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Factors Affecting Adoption of Tissue Culture Bananas in the Semi-Arid Areas of Lower Eastern Region of Kenya

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Abstract: **The importance of bananas cannot be underestimated worldwide. The specific objectives included determining' socio-economic, environmental and policy factors affecting adoption of tissue culture (Tc) bananas in Kalawa, Thaana and Kithimani clusters using 176 respondents randomly selected. The data collected was analyzed using the *SPSS* version 17. The study found that adoption of Tc bananas was the following: The major socio-economic factors affecting adoption of Tc bananas were: gender (p=0.0150); education (p=0.0380); total land size (p=0.0110); farmer's experience (p=0.0168); Tc bananas knowledge (p=0.0100) and Tc bananas market (p=0.0030). Environmental factors mentioned as important factors included: availability of a fence by 64 percent; soil and water conservation measures (92 percent); use of borehole water for irrigation by 22 percent of the respondents. Policy factors were: source of Tc planting materials by 32 percent indicating Kenya Agricultural and Livestock Research Organization as the main source; access to either public or private extension services by 35 percent of the respondents; Tc multiplication by government or stakeholders within the clusters by 77 percent; awareness and acquisition of credit services for farm activities from the financial services by 64 percent. Recommendtaions from the study included: improvement and access to extension services; ways of availing Tc bananas plantlets closer to farmers ; policy to reduce the effect of wild life on Tc bananas ; farmers' education and general capacity building on Tc banana growing; and irrigation for Tc banana growing.**

Keywords: **Tc Banana, Adoption, Food Security.**

1. INTRODUCTION

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. (FAO, 2014).Today, banana is the most cultivated fruit crop globally being grown in 140 countries.

Although the origin and center of diversity for banana is believed to be Southeast Asia, the East African highlands are recognized as a secondary center of diversity. It 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, 1985). Banana fruits have a very high content of potassium (K) and a wide K: Na ratio, imparting a protective effect of K against excessive Na intake in diets (Tripathi *et al.*, 2002). Banana is rich in natural antioxidants such as vitamin C and vitamin E (Someya *et al.*, 2002; Amorim *et al.*, 2009a, b). 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 (Bloem *et al.*, 2005). 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 (Whittaker, 1998). The genetic enhancement of micronutrient content (i.e., biofortification) of banana by conventional breeding combined with the use of biotechnological tools has the potential to increase the concentrations of micronutrients (Fe, Zn) and vitamin A in new cultivars (Amorim *et al*., 2011). Improving the nutritional content of *Musa* spp. would have a significant impact on vitamin and nutrient intake for millions of people who depend on the crop for food. The Kenya National Food and Nutrition Security Policy of 2011(GOK, 2011) states that all Kenyan households should at all times have access to safe food of sufficient quantity and quality to satisfy their nutritional needs for optimal health. The study area has fallen short of this with food insecurity at 60 percent, a status aggravated by the fact that the average poverty level is over 62 percent.

Tissue culture technological development 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).

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.

The aim of the study was therefore to determine and assess the policy related factors influencing adoption of tissue culture bananas in the three representative clusters namely Kalawa, Kithimani and Thaana within the three counties of Makueni, Machakos and Kitui respectively in the lower Eastern Kenya.

Statement of the Problem:

In the lower eastern counties of Makueni, Kitui and Machakos, the adoption of TC bananas is low despite the potential that exist to sustainably apply the technique of improving banana production (Wambugu, 2010).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). There is notable inadequacy in scholarly knowledge in reference to TC 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).

Study Objectives:

General Objective:

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

Specific Objectives:

i. To determine and identify the socio-economic policy related factors affecting adoption of tissue culture bananas in the lower Eastern semi-arid region of Kenya

ii. To enlist the main recommendations from the study towards improvement of adoption of Tc bananas for food security

Research Questions:

i. What are the socio-economic policy related factors affecting adoption of tissue culture banana in the lower eastern semi-arid region of Kenya?

ii. What are the main recommendations from the study towards improvement of adoption of Tc bananas for food security?

Justification of the Study:

Research work in Central Kenya (Wambugu, 2009), Upper Eastern region (Nguthi, 2007) and in Western Kenya (Odhiambo, 2010) 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 Tc banana 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 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 Tc bananas to contribute in mitigating food insecurity in the region.

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 household heads 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.

Assumptions:

The assumption that the study would take six days in total at two days per cluster was hampered by the big 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.

Organization of the Study:

Proper work plan and time management availability and cooperation received from the household heads as well experience and knowledge of the study area worked to the team's success. The training ahead of the study and the pre testing done to the questionnaire was a big step forward in the realization of this work.

2. LITERATURE REVIEW

Importance of TC adoption to household's food security and Households' policy related factors

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 (UNFAO, 2010). 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 % of the population earns a living from agriculture (Nguthi *et al.*, 2007). The agricultural sector contributes about 30 % of the GDP and accounts for 80 percent of national employment, mainly in the rural areas (Mbaka *et al.*, 2008).

