring harm or negatively affect the livelihoods of maize farmers who were actively participating in the study. Finally, an ethical clearance letter from the TREC was used to request permission to start with data collection.

3.6 Chapter summary

This chapter outlined the study area, the research design employed to address the research objectives and the layout for the collection, measurement, and analysis of data. The chapter also gave a description on some of the variables used in formulating questionnaires used in collecting data through purposive and multi-stage sampling techniques for the TELA® Bt maize and snowball sampling techniques for the non-TELA® Bt maize farmers in Mpumalanga Province under Ehlanzeni and Nkangala District Municipalities. The analytical techniques for addressing the objective on the sociodemographic as well as the framework towards conducting the KAPP evaluation were also provided. The chapter further gave a detailed account of the application of the discreet choice experiment to willingness to pay as well as the empirical model (binary logistic regression) used to analyse factors influencing WTP.

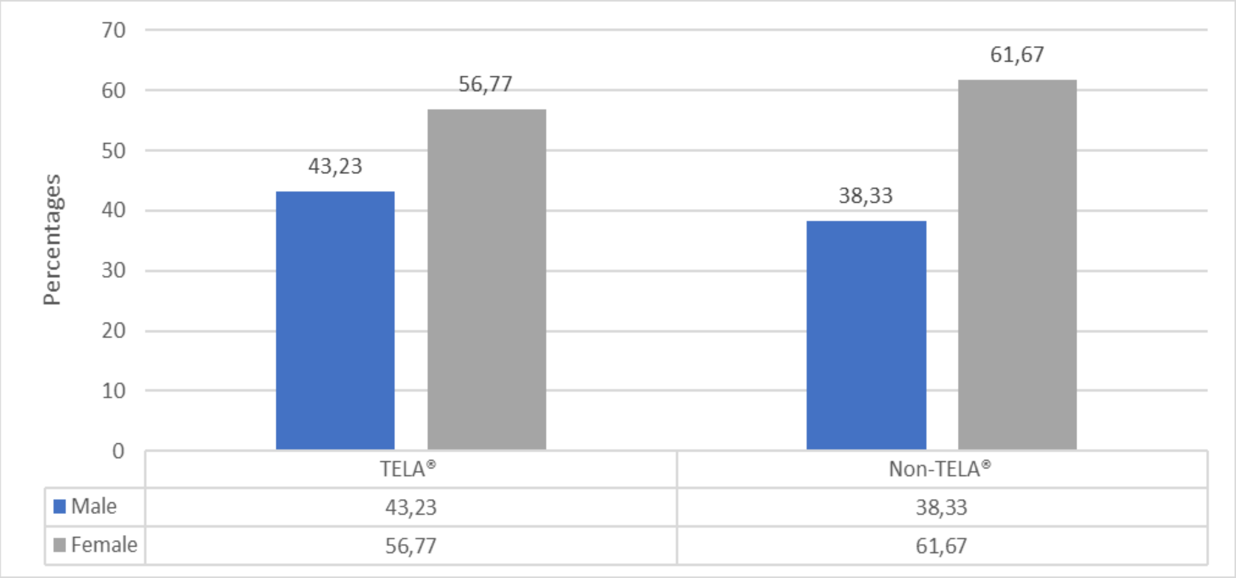
CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents results of the socioeconomic characteristics of the farmers and the KAPP analysis. Descriptive statistics, which included cross tabulations and frequency distributions was used to describe socioeconomic characteristics of smallholder maize farmers are discussed. The Likert-scale and Descriptive statistics were used to assess farmers' knowledge, attitudes, perceptions, and Practice (KAPP) towards the TELA® Bt maize seed technology in the study area concerned. The chapter further represents the results of the regression analysis for determining WTP by using the Bivariate correlation for measuring the strength of coefficients relationships and the Logit scale for parameter estimates used to compute the mean willingness to pay (MWTP). Lastly, the Logistic regression model empirical results were presented in tabular form showing Chi-square tests for model fitness, the estimated and likelihoods coefficients as well as the p-values used to comment on the significant variables.

4.2 Farmer socio-economic characteristics

4.2.1 Gender of household head



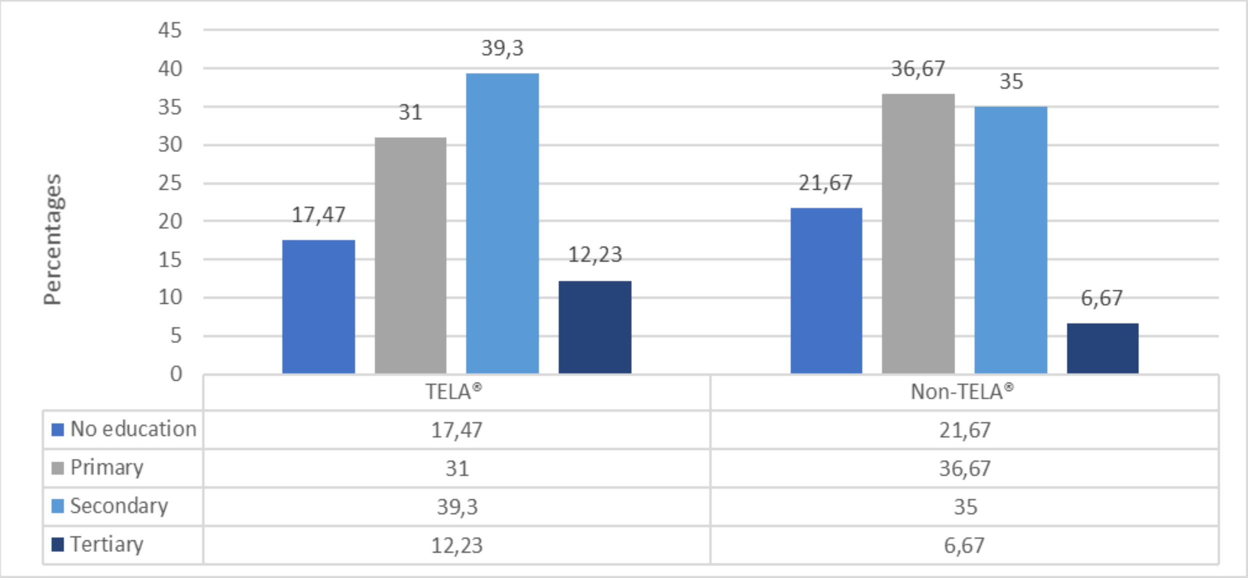
	TELA®	Non-TELA®
🟦 Male	43,23	38,33
⬜ Female	56,77	61,67

Source: Survey data (2022)

Figure 4.2.1 Gender of household head

Figure 4.2.1 above shows the results on gender of household head carried out on maize farmers. The results shown indicated that the majority (57%) of the farmers who were cultivating TELA® Bt maize were females compared to 43% males. Regarding those who were farming with non-TELA® Bt maize, again, the majority (62%) were females as opposed to the 38% males. These results suggest that the majority of the smallholder maize farmers in the study area were females. According to Aromolaran *et al*. (2017), gender is expected to positively influence the adoption of GM seed technology, skewed towards the female side, meaning that males are more likely to be found to be using the new technology, as compared to their female counterparts. In another twist to the claims on the expected proportionality of male versus female composition, Kalantari et al. (2021) mentioned that males are not predisposed to eagerly practice new ways and methods of farming, as they feel comfortable with the conventional methods they had been exposed to over the years. These results suggests that the majority of the smallholder maize farmers in the study area were females.

4.2.2 Education level of household head



	TELA®	Non-TELA®
🟦 No education	17,47	21,67
▨ Primary	31	36,67
🟦 Secondary	39,3	35
■ Tertiary	12,23	6,67

Source: Survey data (2022)

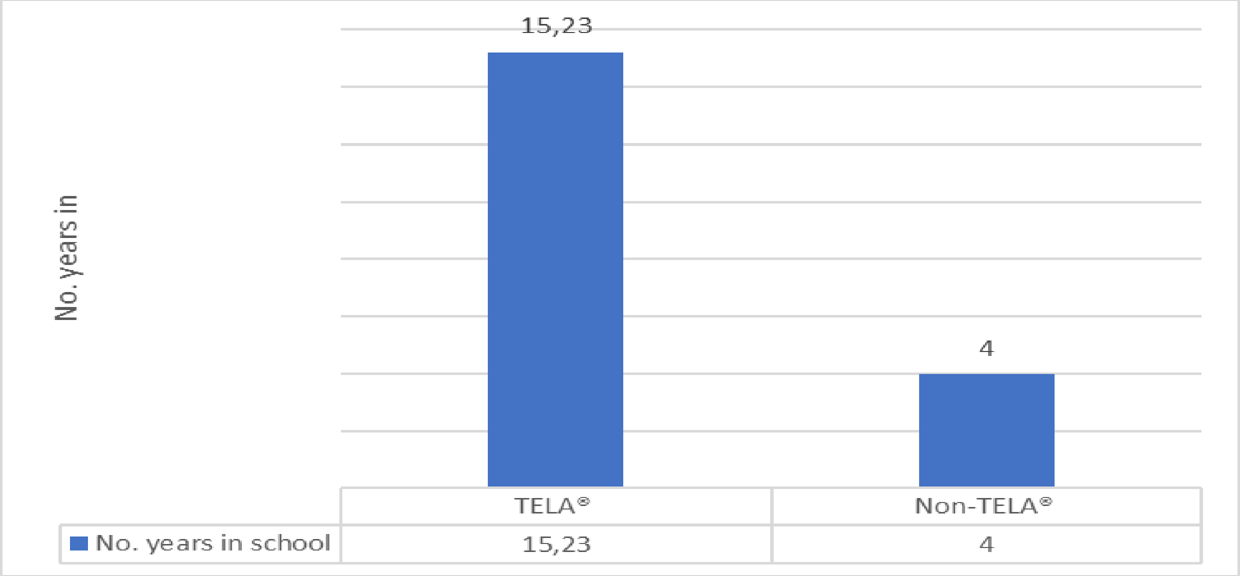
Figure 4.2.2 Education level of household head

The results in Figure 4.2.2 above on education level of household head show that on average, TELA® Bt maize farmers comprise a marginally higher number of individuals who boast high levels of education than the non-TELA® Bt maize. As shown, there were 12% of farmers that had obtained a tertiary qualification, as compared to the 7% of the non-TELA® Bt maize farmers with the same education level. Likewise, the results were also true for farmers with secondary education with non-TELA® Bt maize having only 35%, lower than the 39% for the TELA® Bt maize farmers.

Moreover, relatively higher percentages of non-TELA® Bt maize farmers had either primary level education or had no formal education. The results are not a surprise, Xiong *et al*. (2018) indicated that the more educationally inclined farmers are, the more likely they are to try out new methods that could improve their farming practices more efficiently. The reason for this is that it is fairly easy for such farmers to understand how the new technology works, and it also positively influences their WTP (Song *et al*., 2021). Thus, the level of education that maize farmers attain plays an important role in their WTP and to adopt GM maize crop

On the contrary, most farmers with low-level education perceive improving their education standards as part of increasing costs unnecessarily (Ma *et al*., 2020), which explains their proclivity for their lack of interest in using new farming methods like it was observed in the results for non-TELA® Bt maize farmers. Nevertheless, Harun *et al*. (2015) argued that the variable education level has no significant effect owing to the fact that farmers have little understanding of GM crop interventions to weigh the trade-offs accordingly and adopt such interventions (Ali *et al*., 2019).

4.2.3 Overall average number of years in school

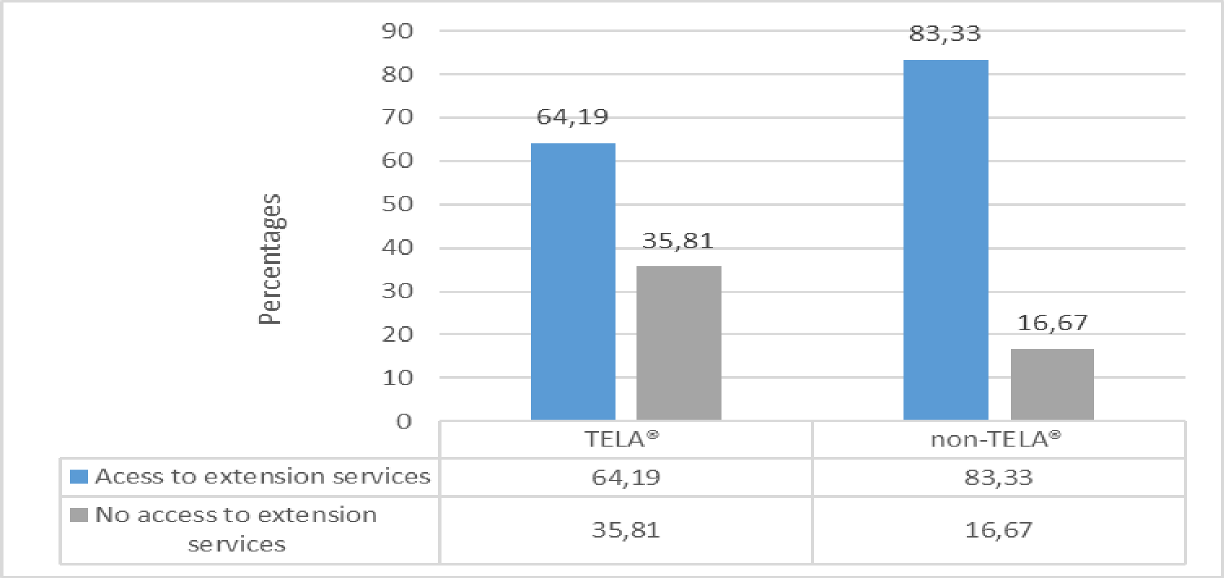


Source: Survey data (2022)

Figure 4.2.3 Overall average number of years in school

The results in Figure 4.2.3 on the overall average number of years in school shows that TELA® Bt maize farmers had attended formal education schooling for a period of 15 years, in comparison to the 4 years period that non-TELA® Bt maize farmers had spent in school. As observed in Figure 4.2.2, the non-TELA® Bt maize farmers were almost two times less than the TELA® Bt maize farmers when it comes to those who had obtained a tertiary education level. Such outcome could explain why more farmers with high level of education are more likely to use the GM technology, Ali *et al.* (2019) explained that exposure to information and knowledge brings with it the advantage of understanding the information regarding new technologies and weighing the trade-offs appropriately. This then suggests that the higher the number of years in school, especially post-secondary, the more a farmer is inclined to use crops with GM technology.

