FARMERS' WILLINGNESS TO PAY FOR CLEAN SWEET POTATO (*Ipomea batatas)* SEED IN KENYA

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DECLARATION

This thesis is my original work and has not been submitted for a degree in any other university.

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This thesis has been submitted for examination with our approval as the university supervisors.

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DEDICATION

This thesis is dedicated to my family. To my parents, Mr. and Mrs. Kiminda, thank you for believing in me, for being a constant source of love, support and encouragement. To my beloved siblings, Poline Wambui and Kiruga Mwangi, thank you for your unconditional support.

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LIST OF ACRONYMS

ASAL	Arid and semi-arid lands
CIAT	International Centre for Tropical Agriculture
CIP	International Potato Center
CVM	Contingent Valuation M1ethod
DCE	Discrete choice experiment
DVM	Decentralized vine multipliers
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization statistics
FIES	Food Insecurity Experience scale
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GOLM	Generalized ordered logit model
KALRO	Kenya Agricultural and Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Service
KES	Kenya shilling
KII	Key Informant Interview
MWTP	Marginal willingness to pay
NGO	Non-Governmental Organization
PCA	Principal component analysis

RTB	Roots, tubers and bananas
SPVD	Sweet potato virus disease
SSA	Sub-Saharan Africa
SSES	Seed security experience score
USD	United States Dollars
VPC	Vegetatively propagated crops
WFP	World Food Programme
WTP	Willingness to pay

ABSTRACT

In the context of climate change, sweet potato (Ipomea batatas) production has the ability to increase ecosystem resilience and alleviate food insecurity and malnutrition. However, sustainable production of the crop is impeded by a scarcity of high-quality seed. Production of sweet potato is currently dominated by use of recycled planting materials often sourced from local social networks. To help reverse this trend, a number of organizations have been involved in the development of clean planting material. However, a sustainable seed-system has not yet been actualized largely due to limited development of clean sweet potato seed systems. In order to inform the clean sweet potato development efforts, it is important to understand whether clean seed multiplication is feasible and whether there is demand for clean seed. The objectives of this study were: 1) To characterize sweet potato seed systems in Kenya, 2) To compare the multiplication costs and willingness to pay for clean sweet potato seed among smallholder farmers in Kenya and 3) To assess the preferences for sweet potato seed attributes in Kenya. Data collection was conducted in Homa-bay County and Kirinyaga County among a sample of 383 sweet potato farmers and 30 sweet potato seed multipliers spread across five counties (Kakamega, Homabay, Bungoma, Embu, Meru) in Kenya. Characterization of seed systems was done using descriptive statistics, WTP was estimated using the contingent valuation method, while the assessment of preferences for sweet potato seed was achieved using a choice experiment approach. Results of the study revealed that access to clean seed is low (9.7%), with most farmers experiencing mild seed insecurity with a score of 4.8 out of a possible maximum score of 12. Further, the estimated mean WTP was KES 578.94, which was higher than the costs of clean seed multiplication (KES. 444.81), suggesting that the business of clean seed multiplication could be economically viable. The findings further indicate that, in general, sweet potato farmers were willing to purchase sweet potato planting material which is disease resistant, bio-fortified, and high yielding in their respective order of importance. The study therefore recommends that awareness creation on clean seed should be done, and an efficient distribution system for clean seed should be established.

CHAPTER ONE

INTRODUCTION

1.1 Background

The agricultural industry contributes significantly to Kenya's economy, accounting for over 25% of the country's total GDP and employing more than 70% of the rural population (Kenya National Bureau of Statistics (KNBS), 2020). Sweet potato (*Ipomea batatas*) contributes significantly to the agricultural sector. The crop is ranked as the fifth most economically important food crop in developing countries, after rice, wheat, maize, and cassava. Sweet potato is also the second most important tuber in Sub-Saharan Africa (SSA), after the Irish potato (International potato centre (CIP), 2018).

The utilization of sweet potato is essential nutritionally and is notably recognized for its role in combating vitamin A deficiency, which is a public health concern in many countries in SSA (Stevens *et al*., 2015). The intake of vitamin A is essential for good health as it contains antioxidants, strengthens the immune system, helps prevent blindness, and is necessary for healthy skin and bones (Huang *et al*., 2018; Low *et al*., 2017). Moreover, compared to the major food crops in SSA (maize, rice and cassava), sweet potato is a richer source of potassium and fiber (Abidin *et al*., 2015; Neela & Fanta, 2019).

In addition to its nutritional benefits, sweet potato is drought tolerant and hence can be grown in a wide range of agro-ecological conditions, including arid and semi-arid lands (ASALs). The crop can therefore address food insecurity challenges in marginal areas (Mabhaudhi *et al*., 2019). Further, sweet potato production requires little to no external inputs and has a short cropping season of three to six months compared to other crops, such as maize, which have longer cropping seasons (Naluwairo, 2011). The crop can also support the manufacturing industry as a source of raw material for the food and feed processing industry (International potato centre (CIP), 2010).

The main sweet potato producing counties in Kenya are Kakamega, Busia, Bungoma and Homabay in Western Kenya, Makueni and Kitui in Eastern Kenya and Kirinyaga in Central Kenya. Other areas include Kwale, Kilifi, Nakuru and Kericho (Makini *et al*., 2018; Mwangi *et al*., 2020). Kenya's annual sweet potato production is estimated at 856,000 tons, which is low compared to 3.5 million tons for Tanzania and 1.9 million tons for Uganda ((Food and Agricultural Organization Statistics (FAOSTAT), 2020). Globally, approximately 105 million tons of sweet potato are produced annually, with developing countries accounting for 95 percent of total production. Asia is the world's largest sweet potato producing region, accounting for 80% of global production (Wang *et al*., 2010). SSA accounts for 15 percent of the global production with Tanzania and Nigeria being the leading producers (FAOSTAT, 2020).

Despite the country having a vast ASAL area (89 percent), only 79,000 hectares of Kenya's land are under sweet potato. The relatively small planted area implies a high-untapped potential for expanding the acreage under the crop (FAOSTAT, 2020). Although the crop has a lot of potential, its production is faced with numerous challenges. Analysis of productivity trends in the country shows that annual sweet potato yields have stagnated at around 12 tons per hectare compared to a potential of 30 tons per hectare.

Sweet potato production in Kenya is hampered by an array of socio-economic, biotic and abiotic factors (Kagimbo *et al*., 2018), with low availability and access to acceptable quality planting material being the most constraining (Etten *et al*., 2017; Kagimbo *et al*., 2018; Wang *et al*., 2010). This is because most farmers (90%) in the region use low-yielding, poor quality, pest and disease-infested planting materials sourced from the previous crop or farmer-to-farmer social networks (Jepkemboi *et al*., 2016; Momanyi *et al*., 2016; Ngailo *et al*., 2016). The pre-dominance of local farmer-to-farmer sweet potato seed systems leads to further build-up of pests and diseases, leading to further yield reduction (Mcewan, 2016).

The common pests in sweet potato production include the sweet potato weevil, the sweet potato moth, aphids, erinoses' whiteflies and the root knot nematodes (Makini *et al*., 2018). Among the sweet potato diseases, viral diseases are the hardest to deal with and are a major factor limiting sustainable sweet potato production (Kagimbo *et al*., 2018; Mwiti *et al*., 2020; Wang *et al*., 2010). The most common virus is the sweet potato viral disease (SPVD), which causes yield losses of about 30% but can reach very high levels (up to 78 percent) depending on the severity of the infection (Wang *et al*., 2010). While empirical evidence shows substantial yield gains due to the use of clean planting material, availability and access to clean sweet potato seed remains problematic among farmers (Etten *et al*., 2017; Kagimbo *et al*., 2018). Like other vegetative propagated planting materials, sweet potato seed is bulky and highly perishable, complicating transportation, storage and distribution. The consequence is that for many developing countries sweet potato seed systems remain underdeveloped (Almekinders *et al*., 2019).

A functional and sustainable sweet potato seed system is necessary in order to ensure the availability and access of clean seed among farmers. In order to assess the levels of access to quality planting material, the International Centre for Tropical Agriculture (CIAT) and the Food and Agricultural Organization (FAO) have made developed a seed security assessment guideline (FAO, 2016b; Sperling, 2008). The guideline is intended to help identify particular aspects of seed security (seed availability, seed access, varietal suitability or seed quality) and geographical locations needing focussed intervention (Sperling, 2008; FAO, 2016). The application of these guidelines has however, received limited research attention, especially in the context of vegetatively propagated crops (VPCs). Consequently, there is a shortage of in-depth understanding of the existing systems for sweet potato seed, including who has access and who is constrained, the levels of access, distribution networks and seed security.

In Kenya, policy and research efforts seeking to improve access to sweet potato seed have primarily focused on breeding, improvement of varieties, quality seed selection, and increasing the scale of sweet potato seed multiplication (International potato centre (CIP), 2010; Mcewan, 2016; SPHI, 2019). These efforts have been spearheaded by state and non-state research and regulatory entities, including the Kenya Agricultural and Livestock Research Organization (KALRO), Kenya Plant Health Inspectorate Service (KEPHIS), and International Potato Centre (CIP). While seed multiplication has been scaled up in the context of supported projects, commercialization of these efforts is limited[1] (Almekinders *et al*., 2019; Mwiti *et al*., 2020). This raises concerns on whether the ongoing efforts would be sustainable without project support.

Against the uncertainty about the sustainability of the sweet potato seed system, it is critical to determine whether smallholder sweet potato farmers would be willing to meet the costs of producing clean seed at a commercial scale. Understanding farmers' willingness to pay (WTP) for clean seed is critical in advising stakeholders on how to price their seed. Equally, understanding preferences will provide insights on the important sweet potato attributes from the farmers' perspective. Moreover, understanding whether farmers' WTP could defray multiplication costs is key for the seed business's profitability and an important driver for private sector participation.

1.2 Statement of the research problem

Sweet potato is ranked as the 5th most important food in Kenya and has been recognized for its role in combating vitamin A deficiency. However, sustainable production of the crop is impeded by a scarcity of good quality seed which leads to build up of pests and diseases and low productivity (Almekinders *et al*., 2019; Momanyi *et al*., 2016; Ngailo *et al*., 2016; Wang *et al*., 2010).

The importance of a well-functioning seed system as a key driver of agricultural transformation is widely recognised in literature (Etten *et al*., 2017; McGuire & Sperling, 2016; SPHI, 2015; FAO, 2016b). As a result, guidelines for assessing vulnerability to seed insecurity among farmers have been developed (CIAT *et al*., 2010; Sperling, 2008).

[1] Key Informant Interviews indicated that most of the clean seed is purchased by NGO's and County governments and given to farmers for free

However, the application of these guidelines is limited in previous studies. The few studies that have used the seed security guidelines (Almekinders *et al*., 2019; CIAT *et al*., 2010), have mainly focused on cereals and pulses in the context of the western world, while giving limited attention to the VPCs such as sweet potato. This is despite the fact that the seed systems of VPCs could be more vulnerable than 'true' seed crops, due to their bulky nature and being highly perishable, which complicates their distribution, especially over long distances.

In Kenya, efforts seeking to expand access to sweet potato planting materials are being implemented (CIP, 2014). These efforts have largely been led by the public sector (KALRO and KEPHIS) and have mainly concentrated on breeding, variety improvement, and quality seed selection, with limited investment by the private sector, which could be a crucial component in the commercialization of new technologies. While the multiplication of clean seed within supported projects is on the rise, commercialization of the seed is limited (Almekinders *et al*., 2019; Mwiti *et al*., 2020). This leads to concerns that the ongoing multiplication efforts might not be sustainable in the absence of project support and subsidies (International Potato Centre, 2019; Mwiti *et al*., 2020). These concerns are primarily driven by the lack of understanding of whether smallholder sweet potato producers would be willing to cover the entire cost of producing clean seed at a commercial level.

Previous studies that have analyzed preferences and willingness to pay for sweet seed include Kagimbo *et al*. (2018); Mwololo *et al*. (2012); Thiele *et al*. (2009). However, these studies provide a limited understanding of how WTP compares to the costs of sweet potato seed multiplication, which is an integral element in assessing the economic viability of a seed system (Pircher & Almekinders, 2021). Moreover, these studies have not considered the important attributes that farmers consider when selecting sweet potato seed and the trade-offs they make when choosing planting materials.

This study addresses existing gaps in the literature by characterizing the sweet potato seed system and comparing the willingness to pay (WTP) for clean sweet potato seed with the costs of seed multiplication. The study also assessed the preferences for sweet potato seed attributes among farmers in the study area. The findings of this research will aid in the development of interventions to enhance the functioning of sweet potato seed systems in developing countries.

1.3 Objectives

1.3.1 General objective

The overall objective of the study is to assess farmers' willingness to pay for clean sweet potato (*Ipomea batatas*) seed in Kenya

1.3.2 Specific objectives

The specific objectives of the study are:

1. To characterize sweet potato seed systems among smallholder farmers in Kenya
2. To compare the multiplication costs and willingness to pay for clean sweet potato seed among smallholder farmers in Kenya
3. To assess the preferences for sweet potato seed attributes among smallholder farmers in Kenya

1.4 Hypotheses

The following null hypotheses were tested:

1. There are no farmer preferred characteristics for sweet potato seed in Kenya
2. The costs of sweet potato seed multiplication are lower than the farmers' WTP for clean seed
3. There are no significant preferences for sweet potato seed attributes among smallholder farmers in Kenya

1.5 Significance of the study

This study characterized sweet potato seed systems and assessed willingness to pay for clean seed among smallholder sweet potato farmers in Kenya. The study also assessed preferences for sweet potato seed attributes. First, the study contributes to the growing body of literature on sweet potato seed security and the existing seed systems. Secondly, the study has provided information on the potential viability of investing in the sweet potato seed business. This is against a backdrop of limited investment by the private sector. Thirdly, the information on preferences for sweet potato seed attributes will help policymakers, seed breeders, and potential seed business investors identify farmer-preferred varieties and attributes. Lastly, farmers of sweet potato will benefit from the study as multiplication efforts by seed breeders will be informed by farmers' preferences.

1.6 Scope of the study

This study targeted smallholder sweet potato tuber producers and sweet potato seed multipliers in Kenya. Data collection was done in two counties in the country: Homabay County in Western Kenya and Kirinyaga County in Central Kenya. The two counties were selected because they are among the country's leading sweet potato producing regions (Makini *et al.,* 2018). In addition, the two counties are located in different geographical regions, which allows for regional comparisons and testing of hypotheses on intercounty variations in sweet potato seed system characteristics (seed access, seed security, willingness to pay, and preferences for sweet potato attributes). Data was collected through household and multipliers surveys, focus group discussions, and key informant interviews.

1.7 Operational definition of terms

i) **Clean seed-** Virus-tested planting material which is free from viruses and other pathogens (Mwiti *et al*., 2020).

ii) **Seed security-** Seed security exists when farming households, both men and women, have access to adequate quantities of quality planting materials of adapted varieties at all times, following both good and bad cropping seasons (FAO, 2015).

iii) **Willingness to pay-** The maximum amount of money a person would be willing to pay in order to obtain a unit of a product or service or for a change in the quality of a good or service (Hanemann *et al*., 1991; Shogren *et al*., 2001).

1.8 Organization of the thesis

This thesis is structured into five chapters. The first chapter presents the background, statement of the problem, objectives, hypotheses, significance and scope of the study. Chapter two focuses on the theoretical and empirical review of literature. The third chapter describes the research methodology used, including theoretical and empirical models, a description of the variables, the study population, sampling frame, and data analysis. Chapter four focuses on the research results and discussions, while the final chapter (chapter five) presents the study summary, conclusions, and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature that is relevant to this study. The chapter is organized into three sections. The first section (section 2.2) focuses on the theoretical literature. Section 2.3 reviews previous empirical studies, while section 2.4 concludes with an overview of the literature and research gaps.

2.2 Theoretical literature

The theoretical literature reviewed in the study includes; approaches for measuring seed security and the theories that provide a basis for understanding the smallholder farmer's decision behavior concerning sweet potato seed. The section also reviews approaches for estimating willingness to pay (WTP) and preferences for sweet potato seed attributes.

2.2.1 Approaches for measuring seed security

Characterization of seed systems has previously focused more on the assessment of constraints facing the seed system, sourcing arrangements for seed, and preferences for sweet potato varieties (Jepkemboi *et al*., 2016; Momanyi *et al*., 2016; Mukras *et al*., 2013; Ngailo *et al*., 2016). More recently, there is recognition that a broader characterization of the seed system would include assessment of seed security (FAO, 2016b). Seed security is defined as a situation where household members, both men and women have sufficient access to adequate quantities of good quality planting material of their preferred crop varieties, at all times, following both bad and good cropping seasons (FAO, 2016b). Seed security consists of four elements: seed availability, access, quality, and varietal suitability.

Availability of seed is a critical element of seed security which involves the ability of farmers to get seed within a sensible proximity (spatial availability) and just in time to enable timely planting (temporal availability) (CIAT *et al*., 2008). Seed availability exists when there is sufficient seed from different sources which include: farmer saved seed, neighbours and other social networks, local markets, seed aid and formal seed suppliers (FAO, 2016b). Seed access, on the other hand, refers to a farmer's ability to obtain planting material in exchange for money, labor, loan, gifting, or purchase. Seed may therefore be available to farmers but they may not be able to access it, due lack of power, influence or status. Seed quality is a parameter that considers a farmers' perception of what they consider typical, normal and acceptable when it comes to planting material (FAO, 2015). Seed quality is vital because it can affect yield, productivity, and the costs associated with crop management in the field. The last element, varietal suitability, is defined as the ability of farmers to have seed of the varieties and characteristics they prefer (FAO, 2015). These characteristics may be different across households based on gender and other socioeconomic characteristics. They may include: productivity, disease resistance, pest resistance, taste, storability and marketability.

The FAO and the CIAT have developed guidelines for measurement of seed security (FAO, 2016b; Sperling, 2008). Additionally, Mucioki *et al*., (2018) developed a set of 20 questions that can be used to measure the level of household seed insecurity. These questions cover experiences of seed sourcing, varietal diversity, varietal quality, seed aid and availability of enough seed. Based on responses to the questions, farmers can be grouped into four levels of insecurity, which are least seed secure, mild seed insecure, moderate seed insecure and severely seed insecure based on the frequency of experience of seed insecurity (CIAT *et al*., 2010; Mucioki *et al*., 2018). This study applies and extends the seed systems security assessment framework developed by FAO, (2016), CIAT *et al*., (2010) and Mucioki *et al*., (2018) in the context of VPCs due to their distinct features (sweet potato vines are bulk and easily perishable).

2.2.2 Theories relevant to understanding of farmers' decisions on sweet potato seed

The study reviews the small holder farmers' decision with regard to use of sweet potato seed using the theory of a firm and the household utility maximization framework.

Theory of the firm

The theory of the firm assumes that a firm is a decision-making unit which through the production process, converts inputs into outputs with an objective of maximizing profits. The theory further assumes that the profit maximizing property is subject to technological constraints and market constraints. Technological constraints is the relationship between inputs and outputs while the market constraints are concerned with the effects actions of other players outside the firm (Jehle & Reny, 2011). Consequently, a firm's production function can be specified as;

$$y = f(X) \tag{2.1}$$

Where y is the quantity of output produced from a set of inputs, which can include inputs like labor, fertilizer and seed used in the sweet potato seed production process. The profit maximizing problem facing the firm can thus be written as:

$$\pi(p, w) = \max pf(X) - wX \tag{2.2}$$

Where p is the price of the output and w is a vector representing the prices of the inputs. The properties of the profit function are that it is increasing in p, it is decreasing in w, it is homogenous of degree one in $(p\ and\ w)$ it is convex in $(p\ and\ w)$ and it's also differentiable in $(p\ and\ w)$.

