AN ASSESSMENT OF ADOPTION OF TISSUE CULTURE BANANAS IN THE SEMI-ARID AREAS OF LOWER EASTERN REGION OF KENYA

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DECLARATION

I understand that plagiarism is an offence and I therefore declare that this thesis is my original work and has not been presented to any other institution for any other award.

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DEDICATION

This work is dedicated to my lovely wife, Veronica, and my children, Ken and Ruth, for their steadfast prayers, encouragement, understanding and support during my studies and when carrying out the research.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADB	African Development Bank
ASAL	Arid And Semi-Arid Lands
ASL	Above Sea Level
BBTV	Banana Bunchy Top Virus
CAADP	Comprehensive African Development Programme
CBS	Central Bureau Of Statistics
FAO	Food And Agriculture Organization/United Nations
GDP	Gross Domestic Product
GWS	Genome Wide Selection
ICRISAT	International Crops Research Institute Of The Semi-Arid Tropics
IDRC	International Development Research Centre
KALRO	Kenya Agricultural Livestock Research Organization (Old Kari)
KD&HS	Kenya Demographic & Health Survey
KEPHIS	Kenya Plant Health Inspectorate Services
KFSSG	Kenya Food Security Steering Group
KI-PSP	Kenya Interim Poverty Strategic Paper
KNBS	Kenya National Bureau Of Statistics
KNDP	Kenya National Development Programme
MABC	Marker-Assisted Backcrossing
MARS	Marker-Assisted Recurrent Selection
MAS	Marker-Assisted Selection
MB	Molecular Breeding
MOALF	Ministry Of Agriculture, Livestock And Fisheries
MT	Metric Tons
QDS	Quality Declared Seeds
RF	Rockefeller Foundation
SEKU	South Eastern Kenya University
SWC	Soil And Water Conservation
THVC	Traditional High Value Crops
URDP	Upland Research And Capacity Development Program

ABSTRACT

The importance of bananas cannot be underestimated worldwide. The main study objective was to assess the adoption and commercialization of tissue culture bananas in the riverine areas of the semi-arid areas of Lower Eastern region of Kenya. The specific objectives included determining respondents socio-economic, environmental and policy factors affecting adoption of tissue culture bananas in the region. This study was necessary due to the fact that there were many production gaps that exist which have limited adoption of the tissue culture bananas in the study region whose population is over three million and which occupies about 20,000 square kilometers. The data collected was analyzed using the SPSS version 17 as well as the internet based chi- square calculator. The study results found that environmental factor like soil and water conservation led to low rate of adoption. It also showed that 68 % of the respondents had soil and water conservation structures on their farms this being found significant in influencing the adoption of Tc bananas in the study area ($p < 0.05$) at ($p = 0.0021$). Others were maturity age in months ($p = 0.021$); availability of fence ($p = 0.0011$); importance of fencing (0.0013). Further still, from the logistic regression results on the socio-economic related factors the following factors were found significant (at $p < 0.05$) in influencing the adoption of tissue culture bananas in the study areas: gender ($p = 0.0150$); education ($p = 0.0380$); total land size ($p = 0.0110$); experience ($p = 0.0168$); tissue culture bananas knowledge ($p = 0.0100$) and tissue culture bananas Market ($p = 0.0030$). The chi-square Pearson's coefficient statistics results on policy related factors found to be significant at $p < 0.05$ included: gender of the respondents growing tissue culture bananas ($p = 0.008342$); livestock ownership as it affects adoption ($p = 0.043105$); training on tissue culture ($p = 0.00001$); education as it affects adoption ($p = 0.003153$); availability of extension services (public or private) ($p = 0.00001$) and group affiliations or membership ($p = 0.020642$). Farmers with access to market easily adopted tissue culture bananas. The study concluded that adoption was low at 22.68 % and was influenced by respondents' socio-economic factors such as gender, education, and tissue culture bananas knowledge, acreage of land under tissue culture bananas, marketing and extension services. The results also revealed that adoption was significantly influenced by the respondents' access to extension services in the study area. Markets significantly influenced the adoption of tissue culture bananas. Policy related factors like extension services delivery, education and training, sourcing and affordability of plantlets, knowledge and experience on tissue culture bananas and high cost of inputs were significant. The study concluded that these factors could be the reason for low adoption of Tc bananas farming and thus the study recommended the government to ensure availability of the same by establishing community nurseries, training them on how to propagate and manage nurseries. The study recommended amongst others, the provision of credit and subsidy, extension services and training of farmers on banana production aimed at increasing adoption of tissue culture bananas. To improve tissue culture bananas availability hence adoption in the study area, establishment of certified sources like nurseries in the wards is also recommended. This will mean availing tissue culture bananas plantlets closer to farmers.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Globally, Bananas (*Musa* spp.) are the fourth most important food security commodity to many households after rice (*Oryza sativa*), wheat (*Triticum aestivum*) and milk (Swennen, 1991). Banana belongs to the family of *Musaceae* and genus *Musa*. Modern day banana is a cross between two wild species, *Musa acuminata* and *Musa balbisiana*. By 1991, bananas had a worldwide production of 74 million metric tons (Mt) per year, of which 34 percent was from Africa (Swennen, 1991). In 2013, this figure had almost tripled to 201million Metric tons per year. (UNFAO, 2014). Today, banana is the most cultivated fruit crop globally being grown in 140 countries.

Tissue culture technological development and adoption is a major scientific milestone widely accepted as a means of addressing food productivity, food unavailability, its access and affordability to many households with surpluses reaching the market to generate the much needed income to many peasant farmers' worldwide (Chandler, 2005). In the Eastern Africa region, Uganda is well known as a major producer of many banana varieties. Tissue culture bananas have been grown in many parts of Kenya, especially in regions like Central Kenya, Upper Eastern Kenya, Rift Valley and parts of Nyanza especially the Kisii area, which have excelled in the production of commercial bananas for both the local and export market (MOALF, 2014). The semi-arid eastern areas of Ukambani (Makueni, Machakos and Kitui) are nearest to Nairobi and Mombasa markets but the region has lagged behind all others despite the favorable climatic and geographical factors (GOK, 2013; MOALF Reports, 2012).

In Kenya, tissue-cultured banana technology was introduced in 1997 in central and upper eastern regions to curtail the declining yields of banana due to pests and diseases. To date in 2017, these two areas are major producers of tissue culture bananas. The lower eastern region is yet to adopt the technology to significant scale (MOA, 2013). The later areas are also nearer to sources of researched certified planting materials like tissue culture (TC) bananas plantlets. These sources include Thika, Embu and Katumani research stations (all under Kenya Agriculture Research

Livestock Organization), and the universities like Jomo Kenyatta University of Agriculture and Technology, university of Nairobi and South Eastern Kenya University, among others. This semi-arid region has not benefited from the advanced technological development of tissue culture bananas due to low adoption linked to a combination of factors that require to be determined in order to overcome the prevailing food insecurity and high poverty level (GOK, 2009).

The aim of the study was therefore to determine and assess the factors influencing adoption of tissue culture bananas in the study area.

1.2 Statement of the research problem

In the Lower Eastern Counties of Kenya that comprise Makueni, Kitui and Machakos, the adoption of tissue culture bananas is low. This is despite the potential that exist to sustainably apply the technique in improving banana production (Wambugu *et al.*, 2004). The low adoption situation threatens food security, employment and income security in potential banana-producing areas, and could affect close to 3 million Kenyans whose livelihoods depend on farming (World Bank, 2009). The problem with tissue culture adoption is in its depressed scale in production compared to other areas. Adoption rate of tissue culture bananas in this region is between 10 -20 percent and the area under bananas is in total less than 5 percent (MOA Report, 2012). The low adoption of tissue culture bananas in Lower Eastern Region could be due to households' related factors, policy oriented factors, socio-economic and environmental related factors which are not so far assessed (MOA, 2013). There is notable inadequacy in scholarly knowledge in reference to tissue culture bananas in the Lower Eastern region counties of Makueni, Kitui and Machakos (MOA, 2013). The average poverty index in the targeted study region is on average above 62 percent with food insecurity at 60 percent (GOK, 2009). Adoption of tissue culture bananas is one way of poverty alleviation through sustainable income generation and enhanced food status in the region (MOA, 2013).

1.3 Study Objectives

1.3.1 General Objective

To assess the adoption of tissue culture bananas in the semi-arid areas of Lower Eastern Kenya.

1.3.2 Specific Objectives

i. To assess the socio-economic factors affecting adoption of tissue culture bananas in the Lower Eastern Region of Kenya
ii. To assess the environmental factors affecting adoption of tissue culture bananas in the study area
iii. To assess policy factors affecting tissue culture bananas in the study area

1.4 Research Questions

i. What are the socio-economic factors affecting adoption of tissue culture bananas in the Lower Eastern Region of Kenya?
ii. What are the environmental factors affecting adoption?
iii. What are the policies related factors affecting adoption?

1.5 Justification of the Study

Research work in Central Kenya (Wambugu *et al*., 2004), Upper Eastern region (Nguthi *et al*., 2007) and in Western Kenya (Wanyama et al., 2013) documented factors affecting banana farming and adoption, but no such studies have been carried out in Makueni, Machakos and Kitui Counties. Though a lot has been done and documented on the subject in other parts of Kenya, adoption of tissue culture bananas is still low in the study area as they are not readily visible in the farms even as one transverses the areas (Diao *et al*., 2007).

The study results would be beneficial to the farmers, the development partners and extension agents in both public and private organizations, in promoting tissue culture bananas technology as an intervention to solving banana production.

The study findings form a basis to inform the county governments of Makueni, Kitui and Machakos on the potential of tissue culture bananas to contribute in mitigating food insecurity in the region. Adoption of tissue culture bananas will be an income generating activity thus reducing poverty.

1.6 Limitations/ Delimitations

This research work had limitations arising from long distances apart to the three clusters, inadequate resources and time to reach the whole population. However, this limitation was sorted by scientifically using a representative samples thus avoiding use of the entire population for the research study which reduced the time. Proper work planning, training of the enumerators and time management, availability and cooperation received from the respondents as well experience and knowledge of the study area worked well to the team's success in data collection. The use of the phone was limited by poor internet strength in the remote parts of Kalawa and Thaana.

1.7 Assumptions

The assumption that the study would take six days in total at two days per cluster was hampered by the large land sizes, the poor terrain as well as communication issues in terms of poor roads and internet connections. Corrections done to the questionnaire by the supervisors and consultations made the work easier.

1.8 Organization of the Study

The study commenced with desk top research and the literature review on the subject, methodology that entailed study area visit for details, development and testing of the questionnaire, research design, sample size determination, data collection and analysis. The training ahead of the study and the pre testing done to the questionnaire was a big step forward in the organization and realization of this work. Proper work plan and time management availability and cooperation received from the respondents as well research teams experience and knowledge of the study area worked to the study success. Study results and their discussion as well as the conclusion and recommendations are also presented. There was the discovery that more study is needed in the following areas: 1) Variety suitability trials on the appropriate tissues culture cultivars in the Lower Eastern Counties; 2) Soil mapping studies for detailed fertility status on riverine areas of Lower Eastern Counties; 3) Economic and nutritional appraisal of tissues culture bananas in kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Tissue Culture bananas adoption to household's food security

Governments' world over have used improved technologies as a major strategy towards increased agricultural productivity; promotion of food and livelihood security; employment creation and poverty alleviation (Diao et *al*., 2007). Kenya government has continued to advocate and promote research and development of new technology to address food security and income generation concerns, in fact about 75 percent of the population earns a living from agriculture (Nguthi *et al.*, 2007). The agricultural sector contributes about 30 percent of the GDP and accounts for 80 percent of national employment, mainly in the rural areas (Marra *et al.,* 2001).

In addition, the sector contributes more than 60 percent of the total export earnings and about 45 percent of government revenue, while providing for most of the country's food requirements (Nguthi *et al.*, 2007). The farming sector is estimated to have a further indirect contribution of nearly 27 percent of GDP through linkages with manufacturing, agro processing, distribution, and other service-related sectors (Mbogo *et al.,* 2003). In the first decade after independence agricultural production grew by 4.7 percent annually (Diao et *al*., 2007). However, this impressive growth rate did not continue in the subsequent decades and today agricultural production has shrunk to an annual growth rate of 1.8 percent (Mbogo *et al.,* 2003). Technology adoption is envisaged to kick start this sorry trend and contribute to food and employment demand by the rising population (Nguthi *et. al*., 2007). Cockburn in 2002, indicated that the world population was less than 2billion at the beginning of 19th century but by the year 2000, the number had tripled to 6 billion (Diao *et al*., 2007). Kenya's population on the other hand has more than tripled from 10.9 million in 1969 to 38.6 million in 2009 (Mbogo *et al.,* 2003). Given the high number of births per woman (an average of 4.6 children per woman), the population will continue to increase steadily (Bacerril *et. al*., 2005). Because more people in the developing world are malnourished (Ruben *et al.,* 2011), it will be necessary to increase current levels of food production more than proportional to population growth, so as to provide them with an adequate diet. This implies that, in future, developing countries such as Kenya that have a high population growth rate will be unable to meet their food demand as opposed to the developed countries, unless a solution is obtained (Qaim *et. al.*, 2012).

Indeed, the gap between food production and food demand in developing countries will worsen the existing problems of hunger, malnutrition and poverty (Qaim *et. al.*, 2012). According to scholars, it is quite unfortunate that technologies widely used during the green revolution, no longer neither provide the needed breakthroughs in yield potentials nor give solutions to complex problems of pests, diseases and drought stress (Karembu *et al.*, 2010). Karembu *et al.*, (2010) further asserts that the current state of agricultural technologies will not be able to meet the production challenge ahead. Therefore, new approaches will be required in order to expand food production (Karembu *et al*., 2010).

Food security is at risk in the next five years. Malnutrition is also rampant while diseases like HIV/AIDS, Kwashiorkor and Marasmus that require proper diets and nutrition for management require attention (Kassie *et al*., 2013). These challenges require stakeholders including governments to develop technologies and policies that meet the needs of affected farming households and to maintain high productivity levels (Nguthi *et al.*, 2007). Some concerned development partners and government agencies have been involved in the development and dissemination of the tissue-cultured banana technology in order to increase income and food security which will ultimately ensure the livelihood security of small-scale farming households is improved (Karembu *et al.*, 2010).

Banana is one of the crops that have received increased research attention over the last ten years in Kenya (Wambugu *et al.*, 2004). Previously the crop was considered a semi-subsistence women's crop that provided more or less continuous income flow throughout the year, even under a low input regime. In recent years the crop has become an important commercial crop and this increase in commercialization is attributed to demand due to increasing urbanization (Qaim *et al.*, 2009). The banana has the potential for food and livelihood security as it can both be consumed at home as a staple food and sold in the market for cash (Qaim *et al.*, 2009). Adoption of tissue culture just like other far reaching technologies has the benefit of enhancing food availability, income generation arising from sales of produce, increased revenue in form of cess to the government and also employment opportunities to both women and youth (Wambugu, 2012). Increased adoption can turn around the current low food security situation at the households levels with bananas becoming a ready source of food (Chandler, 1995) while at the same time a commercial engagement to the affected community for income generation at the market level. This means the target region can be an exporter as well as a consumer of bananas (Qaim *et al.*, 2012).

Wambugu *et al.*, (2004) adds that Eastern Kenya has continued to import ripe bananas from other regions due to low adoption and thus recommends for more studies on reasons to improve adoption and therefore production of tissue culture bananas. In 1990, for example, 1 kilo of banana cost Kshs.5.00; in 1995 the same was Kshs.15; and in 2000 it was Kshs.30 (GOK/CBS, 2012). This growth in pricing is due to increased demand and supply is not adequate and the fact that population is exponentially rising especially in urban areas (Mathenge *et. al*., 2015). Tissue culture in Murang'a County especially Makuyu area is a business employing many people who are directly and indirectly involved (Mathenge *et. al*., 2015). Tissue culture as a technology is more beneficial in addressing the effects of climate change due to its adaptability characteristics (MOALF, 2011). In 2013, unit price for ripe banana fruits ranged from ksh.7-12 in the large towns and between ksh.10-15 as one moves deeper into the non-producing areas (MOALF, 2011). According to Karembu *et al.*, 2002), tissue culture bananas are diverse in cultivars and have additional nutritional benefits and their adoption can tackle food deficit and malnutrition in this region (Karembu *et al.*, 2010).

Banana is the world's most widely known and distributed fruit (Bassette, 2003), eaten either raw or cooked, and may be processed into starch, chips, puree, beer, vinegar or dried. Bananas are rich in energy (128 kilo calories/100 grams), and vitamin C and A (Chandler, 1995). Banana fruits have a very high content of potassium (K) and wide potassium (K): sodium (Na) ratio, imparting a protective effect of K against excessive Na intake in diets (Barrette et al., 2003). Banana is rich in natural antioxidants such as vitamin C and vitamin E. Banana consumption reduces deficiencies that arise in several countries; such as vitamin A deficiency that leads to serious health problems, especially in children in low-income regions of the world, such as parts of Asia, Africa and Latin America (Barrette et al., 2003). Similarly, it reduces micronutrient deficiencies of iron and zinc which results in serious health problems such as mental and physical retardation, reduced resistance to infections and hypogonadism (Karembu *et al.*, 2010).

The introduction of the tissue culture technique for rapid propagation of clean planting material to Eastern Kenya in 1997 was thus perceived as having the potential to help reverse the declining trends of the crop (Kathenge *et al*., 2016). The Kenya Agricultural and Livestock Research Organization (KALRO) in collaboration with the Rockefeller Foundation (RF) and International Development Research Centre (IDRC), engaged in a project for the production and delivery of clean banana planting material to smallholder farmers in the country (Nguthi *et al*., 2007). The production constraints of *Musa* spp have been well documented (Pillay *et al*., 2002; Pillay et al., 2006). The production of bananas worldwide is threatened by a complex of foliar diseases, nematodes, viruses and pests (Kabunga *et al*., 2012). The use of resistant varieties is considered to be the most effective, economical and environmentally friendly approach to controlling diseases and pests. Two of the most important fungal diseases include black Sigatoka Mycosphaerella fijiensis Morelet) and fusarium wilt (Fusarium oxysporum Schlect. f.spp. cubense (Nguthi *et al*., 2007). The main pests include a complex of nematodes (Radopholus similis, Pratylenchus spp. Helicotylenchus-italicize appropriately) and the banana weevil (*Cosmopolites sordidus Germar*). New diseases such as banana Xanthomonas wilt (BXW) have been recently identified in East Africa (Karembu *et al*., 2010).

To improve banana productivity and safeguard sustainable banana production for small-scale farmers, clean, high quality planting material is crucial (Karembu *et al.*, 2010). According to Wanyama *et al.*, 2013, in East African smallholder systems, new banana fields are traditionally planted with suckers. However, the use of tissue culture bananas plants is increasing, because they are pest and disease free, grow more vigorously, are more uniform, allowing for more efficient marketing and can be produced in large quantities in short periods of time, thus permitting faster distribution of planting material and new cultivars. As such, the use of tissue culture bananas plantlets can support farmers to make the transition from subsistence to small-scale commercial farming (Wanyama *et al*., 2013). The most important objectives of Musa breeding include: increased bunch size and yield; host plant resistance against the major pathogens including those causing sigatoka, fusarium and Xanthomonas wilts, and viruses; host plant resistance against nematodes and insect pests; fruit quality traits, e.g., increased vitamin A, iron and zinc levels; better adaptation to abiotic stresses such as drought, heat and other stresses that may be enforced by predictions in climate change (Wambugu *et al*., 2004)..