4.2.4 Access to extension services for farmers



Source: Survey data (2022)

Figure 4.2.4 Access to extension services for farmers

The results in Figure 4.2.4 concerning the availability and accessibility of extension services to farmers reveal that 64% OF farmers who were planting TELA® Bt maize had access to extension services, meanwhile only 36% had no access. Concerning the non-TELA® Bt maize, 83% reported to have had access to extension services, with the remaining 17% reported to have had no access to any form of service by the extension workers. Provision of extension services is known to be characterised by several challenges, which in some cases render the services less effective. For instance, Somanje *et al*. (2021) expressed that the challenges around the agricultural extension service's inability to deliver excellent performance were due to poor financial support systems. This may mean that even though farmers like non-TELA® Bt maize farmers may receive extension services, the information may not be adequate due to budget constraints for funds meant to facilitate the work of extension agents at local government level (Sebaggala & Matovu, 2020). Furthermore, it could be that the transferred technologies and new farming methods that were meant to cater for specific needs of farmers were not appropriate since farmers are predisposed to varying endowments (Antwi-Agyei & Stringer, 2021).

4.2.5 Source of income for households

Table 4.2.1 Source of income for households

Source of income	TELA®		Non-TELA®	
	Average income (R)	Percentage of total income (%)	Average income (R)	Percentage of total income (%)
On-farm	987.15	19.13	21.67	0.82
Small business	485.94	9.42	23.33	0.88
Pension	1 896.11	36.74	1 647	62.24
Social grant	474.66	9.2	482.83	18.25
Remittances	1 317.38	25.52	471.42	17.81
TOTAL	**5 161.24**	**100**	**2 646.25**	**100**

Source: Survey data (2022)

The results in Table 4.2.1 on the source of income for households show that on average, the highest amount of annual income accumulated by TELA® Bt maize farmers was from pension (R1 896.11). The results were also true for the non-TELA® Bt maize farmers, where an average income of R1 647 came from pension. The lowest contributor to the household annual average income for TELA® Bt maize farmers is from social grant (R474.66) constituting only 9.2% of the total income, and for the non-TELA® Bt maize farmers, is from on-farm (R21.67) which constitute 0.82% of the total income.

The results are not so much alarming, given that the non-TELA® Bt maize farmers use maize seeds that do not incorporate such traits like high yield, drought tolerance and persistence, as seen with the TELA® Bt maize. It then has a negative significance, posing a serious threat on yield and output, making it almost difficult for those farmers to accumulate any substantial income from output sales. Another point to mention that seems consistent with the on-farm income accumulation of the non-TELA® Bt maize farmers is the issue of the average number of years spent in school and the highest qualification obtained that were very lower than those of the TELA® Bt maize farmers. What this give prominence to is the fact that farmers with low levels of education are often prone to having little information on factors that have a direct impact on their value chain like access to information, marketing and sales of outputs. Like TELA® Bt maize farmers would be exposed to and benefit.

The results have also shown that the average overall annual income for the TELA® Bt maize farmers is R5 161.24 and R2 646.25 for non-TELA® Bt maize farmers, respectively. Apart from on-farm income being the third largest contributors to the overall income with 19% for TELA® Bt maize farmers, it also signifies the importance of using farming crops that have desired attributes like GM crops. It will help farmers to minimise operation costs and make more profit, which can then be spilled over to other off-farm areas like small businesses for better income generation as it is the case with TELA® Bt maize farmers. Literature has revealed that an increase in farm income leads to a sharp increase in the adoption for GM crops (Bhat & Sinha, 2016). This implies that the more income a farmer accumulates, the more likely they are to use new technological innovations of GM crops. The results of this study tally with Martey *et al*. (2014) findings that farmers' increase in education level, has a positive impact on their improved income accumulation.

4.2.6 Household size

Table 4.2.2 Household size

Variable	TELA®	non-TELA®
Minimum	1	1
Maximum	18	12
Average	6	6
Standard deviation	2.68	2.29

Source: Survey data (2022)

Table 4.2.2 above shows the results on household size that the minimum and the average numbers for household size of TELA® Bt and non-TELA® Bt maize farmers were both evenly poised at 1 and 6, respectively. It is only the TELA® Bt maize farmers with a higher number of household size (18) as compared to the non-TELA® Bt farmers (12), with the data spreading to the right to highlight the leaning of the sampled population more towards the mean.

The results are in conjunction with the differences in the total average income between the TELA® Bt maize farmers and the non-TELA® Bt maize farmers, where those using TELA® Bt had almost double that of the non-TELA® Bt. This explains how an increase in income improves farmers' probability of using new GM technology crops in line with the number of household members who might be getting income either on or from other nonfarm related activities. According to Elias *et al*. (2020) household size plays a significant role in allowing farmers to have more labour force to allow them to carry out farm related activities and divide labour for maximised output. Farmers with large household sizes, more especially above the threshold of 5, differ immensely in the willingness to adopt new technologies into their farming practices from those with a relatively small number (Aydogdu *et al*., 2020). However, the results are contrary to the findings of Okoffo et al. (2016) who noted that farmers with large household size do not find it imperative to spend their income in any other activity except to use it for catering households’ consumption needs.

4.2.7 Age of household heads

Table 4.2.3 Age of household heads

Variable	TELA®	non-TELA®
Minimum	17	24
Maximum	86	84
Average	61.98	62.18
Standard deviation	12.52	15.71

Source: Survey data (2022)

The results in Table 4.2.3 above on the age of household heads show that the average age of both TELA® Bt maize and non-TELA® Bt maize farmers were 62 years old. The minimum age numbers for TELA® and non-TELA® Bt maize farmers were 17 and 24, and the maximums were 86 and 84, respectively. Looking at the analysis, specifically on the minimum ages, what could be drawn is that slightly younger farmers are engaged in the production of TELA® Bt maize, as compared to the non-TELA® Bt maize farmers.

Standard deviation shows how spread the data is around the mean. The results show that the standard deviations of the sampled population for both TELA® and non-TELA® Bt maize farmers were 12.52 and 15.71, respectively. What the results explicitly imply is that of the two categories of maize farmers, there are more farmers in a slightly higher age category using non-TELA® Bt maize than there in TELA® Bt maize farmers. Age remains a significant factor to the adoption of new technology yet bearing varying stakes between both old and younger farmers of maize production. Hence, Desteur *et al*. (2019) brought out the fact that it cannot be said exactly how age significantly would influence adoption and the direction it might come in.

The findings of this study agree with Harun et al. (2015) that relatively younger farmers are more responsive to adoption of new innovations, as compared to older and matured farmers who are reluctant to change. Additionally, young farmers are fond of new technologies due to the long-term effects of learning more about their benefits and expose themselves to making their adoption count through the experiences they would have gathered over time. The results pertaining to education level revealed that more TELA® Bt maize farmers had spent more years in school than the non-TELA®, who subsequently also happened to have obtained higher education level. It means that education is just as important to younger farmers in order to get them deploying new and innovative ways of farming as they pay more attention to details than merely going with methods that are primitive and yet having very low prospect of success growth wise.

4.2.8 Experience in years of household heads

Table 4.2.4 Experience in years of household heads

Variable	TELA®	non-TELA®
Minimum	2	1
Maximum	60	60
Average	26.24	22.1
Standard deviation	15.58	17.17

Source: Survey data (2022)

The results in Table 4.2.4 above on the experience in years of household heads show that the average number of years in farming for TELA® Bt maize farmers is 26 and 22 years for the non-TELA® Bt maize farmers. The minimum number of years in farming for both TELA® and non-TELA® Bt maize farmers were 2 and 1, and the maximums were equally poised at 60, respectively. The analysis on the averages suggests that TELA® Bt maize farmers (26) have been engaged in the production of maize for a slightly longer period, as compared to the non-TELA® Bt maize farmers (22) with less experience. The results further show that the standard deviations of the sampled population for both

TELA® and non-TELA® Bt maize farmers were 15.58 and 17.17, respectively. What the results give an impression to is that of the two categories of maize farmers, there are less farmers closer to the average number of years of those who produce maize using TELA® Bt than are in non-TELA® Bt maize farmers. The TELA® Bt maize farmers have shown to have gathered more knowledge over the years as they had been exposed to high levels of education (15), as compared to the non-TELA® (4). It is worth noting that age and farming experience are closely intertwined factors when it comes to farming, in that you cannot have the latter without growing in the former. The only difference could be that age is directly linked to consumer life cycle and could have influence on how farmers make decision on the use of new farming methods (Slaba, 2019), whereas experience relies on other factors like education. As a result, with experience it is not about how much of it is accumulated, but it is about how much knowledge had been gathered. These findings of this study are close to those by Ojeleye (2018) who discovered that average farming experience for smallholder farmers was about 20 years. Increasing years of farming experience is expected to have positive influence on the adoption of GM maize crops (Afolami et al., 2015).

4.3 Results on knowledge, attitudes, perceptions and practices (KAPP)

4.3.1 Farmers knowledge towards the TELA® Bt maize seed technology

Farmers’ knowledge evaluation measures their level of awareness about the TELA® Bt maize technology (Obedi-Egbedi *et al*., 2020). It has been recoded that most smallholder farmers are not fully aware of GM maize crops as a result of flaws on the dissemination of information, which negatively affects adoption rate (Tianyu & Meng, 2020). An analysis on farmers’ knowledge is shown in Table 4.3.1

Table 4.3.1 Farmers' knowledge towards the TELA® Bt maize seed technology

STATEMENTS	**% Of farmers responses**		**No. of Farmers**	
	Yes	**No**	**Yes**	**No**
Have you ever heard of the TELA Bt maize seed technology?	82.7	17.3	239	50
Do you know the importance of TELA Bt maize seed technology?	79.9	20.1	231	58
Do you know about the attributes of TELA Bt maize seed technology?	81.3	18.7	235	54
Do you know how to control the occurrence of pests and drought?	64.7	35.3	187	102
Do you know that the chemical pesticides used to control pests and drought are harmful to the environment?	45	55	130	159
Do you know of any indigenous practices used to control pests and droughts?	48.4	51.6	140	149
Do you know any other pests and drought control measures besides the ones you have currently adopted?	48.4	51.6	140	149

Source: Survey data (2022)

The research considered farmers who were using TELA® Bt maize seed and those who did not in their farming practices. Therefore, to capture the perception and attitudes of farmers regarding the TELA® Bt maize seed technology, how it affects their practices, the impact it could have on non-TELA® as well, those farmers who had no prior knowledge of the technology were given a brief summary on what it was all about. Table 4.3.1 above represents the results obtained on farmers' awareness and basic knowledge about the use and importance of TELA® Bt maize technology and the traits of the seeds.

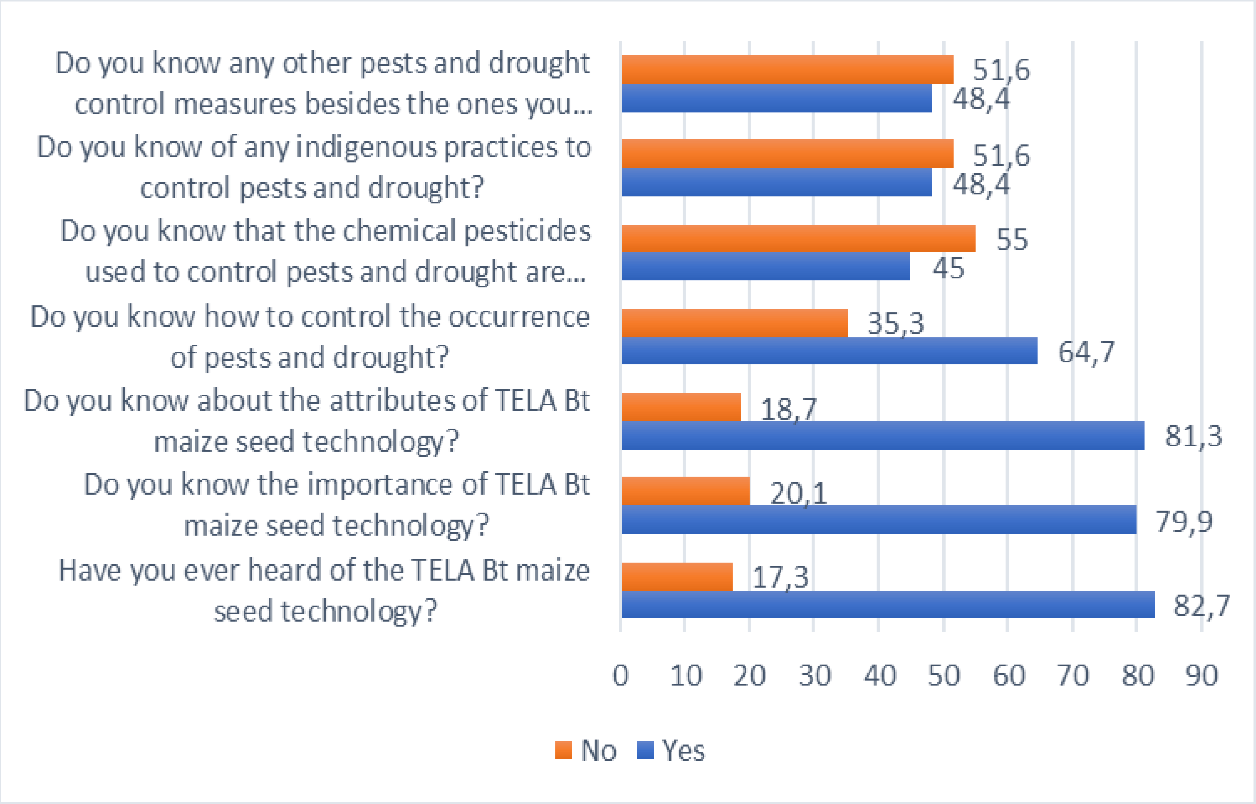
As shown in Table 4.3.1, results were interpreted by showing the frequencies together with the corresponding percentages of yes and no responses to distinguish those who knew about the TELA® Bt maize technology and those who did not. Of the total 289 farmers that were interviewed, 83% of the respondents were observed to have heard about the TELA Bt maize seed technology, unlike the remaining 17%. Knowledge about the importance of any new product in the market is often the greatest driving force behind its adoption. Correspondingly, 80% of farmers answered yes to a question whether they knew about the importance of the GM technology. There are various attributes that come with GM seeds, which includes but not limited to drought tolerance, high yield, early maturity, pest resistance, large grains, etc. With respect to farmers knowledge about the attributes of TELA Bt maize seed technology, more than 81% of farmers where well conscious of what it comprised. About 65% of farmers knew how to control the existence of pests and drought in their farms. Amazingly, more than halve (55%) of them had no idea that the chemical pesticides used to control pests and drought are harmful to the environment.

There was an equal proportion of at least 51% of farmers who did not know of any indigenous practices to control pests and drought, and those who did not know any other pests and drought control measures besides the ones they had been using. Given that the majority of farmers were discovered to have known about the traits and the importance of TELA Bt maize seed, it speaks volume as to how this could significantly influence their use of pests and drought measures in the near future. That is, there could be less farmers who use unsustainable methods for controlling pests and drought, cementing the use of TELA Bt maize seed technology.

The findings of this study coincide with those of Cui & Shoemaker (2018) and Bakar *et al*. (2021) that highlighted that most farmers are not well acquainted with the benefits of GM crops. That is why it is observed that the majority of them were using chemicals in trying to improve production without the awareness of the dire consequences such chemicals could have on the environment. This also brings to question the effectiveness regarding the knowledge that was disseminated to farmers by the relevant institutions such as extension officers. For instance, the indication that most farmers knew about TELA as a GM crop and yet had no idea about the dangers of other farming methods they were practicing is concerning. Kwade *et al*. (2019) outlined that information amongst farmers is either not given properly or it could be that it is asymmetric, and the inconsistencies of farmers' responses in the results of this study attested to this point.