In addition, the sector contributes more than 60 % 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 (Mbaka *et al.*, 2008). In the first decade after independence agricultural production grew by 4.7 percent annually (Karanja, 2002). 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 (Republic of Kenya, 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 (Cockburn, 2002). Kenya's population on the other hand has more than tripled from 10.9 million in 1969 to 38.6 million in 2009 (KNBS, 2013). Given the high number of births per woman (an average of 4.6 children per woman), the population will continue to increase steadily. Because more people in the developing world are malnourished (ACF, 2009), 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 (UNFAO, 2012). According to scholars, it is quite unfortunate that technologies widely used during the green revolution, no longer provide the needed breakthroughs in yield potentials nor give solutions to complex problems of pests, diseases and drought stress (ADB, 2001; Karembu *et al.*, 2010). Karembu *et al.*, (2010) 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).

The total domestic value in the horticulture sector (fruits, vegetables, flowers) in Kenya in 2012 amounted to Ksh.217 Billion occupying an area of 662,835 ha with a total production quantity of 12.6 million tons. As compared to 2011, the total value, area and production increased by 6 percent, 9 percent and 38 percent respectively. This was because of favourable weather conditions in the production areas that saw the increased production and subsequently the value. The major contributors of the increased value were bananas and potatoes. This is associated to increased rates and levels of adoption. Adoption determines productivity. In eastern Kenya for instance, the red cowpea project is an example of a technology whose adoption was not successful with self-diffusion (KARI, 2013).

Food security is at risk in the last five years. Malnutrition is also rampant while diseases like HIV/AIDS, Kwashiorkor and Marasmus that require proper diets and nutrition for management require attention. These challenges require stakeholders including governments to develop technologies 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.*, 2012). 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, 2011).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 (FAO, 2005).

Wambugu (2006) 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; in1995 the same was Kshs.15; and in 2000 it was Kshs.30 (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. Tissue culture in Murang'a County especially Makuyu area is a business employing many people who are directly and indirectly involved (FAO, 2013).Tissue culture 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, 2014). 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.*, 2002).

The introduction of the tissue culture technique for rapid propagation of clean planting material in 1997 was thus perceived as having the potential to help reverse the declining trends of the crop. 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 and Tripathi 2006; Tenkouano *et al.*, 2011). The production of bananas worldwide is threatened by a 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 fijiensis Morelet) and fusarium wilt (Fusarium oxysporum Schlect. f.spp. cubense (Smith *et al.*, 2011). 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.

To improve banana productivity and safeguard sustainable banana production for small-scale farmers, clean, high quality planting material is crucial (Gold *et al.*, 2002). According to Wanyama *et al.*, 2013, in East African smallholder systems, new banana fields are traditionally planted with suckers. However, the use of Tc 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 Tc banana plantlets can support farmers to make the transition from subsistence to small-scale commercial farming (Dubois, 2011). 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.

In Kenya, Tc banana 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 (Njuguna et al., 2010). A recent impact study for Kenya showed positive yield effects of TC banana adoption, but also pointed out the importance of good extension and proper plantation management (Kabunga et al., 2012). Tc plantlets require appropriate handling and management practices to optimize their benefits. Consequently, this additional effort and the cost of TC plantlets (US$1.20–2.00) pose an extra cost for the Kenyan farmer. The Tc banana 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, Tc banana production appears to be highly lucrative for the entrepreneurs, with profit margins estimated at up to 100 percent (Dubois, 2011, unpublished results).

The private sector producing Tc 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 Tc banana plantlets to the Burundian population, there is only anecdotal information on the impact of TC plantlets on banana yields and household welfare. This paper examines the impact of Tc banana 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 for the self-selection that normally arises when technology adoption is not randomly assigned (Rosenbaum and Rubin, 1983; Imbens and Wooldridge, 2009). Karembu (2007) adds that biotechnology 20has the potential to provide rapid solutions in a more precise and cost effective manner. Both Wambugu (1999) and Ogoro (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 (Miller and Mariola, 2009).

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)

Though vulnerability to food insecurity is a general problem among poor farming households, few studies have shown that the problem is more prevalent among female-headed households. For instance, IRIN (2006) conducted an analysis of livelihood, technology adoption and food security status of households and vulnerable groups in Zimbabwe, Zambia and Malawi. It was found that female headed households were more vulnerable to food insecurity with little adoption to food production technology than male-headed households in the three countries. Rural women were poorer than men and had

turned to casual agricultural labour as a primary source of income. Akinsanmi and Doppler, (2005), found that female-headed households in the South-Eastern Nigeria were poorer, with lowly adopting to modern technologies and more vulnerable than their male counterparts. This was caused by unequal access to and control of productive resources including the highly priced technologies. The study concluded that the standard of living of the female-headed households could be enhanced if they are given full legal rights of resources that would make them eligible for loans and make for efficient use of productive resources. Likewise, Owotoki (2005), found that in Kwara state, North-central region of Nigeria, the female-headed households were more food insecure and vulnerable than male-headed households. This implies that the female-headed households are more vulnerable to food insecurity than the male headed households, because according to Hoddinott, (1999), indices of household coping strategies, directly capture notions of adequacy and vulnerability of 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 (Doss *et al.*, 2001). 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 Tc banana farming for use by farmers in eastern and central Kenya including farmers in Ukambani region to enhance productivity (Kanyeka *et al.*, 2007). 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 Tc bananas production is also a variable. For a household participate in Tc bananas as a family business project the household head could be expected to have good knowledge on the benefits of Tc 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 Tc bananas (Qaim *et al.*, 2012).

