ADOPTION OF RECOMMENDED TECHNOLOGIES ALONG BANANA VALUE CHAIN AND ITS EFFECTS ON PRODUCTIVITY IN EMBU WEST SUB-COUNTY, KENYA

DOMINIC NTHUKURI KATHURI

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

Signature ……………………………… Date ………………………

Dominic Nthukuri Kathuri

Department of Agricultural Economics and Extension

A512/1193/2018

This thesis has been submitted for examination with our approval as the University Supervisors.

Signature ……………………………… Date ………………………

Dr. Samuel N. Ndirangu

Department of Agricultural Economics and Extension

University of Embu

Signature ……………………………… Date ………………………

Dr. Bernard Gichimu

Department of Water and Agricultural Resource Management

University of Embu

DEDICATION

I dedicate this work to the Almighty God for the gift of life, strength and guidance during my studies. I also dedicate this work to my loving family.

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LIST OF ACRONYMS AND ABBREVIATIONS

BBMV	Banana Bract Mosaic Virus
BBTV	Banana Bunchy Top Virus
BSV	Banana Streak Virus
DAP	Di-ammonium Phosphate
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GDP	Gross Domestic Product
GTL	Genetic Technology Laboratory
HCD	Horticultural Crop Directorate
KES	Kenya Shillings
Kg	Kilograms
KNBS	Kenya National Bureau of Statistics
MNL	Multi Nominal Logistic
MoALF	Ministry of Agriculture, Livestock and Fisheries
NGOs	Non-Governmental Organizations
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
TC	Tissue Culture
TSP	Triple Supper Phosphate

DEFINITION OF TERMS

Productivity: The amount of output obtained per unit of input used (Ndirangu *et al*., 2018). With regard to this study, productivity is defined as the amount of output of banana obtained per unit of input used.

Technology adoption: The acceptance, integration and the use of new technology in a society (Wachira *et al*., 2013). According to this study, technology adoption is defined as the integration of new technologies in banana production to improve the output.

Value chain: The chain from the producer i.e. the farmer, to the final consumer of the goods and services (Musyoka *et al*., 2020). According to this study, value chain is defined as all the activities from planting, production, management practices, harvesting up to final consumption of bananas.

Deleafing: This is the removal of excess and dry leaves from a banana stool (Isaac, 2012).

Desuckering: This is the removal of excess suckers from the banana stool (Muthee *et al*., 2019).

Debudding: This is the removal of the male bud from the banana bunch (Muthee *et al*., 2019).

Mattacking: This is cutting of already harvested banana tree 60 cm from the ground (Wasala, 2014).

ABSTRACT

Banana is one of the most important fruits in Kenya as it contributes to about 32% of the foreign income of the total exported fruits. Despite this contribution, banana farming is facing numerous challenges such as lack of clean planting material, pest and diseases and poor agronomic and crop husbandry practices leading to low productivity. The purpose of this study was to evaluate technology adoption along banana value chain and its effects on productivity among smallholder farmers in Embu West Sub-County, Embu County. The study was conducted in four wards of the Sub-County namely Gaturi South, Mbeti North, Kithimu and Kirimari. Data was collected from a sample of 384 small-scale banana farmers who were sampled using multi-stage sampling technique and proportionate to size technique. A structured questionnaire was administered to collect primary data from the respondents. To assess the extent of adoption of recommended banana technologies, descriptive statistics were applied in analysis. The results on the extent of adoption of recommended banana production technologies indicated that 63% of the smallholder farmers were at low level of adoption, 25% medium level of adoption and 12% at high level of adoption. The Cobb Douglas Production Function results indicated that amount of credit, cost of the banana plantlets, fertilizer and manure application had positive significant effects on banana productivity. On the effect of the selected recommended banana production technologies on banana productivity the result indicated that tissue culture, deleafing, use of irrigation, debudding, desuckering and banana value addition practice had positive and significant effects on banana productivity. Multinomial logistic model results indicated that farming experience, labour, extension contact, access to credit and farmers group decreases the likelihood of the farmer being in low and medium adoption level of recommended banana production technologies in favor of the preferred category, while age precipitated a negative effect. The study recommends enhanced sensitization of small-scale banana farmers on the importance of adopting the recommended banana technologies for improved banana yields per unit area.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Banana (*Musa spp*.) is an important fruit crop in the world and is cultivated over an area of more than 4,000,000 hectares (Pappu *et al.,* 2015). It is the third important starchy staple food after cassava and sweet potato (FAOSTAT, 2018). Its world production estimates are placed at 49.63 million tons, of which 20.31 million is grown in Asia, 13.31 million in South America, 7.66 million in Central America, 6.44 million in Africa, 1.5 million in Oceania and 0.42 million in Europe (Mugo, 2013). Bananas originated from South East Asia, a region considered as the primary center of diversification of the crop and where the earliest domestication occurred (Mwangi *et al*., 2011). This area borders on the west India and on the east Samoa, Fiji and other South Pacific islands (FAOSTAT, 2018). The dispersal of banana out of East Asia was as a result of human movement across the world. The low land areas of West Africa contain the world's largest range of genetic diversity in plantains. Conversely in East Africa, bananas have highly evolved into an important zone of secondary genetic diversity for the East African highland bananas. Edible *Musa spp*. originated in southeast Asia and spread westwards along the major trade routes that transported other fruits (Perrier *et al*., 2011). The East African region produces half of Africa's banana crop, providing staple food and a source of income to an estimated 20 million people (Mwangi *et al*., 2011). Uganda is the leading producer in the region producing 9.8 metric tons, accounting for 7 percent of the world's total production (Taffesse *et al*., 2012).