The first order condition that maximizes profit can be written as

$$p\frac{dfX^*}{X} = w \tag{2.3}$$

This means that the firm's profits are maximized when the marginal value product is equal to the cost of each production input. Equation 2.3 can be solved to yield the optimal input demand that maximize profits (as shown in equation 2.4).

$$X^* = X^*(p, w) \tag{2.4}$$

Equation 2.4 shows that the input and output prices are important arguments of the optimal input demand function. The equation can therefore be used to estimate the demand for inputs (such as labour, seed and fertilizer). However, the estimation of equation 2.4 is potentially problematic in the case of sweet potato seed given the difficulties of obtaining its market prices (due to the lack of a well-developed market for sweet potato seed). In order, to overcome this challenge, the study employed the WTP approach. WTP is used to predict responses to changes in price and in the modelling of demand functions for non-marketed goods or during new product development (Breidert *et al*., 2006). The approaches for estimating WTP are discussed in section 2.2.3.

Utility maximization and Lancaster framework

Under the utility maximization framework, it is assumed that households make production and consumption decisions with an objective of maximizing utility (Singh *et al*., 1986). This framework is used in studying the demand relationships for market place goods such as seed. Extensions of the utility maximization framework such as Lancaster, (1966), allow for analysis of preferences for individual product attributes, whereby demand for products is based on the product characteristics or attributes rather than the product itself. The approach is based on the idea that goods are made up of attributes or characteristics that result in consumer's demand for the good (Eastwood, 1991; Lancaster, 1966). The framework is useful as it allows for analysis of choices based on the attributes of a product.

The framework has been applied in the assessment of: choice for organic food products among consumers (Onyango *et al*., 2007), preferences for food safety (Loureiro & Umberger, 2007), WTP for food products that are produced locally (Darby *et al*., 2006), purchase of genetically modified food (Canavari & Nayga, 2009) and in the assessment of the importance of bean attributes among farmers (Katungi *et al*., 2011). This study applies this framework in the assessment of preferences for sweet potato seed attributes among farmers in Kenya.

Approaches for estimation of preferences are discussed further under section 2.2.4.

2.2.3 Approaches for estimation of willingness to pay

Willingness to pay (WTP) is a metric for determining the highest price at which a consumer of a product would be willing to pay for a specific quantity of that commodity (Wertenbroch & Skiera, 2002). Therefore, WTP represents the subjective value that a user assigns to a specific quantity of a good. This method entails asking individuals if they would be willing to pay a certain price for a change in the quality of a good or service

(Hanemann *et al*., 1991). Information on WTP aids businesses in estimation of demand of a given product and in the designing of optimal pricing (Li & Ellis, 2014; Wertenbroch & Skiera, 2002).

WTP for products has been assessed by researchers in different ways and can be assessed using either the stated preference or the revealed preference method (Breidert *et al*., 2006). The stated preference approach deals with elicitation of WTP under a hypothetical setting while in the revealed approach, information on actual (previous or current) purchase is used to obtain estimates of WTP (Shee *et al*., 2020). Since clean sweet potato seed is a fairly new product in the Kenyan market, market data for the good is unavailable and hence the stated preference method is preferable since it does not rely on previously revealed purchase data (Mangham *et al*., 2009). The approach involves asking respondents about their WTP a certain amount of money for a hypothetical change in the quality of seed *(*Hanemann *et al*., 1991). This study uses the contingent valuation method (CVM) which is the most frequently used method in valuing non-marketed goods and services such as sweet potato seed (Chelang'a *et al*., 2013; Hanemann *et al*., 1991; Khainga *et al*., 2018; Labarta, 2009; Lieblein *et al*., 2008). Although CVM has traditionally been used in the assessment of WTP for goods that do not have a market value e.g. ecosystem services, it's use has been extended in valuing changes in product quality for producer and consumer goods in emerging markets (Bhattarai, 2019; Chelang'a *et al*., 2013; Chia *et al*., 2020; Kikulwe & Asindu, 2020; Lusk & Hudson, 2004b). Additionally, the CVM method was selected due to its flexibility and simplified nature of the task presented to the farmers when compared to other methods such as auction mechanisms that are more expensive, time consuming and complex to organize and execute, especially where the targeted respondents have low education levels (Brebner & Sonnemans, 2018; Hoyos & Mariel, 2010; Predmore *et al*., 2021).

The CVM can either be assessed using the single-bounded CVM or the double-bounded CVM (Hanemann *et al*., 1991; Hoyos & Mariel, 2010; Lusk & Hudson, 2004a). This study employed the double-bounded CVM which was preferred over the single-bounded CVM since it gives more efficient estimates and more information about a farmer's WTP (Hanemann *et al*., 1991; Lusk & Hudson, 2004a). Under the double bounded CVM, farmers are presented with an initial bid amount and asked if they would be willing to pay that amount and then a follow up bid is given which is dependent to the response to the first bid (Cranfield, 2014; Hanemann *et al*., 1991). Respondents who answer yes to the initial bid are presented with a higher bid while respondents who answer no to the initial bid are presented with a lower bid value. Analysis of the data was done using an ordered probit model due to the ordered qualitative nature of the responses.

2.2.4 Approaches for estimation of preferences for sweet potato seed attributes

Approaches that can be used in eliciting preferences for goods that are not traded in markets are essential as they can be used to assess the demand for these goods such as sweet potato seed (Mangham *et al*., 2009). Choice experiments, have over the years, been used as one of the ways of measuring stated preferences and are used to measure the marginal value of various attributes of a good (Lancaster, 1966; Waldman *et al*., 2017). Choice experiments are based on hypothetical market situations and are thus very useful when it comes to new products and technologies (Lusk & Shogren, 2007).

A choice experiment is therefore used in order to understand the value farmers place on select attributes of sweet potato seed by presenting them with hypothetical alternatives (Mangham *et al*., 2009). Respondents were therefore expected to indicate their choice of various sets based on hypothetical alternatives. Each alternative has several characteristics (attributes) and responses/choices represent the importance of each alternative (Lusk & Hudson, 2004a). A discrete choice experiment (DCE) aims at identifying an individual's indirect utility function associated with different attributes that a product has, by looking at the trade-offs a consumer would make when making a choice (Sánchez-Toledano *et al*., 2017). The dependent variable can be dichotomous or have more than two variables. It can therefore be specified as a probit, logit or multinomial logit model (Mangham *et al*., 2009). This approach was used to assess farmer preferred attributes for sweet potato seed and to provide information on the marginal WTP for the different attributes of sweet potato planting material.

2.3 Empirical literature

This section discusses a number of studies that have been done in relation to sweet potato seed systems, willingness to pay, costs of multiplication and preferences for attributes.

2.3.1 To characterize sweet potato seed systems among smallholder farmers in Kenya

Jepkemboi *et al*. (2016), carried out a study on the factors affecting sweet potato production among smallholder farmers in Kenya. Data collection was done in Kakamega and Elgeiyo Marakwet counties among 152 small scale farmers. Results of the study indicated that most farmers sourced planting material from social networks while about a quarter of the sample sourced their seed from research institutions. According to the findings, the most significant problem in sweet potato production is the use of recycled vines, which is linked to farmers' lack of access to agricultural information, resulting in bad agronomic practices. According to the findings of the study, sweet potato productivity was also influenced by the region of production, the use of manure, sweet potato intercropping with other crops, and access to agricultural information. This study provides insights on characteristics of the seed system that were utilized in the estimation of seed security.

Ngailo *et al.* (2015), assessed the sweet potato farming systems, factors that constrained production of sweet potato among sweet potato farmers in Tanzania. Data was collected in the eastern region of Tanzania in Gaioro, Kilosa, Kilombero and Mkuranga districts. Participatory rural appraisal was done and data were collected using field observation, semi-structured interviews and FGDs. Results of the study revealed that majority of the farmers sourced sweet potato seed from their own farms (65.9%) followed by close social networks (28.7%) and that the sources differed by regions. In addition, the findings also showed that the sweet potato varieties produced differed by district. Farmers had also been asked to state their preferred sweet potato attributes. Results showed that their most preferred trait were high yields (32.7%), disease tolerance (15.1%), high dry matter content (14.0%), drought tolerance (10.3%), marketability (9.8%), maturity period (9.7%), sweet tasting (7.2%) and lastly root shape (1.1%). The study results also showed that the major challenges facing sweet potato production were pests and diseases, unreliability of the market, long periods of no rain and unattractive market prices. This study provided insights on some of the aspects that could be used to characterize sweet potato seed systems and also provided understanding on some of the attributes that could potentially be used when assessing farmer preferred preferences for sweet potato seed in Kenya.

Mucioki *et al*. (2018) assessed seed insecurity among farming households in Tharaka Nithi, Machakos and Makueni counties of Kenya. The study focused on seed security among a number of crops such as maize, pearl millet, sorghum, beans, sorghum, beans, cowpea, green-grams, watermelon pumpkin, cassava among other crops. They developed a set of 20 questions to measure chronic seed insecurity in the region based on various aspects of seed systems. Data analysis was done using the generalized ordered logit model (GOLM). Households were categorized as being either severely seed insecure, moderately seed insecure, mildly seed insecure or least seed insecure. Study results showed that a higher proportion of households faced mild chronic seed insecurity (51.1%) and moderate food insecurity (22.8%). Results of the associated older age, utilizing multiple sources of seed, obtaining seed from informal sources with higher levels of seed insecurity. This present study adapted this seed system assessment guideline developed by (Mucioki *et al*., 2018) and integrated it with the four pillars of seed security developed by FAO (2015) to develop a scale for assessing seed security for VPCs.

2.3.2 To compare the multiplication costs and willingness to pay for clean sweet potato seed among smallholder farmers in Kenya

Shee *et al*. (2020) assessed farmers' willingness to pay for improved agricultural technologies using the contingent valuation method. The study specifically assessed farmers' WTP for hybrid maize seed and inorganic fertilizer. Data were collected among

400 households in Northern Tanzania using a double bounded contingent valuation approach. Results of the study revealed that the average WTP for a 2 KG bag of hybrid maize seed and a 50 kg bag of fertilizer was 5.8 USD and 12.3 USD respectively. Notably, while the WTP for hybrid seed was above the current market price, WTP for inorganic fertilizer was below the current market price. Results further revealed that the factors that influenced WTP for seed and fertilizer were different implying that WTP for products is affected by different factors. Conclusions were therefore made that there was potential to increase adoption of hybrid maize seed and that there was need for interventions to reduce the market price for inorganic fertilizer. The current study borrows the methodological approach (the double bounded CVM) used in this study to assess farmers WTP for clean sweet potato seed.

Mwiti *et al*. (2020) assessed farmer's willingness to pay for sweet potato vines and specifically compared the difference in WTP between bio-fortified and non-bio-fortified varieties. The study evaluated WTP by use of a contingent valuation method using the open-ended approach. One of the main weaknesses of the method is that it is prone to free-riding or don't know responses by respondents as it is not incentive compatible (Carson & Hanemann, 2005). The open-ended approach involved asking farmers to indicate the amount of money they were willing to pay to obtain the vines. Data was gathered from 481 small-scale farmers spread across various regions in Tanzania. Findings of the study indicated that there was a higher WTP for non-bio fortified sweet potato varieties compared to the bio-fortified varieties. Unlike the study which uses the open-ended approach of the contingent valuation method, the current study used the closed-ended -double- bounded contingent valuation method. The open-ended approach leads to larger non-response rates, outliers and zero answers consequently leading to unreliable WTP estimates (Mitchell and Carson, 1989). The closed-ended approaches are considered superior over the open-ended approaches as they lead to more efficient estimates of WTP (Hanemann *et al*., 1991).

Haque *et al*. (2012) assessed the economic viability of maize seed production by analysing profitability of hybrid maize seed production under contract farming in Bangladesh. The main aim of the study was to compare profitability of seed production at various levels of production. Data was collected in Bangladesh among maize seed producers at three levels of production which are a public agency, a private company and a Non-Governmental Organization (NGO). The study sample was comprised of 60 and 120 maize and non-maize seed producers respectively (this consisted of farmers who only produce maize for consumption or for sale). Gross margins were used to calculate operating costs incurred in the production process. Additionally, in order to calculate profitability, gross margins, net return and benefit cost ratios were used. Results of the study indicated that costs of production were highest in the NGO compared to the public agency and the private company. In contrast though, when it comes to the level of yield, the NGO was found to have the highest level of yield compared to the other two levels. The study further compared economic profitability between hybrid seed production and hybrid maize production. Results found gross return under hybrid seed production to be forty percent higher in seed production than in maize production. The current study borrowed from the study by assessing economic viability of clean sweet potato seed production by comparing farmers' WTP with the cost of clean seed multiplication of sweet potato planting material.

2.3.3 To assess the preferences for sweet potato seed attributes among smallholder farmers in Kenya

Sánchez-Toledano *et al*. (2017) assessed farmer preference for improved corn seed in Chiapas Mexico. The study used a discrete choice experiment approach to identify the key attributes and considered them as the main determining factors when selecting improved maize varieties. This was achieved by analyzing the WTP for each attribute and analyzing observed heterogeneity. A semi-structured questionnaire was used for data collection among a sample size of 200 maize farmers in Chiapas, Mexico. The attributes assessed were price, yield, height, ear length and resistance to disease between two corn crop varieties: creole and improved. Results revealed that the corn growers were willing to pay

$2.90 more in order to gain a one percent of resistance to disease, $39.89 more per bag to get an increase in yield by one ton and $15.80 in order to get a one-centimetre increase in corn ear length. While the study was based on a different crop, it provided insights on attributes that are important in the choice of seed by farmers. The insights were useful in designing the choice experiment for assessing preferences for sweet potato seed attributes among smallholder sweet potato producers in Kenya.

Waldman *et al*. (2017) estimated farmer preferences for perennial pigeon pea in Malawi using discrete choice experiment pigeon pea. The study aimed at assessing demand for perennial attributes of pigeon pea that has been intercropped with maize. Before attributes were selected, focus groups and key informant interviews were conducted and the attributes that were finally chosen included cropping system used, soil fertility improvement, amount of biomass production, pigeon pea yield and maize yield. Ngene software was used to generate total of 40 choice sets which were blocked into 8 categories using an orthogonal experimental design. A neither option was also included so as to give farmers the option of opting out. Results of the study showed that the most important attribute among farmers was maize yield. Farmers also expressed preference for soil fertility improvement and high pigeon pea yield. Although this study is based on a different crop, it provides critical understanding on the methodologies used in designing a choice experiment which were used in the present study.

Labarta (2009) analyzed willingness to pay for vegetative propagated orange fleshed sweet potato planting material in Mozambique. Data was collected among 121 small scale sweet potato farmers. This was elicited by use of a real choice experiment by use of 10 choice sets. The real choice experiment involved asking respondents to purchase their preferred seed. The study also assessed the difference in WTP for the four major sweet potato vine varieties produced in Mozambique. A mixed logit model was used to estimate the level and determinants of WTP. The study results revealed that the most preferred sweet potato variety produced was the *Persistente* variety and was preferred because of its level of yield, taste and level of drought resistance when compared to the other varieties. The study provided useful information that was used in the design of the current study's choice experiment. This study used a larger sample size of 383 respondents so as to improve on the efficiency of the results.

2.4 Overview of literature and research gaps of the study

The theoretical literature reviewed is based on the theory of the firm and the utility maximization framework. The theory of a firm is used to model demand for inputs such as labour, seed and fertilizer. Conversely, the utility maximization framework is used in the assessment of farmer preferred attributes for sweet potato seed. These theories provide a basis for the theoretical and empirical specifications applied in the study (chapter three).

From the empirical literature surveyed, it is manifest that there is an emerging body of literature that has started to characterize sweet potato seed systems. The studies done have looked into seed sourcing, varieties of seed used and the challenges faced in sweet potato production. A key finding from the literature is that the application of the seed security assessment is limited, particularly in the context of VPCs. This study addresses this gap by extending and applying the seed security assessment framework in the assessment of sweet potato seed security.

The empirical literature further shows that, the studies done focusing on WTP for sweet potato seed are limited. Two studies have been done in sub-Saharan Africa (Tanzania and Mozambique) (Labarta, 2009; Mwiti *et al*., 2020). The current study differs from the two studies by using an alternative methodological approach of elicitation of WTP by using a close ended approach (the double bounded contingent valuation method) with is considered statistically more efficient. Consequently, the results from the study will give a more efficient estimate of the WTP value. Moreover, the existing studies are limited in terms of how WTP compares to costs of sweet potato seed multiplication. This is an integral element in assessing the economic viability of a seed. The current study addresses this gap by comparing the costs of clean seed multiplication with farmers' WTP, which is an important element when it comes to commercialization. In addition, these studies have not taken into account the important attributes that farmers consider when selecting sweet potato seed and the trade-off they make with regard to sweet potato seed attributes. This information is crucial to the private sector in informing pricing decisions and investment decisions in the sweet potato value chain.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the research methodology used to meet the objectives of the study. The chapter includes the research design (section 3.2), theoretical and framework (section 3.3), the specification of empirical models and the description and measurement of variables (sections 3.4 and 3.5). This is followed by a description of the study population, sampling techniques, data collection and data analysis approach is also presented.

3.2 Research design

The study employed a non-experimental descriptive research design to achieve the research objectives. This research design was considered suitable given the descriptive nature of the study's objectives and the need to examine relationships among variables (Kothari, 2004). Data for the study were collected using a combination of mixed approaches which involved both quantitative and qualitative methods.

3.3 Theoretical and analytical framework

The section presents the theoretical and analytical framework for assessing seed security (one of the elements used in the characterization the of sweet potato seed system), WTP and preferences for sweet potato seed.

3.3.1 Theoretical and analytical framework for analysis of sweet potato seed security

The first objective of this study was to characterize sweet potato seed systems and specifically focused on: sourcing arrangements, preferences on sweet potato varieties, levels of access to clean seed and sweet potato seed security. The characterization of sweet potato seed systems was done using descriptive statistics such as percentages, means, frequencies and standard deviation. The independent sample t-tests and Pearson chi-square tests were used to compare differences in seed system characteristics across the two study counties.

Following the review of literature, four pillars of seed security (seed availability, seed access, seed quality and varietal suitability) were adopted to develop a scale for assessment of sweet potato seed security. Seed security was measured based on a scale of 12 statements that were borrowed from Mucioki *et al*. (2018); Sperling (2008) and later modified to fit the sweet potato context following literature review, Key Informant Interviews (KII) and Focus Group Discussions (FGDs) (Table 3.1). Binary yes or no responses were expected from each sweet potato farmer (n) to the 12 statements (based on a recall period of 1 year). These responses were used to estimate a seed security experience score as shown in equation 3.1.

$$SSES_i = \sum_{j}^{k} W_j \qquad \textit{for}\ j = 1,2,\ldots,12 \text{ and } i = 1,2,\ldots,n \tag{3.1}$$

Where SSES is the seed security level for the i^{th} household and W is the response of a household to the j^{th} seed security statement. The seed security scores ranged between 0 and 12, where higher scores indicate higher levels of seed insecurity, while lower scores indicate lower levels of seed insecurity. Table 3.1 presents the statements used to measure seed security based on four pillars of seed security.