Economics is the key determinant for the application of molecular markers in genetic improvement programs (Dekkers *et al.*, 2002). Other factors that influence the cost of utilizing marker-aided breeding included inheritance of the trait, method of phenotypic evaluation, and high costs. 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. Despite these difficulties some developing countries are making progress in using biotechnology for *Musa* spp. Improvement (Dekkers *et al.*, 2002). 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, 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. 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, 2014).

Rain-fed agriculture in lower eastern region is highly seasonal, unpredictable and carries some inherent Since improved banana planting material like Tc bananas are more expensive relative to ordinary banana suckers, and cost of planting material is hypothesized to negatively influence the adoption of Tc 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 Tc bananas (Sokoni *et al*., 2007).According to Mwankemwa *et al*., (2005), 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 (Mwankemwa *et al.*, 2005).

Some administrative policy strategies are also important consideration in acceleration of TC 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 Tc banana technology. In particular, large farmland and livestock holdings tend to increase the likelihood of adoption. As the Tc banana 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 Tc banana. Such group networks play an important role in disseminating banana TC 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 Qaim, 2009).

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 (GOK, 2010). 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 (GOK, 2012). 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 with73 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 food access, availability, affordability and 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.

The irrigation status in **t**he Ukambani region falls under the semi-arid areas of Kenya, where rainfall regime is inconsistently unreliable to favor crop farming unless through water supplementation or irrigation. This issue could adversely affect uptake and adoption of TC technology (GOK, 2012).

The issues of soil fertility in tissue cultures are known to be tolerant and responsive to soil status as a medium of growth (GOK report, 2015). 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. Irrigation 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 Tc 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).Agricultural productivity levels in sub-Saharan Africa are far below that of other regions in the world, and are well below that required to attain food security and poverty reduction goals (Wambugu, 2014). Wambugu, (2013), 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).

Nationally, the crops sub-sector is the most important to agricultural development with products utilized for industrial, food and horticultural needs. Tea, coffee, sugarcane, cotton, barley, tobacco, cereals and pulses, vegetables, fruits and flowers contribute about 55 percent of agricultural exports (Economic survey, GOK,2015).The agriculture sector is the undisputable mainstay in the Kenyan economy, contributing 30 percent of the GDP and accounting for 80 percent of employment according to Kenya's Economic Survey Report,(GOK,2014). According to this document the leading subsectors in 2013 were dairy, tea, and horticulture, in that order.

The role of agricultural technology in the world's socio-economic growth and even in poverty reduction has been broadly discussed, in particular for low income African countries (Diao *et al.*, 2007). Sub-Saharan Africa is the only region in the world where poverty is still strongly a rural phenomenon, where undernourishment has been increasing over the past 20 years and where those living on less than $1 a day have become poorer (World Bank, 2005). This weak economic performance is closely linked to low technology adoption which slows productivity growth in the agriculture sector (Wolgin (2001); Mwambu (2004); Byerlee *et al.*, (2005); Diao *et al.* (2006); Christiansen (2007).

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 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 TC bananas getting from the work done by Nguthi, (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.

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.*, 2011). According to (TARDA, 2016), River Tana area covers approximately 138,000 km2, 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, 2012). 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

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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 According to Wanyama, *et al.*, (2016), 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 (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 (Davidson *et al.*, 2001).

Agricultural information is a derivative of the extension delivery. 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 nonprofit 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*., 2016). 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 (Odendo, 2006).

3. METHODOLOGY

Study area and its description:

This study was carried out in three clusters (also wards) namely Kalawa, Thaana Nzau and Kithimani, located in Makueni, Kitui and Machakos counties respectively (FIG. 3.1). The clusters 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.

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

The entire region covers 5,713 with a combined population of 363,374where 49 percent are male whereas 51 percent are female. 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 with73 kids in 1000 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).

Research design:

Qualitative research was used for descriptive research whereby a survey targeting households was carried by use of a structured questionnaire. Quantitative data was also collected for regression analysis.

Determination of sample size:

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 TC in the study area is 20 percent.

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

Based on this, a total of 200 households were selected from the list of all the villagers in the three clusters, with each village being represented using random sampling method. These villages were further clustered where Thaana Nzau cluster located along River Thaana villages in Mwingi West in Kitui County, Kithimani cluster 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 selected.