Banana production contributes greatly to the economic development of an economy, nutrition, and food security among other components (Kadi *et al*., 2011). The fruit is eaten either cooked or ripened depending on the varieties but most of the consumers prefer dessert bananas to cooked ones (Aurore *et al*., 2009). Bananas can also be blended with other products to form banana puree, ice cream and baked desserts, and can also be made into beer and wine (Obaga & Mwaura, 2018). In Kenya, banana is mainly grown and managed by smallholder farmers, predominantly peasant women (Kabunga *et al*., 2012). It contributes to about 32 percent of the foreign income of the total exported fruits (Horticultural Crop Directorate, 2016). Bananas are produced mainly in Western, Central and parts of Eastern regions (Wasala, 2014). These regions have high potential for banana production due to their agro-ecological characteristics, which greatly supports the growth of banana crop. Bananas are mainly consumed domestically, with an annual per capita consumption of 220-460 Kg, providing more than 25percent of the total calories consumed (FAOSTAT, 2018). Despite the importance of the crop and availability of suitable producing areas, banana production in Kenya has been declining as a result of pests and diseases, poor agronomic practices and access to clean and affordable planting materials (Kathuri *et al.*, 2021; Kasyoka, 2013). Therefore, there is need to look at the extent of adoption of the recommended technologies in order to improve the productivity levels of banana.

The area under banana and plantain cultivation in Kenya has continued to increase over the years with key production areas being Central, Nyanza, Western and Eastern Provinces. Banana yield is still very low at 4.5-10 tons/ha compared to the potential of 30-40. Pests and diseases are the main production constraints and can reduce yield of bananas by upto 100% depending on pathogen, while quality is also compromised. Other constraints are declining soil fertility, poor crop management, lack of clean planting material, poor marketing infrastructure, postharvest losses, genetic erosion and high cost of inputs. Thrips are emerging as major pests of banana as their infestation causes silvery scarification on the fingers making them less appealing to buyers and consumers. Severe damage may cause cracking of fingers.

Historical experience from Kenya and other countries demonstrate that farmers might adopt a certain component of a technology package, while refusing another component or adopting it at a later stage, based on subjective profitability and risk considerations (Mugo, 2013). Such individual modifications of the package would influence the yield levels to be obtained. However, small scale banana farmers depend on sale of fresh produce for their livelihoods, and these have generated minimal profits due to post-harvest losses (Obaga, and Mwaura, 2018). Therefore, there is a need for banana value addition for small-scale farmers in order to increase the shelf-life of the fruit and also enhance the income among the small-scale farmers (Makindara *et al.*, 2015).