Table 3.1: Statements used to measure seed security

Category	Statement
Seed availability	1.Worry you would not save enough sweet potato planting material for the next season
	2.Unable to grow enough sweet potato due to lack of planting material
	3.Have no sweet potato planting material to plant at the onset of rains
	4.Sell all your planting material saving none for the next season
	5.Have no sweet potato planting material to plant the entire season
Seed access	6.Worry you would not have access to external sources of planting material
	7.Grow limited sweet potato varieties due to lack of resources
	8.Receive seed aid
Seed quality	9.Grow sweet potato using planting material of low quality
	10.Grow varieties that were not well adopted to the conditions of your area
Varietal suitability	11.Grow varieties that were not preferred by the household
	12.Grow new sweet potato varieties that you have not grown before

Source: Borrowed from Mucioki *et al*. (2018) and modified by the study author to fit the study

3.3.2 Analytical framework for assessing WTP and preferences for sweet potato seed

The study considers the decision behaviour of smallholder farming households; who produce sweet potato partly for consumption and partly for sale. These households provide some of the inputs used in the production of sweet potato from their own resources (such as family labour or recycled seed) or buy the inputs they don't own. Following the household utility maximization framework (reviewed in chapter two), sweet potato producing households are assumed to make production and consumption decisions to maximize utility. Utility maximization is subject to time, income and production technology constraints, based on the underlying characteristics of the seed used (Singh *et al.*, 1986). The solution of the household's utility maximization problem yields optimal demand functions for factors of production which typically would include labour, fertilizer and seed.

Well-functioning markets for clean sweet potato seed are not well developed in Kenya and therefore this study uses the WTP approach in empirical analysis of demand for sweet potato seed. In the analysis of WTP, the sweet potato farmer is assumed to face two utility maximization regimes that are associated with the use of clean seed (VC_1) and non-use of clean seed (VC_0). A sweet potato producing households' decision is therefore expected to compare the costs (w), risks (σ) and returns (π) associated with each of the regimes as shown in equation 3.2.

$$V_{C1}(\pi, w, \sigma) - V_{C0}(\pi, w, \sigma) \geq 0 \qquad (3.2)$$

Equation 3.2 indicates that sweet potato farmers will choose clean seed if the utility associated with use of clean seed V_{C1} is greater than the utility associated with not using clean seed V_{C0}. The empirical analysis of WTP followed the contingent valuation method discussed in section 3.4.1.

In assessment of preference of sweet potato seed attributes, a choice experiment approach was used. The approach assumes that utility is derived from the underlying attributes or characteristics associated with sweet potato seed. Therefore, a farmer faced with alternative planting material will select the option whose attributes yield the highest aggregate utility.

The probability that a sweet potato farmer will choose option i over the other options j, can be given as:

$$Prob\ (i \mid C) = Prob\ \{V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}\}, all\ j \epsilon C \qquad (3.3)$$

Where C is a complete choice set, V_{in} represents the value function that is associated with a household n choosing option i, V_{jn} represents the value function that is associated with a household n choosing option j and ε is the error term. The error term is assumed to be independently and identically distributed and therefore the probability of choosing i over the other options j is:

$$Prob\ (i) = \frac{\exp^{\mu v_i}}{\sum_{j \epsilon C} \exp^{\mu v_j}} \qquad (3.4)$$

Where μ is a scale parameter assumed to be 1. Discrete choice models are commonly estimated using conditional logit (CL) regression model and thus equation 3.3 was estimated using the model. The empirical specification of the choice experiment is discussed in section 3.4.3.

3.4 Specification of empirical models

3.4.1 CVM model for assessing willingness to pay for clean sweet potato seed

The study employed a double-bounded version of the CVM, which was preferred over the single bounded approach since it gives more statistically efficient estimates primarily because it yields more information about an individual's WTP compared to a single dichotomous question (Hanemann *et al*., 1991; Lusk & Hudson, 2004a). Under the double-bounded CVM, farmers were asked if they would be willing to pay an initial bid amount and then a second follow up bid (higher or lower) depending on the answer to the first bid (Cranfield, 2018). Farmers who answered yes to the initial bid were presented with a second higher bid, while farmers who answered no to the initial bid were presented with a second lower bid.

In order to inform the design of the bids, secondary data was reviewed, followed by key informant interviews among clean seed multipliers and focus group discussions among sweet potato farmers. The initial bid chosen reflected the lowest price that clean seed was going for. Following this, four bid treatments were designed as shown in Table 3.2.

Table 3.2: WTP bid treatments for a 90 kg bag of clean sweet potato seed used to elicit farmers' WTP for clean seed

Treatments	Initial bid	Higher bid	Lower bid
1	420	590	250
2	840	1010	670
3	1260	1430	1090
4	1680	1850	1510

Each of the respondents was only subjected to only one of the treatments in Table 3.2. The elicitation of WTP from the farmers was preceded by a briefing session to provide information about clean seed and the associated benefits of using clean seed. This was important in order to normalize the information presented to respondents (Cranfield, 2018; Hoyos & Mariel, 2010). The farmers were presented with this information "*Clean seed is virus tested planting material which is free from viruses and other pathogens. Use of clean seed has been shown to increase yield by approximately 40 percen*t". After presenting the definition of clean seed, the respondents were then presented with the randomly assigned bid treatments.

WTP therefore took the form of a multi-response variable that has an intrinsic order and therefore an ordered probit model was used in analysis. WTP for clean sweet potato seed can be modelled as;

$$WTP_i(z_i, u_i) = Z_i'\beta + u_i \text{ and } u_i \sim N(0, \sigma^2) \quad (3.5)$$

Where WTP_i is unobserved WTP which is a multiple response variable with an intrinsic order, Z_i' are explanatory variables (demographic characteristics, socio-economic characteristics, farm characteristics, sweet potato production characteristics) that may influence a farmers' WTP, β is a vector of parameters that shows the relationship between WTP_i and Z_i' and u_i is the error term with a mean of zero and a constant variance.

Since WTP is not directly observed, a range of WTP was identified depending on the answer given to the offered bids. Contingent to the answer to the initial bid (y_i^1), a second bid was offered (y_i^2), which was higher than the initial bid offered for a yes response and lower for a no response. Therefore, if the respondent rejected the initial bid, then the assumption was that $0 \leq WTP < y_i^1$ and if the respondent accepted the bid, it is assumed that $y_i^1 \leq WTP < \infty$.

The WTP for each sweet potato farmer would therefore fall in one of the following categories M:

M1: $y_i^1 \leq WTP_i < y_i^2$, when a farmer gave a yes response to the initial bid a no response to the second bid,

M2: $y_i^2 \leq WTP_i < \infty$, when a farmer gave yes responses to both bids,

M3: $y_i^2 \leq WTP_i < y_i^1$, when a farmer gave a no response to the initial bid and a yes response to the second bid,

M4: $0 < WTP_i < y_i^2$, when a farmer gave no responses to both bids.

Where,

$$\text{M1: } Pr = \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^1}{\sigma}\right) - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right) \quad (3.6)$$

$$M2\text{: } \Pr = \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right) \quad (3.7)$$

$$M3\text{: } Pr = \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right) - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^1}{\sigma}\right) \quad (3.8)$$

$$M4\text{: } Pr = 1 - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right) \quad (3.9)$$

A maximum likelihood function that allows for direct estimation of β and σ is given in equation 3.10.

$$lnL = \sum_{M1} ln\left(\Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^1}{\sigma}\right) - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right)\right) + \sum_{M2} ln\left(\Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right)\right) + \sum_{M3} ln\left(\Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right) - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^1}{\sigma}\right)\right) + \sum_{M4} ln\left(1 - \Phi\left(z_i' \frac{\beta}{\sigma} - \frac{y^2}{\sigma}\right)\right) \quad (3.10)$$

Where M1, M2, M3, M4 take the value of zero or one depending on the responses given by a farmer to the bids presented to them. As a result, each of the farmers only contributed to one of the four parts of the equation. Φ represents the standard normal cumulative distribution function. The *doubleb* command in Stata, created by (Lopez-Feldman, 2012), allows for direct estimation of $\hat{\beta}$ and $\hat{\sigma}$ using maximum likelihood.

From equation 3.10, the empirical mean WTP then be estimated as:

$$Mean\,WTP = -\frac{\bar{Z}\hat{\beta}}{\hat{\beta}_{bid}} \quad (3.11)$$

Where $\bar{Z}$ includes sample means of household demographic characteristics, farm, and institutional characteristics, seed sourcing arrangements and sweet potato production systems, $\hat{\beta}$ is a vector of estimated coefficients and $\hat{\beta}_{bid}$ is the coefficient on the bid t_i.

3.4.2 Estimation of costs of clean sweet potato seed multiplication

Economic viability of clean sweet multiplication was achieved by comparing farmers' willingness to pay for clean seed with the costs incurred during sweet potato multiplication. Sweet potato seed multiplication is done at three levels which are: pre-basic seed, basic seed and quality declared seed. Pre-basic seed is first generation seed produced in research stations, basic seed is produced by large scale and medium commercial vine producers while quality declared seed is produced at a smaller scale level by decentralised vine multipliers (DVMs) (CIP, 2018). This study specifically focused on quality declared seed, which is the third and last stage of multiplication before seed is sold to sweet potato root producers, in the calculation of costs. All the production costs incurred were used to compute the total costs incurred in multiplication. The total production costs were computed as a sum of all variable costs and fixed costs incurred in clean seed multiplication.

$$\text{TC} = \sum_i TFC + \sum_i \text{TVC} \quad (3.12)$$

Where TC is the total cost of seed multiplication, TFC are the total fixed costs, and TVC are the total variable costs incurred in seed multiplication.

The TVC included expenditures on purchase of basic seed, fertilizer, chemicals used (pesticides and foliar), packaging/ gunny bags, irrigation water, irrigation fuel and interest incurred on operating capital. Labour costs were computed as an aggregate of hired labour and unpaid household labour. Household labour was valued by estimating the cost that would have been incurred if hired labour would have been used (FAO, 2016a; E Katungi *et al*., 2011). The fixed cost that was taken into account in this study was the cost of land. In order to value the cost of land, the opportunity cost of land was used (FAO, 2016a). The opportunity cost of land was valued as the foregone revenue to the farmer had the land been used in the production of the second best alternative which in this study was assumed to be maize, which is produced by most households in the two study counties (FAO, 2016a). The costs of transportation and marketing of vines were not integrated in the analysis because sale of sweet potato seed is currently being done at the farm gate level. In addition, managerial costs and other less tangible costs were not included as they were hard to value and quantify because farmers practice mixed farming and manage the farms themselves hence apportioning such costs to a specific enterprise is difficult (E Katungi *et al*., 2011; Taru *et al*., 2010). Costs of certification of seed are paid by the basic seed producers and therefore multipliers of quality declared seed do not normally directly incur this cost. Costs of production were collected per acre and this cost was later divided by the average number of 90 KG bags produced per acre in order to obtain the per unit costs of producing one (90 KG) bag of clean seed.

3.4.3 Empirical specification of choice experiment for assessing preferences for sweet potato seed attributes

The first step in the design of the choice experiment involved selection of desirable characteristics or attributes, namely; disease resistance, bio-fortification, yield, maturity period and the price of seed. The attributes and their level were identified following an in-depth literature review, key informant interviews and focus group discussions. Table 3.3 shows the attributes applied in the CE and their respective levels.

Table 3.3: Product attributes and levels used in the choice experiment

Attribute	Description	Levels
Disease resistance	One of the primary issues facing sweet potato production is disease attack (particularly the sweet potato virus disease) (Kagimbo *et al*., 2018). Disease attack leads to average yield losses of about 40 percent. Use of clean seed acts as a solution to this problem because it is free from viruses and other pathogens (Mwiti *et al*., 2020).	Resistant Not resistant
Bio-fortification	Bio-fortification is the process of increasing the nutritional value of crops through conventional plant breeding practices. Bio-fortified sweet potato is enriched with beta-carotene a pre-cursor of vitamin A and hence it's consumption helps address vitamin A deficiency (Low *et al*., 2017). The colour of the flesh of the sweet potato indicates bio- fortification or the lack there of. The darker the orange colour in the flesh, the higher the amounts of beta carotene.	Bio-fortified Not bio-fortified
Yield (90kg bags per acre)	Yield is the amount of sweet potato tubers that farmers harvest per unit of land, in this case 90 kg bags per acre. Focus group discussions revealed that yield ranges from 10 bags to 20 bags, with farmers using clean seed having an average yield of 25 bags.	10 bags 15 bags 20 bags 25 bags
Maturity period	Maturity period is the total time taken from planting to when the sweet potato can be harvested for sale or consumption. The attribute is included since sweet potato varieties have difference in maturity period, with some farmers preferring faster maturing varieties.	3 months 4 months 5 months 6 months
Price (90 kg bag)	Price reflects the amount of money that farmers pay for a 90 KG bag of seed. Results from focus group discussions revealed that the price of seed acquired through farmer-to-farmer exchange ranges from KES 250 to KES 1000 depending on the availability of seed. In addition to this, results from KII indicated that the price of clean seed goes at a maximum of KES 1700 for a 90 KG bag.	KES. 250 KES. 750 KES. 1250 KES. 1700

In order to generate the choice sets, a bayesian efficient design which was generated using the Ngene software was used (ChoiceMetrics, 2018). The software generated two blocks, each consisting of eight choice sets resulting in a total of 16 choice sets. A block design was used to help reduce fatigue effects that may have occurred if all 16 choice sets were completed by one farmer (Savage & Waldman, 2008).

A pre-test was conducted among 20 sweet potato farmers and this was used to estimate a more efficient design that minimised the error in the final design. In the final survey, each of the farmers was presented with eight choice sets consisting of different attribute bundles. Each of the choice sets consisted of two alternatives and a no choice option. The no-choice option provided farmers an option of opting out when none of the options provided was pleasing to them. In addition, during administration of the choice sets, a randomised order was used to prevent ordering effects which occur if a logical order is used (Loureiro & Umberger, 2007). A sample of the choice sets used is presented in Figure 3.1.

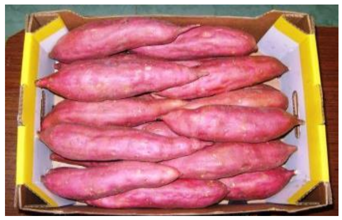
	Option 1	Option 2	Option 3
Disease resistance			**No choice**
Maturity (Months)	 **3 months**	 **6 months**	
Bio-Fortification			
Yield	 **5 bags**	 **25 bags**	
Price per bag of vines	**KES. 1250**	**KES. 750**	

Figure 3.1: Sample choice card

The utility for each sweet potato farmer n, from each of the alternative j, within a choice set t is given by:

$$U_{njt} = \beta_n w_{njt} + \varepsilon_{njt} \tag{3.13}$$

Where w_{njt} are the observed variables that are associated with a sweet potato farmer n and alternative j for choice scenario t, β_n is a vector of coefficients of different sweet potato seed attributes for a sweet potato farmer n and ε_{njt} is a stochastic error term which captures all other unobservable factors having an impact on decision making. For each of the choice sets provided, a sweet potato farmer was therefore expected to choose the alternative that they associated with the highest level of utility.

The study estimates farmer's utility for disease resistance, bio-fortification, yield, price and maturity period. Expanding equation 3.12 to include the attributes in the study, results in:

$$U_{njt} = \beta_1 disease\_res_{njt} + \beta_2 bio\_fortification_{njt} + \beta_3 yield_{njt} + \beta_4 maturity_{njt} + \beta_5 price_{njt} + \beta_6 none_{njt} + \varepsilon_{njt} \quad (3.14)$$

Where $disease\_res$ represents the dummy variable equal to one if the seed is disease resistant and zero if otherwise; $bio\_fortification$ represents the bio-fortification dummy variable which was equal to one if the alternative is bio-fortified and zero if otherwise, $yield$ represents the variable yield which is treated as a continuous variable, $maturity$ represents the continuous variable maturity period and $price$ is the continuous variable for the price attribute. $none$ is a dummy variable equal to one when a farmer selected the option 'no choice'.

Since U_{njt} is not directly observable, it is assumed that a farmer n will only choose option j if and only if the utility derived from j is greater than the utility derived from other alternatives. A representative utility, i.e. the observable part of utility, can be constructed under the assumption that the representative utility is linear in the observed sweet potato attributes of an alternative (equation 3.14).

$$w_{nj} = x'_{nj}\beta \quad (3.15)$$

This study uses the conditional logit (CL) model for estimation which uses the alternatives of the choice sets as the unit of analysis (Hoffman & Duncan, 1988).

The probability that a farmer n chooses alternative j for the CL is specified as:

$$P_{nj} = \frac{\exp(x_{nj}\beta)}{\sum_{k=1}^{j} \exp(x_{nk}\beta)} \quad (3.16)$$

Where P_{nj} is the probability of farmer n choosing alternative j, x_{nj} are the characteristics of alternative j for farmer n, and β represents the vector of parameter for attribute characteristics.

In order to calculate the marginal willingness to pay (MWTP) for each of the sweet potato attributes, the function that was estimated is:

$$MWTP = -1^{*}\left(\frac{\beta_i}{\beta_{price}}\right) \quad (3.17)$$

3.5 Description of variables and their measurement

Table 3.4 presents the description of variables obtained from the sweet potato farmers survey.

Table 3.4: Description of variables obtained from the sweet potato farmers survey

Variable	Variable description and unit of measurement for the variables
Socio-economic variables	
Gender	Sex of the household head (1= Male 0= Otherwise)
Age	Age of the household head, measured in number of years
Household size	Number of people in the household
Children <5 years	Number of children less than 5 years in a household
Education level	This is the level of education attained by the household head
Yearly income	Yearly income from all income sources in the household in Kenya shillings (KES)
Livestock diversity	Number of livestock types kept by a household
Crop diversity	Number of crop types cultivated by a household
Farm size	Area of owned land in hectares
Wealth category	Measure of a household's cumulative living standard (Poorest, Middle, Wealthiest). This study used the World Food Programme's procedure on calculation of a wealth index which was arrived at after data reduction using Principal Component Analysis (PCA). Households were then categorized into three groups. The wealthiest households were those with a wealth index above the mean value plus standard deviation, middle category were those with a wealth index within the range of mean and standard deviation, while the poorest were those with a wealth index below the mean and standard deviation.
Sweet potato production systems	
Plot size	Size of land devoted to sweet potato production in hectares
Sweet potato income	Aggregate annual income from sweet potato production in KES
Seed sourcing arrangements	
Awareness on clean seed	Awareness on clean seed 1=aware 0=otherwise
Use clean seed	Refers to whether a household uses clean seed 1=Uses 0=otherwise
Institutional arrangements	
Group membership	Membership to a farmers group (1=belongs to a farmers group, 0=otherwise)
Extension access	Access to extension 1=access to extension 0=otherwise
Credit access	Access to credit by a farmer (1=has access, 0 =otherwise)
Distance to market	Distance from the homestead to the market measured in kilometres

Distance to all weather road	Distance from the homestead to the nearest all weather road measured in kilometres
WTP variables	
Bid one	Initial bid amount in KES
Bid two	Second follow up bid in KES
Answer 1	Answer to the first WTP question (1=Yes 0=No)
Answer 2	Answer to the second WTP question (1=Yes 0=No)

3.6 Study areas

This section presents the study areas for the sweet potato farmers survey and sweet potato seed multipliers survey.

3.6.1 Study area description of farmers survey

The sweet potato farmers survey was conducted in Homabay County and Kirinyaga county (Figure 3.2).