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), livelihood status, the favourable characteristic for bananas growing conditionsand high poverty index with (62.4 percent living below the poverty line) according to UNWHO (2012) and UNICEF (2011).By a further random sampling, 200 out of 1,989 farm holdings (which represented about 10 percent of the households) out of a target population of 2,065 farmers were selected as respondents. The sample size was as follows:-Thaana cluster- 68, Kalawa cluster- 72 and Kithimani cluster 60.

Data Collection and Analysis:

Data Collection:

A Semi-structured questionnaire was used to elicitinformation on household characteristic (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 TC 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. The questionnaire was pre-tested in a pilot survey involving 2 villages outside 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. Enumerators were trained on data collection.

The pre-tested, structured questionnaire (Appendix 1) was used. This had two sections, the general household 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.

Data Analysis:

The collected data was analyzed as per the counties as follows; Kalawa in Makueni county having 60 respondents; Kithimani in Machakos county having 51 respondents and Thaana Nzau: Kitui: 65 respondents. Out of the total sampled were 200 with the total number of farmers who had been selected 176 were successfully interviewed, with absentees, rejected or spoilt being adding to 24.The data was entered into excel computer sheets.

The data collected using structured questionnaires was analysedto determine the relationship between household characteristics and the level of adoption of TC bananas and factors affecting its adoptionusing Package for Social Science (SPSS) Version 17.

Binary logistic regression model (Hailu (1990), Cramer (1991), Nkamleu *et al.*, (2000)) was used to determine the significant factors and bringing out relationship between household characteristics and the level of adoption of the tissue culture bananas.

Model specification:

The simple reduced form of adoption model is as

Follows, $Zi = f(x)$
$X = xi$
$I = 1, 2 \ldots\ldots\ldots N$
Then the model form is,
$Zi= ß_0 +ß_1X_{1i} +ß_2X_{2i}\ldots\ldots\ldots\ldots ß_nX_{ni} +µi$, 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 household 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 = Household income
X_7 = Farm size in acres under finger millet.
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 TC 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 (Thad *et al.*, 1988) and (Triola *et al.*, 1999), which is an expression of a linear relationship between one variable Zi and two or more independent variables (X1, X2, X13)

4. RESULTS

Households Demographic Characteristics in Thaana, Kithimani and Kalawa clusters:

The results of the household demographic characteristics are shown in Table 4.1. Across the three respective clusters, majority of the households were male headed with Kalawa, Thaana and Kithimani having 65 %, 61 % and 66.2 %, respectively. On average there were 64 % of male headed households and 36 % headed by females. With regard to age, on average, 31 % were between 40-50 years and 36 % between 50-60 years and 11 % above 60 years. People less than 40 years old were the least at 21 %. In Thaana the aged (50-60 years) formed the majority (45 %) compared to Kithimani (37 %) and Kalawa (27.7 %). On Education level, the result showed that all the respondents had attained some level of education. Majority of the respondent had attained secondary education (57 %). The 23 % attained primary education while 20 % had tertiary education.

The average land size per house hold 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 Tc 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 Tc Bananas against total available land size per house hold is 22.23%. The number of households that had family members ranging between 5-10 members was the highest at 57 percent followed by households with 3-5 members at 35 percent. It was also found that 8 percent of households had less than 3 members.

On average 62 percent of the household heads were members of social village groups while 38 percent were not members. On marital status, across the three respective clusters and in all the three counties (Makueni, Kitui and Machakos), over 81.3% of the respondents were married with others being single or divorced at 17 % and 1.7% respectively. ,On marital status, across the three respective clusters and in all the three counties (Makueni, Kitui and Machakos), over 81.3% of the respondents were married with others being single or divorced at 17 % and 1.7% respectively (Table:4.1 below).

Table 4.1 Households Demographic Characteristics

Research Parameters		**Thaana**	**Kithimani**	**Kalawa**	**Mean**	**Std. Deviation**
N=176		**% (f) (n=60)**	**% (f) (n=51)**	**% (f) (n=65)**	**% (f)**	
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
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
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
Total family Land Size	Acres	5.11	6.5	4.92	5.51	2.46
Area under Tc Bananas	Acres	1.35	1.03	1.31	1.23	0.022
Family Size members	Less Than 3	11.7 (7)	2 (1)	9.2 (6)	8 (5)	1.91
	Between (3-5)	40(24)	29.4(15)	35.4(23)	35 (21)	10.58
	Between (5-10)	48.3 (29)	68.6 (35)	55.4 (36)	57 (33)	16.25
Group Affiliation	Yes	60 (36)	59(30)	67 (44)	62 (37)	28.59
	No	40 (24)	41 (21)	33 (21)	38 (22)	17.35
Experience in growing Tc bananas	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
Marital Status	Married	81.7 (49)	74.5 (38)	86.2 (56)	81.3 (48)	0.445
	Single	18.3 (11)	21.6 (11)	12.3(8)	17.0 (10)	0.551
	Divorced	0.0 (0)	3.9 (2)	1.5 (1)	1.7 (1)	0.761
Income Level(In ksh)	(Below 10,000)	40.0 (24)	39.2 (20)	50.8 (33)	43.3 (26)	0.7464
	(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
Tc bananas Knowledge	1 (Without)	88.3 (53)	82.4 (42)	93.8 (61)	88.1 (52)	0.615
	3 (With)	11.7(7)	17.6 (9)	6.2 (4)	11.8 (7)	0.221
Numbers in parenthesis represent frequencies						