Banana is one of the horticultural fruit crop in the agricultural sector that has shown great potential for increased production in Kenya. Banana value chain is important in many regions of Kenya where the crop is grown and acts as a source of income to the rural farmers. Embu County produces 12% of all bananas produced in Kenya and is ranked third after Meru (19%) and Kirinyaga (14%) (Muthee *et al.*, 2019). Other banana producing counties in Kenya are Taita Taveta (9%), Muranga (7%), Kisii (6%), Tharaka Nithi (6%) and Bungoma (5%). According to Ministry of Agriculture Livestock and Fisheries, (2018), Manyatta and Runyenjes sub-counties are leading in banana production in Embu County, producing approximately 50% and 43.8% of the total banana production in the County respectively. The remaining 6.3% comes from Mbeere North and Mbeere South sub-counties. However, the County has continually recorded declining banana yields in recent decades. Previous studies are generally concentrated in measuring banana yield levels without establishing the factors leading to low yields and necessary mitigating actions at the farmer level (Agwara, 2017).

The banana value chain is important for food security and the economic prosperity in the County. Bananas are perennial tropical plants whose fruits are used as a staple food both for cooking (plantains) and as table fruits for direct consumption. Post-harvest production includes collection and bulking, where the bananas are aggregated to a central collection centre and transported to the buyer or market. Value-adding processes include sorting and grading bananas by quality and the production of wine, flour, and crisps or chips (Muthee *et al.*, 2019). The crop serves as a source of food, income and animal feeds in addition to its environmental benefits (Ministry of Agriculture Livestock and Fisheries, 2018). Inspite of this, the sector has been facing numerous challenges as the farmers have inadequate information on agronomic technologies on banana production and have not opted for value addition technologies (MoALF, 2018). Therefore, this study sought to evaluate the level of technology adoption along banana value chain and its effects on productivity among small-scale farmers in Embu West Sub-County.

1.2 Statement of the Problem

Despite the importance of banana in the Kenyan economy, its production has been declining due to numerous challenges such as inadequate clean planting materials, pests and diseases, poor agronomic and crop husbandry practices and lack of value addition. Most of these challenges can be addressed through adoption of recommended technologies. However, farmers chose to adopt a certain component of a technology package, while refusing another component or adopting it at a later stage, based on subjective profitability and risk considerations. The level of adoption of various agronomic and value addition technologies is not yet established in most banana production areas in Kenya. There is also scanty information on factors influencing the adoption of various recommended technologies along banana value chain. Therefore, this study sought to determine the level of adoption and factors affecting adoption of various recommended technologies along banana value chain among small-scale farmers in Embu West Sub-County, in Embu County.

1.3 Research Objectives

1.3.1 General Objective

The overall objective of this study was to evaluate adoption of the recommended technologies along banana value chain and its effects on productivity among small-scale farmers in Embu West Sub-County, Embu County

1.3.2 Specific Objectives

1. To assess the extent of adoption of selected recommended technologies along banana value chain among small-scale farmers in Embu West Sub-County
2. To evaluate the effects of adoption of selected recommended technologies along banana value chain on banana productivity among small-scale farmers in Embu West Sub-County
3. To determine the effect of socio-economic and institutional factors on the adoption of selected recommended technologies along banana value chain among small-scale farmers in Embu West Sub-County

1.4Research Questions

1. What is the extent of adoption of selected recommended technologies along banana value chain among small-scale farmers in Embu West Sub-County?
2. What is the effects of adoption of selected recommended technologies along banana value chain on banana productivity among small-scale farmers in Embu West Sub-County?
3. What is the effect of socio-economic and institutional factors on the adoption of selected recommended technologies along banana value chain among small-scale farmers in Embu West Sub-County?

1.5 Justification of the Study

Banana is one of the most important fruits in Kenya as it contributes to about 32% of the foreign income of the total exported fruits (Horticultural Crop Directorate, 2018). It is also used by many households to earn income and for nutritional security. It can also be used as a raw material for industrial production through blending with other products such as puree, ice cream, baked desserts, beer and wine (Obaga, and Mwaura, 2018). Banana production is an important farming enterprise in Embu West Sub-County due to its agro-ecological characteristics (Kithinji, 2018). This study provides a research-based information on the level and role of technology adoption in improving banana production in the target area. Understanding the effects of technology adoption along banana value chain triggers positive change among the concerned stakeholders thus improving disposable income, food and nutritional security and livelihoods in the rural set-up. This directly contributes to two of the seventeen Sustainable Development Goals (SDGs) namely “end poverty everywhere (SDG 1)” and “end hunger, improve nutrition and promote sustainable agriculture (SDG 2)”.