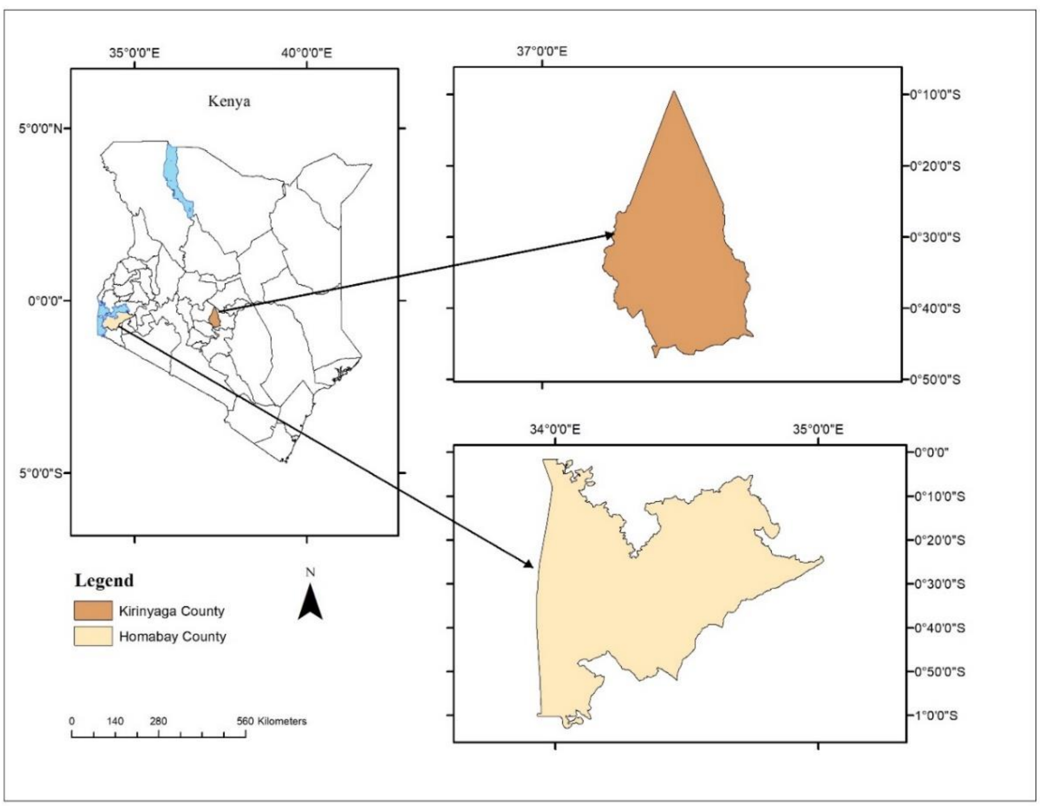


Figure 3.2: A map showing the study counties for the household survey

The two counties were selected for a number of reasons. First, they are among the leading sweet potato producers in the country (Makini *et al*., 2018) hence providing a good base understanding of sweet potato seed systems in Kenya. Moreover, the two counties have key differences in their agro-ecological conditions, as they are located in different agro-ecological zones. The upland plateau (1219m above sea level) and the lakeshore lowlands are the two main agro-ecological zones in Homabay County (1163m- 1219m above sea level) (Republic of Kenya, 2017b). Kirinyaga County, on the other hand, is divided into three ecological zones: lowland areas (1158-2000 meters above sea level), midland areas (2000-3400 meters above sea level), and highland areas (above 3400 meters) (3400- 5380 metres above sea level) (Republic of Kenya, 2017a). In Homabay County, the study targeted Karachuonyo and Kabondo sub-Counties, and in Kirinyaga County, the study targeted Mwea West and Mwea East sub-Counties which are the main sweet potato producing sub-Counties in the selected Counties.

3.6.2 Study area description of multipliers survey

The multipliers survey was done across five Counties in Kenya which included; Kakamega, Homabay, Bungoma, Embu and Meru (Figure 3.3). The counties were chosen because seed multiplication had begun in these areas.

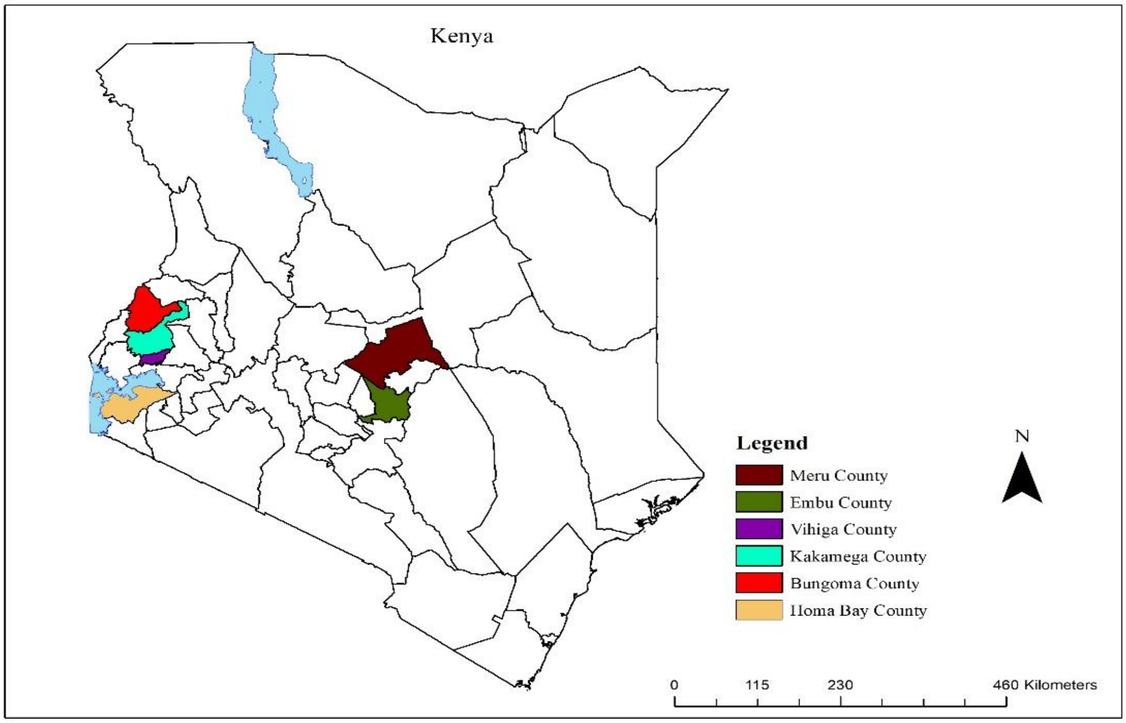


Figure 3.3: A map showing study counties for the multipliers survey

3.7 Sampling procedure

3.7.1 Sampling frame

The study's sampling frame was a list of sweet potato-producing households provided by local area agricultural officers. The sampling frame also consisted of a list of sweet potato seed multipliers which was generated from projects promoting sweet potato seed multiplication and referrals from other multipliers.

3.7.2 Sample size determination

In order to have a representative sample size (n) of sweet potato farmers, the Cochran 1977 method was used.

$$n = \frac{Z^2}{d^2} pq \qquad (3.18)$$

Where n is the sample size, Z is the normal curve distribution (1.96) which corresponds to 95% confidence level, p is the proportion of sweet potato farmers which is normally given as 0.5 when the exact proportion of farmers is not known, q is the proportion of farmers who do not produce sweet potato that is (1-p) and d is the margin error which is set at 95% thus given as 0.05.

Therefore,

$$n = \frac{1.96^2}{0.05^2}\ 0.5\ 0.5 \quad (3.19)$$

$n = 384$

The target sample size was therefore 384 farmers. One questionnaire was rejected during data cleaning due to incomplete information resulting in a sample size of 383 sweet potato farmers.

The target sample size of sweet potato multipliers consisted of 30 multipliers, which was more than 90 percent of the whole population of sweet potato seed multipliers in the country, and also sufficient enough to allow statistical analysis in line with the central limit theorem (Mugenda & Mugenda, 2003). From the snowballing sampling approach used, the spread of the multipliers was: 9 in Kakamega, 7 in Bungoma, 4 in Vihiga, 6 in Homa Bay, 2 in Meru and 2 in Embu.

3.7.3 Sampling technique

The sampling technique for the household survey was done through a number of steps. First, Kirinyaga and Homabay counties were purposively selected because they are among Kenya's leading sweet potato producing counties. The next steps involved a multi-stage approach. Two sub-counties were chosen in each of the study counties (based on concentration of sweet potato farmers). This was followed by selection of two wards in each of the selected sub-counties. Local area agricultural officers aided in the generation of lists of sweet potato producing households. The final step involved random selection of households, from the list of sweet potato producing households, to interview, proportionate to the population of sweet potato farmers in each ward.

The multipliers sampling technique followed a snowballing approach. This was achieved through an initial list of sweet potato multipliers who referred us to other multipliers who then referred us to other multipliers creating a chain of multipliers across the country.

3.8 Data collection

Data collection was done through farmer surveys, focus group discussions (FGDs) and Key informant interviews (KIIs). Five FGDs were held among sweet potato farmers in Kirinyaga and Homabay counties. These FGDs were key in understanding the nature of sweet potato production, sources of sweet potato seed, important attributes in selection of sweet potato seed, preferred varieties and challenges faced in sweet potato production. 10 KIIs were on the other hand held among sweet potato seed breeders and basic seed producers. The goal of the KIIs was to learn more about the nature of sweet potato seed multiplication in Kenya, the buyers of clean seed and pricing of clean seed.

3.9 Data analysis

Data collection was followed by data entry and data cleaning. Data was checked so as to ensure that there were no inconsistencies, no missing values and observations and no errors. This was achieved through the computation of percentages, means and standard deviation, minimum and maximum values. These statistics gave information in case of any deviations from the priori.

For the first objective which is to characterize sweet potato seed systems in Kirinyaga and Homabay counties, descriptive statistics were run. Characterization was done around seed sourcing arrangements, access to clean seed and seed security. The next objective involved assessment of WTP for clean sweet potato seed, whereby a CVM was used. An ordered probit model was run in order to estimate the mean willingness to pay which was done by running a *doubleb* command in STATA. The final objective sought to assess preference for attributes on sweet potato using a choice experiment approach and was analysed using a conditional logit model. Diagnostic tests such as correlation analysis, wald tests and log likelihood were also performed on the data.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results, discussions and findings of the study. The chapter includes a presentation of the descriptive statistics (section 4.2) on the data and the empirical results and their discussions based on the study objectives (section 4.3-4.5).

4.2 Descriptive statistics of household characteristics

To describe the basic features of the data, descriptive statistics based on measures of central tendency (mean), dispersion and frequencies were employed. The analysis also included statistical tests to account for heterogeneities across the study counties. Results are presented in Table 4.1 for continuous variables, Table 4.2 for discrete variables and Table 4.3 for sweet potato multipliers.

Table 4.1: Descriptive statistics for continuous variables of household characteristics

Variable	Total sample n=383		Homabay (0) n=201		Kirinyaga (1) n=182		Difference (1-0)	P
	Mean	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**		
Demographics								
Age	48.6	12.2	47.9	12.4	49.2	11.9	1.3	0.32
Household size	5.2	2.5	6.3	2.6	3.9	1.6	-2.4***	0.00
Children <5yrs	1.5	0.2	2.6	1.8	1.1	1.1	-1.5***	0.00
Farm characteristics								
Land size (ha)	1.0	1.7	1.1	2.1	0.9	0.9	-0.2	0.20
Sweet potato land size per season (ha)	0.2	0.2	0.3	0.3	0.2	0.2	-0.1***	0.00
Years in sweet potato production	10	8.9	11.8	8.6	8.1	8.6	-3.7***	0.00
Institutional factors (market access)								
Market distance-km	2.5	2.3	1.5	1.6	3.7	2.3	2.2***	0.00
Tarmac distance-km	0.9	0.8	0.9	0.8	1.0	0.9	0.1	0.35
Socio-economic factors								
Annual income(KES)	198079	194222	143510	167944	258345	205092	114834.9***	0.00
Per capita income (KES)	51140	63750	27139	36326	77646	75979	50507***	0.00
Food security	2.8	2.9	4.5	2.7	0.9	1.7	-3.6***	0.00

n= number of observations; S.D=standard deviation; *, **, *** denote level of statistical significance at 10% level, 5% level and 1% level respectively; I US$=100KES. Independent sample t-test was used to compare the differences in characteristics between Homabay and Kirinyaga counties

The study considered various demographic variables including age of the household head, size of the households and number of children. Age of the household head is vital in agricultural production given its linkage with the level of farming experience, knowledge, formation of attitudes and risk aversion in uptake of agricultural technologies (Mwangi & Kariuki, 2015). Findings in Table 4.1 show that the mean age of the household head was

48 years indicating that the sweet potato farmers are generally aged, which is consistent with a preference by younger people to migrate to urban areas in search of off farm opportunities that are relatively considered more lucrative (Ayinde *et al*., 2014). While the advanced age of farmers may be an indication of respondents having more experience in farming, it can also suggest higher levels of risk averseness in uptake of clean sweet potato production technologies (Berkowsky *et al*., 2018). The average number of years farmers had practiced sweet potato production was 10 years, suggesting that the surveyed households were relatively experienced in sweet potato production.

Table 4.1 shows that the average size of the household was 5.2 members with a standard deviation of 2.9 of whom 1.5 were children below 14 years. County comparisons show that the households in Homabay had more members (6.3) compared to their counterparts in Kirinyaga County (3.9). The average household size of sweet potato farmers is slightly higher than the Kenyan average of 3.9 per household based on 2019 census (KNBS, 2018). The size of a household has an impact on agricultural production since it affects labor availability, household per capita income, expenditure, and food consumption decisions. As observed by Mignouna *et al*. (2011), larger households tend to have a higher capacity to supply labour especially during the performance of labour intensive activities. In the study, the size of the household is therefore considered important in influencing decisions on sweet potato production, uptake of clean seed and other technologies and the ability or willingness to pay for improved sweet potato seed.

Results of the study further show that farms in the study area are relatively small (1.0 ha), which can be attributed to increased land subdivision in Kenya, especially in the high potential areas (Museleku *et al*., 2018). Results further show that the proportion of land allocated to sweet potato production per season was 33 percent of the total land area. Farmers desire to commercialize the sweet potato enterprise was frequently mentioned during FGDs and KII indicating the rising significance of the crop in the farming systems of households in the study area.

Access to markets was measured using distance to the market and distance to an all-weather road. Access to markets is important among agricultural households, particularly with regard to accessing farm inputs and marketing of farm produce. Longer distances to the market increase transaction costs and hinder access to market information (Ahmed *et al*., 2016). Results of the study (Table 4.1) indicate that the average distance to the nearest market was 2.5 kilometres while that to the nearest all weather road was slightly less than a kilometre. The relatively short distances would be attributed to increased improvement in infrastructure by the Kenyan government over the last two decades (KNBS, 2018).

The socio-economic variables considered in the study were household income, per-capita income, wealth index and household food security. Households' per capita income was calculated by dividing a household's yearly income by the total number of household members. Results show that most households lived on less than the global poverty line of KES 69,350 per year (KES 190 per day) (World bank, 2020). This means that most sweet potato producing households are relatively poor which has implications on resource allocation to agricultural activities and willingness to pay for clean seed. Comparisons between the two counties show that households in Homabay County had significantly lower per capita income than Kirinyaga County. This result is consistent with KNBS, (2018) report showing that Homabay County households have higher proportions of overall poverty (33.5%) compared to Kirinyaga County (20.0%).

Food security was measured using FAO's food insecurity experience scale (FIES) that consists of eight statements requiring a yes or no response (FAO, 2019). A total food insecurity experience score was obtained per household with households at score zero (0) being the most food secure and those at score eight (8) being the most food insecure. Food security was included because of its potential links with critical elements of household sweet potato seed security (i.e. availability, access, quality, suitability/preferences and stability) (FAO, 2015). Seed security is additionally considered as a prerequisite for food security. The FIES mean value revealed that food insecurity was significantly higher in Homabay County than in Kirinyaga County. While sweet potato has been promoted as a food security crop, feedback from FGDs in the two counties revealed that the primary reason why many households engage in the production of sweet potato was for sale of roots and not for consumption.

Table 4.2: Descriptive statistics for categorical variables of household characteristics

Variable		Total sample (n=383)		Homabay (0) (n=201)		Kirinyaga (1) (n=182)		Difference (1-0)	P
	Measurement	**n**	**%**	**n**	**%**	**N**	**%**		
Demographic factors									
Gender	Female	67	17.5	43	21.4	24	13.2	-8.2	0.42
	Male	316	82.5	158	78.6	158	86.8	8.2	0.42
Decision maker	Female head	155	40.5	97	48.3	58	31.9	-16.4***	0.00
	Male head	116	30.3	63	31.3	53	29.1	-2.2	0.22
	Joint	105	27.4	39	19.4	66	36.3	16.9***	0.00
	Farm manager	2	0.5	0	0.0	2	1.1	1.1	0.13
	Child	5	1.3	2	1.0	3	1.7	0.7	0.57
Education level	Semi-illiterate	22	5.7	17	8.5	5	2.7	-5.8	0.58
	Primary	193	50.4	117	58.2	76	41.8	-16.4	0.11
	Vocational	24	6.3	10	4.9	14	7.7	2.8	0.79
	Secondary	90	23.5	37	18.4	53	29.1	10.7	0.29
	Tertiary	54	14.1	20	9.9	34	18.7	8.78	0.39
Marital status	Married	304	79.4	156	77.6	148	81.3	3.7***	0.01
	Not married	79	20.6	45	22.4	34	18.7	-3.7***	0.01
Institutional factors									
Farmers group	Yes	171	44.7	99	49.3	72	39.6	-9.69	0.34
	No	212	55.4	102	50.8	110	60.4	9.69	0.34
Credit access	Yes	137	35.8	102	50.8	35	19.2	-31.6***	0.00
	No	246	64.2	99	49.3	147	80.7	31.6***	0.00
Extension access	Yes	232	60.6	132	65.7	100	54.9	-10.72	0.29
	No	151	39.4	69	34.3	82	45.1	10.72	0.29
Socio-economic factors									
Wealth index	Poor	67	17.5	43	21.4	24	13.2	-8.2	0.42
	Middle	248	64.8	132	65.7	116	63.7	-1.9	0.85
	Wealthy	68	17.8	26	12.9	42	23.1	10.1	0.32

n= number of observations; *, **, *** denote level of statistical significance at 10% level, 5% level and 1% level respectively. Pearson chi-square test was used to determine relationship between categorical variables and sweet potato farmers in Kirinyaga and Homabay counties

Gender of the household head is considered as one of the essential elements in informing decision making and resource allocation such as land and labour in the households (Kang *et al.*, 2020; Mignouna *et al*., 2011). Results of this study show that while most household heads were male (82%), there were proportionately more women involved in decision making on sweet potato production (40.47%). Previous studies have shown a consistent pattern where women tend to be the main decision makers for orphan crops such as sweet potato, while men tend to get more involved in higher value or profitable enterprises (Jepkemboi *et al*., 2016)

Results in Table 4.2 show that more than half of the household heads in sweet potato producing households had primary level of education or lower. The education level of a farmer affects his or her ability to obtain, process, interpret, think critically and make use of information (Mwangi & Kariuki, 2015; Oino & Mugure, 2013). Moreover, higher education levels have been linked to enhancement in access and utilization of agricultural information (M. Mwangi & Kariuki, 2015). The relatively low level of education among sweet potato farmers would have an effect on uptake of clean seed, willingness to pay and decision-making (Chandio *et al*., 2018; Hananu *et al*., 2015; Ayedun *et al*., 2017; Chelang'a *et al*., 2013).. Results on marital status show that more than three quarters of the respondents were married and only 20% of them were not married (single, divorced, separated or widowed).

Access to extension services, membership to a farmers group and access to credit were the institutional factors considered in the study. Extension acts as a gateway between innovators/ researchers and farmers in the creation of awareness and knowledge (Genius *et al*., 2014; Ntshangase *et al*., 2018). Access to extension agents is therefore important in influencing adoption of clean seed. Results indicate that more than half of sweet potato farmers had access to extension services. Findings further showed that 44.65 percent of the respondents were a member of a group. This included all forms of groups including those engaged in non-agricultural activities. Group membership increases social capital, acting as a means through which farmers acquire (from members of the group and outside) and share knowledge on agricultural practices and thus crucial in decision making on uptake of clean seed and on choice of preferred attributes (Desiana & Aprianingsih, 2017; Mignouna *et al*., 2011). Access to credit means that the liquidity constraint among farmers is relaxed and thus they can be able to increase their investments in agricultural technologies and purchase inputs such as seed (Simtowe *et al*., 2019). Most sweet potato farmers in this study did not have access to loans and this may have implications on their WTP for clean seed.