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

of farmers with technical knowledge about the crop husbandry skills of Tc bananas followed by Thaana and Kalawa with 11.7% and 6.2% respectively in the same category.

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

From the logistic regression results in table 4.2 on the socio-economic related factors, the following factors were found significant (at $p<0.05$) in influencing the adoption of Tc bananas in the study areas: gender ($p=0.0150$); education ($p=0.0380$); total land size ($p=0.0110$); experience ($p=0.0168$); Tc bananas knowledge ($p=0.0100$) and Tc bananas market ($p=0.0030$).The following other factors were found insignificant (at $p>0.05$) in influencing the adoption of Tc 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 4.3 shows results of detailed analysis for the households 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, they were found significant ($p<0.05$). On livestock ownership across the study areas, Thaana recorded more households 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 households that had undergone

Training on tissue culture bananas production only Kalawa had more households (48 out of 65) trained while Kithimani and Thaana had more untrained households (39 and 48 respectively).

Table 4.2 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	0.000
Age	-0.004	0.035	-0.008	-0.119	0.906
Gender	-1.155	0.063	-0.149	-2.455	0.015
Education	2.093	0.044	0.120	2.097	0.038
Total Land Size	2.028	0.011	0.166	2.571	0.011
Income Level	-0.088	0.049	-0.131	-1.804	0.023
Experience	0.016	0.009	0.095	1.840	0.0168
TCB Knowledge	1.280	0.051	-0.344	-5.466	0.010
Acreage Under TCB	-1.493	0.070	-0.407	-7.010	0.100
TCB Market	1.178	0.060	0.175	2.968	0.003
Family Size	-0.028	0.048	-0.036	-0.579	0.563
Marital Status	0.181	0.070	0.161	2.603	0.510
Off Farm Employment	-0.025	0.064	-0.025	-0.388	0.698

* **Significant at 0.05 level of significance**

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 households educated up to primary level while Kithimani and Thaana had more households 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 household's heads in the study area, Kalawa and Thaana results revealed non availability (at 40 out of 65 and 41 out of 60 households 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

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of Tc bananas with p-value being 0.020642 at $p < 0.05$ (Table 4.3). However it was reported that 35 farmers out of 60 in Thaana did not belong to the groups. This again was found significant factor in influencing adoption of Tc 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 4.3 Detailed analyses of household factors influencing the adoption of Tc bananas.

Other factors Cluster/Study Area		**F (%)**	**F (%)**	**chi-sq. statistic**	***p*-value***
Gender of the household heads 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
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
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
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
Availability of extension services (public or private)	10.2109Cluster	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
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	7.08420

Numbers in parenthesis represent percentages * Significant at 0.05 level of significance

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 Tc bananas (Table 4.4). 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 with 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 4.4). 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 4.4 Environmental factors influencing adoption of tissue culture bananas-show significance by asterisk (s).

Research Parameters		**Thaana**	**Kithimani**	**Kalawa**	**Mean**	**Std Error**	**t-test**	***Significance**
Maturity Age(months)		9.54	8.75	8.36	8.9	7.21	4.041	0.021
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
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
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

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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
TCB Growing Method								
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
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								

Policy related factors influencing the adoption of Tc bananas:

Table 4.5(a) shows policy related factors that influence adoption of Tc bananas. Most of the respondents indicated that Kenya Agricultural and Livestock Research Organization (KALRO) is the main source of Tc bananas planting materials (32 percent). Other sources of TC banana planting materials were university, nursery dealers and neighbors.

Table 4.5(a): 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.**
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 (	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
Availability of 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;

The result also shows 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 % followed by Kithimani with 69% of the interviewed households. Kalawa reported the highest number of farmers who had access to extension services at 60% while Kithimani had 31% and Thana with 15%.