Effective adoption of banana production technologies would result in increased banana productivity thus contributing positively to the attainment of Vision 2030’s economic pillar which aims at increasing the economic growth by 10 percent. Increased income would also ensure food security among farmers thus contributing to the Food Security and Nutrition pillar of the Big Four Agenda of the Kenyan Government (Government of Kenya, 2018). The findings of this study may be useful to the policymakers, extension officers and other stakeholders in improving banana productivity in Embu West sub-County and other regions in Kenya with similar dynamics.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Botanical Description of Banana

Bananas (*Musa* spp.) are a key domesticate of subsistence farmers across the wet tropics and subtropics, including today the Americas, Africa, South Asia, mainland and Island Southeast Asia, Melanesia and the Pacific. Although bananas are one of the most important commercial crops in the world, it is estimated that 87percent of banana production is for local food consumption (Bioversity International, 2008). Apart from the hundreds of fully domesticated banana varieties, of which many are grown outside their natural range, an uncertain number of varieties cultivated today are still in various stages of domestication, because they are still inter-fertile with wild surrounding populations that continually introduce new genetic material into cultivated stock (De Langhe *et al.,* 2009).

2.2 Recommended Technologies along the Banana Value Chain

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. In Kenya, the government has continued to advocate and promote research and development of new technologies to address food security and income generation concerns (Afari-Sefa *et al*., 2012). In fact, about 75 percent of the population earns a living from agriculture (Salami *et al*., 2010). According to Wanda, (2009), the most important factors affecting banana production are labour and performance of agronomic management practices which include use of quality planting materials, appropriate use of fertilizers, mulch and manure. Value addition is one of the recommended agronomic practices along perishable horticultural produces value chain because of its higher returns to the small-scale farmers that comes with an opportunity to open new markets as well as extending farmers marketing seasons with the ability to create new recognition of the farms (Schiassi *et al*., 2018). Some of the challenges that small-scale banana farmers face is fluctuating prices due to overproduction and lack of storage facilities for ripe bananas (Obaga and Mwaura, 2018). Value addition can therefore be termed as the process of enhancing a product to gain more from it. There are several products that can be made from bananas, such include wine, flour, yoghurt and crisp which are by-products once the bananas have been processed. In this case, then it can be noted that agriculture can be profitable and alleviate poverty in rural areas through value addition of the farm produce (Kumar *et al.*, 2006; Obaga and Mwaura, 2018).

2.2.1 Use of Certified Planting Materials

To improve banana productivity and safeguard sustainable banana production for small-scale farmers, use of clean and high quality planting materials is crucial. In East African smallholder systems, new banana fields are traditionally planted with suckers. However, the use of tissue culture banana plants is increasing, because they are pest and disease free, grow more vigorously, are more uniform, allowing for more efficient marketing and can be produced in large quantities in short periods of time, thus permitting faster distribution of planting material and new cultivars. As such, the use of tissue culture bananas plantlets can support farmers to make the transition from subsistence to small-scale commercial farming (Murongo *et al.*, 2018). Adoption of the new banana varieties in Tanzania was found to significantly reduce banana production losses from infestation of pests and diseases by 5 percent (Nkuba, 2017). Other impacts of the new varieties were on improved food security, increased banana income, improved quality of banana juices and brews, improved social relationships and improved banana biodiversity.

In Kenya, tissue culture bananas were recently estimated to constitute less than seven percent of the total banana coverage area, while adoption rates in Countries like Uganda and Burundi are significantly lower (Murero *et al.*, 2014). An impact study done in Kenya showed positive yield effects of tissue culture banana adoption, but also pointed out the importance of good extension and proper plantation management (Kabunga *et al.*, 2012). Tissue culture bananas plantlets require appropriate handling and management practices to optimize their benefits. Consequently, this additional effort and the cost of tissue culture bananas plantlets (US$1.20–2.00) pose an extra cost for the Kenyan farmers (Ouma *et al.*, 2013).