Wealth index is used as a composite measure of a household's cumulative living standard and incorporates productive assets, non-productive assets and household utilities (World Food Program (WFP), 2017). Results of the wealth index show that a majority of the sweet potato farmers are in the middle-income category (64.75%) as shown in Table 4.2. Wealth level has an influence on access to resources and the ability to access credit hence may potentially affect WTP (Gichuki *et al*., 2020).

In order to describe the characteristics of multipliers, the study considered gender, education level, age of the owner of the multiplication business and land size devoted to sweet potato multiplication. The results are presented in Table 4.3.

Table 4.3: Descriptive statistics of sweet potato multipliers in Kenya

Categorical variables		**Percentage**
Gender of owner	Male	46.15
	Female	53.85
Education level	Primary	19.23
	Secondary	42.31
	Tertiary	38.46
Continuous variables	**Mean**	**Std. dev**
Age	45.34	9.66
Household size	6.72	3.09
Land size under multiplication (acre)	1.23	1.29
Years under multiplication	2.76	1.46

The findings show that slightly over half (53.9%) of the multipliers were women implying that women are more involved in the multiplication business. Results further show that a higher proportion of multipliers (80.8%) had attained secondary school level of education or higher. The mean age of the multipliers was 45 years of age, with the average number of years of involvement in multiplication business being 2.7 years. This indicates that sweet potato seed multiplication business is still nascent in Kenya. Further, the results show that the multipliers devoted about one acre of land to sweet potato multiplication.

4.3 Characterization of sweet potato seed systems among small holder farmers

One of the objectives of this study was to characterize the sweet potato seed systems among smallholder farmers in the study area. In order to achieve the objective, the study focused on four dimensions, namely; 1) the sourcing arrangements for sweet potato seed 2) farmer preferences for sweet potato varieties 3) access to sweet potato seed among small holder farmers and 4) assessment of sweet potato seed security. The results are presented and discussed in section 4.2.1 to section 4.2.3.

4.3.1 Sourcing arrangements and preferences for sweet potato varieties

This section shows the various seed sourcing arrangements utilized by sweet potato producing households. Since sweet potato is vegetatively propagated, the crop has unique characteristics which would make the sourcing arrangements different from ‘true’ seed crops. The analysis of sweet potato sourcing focused on sources of seed, the means through which seed is acquired and transported and common sweet potato varieties. These aspects are expected to play a key role in influencing farmers decision on willingness to pay for clean seed. The results on sweet potato sourcing arrangements are presented in Table 4.4.

Table 4.4: Sweet potato seed sourcing arrangements

Variable	Total sample (%)	Homabay (%)	Kirinyaga (%)
Source of seed			
Home-saved	34.5	27.2	44.0
Friends/ neighbours	59.7	66.8	50.5
Relatives	1.2	0.0	2.7
Local market	0.5	0.4	0.5
Community based seed	0.7	0.9	0.5
NGO	0.5	0.4	0.2
Local multiplier	2.2	3.4	0.5
Contract growers	0.5	0.9	0.0
Other	0.2	0.0	0.5
Total	100%	100%	100%
Means of acquisition			
Saved	37.2	26.4	51.1
Exchange/barter	1.4	0.4	2.7
Freely given	49.2	63.8	30.2
Purchase	10.3	6.4	15.4
Seed loan	1.7	3.0	0.0
Seed for labour	0.2	0.0	0.5
Total	100%	100%	100%
Mode of transport of seed to farm			
Walking	71.1	71.4	70.7
Bicycle	1.0	0.9	1.1
Wheelbarrow	0.5	0.4	0.5
Motorcycle	17.7	15.0	21.2
Vehicle	1.4	1.3	1.6
Donkey	8.4	11.1	4.9
Total	100%	100%	100%

Total sample n=383, Homabay n=201, Kirinyaga n=182

Findings in Table 4.4 show that the two main sources of seed are friends/neighbours and home saved seed which accounted for about 90% of seed used by farmers. These results are consistent with previous studies showing that previous crop and close social networks are the main sources of sweet potato seed (Jepkemboi *et al*., 2016; Ngailo *et al*., 2016). The implication is that there has been no major changes in sourcing arrangements despite the efforts made by government agencies and research institutions such as KEPHIS, KALRO and CIP to multiply clean seed, access to clean seed still remains a challenge among smallholder sweet potato farmers. Consequently, build-up of pests and diseases has persisted in being a major challenge in sweet potato production in the study areas (Figure 4.1).

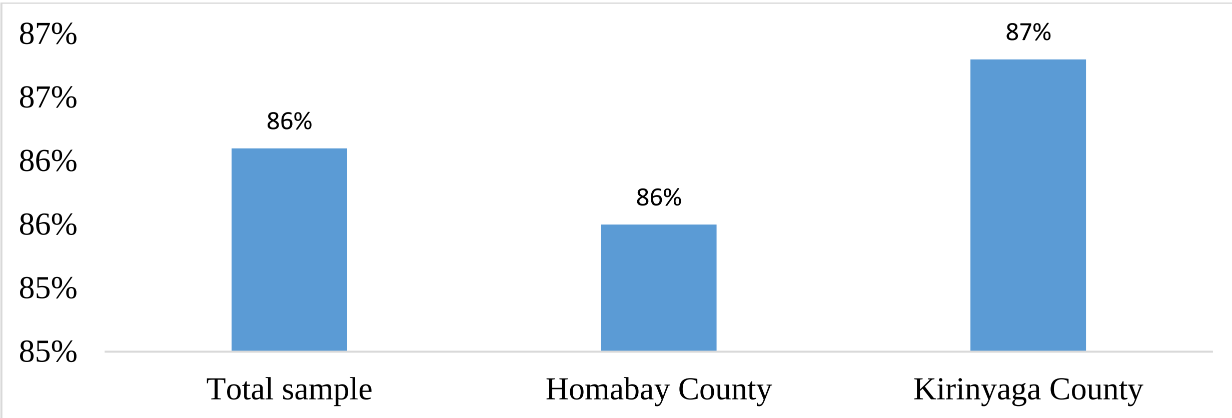


Figure 4.1: Farmers' experience of sweet potato losses due to attack by pests and diseases

Figure 4.1 shows that majority of the study respondents experienced losses during sweet potato production due to attack by pests and diseases. Comparatively, the figure shows that pest and disease attack was higher in Kirinyaga than in Homabay. This may be explained by differences in the uptake of clean seed in the two counties, with a comparatively higher number of farmers in Homabay having used clean seed than in Kirinyaga County.

With regards to seed acquisition, Table 4.4 shows that freely acquired seed (49.2%) and saved seed (37.2%) dominated other forms of acquisition. The WTP of farmers who are currently not paying for seed is likely to be low since they use a production system that does not factor the costs of seed. The main mode of transport used to get sweet potato seed to the farm was by trekking (71%). This can probably be attributed to the acquisition of seed from networks not too far away from household farms. Results further show that use of donkeys to carry loads is a more common mode of transport for planting material in Homabay County than in Kirinyaga County. Other modes of transport included bicycles, wheelbarrow, motorcycle and vehicles.

Information on the common varieties of sweet potato produced is important as the type of sweet potato variety has implications on nutrition, yields and market acceptance (Momanyi *et al*., 2016; Mukras *et al*., 2013; SPHI, 2019). Findings showed that varieties planted differed by study area and this was influenced by the yield, resistance to diseases, maturity period, marketability and taste. In Kirinyaga County, yellow fleshed varieties (*Bungoma* and *Kiganda*) dominated (97%) among the households. In Homabay, yellow fleshed varieties (*Amina* and *Nyathi Odiewo*), were the most popular (65.8%). Other varieties planted included *Nyar Migori*, *Vitaa* and *Kabodee* varieties. The market for *Vitaa* and *Kabodee* (orange fleshed varieties) was majorly from sweet potato processors. This result has implications on WTP for clean seed as seed of preferred varieties is expected to attract a higher WTP.

4.3.2 Access to clean sweet potato seed

This study sought to assess access to clean sweet potato seed among small holder farmers. This was done by assessing awareness about clean seed, prior usage of clean seed and whether farmers who had used clean seed had continued utilising it (Table 4.5).

Table 4.5: Access to clean sweet potato seed among sweet potato farmers

Variable	**Total sample**		**Homabay**		**Kirinyaga**		**p**
	n	**%**	**n**	**%**	**n**	**%**	
Awareness on clean seed	103	26.89	79	39.30	24	13.19	0.01
Prior usage of clean seed	37	9.66	32	15.92	5	2.75	0.00
Are you still using the vines	23	6	20	5.22	3	0.7	0.00

Results in Table 4.5 show that awareness of clean seed among households was low (26.89%) despite the benefits that can be realised from its use. This result points to the need for efforts to enhance awareness of clean seed among smallholder farmers. Some of the commonly mentioned sources of awareness were fellow farmers, cooperatives, NGO’s and extension service providers. Findings further showed that only 9% of the households had used clean seed and only 6% had persisted to use the vines suggesting that usage of clean seed is still very low in the study area. Some of the reasons given for low adoption of clean seed included lack of availability, high cost of clean seed, poor culinary traits of varieties offered and lack of awareness on clean seed. County comparisons showed that farmers in Kirinyaga County were more constrained in awareness on clean seed and usage of clean seed. Overall, the results on access reveal that access to clean seed is low and thus more efforts need to be put in place to enhance access.

4.3.3 Sweet potato seed security

Seed security was one of the indicators used to characterize the sweet potato seed system. The study adopted and customised a seed insecurity assessment scale developed by FAO and CIAT (FAO, 2015; Mucioki *et al*., 2018; Sperling, 2008). The study also incorporated four pillars of seed security which are: availability of seed, access to seed, varietal suitability and seed quality (FAO, 2015). Based on this, the study used a total of 12 statements to assess sweet potato seed security. Results are presented in Table 4.6.

Table 4.6: Sweet potato seed security status in Homabay and Kirinyaga counties

	Total sample n=383	Homabay n=201	Kirinyaga n=182	p
Seed availability	**%**	**%**	**%**	
1.Worry you would not save enough sweet potato seed for the next season	51	57	46	0.30
2.Unable to grow enough sweet potato due to lack of seed	43	48	37	0.28
3.Have no sweet potato seed to plant at the start of rains	33	41	25	0.10
4.Sell all your seed saving no seed for the next season	21	22	20	0.88
5.Have no sweet potato seed to plant the whole season	19	27	10	0.09*
Seed availability insecurity score	**1.68**	**1.95**	**1.38**	**0.00*****
Seed access				
6.Worry you would not access outside sources of seed	46	56	35	0.04**
7.Grow limited sweet potato varieties due to lack of resources	41	44	38	0.53
8.Receive seed aid	9	13	3	0.32
Seed access insecurity score	**0.96**	**1.13**	**0.76**	**0.00*****
Seed quality				
9.Grow seed of low quality	49	58	38	0.06*
10.Grow varieties that were not well adopted to the growing conditions of your farm	45	53	35	0.07*
Seed quality insecurity score	**0.93**	**1.11**	**0.74**	**0.00*****
Varietal suitability				
11.Grow varieties that were not preferred by the household	44	54	32	0.03**
12.Grow new sweet potato varieties that you have not grown before	16	21	11	0.36
Varietal suitability insecurity score	**1.27**	**1.33**	**1.21**	**0.22**
Seed security experience score (SSES)	**4.84**	**5.52**	**4.09**	**0.00*****

Total sample n=383, Homabay n=201, Kirinyaga n=182; n= number of observations

The responses to the 12 statements were used to compute the SSES based on a recall period of one year. The results show that the average SSES was 4.84 out of a total possible maximum of 12 which indicates that the sampled farmers faced mild seed insecurity. Comparatively, the results show that households in Homabay experienced higher levels of sweet potato seed insecurity compared to those in Kirinyaga. The presence of irrigation water in Kirinyaga County may allow farmers to conserve planting material even during the dry season, explaining the disparities in seed security across the counties (Republic of Kenya, 2017a).

Availability of seed was assessed using a set of five statements. According to the findings, half of the respondents were concerned about not being able to conserve enough seed for the following season, and 43% said they couldn't grow enough sweet potato. Furthermore, a significant number of respondents (21%) stated that they had sold all of their seed, leaving them with no seed to sow the next season. Furthermore, some farmers stated that they did not have enough seed to plant for the entire season. County comparisons revealed that households in Kirinyaga County had higher levels (1.38) of seed availability compared to households in Homabay (1.95). This could perhaps be contributed to by the availability of irrigation water in Kirinyaga, allowing for year-round production of seed.

Seed access was measured using three statements, with severity levels ranging from lowest extent (worry) to highest extent (receiving seed aid). According to the findings, 46 percent of the households were worried that they would not access external sources of seed such as from close social networks, 41 percent grew limited varieties and 9 percent received seed aid. Further, the mean seed access insecurity score revealed that households in Homabay County were more access insecure (1.13) compared to Kirinyaga households (0.76). The difference in access between the counties can be attributed to the fact that households in Kirinyaga had higher annual income and therefore more financial resources that can be used to access seed.

With regards to seed quality, results reveal that almost half of the respondents perceived having grown seed of low quality (49%) and growing varieties that were not well adopted to the conditions of their farms (45%). The perception on low quality is consistent with the earlier observation that 85.5 percent of the households reported having experienced attack of their sweet potato by pests and diseases which has been linked to the use of infested planting materials. The results additionally show that households in Homabay County experienced a significantly higher seed quality insecurity score (1.11) compared to those in Kirinyaga County (0.74).

The last parameter looked at varietal suitability which is defined as the ability of farmers to plant seed varieties having the characteristics they prefer (FAO, 2015). Findings from FGDs revealed that choice of varieties was influenced by appearance, taste, storability, marketability, productivity, maturity period and pest and disease resistance. 44 percent of the respondents reported that they had grown seed that was not preferred by the household. Results additionally showed that only 16 percent of the households had planted varieties that they had never planted indicating low adoption of new sweet potato varieties. Similar to other parameters of seed security, households in Homabay County had a higher varietal suitability insecurity score (4.09) compared to households in Kirinyaga County (4.09).

Findings in this section show that farmers are generally experiencing seed insecurity across the four pillars of seed security implying that intervention is required to increase the availability and accessibility of high-quality planting material.

4.4 Willingness to pay for clean sweet potato seed among smallholder farmers

This section presents the results on willingness to pay for clean sweet potato seed among smallholder farmers in the study counties. This section also includes the results on comparison of WTP with costs of clean seed multiplication.

4.4.1 Willingness to pay for clean sweet potato seed

The assessment of WTP was based on a double bounded contingent valuation method. The distribution of respondents per treatment used and bidding pattern observed is presented in Table 4.7.

Table 4.7: Bidding pattern observed across the treatment bids presented to sweet potato farmers

Treatment	Number of respondents	Yes	Yes-Yes	Yes-No	No-Yes	No-No
Column No.	**2**	**3**	**4**	**5**	**6**	**7**
1. (420, 590, 250)	98	64.29%	39.79%	24.49%	14.28%	21.43%
2. (840, 1010, 670)	94	47.87%	30.85%	17.02%	27.66%	24.47%
3. (1260, 1430, 1090)	95	34.74%	26.32%	8.42%	29.47%	35.79%
4. (1680, 1850, 1510)	96	16.67%	5.20%	11.45%	4.16%	79.17%

Results in Column 2 of Table 4.7 shows that the four treatment levels had almost equal number of respondents indicating that there was a good distribution of respondents across the four treatments (Perman *et al*., 2002). The third column shows the proportion of respondents who answered yes to the initial bid. The columns that follow (columns 4,5,6,7) show the frequency of responses for the four expected categories within which WTP falls.

Results from Table 4.7 indicate that the lowest bid amount (treatment 1) had the highest number of yes responses. The results also show that the proportion of yes responses was declining with increase in the bid amount. The pattern is consistent with standard demand theory on expenditure minimization for all rational individuals (Perman *et al*., 2002). Previous studies have also shown that the lowest bid amount attracts the highest proportion of positive responses (Khainga *et al*., 2018; Perman *et al*., 2002).

The estimation of WTP was achieved using the *doubleb* command in STATA (Lopez-Feldman, 2012). The estimating process was split into two stages. WTP was estimated without explanatory variables in the first stage, and explanatory variables were introduced in the second stage. Results for the first stage are presented in Table 4.8.

Table 4.8: Farmers' WTP for clean sweet potato seed excluding explanatory variables

	Total sample	Kirinyaga County	Homabay County
Coefficient	895.27	1000.66	800.69
Std. error	35.52	48.87	50.72
p	0.00	0.00	0.00
Log likelihood	-506.18	-217.03	-285.04

Results in Table 4.8 show that farmers were willing to pay an average of KSH 895.27 for a 90 kg bag of clean sweet potato vines. Results further show that, farmers in Kirinyaga County are willing to pay more (KES 1000.66) for clean seed than farmers in Homabay County (KES 800.69). This could perhaps be influenced by Kirinyaga County households having higher annual per capita incomes (KES 77,646) compared to Homabay County households (KES 27,139). Moreover, the two counties have differences in sweet potato production and marketing systems which could further explain the difference in WTP (Ayedun *et al*., 2017; Migwi *et al*., 2020).

In order to account for the influence of other explanatory variables, a modified ordered probit model incorporating explanatory variables (equation 3.5) was estimated in order to identify the determinants of WTP. For ordered probit model results, only the sign of the coefficient is used to make interpretations (Posri *et al*., 2006). Therefore, only the signs of the coefficients and the p values were used for qualitative inferences.

A Wald test, which follows a Chi-square distribution, was used to examine the simultaneous significance of the 24 independent variables contained in the model (Posri *et al*., 2006). The Wald statistic is 50, and the p-value is significant at 1%, hence the null hypothesis that the independent variables in the study are insignificantly different from zero was rejected. This implies that the independent variables used result in a better fit of the model, suggesting that the model is appropriately specified. The results are presented in Table 4.9.

Table 4.9: Determinants of willingness to pay for clean sweet potato seed

Variable	**Coefficient**	**Std. Error**	**P value**
Gender of household head	-16.71669	91.04743	0.854
Age	-11.27562***	3.350275	0.001
Household size	-35.83699**	17.3493	0.039
Children <5 years	61.92281	46.71847	0.185
Education (primary)	35.37664	155.1243	0.82
Education (vocational)	-59.26453	212.1862	0.78
Education (secondary)	78.40778	166.7919	0.638
Education (tertiary)	182.6189	184.9065	0.323
Farm size (ha)	9.348842	19.88733	0.638
Sweet potato plot size (ha)	-60.79772	44.00655	0.167
Years in sweet potato production	13.49958***	4.593939	0.003
Yearly income	0.0002664	0.0002027	0.189
Sweet potato income	0.0002376	0.000572	0.678
Sweet potato expenditure per acre	0.0018564	0.0018543	0.317
Wealth index (Middle)	-63.52903	86.09531	0.461
Wealth index (Wealthy)	-48.24736	96.16952	0.616
Group membership	18.23691	78.86116	0.817
Market distance-km	14.5048	19.53836	0.458
Extension access	-58.42049	76.75933	0.447
Use of clean seed	321.9335***	113.4633	0.005
Crop diversity	23.62143	36.13395	0.513
Livestock diversity	37.76224	33.064	0.253
County (Kirinyaga=1)	198.0208*	102.9562	0.054
Seed security score	11.61572	13.05116	0.373
Constant	1037.086***	301.5065	0.001
E (WTP)	578.94		
Sample size	383		
Log likelihood	-481.12		
Wald	49.10		

*, **, *** denote level of statistical significance at 10% level, 5% level and 1% level respectively; number of observations=383

The mean WTP for clean sweet potato seed was estimated post estimation of the variables that significantly influence WTP. Results in Table 4.8 show that the mean WTP for clean sweet potato seed was KES 578.94 after inclusion of explanatory variables in analysis. This amount is lower than the mean amount when explanatory variables were not included in the analysis (KES 895.27). This result implies that the explanatory variables included in the study play a key role in influencing WTP for clean seed.