Apart from farmers themselves being the rightful persons to have the capacity to have knowledge about the GM maize crops, by virtue of being actively involved in farming, the other group of personnel relevant to have information are the extension service workers (Biswas et al., 2021). If these farmers have access to extension service provision in large numbers (74%), it then speaks volume that there could be a divide between the extension service providers and institutions (Balloch & Thapa, 2016) that bring the technology to farmers. Hence, there were farmers in the study area who would have heard about TELA Bt maize seed technology, and yet are clueless about the dangers and negative effects of the current chemicals and methods used to control pests and drought on the environment (45%), which the TELA Bt maize seed technology is thought to deal with.

Figure 4.3.1 below, shows the graphical representation of the results in percentages



Source: Survey data (2022)

Figure 4.3.1: Percentages of farmers' knowledge towards the TELA® Bt maize seed technology

4.3.2 Farmers perception towards the TELA® Bt maize seed technology

Farmers' perception evaluates their viewpoint about the benefits of TELA® Bt maize technology as to whether they believe them to be true and just, which most studies have revealed farmers to be doubtful about (Azadi *et al*., 2015). As such, farmers may have varying perceptions, given that their levels of knowledge were different too. Additionally, it could be expected to have the results showing negative perceptions coming from the farmers in this regard. Table 4.3.2 below shows the analysis of Farmers perception towards the TELA® Bt maize seed technology. Table 4.3.2 Farmers' perception towards the TELA® Bt maize seed technology

No	**STATEMENTS**	**Strongly disagree**		**Disagree**		**Not sure**		**Agree**		**Strongly agree**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**n**	**%**
1.	TELA® Bt maize seed technology has potential of increasing farm incomes	4	1,4	2	0,7	73	25,3	87	30,1	123	42,6
2.	TELA® Bt maize seed	3	1	12	4,2	76	26,3	94	32,5	104	36

	technology has potential of reducing fertilizer use in maize production										
3.	TELA® Bt maize seed technology has potential of reducing impacts of drought on maize production	4	1,4	0	0	76	26,3	98	33,9	111	38,4
4.	TELA® Bt maize seed technology has potential of reducing pesticide	3	1	8	2,8	82	28,4	87	30,1	109	37,7

	residues in the environment										
5.	TELA® Bt maize seed technology reduces pesticide residues on food products	5	1,7	7	2,4	77	26,6	95	32,9	105	36,3
6.	TELA® Bt maize seed technology can create foods with enhanced nutritional value	5	1,7	2	0,7	73	25,3	85	29,4	124	42,9

7.	TELA® Bt maize seed technology increases productivity and offers solution to food problems	9	3,1	4	1,4	71	24,6	78	27	127	43,9

Source: Survey data (2022)

The basis used for measuring the perception of farmers towards the TELA® Bt maize seed technology was by using a five points Likert scale (1-5) to indicate their level of agreement regarding each statement provided in the questionnaire. The farmers' viewpoint about the TELA® Bt maize, given their knowledge about the technology were mainly on the benefits to its adoption, and that is how perception was captured.

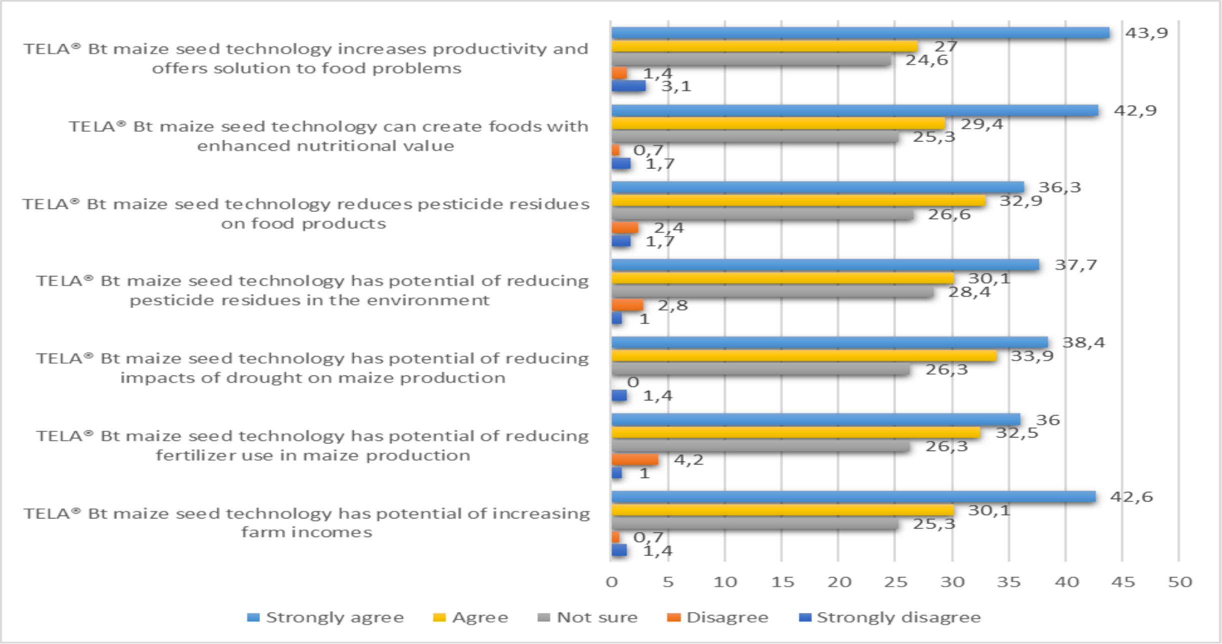
The results shown in Table 4.3.2 were interpreted by combining the given percentages of agree and strongly agree responses to signify the respondents agreeing with the statements. Meanwhile, the disagree and strongly disagree respondents were also categorised, such that they formed one group showing disagreement with the statements. The option for 'not sure' phrase denoted the undecided group of respondents who showed neutrality by neither agreeing nor disagreeing with the statements on TELA® Bt maize seed technology. The results were interpreted in line with the procedures by Hulela et al. (2020) who analysed them focusing only on one high extreme of the responses, more especially the affirmative.

With regards to the perception on whether TELA® Bt maize seed technology had any effect on farm income, 73% of farmers agreed and strongly agreed that TELA® Bt maize seed technology had potential to increase farm incomes, followed by approximately 68.5% who indicated that the technology had potential of reducing fertiliser use in maize farming. Above 72% of farmers agreed and strongly agreed that TELA® Bt maize seed technology had potential of reducing impacts of drought on maize production, whereas 68% and slightly above 69%, respectively, indicated that the technology had potential of reducing pesticide residues in the environment as well as on food products.

About 72% of farmers strongly agreed and agreed that TELA® Bt maize seed technology can create foods with enhanced nutritional value, and also, 71% indicated that it could similarly increase productivity and offer solution to food problems. Of interest is the considerable percentage (28%) of farmers who were neutral on the fact that TELA® Bt maize seed technology had potential of reducing pesticide residues in the environment. It coincides with the 55% who outlined that they did not know that the chemical pesticides used to control pests and drought were harmful to the environment, highlighting their ignorance as to how chemicals negatively affect the environment and make it unsustainable.

This is contrary to the arguments raised by Mnaranara *et al*. (2017) indicating that farmers in developing countries tend to be more sceptical about new innovations in GM technology, and as a result, might be reluctant to perceive the positive sight (Schnurr & Dowd-Uribe, 2021) in the form of benefits the technology might bring. However, despite a majority of farmers seeing the good in TELA® Bt maize seed as a GM crop in the form of increased income and reduced fertiliser use and drought effect, what could then be the reason behind the slow adoption. Schnurr & Mujabi-Mujuzi, (2014) and Sanou *et al*. (2018) noted that these could be as a result of lack of farmer inclusive engagement as major stakeholders, leaving more room for negative public perception to convince them otherwise (Rzymski & Krolezyk, 2016). On the other side, the socioeconomic results on farming experience have revealed that the average number of farming years is 24. This tells us that maize farmers rely more on their expertise about their past experiences to make adoption decisions and not what is brought before them at hand (Liu *et al*., 2015). As Berges *et al*. (2015) has proven that satisfactory previous experience with the crop remains the driving force behind their purchasing decisions where a maize crop with a good track record of solving farmer challenges stands a good chance of being adopted.

Figure 4.3.2 below, shows the graphical representation of the results in percentages



Source: Survey data (2022)

Figure 4.3.2 Percentages of farmers' perception towards the TELA® Bt maize seed technology

4.3.3 Farmers' Attitudes towards the TELA® Bt maize seed technology

Attitude refers to a weighted sum of perceptions towards the TELA® Bt maize technology and its corresponding process (Ongachi et al., 2018), that explains how farmers think, feel or act towards it. Various elements of attitude that are an integral part of WTP were included ethical concern, risk perception and benefits perception (environmental/ economic/ health). What has been observed and proven through literature is the feeling of fear around the safety of GM crops and their long-term effect on the environment, human health and the economy (Rzymski & Krolezyk, 2016). This could also birth fear of resentment from the farmers towards the TELA® Bt maize technology. The analysis of farmers' Attitude towards the TELA® Bt maize seed technology in the study area was done and is presented in Table 4.3.3 below

Table 4.3.3 Farmers' Attitudes towards the TELA® Bt maize seed technology

No	**STATEMENTS**	**Strongly agree**		**Agree**		**Not sure**		**Disagree**		**Strongly disagree**	
		N	**%**	**N**	**%**	**n**	**%**	**N**	**%**	**n**	**%**
1.	My current pests and drought control measures are effective in controlling	114	39.4	55	19.0	42	14.5	70	24.2	8	2.8

	pests and drought										
2.	I would stick with current method to control pests and drought even if I had a choice to use other control measures	107	37.0	31	10.7	37	12.8	89	30.8	25	8.7
3.	Chemical pesticides are not harmful to the environment	53	18.3	45	15.6	117	40.5	61	21.1	13	4.5
4.	There is no need for me to try out other pests and	84	29.1	35	12.1	50	17.3	94	32.5	26	9.0

	drought control measures										
5.	There is no need for me to change the type of seeds I am using for TELA® Bt maize seeds	68	23.5	28	9.7	78	27.0	79	27.3	36	12.5

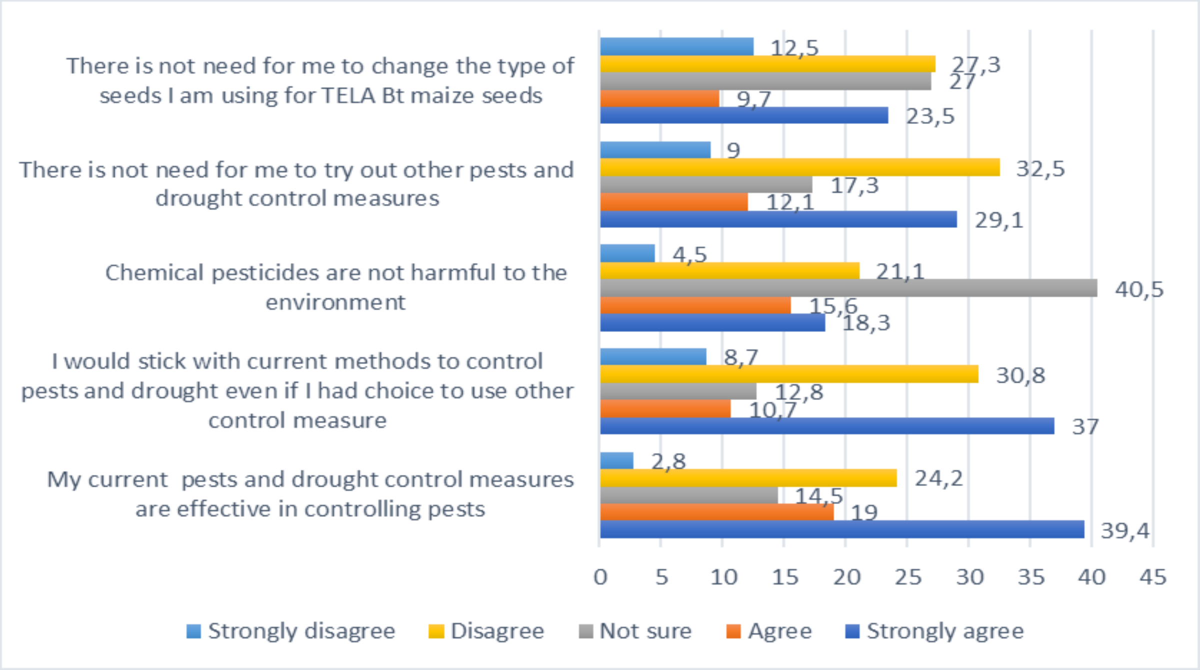
Source: Survey data (2022)

Table 4.3.3 above shows the analytic results on farmers' attitude towards the TELA® Bt maize seed technology. By the same procedure, the basis used for measuring the attitude of farmers towards the TELA® Bt maize seed technology was a five points Likert scale (1-5) to indicate their level of agreement regarding each statement provided in the questionnaire. To create a balanced and unbiased responses regarding their attitudes, the statements were given both in the affirmative and the negative approaches.

On the first question concerning the effectiveness of the control measures that farmers deploy to deal with the invasion of pests and the occurrence of drought, somewhat greater than the average number of farmers (58%) strongly agreed and agreed that their current pests and drought control measures are effective in controlling pests and drought. Contrastingly, 48% of the respondents strongly agreed and agreed that they would stick with their current methods to control pests and drought even if they had a choice to use other control measures. Meanwhile, 40% of them strongly disagreed and disagreed that they would also stick with their current methods to control pests and drought even if they had a choice to use other control measures. The disparity in the responses of farmers on whether they would stick to their current methods to control drought and pests on both sides of the spectrum, strongly suggests that the adoption of TELA® Bt maize seed technology with its attributes has not yet fully played a significant role in their farming practices. About 50% of the respondents were not really sure as to whether chemical pesticides were harmful to the environment or environment user friendly. However, the data set was also skewed to the right with 34% of farmers strongly agreeing and agreeing that chemical pesticides are not harmful to the environment.

With such an outcome, it is not surprising that farmers emphasised that they would still use their current ways of controlling pests and drought as they consider them to be effective. In almost equal proportions, 41% of the respondents strongly agreed and agreed that there was no need for them to try out other pests and drought control measures, and the other 42% strongly disagreed and disagreed that they would do the same.