In Kenya, tissue culture bananas was recently estimated to constitute less than 7 percent of the total banana coverage area, while adoption rates in countries like Uganda and Burundi are significantly lower (Murero *et al*., 2014). A recent impact study for Kenya showed positive yield effects of tissue culture banana adoption, but also pointed out the importance of good extension and proper plantation management (Kabunga *et al.*, 2012). Tissue culture bananas plantlets require appropriate handling and management practices to optimize their benefits. Consequently, this additional effort and the cost of tissue culture bananas plantlets (US$1.20–2.00) pose an extra cost for the Kenyan farmer. The tissue culture bananas market in Burundi is presently served by two private laboratories and a public university and research organization which, together, produce at least 500,000 banana plantlets annually. Their main buyers are international non-governmental organizations (NGOs) and the Food and Agriculture Organization of the United Nations (FAO), which then usually distribute the plantlets at no cost to small-scale subsistence farmers. Plantlets are either directly distributed as part of wider agricultural development projects or through the provincial divisions of the Ministry of Agriculture. It is noteworthy that the free plantlet distribution is largely unaccompanied by training and/or an input package. Despite business entry barriers, tissue culture bananas production appears to be highly lucrative for the entrepreneurs, with profit margins estimated at up to 100 percent (Kabunga *et al.*, 2012).

The private sector producing tissue culture bananas plantlets is, however, not regulated in terms of virus-free certified plantings and proper production standards, thereby leading to high variability in the quality of the plantlets. Despite a thriving private sector and the free distribution of tissue culture bananas plantlets to the Burundian population, there is only anecdotal information on the impact of tissue culture plantlets on banana yields and household welfare (Langyintuo *et al*., 2008). This paper examines the impact of tissue culture bananas technology in Burundi, focusing on yield and gross margin outcomes by employing non-parametric evaluation techniques. Specifically, a propensity score model is employed to control the self-selection that normally arises when technology adoption is not randomly assigned (Ruben *et al*., 2011).

Karembu (2010) adds that biotechnology has the potential to provide rapid solutions in a more precise and cost effective manner. Both Wambugu (2004) and Anyango (2007) acknowledge its potential and assert that Africa, more than any other continent in the world, urgently needed it to improve her food status. But the benefits of biotechnology among smallholder famers can only accrue as long as the technology is in use. In most diffusion-adoption research, there has been a general concern with process of initial adoption decision (Kabunga *et al.*, 2012).

2.2 Social factors affecting adoption of tissue culture banana

2.2.1 Gender of household head

Gender consideration in technology development and dissemination is critical such as those related to women's lack of control over production resources and social capital (e.g. land, attending meetings for new knowledge) and the existing gender differences; male headed households have mobility, participate in different meetings and have more exposure to information related to Tc Bananas; thus hypothesis that male headed households have more access to use Tc Bananas than women (Nyang *et al.,* 2010)

2.2.2 Household heads education level

Education affects the ability to receive, decode and understand information relevant to making innovative decisions (Chandler *et al.,* 1998); thus, the hypothesis that those farmers with more education are more likely to be adopters than farmers with less education. Farmers with higher education are herewith assumed to know how to read and write and are hypothesized to have more exposure to the external information and therefore accumulate new knowledge on agricultural innovations like tissue culture bananas because they have ability to analyze costs and benefits of new innovations (Forson *et al.,* 2001).

Rural education contributed to the adoption of technologies like irrigation for food production such as adoption in rice varieties, tissue culture bananas and chemical fertilizer technology (Nyang *et al*, 2010). Technology index has extremely high coefficient to the aggregate crop output. High elasticity of aggregate crop output with respect to technology indicates that output (Uttam *et al*., 2006). The study reveals that to increase the technology adoption level as well as its utilization to the fullest extent, we need to expand agricultural knowledge oriented education system in the rural areas of Bangladesh (Sani *et al*, 2014). In short, conventional economic theories treat farmer's education and adoption of technology as a catalyst of production (Perret *et al.,* 2006). However, endogenous growth models (Manda *et al*, 2015) have given more emphasis on the knowledge stock of human capital. A recent paper on economic growth theory, (Barrette, 2003), mentions that education (human capital) acts as an input for production with technology adoption being a catalyst. He stresses on four factors of production into account: physical capital, unskilled labor, human capital (for instance, schooling years) and an index of the level of technology. It is believed that the farm's capacity to produce more output from a given bundle of resources depends to a large extent on the knowledge stock of the farmer. Education increases the information acquisition ability and adjustment ability of the farmer, thereby providing awareness about real world possibilities and rational expectation for decision making. Thus, education helps farmers to decide to adopt modern technology and, thereby, increase output (Lidia *et al*., 2012).

Education helps farmers to decide to adopt modern technology and thereby, increase output. In short, conventional economic theories treat education as a catalyst of production, (Uttam *et al.*, 2006). Qaim *et al.*, (2010) mentions that education (human capital), acts as an input for production. The study recommends that farmers be educated to understand and appreciate the benefits of tissue culture technology as a tool for crop propagation. It is also imperative that the potential risks or disadvantages associated with this technology be communicated and carefully explained to the farmers. In this case, the possibility of encountering problems should always be made clear (Mbogo *et al*., 2003). Without proper communication and transparency, the potential of the technology to improve the lives of the rural poor can be easily be lost (Uttam *et al*., 2006).

2.2.3 Household family labor

Tissue culture planting requires deep holes, an expense to family labour. Family size here denoted as the number of people available at the household who work on the farm, is a relative factor to labor availability, and is assumed to influence the adoption of new technologies positively as its availability reduces the labor constraints faced in banana production (Uttam *et al*., 2006). Therefore, family labor is hypothesized to have impact on access, adoption and cultivation of tissue culture bananas. Seasonally-specific cultivation patterns of farm crop enterprises often create periodic labor shortages. New technologies that require labor inputs during such labor-scarce seasons are less likely to be adopted (Thorpe *et al.*, 2007). A case study of a bush fallow agricultural system in the Peruvian Amazon illustrates how seasonal labor shortages lead to farm management tradeoffs that affect the prospects of technology adoption (Thorpe *et al.*, 2007).

Hired labor use may influence the adoption of new tissue culture bananas technologies as its availability affects the labor constraints faced in banana production (Awotinde *et al*., 2012). Adoption of tissue culture bananas is hypothesized to demand additional labour in holes digging, terracing, digging, planting, weeding and harvesting including packaging for sale. The results suggest that the probability of a farmer adopting valuable farming technology increased if the farmer was more integrated with farmers' organizations, had contacts with nongovernmental organizations, was aware of the negative effect of chemicals on health and the environment, could rely on family labor, with availability of hired labour at the farm vicinity and had a farm located in an area with better soil conditions (Thorpe *et al.*, 2007). On the other hand, the probability of adoption of a high value technology such as tissue culture bananas was reduced by increases in farm size with reduced chance and availability of hired labour (Awotinde *et al.*, 2012).

2.2.4 Marital status of farm household heads

According to Uaiene *et al.*, (2012), marriage is equally hypothesized to influence the adoption of tissue culture bananas. Man or woman in a given family will have different believes about adoption of tissue culture bananas. There is mixed perception on genetically modified organisms amongst members in a family with married women more aware of genetically modified organisms (GMOs). Individuals in a marriage relationship have varying perceptions regarding GMOs, and some of these beliefs may affect adoption to tissue culture bananas.

Farmers have been testing the technology and a number of empirical studies have been undertaken over the years to identify the marital related factors influencing farmers' decision to adopt the technology (Pitt *et al*., 2003). This paper presents a synthesis of the results of adoption studies and highlights generic issues on the adoption of improved fallows in Zambia. The synthesis indicates that farmers' decision on technology adoption does not have a simple direct relationship of some technological characteristics only, but constitutes a matrix of factors including household characteristics, marital status, community level factors, socioeconomic constraints and incentives that farmers face, access to information, local institutional arrangements and macro policies on agriculture (Rodgers *et al*., 1995). Houses with developed marital lines and ideal family dimensions exhibited higher adoption of technologies and were able to meet their food security objectives (Pitt *et al*., 2003).

In a bid to address family efforts in achieving food security and wealth, there is need to adopt the proven agricultural technologies so as to heighten production as well as productivity and thereby the living condition of the rural poor (Pitt *et al*., 2013). Furthermore, for developing countries, the best way to catch up with developed countries is through agricultural technology diffusion and adoption (Forson *et al*., 2001). Additionally, in Nigeria, studies have acclaimed that production and productivity of tissue culture bananas would likely slow down and rural poverty would prevail more if attention is not given to the use and adoption of agricultural technologies (Uaiene *et al.*, (2011). and Nguluu *et al.,* (2014) purported that, since the need of the rapidly growing population could not be met by expanding the area under cultivation, developing, employing and disseminating yield increasing agricultural technologies is imperative. In their finding, (Couros *et al.,* (2003) purported about the direct effect of technology adoption on the farmer's income resulting from higher yields and prices (Couros *et al.*, (2003); Nguluu *et al.*, (2014).

It is perceived that farmers growing tissue culture bananas unlike other varieties have larger bunch and fingers, attractive colour and size, and are more palatable unlike the locally grown varieties. Their value rating and thus intensity of adoption are hypothesized to be higher (Kabunga *et al*., 2012). Yield effects of tissue culture bananas studies in Kenya, concludes the difference in yield between yields of traditional varieties compared to tissue culture, showing significant adoption of the later due to the recorded high yields (Pitt *et al*., 2003). Tissue culture production in Meru central area recorded upto seven times by weight in yield for tissue culture compared to the traditional ones (Qaim *et al*., 2012).

2.2.5 Extension services contact to the households

According to Adesina *et al.,* 2005, the adoption rate is directly related to persuasion and persistent information passage to the farmers about a technology. Agricultural extension can enhance the efficiency of making adoption decisions. Based on the innovation-diffusion literature (Adesina and Forson, 2005), it is hypothesized that extension visit to farmers is positively related to adoption by exposing farmers to new information and technical skills. In this study, this is referred to as the number of extension contacts with the respondent in a year. Although farmers may be experts in what they do, intensified production requires information and training on methods and the scientific properties of the inputs and their application (Pitt *et al*., 2003 and Nguluu *et al.,* (2014).
Therefore, there is still an opportunity for increased production for this crop in area and hence poverty reduction through use of improved agricultural technologies (Wambugu *et al*., 2012). Similar to other crops, for several years (more than 20 years) KALRO has been engaged in generation of improved agricultural technologies for tissue culture bananas farming for use by farmers in eastern and central Kenya including farmers in Ukambani region to enhance productivity (Mathenge *et al.,* 2015). Researchers have remained the main link through extension

staff in the dissemination of technology to bring the materials to close proximity of farmers (Wambugu *et* al., 2012). The Participation of households in tissue culture bananas production is also a variable (Langat *et al*., 2013). For a household participate in tissue culture bananas as a family business project the household head could be expected to have good knowledge on the benefits of tissue culture bananas technology, and thus adopting it easily (Nyang *et al*., 2010). Membership in farmer groups is a variable which takes a value for being a member to a registered farmer group (Nyang *et al.,* 2010). Some of the households who are members of merry-go-round groups could be provided avenue to multiple services like credit and access to cash. Therefore, it is hypothesized that farmers who are members of groups could have more access to new technologies like tissue culture bananas (Qaim *et al.*, 2012).

2.2.6 Households age and experience in banana farming

This refers to the number of years the household head has been involved in banana farming. A farmer having more experience in banana farming can have higher tendency towards using the new technologies and vice versa (Chandler, 2005). The farm household heads' age measured in years may influence both the decision to adopt and extent of adoption of improved tissue culture bananas (Awotinde *et al*., 2012). The older farmers are more risk averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies like Tc bananas (Qaim *et al.*, 2012).

The age distribution of widows is much flatter and nearly normally distributed as compared to men (Beshir *et al*., 2014). This leftward shift in the age distribution of widows is especially strong in the regions highly affected by war making the community to adopt technology in farming very low. Bandiera et *al.,* (2009) argues that age is a significant factor to technology adoption like in tissue culture. This refers to the number of years the household head has been involved in farming.

2.3. Economic factors influencing adoption of Tissue Culture bananas

2.3.1 Households' economic related factors

Economics is the key determinant for the application of molecular markers in genetic improvement programs (Adesina *et al.*, 2005). Other factors that influence the cost of utilizing marker-aided breeding included inheritance of the trait, method of phenotypic evaluation, and high costs (Couros *et al*., 2003). The main factors that slow down using molecular breeding technologies in most developing countries include poor infrastructure; inadequate capacity and operational support; and lack of an enabling policy, statutory and regulatory framework at country level, which in turn affects research institutions (Dekkers, 2002). Despite these difficulties some developing countries are making progress in using biotechnology for *Musa* spp (Couros *et al*., 2003). According to Thorpe, (2007), today in countries like Uganda, banana, beer and wine are found quite lucrative. Elsewhere banana marketing is a major economic activity as the fruits are sold in the local markets and major towns (Thorpe *et al*., 2007). It is grown for both subsistence and commercial purposes but the potential benefit of tissue culture materials is yet to be fully realized amongst Kenyan population due to low adoption (Rodgers *et al*., 2005). Though adoptable, the tissue culture bananas are highly suitable in the eastern region of Kenya and may significantly contribute to the improved food situation in areas very vulnerable to food insecurity (Wambugu *et al*., 2004).

According to Wambugu *et al.*, (2004), banana is a crucial fruit in many Kenya communities. Qaim *et al*., (2010) gives an in-depth socioeconomic study through analysis of preliminary benefits and impacts that could be brought about by the dissemination and adoption of tissue culture banana plantlets to resource-poor farmers in Kenya. This study reveals that if tissue culture is well adopted, it could transform food access, availability, affordability and adequacy, in the long run turning around food deficit situation in arid and semi-arid areas (Qaim *et al*., 2012). Wambugu *et al*., (2004) asserts that bananas have become increasingly costly and no longer serve as a ready supply of highly nutritious food and cash for the Kenyan population, particularly women and children. They are costly because supply is low due to the low adoption and demand is very high. According to Rodgers *et al*., (2005), the process of adoption consist of a series of intricate actions and choices through which for an individual to be an adopter, evaluates a new innovation or idea and then decides on whether to adopt or reject the practice. Adoption theory states that following the period of rapid growth, the innovations rate of adoption will gradually stabilize and finally decline. That is, innovations go through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth (Bandiera *et al*., 2002). Extension services and training to the adopter can accelerate the adoption level of a given technology; the analysis of the study herein was based on adoption theory in extension services as it corresponds to the Tc bananas in the study area which includes different stages. Awareness and knowledge stage involves a stage where individual or group gets the idea about the issue to be adopted for the first time, but lacks sufficient information about it, this limiting the attempt to adopt (Rodgers, 2005). This is followed by the interest stage whereby the group or individual becomes interested in the new idea and seeks more information about it prior to adopting or knowing about it (Rodgers, *et al.*, 2005). After this stage there is the evaluation stage.

The individual or group weighs the advantages and disadvantages of the new idea, before deciding whether or not to adopt. Then the person tries to adopt the new idea on a small scale to find out its utility. The group or individual accepts the new idea and makes it part of his or their lifestyle. The rate at which a new idea will be adopted will depend on the characteristics of the idea (Rodgers, *et al.*, 2005). This regards the degree to which the new idea is better than the old or current. If the new idea is better relatively to the current it will take a very short time before it is adopted. Compatibility is another stage that refers to the degree of consistency of the new idea with the existing values of the people intended to adopt it.

The distance to the market, both for inputs and output, has been found to be a key issue in productivity analysis. Mbogo *et al.,* (2003), found that distance to the market and related transportation costs affect crop choice decisions and even adoption of technology. Distance to particularly inputs markets has a bearing on the inputs use and consequently productivity of a certain crop enterprise. According to a Tegemeo study, Barrette *et al.,* (2003), farmers can only invest their time and money in dairy production if they are assured of making profits thereof. Profit levels can thus affect adoption.

Price of the banana fruits in the market may also have a direct impact on the adoption behavior of farmers. If farmers perceive that there will be attractive price for the banana fruits, the probability of adoption and proportion of banana area under the tissue culture bananas cultivars would increase. Farmers' access to credit shows that tissue culture bananas cultivation is likely to be seen as an expensive venture. Many households have resorted to village economic empowerment groups Most smallholder farmers are expected to form a group (that can serve as collateral) to take credit from different credit sources. It is therefore hypothesized that, farmers who are unable to get credit are not likely to invest in tissue culture bananas production (Nyang *et al.*, 2010).

Farmers are expected to have good knowledge on benefits of tissue culture bananas. Therefore, it is expected that farmers who have positive information on tissue culture bananas will rate the technology highly (Nyang *et al.*, 2010). Physical distance of farmers from Tc banana sources; farmers who live near the certified tissue culture bananas plantlet sources materials are very likely to have the advantage of reducing cost of transportation and are likely to acquire them cheaply than those who live in more distant locations. Tissue culture bananas plantlets are bulky (Rodgers *et al.*, 2005), therefore, locational advantage is hypothesized to increase access and thereto adoption of tissue culture bananas. Access to good infrastructure can form a backbone for rural household commercialization. Farmers will grow perishable crops for markets only when they are assured that they can market them easily. Distance to the nearest road or market centre is used as a proxy for the cost of taking the produce to the market (Nyang *et al.*, 2010).

The proportion of income from banana is hypothesized to influence farmer's adoption of tissue culture bananas. This is because of the high-yielding attributes of tissue culture bananas compared to other varieties. Bananas preference thus adoption is related to its final use at the end of the value chain. Those that have multiple use or utilization (eaten fresh, cooked or ripened) are quite valuable. This has significant relationship to their adoption (Nyang *et al.*, 2010).

2.3.2 Off-farm income

The availability of off-farm income can affect the probability of adoption positively since it can increase the farmer's financial capacity to pay for improved inputs like buying tissue culture bananas plantlets, fertilizer, manure and hiring labour (Thorpe *et al.*, 2007). There is a need to adopt the proven agricultural technologies so as to heighten production as well as productivity and thereby the living conditions through improved incomes of the rural poor (Rodgers *et al.*, 2005). Furthermore, for developing countries, the best way to catch up with developed countries is through agricultural technology diffusion and adoption (Foster *et al.*, 2010). Additionally, in Nigeria, Uaiene *et al*., (2009) acclaimed that if attention is not given to the use and adoption of agricultural technologies they would likely slow down production and rural poverty would prevail. Pitt *et al.*, (2013) and Uaiene *et al.*,(2009) have purported that, since the need of the rapidly growing population could not be meet by expanding the area under cultivation, developing, employing and disseminating yield increasing agricultural technologies is imperative.