Results on determinants of WTP for clean seed show that five of the variables included in the model are statistically significant. The variables that had a positive influence on WTP for clean seed were the geographical location of the household (County), experience (number of years) in sweet potato production and prior use of clean seed. Conversely, two demographic variables, household size and age of the household head were negatively associated with WTP.

Findings in Table 4.9 show that age of the head of the household head had a negative influence on WTP for clean sweet potato seed. The result suggests that WTP decreases with age of the farmer. Previous studies have shown that younger farmers are more interested in utilizing new technologies, which has majorly been contributed to by better access to information which results in a higher likelihood to adopt these technologies (Berkowsky *et al*., 2018; Mwangi & Kariuki, 2015). Additionally, older farmers have been found to have a higher risk averse attitude towards new technologies which could further contribute to their lower WTP (Jin *et al*., 2017).

The results also show a negative association between household size and WTP. This implies that larger households have a lower WTP for clean seed than smaller households. Previous literature has associated larger household sizes with higher household expenditures especially on food (Smith *et al*., 2017). This may consequently result in lower disposable incomes to be used in the purchase of agricultural technologies such as sweet potato seed. The study results are consistent with (Ayedun *et al*., 2017) who also found a negative association between WTP for seed and larger household sizes.

Results additionally show that sweet potato farming experience is positively associated with WTP for clean sweet potato seed. This implies that WTP for clean sweet potato seed increased with a farmer's years of sweet potato farming experience. Farming experience has been found to play an important role in influencing WTP and adoption of agricultural technologies (Ainembabazi & Mugisha, 2014; Mwiti *et al*., 2020). This finding may suggest that using experienced farmers to act as model farmers at the community level may work as an introduction strategy of clean seed. Interestingly, farmers who had prior experience using clean sweet potato seed had a higher WTP than farmers who had not used clean seed (Table 4.9). Experience with use of clean seed allows a farmer to appreciate the benefits of using clean seed including higher yields, low disease and pest attack which may result in a higher WTP for clean seed (Simtowe *et al*., 2019). These results are in line with Mastenbroek *et al*. (2020) who found that prior use of an agricultural technology allows farmers to appreciate the benefits of use of the technology subsequently affecting their purchase decisions. The implication of this result is that awareness programs on clean seed, especially those that allow farmers to directly interact with clean seed such as demonstration farms may increase the WTP for clean seed.

Finally, results in Table 4.9 show that the sign of the coefficient of the county variable was positive implying that households in Kirinyaga County had a higher WTP for clean sweet potato seed compared to farmers in Homabay County. This could be attributed to differences in sweet potato production systems, income levels, marketing systems and institutional arrangements. This result may suggest that efforts seeking to promote adoption of clean sweet potato seed should take into account location specific differences when designing their pricing other promotional strategies.

Overall, results show that farmers are willing to pay for clean sweet potato seed. The findings suggest that efforts aiming at introducing clean seed to farmers may target experienced sweet potato farmers who may act as model farmers to the rest of the community. Additionally, efforts can be made to aid farmers' interaction with clean seed which would in turn help them appreciate the benefits of clean seed, resulting in a high

WTP for clean seed. Some of these strategies may include seed aid, subsidised seed or use of demonstration farms. Additionally, programs aiming at creating awareness and training farmers on clean seed and its benefits may play a key promotional strategy for the seed. Moreover, household context variables such as age and household size are also important in influencing WTP and hence promotional strategies should consider different pricing strategies for different farmer categories.

4.4.2 Comparison of WTP with costs of clean seed multiplication

Comparison of WTP for clean sweet potato seed with the costs of clean seed multiplication was conducted in order to understand whether at a commercial scale, small holder farmers would be able to meet the full costs of clean seed production. This is important as it is a key element of the success and economic viability of any seed system. The costs of sweet potato seed multiplication were computed as a sum of the fixed and variable costs incurred in seed multiplication.

Sweet potato seed is produced at three levels: pre-basic seed, basic seed and quality declared seed. Pre-basic seed is the initial generation of seed produced in research stations. Large-scale and medium-scale commercial vine growers multiply the seed produced at research stations to yield basic seed. Decentralised vine multipliers (DVMs) generate quality declared seed on a smaller scale (CIP, 2018). In the cost calculation, this study focused on quality declared seed, which is the third and last stage of multiplication before seed is sold to sweet potato root producers.

Sweet potato planting material is commonly harvested three times after planting during an entire season of seed multiplication. The first harvest is done eight weeks after planting, the second harvest is done six weeks after the first harvest while the third harvest is done six weeks after the second harvest. After the three harvests, sweet potato roots are overgrown hence cannot be sold in the market. The multiplication costs presented therefore relate to the three cycles of described (Table 4.10).

Table 4.10: Average costs of clean sweet potato seed production per acre

Item	Description	Cost in KES
Basic seed	One acre requires approximately 25 bags of seed and one bag costs KES 2000	50000
Seed transport	It costs an average of KES 200 to transport one bag of seed and one acre requires 25 bags of seed	5000
Fertilizer	50 KGs of fertilizer are needed per acre at the initial stage of planting. After each of the two harvests, about 34 KGs are needed. One KG goes for about KES 70.	8300
Chemicals	These are the costs of foliar and pesticide. About 1 litre of Foliar and 500 ml of pesticide are required for the entire season of seed multiplication	760
Gunny bags	One gunny bag costs about KES 50 and an average of 360 bags are harvested in one acre	18000
Irrigation water	An average of KES 300 incurred per month for five months	1500
Fuel and electricity	An average of KES 300 incurred per month for five months during irrigation on fuel and electricity	1500
Interest on operating capital	The interest (7 percent) on operating costs (total cost of basic seed, fertilizer, chemicals, bags, irrigation water, electricity and fuel). 7% is the average interest rate by the Central Bank of Kenya.	5954.2
Opportunity cost of land (maize)	The foregone revenue had the land been used for the next best alternative assumed to be maize	27000
Labor		
Land preparation	Includes costs of first ploughing, second ploughing and ridge preparation. About 60 working days are required at a rate of KES 400 per day	24000
Planting	Eight working days at a rate of KES 400 per day	3200
Weeding	15 working days at a rate of KES 400 per day	6000
Roguing	Three working days at a rate of KES 400 per day	1200
Irrigation	Irrigation is done at the initial stages of each cycle. 23 working days are required at a rate of KES 400	9200
Spraying	Two working days at a rate of KES 250	500
Harvesting	Harvesting is done thrice; after 1st and 2nd harvest, seed is allowed to regrow thus the	18000

	harvesting cost covers 3 cycles. Harvesting labor is paid at KES. 50 per bag harvested	
Total costs		180114.2
Cost of producing a 90 Kg bag	This the total cost of production divided by the number of bags harvested (360)	**500.31**
Cost reduction from harvested roots	Income from selling harvested sweet potato roots which are sold at a discounted price of about 20 percent of the market value. Based on an average yield of 40 bags per acre and a market price of KES 2500, the income (KES 28000 per acre) translates to a cost reduction of KES 55.50 per bag of seed (since 360 bags of seed are produced from one acre).	**55.50**
Net cost of producing a 90 Kg bag		**444.81**

1USD= KES 101.99; Note: Costs may vary depending on factors such as land condition, disease/ pest infestation, topography, rainfall patterns, etc.

Table 4.10 shows that the average costs of multiplying clean seed was KES 180114.2 per acre (Approximately US$ 1766). This translates to a cost of KES 500.31 for producing one 90 Kg bag of clean seed based on an average of 360 bags (90 Kgs) of sweet potato seed that can be harvested from one acre. After accounting for cost reduction of harvested roots, the net cost of producing one 90 Kg bag of clean seed was estimated to be KES 444.81. Results in Table 4.10 further showed that the major costs incurred in clean seed multiplication are seed purchase costs and costs of labor. The high labor and seed multiplication costs imply that efforts should be made to make the seed affordable and target mechanisms for making seed multiplication less labor intensive e.g. through mechanization.

One of the objectives of this study was to compare the costs of clean seed multiplication with farmers' WTP for clean seed. Results show that the cost of multiplying one (90 KG) bag of clean seed was KES 500.3. This cost is lower than the costs that farmers were willing to pay for a bag of clean sweet potato seed (KES 647.75) suggesting that clean seed multiplication business could be economically viable. However, some of the costs that are incurred in production of clean sweet potato seed were not included such as farm management costs and depreciation costs as they are difficult to quantify and value. Additionally, marketing and distribution costs were not included in the analysis because sale of seed is being done at the farmgate level. At a commercialization level, these costs would be incurred and hence an efficient system of management, marketing and transportation would need to be put in place. Moreover, the mean WTP should be considered as the maximum price farmers would pay for seed (Lusk & Hudson, 2004a).

Overall, these results suggest that the business of clean seed multiplication could be economically viable and sustainable based on the farmers WTP. However, commercialization of sweet potato seed business would require establishment of efficient seed distribution systems, so as to minimise on other transaction costs that may be incurred in the business. Based on these results, industry stakeholders should focus on development of commercialization models especially the distribution of seed given the bulkiness and perishability nature of sweet potato seed.

4.5 Assessment of preferences for sweet potato seed attributes among small holder farmers

A choice experiment was conducted to assess preferences for sweet potato seed attributes which was later analysed using a conditional logit model. Results from the conditional model results are presented in Table 4.11.

Table 4.11: Farmers' preferences for sweet potato seed attributes

Attribute	Total sample			Homabay County			Kirinyaga County		
	Coefficient	SD	P	Coefficient	SD	P	Coefficient	SD	P
Price	-0.00**	0.0	0.03	-0.00	0.00	0.26	-0.00**	0.00	0.03
Disease resistance	1.38***	0.05	0.00	1.61***	0.06	0.00	1.18***	0.07	0.00
Maturity	0.02	0.02	0.201	0.11***	0.03	0.00	-0.06**	0.02	0.02
Bio-fortification	0.38***	0.05	0.00	0.14**	0.07	0.03	0.64***	0.07	0.00
Yield	0.05***	0.00	0.00	0.04***	0.01	0.00	0.06***	0.00	0.00
Intercept	-0.19***	0.04	0.00	-0.25***	0.06	0.00	-0.15***	0.06	0.01
No. of observations	9188			4824			4364		
Log-likelihood	-2020.64			-928.91			-1045.04		
Pseudo R2	0.39			0.47			0.34		

*, **, *** denote level of statistical significance at 10% level, 5% level and 1% level respectively

Findings show that coefficients for price, disease resistance, bio-fortification and yield attributes were significant. The findings further indicate that in general, sweet potato farmers were willing to purchase sweet potato planting material which is disease resistant, bio-fortified and high yielding in their respective order of importance. The coefficient for the purchase price for seed was negative, indicating that sweet potato farmers preferred to pay less in order to obtain improved seed. Results on the Pseudo R2 (0.39) indicated that the overall fit of the model used was good as it ranges between 0.2 to 0.4 (McFadden, 1977).

Results in Table 4.11 show that the sign of the coefficient for price was negative (-0.000092) meaning that an increase in the price of seed reduced the probability of a household choosing an alternative. This means that households were sensitive to high purchase price of seed, and they would therefore prefer to obtain seed at affordable costs.

The study results are consistent with other studies that have shown that farming households are sensitive to prices of farm inputs, with increase in prices reducing probability of purchase (Chawala *et al*., 2019; Mastenbroek *et al*., 2020). This implies the need to promote interventions that can relax farmer's budgetary constraints such as price subsidies, credit or efforts that ensure that seed is available to farmers at the least possible costs should be promoted. County comparisons showed that price of seed was significant in Kirinyaga County and yet not significant in Homabay County. The possible reason for this is that the other attributes were comparatively more important for farmers in Homabay County resulting in the respondents putting little weight on the price attribute (Carlsson *et al.*, 2009). Nevertheless, the attribute is significant for the whole sample and hence it can be used to make possible policy implications.

Results further show that disease resistance was a significant attribute (p=0.00) when selecting the preferred alternative. Farmers preference towards disease free planting material would perhaps be attributed to the dominance of recycled seed in the sweet potato seed systems (Jepkemboi *et al*., 2016; Kagimbo *et al*., 2018; Momanyi *et al*., 2016) which leads to spread of diseases consequently leading to yield losses of up to 80 percent (Wang *et al*., 2010). Moreover, these results are also corroborated by findings from FGDs where farmers expressed that they would prefer disease resistant seed as disease attack was one of the main challenges facing sweet potato production. This means that more emphasis should be given to breeding of disease resistant sweet potato varieties compared to the other attributes.

Additionally, when choosing alternatives, farmers expressed a preference for bio-fortified sweet potato varieties (yellow or orange fleshed) to the non-bio-fortified (white) varieties. Bio-fortified sweet potato has been promoted in the recent few years due to its ability to help combat vitamin A deficiency which is widespread in sub-Saharan Africa (Stevens *et al*., 2015). As a result, this may have led to an increase in demand for the bio-fortified varieties over non-bio-fortified varieties. In addition, findings from FGDs revealed that bio-fortified sweet potato is more marketable compared to non-biofortified further explaining the preference for bio-fortification.

Results also show that respondents had a strong preference for increased yields (p=0.00). An increase in yield per unit area of production increased the probability of a respondent choosing a given alternative. This was expected given that yield has an important influence on profitability of sweet potato enterprise. These results are consistent with previous literature showing that high yields is one of the main drivers in selecting quality seed (Toledano, 2017; Waldman *et al*., 2017). This result is also in line with findings from FGDs where higher yielding varieties were preferred to lower yielding varieties.

Findings further show that maturity was not a significant attribute for the total sample (p=0.20), while at the County level the attribute was significant. The sign of the coefficients of the maturity period (0.11 Homabay; -0.06 Kirinyaga) indicate that households in Kirinyaga County preferred shorter sweet potato maturing varieties compared to their counterparts in Homabay who preferred longer maturity varieties. This would perhaps be affected by the difference in crop production systems whereby households in Kirinyaga County majorly plant short time maturity crops while (Republic of Kenya, 2017a, 2017b).

The study further assessed the Marginal Willingness to Pay (MWTP) for sweet potato seed attributes (Table 4.11). MWTP indicates the marginal rate of substitution (MRS) between the non-monetary attributes (yield, disease resistance, bio-fortification, maturity) and the monetary attributes (price). It shows the amount of money farmers are willing to pay in order to acquire seed with the desired attribute over the non-desired attribute i.e. seed that is disease resistant over seed that is not disease resistant. Therefore, the higher the MWTP, the more preferable the attribute is to farmers.

Table 4.12: Farmer's marginal willingness to pay for each sweet potato seed attribute

	Total sample	**Homabay County**	**Kirinyaga County**
Disease resistance	KES. 13806.74***	KES. 20356.79***	KES. 8090.21***
Maturity	KES. 221.94	KES. 1369.45***	KES. -396.72**
Bio-fortification	KES. 3829.96***	KES. 1801.31**	KES. 4374.02***
Yield	KES. 524.11***	KES. 539.77***	KES. 430.35***

*, **, *** denote level of statistical significance at 10% level, 5% level and 1% level respectively; number of observations=383

Table 4.11 indicates that for the overall sample, all the attributes (Disease resistance, maturity, bio-fortification and yield) had a positive MWTP. This means that farmers were willing to pay a higher amount to acquire seed that is disease resistant, with a shorter maturity period, bio-fortified and with higher yield levels. Findings further indicate that disease resistance had the highest amount of MWTP (KES. 13806.74), followed by bio-fortification (KES. 3829.96), yield (KES. 524.11) and lastly maturity period (KES 221.94). This implies that farmers are willing to invest more in the disease resistance attribute further emphasising the importance of the attribute.

County comparisons indicated that farmers in Homabay County had a higher marginal WTP for disease resistance, maturity and yield while farmers in Kirinyaga County had a higher MWTP for bio-fortification. The results also indicate that Kirinyaga County households had a negative MWTP for the attribute on maturity (KES -396.72), implying that an increase in the maturity period reduced their MWTP while households in Homabay had a positive MWTP for maturity, implying that an increase in the maturity period increased their MWTP.

Overall, the results on preferences for sweet potato seed attributes suggest that sweet potato breeding programmes should continue to focus on breeding of disease resistant sweet potato varieties and by implication other biotic stressors of sweet potato production such as pests. Additionally, traits relating to nutrition enhancement and yield enhancement should be key in these breeding programmes.

CHAPTER FIVE

SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

5.1 Introduction

This chapter presents the study summary, conclusion and policy implications. The chapter is organized into four sections. The first section (section 5.2) focuses on the summary of the study. Section 5.3 provides the conclusion of the study, while section 5.4 presents the policy implications while section 5.5 concludes with areas of further research.

5.2 Summary

Sweet potato is ranked as the 5^{th} most important food in Kenya and has been recognized for its role in combating vitamin A deficiency. Despite of this potential, sweet potato productivity is low in Kenya, with an average annual production of 11.7 tons per hectare compared to the potential productivity of 30 tons per hectare. One of the major reasons linked to this low productivity is the crops attack by pests and diseases especially the sweet potato virus disease which is very rampant in East Africa. Farmers in the country mainly acquire sweet potato planting material from previous crop and this has further enhanced spread of pests and diseases. To help reverse this trend, a number of organizations have been involved in the multiplication of clean planting material but it is of concern that a sustainable seed-system has not yet been actualized as recycling of seed continues to dominate.

In order to inform the clean sweet potato development efforts, it is important to understand whether clean seed multiplication is feasible and whether there is demand for clean seed. The objectives of this study were therefore: 1) To characterize sweet potato seed systems in Kenya, 2) To compare the multiplication costs and willingness to pay for clean sweet potato seed among smallholder farmers in Kenya, and 3) To assess the preferences for sweet potato seed attributes in Kenya. Data collection was done in Homabay County and Kirinyaga County among a sample of 383 sweet potato farmers and 30 sweet potato seed multipliers spread across five counties in Kenya. Characterization of sweet potato seed systems was done using descriptive statistics across various characteristics, including sourcing arrangements, preference on sweet potato varieties, levels of access to clean seed and seed security. WTP was estimated using the contingent valuation method and this was also compared to the costs of sweet potato seed multiplication and preferences for sweet potato seed was assessed using a choice experiment approach.

Results on the characterization of sweet potato seed systems show that seed sourcing from close social networks dominated (about 90%) with most of the seed being exchanged freely. Another key characteristic of the sweet potato seed system is low usage of clean seed (9.7%) and low awareness of clean seed (26.9%). Further, the seed security experience score was at 4.8 out of a maximum possible score of 12 across the four elements of seed security- availability, accessibility, varietal suitability and seed quality.

With regard to WTP for clean sweet potato seed, farmers were willing to pay KES 578.94 for a 90 kg bag of clean sweet potato seed. Results further showed that WTP increased with prior use of clean seed and years of experience in sweet potato production while it reduced with increase in age and larger household sizes. Comparison of results on WTP with costs of seed multiplication showed that costs of seed multiplication were lower (KES. 444.81 for a 90 kg bag) than the amount farmers' were WTP.

Finally, results from the choice experiment show that the most important attributes that farmers consider are disease resistance, bio-fortification, yield and price in their order of preference. Farmers therefore have a higher MWTP for disease resistance, followed by bio-fortification and yield.

5.3 Conclusion

Based on the findings on characterization of sweet potato seed systems, the study concludes that sweet potato seed systems in the country are weakly developed. They are characterized by: free acquisition of seed, sourcing of seed from informal sources, build-up of pests and diseases, low awareness on clean seed, low uptake of clean seed and mild levels of seed insecurity. This implies that interventions are required to increase the awareness on clean seed, availability and accessibility of high-quality planting materials. Additionally, there exists potential to increase the availability and accessibility of high-quality planting material.