Finally, 40% of the respondents strongly disagreed and disagreed that there was no need for them to change the type of seeds they were using for TELA® Bt maize seeds, unlike the 33% who strongly agreed and agreed that they would stick to their normal maize seeds for farming. Conclusively, given the neutrality and equal proportions in most of the responses on farmers' attitude towards the TELA® Bt maize seed technology, it could be deduced that farmers are not yet fully convinced and ready to adopt the technology, more especially because it just recently got introduced, nevertheless most responses show positive signs. In line with the 33% of farmers who alluded that they would rather stick to the normal conventional seeds, part of the elaboration is that the adoption of GM maize seeds leads to high dependence on agents and loss of farmers' identities (Mahlase, 2014; Almeida *et al*., 2015). Overall, the differences in these attitudes that seem to be in equal proportion for both sides are due to the fact that people tend to fear what they don't have full comprehension of and that is where scepticism come in (Autade *et al*., 2015). This then takes to a considerable argument that the success of GM crops relies mainly on farmers being prioritised (Muringai, 2018) in all aspects of the crops in question, from their inception until implementation in the farming systems, as far as farmers' opinions are concerned. About 60% of the interviewed respondents were women, and one of the current trends globally is the need for structural changes to the economy that include women participation. Furthermore, Steur et al. (2019) proved that farming in rural areas is generally female dominated. This implies that women inclusion for participation in every step of crop adoption could be a good step in the right direction for new and innovative ideas in farming. Figure 3 below, shows the graphical representation of the results in percentages.

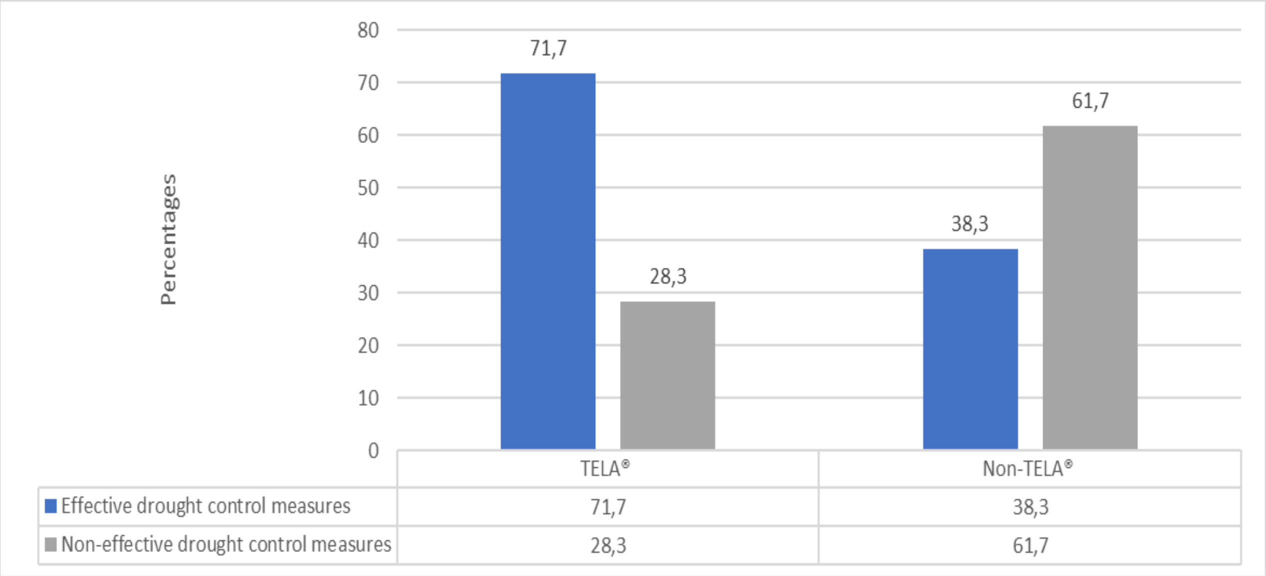


Source: Survey data (2022)

Figure 4.3.3 Percentages of farmers' attitude towards the TELA® Bt maize seed technology

4.3.4 Farming practices and the effectiveness of farmers' drought control measures

Practices refers to what farmers are currently doing as informed and influenced by their knowledge, perceptions and attitudes related to maize production, management of droughts (erratic rainfall) and excessive heat, and studies have revealed that farmers still rely on old methods of farming and the use of conventional maize (Nguyen *et al*., 2018). The results in Figure 4.3.4 below give explicit details into farmers' practices and the effectives thereof.



Source: Survey data (2022)

Figure 4.3.4 Farming practices and the effectiveness of farmers' drought control measures

The two categories of farmers who were using TELA® Bt maize seed and those who used non-TELA® Bt maize seed for farming practices, was further subdivided into a stratum based on how effective their drought control measures were. The results in Figure 4.3.4 above shows that amongst farmers who were farming with TELA® Bt maize, 72% were using measures that assumingly proved effective in drought control, while 28% settled for measures that were not satisfactory in controlling drought. On the other side of the spectrum, only 38% of non-TELA® Bt maize farmers were discovered to have used effective drought control measures, and the largely 62% were using non-effective measures.

The high percentage of farmers that have adopted the TELA® Bt maize seed technology in Mpumalanga Province signifies what most literature refer to as sense of urgency for better production methods necessitated by ever growing population and poverty rates (Azadi *et al*., 2015) as well as the unfavourable climatic conditions around (Sanou *et al*., 2018). It is encouraging also to see that the challenge of drought persistence gives a slight edge for more production of more and better farming methods with more benefits for farmers and the agricultural sector at large.

Given that the majority of farmers have a positive perception and attitude towards the TELA Bt maize seed technology, what could be of concern is the number of those who admitted that their ways of dealing with drought is non-effective and yet do not use the technology. Some of the reasons why this is happening could be attributed to their social and economic endowments, which dictates their terms of adoption. Firstly, the on-farm income that farmers accumulate from maize production contributes only 10% of the total sources of income. It means they may not have enough money at their disposal to purchase the TELA Bt maize seed when their income is exhausted. The average household age for both TELA and non-TELA Bt maize farmers is 62 years, which could prove true what Evans et al. (2017) highlighted in their study that at such age, farmers have less interests in using GM crops despite their potential benefits. Another factor that could come into play and explain why most maize farmers have not adopted the TELA Bt maize is household size. The average number for household size is 6, and most studies have revealed that the larger the household size, the lesser the willingness to adopt new farming technologies (Okoffo et al., 2016). This is true for households over the threshold of 5 family members (Aydogdu *et al*., 2020), as they rely on the availability of labour to improve production and output using traditional methods of farming **(**Elias *et al*., 2020).

4.4 Results on maize farmers' WTP for the TELA® Bt maize seed technology.

4.4.1 Bivariate correlation between the discrete choice experiment variables

The bivariate correlation between the discrete choice experiment variables is presented in Table 4.4.1 Strong positive correlations were found between two variables and those were, drought tolerance and maize yield (0.933**), and the other one was between pest resistance and maize price (0.976**). The final decision made involved discarding the pest resistance and yield variables to remain with the price and drought tolerance variables only. The price variable is important for measuring WTP as an intrinsic value (Perez-Troncoso, 2020), whereas the drought tolerance variable is regarded as the most desirable trait by maize farmers (Kassie *et al*., 2015).

Table 4.4.1 Bivariate correlation for discrete choice experiment variables

	Maize	**Drought**	**Yield**	**Pest resistance**
	price per tolerance in tonne per in percentages kg percentages hectare			
Maize price 1 per kg		.740**	.449**	.976**
Drought tolerance in percentages		1	.933**	.868**
Yield tonne per hectare			1	.631
Pest resistance in percentages				1

**. Correlation is significant at the 0.01 level (2-tailed).

4.4.2 Logit scale parameter results.

Table 4.4.2 below shows the analytical results from the Logit scale parameter results from which WTP was measured.

Table 4.4.2 The Logit scale parameter estimates results

	Estimate	**Std. Error**	**Wald**	**df**	**Sig.**
Drought	-2,847	5,947	0,229	1	0,632
Price	0,432	0,043	99,416	1	0.000

The index that was used to measure WTP of the most preferred attribute by farmers was written as indicated in the formula below to denote the ratio of coefficients related to the marginal rate of substitution between cost and the marginal utility of the product attribute (Petcharat, 2020): $\overline{MWTP_j} = \frac{\beta_j}{-\beta_{WTP}}$

The results revealed that the marginal WTP was R6.59, which gives the explicit additional amount of money farmers are willing to pay for 1kg of the TELA Bt maize seed technology.

4.5 Results on determinant factors influencing smallholder maize farmers’ WTP

Table 4.5.1 Omnibus Tests of Model Coefficients results

Omnibus Tests of Model Coefficients			
	Chi-square	df	Sig.
Step	37,462	13	0,000
Block	37,462	13	0,000
Model	37,462	13	0,000

The Omnibus Tests of Model Coefficients was used to test model fitness and was assessed using the Chi-square which gave a value of 37.462 and the p-value that was less than 0.005. This proves that there is a statistically significant relationship between the dependent variable and the independent variables in the final model, relative to the null model with no predictors.

Table 4.5.2 Model summary results

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	363.007a	0,652	0,692

The Model Summary shows the Pseudo R-square. Pseudo means that it is not necessarily explaining the variation technically, however they could be deployed as approximate variation in the criterion variable. The Pseudo R-square measures in this case are Cox and Snell (0.652) and Nagelkerke's (0.692), of which the normally used one is the Nagelkerke's. The results reveal that in this case, 69.2% change in the criterion variable can be accounted for by the predictor variables in the model.

Table 4.5.3 Hosmer and Lemeshow Test results

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	4,671	8	0,792

The Hosmer and Lemeshow Test is also a test of model fitness. The Hosmer and Lemeshow statistical results will indicate a poor fit if the significance value is less than 0.05. The results therefore indicate that the model adequately fits the data (0.792).

4.5.1 Binary logistic regression results.

Table 4.5.4 Binary logistic regression results on determinants of WTP (n=289).

Explanatory Variables	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**
Constant	-2,719	1,425	3,640	1	0,056	0,066
Age	0,013	0,008	2,673	1	0,102	1,013
Gender	0,143	0,270	0,279	1	0,598	1,153
Level of education	0,032	0,029	1,243	1	0,265	1,033
Household size	-0,096	0,046	4,484	1	0,034**	0,908
Household income	0,000	0,000	2,020	1	0,155	1,000
farming experience	-0,013	0,010	1,675	1	0,196	0,987
Access to extension services	0,609	0,287	4,505	1	0,034**	1,838
Health perception	0,988	0,510	3,752	1	0,053**	2,687
Trust in Government	-0,994	0,328	9,164	1	0,002***	0,370
Ethical concern	0,731	0,469	2,432	1	0,119	2,077
Environmental concern	-0,137	0,172	0,637	1	0,425	0,872
Benefits perception	0,346	0,172	4,062	1	0,044**	1,414

Knowledge TELA® Bt	-0,096	0,415	0,054	1	0,817	0,908

Reference category: Willingness to pay
Number of observations: 289

Note: ***, **, * are significant levels at 1%, 5%, and 10%, respectively

4.5.2 Willingness to pay determinant factors analysis.

Among farmers who were willing to pay for the TELA® Bt maize technology, household size, access to extension services, health perception, trust in government and benefits perception had a significant impact in their WTP. Holding all other factors constant, for every incremental unit in household size, the odd ratio *(B=-0,096, P<0.05)* of decreasing their WTP for TELA® Bt maize technology, was *0.034* times than those who were not willing. What this reveal is that it is most likely that maize farmers who would not mind adopting TELA® Bt maize technology are those who are either younger or in their active age.

Just like Kamthan *et al*. (2016) has mentioned in their study, the adoption of GM crops thrives more among smallholder farmers at an unprecedented rate when they are still relatively young. This is also in line with the arguments made by Harun *et al*. (2015) that older and matured farmers are reluctant to change, implying that their WTP declines with age. The findings also concur with Evans *et al*. (2017) where age was found to be statistically significant and having a negative sign.

Furthermore, the odd ratio of farmers who had access to extensions services' *(B=0.609, P<0.05)* probability to increase their WTP for TELA® Bt maize technology relative to those who were not willing to pay, was *1.838* times than those who had no access to extension services. Farmers' access to extension service is by far the most important and significant factor that positively influence farmers' WTP in the sense that they are better exposed to processes that assists them in becoming conscious of improved technologies and adopt them for improved farm productivity, and as a results, their welfare (Sebaggala & Matovu, 2020).

Part of the extension service workers' responsibility is in the distribution of information amongst smallholder farmers, for a successful and immediate adoption of new technologies (Kotey *et al*., 2017; Biswas *et al*., 2021). Cawley *et al*. (2015) also mentioned in line with what the results of the study showed that constant interaction between farmers and extension services positively affects farmers' WTP which could be the case also with maize farmers in Mpumalanga province.

The results also showed that the odd ratios of farmers who had no concerns about the effects of GM crops on health *(B=0.988, P<0.05)* and their benefits regarding farm productivity's *(B=0.346, P<0.05)* probability to increase their WTP for TELA® Bt maize technology relative to those who were not willing, was *2.687* and *1.414* times, respectively than those who were more concerned. Respondents who had no concerns are more likely to show WTP for TELA® Bt maize technology than those who were sceptical about health and benefits implications, as far as their perception is concerned.

The arguments that most scholars and empirical studies raise concerning the adoption of GM crop technology revolve around the safety of transgenic procedures and their undefined long-term effects on human lives (Rzymski & Krolezyk, 2016). Nevertheless, the perceived food security, health and economic benefits greatly compensate for the alleged risks, hence, farmers would under these circumstances opt to overlook the risks and adopt the technology (Bocher *et al*., 2019; Makweya *et al*., 2019).

Finally, the odd ratio of farmers who did not trust in the government's *(B=-0.994, P<0.05)* probability to decrease their WTP for TELA® Bt maize technology relative to those who were not willing, was *0.370* times than those who trusted in the government. Respondents who trusted in the government are more likely to show willingness to pay for TELA® Bt maize technology than those did not have faith in them. From this, it could be justifiably presumed that the government's role on GM technology distribution plays a pivotal role in defining farmers' stance on WTP, as alluded by Mnaranara *et al*. (2017). The main idea is that since farmers are the primary recipients of GM crop innovations by private and government institutions, they should not be excluded from any form of decision making (Zakaria *et al*., 2014) that concerns farming and production (Kikulwe & Asind, 2020).

4.6 Chapter summary

The previous section discussed at length the socioeconomic characteristics of the farmers using descriptive statistics, which included cross tabulations and frequency distributions for two categories of farmers, TELA® and non-TELA® Bt maize farmers. The Likert-scale and descriptive statistics were used to assess farmers' knowledge, attitudes, perceptions and Practice (KAPP) towards the TELA® Bt maize seed technology in order to get more insight as to how these concepts further influence adoption for TELA Bt maize seed technology. The chapter also represented the results of the regression analysis for determining WTP by using the Bivariate correlation for measuring the strength of coefficients relationships and the Logit scale for parameter estimates used to compute the mean willingness to pay (MWTP). The results showed that the additional amount farmers were willing to pay for a 1 kg bag of the TELA Bt maize seed technology was R6.59. The Logistic regression model empirical results showed that among farmers who were willing to pay for the TELA® Bt maize technology, household size, access to extension services, health perception, trust in government and benefits perception had a significant impact in their WTP.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The main aim of the study was to model willingness to pay (WTP) for genetically modified TELA® Bt maize seed technology in Mpumalanga Province, South Africa. The specific objectives were: (i) To profile socio-economic characteristics of smallholder maize farmers, (ii) to assess farmers' knowledge, attitudes, perceptions, and practices (KAPP) towards the TELA® Bt maize seed technology and (iii) To determine smallholder maize farmers' WTP for the TELA® Bt maize seed technology. In the next subsections the summary of the results, the conclusion drawn from the analysis and the recommendation based on the study will be presented.