Since improved banana planting material like tissue culture bananas are more expensive relative to ordinary banana suckers, and cost of planting material is hypothesized to negatively influence the adoption of tissue culture bananas technology. The lower the price of the tissue culture planting material per unit sucker, the higher the adoption level and vice versa (Chandler, 2005). Cost is subjective to availability of funds (Qaim *et al.*, 2012). However, poverty and therefore lack of purchasing power significantly narrows the ability of households to procure technology like tissue culture bananas (Wanyama *et al*., 2007). According to Mbogo *et al*., (2003), high incidences of poverty and poor living standards have been some of the major development challenges in Mbeya rural district in Southern highlands zone of Tanzania (SHZ). Statistics show that in the year 2001 nearly one-third of the population in the area was living below poverty line (Robinson et *al.*, 1996; Qaim *et al.*, 2012). However, Mbeya rural district has relatively good climatic conditions that favor production of various types of crops (Qaim *et al.*, 2012). In order to make use of technologies, farmers should be able to get planting material either in the formal or informal distribution systems. Thus, seed availability is hypothesized to positively influence the adoption of tissue culture bananas technology. There is a correlationship between availability of technology to the information about it (Murero *et al*., 2007). There is dearth of information on the adoption of the disseminated technologies and factors hindering or promoting their adoption, information important for more informed decisions and programmes aiming at improving round potatoes production in the study area (Qaim *et al.*, 2009).

Rain-fed agriculture in lower eastern region is highly seasonal, unpredictable and carries some inherent risk sometimes coming in floods and storms. One form of self-insurance is engaging in off-farm employment. In poor countries where agriculture marketing is in the initial stages of development, other sources of income like salaries and money transfer through phones are very significant. The extra income could be used as an important source of income when it comes to investment in farm enterprises. The non-farm income could play an important role in enterprises choices and investments decisions like in the adoption of tissue culture bananas, (Rodgers *et al.*, 2005).

2.4 Environmental related factors in adoption of TC bananas

The study region is environmentally challenged in terms of aridity, topography and general climate. This has some relationship to the region's food basket. Environmental factors dictate food availability. The prevalent cases of hunger and malnutrition in parts of Eastern Kenya are partly a result of non-adoption of technological crop packages like tissue culture bananas yet in most of these areas there is favorable environment suitable to adoption (Qaim *et al*., 2009).

According to Karembu *et al.*, (2002), little information exists on why farmers have not adopted the tissue culture bananas even where soils are fertile, temperature and precipitation being favorable. Karembu *et al.*, (2002), concludes on the need to have more studies to determine the other factors such as those related to environment in order to answer to the question of why adoption of tissue culture bananas is not significant. Karembu *et al.*, (2002) found the tissue culture bananas technology as an appropriate intervention for the persistent decline in banana production due to infestation by pests, diseases and environmental degradation. The study shows the relationship between environmental factors and the prevalence of pests and diseases. The effects and economic importance of pests and diseases in bananas is further cited by Thorpe *et al.,* (2007). The benefits of adoption to the transformation of the youth and women in agriculture through horticulture farming in Kenya, is well elaborated by Rine *et al.*, (2009). The environment within the semi-arid areas has potential for establishment of banana plantation that could create income, food and employment, if only water harvesting and soil conservation can be done, (Robinson *et al*., 1996).

Tegemeo (2011) in a report on land ownership in Kenya notes that household land holdings have generally declined from 6.1 acres in 1997 to 5.8 acres in 2007. This is associated with environmental degradation through mismanagement. This decline was experienced in five out of the eight agro-regional zones, with marginal rain shadow registering the highest decline of 15 percent from 6.1 acres in 1997 to 4.4 acres in 2007 (Marra *et al.*, 2001). Western highlands, however, shows a slight increase in mean household land sizes from 2.2 to 2.4 acres during the panel period. The general decline in sizes of landholding reflects the effects of increased population pressures and sub-division in most areas of rural Kenya. This disruption on the environment may be irreversible or too expensive to rehabilitate. Heavy soil erosion causes shift in the soil elements important for the growth of plants. This is worsened by mineral leaching. This is a major concern in soil fertility. Land is denuded and thus degraded even in value. This is one reason contributing to poor adoption of the tissue culture bananas, (Wambugu *et al.*, 2004). The trends also show regional differences in the size of household land holdings, with households in the high potential maize zone owning an average of 10 acres. Households in the western and central highlands have the smallest land holdings (between 2 and 3 acres) while in Lower Eastern it is 5.0acres per household, (Tegemeo, 2011). The average cropped land per household has declined from 3.5 acres in 1997 to 3.4 acres in 2007. The declining trend in cropped area is also observed in all the regions except Eastern lowlands, where convergence of environmental factors like soils, temperatures and moisture and land use management interacts with heavy consequences to reduced adoption. Here the average area rose from 3.1 to 4.0 acres between 1997 and 2007.

The expansion in area in the Eastern lowlands may reflect less intense land pressures in this less densely populated zone and continued reliance on land intensification. Where environment factors like good precipitation occur such as in upper hill masses of Makueni (Mbooni, Kaiti, Kilome and Mbitini) and Kangundo and Kathiani in Machakos County land pressure from increased population density has had heavy repercussions to the available land thus farmers adoption to technologies like tissue culture bananas being low (MOALF,2012).

In the less privileged environments prolonged drought, undeveloped infrastructure, overreliance on rain fed agriculture, limited employment opportunities, weak market systems, inaccessibility to credit facilities, continued environmental degradation and poor agricultural practices are some factors affecting adoption of most preferred farm technologies that include tissue culture bananas (GOK report, 2015). The Critical environmental factors affecting Environmental factors (EF) include environmental factors, physical and natural characteristics such as location and area of land under cultivation, acreage, soil fertility status and access to water all year round are important in affecting tissue culture adoption (Adesina *et al.*, 2002). Geographical location of farmers positively and significantly influenced tissue culture bananas technology uptake. This implies that farmers located in that county were more likely to participate in tissue culture bananas technology production than those located in other areas. This is consistent with the fact that the hinterland county areas and environs are favourable banana production zones and is also one of the main banana growing regions (Matuschke *et al.*, 2009).

Similar results have been reported by studies undertaken in Uganda on determinants of farm-level adoption of cultural practices for banana *Xanthomonas* wilt control. In addition, agro-ecological zone has been shown to influence the performance of banana varieties (Barrett *et al.*, 2003). This trade orientation significantly contributes to farm revenue and probably the likelihood in tissue culture bananas participation (Mbogoh *et al.*, 2003). Soil fertility levels results especially from variable farm fertility level experiments were negative and significant, implying that the lower the perceived fertility level, the higher the tissue culture bananas intensification and vice versa (Langat *et al.*, 2003). Since bananas generally require relatively high fertility levels, if the farms are relatively low in fertility levels, then expansion of tissue culture bananas is likely to be high but probably with relatively enhanced use of manure. This could also be attributed to low yield of tissue culture bananas technology under low fertility regimes. Reversing this trend requires optimal application of organic and inorganic fertilizers (Matuschke *et al.*, 2009).

Manure and mulch application experimental treatment results, are considered the traditional techniques for maintaining banana plot productivity. Farmers who applied manure intensified tissue culture bananas technology and had significant yield results. This was attributed to the fact that manure was available among the farmers and also not as expensive as inorganic fertilizers among farmers in the study region (Beshir *et al.*, 2003). Further experiments and results showed that farmers were aware that use of manure was part of the agronomic package of tissue culture bananas technology for one to realize full benefits of the technology. It was observed that farmers apply manure in banana orchards, with a majority of them applying at least half of 20-kg tin per stool. The results also showed a significant effect of manure on banana production. This contributed to the enhanced use of manure among farmers who were expanding tissue culture bananas technology (Beshir *et al.*, 2003)

The pressure of an increasing population and consequent increase in demand for food on the one hand and the depletion of arable land on the other have placed new emphasis on conventional plant breeding (Pillay *et al.*, 2011). However, conventional breeding of *Musa* spp. is handicapped by sterility and a number of other factors that are discussed in work done by Pillay *et al.*, (2011). The rapid development of molecular techniques based on relevant suitable media environment and their application to plant breeding has resulted in significant genetic gains in agricultural crops, some of which have already entered the market (Beshir *et al.*, 2003). The production of bananas worldwide is threatened by environmental related factors like complex of foliar diseases, nematodes, viruses and pests. The use of resistant varieties is considered to be the most effective, economical and environmentally friendly approach to controlling diseases and pests. Two of the most important fungal diseases include black Sigatoka (Mycosphaerella-italics spp) and fusarium wilt (*Fusarium oxysporum-spp*) (Kabunga *et al*., 2012). The issues of soil fertility in tissue cultures are known to be tolerant and responsive to soil status as a medium of growth (Kathenge *et al*., 2016). However, they are equally tolerant to poor soil status. Fertility conditions of the soil are hypothesized to be positively related to the high probability, use and intensity of Tc bananas varieties (Kathenge *et al*., 2016).

The farm size in hectares is the total land size owned by the household head, and it is a variable (Kabunga *et al.,* 2012). The larger the farm sizes the more the likelihood of allocating more land and accompanying resources to tissue culture bananas. The main hypothesis is that the farmer who cultivates larger size of land can utilize more capital and will demand tissue culture bananas the more. The soil and water conservation structures embraces a common belief that soil and water conservation is a major pre-requisite to success of most crop technology adoption in lower eastern region (Kathenge *et al.,* 2016).

The total livestock ownership is an environmental based factor and it is also an economic factor. The question will target the total number of animals possessed by the household measured in tropical livestock unit (TLU). Livestock manure when well decomposed could be used to add nutrient to the tissue culture bananas fields thus contributing to improved soil fertility. As the total number of animals in the household increases, the household would be less likely to go for new technology. This could be attributed to increased wealth and income base of farm households which makes more money available in the households that minimizes demand for innovation (Qaim *et al*., 2012).

The pests and diseases, are other factors which are perceived to influence the household's access to Tc bananas is their attitude on tissue culture bananas pests and diseases tolerance. Many farmers, as can be expected to have perception of tissue culture bananas being tolerant to pests and diseases. This is because tissue culture bananas are assumed to be certified clean material without any infections; pest and disease damage (Kathenge *et al.,* 2016). Other tissue culture bananas characteristics such as tolerance for biotic and abiotic stresses are likely to be perceived to have better fruit formation, good consumer attraction, good colour, better diseases, pests, and lodging tolerance, better yield potential (finger size, bunch size) and storability, early maturity and drought tolerance. The East African highland bananas are derived from the *acuminata* bananas of Southeast Asia and, like the dessert bananas; they are triploids. In genetic terms, crops that possess three sets of chromosomes (triploid) rather than two or four are sterile and produce no pollen (Kathenge *et al*., 2016).

According to Thorpe *et al.,* (2007), apart from their use as a tool of research, plant tissue culture techniques have in recent years, become of major industrial importance in the area of plant propagation, disease elimination, plant improvement and production of secondary metabolites.

The necessary conditions for tissue culture bananas propagation include proper supply of nutrients, appropriate pH medium, adequate temperature and proper gaseous and liquid environment. Adoption of Plant tissue culture technology is being widely used for large scale plant multiplication (Kathenge *et al.,* 2016).

According to Thorpe *et al.*, 2007, small pieces of tissue (named explants) can be used to produce hundreds and thousands of plants in a continuous process. A single explant can be multiplied into several thousand plants in a relatively short time period and space under controlled conditions, irrespective of the season and weather on a year round basis. Endangered, threatened and rare species have successfully been grown and conserved by micro propagation because of high coefficient of multiplication and small demands on number of initial plants and space.

In addition, plant tissue culture is considered to be the most efficient technology for crop improvement by the production of somaclonal and gametoclonal variants (Thorpe *et al.*, 2007). The introduced tissue culture bananas cultivars matured earlier and harbored fewer pests and diseases, and the technology is now embraced in schools. Hence, tissue culture bananas technology is replicable and transferable as a model to other parts of Kenya. The tissue culture bananas produce attracts higher sales incomes, while viewing tissue culture bananas production as a genuine business creates employment opportunities (Thorpe *et al.*, 2007). (Wambugu *et al.,* 2004) asserts that Agriculture continues to be the sole occupation in the continent and calling for inclusion of advanced technological transformation through adoption to enhance food availability to the expanding population. Adoption of tissue culture bananas technology, expanded irrigated area, exposure of farmers to modern agronomic practices, packaging and standardization (kg as unit weight instead of bunch size) and innovative post-harvest handling practices such as bulky ripening by bio ethylene sources and commercial grade acetylene; and inbuilt banana collection centres and linking farmers to buyers. In 2012, banana production constituted 38 percent of the total value of fruits produced in the country (Wambugu *et al.*, 2015).

The leading counties in banana production were: Meru (40 percent), Kirinyaga (21 percent), Tharaka-Nithi (19 percent), Murang'a (15 percent) and Embu (14 percent), among others (Wambugu *et al.,* 2015). The USAID-KHCP sponsored report by Fintrac Inc. dated July 2013 underscores the challenges in banana production as prevalence of insect pests and diseases and high post-harvest losses. The panama disease (banana Fusarium wilt) is caused by a soil borne fungus *Fusarium oxysporum* F. sp. cubense (Foc) and has specifically led to decline of production of banana in Kisii and other areas. Another disease of significance to banana production in Kenya is Bacteria Wilt Disease (BW). Other major challenges noted in this important document include poor marketing channels and market structure. Despite these widely documented challenges, appropriate interventions such as provision of clean planting material through the tissue culture technology and capacity building in crop husbandry have significantly minimized the impact of pest and diseases although not widely adopted (Wambugu *et al.*, 2015).

2.5 Policy factors influencing adoption of tissue culture banana

Despite the above difficulties some developing countries are making progress in using biotechnology for Musa improvement through policy intervention. Policy is a key factor in terms of accelerating adoption of new agricultural technologies and particularly in addressing such concerns as food security, income generation, poverty and employment (GOK, 2012).This policy is in recognition and understanding of the current constitution under economic and social rights where every citizen has the right to be free from hunger and to have adequate food of acceptable quality (Langyintuo *et al.,* 2008). Although conventional breeding programs have their limitations, they have shown over time that they can be highly successful where policy in research is fast tracked (Langyintuo *et al.*, 2008). Genome manipulations and interspecific crosses have allowed considerable genetic progress in Musa breeding in research stations where relevant policy is inducted but much remains to be done in the identification of parental combinations that are likely to produce progenies with both high mean and genetic variability (Kassie *et al.,* 2013). The development of modern plant molecular and quantitative genetics in the last two decades has the potential to revolutionize what has mostly been experience-based empirical plant breeding (Kassie *et al.,* 2013).

Some administrative policy strategies are also important consideration in acceleration of tissue culture bananas adoption. in the work done by Quim *et al.*, 2009, a number of farm-level and institutional policy related variables were found to influence the likelihood of adopting Tissue Culture bananas technology. In particular, large farmland and livestock holdings tend to increase the likelihood of adoption. As the tissue culture bananas plantlets are given out free, it is possible that farmers with larger land areas and livestock holdings are targeted by development organizations or extension agents for technology dissemination. Access to agricultural technology information and membership of social groups also plays an important role in facilitating the adoption of tissue culture bananas. Such group networks play an important role in disseminating banana tissue culture information. The importance of social groups, as well as close interactions with neighbours and local institutions, such as churches, in agricultural technology dissemination has been widely documented. In their conclusion, the study suggested policy on subsidy to allow propagation materials to reach more farmers (Bandiera and Rasul, 2006; Matuschke and Quim *et al.*, 2009).

Food and nutrition security is said to exist when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. These require a nutritionally diverse diet which, combined with a sanitary environment, adequate health services and proper care and feeding practices, ensure a healthy life for all household members (Kassie *et al.*, 2013).

According to the National Food and Nutrition Security Policy of 2012 (GoK, 2012), about one-half of Kenya's estimated 42 million people, are resource-poor, with over 10 million suffering from chronic food insecurity and poor nutrition annually. The poverty index is at a mean score of 62.4 percent means 553,111 of the 884,978 people of Makueni County live under a dollar, with more than 63 percent or 557,536 being food insecure. These figures denote the extent of poverty and an alarming population density at a mean of 73.3 persons per square kilometre. According to UNICEF, (2011), the youthful population of under 18 years was 55 percent while according to UNWHO(2012), the child nutrition index showed an average of 16.4 percent of children below 5 years were underweight with 73 kids in 1000 likely to die before they are 5 years. These later figures indicate the grave food insecurity situation as well as the available youth perhaps majorly unemployed in the three counties. The UNWHO defines the study area as highly vulnerable in terms of (1) food access, (2) availability, (3) affordability and (4) food adequacy (UNWHO, 2012).The region has two rain seasons that is March, April and May known as the long rains and October, November and December comprising the short but incidentally the more reliable rains. June - October is a long dry period, while January - February is a shorter dry season (Kassie *et al.*, 2013).

The county experiences periodic food deficits. A large proportion of the population is either malnourished or undernourished leading to serious health complications. About 30 percent of Kenyan children are classified as undernourished. Micro-nutrient deficiencies are widespread. Household food and nutrition insecurity exposes families to disease risks, interferes with growth and development of children and limits work performance. In recent years, it is estimated that at any one time, about 2 million people require assistance to access basic food requirements. During periods of drought, torrential rains and floods, the number of people in dire need of food substantially increases (Bacerril *et al.,* 2005). Tissue culture material is more or less disease-tolerant and withstands adverse weather with harvesting time being between 6-18 months after planting and yields at between 30-40 tonnes per hectare (Kassie *et al.*, 2013).

Irrigation policy is one other factor that if used is highly recommended. Counties in the study area of Lower Eastern Region can easily take up water harvesting and irrigation policies from the major rivers like Tana, Athi, Kaiti and Thwake in a bid to opening up more land under tissue culture bananas in order to solve food insecurity and hunger in the region (TARDA, 2012). The Economic lifespan of a banana plantation is 8-15 years which gives the community a reliable lifeline to food availability and access as well as a sustainable means of engagement. Bananas can be utilized as ripened fruits used for dessert, flavoring ice-cream, yoghurt, making jam, juice, male flowers are used as vegetables. They are also cooked, dried into chips and flour. A nutrition policy is advised to accelerate the adoption (Chandler, 2005). Wambugu *et al.*, 2015, adds that the rate of agricultural productivity growth since the early 2000s has been quite impressive in many African countries, including Kenya, yet this is no cause for complacency. Sustained and accelerated growth requires a sharp increase in productivity of smallholder farmers. Adoption of new production technologies is clear parameter of sustainable agricultural productivity (UNFAO, 2014). Literature like the Strategy to Revitalize Agriculture (SRA, 2010), Kenya Vision 2030 (Vision 2030 Revised, 2013), (GOK, 2014) Comprehensive African Agricultural Development Program (CAADP, 2014) and Alliance for Green Revolution in Africa (AGRA, 2012) have underscored the importance of increasing agricultural productivity in the fight against poverty. In the past, agricultural production was largely a function of acreage, but further growth in production will have to be driven by productivity growth caused by accelerated adoption of technologies (UNFAO, 2014). According to the Kenya National Bureau of Statistics and the Economic Survey (KNBS, 2014), the agricultural sector in Kenya contributes greatly (over 30 percent, 2015) to the National Gross Domestic Product (GDP) (Bacerril *et al.*, 2005).