The study also concludes that farmers are willing to pay for clean sweet potato seed and that the average WTP for clean seed (KES 578.94) is higher than the costs of seed multiplication (KES. 444.81). Therefore, the seed multiplication business may be economically viable but this will rely on efficient mechanisms that can help lower transaction costs on marketing and distribution of clean seed. It is also concluded that locational differences have an impact on households' willingness to pay for clean seed. Additionally, prior use of clean seed and years of experience have a positive influence on WTP while age of the household head and household size are negatively associated with WTP.

Based on the results on preferences for sweet potato seed attributes, the study concludes that the farmer preferred attributes for sweet potato seed are disease resistance, bio-fortification and high yields in their order of importance. This suggests that sweet potato breeding programmes should focus on farmer preferred attributes such as disease resistance, bio fortification and yield.

5.4 Policy implications

Some policy implications are suggested based on the study's major findings. First, there is need for awareness creation on clean seed among sweet potato farmers. This can be done through extension creation via farmer groups and farmer cooperatives. In addition to this, practical knowledge on benefits of usage of clean seed should be passed to farmers through use of demonstration farms in the local areas and training farmers on the use of clean seed may influence farmers' knowledge on the benefits of using clean seed resulting in WTP for the seed.

Secondly, while the study findings indicate that the business of clean seed multiplication may be economically viable, it is important for an efficient distribution system of clean seed to be established. This is very critical because sweet potato is a vegetative propagated crop and hence the unique characteristics of the crop make the distribution system comparatively more complex. The distribution system should ensure that transaction costs are minimized. Industry stakeholders should therefore focus on development models that focus on localized multiplication of clean seed for example through decentralized vine multipliers at the local administrative levels. This will not only ensure that the cost of distribution is minimized but also ensure that clean seed is easily available to farmers especially during the onset of rains.

Lastly, sweet potato seed breeders and other stakeholders in the multiplication business are advised to multiply seed that prioritizes farmer preferences. Breeding programmes should focus on breeding of disease resistant sweet potato varieties and by implication other biotic stressors of sweet potato production such as pests. In addition, nutrition and yield enhancement traits should be key in these breeding programmes. This is because the market mainly drives farmer needs therefore, this will lead to an overall efficient system.

5.5 Areas for further research

In order to ensure viability of the system, this study recommends that areas for further research should include models that would ensure efficient distribution of vegetatively propagated seed, that is, how the distribution system can be localized to integrate actors such as agro-dealers and local traders in the system.

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APPENDICES

Appendix I: Sweet potato farmers' questionnaire

<table>
<tr><td colspan="2">Questionnaire on farmers' willingness to pay for clean sweet potato seed in Kenya</td></tr>
<tr><td colspan="2">WE ARE A TEAM OF RESEARCHERS FROM JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UNDERTAKING A STUDY THAT SEEKS TO UNDERSTAND SWEET POTATO SEED SYSTEMS IN KENYA. AS PART OF THE STUDY, WE ARE CONDUCTING A SURVEY OF SWEET POTATO PRODUCING HOUSEHOLDS IN KENYA AND YOU HAVE BEEN IDENTIFIED AS ONE OF THE RESPONDENTS. YOUR PARTICIPATION IS ENTIRELY VOLUNTARY AND THE INFORMATION YOU GIVE WILL BE TREATED CONFIDENTIALLY. YOU CAN CHOOSE TO ANSWER OR NOT ANSWER ANY QUESTION. THE INFORMATION YOU GIVE WILL BE REPORTED TOGETHER WITH THAT OF OTHERS AND YOU WILL NOT BE SPECIFICALLY IDENTIFIED IN THE REPORT. IN CASE YOU DECLINE, YOUR LACK OF PARTICIPATION WILL NOT HAVE ANY ADVERSE CONSEQUENCES ON YOU. YOU ARE FREE TO WITHDRAW FROM THE RESEARCH ANY TIME YOU FEEL UNCOMFORTABLE. THE QUESTIONNAIRE WILL TAKE 20-40MINUTES TO COMPLETE. BY ANSWERING THE QUESTIONNAIRE, YOU ARE ACKNOWLEDGING THAT YOU UNDERSTAND THE TERMS OF PARTICIPATION AND THAT YOU CONSENT TO THOSE TERMS.
A01) Consent given Yes=1 (___) No= 0 (___) (If yes, proceed to the next question; If no, find out reason why and terminate interview)</td></tr>
<tr><td colspan="2">Section A: Identification</td></tr>
<tr><td>A02) Day/Month/Year of interview _____ /______ / 2019
A03) Interview start time (hh.mm): ____________________
A04)Interview end time (hh.mm): ____________________
A05) Time taken :______________________</td><td>Enumerator ID
A11) ID __________________
A12) Number _____________________</td></tr>
<tr><td>Interview area
A06) County ____________________ 1=Kirinyaga 2=Homabay
A07) Sub-County _________________________
1=Mwea West 2=Mwea East 3=Kirinyaga West
A08) Ward_________________________</td><td>GIS coordinates of interview location
A13) Latitude: ________________________
A14) Longitude: _______________________</td></tr>
</table>

1=Kangai ward 2=Kiini ward 3=Nyangati ward 4=Murinduko ward	
Respondent A09) Name _________________________ A10) Gender _________________________ 1=male 0=female	Data entry clerk ID A15) Name - _____________________________ ____________ A16) Number_____________________ ____________

Section B: Household Schedule

Gender of HH (B01)	**Age of HH (B02)**	**Education Level of HH (BO3)**	**Marital Status (BO4)**
1=M ale 0= Female	Indicate age (*Can also ask year born and calculate age*)	1 =Informal 2= Primary 3=Vocational 4 =Secondary 5=Tertiary	1=Never married 2=Marri 3=Divorced/separated 4=Widow/widower

Section C: Land Resource base

C01) Do you possess land or use land for crop production, livestock production, commercial purposes, agroforestry Yes=1 (___) No=0(____)
If yes, please provide data on the variables below if no (888). What is:

Parcel No	Land Area (Acres)	Land Use	Distance from household to parcel of land (KM)	Nature of tenure
	C02	C03	C04	C05
1				
2				
3				
4				
5				

Codes for land use	**Codes for Nature of tenure**
1=Crop production 2=Livestock production 3= Mixed farming 4=Idle land 5=Woodlot 6=Commercial	1= Owns with title 2= Owns with no title 3= leasehold/rented 4= communal(pastoral, trust land, group, ranch land) 5=Squatter (uses land that they consider their own but has not been allocated) 6= other specify

Section D: Sweet potato production systems

<table>
<tr><td>D01) In the last one year have you engaged in sweet potato production?</td><td>1=Yes 0=No</td><td></td></tr>
<tr><td>D02) Apart from the last one year, have you ever been engaged in sweet potato production?</td><td>1=Yes 0=No</td><td></td></tr>
<tr><td>D03) If yes to D02, why did you not engage in the last 1 year?</td><td>1= No access to vines 2=Prefer other crops 3=Lack of market 4=Lack of knowledge on production 5=Low yields 6=High cost of vines 7=Land constraints 8=Attack by pests and disease 9=Spouse refusal 10=Other Specify</td><td></td></tr>
<tr><td>D04) What is your main reason for sweet potato production?</td><td>1=Sale of tubers 2=Consumption of tubers 3=Both sale and consumption 4=Livestock feed 5=Consumption of sweet potato leaves 6=Gift for friends/relatives</td><td></td></tr>
<tr><td>D05) Experience in sweet potato farming in years</td><td>Number of years</td><td></td></tr>
<tr><td>D06) In every 12 months, how many times do you plant sweet potato? (No of seasons)</td><td>1= one 2= two 3=three 4=four</td><td></td></tr>
<tr><td>D07) In the last 12 months, what size of land was allocated to sweet potato production?

(Calculate total size of land)</td><td colspan="2"><table>
<tr><td>Season</td><td>Size of land</td><td>Time when planted</td></tr>
<tr><td>Season 1</td><td></td><td></td></tr>
<tr><td>Season 2</td><td></td><td></td></tr>
<tr><td>Season 3</td><td></td><td></td></tr>
<tr><td>Season 4</td><td></td><td></td></tr>
<tr><td>Total size</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>D08) Over the past 2 years, has the land size allocated to sweet potato production increased, decreased or remained the same?</td><td>1= increased 2= decreased 3= remained the same</td><td></td></tr>
<tr><td>D09) If different (Increased or decreased), explain</td><td>Open ended</td><td></td></tr>
<tr><td rowspan="4">Which member of the household makes most decisions on:

Codes
1=husband 2=wife 3=both husband and wife 4=farm manager 5=child 6=other</td><td>D10) Production</td><td></td></tr>
<tr><td>D11) Marketing</td><td></td></tr>
<tr><td>D12) Consumption</td><td></td></tr>
<tr><td>D13) Labor on the sweet potato farm</td><td></td></tr>
</table>

Section E
Now think about the last season you planted sweet potato and answer the following questions

ID no	Which variety was planted (If variety name is not known, skip to E02)	Variety characteristic (Can give more than one characteristic)	Source of seed planted (Can indicate more than one)	Among sources listed, which is the most important source	How did you acquire the seed?	Did you experience any loss in the field due to attack by pests and diseases?	As per enumerators assessment is the seed used clean?
	E01	E02	E03	E04	E05	E06	E07
	1= Bungoma 2=Kiganda 3= Kipunda 4= Kabodee 5=Vitaa 6= mtwapa 8 7=Kenspot 20 8= Sumia 9= Ex-Rwambiti 10= Tainuy 64 11=Purpie 12=Cheb olol	1= Red skin 2=white skin 3=Orange fleshed 4=White fleshed 5=Purple flesh 6=yellow flesh	1=home-saved 2=friends/ neighbours 3=relatives 4= local market 5=community-based seed 6=NG0 7=local multiplier 8= contract growers 9=Others specify		1=save/own stock from previous season 2=exchange/barter 3=gift (friend/neighbour/relatives) 4=purchase/buy 5= vouchers/coupons 6= seed loan 7=food aid 8= money credit 9=seed for labor	1=Yes 0=No	1=Yes 0=No
1							

2							
3							
4							

Section F: Seed costs **Now think about the last season you planted sweet potato and answer the following questions**

ID no	Variety name (This should not be asked again. List according to order above in section E)	Size of land planted in the last season	Unit of measurement	Quantity	If the vines were bought state price per unit. Price per unit	If exchanged for labour, barter, estimate amount in Ksh	Total cost	What is the distance from place of acquisition to the farm planted ?	Mode of transport used to get to the farm
	F01		F02	F03	F04	F05	F06	F07	F08
	1= Bungoma 2=Kiganda 3= Kipunda 4= Kabodee 5=Vitaa 6= mtwapa 8 7=Kenspot 20 8= Sumia 9= Ex-Rwambiti 10= Tainuy 64	In acres	1=kg 2=No in 30 cm long 3=90 kg bag 4=50 kg bag 5=small bundle 6=medium bundle 7=big bundle 8=other specify	Number				Distance in KM	1=Walking 2=bicycle 3=wheelbarrow 4=motorcycle 5=vehicle

	11=Purpi e 12=Cheb olol								
1									
2									
3									
4									

Section G: (Part 1) Seed systems		
G01) Are you aware of clean sweet potato vine or variety (*If yes, continue to G02; If no, skip to part 2)*	1=Yes 0=No	
G02) What was your source of information?	1=Government extension 2=Private extension 3=Fellow farmers 4=TV 5=Radio 6=Newspaper 7=KALRO/ Universities 8=Internet 9=NGO's 10=Cooperative/farmer association	
G03) Are you aware of where you can get clean sweet potato seed	1=Yes 0=No	
G04) What is the distance from your homestead to the place of acquisition	distance in KM	
G05) Have you ever used the clean vines? (*If yes go to G06, If no go to Part 2)*	1=Yes 0=No	
G06) Are you still using clean vines	1=Yes 0=No	
G07) If no, why did you stop using clean vines? (*Proceed to part 2)*	1= No access to seed 2=Low yields 3=attacked by pests 4=attacked by diseases 5=Preferred old variety 6=No market 7=Poor culinary traits	

Section H: Seed security Did you or anyone in your household in the past one year,	1= Yes 0=No
1.Worry you would not save enough sweet potato planting material for the next season	
2.Unable to grow enough sweet potato due to lack of planting material	

3.Have no sweet potato planting material to plant at the onset of rains	
4.Sell all your planting material saving none for the next season	
5.Have no sweet potato planting material to plant the entire season	
6.Worry you would not have access to external sources of planting material	
7.Grow limited sweet potato varieties due to lack of resources	
8.Receive seed aid	
9.Grow sweet potato using planting material of low quality	
10.Grow varieties that were not well adopted to the conditions of your area	
11.Grow varieties that were not preferred by the household	
12.Grow new sweet potato varieties that you have not grown before	

Section I: Marketing of tubers

Think about the past 12 months and answer the following questions

		I01) How many times did you harvest sweet potato 1=One 2=Two 3=Three 4=Four 5=Piecemeal harvesting (all year round)								
		ID No	What quantities were harvested per season/ harvest? **I02**		Was any output marketed? 1=Yes 0=No	If yes, where did you market your produce	What quantities were sold per season/harvest? **I05**		Price per unit	Total income
	Land area		quantity	unit	103	I04	quantity	unit	I06	I07
Season 1	______ _ acres	Harvest 1								
		Harvest 2								
		Harvest 3								
		Harvest 4								
Season 2	______ _ acres	Harvest 1								
		Harvest 2								

	Harvest 3								
	Harvest 4								
	Codes for market 1=local open air market 2=super market 3=farm gate 4=contracted buyer 5=other(specify)			**Codes for units** 1= KG 2=Pieces 3= 210 -190 kg bag (extended bag) 4= 120 kg bag (extended bag) 5=100kg bag (flat bag) 6=90kg bag 7=70kg bag 8=50kg bag 9=25 kg bag 10=10kg bag 9=25 ltr can 10=20 ltr can 11=10 litre can 12=Debe 13=Other specify					

Section J: Expenditure

Apart from seed, what are the other costs incurred in sweet potato production per season? **Land area __________________ acres**

Input	Quantity	Unit	Price per unit	Total cost
	J01	J02	J03	J04
1.Fertilizer				
2. Manure				
3.Pesticides				
Herbicides				
Fungicide				
Insecticides				
4.Hired machinery				
7.Transport				
8. Irrigation				
Water				
Fuel (pumping petrol)				

Input	Provider 1=Hired 0=own	Man days	Rate	Piece rate	Total Ksh
	J05	J06	J07	J08	J09
9. Labor					
Land preparation					
Planting					
1st weeding					
2nd weeding					
Irrigation labor					
Harvesting					
Sorting and bagging					
10. Seed					

Section K: PART 1-Willingness to pay (CVM)

Clean sweet potato seed refers to seed which is free from insect pests and diseases and of a good physiological state. Use of virus free planting material has been shown to increase yield by approximately 40%. If this clean planting material was offered to you, what price would you be willing to pay for it? (Bids are as in the table below. Randomly select a bid and if the respondent answers yes to the bid offered, offer the higher bid from the initial bid. If the respondent answers no, to initial bid, offer the lower bid.

No	Initial bid	K01)Response 1=Yes 0=No	Higher bid	K02)Response 1=Yes 0=No	Lower bid	K03)Response 1=Yes 0=No
1	420		590		250	
2	840		1010		670	
3	1260		1430		109	
4	1680		1850		1510	

Bids are in Kenyan shillings. Prices are for a 90 Kg bag

Codes 1= Yes Yes 2= Yes No 3=No No 4= No Yes

Section K: Part 2- Willingness to pay (CE)
Block 1

	Choice (1/ 2/ Neither)		Choice (1/ 2/ Neither)
K04) Choice card 2		K08) Choice card 7	
K05) Choice card 4		K09) Choice card 9	
K06) Choice card 5		K10) Choice card 10	
K07) Choice card 6		K11) Choice card 11	

Section K: Part 2- Willingness to pay (CE)
Block 2

	Choice (A/ B/ Neither)		Choice (A/ B/ Neither)
K12) Choice card 1		K16) Choice card 13	
K13) Choice card 3		K17) Choice card 14	

K14) Choice card 8		K18) Choice card 15	
K15) Choice card 12		K19) Choice card 16	

Section K: Part 2- Willingness to pay (CE)

How far did you consider each of the five product characteristics while making your choices? **1=Never 2=Rarely 3=Sometimes 4=Often 5=Always**

K20) Disease resistance	
K21) Maturity	
K22) Fortification	
K23) Yield	
K24) Price	

How much do you agree with the following statements **1=Strongly disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly agree**

K25) All the characteristics were important in my decisions in the 8 questions	
K26) I was able to fully understand the choice questions I was faced with	
K27) I was able to make decisions as I would in a real world shopping scenario	

Thinking about the 5 Characteristics, how would you rank them in terms of importance when you were making your choice?

K28) 1st ______________________________

K29) 2nd ______________________________

K30) 3rd ______________________________

K31) 4th ______________________________

K32) 5th ______________________________

SECTION L: On a scale of 1 to 5, where 1 is Very Important and 5 is very Unimportant, how important are the following attributes when making a choice on the sweet potato variety to plant 1=Very important 2=Important 3=Neutral 4=Unimportant 5=Very unimportant

L01) Reduced cooking time/Cooks quickly		L09) Red skin	
L02) Tubers taste		L10) White skin	
L03) Tuber has low sugar content		L11) Yellow/orange flesh/ fortification	
L04) Tuber not watery/Dry matter content		L12) White flesh	
L05) Taste of leaves		L13) Certification of seed	

Section M: Farming systems:

M01) How many crop production enterprises did your household engage in in the last one year? (*state number)*____________________

M02) Please list the enterprises (open ended) ____

M03) How many Livestock production enterprises did your household engage in in the last one year? (*state number)*____________________

M04) Please list the enterprises (open ended) ____

Please give us information on 4 major crop production enterprises apart from sweet potato practiced by the household. (6 Major)

S/no	Enterprise	Proportion of land devoted to the crop per season	Source of seed	Amount of money spent on purchase of seed per season (If cant remember per unit price, put total) Units	Price/unit	Total amount
	M05	M06	M07	M08	M09	M10
1						
2						
3						
4						
	Enterprise codes 1=French beans 2=tomatoes 3=Green maize 4=Dry maize 5=green grams 6=cow peas 7=beans 8=tea 9=coffee 10=Leafy vegetables 11=cassava 12=potato 13=Rice 14=Bananas 15=Pigeon peas 16=Arrow roots	Source codes: 1=home-saved 2=friends/ neighbours 3=relatives 4= local market 5=community-based seed 6=NG0 7=local multiplier 8= contract growers 9=Seed for labor 10=Government				

Section N: Institutional Arrangements		
N01) Are you or any member in your household a member of a registered farmers' group or association?	1=Yes 0=No	
N02) If yes, to N01 what type of group?	1= Self-help group 2= SACCO 3= CBO 4= A producer cooperative society5= other (specify)	
N03) Did any of the household members try to obtain or access credit over the last one year	1= Yes 0=No	
N04) Did you obtain or get the loan/credit	1= Yes 0=No	

N05) If yes to N04 who was the provider?	1= Commercial bank 2= Micro-finance institution 3=cooperative 4= shylock/ local money lender 5=mobile credit (Mshwari,branch,tala) 6=Sacco 7=Family/friends 8=Chama group 9= contractual outgrower arrangement 10=Other(please specify)	
N06) Was any part of the credit used for agricultural production?	1=Yes 0= No	
N07) If yes to N06 above, what was the loan used for	1= purchase farm inputs 2= for marketing and value addition activities 3= buy land 4= construction of farm structure 5=purchase of agricultural machinery 6= payment of labour	
N08) Name of nearest town/market	Indicate name	
N09) What is the distance from the homestead to nearest market	Km	
N10) What is the distance from the homestead to the nearest tarmac road?	Km	
N11) Did you receive any extension services in the last 12 months	1=Yes 0=No	
N12) If yes to N11, what type of extension was it	1=Crop 2=Livestock 3=Crop and livestock 4=Other specify	
N13) Was any extension provided on sweet potato production?	1=Yes 0=No	
N14) If yes to N11 who (main) provided the extension services	1=Government 2=private extension 3= cooperative/farmer association 4=NGO'S 5=Others(please specify)	
N15) Who in the household accessed the service	1= HH 2= spouse 3=child 4= farm manger 5=other (specify)	
N16) What was your level of satisfaction with the extension service	1= very dissatisfied 2=dissatisfied 3=neutral 4=satisfied 5=very satisfied	