5.2 Summary

This section gives a brief summary on some of the crucial sections that were included in the study. The study was conducted under Ehlanzeni and Nkangala District Municipalities of Mpumalanga province. These two municipalities were selected because they are amongst the major growing regions of TELA® Bt maize where 289 maize farmers were selected and interviewed. The variables used in formulating questionnaires used in collecting data through purposive and multi-stage sampling techniques for the TELA® Bt maize and snowball sampling techniques for the non-TELA® Bt maize farmers were also discussed.

The descriptive statistics, which included cross tabulations and frequency distributions were used to describe socioeconomic characteristics of smallholder maize farmers and their typology, which addressed the first objective of the study. To address the second objective of the study, the Likert-scale and descriptive statistics were used to assess farmers' knowledge, attitudes, perceptions and Practice (KAPP) towards the TELA® Bt maize seed technology in the study area concerned. A discrete choice experiment was deployed to solicit and compute the mean willingness to pay (MWTP) from the farmers, and finally, the Logistic regression model was used to identify determinant factors significant towards WTP for TELA® Bt maize seed technology.

The results on the descriptive statistics used to address the first objective on the socioeconomic characteristics have revealed that there were more female farmers headed households than are males in each category who were also dominant in cultivation of maize. TELA® Bt maize farmers had had more years in school, implying high level of education on average. Non-TELA® maize farmers were found to have had more access to extensions services, highlighting the inadequacy of information disseminated on GM crops. TELA® maize farmers also had more income generation from multiple sources, demonstrating the significance of income on purchasing decisions for farmers. TELA® farmers had the largest household size, crucial for more labour force and division of labour for farming purposes and adoption. On average there were more farmers in a slightly higher age category using non-TELA® which revealed that the older the farmer, the less likely the prospects of purchasing new innovations into farming. Additionally, TELA® farmers had more years of farming experience, closely linked with knowledge about new farming methods that farmers might want to adopt in their farming practices.

The Likert-scale and descriptive statistics were used to assess farmers' knowledge, attitudes, perceptions and Practice (KAPP) towards the TELA® Bt maize seed technology in order to get more insight as to how these concepts further influence adoption. The results have revealed that majority of farmers had heard about the TELA® Bt maize seed technology, its importance, and the comprised attributes. Farmers' viewpoint about the benefits of TELA® Bt maize technology given their awareness about it, suggested that they were in favour of the possible positive effects it could have on their farming practices, more especially productivity, reduced chemical use, food security and income generation.

Farmers' attitude, that is their weighted some of perceptions towards TELA® Bt maize technology and its corresponding process was found to influence their decision to adopt the technology. The general feeling from among the farmers was that the methods used in their farming to control pests and drought was not effective, hence were willing to change the type of seeds they were using for TELA® Bt maize technology. The results revealed that farmers practices, as informed and influenced by their knowledge, perceptions and attitudes related to maize production, management of droughts (erratic rainfall) and excessive heat were not effective, more especially the non-TELA®.

The study further represented the results of the regression analysis for determining WTP by using the Bivariate correlation for measuring the strength of coefficients relationships and the Logit scale for parameter estimates used to compute the mean willingness to pay (MWTP). The results showed that the additional amount farmers were willing to pay for a 1 kg bag of the TELA Bt maize seed technology was R6.59.

Finally, the Logistic regression model empirical results showed that among farmers who were willing to pay for the TELA® Bt maize technology, household size, access to extension services, health perception, trust in government and benefits perception had a significant impact in their WTP, and these were there only variables discussed.

5.3 Conclusions

The study had intended to answer the following three hypotheses: (i) Farmers' knowledge towards the TELA® Bt Maize seed Technology in Mpumalanga Province of South Africa, which influences different factors including perception and attitude do not influence their practices. The hypothesis was therefore rejected since the results revealed that farmers practices, as informed and influenced by their perceptions and attitudes towards the TELA® Bt Maize seed Technology was influenced by their knowledge. The results revealed that farmers had heard about the TELA® Bt maize seed technology.

Furthermore, Farmers' perceptions about the benefits of TELA® Bt maize technology suggested that they were in favour of the possible positive effects it could have on their farming practices. Farmers' attitude, that is their weighted some of perceptions towards TELA® Bt maize technology and its corresponding process was found to influence their decision to adopt the TELA® Bt Maize seed technology.

(ii) The TELA® Bt Maize seed Technology attributes preferences in Mpumalanga

Province of South Africa do not determine smallholder maize farmers' WTP. The hypothesis was also rejected since the regression analysis using the Logit scale for parameter estimates, used to compute the mean willingness to pay (MWTP) results, showed that farmers were willing to pay additional amount of R6.59 for a 1 kg bag of the TELA Bt maize seed for attributes such as drought tolerance and price.

(iii) The determinant factors do not influence smallholder maize farmers' WTP for TELA® Bt maize seed technology in Mpumalanga Province, South Africa. The hypothesis was rejected because the Logistic regression model empirical results showed that among farmers who were willing to pay for the TELA® Bt maize technology, household size, access to extension services, health perception, trust in government and benefits perception had a significant impact in their WTP.

5.4 Recommendations

To ensure an improvement in the adoption and incorporation of GM maize technology in farming, several recommendations were made in relation to findings of the study.

1. It is the recommendation of this study that there should be a concerted effort from the side of the government to ensure frequent exposure of farmers to extension services. The introduction of more interactions between the farming communities and the extension services workers could be crucial for a positive response and a more widespread use of GM crops through better knowledge and understanding of their importance.

2. The private institutions and NGOs responsible for the introduction of GM technology ought to work cohesively with the members of the public and the media to help facilitate the dissemination of relevant information about GM crops. That way, it would help to deal with conflicting opinions and mixed feelings about the benefits of GM technology to farmers, widely spread without a full comprehension of what the technology is all about.

3. There is a need for the government to ensure a collective engagement for decision making on the growth and development of the farming sector and communities. A more bottom-up approach could prove more useful in ensuring trust between the government and farmers for solidarity in dealing with farm related issues as well as improving their perceptions on GM technology.

4. Consideration of farmer demographics cannot be overemphasised enough, as it allows for the scrutinization of the endowments of farmers when developing programmes to impact their farming practices like household size.

5.5 Areas for further research

This study only focused on the predetermined socioeconomic characteristic and determinant factors that influence farmer willingness to pay for TELA® Bt maize technology. It further expanded on the knowledge, perception, attitudes and practices towards the TELA® Bt maize technology. What still remains to be discovered, which the study has not yet fully given a light on and has not been discovered in other literature is the influence and effectiveness of the institutions relevant for dissemination of GM technology and its corresponding information on farmer adoption levels.

Institutional capacity development for adoption of GM technology into farming is important for the success, not only of the technology concerned but the enlightenment of the farming communities on new innovations, hence the study suggests such to be taken into consideration.

REFERENCES

Abu Bakar, N. A., Marikan, D. A. A., Edman, S., & Ali, D. H. A. (2021). Willingness to Pay for Kubah National Park: Evidence from the Contingent Valuation Method. International Journal of Academic Research in Business and Social Sciences, 11(1), 500–514.

Agrimag, 2019. Maize farming in South Africa. *South African grain information services.*

Ahmed, A. et al., 2015. Exploring factors influencing farmers' willingness to pay (WTP) for a planned adaptation programme to address climatic issues in agricultural sectors.. *Environ Sci Pollut Res.*

Ali, S., Ghufran, M., Nawaz, M. A. & Hussain, S. N., 2019. The psychological perspective on the adoption of approved genetically modified crops in the presence of acceptability constraint: the contingent role of passion. *GM Crops & Food,* 10(4), pp. 220-237.

Almeida, C., Massarant, L. & Moreira, I. D. c., 2015. Perception of Brazilian small-scale farmers about Genetically Modified crops. *Ambiente & Sociedade,* V(XVIII), pp. 193-210.

Anon., 2016. The effects of emotion on consumer willingness to pay (WTP) for Ecolabeled fresh produce. *Xuqi Chen; Zhifeng Gao.*

Antwi-Agyei, P., Amanor, K., Hogarh, J. N. & Dougill, A. J., 2021. Predictors of access to and willingness to pay for climate information services in north-eastern Ghana: A gendered perspective. *Environmental Development,* Volume 37.

Aryal, K. P., Chaudhary, P., Pandit, S. & Sharma, G., 2009. Consumers' Willingness to pay for organic products: A casew study from Kathmandu Valley. *The Journal of Agriculture and Environment,* Volume 10.

Asmamaw, B. et al., 2016. Estimating Willingness to Pay for Labeobarbus Fish Species Conservation in Lake Tana, Ethiopia: A Contingent Valuation Study. *International Journal of Natural Resource Ecology and Management,* 1(4), pp. 155-161.

Asrat, S., Yesuf, M., Carlsson, F. & Wale, E., 2010. Farmers' Preferences for Crop Variety Traits: Lessons for On-Farm Conservation and Technology Adoption. *Ecological Economics,* Volume 357.

Autade, R. H. et al., 2015. Farmers perception, knowledge and attitude towards Biotech (GM) crops at Agrowon AgriExpo – A survey.. *International Journal of Agriculture, Environment and Biotechnology,* 8(3), pp. 753-761.

Aydogdu, M. H., 2017. Evaluation of Farmers' Willingness to Pay for Agricultural Extension Services in GAP-Harran Plain, Turkey. *J. Agr. Sci. Tech. ,* Volume 19, pp. 785796.

Aydogdu, M. H. et al., 2020. Determination of Farmers' Willingness to Pay for Sustainable Agricultural Land Use in the GAP-Harran Plain of Turkey. *Land,* 9(261).

Azadi, H. et al., 2015. Genetically modified crops and small-scale farmers: main opportunities and challenges. *Critical reviews in biotechnology,* pp. 1-13.

Baloch, M. A. & Thapa, G. B., 2016. The effect of agricultural extension services: Date farmers' case in Balochistan, Pakistan. *Journal of the Saudi Society of Agricultural Sciences,* pp. 283-289.

Barrows, G., Sexton, S. & David, 2014. Agricultural Biotechnology: The Promise and Prospects of Genetically Modified crops. *Journal of Economic Perspectives,* 28(1), pp. 99-120.

Basarir, A., Sayili, M. & Muhammad, S., 2009. Analysing produers' willingness to pay for high quality irrigation water. *Bulgarian Journal of Agricultural Science,* 15(6), pp. 566-573.

Bass, D. A., McFadden, B. R. & Messer, K. D., 2021. A case for measuring negative willingness to pay for consumer goods. *Food policy,* Issue 104.

Bengochea-Morancho, A., Fuertes-Eugenio, A. M. & Saz-Salazar, S. d., 2005. A comparison of empirical models used to infer thewillingness to pay in contingent valuation. *Empirical Economics.*

berges, M., Casellas, k., Rodriguez, R. & Errea, D., 2015. Wllingness to pay for quality attributes of fresh beef, implications on the retail marketing. *International Conference of Agricultural Economics,* pp. 8-14.

Bett, E. K., Nyairo, D. N., Ayieko, M. & Amolo, J. O., 2014. Determinats of consumer perception towards Genetically Modified(GM) foodsin higher learning institutions in kenya. *Journal of Economics and Sustainable Development,* 5(24), pp. 35-45.

Beyene, Y., Ertiro, B. T., Das, B. & Mugo, S. N., 2017. Combining ability and testcross performance of drought-tolerant maize inbred lines under stress and non-stress environments in kenya. *Plant breeding,* 136(2), pp. 197-205.

Beyene, Y. et al., 2016. Improving maize grain yield under drought stress and non-stress environments in Sub-Saharan Africa using marker-assisted recurrent selection. *Crop Science,* 56(1), pp. 344-353.

Bhattarai, K., 2019. Consumers' willingness to pay for organic vegetables: Empirical evidence from Nepal. *Economics and Sociology,* 12(3), pp. 132-146.

Biswas, B., Mallick, B., Roy, A. & Sultana, Z., 2021. Impact of agriculture extension services on technical efficiency of rural paddy farmers in southwest Bangladesh. *Environmental Challenges,* Volume 5.

Bocher, T. et al., 2019. Investigating consumer preferences and willingness to pay for Orange-fleshed Sweet potato (OFSP) juice in Rwanda. *Open Agriculture,* Volume 4, p. 227–236.

Breidert, C., Hahsler, M. & Reutterer, T., 2006. A review of methods for measuring willingness-to-pay. *Innovative Marketing.*

Bulletin & Food and Agriculture Organisation, S., 2017. Food and Agriculrural Organization of the United Nations. pp. 1-12.

Campbell, D. & Erdem, S., 2018. Including opt-out options in discrete choice experiments. *Issues to consider.*

Carson, R. T. & Czajkowski, M., n.d. The Discreet choice experiment approach to environmetal contingent valuation. *2014.*

Cawley, A., Heanue, K., O'Donoghue, C. & Sheehan, M., 2015. The Impact of Extension Services on Farm Level Outcomes: An Instrumental Variable approach. pp. 22-23.

Chagwena, D. et al., 2019. Knowledge, Attitudes and Perception towards Genetically Modified foods in Zimbabwe. *African journal of food, agriculture, nutrition and development,* 19(3).

Chen, X. & Gao, Z., 2016. *Agricultural & Applied Economics Association Annual Meeting.*

Chini, J. & Spers, E. E., 2019. The influence of signal attributes on the willingness to pay for pasture-raised beef. *Management Journal.*

Corte, K. D., Cairns, J. & Grieve, R., 2021. Stated versus revealed preferences: An approach to reduce bias. *Health Economics,* 30(5), pp. 1095-1123.

Cui, K. & Shoemaker, S. P., 2018. Public perception of genetically-modified (GM) food: A Nationwide Chinese Consumer Study. *Science of food,* 2(10).

Danso, G. K., Otoo, M., Linh, N. D. & Madurangi, G., 2017. Households' Willingness-toPay for Fish Product Attributes and Implications for Market Feasibility of WastewaterBased Aquaculture Businesses in Hanoi, Vietnam. 6(30).

Davel, R., 2019. Mpumalanga Landbou and Agriculture.

Deng, H., Hu, R., Pray, C. & Jin, Y., 2019. Perception and Attitude toward GM Technology among agribusiness managers in China as producers and as consumers. *Sustainability,* Volume 11.