2.2.2 Soil Fertility Management in Banana Production

Use of recommended fertilizers have been shown to address key nutrients deficiencies (Wairegi and Asten, 2010). Therefore, fertilizer information system for banana plantation is developed to support farmers to manage information for banana farm in an effective way (Shuen *et al*., 2017). A study by (Fonsah *et al*., 2011) on optimization of soil management strategies to enhance banana productivity found that fertilization at 153 kg N ha^{-1} $year^{-1}$ derived solely from urea significantly resulted to high 42percent yield among small-scale farmers. However, the productivity was highest 52percent in nutrients derived from cattle manure in combination with Urea at 50percent substitution (Meya *et al*., 2020). Bananas perform best in deep, rich loamy and silty clay loam soil with pH of 5.8 - 7.5 (Pan *et al*., 2012). The soil should be rich in organic material with high nitrogen content, adequate phosphorus level and plenty of potash.

Agricultural lime, preferably dolomitic limestone (Ca + Mg content), is recommended to be added to soils that are very acidic in order to make them less acidic and better suited for banana production (Fageria and Baliger, 2008). This should be done before planting and should be based on soil analysis (Pan *et al*., 2012). The best fertilization regime should be based on leaf or soil analysis which provides a guide on exact applications for particular soils and management conditions from year to year. The recommended average rates of nutrients applications for tropical bananas are: Nitrogen(N) - 400-600 kg/ha/year, Phosphorous (P_2O_5) - 200-300 kg/ha/year, Potassium (K) - 850-1100 kg/ha/year, and 2 tones/ha/year of lime/dolomite. These relatively high fertilizer rates are necessary because high yielding banana crops extract large quantities of nutrients from the soil (Pan *et al*., 2012). Application of inorganic fertilizers is not common among banana farmers in Embu County (Muthee *et al*., 2019). In this case inorganic fertilizers improve soil fertility hence increase productivity per unit area under banana production.

2.2.3 Pests and Diseases Management in Banana Production

Viral diseases are considered as a major concern for banana production, this is because of their effects on the yield and quality as well as limitations to the germplasm multiplication and the international germplasm exchange (Tripathi *et al*., 2016). There are so many viral diseases which attack banana reported worldwide (Iskra-Caruana *et al*.,2014) However, the economically most important banana viral diseases are: Banana bunchy top virus (BBTV), Banana streak viruses (BSV), Banana bract mosaic virus (BBMV), and Cucumber mosaic virus (CMV) (Tripathi *et al*., 2016). Among these diseases BBTV and BSV are major threats to banana production. Due to lack of durable virus resistance in the *Musa spp.,* measures such as phytosanitation, use of virus free planting materials, strict regulation on movement of infected planting materials are effective means to control viral diseases in banana (Tripathi *et al*., 2016). The banana weevils, (*Cosmopolites sordidus* Germar) is the most important pest of banana and plantain throughout the tropics (Tinzaara *et al*., 2006). The weevil has a narrow host range and attacks only plants in the genera *Musa* and *Ensete*.

2.2.4 Other Recommended Agronomic Practices

Promotion of use of complementary agronomic practices such as weeding, irrigation, deleafing, desuckering, debudding among others in addition to inputs should be given adequate emphasis in the extension package to enable farmers achieve stable yield levels (Wanda, 2009). In order to achieve good yields, bananas should consistently receive 200 to 220 mm of water per month (Bio vision, 2016). Failure to practice irrigation implies that moisture stress affects the yields. Failure to practice weeding in banana orchards may not only reduce yields but certain weeds associated with banana are also known to harbor pests that cause major losses in production (Isaac *et al*., 2012). A study conducted by Muthee *et al*. (2019) in Embu County showed that very few farmers practice deleafing 4.4percent, mulching 4.4percent, pests and disease management 4.2percent, desuckering 2.5percent, mattacking 2.3percent, denaveling 2.2percent, and bagging 2.1percent. Therefore, there is need to look at the extent of adoption of this agronomic practices among small-scale banana farmers hence this study comes in to fill the identified gap above.