In the Ukambani counties (Makueni, Kitui and Machakos) generally, agriculture supports over 78 percent of the total population with the major crops including cereals and pulses, fruits and vegetables (MOA Makueni, 2014).The vast majority of bananas producers in the upper eastern

Kenya region are small scale farmers growing the crop either for home consumption or for local markets (MOA, 2011). Because bananas and plantains produce fruit year-round, they provide a valuable source of food during the hunger season and it is for these reasons that bananas and plantains are of major importance to food security (Chandler, 1995). In terms of volumes of food consumed by human, bananas are ranked fourth in the world after rice, wheat and maize (Wambugu *et al.,* 2004). According to Nyang, (2010), women groups' empowerment from poverty is a workable area but depends on the economic activities the women have. This thinking is compounded by Mbogoh, *et al.*, (2003). There is more to do with good planning for adoption of technologies like tissue culture bananas according to Nguthi *et al.*, (2007). According to Adesina *et al.*, (2011), however, environment factors are generally very important consideration in the adoption of new agricultural technology in the sub Saharan Africa. To increase and instigate the likelihood of adopting modern agricultural technologies by smallholder farmers, policy makers should put emphasis on overcoming credit market failures, irrigation problems by introducing drip and pipe irrigations, securing land ownership status of farm households and empowering female headed households to be participants and agents of change by considering a comprehensive and an integrated development of the country where their involvement is pertinent in all endeavors of the country's overall development (Karembu *et al.*, 2012)

Policy-makers and development agents targeting agricultural technology development for food security and poverty reduction should take into account the diversity of farming households. Farming household capabilities, assets and activities should play a major role in shaping policy on agricultural technology development (Nguthi *et al.*, 2007). The policies on the agricultural extension system indicate that the government recognizes the crucial role that the institution plays in agricultural development. However, given the prevailing human capacity and budgetary constraints, a new approach needs to find ways and means of doing more with less. A land policy that is clear on rules governing land rental is required. Developing such a policy will assist households earn revenues from renting land that would otherwise go un utilized. This will enable them to raise cash for various household needs including purchasing of farm inputs required in technology adoption. Technology development should pay attention to the crops that women grow, to avoid social relations and institutions by which gender inequality is perpetuated over time (Nguthi *et al.*, 2007). This may involve ensuring that women continue to have access and control over their labour outputs on these crops as well as ensuring household food security. Besides, access to water and energy sources must be improved, particularly given that access relates to activities that are socially determined to be the responsibility of women. This responsibility has a direct effect on women's time for productive as well as reproductive roles (Karembu *et al.*, 2012). Furthermore, water is an essential component in the adoption of tissue-cultured banana and most improved crop varieties and water management policies that ensure access to water both for domestic consumption and irrigation needs to be pursued. Consequently, development practitioners will have to take into account women's opinion and constraints in introducing interventions and solutions to agricultural problems (Wambugu *et al.*, 2015).

According to (TARDA, 2016), River Tana area covers approximately 138,000 km^2, comprising 100,000 km2 of the Tana Basin and 38,000 km^2 of the Athi Basin. This includes most of the Central province, the Southern Counties of Eastern region like Machakos, Kitui and Makueni. Upper zone include the Catchment areas of Mt Kenya and Aberdares region to lower reaches of Murang'a District. The Middle Zone includes the Catchment areas in the lower reaches of Murang'a through Machakos, Kitui and up to Garissa and finally the Lower Zone – Catchments areas below Garissa town, the Sabaki area and the coastal region Population (GOK.2016). According to the (FAO, 2013), the Machakos, Makueni and Kitui, River Athi stretch is approximately 170 km of deep fertile alluvial clay loams soils and very significantly potential for bananas production. This is home to approximately 700,000 of the almost 3,500,000 people in the three counties (TARDA, 2016). According to the (KNBS,2009), and based on the 2009 population census, the population in the two river (Athi and Tana) basins was estimated at 15 million people, which is about 38 percent of the National population of 40 million. The River Athi (also referred to as Galana- Sabaki River is the second longest river in Kenya (after the Tana River). It has a total length of 390 km, and drains a basin area of 70,000 km^2. The river rises at 1° 42' S. as Athi River and enters the Indian Ocean as Galana River (also known as Sabaki River). Athi River flows across the Kapote and Athi plains, through the Athi River town, takes a northeast direction and is met by the Nairobi River. Near Thika, it forms the Fourteen Falls and turns south-south-east under the wooded slopes of the Yatta ridge, which shuts in its basin on the east. Apart from the numerous small feeders of the upper river, almost the only tributary is the Tsavo River, from the east side of Kilimanjaro, which enters in about 3° S. It turns east, and in its lower course, known as the Sabaki (or Galana), traverses the sterile quartz-land of the outer plateau. The valley is in parts low and flat, covered with forest and scrub, and containing small lakes and backwaters connected with the river in the rains. At this season the stream, which rises as much as 10 m in places, is deep and strong and of a turbid yellow colour; but navigation is interrupted by the

Lugard falls, which is actually a series of rapids. Onwards it flows east just like River Tana and enters the Indian Ocean in 30 12' S., just 10 km north of Malindi Town. Both the Tana and Athi Rivers traverse the three Ukambani counties presenting an interesting case of the nexus between conflict and food security. A recent survey prepared by Kenya Food Security Steering Group (KFSSG), these counties located along the two major rivers plus their tributaries presented (KFSSG GOK, 2014) found that the counties' were between 70-79 percent food insecure, the document calls for more technological advancement in farming, mainly through policy intervention especially in horticulture development citing fruits and vegetables as examples (Bacerril *et al*., 2005 and Wambugu et al., 2015)..

Kenya Interim Poverty Strategy Paper (I-PSP) of 2000–2003,) (GOK, 2007) shows incidence of poverty at an average of 62 percent on average for the three counties of Kitui, Machakos and Makueni, with the later leading the rest at 64 percent, with suggestions of arresting this through policy and promotion of rural investment targeting the youthful class of population. There are suggestions appearing in the Kenya Demographic and Health Survey (KDHS), (*KDHS Report/GOK, 2014/*GoK, 2014) on how to tackle poverty trends through investing in modern farming practices that create employment. Bacerril *et al.*, (2005) suggests that if policy is well incorporated and factored it can turn around low adoption of technology in all spheres of livelihood to make the world better in terms of food security, employment creation, income generation and better environment management for growth and development (Bacerril *et al.*, 2005).

According to Wanyama *et al.*, (2013), Agriculture extension in Kenya, has been highlighted as a critical agent for transforming subsistence farming to modern and commercial agriculture thereby improving household food security Agriculture is a very dynamic undertaking. New technological changes are occurring daily arising from research. Farmers must embrace these changes. One way of acquiring these technological milestones is through information delivery to the farmers. The term "extension" is used interchangeably with "advisory services", or "agriculture education and its purpose is to bridge the gap between farmers and sources of information/knowledge. The importance of agricultural extension has further been underscored in the Agriculture Sector Development Strategy (ASDS) as a critical agent needed to transform subsistence farming into a modern and commercial agriculture to promote household food security, improve income and reduce poverty (ASDS / GOK, 2012). The current constant technological development requires that farmers are made aware of the existing technologies and know how to use these innovations for the exploitation of inherent yield potentials (Bacerril *et al.,* 2005).

Agricultural information is a derivative of the extension delivery policy. Agriculture information within the reach of farmers plays a vital role towards improved productivity and enhanced economic development. Globally, agriculture extension has been used as a tool for disseminating agriculture information to farmers. Extension services are seen as key investments that if efficiently utilized can enhance sustainable agriculture, incomes and reducing poverty. Traditionally, delivery of extension services to farmers was predominantly the government’s role. However, recent transformation in extension has resulted to adoption of a pluralistic system which comprises multiple sources of information. Despite of this, literature on the effect of these factors to technology adoption through agricultural extension and information on farm productivity is limited. The agents found here are public, private for-profit and private non-profit extension service providers. Where these agents are reportedly inactive or inadequate, adoption of technologies and thus the productivity is very minimal (Mathenge *et al*., 2016). Agricultural policy that enhances adoption of production technologies will be beneficial to increased productivity (Wanyama *et al*., 2013). Although researchers have developed many technologies, their adoption is low due to inadequate awareness of existing technologies, exacerbated by wide communication gap between researchers and farmers (Diao *et al*., 2006).

Moreover, the modalities for technology transfer both in research institutions and extension systems have remained weak and not adequately funded and require policy interventions (Wanyama *et al.,* (2013). Research shows that development of agricultural technologies requires among other inputs a timely and systematic transmission of useful and relevant agricultural information (messages) through relatively well educated technology dissemination (extension) from formal technology generation system (research/source) via various communication media (channel) to the intended audience. Evidence shows that public extension services have consistently failed to deal with the site-specific needs and problems of the farmers (Diao et al., 2006). Despite the existence of various sources of agricultural information, only a small proportion of smallholder farmers are accessing such information in the study area. Inadequate access to extension is a key constraint to agricultural production, food security and improved livelihoods. A major limitation in accessing extension is inadequate qualified personnel in the sector. For instance, the national extension staff to farmer ration is 1:1000 compared to the recommended 1:400 (GoK, 2012). This is quite low considering the large number of smallholder farmers that require extension services. Enhanced agricultural extension policy development and increased investment in extension is therefore necessary in order to achieve the desired impact of transforming subsistence farming through increased technology adoption into a modern commercial agriculture that will promote household food security, improve income and reduce poverty (GoK, 2012). The New Economic Partnership for Africa's Development (NEPAD), is an integrated socio-economic development framework for Africa, is designed to address the current challenges facing the African continent such as the escalating poverty levels, underdevelopment and the continued marginalization of Africa. This is a new policy vision pursuing Africa's renewal and which is spearheaded by African leaders. Two policy initiatives of NEPAD, the African Peer Review Mechanism (APRM) and the Comprehensive Africa Agriculture Development Programme (CAADP), are the most important pan-African initiatives concerning agricultural policies and Institutions in Sub-Sahara Africa, with CAADP for the agricultural sector policies. The primary objectives of NEPAD are: to eradicate poverty; place African countries, both individually and collectively, on a path of sustainable growth and development; halt the marginalization of Africa in the globalization process and enhance its full and beneficial integration into the global economy; and accelerate the empowerment of women (NEPAD, 2003).

Comprehensive Africa Agriculture Development Programme (CAADP), are the most important pan-African initiatives concerning agricultural policies and institutions in Sub-Sahara Africa, with CAADP for the agricultural sector policies. CAADP is an agricultural programme under NEPAD. It was formed through the facilitation of the FAO in close collaboration with the NEPAD secretariat at the invitation of the NEPAD Steering Committee. The programme was formed in 2002 in a Consultative process that started with the presentation of the main themes of the potential CAADP contents by the Director General of FAO to the NEPAD Heads of State Implementation Committee in Abuja in March 2002 (AUNEPAD, 2002). CAADP has been organized along five key pillars firstly,: Sustainable land management and reliable water control systems; Followed by Improving rural infrastructure and trade related capacities for market access; third is increasing food supply and reducing hunger; and fourthly, Agricultural research, technology dissemination and adoption and finally the improving delivery of Research and Extension Services. This will include strengthening research and extension services (both public and private Supported) to ensure improved adoption rates of new technologies thus increasing agricultural productivity (Diao *et al*., 2006).

2.6 Conceptual frame work

The conceptual framework was derived and based on the fact that low adoption of tissue culture bananas technologies and practices was dependent upon the households' factors, policy related factors, socio economic factors as well as the environmental ones; (Figure 1 below)

Adoption model used was as Follows,

$Z_i = f(x)$; $X = x_i$; $I = 1, 2, 3, 4 \ldots N$ (independent variables; households' factors, policy related factors, socio-economic factors as well as the environmental based factors)

Then the model form was,

Y_i (dependent adoption variable) $= ß_0 + ß_1x_{1i} + ß_2x_{2i} \ldots\ldots ß_nx_{ni} + \mu_i$, the so called Linear Multiple Regression Model (Murray *et al.*, 1999) Where;

Y_i = Tc bananas adoption (dependent variable) or regresand, ß is the typical coefficient while x_1, x_2 are the explainable independent variables (or Regressors = factors affecting adoption of Tc bananas); the Disturbance μ, the error term, is considered to be a random term that represents pure chance factors in the determination of Y. X_1 = Age of household head in years; X_2 = Education level of the household head ;

- X_3 = Farm size in acres

- X_4= Access to extension service,
- X_5=Gender of the farmer/household head;
- X_6 = Household head income;
- X_7 =Farm size in acres under Tc bananas; X_8=Experience of the household head;
- X_9=Off Farm Employment;
- X_{10}=Marital status; X_{11}=Family Size;
- X_{12}=TC Bananas Market;
- X_{13}=TC Bananas Knowledge
- μ = error term; n= 1, 2,3,4,5,6,7,8,9,10,11,12 and 13

Conceptual Framework on factors affecting adoption of Tissue Culture Banana

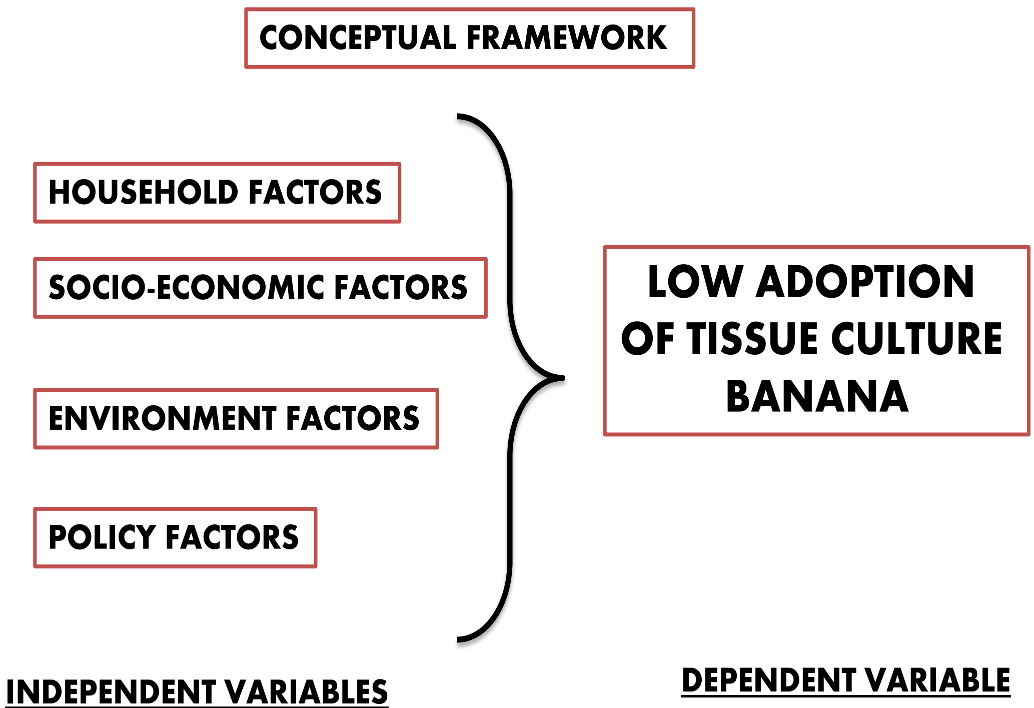

Figure 1: Conceptual framework on factors affecting adoption of tissue culture banana

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study area and its description

This study was carried out in three areas (also wards) namely Kalawa, Thaana Nzau and Kithimani, located in Makueni, Kitui and Machakos counties respectively (Figure 2 below). The sites are situated along the major rivers of Athi in Makueni and Machakos counties, Thaana (also variously called Tana) in Kitui County and along the tributaries of Athi, namely Thwake and Kaiti all in Makueni County.

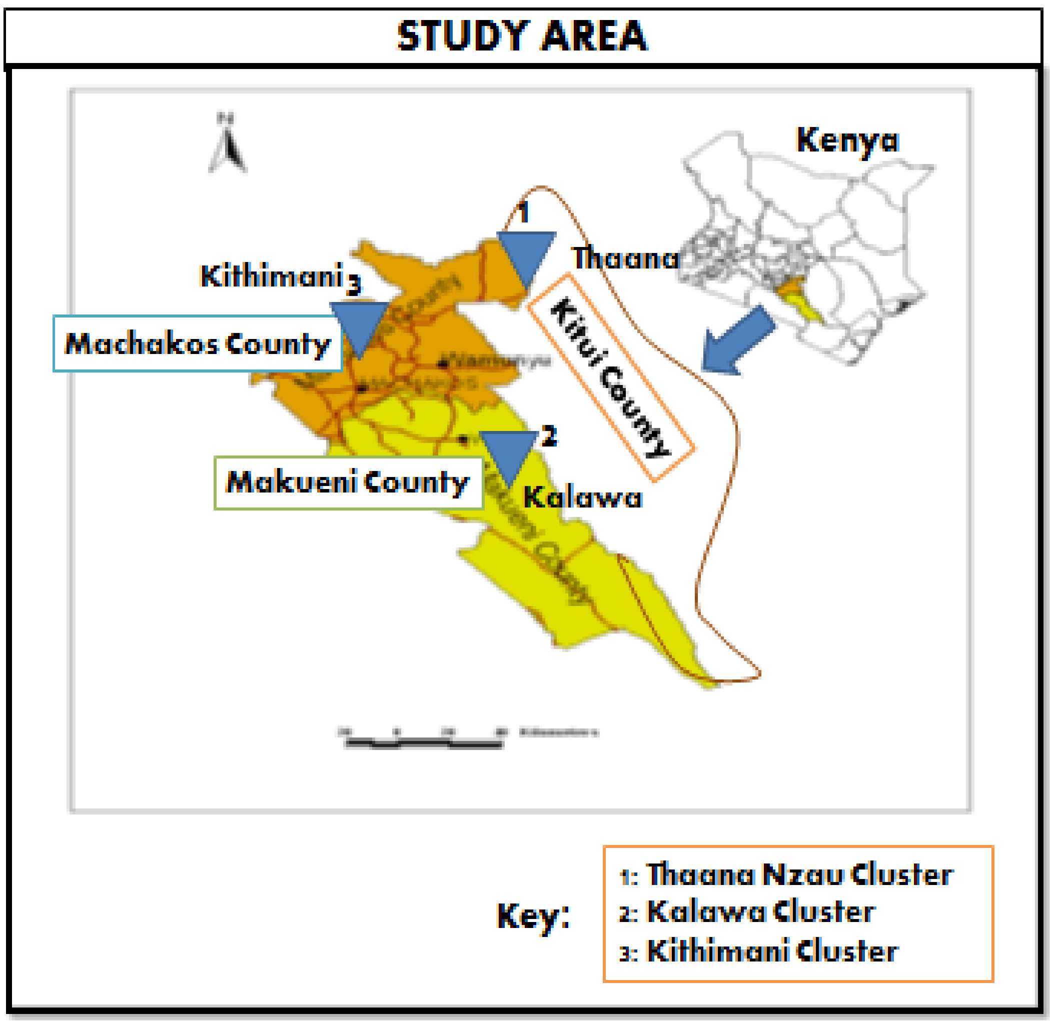

Figure 2: Map of the study area (Source: Author).

Soils

According to Nguluu *et al* (1998), the study area soils are derived from the rich fertile alluvial clay loamy deposits over the years. The soils are well-drained and ranging from deep to very deep. The soils are dark brown-red to strong brown-black cotton, moderately friable ranging from sandy-clay-; loams to clay-loamy of Rhodic and Orthic Ferralsols (Nguluu *et al*, 1998).

Climate

The study area actual mean temperature range is from 200 C - 28^0 C, (MOA, 2014). The high temperature experienced in Lower Medium zone 4 and Lower Medium zone 5 areas cause high evaporation, thus adverse effects on rain-fed agriculture and fodder availability. The main livelihood ranges from mixed farming to marginal farming across all the villages (Nguluu *et al*, 1998).