Department of Agriculture Forestry and Fisheries, 2017. A profile of the South African maize market value chain. *Economic review of the South African agriculture.*

Department of Agriculture Forestry and Fisheries, 2017. A profile of the South African maize market value chain.

Department of Agriculture Forestry and Fisheries, 2017. A profile of the South African mango market value chain. pp. 1-27.

Department of Agriculture Land Reform & Rural Development, 2020. Economic review of the South African agriculture.

Department of Agriculture Rural Developmemt and Land Administration, 2015. AgriHubs. *Agri-Hubs identified by the Province.*

Departmet of Agriculture Forestry and Fisheries, 2014. Lets grow South Africa together. *SA yearbook.*

Diko, A. & Jun, W., 2020. Influencing Factors of Maize Production in South Africa: The Case of Mpumalanga, Free State and North West Provinces. *Asian Journal of Advances in Agricultural Research,* 14(1), pp. 25-34.

Dogan, H. P., Aydogdu, M. H., Sevinç, M. R. & Cançelik, M., 2020. Farmers' Willingness to Pay for Services to Ensure Sustainable Agricultural Income in the GAP-Harran Plain, ¸Sanlıurfa, Turkey. 10(152).

Donatelli, M. et al., 2017. Modelling the impacts of pests and diseases on agricultural systems.

Dwivedi, A., Nayeem, T. & Murshed, F., 2018. Brand experience and consumers' willingness-to-pay (WTP) a price premium: Mediating role of brand credibility and perceived uniqueness. *Journal of Retailing and Consumer Services,* Volume 44, pp. 100107.

E.Mnaranara, T., Zhang, J. & Wang, G., 2017. Public perception towards Genetically Modified foods in Tanzania. *The Journal of Animal & Plant Sciences,* 27(2), pp. 589-602.

Edge, M. et al., 2018. Water efficient maize for Africa: A public-private partnership in technology trasnsfer to smallholder farmers in Sub-Saharan Africa. *From agriscience to agribusiness,* Volume 136, pp. 391-412.

Edmeades, G. O., 2008. Drought tolerance in maize: an emerging reality. *International service for the acquisition of Agric-Biotec Applications (ISAAA) .*

Ehn, R. C. & Fox, J. R., 2019. A Comparative Analysis of Conventional, Genetically Modified (GM) Crops and Organic Farming Practices and the Role of Pesticides in Each.

Elias, A., Nohmi, M., Yasunobu, K. & Ishida, A., 2015. Farmers' Satisfaction with Agricultural Extension Service and Its Influencing Factors: A Case Study in North West Ethiopia. *J. Agr. Sci. Tech. ,* Volume 17, pp. 39-53.

Evans, E. A., Ballen, F. H. & De, B., 2017. Willingness of South Florida Fruit Growers to Adopt Genetically Modified Papaya: An Ex-ante Evaluation. *AgBioForum,* 20(2), pp. 156162.

Fezzi, C., Bateman, I. J. & Ferrini, S., 2014. Using revealedd preference to estimate the value of travel time to recreation sites. *Journal of Environmental Economics and Management ,* 67(1), pp. 58-70.

Fischer, K., Berg, J. V. d. & Mutengwa, C., 2015. Is Bt maize effective in improving South African smallholder agriculture?. *South African Journal of science ,* Volume 111, pp. 1-2.

Flachs, A., 2015. Persistent agrobiodiversity of Genetically Modified cottton farms in Telangana, India. *Journal of Ethnobiology,* 35(2), pp. 406-426.

Flachs, A., 2015. Persistent Agrobiodiversity on Genetically Modified Cotton Farms in Telangana, India. *Journal of Ethnobiology,* 35(2), pp. 406-426.

Flaten, O., Lien, G. & Tveteras, R., 2011. A comparative study of risk exposure in agriculture and aquaculture. *Food economics-Acta Agriculture Scandinavica , Section C,* vii(8), pp. 20-4.

Font, M. C., 2009. Consumer Acceptance, Choice and Attitudes towards Genetically Modified (GM) Food.

Gebrezgabher, S. A., Amewu, S. & Amoah, P., 2015. Consumer preference and willingness to pay for fish farmed in treated wastewater in Ghana.

Ghazanfa, S. et al., 2015. Farmers' willingness to pay for crop insurance in Pakistan. *Journal of Business, Economics & Finance,* 4(2).

Gouse, M., Sengupta, D., Zambrano, P. & Zepeda, J. F., 2016. Genetically Modified Maize: Less Drudgery for Her, More Maizefor Him? Evidence from Smallholder Maize Farmers in South Africa. *World Development,* Volume 83, p. 27–38.

Greyling, J. C., 2019. Policy, production, and productivity: Spatial dynamics in the South African maize industry during the 20th century..

Guerriero, V. D. a. C., 2019. Children's Willingness to Pay for environmental protection.

Guijaro, F. & Tsinaslanidis, P., 2020. Analysis of academic literature on environmetal valuation. *International Journal of Environmental Research and Public health,* 17(7).

Haarhoff, S. J., Kotzé, T. N. & Swanepoel, P. A., 2020. A prospectus for sustainability of rainfed maize production systems in South Africa. *Crop Science,* pp. 14-28.

Hameed, T. S. & sawicka, B., 2019. Farmers’ knowledge of sustainable potato cultivation techniques in Poland. *Agronomy science,* LXXIV(3).

Harun, R. et al., 2015. Analysis of Factors that Influence the Willingness to Pay for Irrigation Water in the Kurdistan Regional Government, Iraq. *Sustainability,* Volume 7, pp. 9574-9586.

Hayran, S., Gul, A., Saridas, M. A. & Dowload, P., 2018. Farmers' sustainable agriculture perceptionin Turkey: The case of Mersin province. *New Medit ,* Volume 3, pp. 69-78.

Hernandez, J. E. et al., 2017. Challenges and Solutions for Enhancing Agriculture Value Chain Decision-Making. A Short Review. *Springer International Publishing AG ,* Volume 506, pp. 761-774.

Janko, M. & Assefa, L. Z., 2015. Fishermen’s willingness to pay for fisheries management: The case of lake Zeway, Ethiopia. *International Journal of Fisheries and Aquatic Studies,* pp. 320-325.

Judge, G. G. et al., 1988. Introduction to the Theory and practice of Econometrics.

Kalantari, H. D., Johnson, L. W. & Perera, C. R., 2021. The effect of gender on willingness to pay for mass customised running shoes. *Journal of global fashion marketing,* 12(2), pp. 161-175.

Kassie, G. T. et al., 2014. Willingness to pay for Drought Tolerance in Maize in Communal Areas of Zimbabwe.

Kassie, G. T. et al., 2012. Characterization of Maize Production in Southern Africa: Synthesis of CIMMYT/DTMA Household Level Farming System Surveys in Angola, Malawi, Mozambique, Zambia and Zimbabwe.. *Socio-Economics,* Issue 4.

Khan, I. et al., 2019. Public Attitudes, Preferences and Willingness to Pay for River Ecosystem Services. *International Journal of Environmental Researchand Public Health,* Volume 16.

Khwidzili, R. H. & worth, S., 2020. Promotion of sustainable agriculture by mpumalanga agricultural extensionservices: perspective of public extension praticioners. *South African Journal of Agricultural Extension,* 41(8), pp. 1-16.

Kikulwe, E. M. & Asindu, M., 2020. A contingent valuation analysis for assessing the market for genetically planting materials among banana producing households in Uganda. *Gm crops & food,* 11(2), pp. 113-124.

Kimenju, S. C. et al., 2005. Consumer awareness and attitudes toward GM foods in Kenya. *Academic Journals,* iv(10), pp. 1066-1075.

Kokoye, S. E. H. et al., 2018. Farmer willingness to pay for soil testing services in Northen Haiti. *Journal of Agricultural and Applied Economics,* 50(3), pp. 429-451.

Kotey, D. A., Assefa, Y. & Obi van den Berg, J., 2016. Disseminating Genetically Modified (GM) maize technology to smallholder farmers on the Eastern Cape Province of South Africa: Extension personnel's awareness of stewardship requirements and dissermination practices. *S.Afr,* 44(1), pp. 59-74.

Kotey, D. A., Assefa, Y. & Van den Berg, J., 2017. Enhancing smallholder farmers' awareness of GM maize technology, management practices and compliance to stewardship requirements in the Eastern Cape Province of South africa: The role of public extension and advisory services. *S. Afr. J. Agric. Ext,* 45(2), pp. 49-63.

Kucher, A., Hełdak, M., Kucher, L. & Raszka, B., 2019. Factors Forming the Consumers’Willingness to Pay a Price Premium for Ecological Goods in Ukraine. *Int. J. Environ. Res. Public Health,* 16(859).

Kunert, K. J., 2011. How effective and safe is Bt-maize in South Africa?. *S Afr J Sci.,* 107(9).

Kwade, P. C., kweku, B., Lukman, L. S. & Ouist, C. E., 2019. Framers' attitude towards the use of Genetically Modified crop technology in Southern Ghana: The mediating role of risk perception. *AIMS Agriculture and food ,* 4(4), pp. 833- 853.

Lemons, S., Halstead, J. M. & Huang, J.-C., 2022. The effect of information about price anchoring: evidence from a choice experiment. *Agricultural and resource economics review,* Volume 51, pp. 240-265.

Lipton, D. W., Wellman, K., Sheifer, I. C. & Weiher, R. F., 1995. Economic valuation of natural resources. *Science for Solutions,* Issue 5.

Lusk, J., 2011. Chapter 10 Consumer Preferences for Genetically Modified Food. *Frontiers of Economics and Globalization,* Volume 10.

Lybbert, T. J. & Bell, A., 2010. Stochastic benefit streams, learning, and technology diffusion: Why drought tolerance is not the new Bt. *AgBioForum,* 13(1), pp. 13-24.

M.Wooldridge, J., 2013. *Introductory Econometrics.* 5th ed. s.l.:Cengage.

Mahlase, M. H., 2016. Exploring the uptake of genetically modified white maize by smallholder farmers: The case of Hlabisa, South Africa.

Makweya, F. L. & Oluwatayo, I. B., 2019. Consumers’ preference and Willingness to Pay for beef in Polokwane municipality, South Africa. *Italian Journal of Food Safety,* Volume 8:7654.

Makwinja, R., Kosamu, I. B. M. & Kaonga, C. C., 2019. Determinants and Values ofWillingness to Pay for Water Quality Improvement: Insights from Chia Lagoon, Malawi. *Sustainability,* 11(17).

Martey, E., Etwire, P. M., Wiredu, A. N. & Dogbe, W., 2014. Factors influencing willingness to participate in multi-stakeholder platform by smallholder farmers in Northern Ghana: Implication for research and development. *Agricultural and Food Economics,* Volume 2, pp. 1-15.

Maruapula, S. & Peters, H., 2020. Consumer Knowledge and Perceptions Regarding Genetically Modified Foods:A Case Study of Two Cities in Botswana. *Gene Technology: Open access,* 9(1).

Masuka, B. et al., 2017. Gains in maize genetic improvement in Eastern and Southern Africa: II CYMMIT open-pollinated variety breeding pipeline. *Crop science society of America.*

Ma, Y. et al., 2020. Perceived Value Influencing the Household Waste Sorting Behaviors in Rural China. *Environmental Research and Public Health,* Volume 17.

McFaddena, J. R. & Huffman, W. E., 2017. Willingness-to-Pay for Natural, Organic, and Conventional Foods: The Effects of Information and Meaningful Labels.

Mohsin, A., 2016. A Manual for Selecting Sampling Techniques in Research. *Munich Personal RePEc Archive.*

Mu, L. et al., 2019. Assessing the impact of water price reform on farmers' willingness to pay for agricultural water in northwest China. *Journal of Cleaner Production,* pp. 10721081.

Munthali, G. T., 2013. Assessing farmers' Willingness-to-pay for improved common bean seed varieties in Malawi: A case study of Kasungu and Dedza district.

Muringai, V., 2018. Canadian Consumer Acceptance of Gene-Edited Versus Genetically Modified Potatoes: A Choice Experiment Approach.

Muzhinji, N. & Ntuli, V., 2020. Genetically modified organisms and food securityin Southern Africa: conundrum and discourse. *Biotechnology in Agriculture and the Food Chain,* 12(1), pp. 25-35.

Nang'ayo, F., simiyu-Wafukho, S. & Oikeh, S. O., 2014. Regulatory challenges for GM crops in developing economies: the African experience. *Transgenic research,* 23(6), pp. 1049-1055.

Nguyen, T. M., Le, N. T. T., Havukainen, J. & Hannaway, D. B., 2018. Pesticide use in Vegetable Production: A Survey of Vietnamese Farmers' Knowledge. *Plant Protect. Sci.,* 54(4), pp. 203-214.

Ntawuruhunga, D., 2016. Farmers' Knowledge, Attitude and Practice towards African Indigenous Vegetables in Kenya.

Obadha, M. et al., 2019. Attribute development and level selection for a discreet choice experiment to elicit the preference of health care providers for capitation payment mechanism in Kenya. *Health Economics Review,* 9(30).

Obi-Egbedi, O., Oluwatayo, I. B. & Ogungbite, O., 2020. Genetically Modified Crops' technology and its Awareness among Smallholder Farmers in Nigeria. *Problem of World Agriculture,* Volume 20, pp. 58-67.

Okoffo, E. D., Denkyirah, E. K., Adu, D. T. & Fosu-Mensah, B. Y., 2016. A double-hurdle model estimation of cocoa farmers' willingness to pay for crop willingness to pay for crop. *SpringerPlus,* Volume 873, p. 5.

Omotayo, A. O. et al., 2021. Determinants of Household Income and Willingness to Pay for indigenous Plants in North West Province, South Africa: A Two-Stage Heckman Approach. *Sustainability,* Volume 13.

Ongachi, W. et al., 2018. Farmers' knowledge, attitude, and perception of video mediated learning vis-à-vis Farmer Field School on Striga weed management in Western Kenya.

International Journal of Education and Development using Information and Communication Technology, Volume 14, pp. 195-210.

Onyango, B. & Govindasamy, R., 2005. Consumer Willingness to Pay for GM Food Benefits: Pay-off or Empty Promise? Implications for the Food Industry. *American Agricultural Economics Association,* xx(4).

Oparinde, A., Abdoulaye, T., Mignouna, D. B. & Bamire, A. S., 2017. Will farmers intend to cultivate Provitamin A genetically modified (GM) cassava in Nigeria? Evidence from a k-means segmentation analysis of beliefs and attitudes.

Opoku, E., 2017. Willingness to pay for quality cowpea seeds: experimental evidence from Northern Ghana.

Pan, Y., Smith, S. C. & Sulaiman, M., 2018. Agricultural extension and technology adoption for food security: Evidence from Uganda. *Amer. J. Agr. Econ.,* 00(0), pp. 1-20.

Panzarini, N. H. et al., 2015. Biotechnology in agriculture: The perception of farmers on the inclusion of Genetically Modified Organisms (GMOs) in agricultural production. *African Journal of Agricultural Research,* 10(7), pp. 631-636.