Section P: Household Living Conditions Observe and make notes on the following	
P01) What is the roofing of the main house 1=grass/makuti 2=Iron sheets 3=Tiles 4=Tent or canvas 5= Other (specify)	
P02) What is the wall of the main house 1=Wood 2=Iron sheets 3=Tent 4=bricks/Stone 5=mud 6= Other (specify)	
P03) What is the material of the floor of the main house 1=Earth 2=cement 3=Wood 4=tiles 5=Other specify	
P04) What is the mode of ownership of the house 1=owned 2=rented 3=owned by relative 4= other specify	

P05) What type of toilet do you use 1=pit latrine 2=bush 3=flush toilet 4=Other, specify	
P06)What is the main source of domestic water during the wet season 1=pond 2=dam 3=lake 4=stream/river 5=spring 7=well 8=borehole 9=piped 10=water tankers 11=roof catchment 12=water hawkers 13=Other specify	
P07) What is the main source of domestic water during the dry season 1=pond 2=dam 3=lake 4=stream/river 5=spring 6=well 7=borehole 8=piped 9=water tankers 10=roof catchment 11=water hawkers 12=Other specify	
P08) What is your main cooking fuel 1=electricity 2=paraffin 3=firewood 4=gas 5=charcoal 6=solar power 7=other specify	
P09) What is your main type of lighting 1=electricity 2=pressure lamp 3=tin lamp 4=fuel wood 5=lantern 6=solar power 7=other specify	

Section Q: Asset Ownership							
Asset	Do you own 1=Yes 0=No	Quantity (K02)	Estimated value of asset (If respondent can't estimate value, ask how much they would sell it for)	Asset (K01)	Do you own 1=Yes 0=No	Quantity (K02)	Estimated value of asset (If respondent can't estimate value, ask how much they would sell it for)
	Q01	Q02	Q03		Q01	Q02	Q03
1.Storage facility for crops				15.Irrigation equipment			
2.Water tank				16.Cart			
3.Radio/cassette player				17.Plough			
4.TV				18.Motorcycle			
5.Telephone/mobile				19.Car/truck			
6. Smart phone				20.Tractor			

7.Gas cooker				21.Generator			
8.Bicycle				22.Watering can			
9.Wheelbarrow				23.Axes, rakes hoe			
10.Milking equipment				24. Solar panels			
11.Chaff cutter				25.Cows			
12. Refrigerator				26.Sheep			
13.Borehole or well				27.Goats			
14.Weighing machine				28.Chicken			

Total estimated value of assets____ (*Calculated by enumerator*

Section R **Part 1: Dietary Diversity** Please describe the foods (meals and snacks) that you or any member of your household ate or drank yesterday during the day and night. Start with the first food or drink of the morning. Write down all foods and drinks mentioned. When composite dishes are mentioned, ask for the list of ingredients. When the respondent has finished, probe for meals and snacks not mentioned					
	Breakfast	Snack	Lunch	Snack	Supper
Code	**Food group**				**1=Yes 0=No**
R01)	Cereals and derived products: maize, rice, sorghum, millet, wheat, oats, pearl millet, ugali, porridge, chapati, mandazi, bread, pasta and breakfast cereals [PROBE: flour from own grains milled at small mills]				
R02)	White roots and tubers, plantains: Irish potato, white sweet potato, cassava, yams, arrowroot, green banana, plantain)				

R03)	Vitamin A rich vegetables and tubers: carrots, pumpkins, butter nuts, orange-fleshed sweet potato, red sweet bell pepper	
R04)	Dark green leafy vegetables: spinach, kales (Sukuma wiki), cow peas leaves (kunde), bean leaves, managu, amaranthus (terere), stinging nettle (thabai/oilo), sweet potato leaves (matembele), non-poisonous cassava leaves (kisamvu), spider weed (saget/dek/akeyo/sagaa), pumpkin leaves (susa), arrow root leaves (matekyo)	
R05)	Other vegetables: green pepper, onions, cauliflower, cabbages, cucumbers, eggplant, courgettes, French beans, okra, leeks, broccoli, celery	
R06)	Vitamin A rich fruits and their natural juices: mango, papaya	
R07)	Other fruits and their natural juices: guava, avocado, pineapples, green plums, green grapes, gooseberries (nathi), oranges*, lemons, limes, tamarind, loquats, zambarao (jamna), ripe bananas, custard apples, peaches, thorn melon, melons, pomegranates (kungu manga), wild fruits	
R08)	Legumes and pulses: Bambara nuts (njugumawe/bande), beans, peas cow peas, pigeon peas (mbaazi), soya beans, dolicos beans (njahi), green grams, lentils	
R09)	Organ meats: Liver, kidney, heart, other organ meats or blood-based food	
R10)	Flesh meats: Edible insects, goat meat, game meat, pork, beef, mutton, rabbit, donkey, chicken, guinea fowl, turkey, geese, ducks, quail, wild birds, doves	
R11)	Eggs	
R12)	Fish and sea foods: include all fresh, frozen or dried fish	
R13)	Milk and milk products: Milk from goats, camels, cows and sheep, fermented milk, mursik, amarurano, yoghurt, cheese and other products	
R14)	Sugar, sweets and soft drinks: Table sugar, juggary, sugar cane, honey, sugar-based cold drinks (sodas, pops, fruit drinks with added sugar), other savored drinks and concentrates; sugary foods like candies, cakes, chocolate etc.	
R15)	Oils And Fats Oil, fats or butter added to food or used for cooking	
R16)	Spices, Condiments, Beverages Spices (chili, salt), condiments (fish sauce, sauce, hot sauce), coffee, tea, alcoholic beverages, local brew	

Section R **Part 2: Food Security** In the last 12 months, was there a time when	1=Yes 0=No

R17) You or others in your immediate household were worried you would run out of food because of lack of money or other resources	
R18) You or others in your immediate household were unable to eat healthy and nutritious food because of lack of money or other resources	
R19) You or others in your immediate household ate only a few kinds of food because of lack of money or other resources	
R20) You or others in your household had to skip a meal because there was not enough money or other resources to get food	
R21) You or others in your immediate household ate less than you thought you should because of a lack of money or other resources	
R22) Your immediate household ran out of food because of the lack of money or other resources	
R23)You or others in your household were hungry but did not eat because there was not enough money or other resources for food	
R24) You or others in your household went without eating for a whole day because of lack of money or other resources	

Section S: Household income

Income Source	Did anyone in your household earn income from this source last year)? 1=yes, 0=no skip	If Yes, what is the total income per month (KES)		If yes w per year
	S01	S02		SO3
1.Informal Employment /casual labour				
2.Formal employment				
3.Agricultural /agribusiness				
4.Business				
5.Remittances				
6.Petty trade (sale of wares or other products in the market apart from the listed items)				
7.Pension				
8.Rented out properties				
9.Others (Specify)____				

Section T: Household expenditure

Please estimate how much the household spent on each item in a weekly, monthly, annual basis (Ksh)

Item	Monthly (T01)	Yearly (T02)	Item	Yearly (T03)
Food				
Clothes, shoes, bags, accessories			School fees	
Washing powder, soap			Student uniform	
Hairdressing			Tuition fee	
Electricity			Rental fee	
Water			School bus	
Rent			Pocket money& lunch	
Gas, charcoal. firewood			Medicinal purchases	
Waste			Doctor fee	
Fuel for car			Hospital bills	
Public transport			Donations	
Airtime, charging			Religious fee	
Other transportation, communication			Remittances	
Insurance for car, motorbike			Gambling	

If respondent cannot estimate/recall expenditure on food, break it down as follows What is the average amount of money spent on the following In every 7 days?			
Food commodity	**Price**	**Food commodity**	**Price**
Rice		Herbs and spices e.g. onion, chilli	
Maize/maize flour		Roots and tubers e.g. potatoes, cassava	
Millet		Fats and oils e.g. cooking fat	
Banana		Beef/pork/mutton	
Beans, grains, other pulses		Eggs	
Milk and milk products		Vegetables	
Bread		Fruits	
Take away food and eat outs		Food ingredients e.g. spices, salt, sugar	
Beverages: coffee cocoa, juice			

Total		Total	

Total yearly income ____

(*To be computed by enumerator)*

Appendix II: Choice experiment blocks

Choice card 1

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these
Disease resistance	1	0	
Yield	5	25	
Maturity period	6	3	
Price	750	750	
Your choice			

Choice card 2

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	0	1	
Yield	5	25	
Maturity period	4	6	
Price	750	1700	
Your choice			

Choice card 3

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	0	1	
Yield	12	12	
Maturity period	5	5	
Price	1250	1700	
Your choice			

Choice card 4

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these

Disease resistance	1	0	
Yield	5	25	
Maturity period	3	6	
Price	1250	750	
Your choice			

Choice card 5

	Option 1	**Option 2**	**Option 3**
Bio-fortification	1	0	None of these
Disease resistance	0	1	
Yield	18	12	
Maturity period	4	5	
Price	250	1250	
Your choice			

Choice card 6

	Option 1	**Option 2**	**Option 3**
Bio-fortification	0	1	None of these
Disease resistance	1	0	
Yield	12	25	
Maturity period	6	3	
Price	250	1700	
Your choice			

Choice card 7

	Option 1	**Option 2**	**Option 3**
Bio-fortification	1	0	None of these
Disease resistance	0	1	
Yield	5	18	
Maturity period	5	4	
Price	1250	1250	
Your choice			

Choice card 8

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	1	0	
Yield	18	5	
Maturity period	4	5	
Price	1700	750	
Your choice			

Choice card 9

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these
Disease resistance	1	0	
Yield	25	5	
Maturity period	6	3	
Price	1700	250	
Your choice			

Choice card 10

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	0	1	
Yield	25	5	
Maturity period	6	3	
Price	750	750	
Your choice			

Choice card 11

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	1	0	

Yield	25	5	
Maturity period	3	6	
Price	1700	250	
Your choice			

Choice card 12

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	1	0	
Yield	18	18	
Maturity period	3	5	
Price	250	1700	
Your choice			

Choice card 13

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these
Disease resistance	0	1	
Yield	25	12	
Maturity period	5	4	
Price	750	1250	
Your choice			

Choice card 14

	Option 1	Option 2	Option 3
Bio-fortification	0	1	None of these
Disease resistance	0	1	
Yield	12	18	
Maturity period	5	4	
Price	1250	250	
Your choice			

Choice card 15

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these
Disease resistance	1	0	

Yield	18	12	
Maturity period	4	4	
Price	250	1250	
Your choice			

Choice card 16

	Option 1	Option 2	Option 3
Bio-fortification	1	0	None of these
Disease resistance	0	1	
Yield	12	18	
Maturity period	3	6	
Price	1700	250	

Appendix III: Multipliers questionnaire

We are a team of researchers from Jomo Kenyatta University of Agriculture and Technology, undertaking a study that seeks to understand **sweet potato seed systems in Kenya**. As part of the study, we are conducting a survey among sweet potato vine multipliers and you have been identified as one of the respondents. Your participation is entirely voluntary and the information you give will be treated confidentially. You can choose to answer or not answer any question. The information you give will be reported together with that of others and you will not be specifically identified in the report. In case you decline, your lack of participation will not have any adverse consequences on you. You are free to withdraw from the research any time you feel uncomfortable. The questionnaire will take 20-30minutes to complete. By answering the questionnaire, you are acknowledging that you understand the terms of participation and that you consent to those terms.

Identification	
Date	
County	
Sub-county	
Ward	
Latitude	
Longitude	
Name of interviewee	
Gender 1=Male 0=Female	
Type of multiplication 1=Individual 0=Group	
Relationship to multiplier/owner 1=Owner 2=Spouse 3=Employee 4=Child	

	Question	Indicator	Response
1	Type of ownership	1=Individual 0=Group	
2	If individual, what is the gender of the owner	1=Male 0=Female	
	Age of the owner		
	Education level	1 =Informal 2= Primary 3 =Secondary 4=Tertiary	
	Total land owned	(acres)	
	Total land size under sweet potato multiplication per season	(acres)	
3	If Group, what is the gender of the members	1= Male 2=Female 3=Both male and female	

	Age range of the members	(youngest-oldest)	
	Land cultivated by the group	(acres)	
	Total land size under sweetpotato multiplication per season	(acres)	
4	Experience in sweet potato seed multiplication	Years	
5	Multiplication level	1=Basic seed 2=DVM- rapid multiplication 3=DVM- conventional multiplication	
6	What is your source of planting material	1=Multiplier 2=Institution (please state) 3=Sweetpotato processor 4=Own farm 5=Other farmers	1. 2. 3.
7	Who are the customers of your planting material	1= Farmers 2=Institutions 3=Traders 4=Events e.g. ag shows	
8	How much do you sell your planting material	___________________ Ksh/small bundle ___________________ Ksh/large bundle ____________________Ksh/_________kg bag	
9	Are you contracted to produce planting material	1=Yes 0=No	
	If yes, by who?		
10	Where do you source water for your multiplication cite	1=Rains 2=Stored rain water 3=well/borehole 4=Irrigation 5=River/stream	
	Distance to the source of water	(in metres)	
Clean planting material			
1	Have you ever heard of clean planting material	1=Yes 0=No	
2	Have you ever obtained clean seed	1=Yes 0=No	
	If yes: Which year		
	What was the source	1=Multiplier 2=Institution (please state) 3=Sweetpotato processor 4=Own farm 5=Other farmers	
	Have you ever obtained replacement material?	1=Yes 0=No	
	If yes, How frequent do you obtain the replacement material	1=Yearly 2=Every season	

3	If no, to 10 why have you never multiplied clean seed?	1=Lack of access to clean material 2=Cost of clean material 3=Lack of desired varieties of clean material 4=Farmers would not be willing to buy clean material	
4	Would you be willing to multiply clean material	1=Yes 0=No	
	Training		
1	Have you ever obtained training on multiplication	1=Yes 0=No	
2a	If yes, Who was the provider of the training	1=Farmer field schools 2=Demonstration trials 3=Institution(state) 4=Govt extension officer 5=Private extension	
	What was the training on	1=Production practices 2=Clean seed 3=Marketing 4=Construction of net screens	
3	Would you like to receive (more) training?	1=Yes 0=No	
4	Which specific areas would you want to be trained on?		

Practices In the last 12 months, have you practiced the following: (1=Yes 0=No)			
Conserving vines during dry season		Labelling of multiplication plot	
Weeding		Labelling planting material	
Use of seed beds		Close spacing	
Use of short cuttings (30cm)		Rotation	

Social norms/ Social obligation 1=Strongly disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly agree	
1) I can only gift vines from root production field not multiplication plot	
2) I can gift small quantities of vines from multiplication plot	
3) Gifting serves as a way of risk spreading to avoid loss of a variety	
4) I would only give out vines while they are in plenty	

5) Gifting of vines helps to avoid theft of vines from multiplication plot	

In the past one year:								
Which varieties were multiplied?	Variety Characteristic	Source of seed planted	How did you acquire the seed	Units of seed measurement	Quantity	Price per unit	Total cost	Distance from place of acquisition
1= Bungoma 2=Kiganda 3= Kipunda 4= Kabodee 5=Vitaa	1= Red skin 2=white skin 3=Orange fleshed 4=White fleshed 5=Purple flesh 6=yellow flesh	1=Public entity e.g. KALRO 2=Private company 3=Individual multiplier	1=Purchased 2=Credit 3=Gifted/Freely given	1=KG 2=No in 30 cm long 3=90 kg bag 4=50 kg bag	Number			

Expenditure
Costs incurred in sweet potato seed multiplication per season

Input	Quantity	Unit	Price per unit	Total cost
Fertilizer				
Manure				
Pesticides				
Hired machinery				
Transport				
Irrigation				
Irrigation Water				
Electricity				
Fuel				
Seed purchase				
Gunny bags				

Labor	Provider 1=Hired 0=own	Man days	Rate	Total Ksh
Permanent labor				
Land preparation				
Planting				
1st weeding				
2nd weeding				
Irrigation labor				
1st Harvesting				
2nd harvest				
3rd harvest				
Sorting and bagging				

Institutional Arrangements		
1. Did any of the household members obtain or access credit over the last one year	1= Yes 0=No	
2. If yes who was the provider?	1= Commercial bank 2= Micro-finance 3=cooperative 4= shylock 5=mobile credit 6=Sacco 7=Family/friends 8=Chama group 9= contractual outgrower arrangement 10=Other(please specify)	
3. Was any part of the credit used in the sweet potato multiplication business?	1=Yes 0= No	
4. If yes, what was the loan used for	1= purchase seed 2= for marketing and value addition activities 3= buy land 4= construction of farm structure 5=purchase of agricultural machinery 6= payment of labour	
5. Do you have certification as a multiplier	1=yes 0=No	
6. Do you have a multiplication license?	1=yes 0=No	
7. Is there any fees paid for multiplication?	1=yes 0=No	
8. Are you aware of KEPHIS regulations on seed multiplication	1=Yes 0=No	

9. Distance to the nearest market		
10. Distance to nearest all weather road		

Apart from sweetpotato, do you multiply any other material?	1=Yes 0=No	
If yes, for which crop?		
Do you produce sweet potato tubers?	1=Yes 0=No	
No. of crops cultivated		
List of the crops cultivated		

What are the challenges faced in your multiplication business?

Appendix IV: FGD tool

Date	
Location: (Indicate: county, sub-county, ward)	
In attendance: Male Female	

1) What are the main crops grown in the area and how would you rank them in their order of importance
2) What is the importance placed n sweet potato in your area
3) What are the main purposes or reasons for sweet potato production
4) State and rank the challenges faced in sweet potato production
5) Are there extension services received on sweet potato production in the area? If yes, who are the providers and are the services beneficial?
6) What are the arrangements involved in sweet potato sale and marketing?
7) In production of sweet potato, which diseases and pests are the most prevalent?
8) What level of damage and losses is caused by pests and diseases?
9) Where do you source sweet potato vines?
10) What arrangements are used during sourcing of sweet potato vines?
11) Are you able to recognize whether planting material is infested with pest and diseases?
12) Are you able to obtain sweet potato planting material in a timely manner?
13) Which varieties of sweet potato are planted in the area?
14) Have you ever heard of clean seed and what do you know about clean seed?
15) Would you be willing to pay for clean seed? What amounts would you be willing to obtain a 90 KG bag of clean seed?
16) What are your preferences on sweet potato attributes (probe for disease resistance, pest resistance, drought tolerance, early maturity, yield level, price of seed, fortification of sweet potato, color of the skin, taste of the tuber, cooking time of the tuber)

Appendix V: Key Informant Interview tool

Date	
Location: (Indicate: county, sub-county, ward)	
Name of Key Informant	
Occupation of key informant	

1) What crops do you breed?
2) Where do you source breeding material?
3) What would you say are the most preferred attributes for seed among farmers?
4) Is breeding being done for all these attributes?
5) Which varieties of sweet potato do you breed?
6) Where do you sell planting material?
7) Is the region of sale influenced by the varieties bred?
8) At what price are you selling seed?
9) Would you say that the profits you make are able to cover production costs?
10) Are you able to meet demand for seed?
11) Has demand for planting material been changing over the years?
12) What opportunities exist to increase adoption of clean seed?