2.2.5 Post-harvest Technologies in Banana Production

Post-harvest technologies are majorly associated with transportation, storage and value addition through development of products and by-products that capitalize the genetic diversity of the banana (Kikulwe *et al*., 2018). Banana value addition through processing into crisps, wine, juice and flour was found to have a significant influence on household welfare (Obaga & Mwaura, 2018). The main determinants of banana post-harvest losses include market distance, duration of transport, storage condition, storage duration, duration of ripening, type of ripening rooms, means of bunch transport, experience in banana marketing (Woldu *et al*., 2015).

2.3 Adoption of Recommended Technologies in Banana Production

Farmers are responsible for the decision to adopt or reject the recommended technologies in banana production (Ainembabazi and Mugisha, 2014). This decision is influenced by age and gender of the household head, land tenure systems and sources of labour. The sustainability of the yield supports the decision for the smallholder farmers to adopt and sustain the technology, fall back to the former and or reject and sustain the rejection of the technology (Murongo *et al*., 2018). Farming experience was found to be a very influential among smallholder farmers in Uganda in early stages of adoption of a given technology when farmers are still testing for its potential benefits (Ainembabazi & Mugisha, 2014). Thanh and Yapwattanaphun, (2015) reported that sustainable agricultural perception, economic status, extension courses, education and feasibility of practices were effective factors affecting banana farmers' sustainable agricultural perception in Vietnam. In another study conducted in Southern Ethiopia, age of banana plants, family size, age of farmers and availability of labour were found to have a positive and significant influence on banana production and adoption of recommended technologies (Mamuye, 2015). However, these studies did not consider other socio-economic and institutional factors such as gender, household income, market information, market price and market access were not considered in the analysis.

The availability of tissue culture (TC) banana seedlings, proportion of the banana income to the total farm income, per capita household expenditure and the location of the farm was found to significantly influence the likelihood of adoption of TC banana in the four counties of Western Kenya (Obare & Owuor, 2013). The study further found that occupation of the farmer, family size, labour source, farm acreage, farm fertility status significantly influenced the intensity of adoption of banana TC technology. In another study, gender, education, total land size, TC banana knowledge and TC banana market were found to significantly influence the rate of adoption of the TC technology among small-scale farmers lower Eastern Kenya (Thuo, 2018). These studies did not consider other key farm and farmers' characteristics such as size of the farm that might also influence the adoption of banana tissue culture. A study to evaluate factors influencing adoption of tissue culture planting materials in Uganda found that social influence and farmers' innovativeness were among the key factors (Murongo *et al*., 2018). In a similar study that was also conducted in Uganda, the scale of production, banana verities, socio-demographic and management characteristics were the factors that influenced the adoption of tissue culture banana technology among small-scale farmers (Flarian *et* al.,2018). However, both of these studies did not assess the effect of economic and institutional factors affecting the adoption of tissue culture bananas.

2.4 Theoretical Framework

This study will adopt Innovation Diffusion Theory by Rogers (2015) to help ground study on adoption of banana recommended technologies process from innovation to adoption. This theory focuses on understanding information, diffusion and the level of technology acceptance in a social system. According to Rogers, (2015), Innovation is the practice perceived as new characterized by knowledge, persuasion and decision by individual or a social system. On the other hand, diffusion is deemed as the process that entails communication channel, time and social system. He stated that potential adopters assessed attributes of technology majorly relative advantage, compatibility, complexity, trial-ability and observability. This theory will be relevant in this study in many ways. First it will evaluate the extent of adoption of banana recommended technologies among small-scale farmers in Embu West Sub-County. Besides, the study will also evaluate the effect of adoption of the banana recommended technologies on productivity.

2.5 Conceptual Framework

The figure 2.1 shows the conceptual framework for the study depicting the relationship between the independent variables and the dependent variables. The independent variables include the economic and institutional factors such as extension services, household income, access to credit, labour availability, membership into farmer's groups as well as farm and farmer's characteristics such as size of the farm, farmer's education and farmers experience. The dependent variables were the adoption of the banana agronomic practices such as irrigation, pest and disease management, improved varieties, deleafing, debudding, mattacking, and use of tissue culture bananas. Other dependent variables included the adoption of banana value addition technologies such as ripening, making juices, banana crisps, banana flour etc. Banana productivity was measured in terms of yield per acre and income per acre. The expected output of this study was food security, poverty eradication and improved livelihood among smallholder rural farmers.