Patidar, D. S. & Patidar, H., 2015. A Study of Perception of Farmers towards organic farming. *I nternational Journal of Application or I nnovation in Engineering & M anagement (I JAI EM) ,* 4(3), pp. 2319 - 4847.

Paull, J., 2018. Genetically Modified Organisms (GMOs) as Invasive Species. *Journal of Environment Protection and Sustainable Development,* 4(3), pp. 31-37.

Perez-Troncoso, D., 2020. A step-by-step guide to design, implement, and analyze a discreet choice experiment.

Pérez-Troncoso, D., 2020. A step-by-step guide to design, implement, and analyze a discrete choice experiment.

Petcharat, A., Lee, Y. & Chang, J. B., 2020. Choice Experiments for Estimating the NonMarket Value of Ecosystem Services in the Bang Kachao Green Area, Thailand.

Sustainability, Volume 12.
Rapsomanikis, G., 2015. The economic lives of smallholder farmers. *Food and Agriculture Organization of the United Nations ,Rome.*

Rzymski, P. & Królczyk, A., 2016. Attitudes toward genetically modified organisms in Poland: to GMO or not to GMO?. *Food Sec,* Volume 8, pp. 689-697.

Sanou, E. I. et al., 2018. Farmers' knowledge and opinions towards bollgard II implementation in cotton production in western Burkina Faso. *New Biotechnology.*

Santpoort, R., 2020. The Drivers of Maize Area Expansion in Sub-SaharanAfrica. How Policies to Boost Maize ProductionOverlook the Interests of Smallholder Farmers.. *Land Perspective,* 9(68).

Schnurr, M. A. & Addison, L., 2017. Which Variables Influence Farmer Adoption of Genetically Modified Orphan Crops? Measuring Attitudes and Intentions to Adopt GM Matooke Banana in Uganda. *AgBioForum,* 20(2), pp. 133-147.

Schnurr, M. A. & Dowd-Uribe, B., 2021. Anticipating Farmer Outcomes of Three Genetically Modified Staple Crops in sub-Saharan Africa: Insights from Farming Systems Research.

Schnurr, M. A. & Mujabi-Mujuzi, S., 2014. ''No one asks for a meal they've never eaten.'' Or, do African farmers want genetically modified crops?. *Agric Hum Values,* Volume 31, pp. 643-648.

Sebaggala, R. & Matovu, F., 2020. Effects of Agricultural Extension Services on Farm Productivity in Uganda. *African Economic Research Consortium, Nairobi.*

Sechube, M. P., Belete, A. & Hlongwane, J. J., 2020. Analysing the effects of access to tractor service on the technical efficiency of small-scale maize farmers in Mpumalanga province: a case study of masibuyele emasimini programme. *Journal of Agribusiness and Rural Development,* 3(57), p. 317–326.

Sekyere, E. O., 2014. Consumer preferences and willingness to pay for beef attributes in Ghana.

Sen, G. A., 2016. Application of Full Factorial Experimental Design and Response Surface Methodology for Chromite Beneficiation by Knelson Concentrator.. *Minerals ,* 6(5).

Setia, M. S., 2016. Methodology Series Module 3: Cross-sectional Studies. *Indian Journal of Dermatology.*

Sharma, H. R., Mugaonkar, P., Mahida, N. & Gawa, S., 2017. Consumer’s Willingness to Pay more for Preferred Fish (Labeo rohita) in Manipur. *Researchgate.*

Shausi, G. L., Ahmad, A. K. & Abdallah, J. M., 2019. Factors determining crop farmers’ willingness to pay for agricultural extension services in Tanzania: A case of Mpwapwa and Mvomero Districts. *Journal of Agricultural Extension and Rural Development,* 11(12), pp. 239-247.

Sheahan, M. & Barret, C. B., 2017. Ten striking facts about agricultural input use in SubSaharan Africa. *Food policy,* Volume 67, pp. 12-25.

Shee, A., Azzarri, C. & Haile, B., 2019. Farmers' willingness to pay for improved agricultural technologies: Evidence from a field experiment in Tanzania. *Sustainability,* 12(1).

Simelane, M., Masuku, M., Rugambisa, J. & Earnshaw, D., 2016. Analysis of consumer willingness to pay for genetically modified maize food in Swaziland. *International Journal of Sustainable Agricultural Research,* I(3), pp. 19-28.

Skevas, T. et al., 2013. Do European Union farmers reject genetically modified maize?: farmer prefernces for genetically modified maize in greeze. *AgBioForum,* 15(3), pp. 242256.

Slabá, M., 2019. The impact of age on the customers buying behaviour and attitude to price. *Littera Scripta,* 12(2).

Slabá, M., 2019. The impact of age on the customers buying behaviour and attitude to price. *Littera Scripta,* 12(2).

Smale, M., 1995. Maize is life: Malawi's delayed Green Revolution. *World development,* 23(5), pp. 819-831.

Smale, M. & Jayne, T. a., 2003. Maize in Eastern and Southern Africa: seeds of success in retrospect.

Somanje, A. N., Mohan, G. & Saito, O., 2021. Evaluating farmers’ perception toward the efectiveness of agricultural extension services in Ghana and Zambia. *Agriculture & Food Security,* 10(53).

Steur, H. D. et al., 2019. Framers' willingness to adopt late blight-resistant genetically modified potatoes. *Agronomy,* 9(6).

Taherdoost, H., 2016. Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research.

Temesgen, D. & Tola, T., 2015. Determinates of Small Holder Farmers Willingness to Pay for Agricultural Extension Services: A Case Study from Eastern Ethiopia. *Afr. J. Agric. Res,* 10(20).

The Southern African Grain Laboratory, 2019. *South African commercial maize quality,* Pretoria: s.n.

Tobin, J., 1958. Estimation of Relationships for Limited Dependent Variables. *Econometrica,* pp. 24-36.

Todua, N. & Gogitidze, T., 2017. Georgian Farmers’ Attitudes Towards Genetically Modified Crops. *Economics World,* 5(4), pp. 362-369.

Toledano, B. I. S., 2017. Farmers' preference and rthe factors affecting theri decision to improve maize crops in mexico.

Udomkun, P. et al., 2018. What are the key factors influencing consumers’ preference and willingness to pay for meat products in Eastern DRC?. *Food Science and Nutrition.*

Urrutia, A. C., García, L. Y., Ortega-Farías, S. & Ubilla, Á., 2012. Consumer preferences and willingness to pay for organic apples. *agricultural economics,* xi(1), pp. 47-59.

Veldwijk, J. et al., 2014. The Effect of Including an Opt-Out Option in Discrete Choice Experiments.

Waite, A. A., 2017. Consumer Knowledge, Perception and Attitudes of Unlabeled Genetically Modified Foods of an Educated Population in the State of Kentucky.
TopScholars.

Wandile, S., 2016. An evaluation of competitiveness of South African maize exports.

Whittington, D., 2010. What have we learnt from 20 years of Stated Preference research in less-developed countries?. *Annual review of resource economics.*

WJ Van Der, W., 2011. After 33 years of biotech communication and 21 years of GM crop testing and adoption, where to now for South Africa?. *Genetically Modified Organisms in Horticulture Symposium,* pp. 37-42.

Yi, S., 2019. Willingness-to-Pay for Sustainable Aquaculture Products: Evidence from Korean Red Seabream Aquaculture. *Sustainability,* Volume 11.

Zakaria, H., Adam, H. & Abujaja, A. M., 2014. Knowledge and Perception of Farmers towards Knowledge and Perception of Farmers towards Based Organizations in Northern Region of Ghana. Volume 1.

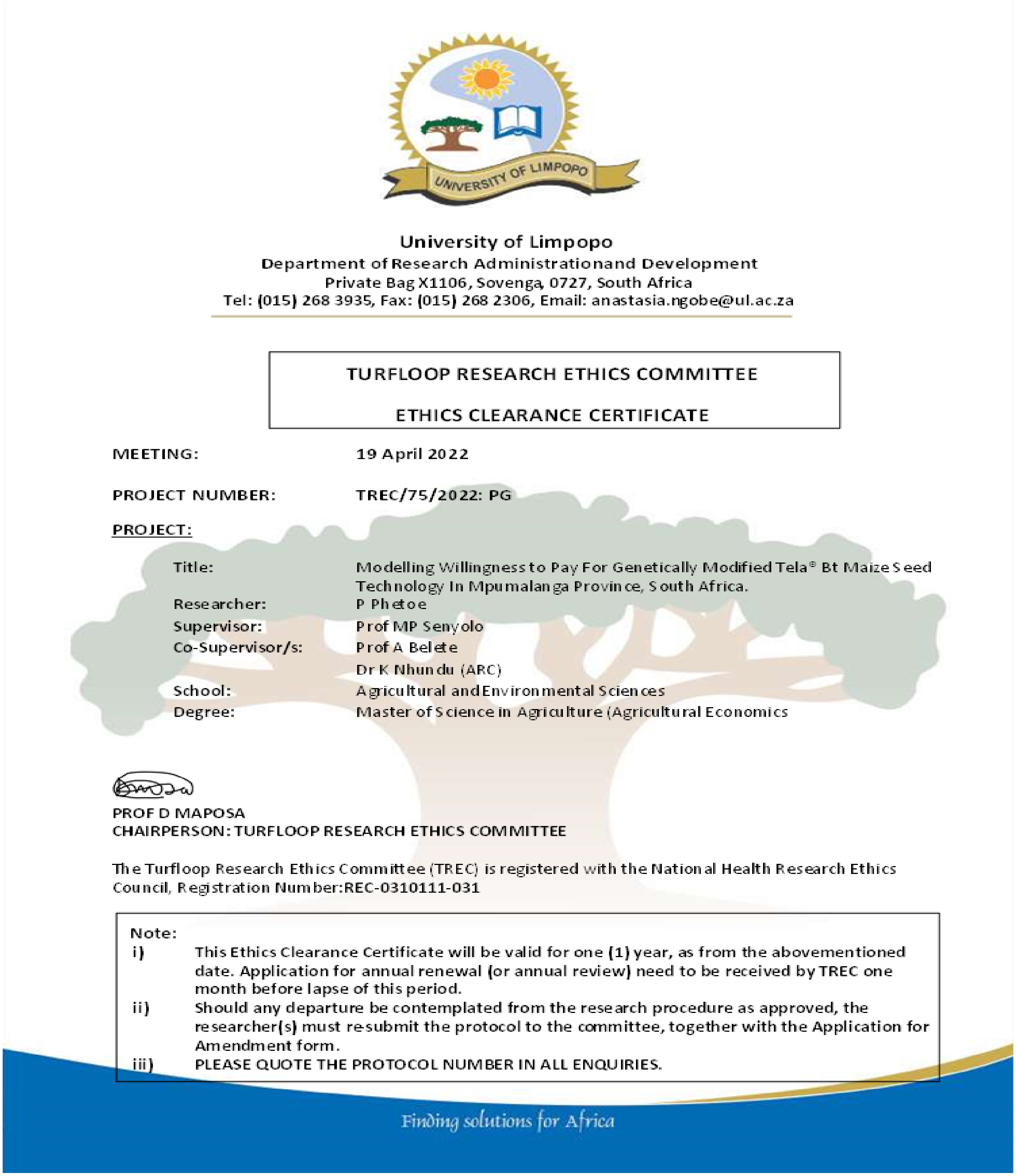
Zander, K. & Feucht, Y., 2018. Who is Prepared to Pay For Sustainable Fish? Evidence from a Transnational Consumer Survey in Europe. *System Dynamics and Innovation in Food Networks,* pp. 99-112.

Zhang, X. et al., 2020. Factors Influencing Farmers' Willingness to Pay for Weather Index Insurance Through Fuzzy-Set Qualitative Comparative Analysis: Insights from a Pilot in Jiangxi Province, China. *Modern Management based on Big Data .*

Zilberman, D., Hollan, T. & Trilnick, I., 2018. Agricultural GMOs- What we know and where scientists disagree. *Sustainability,* Volume 10.

ANNEXURES

Annex 1: Ethical clearance certificate



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TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **19 April 2022**

PROJECT NUMBER: **TREC/75/2022: PG**

PROJECT:

Title:	Modelling Willingness to Pay For Genetically Modified Tela® Bt Maize Seed Technology In Mpumalanga Province, South Africa.
Researcher:	P Phetoe
Supervisor:	Prof MP Senyolo
Co-Supervisor/s:	Prof A Belete Dr K Nhundu (ARC)
School:	Agricultural and Environmental Sciences
Degree:	Master of Science in Agriculture (Agricultural Economics

PROF D MAPOSA
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: REC-0310111-031

Note:
- i) This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.
- ii) Should any departure be contemplated from the research procedure as approved, the researcher(s) must resubmit the protocol to the committee, together with the Application for Amendment form.
- iii) PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

Annex 2: Faculty approval letter

UNIVERSITY OF LIMPOPO
Faculty of Science and Agriculture

26/01/2022

NAME OF STUDENT: Phetoe P

STUDENT NUMBER: 201600283

DEPARTMENT: Agricultural Economics and Animal Production

SCHOOL: Agricultural and Environmental Sciences

QUALIFICATION: MSA02

Dear Mr Phetoe

FACULTY APPROVAL OF PROPOSAL (PROPOSAL NO. 03 OF 2022)

I have pleasure in informing you that your **masters** proposal served at the Faculty Higher Degrees Committee meeting on **09 September 2021** and your title was approved as follows:

“**Modelling willingness to pay for genetically modified Tela® BT maize seed technology in Mpumalanga Province, South Africa.**”

Note the following: The study

Ethical Clearance	**Tick One**
Requires no ethical clearance Proceed with the study	
Requires ethical clearance (Human) (TREC) (apply online) Proceed with the study only after receipt of ethical clearance certificate	√
Requires ethical clearance (Animal) (AREC) Proceed with the study only after receipt of ethical clearance certificate	

Yours faithfully

Prof P Masoko Research Professor: Faculty of Science and Agriculture

CC: Dr MP Senyolo Prof JJ Hlongwane Prof TP Mafeo

Annex 3: Research questionnaire

Questionnaire ID:

Dear respondent:

The Agricultural Research Council and the African Agricultural Technology Foundation in collaboration with the:

1. Department of Agricultural Economics and Extension, Faculty of Science and Agriculture, at the University of Fort Hare and
2. Department of Agricultural Economics and Animal Production, Faculty of Science and Agriculture at the University of Limpopo

are respectively conducting the following studies in Mpumalanga and Limpopo Provinces, South Africa:

1. **Impact assessment of Genetically Modified TELA® Bt maize variety adoption on productivity, household income and food security and**
2. **Willingness to Pay for Genetically Modified TELA® Bt Maize Seed Technology**

These is studiesy will also lead to awarding of Masters Degrees for the following students:

Ms. Lesiba P. Mailula and Mr. Patrick Phetoe

Hence, we would like to ask a few minutes of your time to discuss this. Since I understand that you are very busy, our discussion will take approximately 2030 minutes of your time.

The information collected shall be private, confidential and only used for the purpose and benefits of the study. Please note, participation in this survey is voluntary.