Rainfall and Altitude

The region has two rain seasons, March, April and May known as the long rains and October, November and December form the short rainy season. The short rainy season is more reliable than the long rain season. June - October is usually a long dry period, while January - February is the short dry season. The hilly parts of the Makueni County mainly Kilungu, Ilima, Mbooni, Kithungo/Kitundu receive 900mm to 1,200 mm of rainfall per year. The rest of the region receives less rainfall, ranging from 250 mm to 750 mm annually. Their mean elevation range is 600m - 1000m above sea level (Nguluu *et al*, 1998).

3.2. Socio-economic characteristics

The study area geographical statistics is summarized in the Table 1.

Table: 1: Socio-Economic Characteristics of the Study Area

Study site	Population	Area (Kms sq.)	Study Cluster	Population Density	Poverty Index	Coordinates (Lat/Long)
Thaana Nzau	82,368	2,496	Thaana Nzau	33	63.5	$1^0$22’1.06’S/ $38^0$00’37.98’E
Kalawa	110,990	1,009	Kalawa	110	64.1	$1^0$39’12.8’S/ $3^0$7’42’08.6’E
Kithimani	170,016	2,208	Kithimani	77	59.6	$1^0$11’11’S/ $37^0$26’45’E
Total	363,374	5,713		73.3	62.4	

Source: GoK, 2013

Other characteristics

The entire Lower Eastern region covers 5,713 km^2 with a combined population of 363,374 where 49 percent are males whereas 51 percent are females. The poverty index is at a mean score of 62.4 percent. According to UNICEF (2011), the youthful population of less than 18 years was 55 percent while according to UNWHO (2012); the child nutrition index showed an average of 16.4 percent of children below 5 years were underweight with 73 kids in 1,000 likely to die before age 5. These latter figures indicate the grave food security situation as well as the available youth perhaps majorly unemployed in the three counties. The UNWHO defines the study area as highly vulnerable in terms of food access, availability, affordability and adequacy (UNWHO, 2012).

3.3 Research design

Qualitative research was used for descriptive research whereby a survey targeting the respondents in the study area was carried by use of a structured questionnaire.

3.4 Determination of sample size

Kalawa, Kithimani and Thaana were randomly selected out of 9 Wards; 3 Per County; the total Population of 2,550 for the selected study area. The sample research size was determined as follows:

The sample size for the study was determined using the following formula (Magnani *et al.*, 2007).

$$n = \frac{t^2 \times p(1-p)}{m^2}$$

Where:

n = Required sample size

t = Confidence level at 95 percent (standard value of 1.96)

p = Estimated percent of adoption of technological practices like tissue culture bananas in the study area is 20 percent.

m = Margin of error at 5 percent (standard value of 0.05).

= 1.96)2 *0.2(1-0.2) divided by (0.05)2.

= 3.84166*0.2*0.8 divided by 0.0025.

= 245.8624 (approximated to 246 in the study)

Based on this, a total of 246 respondents were selected from the list of the 2,550 households / villagers in the three wards, with each village being represented by 82 respondents using random sampling method. Out of the 246 sample size, 70 respondents were used to pre- test the Questioneer. The balance of 176 respondents was interviewed for data collection in the study area. The study area was divided into three; where Thaana Nzau located along River Thaana villages in Mwingi West in Kitui County, Kithimani situated along River Athi and the Yatta furrow in Machakos and Kalawa cluster found along tributaries of River Athi (Thwake and Kaiti) in Makueni County were randomly selected from a list of 9 wards presented by the government administrators..

3.5 Sampling Procedure

The basis used for selecting Makueni, Kitui and Machakos Counties included Agro Ecological Zones (AEZ) (Thaana Nzau and Kalawa are in AEZ 5 whereas Kithimani is in AEZ 4/5), livelihood status, the favourable characteristic for bananas growing conditions and high poverty index with (62.4 percent living below the poverty line) according to UNWHO (2012) and UNICEF (2011). By a further random sampling, 176 out of 246 farm holdings (which represented about 9.64 percent of the respondents) out of a target population of 2,550 farmers were selected as respondents. The sample size was as follows: - Thaana - 65, Kalawa - 60 and Kithimani 51 which totals to 176 (without repeating the 70 respondents involved in testing the Questioneer).

3.6 Methods of data ccollections and aanalysis

3.6.1. Data Collection

Table 2. Type of data

Type of Data			
Household Factors	Environment Factors	Policy Factors	Socio Economic Factors
Age	Land Size	Extension Service	Income
Gender	Soil & Water Conservation	Subsidy	Off Farm Employment
Experience	Fencing	Wild Life	Market
Education	Sources Of Tc	Credit	Group Affiliation
Knowledge	Irrigation Water Source		Livestock Ownership
Family Size	TCB Cultivated Varieties		

A Semi-structured questionnaire was used to elicit data and information on the respondents characteristic (Age, Gender, Family size, Land holding, Composition, Sources of income, and their Quantitative aspects), banana potential growing villages, social factors, economic, environmental and policy related factors affecting growing of tissue culture bananas in the areas along the Rivers Tana (Kitui County) and Athi (Machakos and Makueni) and the tributaries of the Athi (Thwake & Kaiti) in the Makueni County. Enumerators (6) were trained on data collection. The questionnaire was pre-tested in a pilot survey involving 70 respondents of the 246 population sample in 2 villages within the study area but in a place near the study sites (Kyase sub-location) before the main survey. Some questions were modified or removed in cases of repetitions. The pre-tested, structured questionnaire (Appendix 1) was used. This had two sections, the general respondents characteristics as well the technical part that had details of environmental as well as socio-economic and policy parameters. The data collection took twelve days with a group of 6 enumerators. The full scale data collection was largely successful except for mobility and poor service provider network.

3.6.2 Data Analysis

The collected data was analyzed as follows; Kalawa in Makueni county having 60 respondents; Kithimani in Machakos county having 51 respondents and Thaana Nzau: Kitui: 65 respondents. 176 respondents were successfully interviewed. The data was entered into excel computer sheets. The data collected using structured questionnaires was analysed to determine the relationship between household characteristics and the level of adoption of tissue culture bananas and factors affecting its adoptionusing Package for Social Science (SPSS) Version 17. Binary logistic regression model (Murray *et al.,* 1999) was used to determine the significant factors and bringing out relationship between household characteristics and the level of adoption of the tissue culture bananas. Tables 3, 4, 5 6, 7 and 8 on the kind of data analysis against the type of data are tabulated.

3.6.3 Model specification

The simple reduced form of adoption Pierson's Linear Multiple Regression Model is as Follows, $Zi = f(x)$

$X = xi…….I = 1, 2 ………. N$ Then the multiple model form is,

$Zi = ß_0 + ß_1X_{1i} + ß_2X_{2i} \ldots\ldots\ldots\ldots ß_nX_{ni} + \mu i$, the so called linear multiple regression model.

Where;

Zi = TC Bananas adoption (dependent variable) or regresand while X1, X2 are the explainable variables (or regressors); the disturbance µ, the error term, is considered to be a random term that represents pure chance factors in the determination of Z.

X_1 = Age of respondent in years

X_2 = Education level of the farmer

X_3 = Farm size in acres

X_4= Access to extension service by farmers

X_5 = Gender of the farmer

X_6 = respondents income

X_7 = Farm size in acres under tissue culture bananas.

X_8 = Experience

X_9 = Off Farm Employment

X_{10} = Marital status

X_{11}= Family Size

X_{12} = TC Bananas Market

X_{13} = TC Bananas Knowledge

µ = error term; n= 1, 2,3,4,5,6,7,8,9,10,11,12 and 13.

The dependent variable is the natural log of the probability of adopting tissue culture bananas variety (p) divided by the probability of not adopting it (1-p). The value of the dependent variable is therefore a linear combination of the value of independent variables plus an error term. The error term is assumed to be normally distributed with a mean of zero and constant. This is the principle underscored by multiple regression, which an involvement of more than one explanatory variable in a single regression equation (Murray *et al.*, 1999), which is an expression of a linear relationship between one variable Zi and two or more independent variables (X1, X2,,,,,, X13).

The Chi-Square (χ^2) test was used to determine if there was a significant relationship between nominal (categorical) variables like credit, subsidy, labour, environment, land, sources of tissue culture materials, wild life, etc. The frequency of one nominal variable is compared with different values of the second nominal variable with resultant p-value used to determine the significance of the variable in influencing the adoption of the tissue culture bananas, (Murray *et al.*, 1999).

CHAPTER FOUR

4.0 RESULTS

4.1 Respondents' demographic characteristics in Thaana, Kithimani and Kalawa clusters

The results of the demographic characteristics of respondents are shown in Table 3. Across the three respective clusters, majority of the respondents were males with Kalawa, Thaana and Kithimani having 65 percent, 61 percent and 66.2 percent, respectively. On average there were 64 percent of males and 36 percent females. With regard to age, on average, 31 percent were between 40-50 years and 36 percent between 50-60 years and 11 percent above 60 years. People less than 40 years old were the least at 21 percent. In Thaana the aged (50-60 years) formed the majority (45 percent) compared to Kithimani (37 percent) and Kalawa (27.7 percent).

On education level, the results in Table 3 show that all the respondents had attained some level of education. Majority of the respondent had attained secondary education (57 percent). The 23 percent attained primary education while 20 percent had tertiary education. The average land size per respondent was 5.51 acres, with Kithimani having the largest parcels at 6.5 acres while Thaana and Kalawa reported 5.11 and 4.92 acres respectively. The average area under the tissue culture bananas was 1.23 acres per house hold, with Kithimani having the largest parcels at 1.35 acres while Thaana and Kalawa reported 1.03 and 1.31 acres respectively. The percentage acreage under tissue culture bananas against total available land size per house hold is 22.23 percent. The number of respondents that had family members ranging between 5-10 members was the highest at 57 percent followed by respondents with 3-5 members at 35 percent. It was also found that 8 percent of respondents had less than 3 members.

On average 62 percent of the respondents were members of social village groups while 38 percent were not members (Table 3). On marital status, across the three respective clusters and in all the three counties (Makueni, Kitui and Machakos), over 81.3 percent of the respondents were married with others being single or divorced at 17 percent and 1.7 percent respectively (Table: 3 below).

Table 3 Respondents Demographic Characteristics

Research Parameters N = 176		Thaana % (f) n = 60)	Kithimani % (f) (n = 51)	Kalawa % (f) (n = 65)	Mean % (f)	Std. Deviation
1. Gender	Males	65 (39)	61(31)	66.2 (43)	64 (8)	29.29
	Females	35 (21)	39 (20)	33.8 (22)	36 (21)	16.01
2. Age	Less than 40yrs	20 (12)	22 (11)	21.5 (14)	21 (12)	9.53
	40-50 yrs	31.7 (19)	28 (14)	33.8 (22)	31 (18)	14.33
	50-60yrs	45 (27)	37 (19)	27.7 (18)	37 (21)	18.79
	More than 60yrs	3.3 (2)	14 (7)	16.9 (11)	11 (7)	8.1
3. Education	Primary	28.3 (17)	20 (10)	21.5 (14)	23 (14)	11.23
	Secondary	65 (39)	47 (24)	58.5 (38)	57 (34)	26.45
	Post-Secondary	6.7 (7)	33 (17)	20 (13)	20 (12)	8.99
4. Group Affiliation	Yes	60 (36)	59(30)	67 (44)	62 (37)	28.59
	No	40 (24)	41 (21)	33 (21)	38 (22)	17.35
5. Experience in growing Tcb	Less than 5 years	41.2 (29)	49 (25)	43 (28)	44 (37)	28.14
	10 years	34.1 (16)	29 (15)	29 (19)	31 (17)	25.52
	15 years	13.6 (10)	16 (8)	17 (11)	16 (10)	4.77
	More than 20 years	11.4 (5)	6 (3)	11 (7)	9 (5)	7.08
6. Income Level (In ksh)	Below 10,000	40.0 (24)	39.2 (20)	50.8 (33)	43.3 (26)	0.746
	10,001-30,000	45.0 (27)	41.2 (21)	29.2 (19)	38.5 (22)	0.665
	Over 30,000	15.0 (9)	19.6 (10)	20.0 (13)	18.2 (11)	0.776

Numbers in parenthesis represent frequencies(f) ;(n) represents sample per site

Majority of the respondents (43.3 percent) had an income of below Kshs 10,000 per month with those earning between ksh.10, 001-30,000 being 38.5 percent on average. The lowest (18.2 percent) earned over ksh.30, 000. Kalawa had more respondents earning ksh.10, 000 at 50.8 percent followed by Thaana and Kithimani at 40 and 39.2 percent. The results showed 45 percent of the respondents earned between ksh.10, 001-30,000, this being followed by Kithimani and Kalawa at 41.2 percent and 29.2 percent in the same order and category of income. However, Kalawa data showed more farmers earning over ksh.30, 000 at 20 percent compared to Kithimani at 19.6 percent and Thaana at 15 percent. On tissue culture bananas knowledge, the highest number of respondents at 88.1 percent had no technical knowledge about the crop husbandry skills of tissue culture bananas while 11.8 percent had knowledge or were knowledgeable about tissue culture bananas. Kalawa data showed the highest at 93.8 percent without tissue culture bananas knowledge followed by Thaana and Kithimani at 88.3 percent and 82.4 percent respectively in the same category. However Kithimani with 17.6 percent had the highest number of farmers with technical knowledge about the crop husbandry skills of tissue culture bananas followed by Thaana and Kalawa with 11.7 percent and 6.2 percent respectively in the same category.

4.2 Socio-economic factors influencing the adoption of Tc banana in the lower Eastern region.

From the logistic regression results in table 4 on the socio-economic related factors, the following factors were found significant ($p < 0.05$) in influencing the adoption of tissue culture bananas in the study areas: gender ($p = 0.0150$); education ($p = 0.0380$); total land size ($p = 0.0110$); experience ($p = 0.0168$); tissue culture bananas knowledge ($p = 0.0100$) and tissue culture bananas market ($p = 0.0030$). The following other factors were found insignificant (at $p > 0.05$) in

Table 4. Regression results of socio-economic factors influencing the adoption of Tcb

Variables	Unstandardized Coefficients	Std. Error	Standardized Coefficients	t-test	*Significance.
Constant	1.269	0.263		4.832	0.0000
1. Age	-0.004	0.035	-0.008	-0.119	0.9060
2. Gender	-1.155	0.063	-0.149	-2.455	0.0150
3. Education	2.093	0.044	0.120	2.097	0.0380
4. Total Land Size	2.028	0.011	0.166	2.571	0.0110
5. Income Level	-0.088	0.049	-0.131	-1.804	0.0230
6. Experience	0.016	0.009	0.095	1.840	0.0168
7. TCB Knowledge	1.280	0.051	-0.344	-5.466	0.0100
8. Acreage Under TCB	-1.493	0.070	-0.407	-7.010	0.1000
9. TCB Market	1.178	0.060	0.175	2.968	0.0030
10. Family Size	-0.028	0.048	-0.036	-0.579	0.5630
11. Marital Status	0.181	0.070	0.161	2.603	0.5100
12. Off Farm Employment	-0.025	0.064	-0.025	-0.388	0.6980

* Significant at 0.05 level of significance

influencing the adoption of tissue culture bananas in the study areas: Age (0.9060); income level ($p = 0.0730$); groups affiliation ($p = 0.5420$); family size ($p = 0.5630$); marital status ($p = 0.5100$) and off farm employment ($p = 0.6980$).

Table 5 shows results of comparative analysis for the respondents' factors as they influence adoption. On gender Thaana and Kithimani, had more females growing the bananas at 39 percent and 32 percent, respectively compared to Yatta which had more men (39 percent) than female adopters (26 percent). The chi- square statistics at 9.5729, with a p-value of 0.008342, were found significant ($p < 0.05$). On livestock ownership across the study areas, Thaana recorded more respondents without livestock at 34 percent out of 60 percent while Kithimani (33 out of 60) and Kalawa (40 out of 65) had livestock. The chi- square statistics at 6.2882, with a p-value of 0.043105, the results were found significant ($p < 0.05$). Regarding respondents that had undergone training on tissue culture bananas production only Kalawa had more respondents (48 out of 65) trained while Kithimani and Thaana had more untrained respondents (39 and 48 respectively).

The chi- square statistics at 36.6464, with a p-value of 0.00001, the results were found significant ($p<0.05$). On Education characteristic as it affects adoption of tissue culture bananas, Kalawa (38 out of 65 had more respondents educated up to primary level while Kithimani and Thaana had more respondents educated up to secondary level and beyond. The chi- square statistics at 11.519 with a p-value of 0.003153, the results were found significant ($p < 0.05$). On the Availability of extension services (public or private) to the respondents in the study area, Kalawa and Thaana results revealed non availability (at 40 out of 65 and 41 out of 60 respondents heads respectively) compared to Kithimani which had extension services available (at 31 out of 51). The chi- square Statistics at 25.3359 with a p-value of 0.00001, the results were found significant at $p < 0.05$ compared to Kithimani which had extension services available (at 31 out of 51). The chi- square statistics at 25.3359 with a p-value of 0.00001, the results were found significant at $p < 0.05$ Similar results were found in household heads group affiliations or membership which again was found a very significant factor in influencing adoption of Tissue Culture bananas with p-value being 0.020642 at $p < 0.05$ (Table 4). However it was reported that 35 farmers out of 60 in Thaana did not belong to the groups. This again was found a significant factor influencing adoption of tissue culture bananas with p-value being 0.020642 ($p < 0.05$). Kithimani and Kalawa recorded 39 and 34 farmers who belonged to the groups respectively.

Table 5: Detailed analyses of respondents' factors influencing the adoption of Tc bananas.

Other factors Cluster/Study Area	F (%)	F (%)	chi-sq. statistic	*p*-value*
1. Gender of the respondents' growing tissue culture bananas				
Cluster	Male	Female		
Kalawa (n = 65)	60(39)	40(26)	9.5729	0.00834
Thaana (n = 60)	35(21)	65(39)	8.0041	0.00322
Kithimani(n = (51)	37(19)	68(32)	7.3002	0.00680
2. Livestock ownership as it affects adoption of tissue culture bananas				
Cluster	With Livestock	Without Livestock	6.2882	0.04311
Kalawa (n = 65)	62(40)	38(25)	5.8021	0.0324
Thaana (n = 60)	43(26)	57(34)	6.1072	0.0411
Kithimani (n = 51)	65(33)	35(18)	6.2100	0.0364
3. Training on tissue culture				
Cluster	Trained	Not Trained	36.6464	0.00001
Kalawa (n = 65)	74(48)	26(17)	29.0121	0.00089
Thaana (n = 60)	37(22)	63(48)	28.0124	0.00001
Kithimani (n = 51)	24(12)	76(39)	32.2132	0.00002
4. Education as it affects adoption of tissue culture bananas				
Cluster	0-Primary	Post secondary		
Kalawa (n = 65)	58(38)	42(27)	11.519	0.00315
Thaana (n = 60)	28(17)	72(43)	9.0012	0.00219
Kithimani (n = 51)	43(22)	57(29)	9.3201	0.00311
5. Availability of extension services (public or private)				
Cluster	Available	Not Available		
Thaana (n = 60)	42 (25)	(40) 58	25.3359	0.00001
Kithimani (n = 51)	37 (19)	(41) 63	28.0724	0.00021
Kalawa (n = 65)	60 (39)	(12) 40	32.2312	0.00002
6. Group membership				
Cluster	Yes	No		
Kalawa (n = 65)	60 (39)	40 (26)	7.7608	0.02064
Thaana (n = 60)	42 (25)	58 (35)	7.2110	0.01453
Kithimani (n = 51)	69 (34)	31(17)	6.9005	0.08420

Numbers in parenthesis represent frequencies(f) ; (n) represents respondents ;
* Significant at 0.05 level of significance

4.3 Assessment of environmental factors influencing adoption of tissue culture bananas

Availability of a fence (64 percent) was reported as an environmental factor influencing adoption of tissue culture bananas (Table 5). About 86 percent of the respondents indicated that fencing was very important. On average 64 percent respondents had fenced their farms, whereas 36 percent of the respondents' farms were without fence. With regard to soil and water conservation measures, 92 percent of the respondents perceive soil and water conservation measures as very important but only 68 percent of the respondents indicated that they were practicing soil and water conservation measures (Table 5). Approximately 22 percent of the respondents used borehole as source of water for irrigation. River was the main water source of irrigation water where majority of the respondents (47 percent) reported using river water to irrigate).