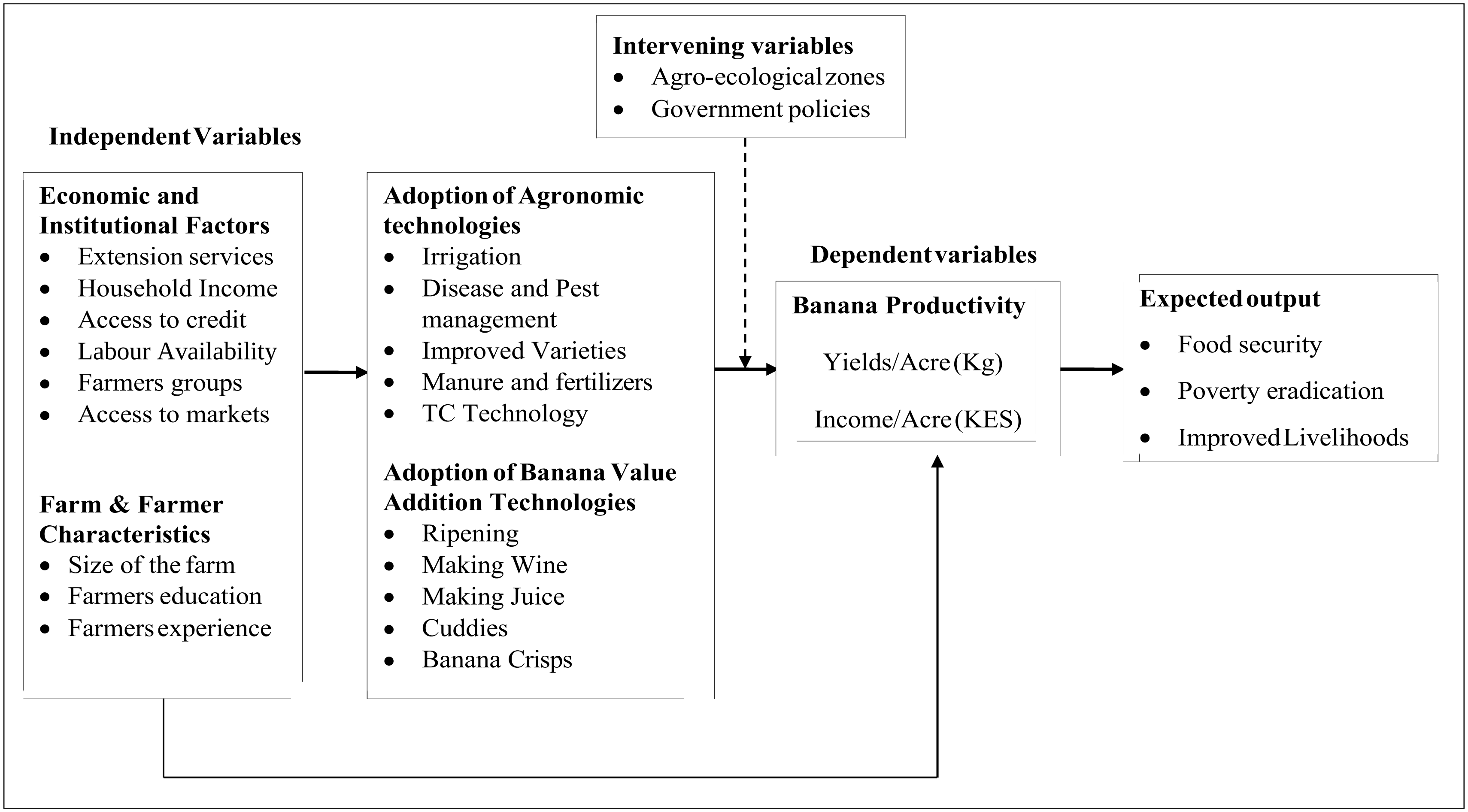

Fig. 2.1: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Study area

The study was conducted in four administrative wards (Gaturi South, Mbeti North, Kithimu and Kirimari) of Embu West Sub-County in Embu County. Embu West Sub-County was considered for this study because of its high production of bananas (MoALF, 2018). The Sub-County covers an area of 88.7 km^2 with a population of 127,100 (KNBS, 2019). The Sub-County lies between latitude 0^0 8' and 0^0 50' South and longitude 37^0 3' and 37^0 9' East. The temperatures in the area range between 20^0C to 30^0C with an average rainfall ranging from 640 mm to 1495 mm per annum (Government of Kenya, 2018). The long rains occur between the months of March and June while the short rains fall between October to December. The main cash crops grown in the area are tea and coffee. The main food crops grown include banana, maize, sorghum, cassava and millet. The farmers in this area also practice substantial dairy keeping.