The results in Table 4.6(b) below depict other policy related factors influencing adoption of tissue culture bananas, Tc bananas multiplication by government or stakeholders within the clusters was endorsed by 137 respondents (60 in Kalawa, 48 Thaana and 29 Kithimani) out of the 176 (78% of the households interviewed) as an important factor to enhance adoption of Tcb. Another 39(5 in Kalawa 12,

Thaana and 22 in Kithimani) household heads (about 43 percent) did not suggest the endorsement. The clusters Kalawa, Thaana and Kithimani in that order endorsed as . Regarding the awareness of credit services for farm activities from the financial services, the respondents were mostly aware at 49, 36 and 29 from household heads 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% of the respondents in Kalawa (34 out of 65) and 65% in Kithimani (33out of 51) and 20% or 12 out of 60 households in Thaana were found to have land registered with tittle deeds. In the thaana clusters 80% (48 out of 60 households) of the respondents had their land without tittle deeds.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. 4.5(b). There was mixed results on awareness of farm inputs subsidy scheme in form of National Cereals Produce Board fertilizers supply, 99 households heads (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

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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) households heads were found to be affected Kithimani reported low effect of the wildlife to the Tc bananas at 54 (17 in kalawa, 32 in Thaana and 5 in Kithimani). (Table. 4.5(b)).

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. 4.5(b) Other Policy related factors influencing adoption of tissue culture bananas

	Other policy factors	**(F) %**	**(F) %**	**chi-square statistic**	***p*-value**
Multiplication centres		HH endorsing establishment of Tc multiplication centres	HH not endorsing establishment of 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
Credit Services		HH Aware of Credit services	HH Unaware of credit services		
	Kalawa(n=65)	75(49)	25(16)	5.2054	0.074074
	Thaana(n=60)	60(36)	40(24)	0.1118	0.73809
	Kithimani(n=51)	57(29)	43(22)	4.5476	0.08712
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
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
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
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
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;					

5. DISCUSSION

Gender was found to be a very significant factor in the determining 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 headed households were found to be adopting the Tc banana less than female headed households. This could be due to the fact that male headed household are likely to have more access to resources and information than women household heads due to traditional and cultural gender roles which tend to discriminate against women in agreement with results by Nyerere *et al*., (2000) who showed that men usually have more access. These findings were also reported by Nyang *et al.*, (2011), that male 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. Women have no security of tenure for the land which makes it difficult for them to access resources such as credit (reference it or remove). Lack of security on tenure is a disincentive for women to invest in modern technologies such as Tc bananas. Rine, (2004) confirms this scenario, and further notes that gender is a determinant for technological adoption. -this point is already made above. While assessing the impact of banana biotechnology in Kenya, Qaim (2010), noted that households' 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.

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% having attained secondary education and 27% 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.*, 2007). Therefore, a strategy to increase farmer's education would greatly lead to increased adoption of Tc bananas (Wambugu *et al.*, 2007).

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 (UN, 2015).

Nyang *et al.*, (2011) 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.*, 2014). 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 policymakers to determine how best to reach the populations they serve (GoK, 2012).

The results indicated that farmers training was significant at ($p<0.05$) with households 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 households (38 and 48 respectively). 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.*, 2011).

This study revealed that most respondents (62%) 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 Tc bananas plantlets, and group production and marketing which enhances economies of scale. The household's heads group affiliation was equally found a significant factor in influencing adoption of Tc 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. The advancement of subsidy and credit facilities to farmers is easy when members guarantee each other thus enhancing adoption (Anyango *et al.*, 2007).

It was evident from the findings that availability of extension services was a significant factor in influencing adoption of Tc bananas in the study areas. This was confirmed by Wambugu *et al.*, (2010) who found that households require practical training through demonstrations and extension services to improve productivity and adoption of Tc bananas. Opening up more Tc banana 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 Tc banana production would enhance the impact of this and other technologies in the target counties. Farmer's exposure to more extension services leads to increased adoption since farmers are able to gain knowledge on Tc bananas farming (Wanyama, 2014). 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.

Socio-economically, majority of the respondents (66 %) 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. 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 % 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 % and 43 % compared to the high potential agricultural regions. 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 (Mutero, 2012).

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 Mwangi (2011), 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 % in 1997, 50 % in 2000, 46 % in 2004 and 44% 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. 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.

The results showed that the major economic activity was farming at 32% and non-farm employment in other areas like in towns (28 %). This means that majority of household heads were available on their farms. This gives an incentive for adoption of technologies like Tc bananas. Wambugu (2009), showed that the success of Tc banana 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 Tc 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.

The results showed that farmers who owned bigger land could utilize more capital and had demand for Tc bananas. The study showed that land under the Tc 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 Tc 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 Tc bananas production in order to solve food insecurity (GoK, 2014).

After regression analysis in this study, land size under Tcbananas was found to have significant influence on the adoption of Tc bananas ($p<0.05$). This means that the land size a household set aside for Tc bananas affects the scale of adoption.

The findings revealed that a unit increase in land size in Tc bananas would result into an increase in adoption of Tc bananas. This was confirmed by Thorpe (2007) who found that intensive land use increased with increase in land size due to better application of technology such as Tc bananas adoption and vice versa

Land ownership defined in the status results which concluded that it was a significant factor influencing adoption of Tc 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 Tc bananas (Uaiene, 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, 1994).