Table 6: Environmental factors influencing adoption of tissue culture bananas

Research Parameters		Thaana	Kithimani	Kalawa	Mean	Std Error	t-test	*Significance
1. Maturity Age(months)		9.54	8.75	8.36	8.9	7.21	4.041	0.0210*
2. Fence Availability	Available	66(39)	61(31)	66(43)	64 (38)	53.99	3.243	0.0011*
	Not Available	34(21)	39(20)	34(22)	36(21)	35.67	3.821	0.0012*
3. Importance of Fencing	Very important	80(48)	90(46)	87(57)	86(50)	4.51	2.419	0.0013*
	Not important	20(12)	10(5)	3(8)	14(8)	9,69	2.897	0.0015*
4. Availability of S & W Conservation	Available	68(41)	65(33)	70(46)	68 (40)	6.43	3.312	0.0021*
	Not Available	32(19)	35(18)	30(19)	32 (19)	1.04	3.217	0.0011*
5. Importance of S & W Conservation	Very important	88(53)	90(46)	97(63)	92 (54)	9.48	4.214	0.0022*
	Not important	12(7)	10(5)	3(2)	8 (5)	6.29	12.11	0.0971
6. Irrigation Water Source	River	58(35)	45(23)	38(25)	47 (28)	14.34	2.102	0.065
	Dam	33(20)	20(10)	15(10)	23 (13)	13.67	2.100	0.085
	Well/Springs	5(3)	10(5)	12(8)	9 (5)	5.19	2.313	0.061
	Boreholes	3(2)	25(13)	34(22)	21 (12)	21.92	2.031	0.072
7. TCB Cultivated Varieties	Cooking	2(1)	10(5)	12(8)	8 (5)	4.55	0.210	0.523
	Ripening	26(20)	20(10)	40(26)	29 (19)	10.5	0.774	0.465
	Both Cooking/ Ripening	72(39)	71(36)	48(31)	64 (35)	6..94	2.005	0.092*

Numbers in parenthesis represent frequencies; * Significant at 0.05 level of significance

4.5 Policy related factors influencing the adoption of Tc bananas

Table 7 shows policy related factors that influence adoption of tissue culture bananas. Most of the respondents indicated that Kenya Agricultural and Livestock Research Organization (KALRO) is the main source of tissue culture bananas planting materials (32 percent). Other sources of tissue culture bananas planting materials were university, nursery dealers and neighbors. The results also showed that majority of the respondents do not have access to either public or private extension services. On average only 35 percent of the respondents showed that they have access to extension services. Thaana recorded the highest number of respondents with lack of extension services at 85 percent followed by Kithimani with 69 percent of the interviewed households. Kalawa reported the highest number of farmers who had access to extension services at 60 percent while Kithimani had 31 percent and Thaana with 15 percent. The results in Table 7 depict other policy related factors influencing adoption of tissue culture bananas. Tissue culture bananas multiplication by governments or stakeholders within the study area was endorsed by 137 respondents (60 in Kalawa, 48 Thaana and 29 Kithimani) out of the 176 (78 percent of the respondents interviewed) as an important factor to enhance adoption of tissue culture bananas. Another 39 (5 in Kalawa 12, Thaana and 22 in Kithimani) respondents (about 43 percent) did not endorse the idea. Kalawa, Thaana and Kithimani in that order endorsed. Regarding the awareness of credit services for farm activities from the financial services, the respondents were mostly aware at 49, 36 and 29 from respondents in Kalawa, Thaana and Kithimani respectively, totaling to 113 out of 176 respondents. On land status in the study area, the results showed that, 52 percent of the respondents in Kalawa (34 out of 65) and 65 percent in Kithimani (33 out of 51) and 20 percent or 12 out of 60 respondents in Thaana were found to have land registered with tittle deeds. In the thaana clusters 80 percent (48 out of 60 households) of the respondents had their land without tittle deeds.

Table 7 : Sources of Tc bananas and availability of extension services as policy factors

Variables N=176		**Thaana n=60**	**Kithimani n=51**	**Kalawa n=65**	**Mean**	**Std dev.**
1. Sources of Tc bananas						
TC banana sources	KALRO	28 (17)	39 (20)	29 (19)	32(19)	0.50913
	University	20 (12)	4 (2)	14 (9)	13(8)	1.48663
	Dealers (Nurseries)	18 (11)	8 (4)	6 (3)	11(6)	0.78418
	Neighbours	20 (12)	16 (8)	31 (20)	14(10)	0.45108
	Others	13 (8)	33 (17)	20 (13)	22(13)	1.44653
2. Availability of extension services (public or private)						
Extension services (public or private)	Available	15 (25)	31(19)	60 (39)	35(28)	0.50062
	Not available	85 (40)	69 (41)	40 (12)	65(31)	0.50148

Numbers in parenthesis represent frequencies;

Regarding the awareness of extension services in the study area, 108 (26 in Kalawa, 48 in Thaana and 24 in kithimani were aware that the government or private extension services providers existed in the area though they rarely visited the respondents since they were few and the area was expansive. About 68 (39 in Kalawa, 12 in Thaana and 17 in Kithimani) out of 176 respondents were not aware of the existence of either government or private extension services providers in the area (Table. 7). There was mixed results on awareness of farm inputs subsidy scheme in form of National Cereals Produce Board fertilizers supply, 99 respondents' (32 in Kalawa, 42 in Thaana and 25 in Kithimani) were found to be aware with 77 (33 in Kalawa, 18 in Thaana and 26 in Kithimani) not aware of its existence

Regarding the wild life menace effect to the crops in the farms in the study area, 122 (48 in Kalawa, 19 in Thaana and 55 in Kithimani) respondents heads were found to be affected Kithimani reported low effect of the wildlife to the tissue culture bananas at 54 (17 in kalawa, 32 in Thaana and 5 in Kithimani). (Table. 7).

When the respondents were asked to show if they had obatained credit, 53, 28 and 51 of those interviewed from Kalawa, Thaana and Kithimani respectively indicated that they had not borrowed any credit while 12, 23, and 9 from Kalawa, Thaana and Kithimani had borrowed credit indicating low credit possession in the region.

Table. 8 Other Policy related factors influencing adoption of tissue culture bananas

Other policy factors	**(F) %**	**(F) %**	**chi-square statistic**	***p*-value**
1. Multiplication centres	HH endorsing establishment of multiplication centres	HH not endorsing establishment of Tc multiplication centres for Tc bananas		
Kalawa (n=65)	92(60)	8 (5)	21.0609	0.000027
Thaana (n=60)	80 (48)	20 (12)	10.0385	0.001533
Kithimani(n=51)	57 (29)	43 (22)	6.9454	0.008403
2. Land Status	Farms with tittle deeds	Farms without tittle deeds		
Kalawa(n=65)	52(34)	48(31)	24.5663	0.00001
Thaana(n=60)	20(12)	80(48)	21.0866	0.00112
Kithimani(n=51)	65(33)	35(18)	4.0543	0.00211
3. Extension Services	HH Aware of extension services	HH Unaware extension services		

Kalawa(n=65)	40(26)	60(39)	21.9073.	0.000017
Thaana(n=60)	80(48)	20(12)	9.0552	0.00011
Kithimani(n=51)	67(34)	33(17)	22.7312	0.000221
4. Farm Inputs Subsidy	HH Aware about subsidy	HH Unaware about subsidy		
Kalawa(n=65)	49(32)	51(33)	6.9943.	0.030284
Thaana(n=60)	70(42)	30(18)	5.9550	0.022110
Kithimani(n=51)	49(25)	75(26)	7.9221	0.03100
5. Wildlife	HH affected by Wildlife	HH not affected by Wildlife		
Kalawa(n=65)	74(48)	26(17)	39.3692.	0.00001
Kithimani(n=51)	37(19)	63(32)	22.0721	0.00011
Thaana(n=60)	92(55)	8(5)	35.2002	0.00021
6. Credit	HH with any form of farm credit	HH without credit		
Kalawa(n=65)	18(12)	72(53)	15.6690	0.000396
Kithimani(n=51)	45(23)	55(28)	12.0732	0.000312
Thaana(n=60)	15(9)	85(51)	13.0061	0.000317

Numbers in parenthesis represent frequencies;

The respondents results (in table. 8 above) that tested as being significant in influencing adoption of tissue culture bananas at 95% level of confidence (with $p < 0.05$) were as follows:-

- Endorsing establishment of Tc multiplication centres in the study area
- Extension Services : respondents aware of extension services
- Land Status: Farms with tittle deeds
- Farm Inputs Subsidy respondents aware about subsidy
- Wildlife : respondents affected by Wildlife
- Credit : respondents with any form of farm credit

CHAPTER FIVE

5.0 DISCUSSION

Gender was found to be a significant factor in influencing adoption of tissue culture bananas in the study area ($p < 0.05$). Thaana and Kithimani had more females growing the bananas than in Kalawa. Male respondents were found to be adopting the tissue culture bananas less than female respondents. This could be due to the fact that male respondents are likely to have more access to resources and information than women respondents due to traditional and cultural gender roles which tend to discriminate against women. This was in agreement with findings by Nyerere *et al*., (2000) who showed that men usually have more access. These findings were also reported by Nyang *et al.,* (2010), that males have more power to make decisions regarding the factors of production on the farms. Therefore, there is need for gender mainstreaming in programs involving adoption of technologies (Perret *et al.*, 2006). Women have no security of tenure for the land which makes it difficult for them to access resources such as credit (Barrette *et al.*, 2003). Lack of security on tenure is a disincentive for women to invest in modern technologies such as tissue culture bananas. Rine *et al.,* (2004) also confirms this scenario, and further notes that gender is a determinant for technological adoption in the semi arid areas. While assessing the impact of banana biotechnology in Kenya, Qaim *et al.,* (2010), noted that respondents' food security management has significant relationship to the participation of the male and female that composes the family unit. This means that decision to adopt is more consultatively done in a family unit setting (Barrette *et al.*, 2003).

Most of the farmers were aged between 50-60 years comprising of 37 percent followed by 40-50 years with 31 percent then 21 percent (less than 40 years) and 11.4% (above 60 years) respectfully. This could be because farmers aged 50-60 years have resources to commission to tissue culture bananas farming. Those above 60 years were few since they were old and less productive while youth had moved to urban areas leaving the aged in the rural areas. According to Wanyama *et al.,* (2013), age of the farm household head is a continuous variable, defined as the farm household heads' age at the time of interview measured in years. The study argues that the farmer's age may negatively influence the decision to adopt appropriate technologies on tissue culture bananas farming. The study hypothesized that older farmers were more at risk to averse and less likely to be flexible than younger farmer counterparts and thus have a lesser likelihood of adopting new technologies like tissue culture bananas.

Tissue culture bananas' farming is directly related to the experience and age of respondent (Ruben *et al,* 2010). The study adds that knowledge in tissue culture bananas farming significantly influences the adoption of tissue culture bananas. From the analysis, a unit increase in farmer tissue culture bananas knowledge would lead to an increased adoption of tissue culture bananas by 1 percent while a decrease in farmers' tissue culture bananas knowledge would result to decreased adoption. The county governments should put in place strategies to improve farmer's knowledge about tissue culture bananas. The results showed that 64 percent of the respondents cultivated banana varieties of dual purpose, both cooking and ripening types while 29 percent grew the ripening varieties only. The latter may be linked to the need for cash while the former could be due to food security and income generation reasons. As noted earlier, the area under study had past food insecurity constraints, thus the need to balance cash and food availability demands. Wambugu (2004) described the upper eastern Kenya region to have had perennial food deficits occurrences, thus calling for technologies that could improve food security and poverty alleviation. Experience amongst farmers on tissue culture bananas was low, which was comparable to a study done by Wambugu (2004) on promoting tissue culture banana plantations. This suggests that investment in farmers training on production skills on the tissue culture bananas could lead to increased adoption as was the case in Middle Eastern region of Embu, Tharaka, Meru and Mbeere (Wambugu *et al.*, 2004).

It was also found that education significantly affected adoption of tissue culture bananas in the study area ($p < 0.05$). Majority of the respondents had attained some level of education as indicated by 57 percent having attained secondary education and 27 percent having primary education. According to KDHS (2014), education and knowledge are key determinants of the lifestyle and status of an individual in a society. Adoption of new food sources increases with education and knowledge on the importance of this to nutrition and health. Farmers' education significantly influences the adoption (Wambugu *et al.*, 2004). Therefore, a strategy to increase farmer's education would greatly lead to increased adoption of tissue culture bananas (Wambugu *et al.*, 2004). According to the World Bank (2014), education influences farmers' decision to adopt new technologies like tissue culture bananas with countries being advised to invest heavily on education and skills development to enhance adoption levels (World Bank, 2014). Developing countries should promote exposure of their farmers to new spheres of modern farming through improved adoption of technologies in their effort to solve issues of food insecurity (UNFAO, 2015).

Nyang *et al.*, (2010) suggest that education can significantly affect the entry and adoption of new technological innovations, with the educated community members being able to calculate the pros and cons of new packages, and if found superior to adopt and practice with ease. Tissue culture is a new technology and its adoption could create challenges to the less educated members of the society unless backed up by farmer education and exposure (Wambugu *et al.*, 2004). In addition, poverty has a major bearing on education and one way to eradicate poverty is by giving space to education (FAO, 2014). Literacy statistics are important for policy makers to determine how best to reach the populations they serve (Barrette *et al.*, 2003).

The results indicated that farmers training was significant at ($p < 0.05$) with respondents that had undergone training on tissue culture bananas production in Kalawa being more (48 out of 65) while others Kithimani and Thaana had more untrained respondents (38 and 48 respectively). According to Nyang *et al.*, 2010, the adoption of new technologies in Western Uganda was greatly influenced by farmer training opportunities. Exposure of farmers through capacity building improved skills of production thus enhancing improvement of their standards of living (Nyang *et al.*, 2010).

This study revealed that most respondents (62 percent) belong to a formal or informal group. This provides an opportunity for extension services through groups, which saves time and resources in the training of farmers, sourcing of inputs and tissue culture bananas plantlets, and group production and marketing which enhances economies of scale. The respondents group affiliation was equally found a significant factor in influencing adoption of tissue culture bananas in the study areas, with two clusters (Kalawa and Kithimani) having more farmers belonging to the groups. According to Nyang *et al.*, (2010), farmers in groups are easy to work with during extension services delivery, training, demonstrations and field days. The farmers' groupings also enhance bargaining power while sourcing for inputs and planting materials (Marra *et al.*, 2015). The advancement of subsidy and credit facilities to farmers is easy when members guarantee each other thus enhancing adoption (Anyango *et al.*, 2007). These observations are complimented by Langat *et al.*, (2013), who wrote of subsidies as drivers of technology adoption and Awotide *et al.*, (2012) while analyzing seed voucher subsidy system.

It was evident from the findings that availability of extension services was a significant factor in influencing adoption of tissue culture bananas in the study areas. This was confirmed by Uphoff *et al.,* (2002) who found that households require practical training through demonstrations and extension services to improve productivity and adoption of tissue culture bananas. Opening up more tissue culture bananas multiplication and demonstration centres and widening the technology transfers scope amongst farmers through investment by government and development partners in farmer training and extension, education excursions or tours to contemporary areas on Tissue Culture bananas production would enhance the impact of this and other technologies in the target counties (Robinson *et al*., 2014). Farmer's exposure to more extension services leads to increased adoption since farmers are able to gain knowledge on tissue culture bananas farming (Wanyama *et al.,* 2013). Due to this knowledge, the national and county governments and other development partners should put in place measures to improve extension services through extension officer's facilitation as well as increasing the service providers' number (Barrette *et al.*, 2003).

Extension services were important in tissue culture bananas farming as a means to modern technology transfer between researchers and the farmers (Wanyama *et al.*, (2013). This calls for more extension services from both the public and private sectors to enhance adoption of such technologies like tissue culture bananas. The results suggest that the probability of adoption of tissue culture bananas could be enhanced by taking cognizance of these variables in order to meet the priority needs of smallholder farmers who were target group to alleviate the food shortage problem in the country and particularly in the study area (Wanyama *et al.*, (2013).

Socio-economically, majority of the respondents (66 percent) had an income of less than Ksh. 10,000 per month which was low as per the UNDP, 2015 statistics. Thus, there would be need for intensive agriculture investment through adoption of modern farming technologies to supplement source of family income and food availability especially in the arid and semi-arid areas. Income generation from farming in ASALs is highly weather-driven (Murero *et al*., 2014). Adoption of technologies that counteract the adverse weather like drought tolerant cropping systems and new crop varieties are notable options in solving food insecurity in the arid areas (UN-FAO, 2014). Regionally, crop incomes have remained an important contributor to household income in the western and central highlands, western transitional and high potential maize zones, contributing between 41 percent and 65 percent over the decade (Mutero, 2012). In the semi-arid areas such as coastal and eastern lowlands and marginal rain shadow, crops generally contribute less to total household incomes between 10 percent and 43 percent compared to the high potential agricultural regions (Murero *et al*., 2014). The production interventions such as adoption of tissue culture bananas, using water harvesting and efficient water use systems like drip irrigation along water sources like dams and rivers are visible today though highly dependent on households income, education and knowledge (Murero *et al*., 2014). According to Ruben *et al.,* (2011), soil and water conservation measures are highly advised and community participation is important in order to have sustainable production trends.

Adoption of new production techniques like tissue culture bananas is driven by the need to produce more for attainment of food security and income generation (UN-FAO, 2014). According to Wambugu (2004), decomposition of household income revealed that crop income related to adoption of high value crops like fruits and vegetables is a major component of household income today, contributing to over 40 percent in 1997, 50 percent in 2000, 46 percent in 2004 and 44 percent in 2007. Low incomes reflect poor adoption for technologies whose acquisition is assumed to be costly, while improved incomes create more opportunities to adoption of technologies such as tissue culture bananas (Perret *et al.*, 2006). Variations over time in agriculture within the arid and semi-arid areas are linked to adoption of technologies or even the non-adoption to the same (Sani *et al.*, 2014).