Do you give consent to proceed with the interview: **YES** **NO**

Should you have any questions or concerns about your participation in the study, please contact:

1. Dr. K. Nhundu, Agricultural Research Council, Tel: 012 427 9829: E-mail: NhunduK@arc.agric.za or
2. Prof. MP Senyolo, University of Limpopo, Tel: 015 268 4628; E-mail: mmapatla.senyolo@ul.ac.za or
3. Prof. A. Mushunje, University of Fort Hare; Tel: 040 602 2124; E-mail: AMushunje@arc.agric.za

Name of enumerator		**Province**
Date of interview		1. Mpumalanga
Time of interview		Village:

SECTION A: RESPONDENT DEMOGRAPHICS

A1	A2	A3	A4	A5	A6	A7	A8
Year of birth	Gender 1 = male 0 = female	Marital status 1 = married 2 = single 3 = divorced 4 = widowed 5 = separated 6 = (other, *specify*)	Years spend in school ………………………… What is your highest level of education? 1 = no formal education 2 = primary education 3 = secondary education 4 = tertiary education	Household size	Sources of income (per month) *(you can tick more than 1 if applicable)* 1 = on-farm (R…………………….) 2 = small business (R……………...……) 3 = pension money (R…………….…….) 4 = social grants (R…………………....) 5 = remittances (R…………………....) 6 = other (specify) (R……………….…...)	Main employment status 1 = formallyemployed 0 = informallyemployed	Are you a full time farmer? 1 = yes 0 = no

					…………………… (R…………………...) …………………… (R…………………...) …………………… (R…………………...)		

SECTION B: FARM AND FARMING INFORMATION

B1	B2	B3	B4	B5	B6	B7	B8	B9
Farm size	Do you own land? 1 = yes 0 = no	Type of ownership 1 = leasehold 2 = rent 3 = freehold 4 = bought 5 = inherited 6 = other (specify)	Three main crops grown at the farm: 1…………………… 2…………………… 3……………………	What is the **MAIN** reason for engaging in crop production 1 = income generation 2 = employment 3 = home consumption 4 = other *(specify)*	Years in farming …………	Maize variety used 1 = TELA® Bt GM 2 = Non-TELA GM 3 = Conventional *If 2 & 3, proceed to Question B10*	a) If TELA® Bt GM, how long have you been using this technology …………………… b) Why did you adopt?	Where did you hear about TELA® Bt GM? 1 = Government 2 = ARC 3 = Seed producers 4 = Other (specify)

<table>
<tr><th>B10</th><th>B11</th><th>B12</th><th>B13</th><th>B14</th><th colspan="3">B15</th></tr>
<tr>
<td>Reasons for not adopting TELA® Bt GM
1 = don't know about it
2 = Negative GM perceptions
3 = Other (specify)</td>
<td>Area put under maize production (ha)</td>
<td>MAIN reason for maize production
1 = income generation
2 = employment
3 = home consumption
4 = other <i>(specify)</i></td>
<td>a) Do you have access to good quality seeds of maize, if you wanted to purchase it?
<table>
<tr><th>Seed variety</th><th>Y/N</th></tr>
<tr><td>1 = TELA® Bt GM</td><td></td></tr>
<tr><td>2 = Non-TELA GM</td><td></td></tr>
<tr><td>3 = Conventional</td><td></td></tr>
</table>
b) Would you be interested to know:
1 = Yes
2 = No</td>
<td>Where is the nearest source of good quality seed of maize?
<i>1. Seed producers</i>
<i>2. From a seed trader/vendor in the market</i>
<i>3. Farmer organisation (e.g. ask)</i>
<i>4. others, specify</i></td>
<td colspan="3">Name of the maize seed variety planted in the last growing season
<table>
<tr><th>Seed type</th><th>Variety</th><th>Source
<i>1=donation from seed company</i>
<i>2=purchased as seed from a farmer in the community</i>
<i>3=purchased as seed from market</i>
<i>6=given by NGO/Govt. program</i>
<i>6=other (specify).........</i></th><th>Seasons seed was planted</th><th>Rate seed quality
<i>1=Excellent; 2=Good;</i>
<i>3=Bad; 99= don't know</i></th><th>3 main reasons fo choosing the variety
<i>(choose any 3)</i>
<i>1=pest resistance</i>
<i>2=high yielding;</i>
<i>3=tolerance to d</i>
<i>4=tolerance to di</i>
<i>5=early maturity</i>
<i>6=large grain size</i>
<i>7=ot (specify)...............</i></th></tr>
<tr><td>TELA® Bt GM</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Non-TELA GM</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Conventional</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
9*= don't know</td>
</tr>
<tr><th colspan="2">B16</th><th>B17</th><th>B18</th><th>B19</th><th>B20</th><th>B21</th><th>B22</th></tr>
</table>

s

Would you recommend GM maize seeds to other farmers? 1=yes 2=no If no, what are the reasons? 1=lack of seed 2=lack of cash for seed 3=local varieties are better 4=no information or technical advice on farming practices 5=insect and disease problem 6=seeds of preferred traits not available 7=no market for crop 8=other (specify)	Cost of maize seed per/ha (Rands)	Maize output per annum (kgs) ………………………….. Maize output price per annum (Rands) ……………………….….	How many hours/day do you spend in the field? ………………………….	Do you hire labour 1 = yes 0 = no If yes, how many: 1 = part timers……. 2 = permanent ……	If yes, for what purpose and how much?	If no, how do you manage farming activities ……………………….

Activity	**Cost per season**
1 = land preparation	
2 = planting	
3 = weeding	
4 = fertilizing	
5 = watering	
6 = harvesting	
7 = other (specify)	

	Name of fertiliser	**For what purpose**	**Application/ha**	**Cost (Rands)/unit**
B.23 Do you use inorganic fertiliser? 1 = yes 0 = no				
	Name of chemical	**For what purpose**	**Application/ha**	**Cost (Rands)/unit**

B.24 Do you use chemicals 1 = yes 0 = no				

SECTION C: INSTITUTIONAL INFORMATION

C1	C2	C3	C4	C5	C6	C7	C8
Are you affiliated to any organisation or farming cooperative? *1 = yes* *0 = no*	If yes, what is/are these organisation(s)?	What services do they offer? *1 = training 2 = record keeping 3 = marketing* *4 = other (specify)*	Do you have access to extension services? *1 = yes; 0 = no* Frequency of visits *1 = daily* *2 = weekly* *3 = fortnightly* *4 = monthly* *5 = other (specify)*	If yes, what kind of services do they offer? (*You can tick more than one service if applicable*) *1 = production* *2 = marketing* *3 = training* *4 = information provision* *5 = other (specify)*	a) Have you received any agricultural credit support in the past 12 months? *1 = yes 0 = no* b) If yes, from who? **Sources:** *1 =formal financial institution* *2 = relatives 3 = money lenders* *4 = other (specify)*	If yes, what is the source? **Source** **Amount (p.a.)** *1= <R3,500* *2 = R3,500– R5,000* *3 = >R5 000*	a) What was the purpose of the credit? b) Have you managed to pay back the credit? 1 = Yes 2 = No 3 = still paying
					c) If No, what are the reasons?		
C9	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**

Access to market *1 = yes* *0 = no*	Markets accessed *1 = formal (specify)* *2 = informal (specify)*	Transport use to markets? *1 = own car* *2 = hire* *3 = taxi* *4 = other (specify)*	Distance between farm and the **INPUT** market? *1 = 0 – 5km* *2 = 5,1 – 10km* *3 = 10,1 – 15km* *4 = 15,1 – 20km* *5 = >20km*	Distance between farm and the **OUTPUT** market? *1 = 0 – 5km* *2 = 5,1 – 10km* *3 = 10,1 – 15km* *4 = 15,1 – 20km* *5 = >20km*	Who pays for transport to **Input market?** *1 = farmer 2 = marketing agency* *3 = other (specify* **Output market?** *1 = farmer 2 = marketing agency* *3 = other (specify*	What challenges do you face during marketing?	What do you think can be done to address these?

SECTION D: FARMERS KNOWLEDGE, ATTITUDES, PERCEPTION AND PRACTICES

D1	D2	D3	D4	D5	D6	D7
Farmers' Knowledge						
Have you ever heardseed the TELA® Bt maize technology? *1 = yes* *2 = no 3 = don't know* *If Yes, from who?*	Do you know the importance of TELA® Bt maize seed technology? *1 = yes* *2 = no* *3 = don't know*	Do you know about the attributes of TELA® Bt maize seed technology? *1 = yes* *2 = no* *3 = don't know*	Do you know how to control the occurrence of pests and drought? *1 = yes* *2 = no* *3 = don't know*	Do you know that the chemical pesticides used to control pests and drought are harmful to the environment? *1 = yes* *2 = no* *3 = don't know*	Do you know of any indigenous practices to control pests and drought? *1 = yes* *2 = no* *3 = don't know*	Do you know any other pests and drought control measures besides the ones you have currently adopted? *1 = yes* *2 = no* *3 = don't know*

D8	D9	D10	D11	D12
Farmers' Attitudes				
My current pests and drought control measures are effective in controlling pests and drought *1 = strongly agree* *2 = agree* *3 = not sure* *4 = disagree* *5 = strongly disagree*	I would stick with current method to control pests and drought even if I had a choice to use other control measures *1 = strongly agree* *2 = agree* *3 = not sure* *4 = disagree* *5 = strongly disagree*	Chemical pesticides are not harmful to the environment *1 = strongly agree* *2 = agree* *3 = not sure* *4 = disagree* *5 = strongly disagree*	There is not a need for me to try out other pests and drought control measures *1 = strongly agree* *2 = agree* *3 = not sure* *4 = disagree* *5 = strongly disagree*	There is no need for me to change the type of seeds I am using for TELA® Bt maize seeds *1 = strongly agree* *2 = agree* *3 = not sure* *4 = disagree* *5 = strongly disagree*

D13	D14	D15	D16	D17	D18	D19
Farmers' Perceptions						

TELA® Bt maize seed technology increases productivity and offers solution to food problems *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology can create foods with enhanced nutritional value *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology reduces pesticide residues on food products *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology has potential of reducing pesticide residues in the environment *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology has potential of reducing fertiliser use in maize production *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology has potential of reducing impacts of drought on maize production *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*	TELA® Bt maize seed technology has potential of increasing farm incomes *1 = strongly disagree* *2 = disagree* *3 = not sure* *4 = agree* *5 = strongly agree*

<table>
<tr><th>D20</th><th>D21</th><th>D22</th><th>D23</th></tr>
<tr><td colspan="4">Farmers’ Practices</td></tr>
<tr>
<td>Farming practices
<i>1 = Conventional</i>
<i>2 = Organic</i>
<i>3 = GMOs</i>
<i>4 = other (specify)</i></td>
<td>Pests and drought control measures
<i>1 = Biological controls</i>
<i>2 = Chemical controls</i>
<i>3 = Physical control</i>
<i>4 = other (specify)</i></td>
<td>Give 3 examples of the selected measures
<table>
<tr><th>Biological control</th><th>Chemical control</th><th>Physical control</th><th>Other (specified)</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>
</td>
<td>Cropping systems
<i>1 = Monoculture</i>
<i>2 = Mixed cropping</i>
<i>3 = Intercropping</i>
<i>4 = Crop rotation</i>
<i>5 = other (specify)</i></td>
</tr>
</table>

D24. Health perception

Do you agree that Consuming TELA® Bt. maize seed technology foods can **damage** one’s **health**?

Extremely disagree	**Disagree**	**Neutral**	**Agree**	**Extremely agree**
1	**2**	**3**	**4**	**5**

D25. Trust in government

Do you think the government has the best interest of maize farmers at heart by introducing TELA® Bt. maize seed technology?

Extremely disagree	**Disagree**	**Neutral**	**Agree**	**Extremely agree**
1	**2**	**3**	**4**	**5**

D26. Ethical concern

TELA® Bt. maize seed technology **makers** are **playing god**?

Extremely disagree	**Disagree**	**Neutral**	**Agree**	**Extremely agree**
1	**2**	**3**	**4**	**5**

SECTION E: TECHNICAL INFORMATION

E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**		
Do you have an irrigation system? *1 = yes* *0 = no*	If yes, what type of system? 1 = drip 2 = gravity 3 = sprinkler 4 = centre pivot 5 = other (specify)	How often do you irrigate per week? 1 = once 2 = twice 3 = thrice 4 = > thrice	What challenges do you face with your irrigation system (elaborate)	Do you have access to a machinery? 1 = yes 0 = no	If yes, please state what type? 1 = tractor 2 = harvester 3 = other (specify)	Do you hire any machinery and for what purpose? ***If other, specify***		
						Machinery	**Purpose**	**Cost**

SECTION F: FOOD SECURITY ASSESSMENT - HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS) MEASUREMENT TOOL

F1. Has the household consumed the following 12 food groups during the day or night prior to the survey?

Food groups	0 = if not consumed; 1 = if consumed		Food groups	0 = if not consumed; 1 = if consumed
A. Cereals			G. Fish and sea food	
B. Roots and tubers			H. Legumes, pulses, nuts	
C. Vegetables			I. Milk and milk products	
D. Fruits			J. Fats	
E. Meat, poultry			K. Sugar	
F. Eggs			L. Honey	

SECTION G: DISCRETE CHOICE EXPERIMENT SCENARIOS.

Scenario of TELA® Bt. maize seed technology

It is a known fact that maize is an important cash and food crop for most farmers in South Africa, as part of promoting the crop, various crop breeders from CYMMYT, WEMA (TELA), Monsato, etc. in collaboration with ARC have come up with quite a number of improved varieties with desirable characteristics like drought tolerance, disease resistance, high yield, marketable, early maturity, just to mention a few. The whole breeding programme has now being decentralised by involving farmers in participatory varietal selection so that they can come up with varieties they prefer so that breeders should base their breeding programmes on that instead of old system of imposing the varieties scientists think are good for farmers. If all farmers could access seeds produced by the above mentioned organisations collaboration (CYMMIT, WEMA (TELA) and ARC) through traders and given that money is not a problem, the researcher wants to assess the most preferred attributes farmers would willing to pay given the benefits that come with the technology.

It should be noted that the information collected here is for research purposes only, meaning we are not going to sell any seed here and you are not going to pay anything.

13. Assuming that the following TELA® Bt maize seed technology were your ONLY options, which one would you prefer to plant?

Attributes	**Choice 1**	**Choice 2**	**Choice 3**
Price (R/Kg)	41.25	22.5	52.5
Drought Tolerance (%)	10	50	20
Yield (tha^{-1}).	0.5	2.0	3.5
Pest resistance (%)	50	20	10

I would prefer to plant maize variety under **choice 1**..............**choice 2**............**choice 3**.............

(Please tick one option)

H1. Is there anything you would like to add or would like me to know? It could be about your future plans regarding maize production, marketing and processing, etc.?

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……………

THANK YOU FOR PARTICIPATING IN THIS STUDY AND KINDLY INFORMING US!