Most farmers, (69.9 %) sold their produce in the local markets. This could be due to high demand of Tcbananas in the market as well as low supply of the bananas. This was followed by neighbors who purchased 27.3% and only 2.8% for brokers. In all the study clusters, 71% of respondents indicated that Tc banana 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 Tc 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%. Farmers knew where the Tc bananas were found though they were very far away. For majority of respondents (58 %), 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 Tc banana 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*, (2007), access of Tc bananas market significantly influenced the adoption of Tc banana ($p<0.05$). Farmers with access to market easily adopt Tc banana unlike those without market access. A unit increase in Tc bananas markets would lead to increase in Tc bananas adoption. This calls for the county government to source for more markets of Tc bananas so as to encourage more farmers to adopt tissue culture banana farming hence its commercialization.

Extension services were important in TC bananas farming as a means to modern technology transfer between researchers and the farmers (World Bank, 2006). This calls for more extension services from both the public and private sectors to enhance adoption of such technologies like TC bananas. The results suggest that the probability of adoption of Tcbananas 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.

Most of the farmers were aged between 50-60 years comprising of 37% followed by 40-50 years with 31% then 21% (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 Tc 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.*, (2014), 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 Tc 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 TC bananas.

TC bananasfarming experience is directly related to the experience and age of household head (Robert *et al*, 2010). The study adds that knowledge in Tc bananas farming significantly influences the adoption of Tc bananas. From the analysis, a unit increase in farmer TC bananas knowledge would lead to an increased adoption of Tc banana by 1% while a decrease in farmers TC bananas knowledge would result to decreased adoption. The county governments should put in place strategies to improve farmer's knowledge about Tc banana. The results showed that 64 % of the respondents cultivated banana varieties of dual purpose, both cooking and ripening types while 29 % 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 (2013) 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 Tc bananas was low, which was comparable to a study done by Wambugu (2009) on promoting tissue culture banana plantations. This suggests that investment in farmers training on production skills on the Tc bananas could lead to increased adoption as was the case in Middle Eastern region of Embu, Tharaka, Meru and Mbeere (Wambugu, 2009).

Regarding environmental factors affecting adoption, the data showed that 68% of the sampled household 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 (Jaetzold *et al.*, 2006).The results showed that livestock ownership significantly influenced Tc bananas adoption in the study area ($p<0.05$). Thaana recorded more households without livestock than Kithimani and Kalawa and therefore with less Tc bananas farming than the latter two clusters. This was attributed to lack of finances and manure to enhance Tc bananas farming. Livestock is wealth as well as income in the region and also a major source of farm yard manure (Jaetzold *et al.*, 2006). Farm yard manure importance in soil fertility improvement and supply of vital soil elements to crops is well documented by Wanyama, *et al*., (2016). Soil fertility is a significant factor to increased adoption of crop technologies (Mathenge *et al*., 2016).

The results showed that bananas mature in an average of 8.9 months in the study area though Kimenye (2013) recorded that they could take upto 18 months to mature. Accordingly, any adverse weather restricts growth to maturity of Tc bananas. They respond to growth factors such as soil fertility and available moisture. This means that the study area is highly favorable to Tc bananas cultivation with early maturity and thus optimal solution to income generation and food supply to the households. 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 (Kimenye, 2013). The results confirmed the study area as potentially suitable for Tc bananas production. The major constraints affecting the adoption of Tc 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% of the respondents. A policy on subsidized fertilizers and improved Tc bananas plantlets could as well be relevant in enhancing Tc bananas cultivation in the study area (Wambugu *et al.*, 2011). 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 Dorward, (2009) 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 (Dorward, 2009).

This position on contribution of subsidies to technology adoption was argued by Timmer (2004) whoassertedthat the importance of subsidies crop farming in Indonesia.

Dorward *et al.*, (2004) in a review of green revolution experience in Asia argued that sustained input subsidies were a major part of successful Green evolution packages, making a critical contribution to thickening and thus 'kick starting markets' first within staple food supply chains and then in the wider rural economy. Djurfeldt *et al*., (2005) also argued that input subsidies were a critical element within green revolution policies, drawing on detailed policies reviews across a range of Asian countries. Fan *et al.*, (2007) provided empirical evidence on the contribution of input subsidies to growth and poverty reduction in India in the early stages of the green revolution but not later. This confirmed the report by Dorward *et al.*, (2004), that later ineffectiveness and inefficiencies of input subsidies should not obscure their initial contribution in driving agricultural develeopment growth forward. Farmers who appear poor and unable to access the expensive inputs but have land to grow the crops are potential candidates of picking up or adopting new innovation technologies from research (Djurfeldt *et al*., (2005). Cohessive groups in Meru and Embu counties that combined several households members have been reported to organizing procurement of improved tissue culture bananas planting materials at relative good econmies of scale (wambugu *et al*., 2009).

6. CONCLUSION AND RECOMMENDATIONS

From the study it was 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 regression and chi squares analysis concluded that gender, education, total land size, Tc bananas knowledge, acreage under Tc bananas, Tc bananas market and extension services were significant at $P<0.05$ and influenced the adoption of Tc bananas adoption.