The results showed that the major economic activity was farming at 32 percent and non-farm employment in other areas like in towns (28 %). This means that majority of respondents were available on their farms. This gives an incentive for adoption of technologies like tissue culture bananas. Wambugu (2004), showed that the success of tissue culture bananas adoption was due to the agronomical support provided by Africa Harvest NGO which resulted into significant increase of farmers' incomes in Upper Eastern Embu, Meru and Tharaka as well as central region in Nyeri, Kirinyaga, Murang'a and Kiambu counties.

The study revealed that total land size influenced adoption of tissue culture bananas. Most of the respondents had less than 10 acres of land at an average of 5.51 acres. Majority of the farmers' land size range was between 3 and 5 acres. This means that they were small-scale growers according to FAO (2013). This might be because the clusters were densely populated and most of them were small scale farmers. Wanyama *et al.*, (2013) argues that farm size affects adoption of any farm technology in a significant way. The larger the farm sizes, the more the likelihood of allocating more land and accompanying resources to the new crop (Mclutyre *et al.*, 2009).

The results showed that farmers who owned bigger land could utilize more capital and had demand for tissue culture bananas. The study showed that land under the tissue culture bananas though significantly influencing adoption was low compared to the available total household land. The Kenya Vision 2030 envisions an additional 1 million hectares of idle land in existing farming areas to be brought under production, and additional 1.2 million hectares in ASALs to be under irrigation. The tissue culture bananas promotion envisaged in the Makueni County Vision 2025 aims at increased adoption in the study areas in a bid to bring more of the existing idle land under commercial tissue culture bananas production in order to solve food insecurity (GoK, 2014).

After regression analysis in this study, land size under tissue culture bananas was found to have significant influence on the adoption of tissue culture bananas ($p < 0.05$). This means that the land size respondents set aside for tissue culture bananas affects the scale of adoption. The findings revealed that a unit increase in land size in tissue culture bananas would result into an increase in adoption of tissue culture bananas. This was confirmed by Thorpe *et al.*, (2007) who found that intensive land use increased with increase in land size due to better application of technology such as tissue culture bananas adoption and vice versa. Land ownership defined in the status results which concluded that it was a significant factor influencing adoption of tissue culture bananas technologies in the study area. Land is an important resource in farming activities in the arid semi-arid lands as shown by Manda *et al.*, (2015). Evidence of rapid adoption of land rehabilitation techniques in parts of Niger and Burkina Faso is credited to effective farmer to farmer extension education, although this factor is often underrated (Critchley *et al.*, 2002). Policy evolution provides support for institutional mechanisms designed to provide support for the diffusion of knowledge among farmer’s adopters and demonstration of gains from new technologies like tissue culture bananas (Uaiene *et al.*, 2011). The author adds that Donors, national policy-makers and extension personnel should be more concerned about frequent food deficits and accelerating degradation of land resources in the ASAL areas with attention being focused on achieving both technical change in agricultural production practices and improved natural resource management. These findings are in agreement with Forson *et al*., (2001), who showed implications land title deeds as the most positive sign and that its availability is an enhancement to greater technologies adoption that provide long term profitability leading to a greater probability of the level of adoption and intensity of land use. This confirms observation that farmers of the Sahel zone exhibit preference for policies that lead improved land ownership through title deeds for enhanced land investments and development (Baidu-Forson *et al.*, 1994).

Most farmers, (69.9 percent) sold their produce in the local markets. This could be due to high demand of tissue culture bananas in the market as well as low supply of the bananas. This was followed by neighbors who purchased 27.3 percent and only 2.8 percent for brokers. In all the study clusters, 71 percent of respondents indicated that tissue culture bananas plantlets were not available in the local market. This could also be the reason for low adoption of this type of farming. The supply was low in Kithimani (Yatta, Machakos), Kithyoko (Masinga, Machakos), and Kanyonyo (Yatta, Machakos) or Nguutani (Mwingi West, Kitui) (MOA, 2014).

Most respondents suggested that the supply of bananas can be improved through support, collaboration and networking with accredited tissue culture bananas producers and stakeholders at the onset of the rains using the local markets. The number of respondents who agreed on availability of certified sources of tissue culture bananas equals the number of respondents at 48.3 percent. Farmers knew where the tissue culture bananas were found though they were very far away. For majority of respondents (58 percent), the distance from their farms to the nearest market was less than 50 Kms. This showed that farmers were able to move to the market and purchase the tissue culture bananas plantlets if availed. Many of respondents named KALRO as their sole source of tissue culture banana plantlets. A large number of respondents were not aware of any source. This showed that there was need for KALRO to move closer to banana farmers in lower eastern region by devolving to counties, sub counties and wards. According to Wanyama *et al*, (2013), access of tissue culture bananas market significantly influenced the adoption of tissue culture bananas ($p < 0.05$). Farmers with access to market easily adopt tissue culture bananas unlike those without market access. A unit increase in tissue culture bananas markets would lead to increase in tissue culture bananas adoption. This calls for the county government to source for more markets of tissue culture bananas so as to encourage more farmers to adopt tissue culture banana farming hence its commercialization.

Regarding environmental factors affecting adoption, the data showed that 68 percent of the sampled respondents had soil and water conservation structures on their farms, an indication of high level of awareness in soil and water conservation practices in the study area. Also most respondents had this as a major farm practice. This study showed significance of the environmental factors affecting adoption of tissue culture bananas in the semi-arid areas of lower eastern Kenya. These factors included soil and water conservation as well as growing methods, and general climatic factors that influence growth and maturity of bananas. Ecological factors are key determinants to growth of any crop (Mathenge *et al.*, 2015). The results showed that livestock ownership significantly influenced tissue culture bananas adoption in the study area ($p < 0.05$). Thaana recorded more respondents without livestock than Kithimani and Kalawa and therefore with less tissue culture bananas farming than the latter two clusters. This was attributed to lack of finances and manure to enhance tissue culture bananas farming. Livestock is wealth as well as income in the region and also a major source of farm yard manure (Mathenge *et al.*, 2015). Farm yard manure importance in soil fertility improvement and supply of vital soil elements to crops is well documented by Wanyama *et al.*, (2013). Soil fertility is a significant factor to increased adoption of crop technologies (Nguluu *et al.*, 2014).

The results showed that bananas mature in an average of 8.9 months in the study area though Uphoff, (2002) recorded that they could take upto 18 months to mature. Accordingly, any adverse weather restricts growth to maturity of tissue culture bananas. They respond to growth factors such as soil fertility and available moisture. This means that the study area is highly favorable to tissue culture bananas cultivation with early maturity and thus optimal solution to income generation and food supply to the respondents. Maturity of crops is a derivative to the factors related to climate and soils. These favourable factors include good soils, temperatures and moisture among others. Any assurance of such factors enhances faster growth to maturity of tissue culture bananas (Mazvimavi *et al.*, 2009). The results confirmed the study area as potentially suitable for tissue culture bananas production. The major constraints affecting the adoption of tissue culture bananas were found to be high cost of suckers, wild animals, high cost of other inputs and lack of extension services ($p < 0.05$) thus posing a serious challenge in the cultivation of the crop in the study area.

There could be issues of policy that could turn around the low adoption and therefore enhancing food security and poverty alleviation in the area (Quim *et al.*, 2012). A policy aimed at reduced cost per sucker, could address the constraint of high cost of planting materials that was facing 29.8

per cent of the respondents. A policy on subsidized fertilizers and improved tissue culture bananas plantlets could as well be relevant in enhancing tissue culture bananas cultivation in the study area (Mazvimavi *et al.*, 2009). Farm inputs subsidy as a policy factor influencing adoption of tissue culture bananas was found to be significant ($p < 0.05$) with all clusters being aware of its place and importance in agriculture. Countries and counties considering the introduction of agricultural input subsidies should recognise the different potential benefits they can yield, the conditions required for those benefits to be realized, and the possible very significant pitfalls from ineffective implementation (Mazvimavi *et al.*, 2009).

This deduction was complemented by Wambugu *et al.*, (2004) who noted that input subsidies have played an important role in successful agricultural technology adoption and broader development in the past, with major gains when effectively applied to overcome market failures constraining their productive use, but with substantial risks of costly and ineffective implementation using large amounts of scarce resources for little gain. The same author added that inputs subsidies have greatest (but not exclusive) potential in contributing to wider technological adoption and growth when applied to production of staple food crops with a key contribution to consumers' welfare and real incomes through lowering food prices, but this requires large programmes with complementary investment and output market development policies to bring prices down (perhaps below import parity) and involves substantial costs and risks. He concluded that policy objectives of input subsidies are, like policy objectives in wider agricultural development, paradoxical – with investments in staple crop production and agriculture needed to stimulate diversification out of staple food and agricultural production (Mazvimavi *et al.*, 2009).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the study it can be concluded that the adoption of tissue culture bananas in Kalawa, Kithimani and Thaana located in the Lower Eastern Semi-Arid areas of Kenya was evidently low. The majority of the respondents did not adopt due to house hold related factors like gender and experience, socio economic related factors like markets factors and group affiliated issues, some policy related factors like unavailability of extension services, farmer training and education. Other factors include environment related issues like soil and water conservation structures, fencing, land use (livestock ownership) practices that affect soil fertility, wildlife menace, credit and subsidy issue and membership to groups in the village. The regression and chi - squares analysis concluded that gender, education, total land size, tissue culture bananas knowledge, acreage under tissue culture bananas, tissue culture bananas market and extension services were significant at $P < 0.05$ and influenced the adoption of tissue culture bananas adoption.

Gender and experience were found to be significant factors in determining adoption of tissue culture bananas in the study area ($p < 0.05$). Therefore, there is need for gender mainstreaming in programs involving adoption of technologies by respondents in order to address food security management in the study areas of Thaana, Kalawa and Kithimani. Gender was concluded to have significant relationship especially to the participation of the male and female that composes the family unit in the adoption of tissue culture bananas, meaning that decision to adopt is more consultatively done in a family unit setting. More respondents should be exposed to get more tissue culture bananas farming experience to enhance adoption and development of the sub sector.

The study concluded that education significantly affected adoption of tissue culture bananas in the study area ($p < 0.05$). Education and knowledge are key determinants of the lifestyle and status of an individual in a society. Adoption of new food sources increases with education and knowledge on the importance of this to nutrition and health. Other studies also confirmed that Farmers' education significantly influences the adoption. The study concluded that education can significantly affect the entry and adoption of new technological innovations, with the educated community members being able to calculate the pros and cons of new packages, and if found superior to adopt and practice with ease.

The results concluded that farmers' training was significant ($p < 0.05$) with respondents that had undergone training on tissue culture bananas production in the entire study areas of Kalawa, Kithimani and Thaana. It was concluded that adoption of new technologies was greatly influenced by farmer training opportunities. Exposure of farmers through capacity building improved skills of production thus enhancing improvement of their standards of living.

The study concluded that availability of extension services was a significant factor in influencing adoption of tissue culture bananas in the study areas. The study results concluded that Farmer's exposure to more extension services leads to increased adoption since farmers are able to gain knowledge on tissue culture bananas farming and that the national and county governments and other development partners should put in place measures to improve extension services through extension officer's facilitation as well as increasing the service providers' number.

This study concluded that most respondents (62 percent) belong to formal or informal groupings. This provides an opportunity for extension services delivery through groups, which saves time and resources in the training of farmers, sourcing of inputs and tissue culture bananas plantlets, and group production and marketing which enhances economies of scale and sustainability. The study concluded on the use of the groups available in the study area as farmers' groupings in extension services delivery.

The study concluded that Socio-economically, majority of the respondents (66 percent) had an income of less than Ksh. 10,000 per month which was low. Thus, there would be need for intensive agriculture investment through adoption of modern farming technologies to supplement source of family income and food availability especially in the arid and semi-arid areas. Low incomes reflect poor adoption for technologies whose acquisition is assumed to be costly, while improved incomes create more opportunities to adoption of technologies such as tissue culture bananas.

Most respondents suggested that the supply of bananas can be improved through support; collaboration and networking with accredited tissue culture bananas producers; support of capacity building on establishment of village level hardening nurseries, and facilitation of research on banana preferences, varieties value addition and utilization. The study concluded that most farmers, (69.9 percent) sold their produce in the local markets and that there was high demand of tissue culture bananas in the market as well as low supply of the bananas. In all the study clusters, the study concluded that 71 percent of respondents indicated that tissue culture banana plantlets were not available in the local market. These results helped to conclude that this was the reason for low adoption of tissue culture bananas farming. Most respondents were in conclusion that the supply of bananas can be improved through support, collaboration and networking with accredited tissue culture bananas producers and stakeholders. The study results showed conclusively that Kenya Agricultural Livestock Research Organization as the best source of the tissue culture bananas plantlets and that more sub stations are recommended to encourage more farmers to adopt tissue culture banana farming hence its commercialization.

Regarding environmental factors affecting adoption, the study concluded on the significance of the environmental factors such as soil and water conservation as well as growing methods, as factors that influenced growth and maturity of bananas affecting adoption of tissue culture bananas in the semi-arid areas of lower eastern Kenya. The results concluded the study area as potentially suitable for tissue culture bananas production since the results showed that bananas mature in an average of 8.9 months in the study area unlike 18 months observed from other areas. The study concluded that total land size influenced adoption of tissue culture bananas, that most of the respondents had an average of 5.51 acres. Land ownership status results concluded that it was a significant factor influencing adoption of tissue culture bananas. The study showed implications of land title deeds as the most positive sign and that its availability is an enhancement to greater technologies adoption that provide long term profitability leading to a greater probability of the level of adoption and intensity of land use.

The issue of a strategic subsidy policy plan was concluded as a suitable option given the high level of povety at above 60 percent index with Farmers who appear poor and unable to access the expensive inputs but have land to grow the crops being potential candidates of picking up or adopting new innovation technologies like tissue culture bananas.

On wildlife as a factor significantly influencing adoption of tissue culture bananas in the study area, the respondends were in conclusion that this was a constraint that required policy intervention.

6.2 Recommendations

The following are the recommendations based on the preceding conclusions of the study:-

1. The National, County Governments and other development partners should put in place measures to improve extension services and training aimed at increasing adoption and thus acreage under tissue culture bananas in the study areas.
2. Reducing the cost of the improved tissue culture bananas plantlets as incentive to adoption of tissue culture bananas is equally important.
3. Decentralization of tissue culture banana technology like KALRO centres to areas near the farmers to increase their availability is recommended to enhance the adoption.
4. Improving the awareness and provisions of credit facilities to tissue culture bananas farmers to enable them commercialize the fruit production.
5. Wildlife is a major concern and quite significant in the area under study and sustainable solution through policy intervention is recommended.
6. The three County Governments in collaboration with the National Government and other development partners should address farmers' education and general capacity building in line with acceleration of adoption of tissue culture bananas across the entire value chain in the study areas.
7. Also recommended are policies aimed at exploiting the rivers and their tributaries to addressing the perennial food insecurity in the region by putting more acreage under tissue culture bananas thereby increasing adoption.
8. A policy to accelerate adoption of the tissue culture bananas technology through a well-designed and strategic subsidy scheme is also recommended. Reduced unit costs of the plantlets through subsidy policy interventions can be a significant milestone to the enhanced adoption of tissue culture bananas. in the study areas
9. More multiplication centres or nurseries should be established in the study area and the community through organized registered farmer groups trained on how to propagate the suckers' hence increasing adoption and sustainability of the tissue culture bananas initiatives.
10. More study is needed in the following areas: 1) Variety suitability trials on the appropriate tissues culture cultivars in the Lower Eastern Counties; 2) Soil mapping studies for detailed fertility status on riverine areas of Lower Eastern Counties; 3) Economic and nutritional appraisal of tissue culture bananas in kenya.

REFERENCES

1. Adesina A, A. (2002). "Smallholder Technical Efficiency Controlling for Environmental Production Conditions." *Journal of Development Economics* 69 (1*):* 85–101.
2. Adesina, A, A and Zinnah, M.M (1993). Technology Characteristics, Farmers' Perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone; *Agricultural Economics* 1993;9: 297-311
3. Adesina, A. A. and Baidu, J.F (2011), Revised Edition). "Farmers' perception and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, west Africa." *Agricultural Economics* 13(1995): 1-9
4. Adesina, A.A and Forson. B, (1995). Farmers' Perception and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, *West Africa. Agricultural economics*. 1995; 13: 1-9.
5. Anyango, J.J., Wambugu, F.M., Nkanya, J. and Kyalo G., (2007). :Introduction of Tissue Culture Banana Technologies and Their Impact on Producer Well being (2007)., *Journal Of Advanced Agricultural Technologies, Vol.12*
6. Awotide, B.A, Diagne A, Awoyemi, T.T. and Ojehomon, V.E.T, (2012). Impact of Seed Voucher System on Rice Yield, Income Inequality and Poverty Reduction in Rural Nigeria: A Randomized Control Trial Approach. Proceedings at the 26th International Conference of the Centre for the Studies of African Economies (CSAE), St. Catherine's College Oxford, U.K. 18th-20th March, 2012. 2012: 1-33.
7. Bandiera, O. and Rasul, I. (2002). *Social networks and technology adoption in northern Mozambique*. Technical Report 3341, CEPR Discussion Paper.
8. Bandiera, O. and Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The Economic Journal* 116, 869–902.
9. Barrett, C. B. (2003). "The Disappointing Adoption Dynamics of a Yield-Increasing, Low External-Input Technology: The Case of SRI in Madagascar." *Agricultural Systems* 76 *(*3*):* 1085–1100.
10. Becerril, J. and Abdulai, A. (2009). The impact of Improved Maize Varieties on Poverty in Mexico: A Propensity Score-Approach. *World Development Journal VOL.33*, 38:1024-1035.
11. Beshir, H, (2014). Factors Affecting the Adoption and Intensity of Use of Improved Forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*. 2014; 4(1):

12-27. Biological factors affecting seed production in East African Highland bananas. J Crop Imp 16: 67–77.

12. Chandler, S. (1995*).* The nutritional value of bananas. *P.*468–480. In: S. Gowen (ed.), Bananas and Plantains. Chapman and Hall, London. *International world Journal,Vol.12*

13. Cockburn , D L , 2002 ; World classical demographic studies; pp 125-198, *International Food Policy Research Institute journal*, Washington, DC, USA

14. Couros, A. and Kesten C, (2003). Innovation, Change Theory and the Acceptance of New Technologies: *A Literature Review*. 2003: 1-42.

15. Critchley, W.R.S., Reij, C.P., and Turner, S.D., (1992). Soil and water conservation in sub-Saharan Africa: towards sustainable production by the rural poor. A report prepared for the International Fund for Agricultural Development (IFAD) by the Centre for Development Cooperation Services, Free University, Amsterdam.

16. Dekkers, J.C.M, and Hospital, F (2002). The use of molecular genetics in the improvement of agricultural populations. *Nat Rev Genet* 3: 22–32.

17. Diao X, Hazell P, Resnick D and Thurlow J. (2006). The role of agriculture in development: implications for Sub-Saharan Africa. DSGD Discussion Papers 29. *International Food Policy Research Institute journal*, Washington, DC, USA

18. UNFAO. (1995). Planning for Sustainable Use of Land Resources. Towards New Approach. Rome, Italy. 1995:1-60.

19. Forson, B, (1994). Adoption of soil and water conservation practices in the Sudano-Sahelian Zone: constraints and incentives. In: Napier, T.L., Camboni, S.M., EI-Swaify, S.A. (Eds.), *Adopting Conservation on the Farm: An International Perspective on the Socioeconomics of Soil and Water Conservation*, 13. Soil and Water Conservation Society (U.S.), Ankeny, IA, pp. 157-169.

20. GoK, (2004). *Strategy for revitalizing agriculture, 2004-2014*. In Nairobi, Kenya. Ministries of Agriculture, Livestock and Fisheries Development, and Cooperative Development and Marketing. 2004.

21. GoK, (2007). *Kenya Vision 2030. The Popular Version*. In Nairobi, Kenya, Government Ministry. 2007:1-32.

22. Kabunga, J., Nassul, S., Thomas, D. and Qaim, M (2012). Yield Effects of Tissue Culture Bananas in Kenya: Accounting for Selection Bias and the Role of Complementary Inputs. *Journal of Agricultural Economics* 63(2): 444–464. DOI**:** 10.1111/j.1477-9552.2012.00337.

23. Kabunga, N.S., Dubois, T., and Qaim, M. (2012). Heterogeneous Information Exposure and Technology Adoption: The Case of Tissue Culture Bananas in Kenya. *Journal of Agricultural Economics*; 43: 473–86. DOI: 10.1111/j.1574-0862.2012.00597.x
24. Kassie, M., M, Jaleta, B., Shiferaw, R, Mmbando, F., and Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, 80(3), 525–540. http://dx.doi.org/10.1016/j.agsy.2009.01.001.
25. Kassie, M., Teklewold H and Jaleta M., (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy*, 42, 400–411. http://dx.doi.org/10.1016/j.landusepol.2014.08.016
26. Kassie, M. Khonje, M., J. Manda, A.D. and Alene, G. (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. *World Development*, 66, 695–706. doi.org/10.1016/j.worlddev.2014.09.008.
27. Kathage, J. M., Kassie, B. Shiferaw L K, and Qaim M. (2016). Big constraints or small returns? Explaining non adoption of hybrid maize in Tanzania. *Journal of Applied Economic Perspectives and Policy*, 38(1), 113–131. DOI: 10.1093/aepp/ppv009.
28. Langat, B.K, Ngeno, V.K, Nyangweso, P.M, Mutwol M. J, Kipsat, M.J, Gohole, L and Yaninek S (2013). Drivers of Technology Adoption in a Subsistence Economy: The case of Tissue Culture Bananas in Western Kenya. Invited Paper Presented at The 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia. 2013: 1-17, *Journal Of Agricultural Economics, Vol.6*,
29. Langyintuo, A. S., *and Mungoma, C. (2*008). The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food policy*, 33(6), 550–559. http://dx.doi.org/10.1016/j.foodpol.2008.04.002.
30. Lidia, D. J., Aliou, D., Gauthier B, Simon N.C., and Kifouly, S.M, (2012). Determinants of diffusion and adoption of improved technology for rice parboiling in Benin. - *Review of agricultural and environmental studies*, INRA Editions, 93 (2), pp.171–191.
31. Manda, J., A.D., Alene, C., Gardebroek, Kassie, M., and G. Tembo (2015). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. *Journal of Agricultural Economics*, 67(1), pp. 130–153. DOI: 10.1111/1477-9552.12127.

32. Marra, M., B. Hubbell, G. C and. Carlson G, (2001). Information Quality, Technology Depreciation and Bt Cotton Adoption in the Southeast. *Journal of Agricultural and Resource Economics*, 26(1), 158–175.
33. Mathenge, M.K., Smale, M., and D. Tschirley (2015). Off-farm Employment and Input Intensification among Smallholder Maize Farmers in Kenya. *Journal of Agricultural Economics*, 66(2), 519–536. DOI: 10.1111/1477-9552.12093.
34. Matuschke, I. and Qaim, M. (2009). The Impact of Social Networks on Hybrid Seed Adoption in India. *Journal of Agricultural Economics;* 40 (5): 493–505.
35. Mazvimavi, K., and Twomlow, S. (2009). Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. *Agricultural Systems*, 101(1), 20–29. http://dx.doi.org/10.1016/j.agsy.2009.02.002.
36. Mbogoh, S. G., Wambugu, F. M. and Wakhusama, S., (2003). Socio-economic impact of biotechnology Applications: some lessons from the pilot tissue culture (Tc) banana production promotion project in Kenya, 1997-2002. Proceedings of the 25th International Conference of Agricultural Economists (IAAE), Durban, South Africa, *Document Transformation Technologies.*
37. McIntyre, B.D, Herren, H.R., and Wakhungu, J, and Watson, R.T. Agriculture at a Crossroads. Sub-Saharan Africa (SSA) Report. In Beverly D. McIntyre HRH, Judi Wakhungu, Robert T. Watson (ED). Volume V, Island Press, *International Assessment of Agricultural Knowledge, Science and Technology for Development*. 2009:1-606.
38. Murray R Spiegel, Larry J. Stephens (1999) statistics third edition; McGraw-Hill international editions; Schaums outline of theory and problems of statistics(1999)
39. Murero, J. S. (2014). Technology Adoption , A case of Semi-Arid Areas of kenya, *International Journal Of Biotechnology*,17 (2014)
40. Nguluu, S. N., Karanja, J., Kimatu J.N., Gicheru, P.T., Musimba, N., Njiru, E., Kathuli, P., Nzioki, H., Akuja, T., Muli, B.K., Nzombe, N.N. 2014. Refining Dryland Farming Systems as a Means of Enhancing Agro diversity and Food Security in Eastern Kenya: A review. Journal of Advances in Agriculture,Vol.3, No.1, pp. 142-149
41. Nguluu, S.N. 1994. Effects of Phosphorus on Nitrogen Contribution of Legumes in Farming Systems of the Semi-Arid tropics: Chapter 7: Use of model to extrapolate to a Kenyan situation (Wamunyu). PhD Thesis, University of Queensland, Australia.

42. Nguthi, F. N. (2007). Adoption of agricultural innovations by smallholder farmers in the context of HIV/AIDS: The case of tissue-cultured banana in Kenya. PhD Thesis: University Of Nairobi, Pp 1-226.
43. Nyang, M.N, Webo, C. and R.L Roothaert, (2010). *The Power of Farmers Organisations in Smallholder Agriculture in East Africa Working Papers*. A review of 5 project initiatives of the Maendeleo Agricultural Technology Fund. In FARM-Africa Working Paper, London, UK, FARM-Africa. 2010: 1-44.
44. Nyerere, M. K. (2000). *The African Socialism; leadership lessons* (Revised, 2000) East Africa Publishing House, Nairobi, Kenya, pp.12-144
45. Perret, S.R, Stevens, Y. and Joseph B. (2006). "Socio-economic Reasons for the Low Adoption of Water Conservation Technologies by Smallholder Farmers in Southern Africa: A Review of the Literature." *Development Southern Africa*, 23 461–76.
46. Pillay, M, Nwakanma, D, C. and Tenkouano, A. (2000). Identification of RAPD markers linked To A and B genome sequences in Musa. Genome 43: 763–767.
47. Pillay, M, Tenkouano, A. and Hartman, J (2002). Future challenges in Musa breeding in: Crop Improvement: Challenges in the twenty-first century. MS Kang (ed) Food Products Press, Inc New York, pp 223–252.
48. Pitt, M.M. (1983). "Farm-Level Fertilizer Demand in Java: A Meta-Production Function Approach." *American Journal of Agricultural Economics,* 65 *(*3*):* 502–8.
49. Qaim, M (2010). Agricultural Economist Center for Development Research (ZEF): Assessing the Impact of Banana Biotechnology in Kenya, *Journal of Agricultural Economics*, Vol.12
50. Republic of Kenya. (2004). *Strategy for Revitalizing Agriculture 2004–2014*. Ministry of Agriculture and Ministry of Livestock and Fisheries Development, Nairobi, Kenya
51. Rine, D.L, (1994). Kenya Country Gender Profile. Royal Netherlands Embassy (RNE), Directorate-General for International Cooperation (DGIS), Nairobi. *International Journal Of Advanced Technologies, Vol.*6., 1994
52. Robinson, J.C. (1996). Bananas and Plantains. Crop Production Science in Horticulture Series No. 5, CAB International, Wallingford, UK, *American Journal of Agricultural Economics,* 65 *(*3*):* 212–8
53. Rogers, E.M. (1995). *Diffusion of Innovations (4th Ed.).* New York: The Free Press. 1995.
54. Ruben, R. (2010). "From Participation to Adoption: Comparing the Effectiveness of Soil Conservation Programs in the Peruvian Andes." *Journal of Land Economics,* 86 *(*4*):* 645–67.

55. Sani, A, Abubakar, B.Z, Yakubu, D.H, Atala, T.K. and Abubakar, L (2014). Socio Economic Factors Influencing Adoption of Dual-Purpose Cowpea Production Technologies in Bichi Local Government Area of Kano State, Nigeria. *Asian Journal of Agricultural Extension, Economics and Sociology* 2014; 3(4): 258-279
56. Swennen, 1991. Analysis of genetic diversity and relationships in East African banana germplasm. TheorAppl Genet 102: 965–970; Taxonomy understanding of musa spp
57. Thorpe, T. (2007), History of plant tissue culture. J. Mol. Microbial Biotechnology. 37: 169-180. *Journal of Agricultural technologies, vol.13.2007*
58. Uaiene, R. (2011). Determinants of agricultural technology adoption in Mozambique. In *African Crop Science Conference Proceedings*, Vol. 10, 375–380.
59. Uphoff, N. (2002). Opportunities for raising yields by changing management practices: the system of rice intensification in Madagascar. *Agro-ecological Innovations: Increasing Food Production with Participatory Development*, 145–161.
60. Uttam, K.D. and Mahabub, H. (2006); effect of education on technology adoption and aggregate crop output in Bangladesh, *Asian Journal of Agricultural Extension, Economics and Sociology* 2014; 3(4): 258-279
61. Wambugu, F. M, (2004). Food, Nutrition and Economic Empowerment: The Case for Scaling up the Tissue Culture Banana Project to the Rest of Africa. Proceedings of the NEPAD/IGAD Regional Conference held in Nairobi, Kenya on November 22nd - 25th, 2004.
62. Wambugu, F.M, Mbogoh, S.G. and Wakhusama, S (2015). Socio-Economic Impact of Biotechnology Applications: Some Lessons from the Pilot Tissue Culture (TC) Banana Production Promotion Project in Kenya, 1997-2002. Document Transformation Technologies. Proceedings of the 25th International Conference of Agricultural Economists (IAAE). Durban, South Africa, 16--22 August 2003. *Journal Of Scientific Research*, Vol.11
63. Wanyama, J., Masinde, G. and Obare A. 2013. Factors Influencing Adoption of Tissue Culture ; proceedings of the 4th International Conference of AAAE held at Diar Lemdina Hotel – Yasmine Hammamet, Tunisia on 22nd – 25th September , 2013
64. World Bank. (2005). Food safety and agricultural health standards and developing country exports: Re-thinking the impacts and the policy agenda. The World Bank, Washington, DC
65. World Bank. (2008). Enhancing agricultural innovation: World Development status report,15 (7):911–929

APPENDICES

APPENDIX 1 : Questionnaires/Plates

Tissue Culture Adoption Questionnaire Serial No……………

Part A : General

A1. Geographical Location: County………………..

Sub County……………Ward………………

A2. Name of farmer (optional)…… ………………………………

A3. Marital status……………

A4. Gender (1) Male……….. (2) Female…………………

A5. Are you a member of any local merry go round group?

1). Yes…………………

2). No……………..

A6. Do you own any livestock?

1). Yes…………………

2). No……………..

A7. Do you hire labour……………

1). Yes…………………

2). No……………..

A8. Age …………….

1) Less than 40yrs.…

2) ksh.40-50 yrs…

3) 50 - 60yrs……

4) More than 60yrs………

A9. What is your level of education of the respondent (*Tick the most applicable choice*)

1). None………………….

2). Primary level…………………

3). Secondary level…………………

4). Tertiary level/Post-Secondary……………….

A10. Size of the land in acres (Total family land)……………………………….

A11. Land under tissue culture bananas in acres …………………

A12. Are you engaged in any other employment elsewhere (Off-farm employment)

1). Yes…………………

2). No……………..

A13. What is your level of monthly farm income? (*Tick the most applicable choice*)

1). Below ksh.10, 000…………

2). Ksh. 10,001-30,000…………..

3). Above ksh 30,000……………..

A14. Family size: (*Tick the most applicable choice*)

1). Less than 3 members; ……………….

2). Between (3-5) members;

3). Between (5-10);………………..

4). More than ten……………….

Part B : Technical information

B1. (a) Do you grow tissue culture bananas on your farm?

1) Yes………..

2) No…………………

(b) If yes, which variety of banana do you grow on your farm?

1) Local variety

2) Tissue culture variety

3) Both varieties

B2. How long have you grown this banana variety on your farm?

1) Less than 5yrs………..

2) 10yrs…………..

3) 15yrs…………..

4) More than 20yrs……………

B3. The acreage under the tissue culture bananas?..................................

B4. The total number of the tissue culture bananas stools?.............................

B5. What do you know about tissue culture bananas?

1) No knowledge at all………..

2) Scanty knowledge…………..

3) A lot,,,,,,,,,,,,,

B6. If you don't grow tissue culture bananas, give reasons for not growing

1) Never interested to grow …………….

2) Don’t have money to buy the seedlings …………

3) Don’t know where to get seedlings ……………..

4) No technical knowhow to grow it………………..

5) Fear they are GMOs…………………….

6) Others…..(Please specify)-…………………..

B7. What is the average maturity age of tissue culture bananas?............................

B8. Do you have any certified sources of tissue culture bananas near your farm?

1) Yes……….. 2) No…………………

B9. If yes, what are the sources?

1) KARI……………………

2) University……………….

3) Dealers………………………

4) Others (specify)……………

B10. Distance to the nearest major market?

1) Less than 50 kms………

2) 50-100 kms……….

3) 100-150 kms………

4) More than 200 kms………

B11. What is the price per potted sucker?

1) Less than ksh.50/=………

2) ksh.50-100/=……….

3) ksh.100-150/=………

4) More than ksh.200/=………

B12. Are tissue culture bananas always available in the market/source suggested in 8 above?

1) Yes………..

2) No…………………

B13. Do you have fence on your bananas farm? 1) Yes………. 2) No…………………

B14. If yes, is fencing important in the cultivation of bananas?

1). Very important

2). Not important

3).Undecided

B15. Do you have soil and water conservation structures like terraces/benches on your bananas farm?

1) Yes………..

2) No…………………

B16. What difference is there on the bananas planted on land with soil and water conservation structures?

1) Good growth
2) Poor growth
3) No difference

B17. (a) How do you grow tissue culture bananas? Do you do it through Irrigation or Rainfed?

1). Irrigation

2). Rainfed

(b) What is the source of the irrigation water?

1). River

2). Dam

3). Piped irrigation water

4). Well or spring

5). Borehole

B18. What constraints do you face in tissue culture bananas cultivation (please tick: Score with the most important by ranking 1 (most important); 10 (least important)

1) Unavailability of planting materials………..(………..)
2) High cost of planting suckers………..(………..)
3) Poor knowledge in bananas cultivation………..(………..)
4) Water not available………..(………..)
5) Pests and diseases………..(………..)
6) Theft ……….. (………..)
7) Wild animals……….. (………..)
8) Lack of extension services-……….. (………..)
9) Poor marketing.……….. (………..)
10) High cost of other farm inputs like Fertilizers/Pesticides/Labour….. (………..)

B19. What types of tissue culture bananas do you cultivate?

1) Cooking……………..

2) Ripening………………...

3) Both Cooking/Ripening……………………

B20. Where do you sell your tissue culture bananas?

1) Neighbours
2) Local market
3) Brokers
4) Company/institutions

B21. What is the total income from tissue culture bananas annually?..

B22. Have you attended any training/show/field day where you learnt about tissue culture bananas?

1) Yes……….
2) No…………………

B23. If yes……………What did you learn? (Please tick: Score with the most important by ranking 1 (most important); 10 (least important)

1) General bananas cultivation………..(………..)
2) Pests and diseases………..(………..)
3) Soil fertility and fertilizers application………..(………..)
4) Marketing of bananas………..(………..)
5) Utilization of bananas………..(………..)
6) Post-harvest/Value addition in bananas………..(………..)
7) Bananas nurseries management………..(………..)
8) Soil and water conservation………..(………..)
9) Orchard establishment………..(………..)
10) Tissue culture bananas research/sources………..(………..)

B24 Which of the above practices have you adopted in tissue culture bananas Production in your farm?...

B25. What do you suggest as 3 –Most important solutions/recommendations to the challenges faced by the tissue culture bananas farmers?

1.……………………………………………………………………………
2.………………………………………………………………………………

Thank you for your time

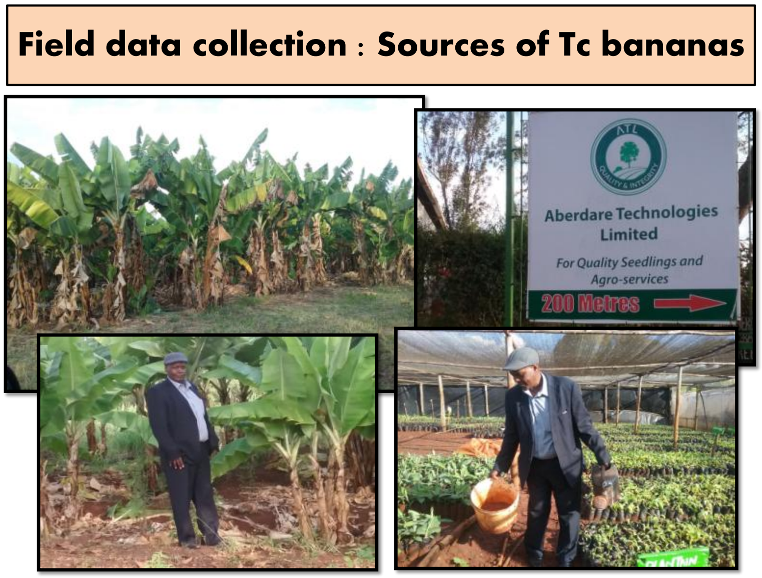

Plate 1:Author at work

plate 2:Author at work

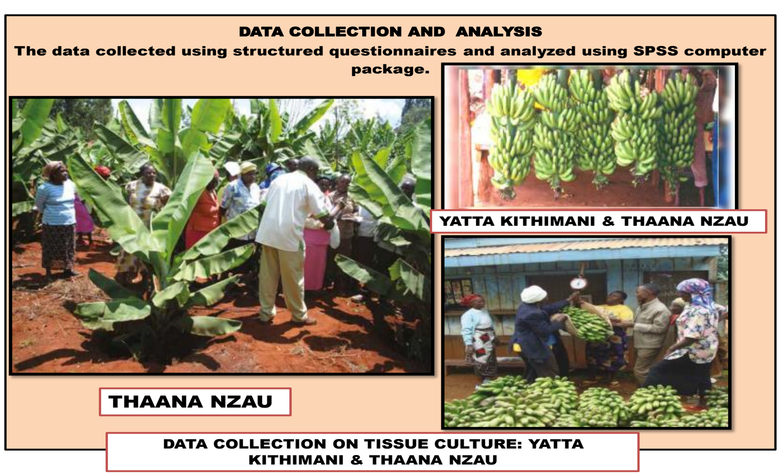

Plate 3:Author at work