Most respondents suggested that the supply of bananas can be improved through support; collaboration and networking with accredited Tc banana 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 respondents said inadequate knowledge and skills on use of irrigation technologies is limits increased production of Tc bananas. About 71 percent of respondents said tissue culture banana plantlets were not available in the local market. Markets significantly influenced the adoption of Tc banana. Farmers with access to market would easily adopt Tc banana unlike those without market access ($P<0.05$). A unit increase in Tcbananas markets would lead to increase in Tc bananas adoption whereas a unit decrease in the markets would similarly lead to decreased adoption.

The study concluded that most farmers, (69.9 %) sold their produce in the local markets and that there was high demand of Tc bananas in the market as well as low supply of the bananas. In all the study clusters, the study concluded that 71% of respondents indicated that Tc banana plantlets were not available in the local market. These results helped to conclude that this was the reason for low adoption of Tc banana farming. Most respondents were in conclusion that the supply of bananas can be improved through support, collaboration and networking with accredited Tc 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%. Farmers knew where the Tc bananas were found though they were very far away. The study results showed conclusively that Kenya Agricultural Livestock Research Organization as the best source of the Tc bananas plantlets and that more sub stations are recommended to encourage more farmers to adopt tissue culture banana farming hence its commercialization.

Gender was found to be a very significant factor in the determining adoption of tissue culture bananas in the study area ($p<0.05$) and therefore, there is need for gender mainstreaming in programs involving adoption of technologies by households' 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 Tc bananas meaning that decision to adopt is more consultatively done in a family unit setting. 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. Therefore, a strategy to increase farmer's education would greatly lead to increased adoption of Tc bananas. 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.

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

This study revealed that most respondents (62%) 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 Tc bananas plantlets, and group production and marketing which enhances economies of scale. The study concluded that all efforts should be directed to use the groups available in the study area as farmers' groupings also enhance bargaining power while sourcing for inputs and planting materials.

The study concluded that availability of extension services was a significant factor in influencing adoption of Tc bananas in the study areas and that those households require practical training through demonstrations and extension services to improve productivity and adoption of Tc bananas. It was also important to open more Tc banana multiplication and demonstration centres in order to widen the technology transfers scope and adoption amongst farmers. The respondents implored investment by government and development partners in farmer training and extension, education excursions or tours to contemporary areas on Tc banana production in order to enhance the impact of this and other technologies in the target counties. The study results were towards the conclusion that Farmer's exposure to more extension services leads to increased adoption since farmers are able to gain knowledge on Tc 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.

The study concluded that Socio-economically, majority of the respondents (66 %) 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. 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. 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.

The study revealed and concluded that total land size influenced adoption of Tc bananas and that most of the respondents had an average of 5.51 acres and that the households heads were the more the likelihood of allocating more land and accompanying resources to the new Tc bananas crop. Land ownership defined in the status results which concluded that it was a significant factor influencing adoption of Tc bananas technologies in the study area and tat land was an important resource in farming activities in the arid semi-arid lands. 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. Regarding environmental factors affecting adoption, the data concluded that 68% of the sampled household 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. The study concluded on the significance of the environmental factors such as soil and water conservation as well as growing methods, and general climatic factors that influence growth and maturity of bananas affecting adoption of tissue culture bananas in the semi-arid areas of lower eastern Kenya. The results confirmed the study area as potentially suitable

for Tc 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 this being due to prevailing favorable factors include good soils, temperatures and moisture among others.The issue of a strategic subsidy policy plan was concluded as a suitable option given the high level of povety at above 60% 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 Tc bananas. On wildlife as a factor significantly influencing adoption of tc bananas in the study area, the respondends were in conclusion that this was a constraint that required policy intervention.

RECOMMENDATIONS:

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

- 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 in the study areas.
- Provision of extension services and training of farmers on banana production aimed at increasing acreage under Tcbananas is also recommended.
- Ways of availing Tc bananas plantlets closer to farmers through establishment of certified sources like nurseries or calling stations in the wards are recommended.
- Reducing the cost of the improved Tc bananas plantlets as incentive to adoption of Tcbananas is equally important.
- Decentralization of tissue culture banana technology like KALRO centres to areas near the farmers to increase their availability is recommended.
- Improving the awareness and provisions of credit facilities to Tc banana farmers to enable them commercialize the fruit production.
- Wildlife is a major concern and quite significant in the area under study and sustainable solution through policy intervention is recommended.
- 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.
- 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 Tc bananas thereby increasing adoption.
- A policy to accelerate adoption of the Tc bananas technology through a well-designed and strategic subsidy scheme is also recommended.
- More multiplication centres or nurseries should be established in the three clusters and the community trained on how to propagate the suckers' hence increasing adoption of the Tc bananas.
- Reduced unit costs of the plantlets through a subsidy policy interventions can be a significant milestone to the enhanced adoption of Tc bananas in the study areas

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