3.1 Research Design

This study employed a cross-sectional survey design (Kothari, 2019). This design was the most suitable for this study as it enabled collection of data at a single point in time without manipulating the environment of the study. It is also cheap and quick to perform using questionnaires.

3.2 Target Population and Sample Size

The target population was banana farming households in the four wards of Embu West Sub-County namely Gaturi South, Mbeti North, Kithimu and Kirimari. The sample size was calculated using Cochran's formula as described by Mugenda & Mugenda (2015) which applies when the target population is more than 10,000 and the farmers have more than 50% of the desired characteristics:

$$n = \frac{Z^2pq}{d^2} \quad \text{……………………………………………………………………} \quad (3.1)$$

Where: n = desired sample size;

Z = standard normal deviate at 95 percent (1.96) confidence level;

p = the estimated proportion of the target population having the characteristics being measured (0.5); and

d = level of statistical significance (0.05)

Therefore: $q = 1 - p$ = 1-0.5 = 0.5 thus n = $(1.96)^2$ (0.5) (0.5) / $(0.05)^2$ = 384 banana farming households.

3.3 Sampling Procedure

The study applied multi-stage sampling technique involving purposive sampling, random sampling and probability proportionate to size sampling techniques in selecting the sample households. In the first stage, all the four wards in Embu-West Sub-county were sampled on the basis of their engagement in banana production. Banana farming households were then randomly selected from each ward to form a sample size of 384. Probability proportionate to size technique was used to determine the number of banana farming households to be interviewed in each ward. The sampling frame in Table 3.1 shows the different sample sizes across the four wards.

Table 3.1: The total population and the sample sizes of the four wards

Ward	Total number of farmers	Sampled farmers
Gaturi South	3750	104
Mbeti North	593	17
Kithimu	9000	251
Kirimari	450	12
Total	**13,793**	**384**

3.4 Data Collection Instruments

A structured questionnaire was used to collect data from the banana farming households. It consisted of questions related to banana agronomic management practices and banana value addition technologies mainly targeted to assess their levels of adoption, effects of their adoption on productivity as well as social economic and institutional factors affecting their adoption.

3.6. Reliability of the Data Collection Instrument

A pilot test was done with 15 randomly sampled banana farming households to ascertain the reliability of the interview schedules. Split-halves method was used to test for reliability. Correlation coefficient (r) between halves of the items was calculated using Pearson Product linear correlation coefficient formula;

$r = N\Sigma Y - [\Sigma(X)(\Sigma(Y)]/\surd[N\Sigma X^2 - (\Sigma(X^2)][N\Sigma Y^2 - (\Sigma(Y^2)$..............................(3.2)

Where: X = odd scores, Y = even scores, $\Sigma(X)$ = sum of X scores, = $\Sigma(Y)$ sum of Y scores, $\Sigma(X^2)$ = sum of squared X scores, ΣY^2 = sum of squared Y scores, ΣXY = sum of the product of paired X and Y scores, N = number of paired scores and r = coefficient correlation between halves. Since *r* represents one half of the instrument, Spearman-Brown Prophesy was used to determine reliability of the full instrument.

$Re = \frac{2r}{1+r}$ = 2 × reliability for ½ tests / 1 + reliability for ½ tests; r lies between 0 and 1. The reliability was assumed to be stronger for *r* values approaching 1.

3.7 Validity of Instrument

Validity refers to the accuracy of the data obtained. In order to achieve this, all questions representing the variables to be measured and the appropriate indicators were used to capture the data required. About 15 sampled questionnaires for pilot study were used to help in assessing the accuracy of data collection instrument. Items found ambiguous and inadequate were correctly worded or modified to avoid misinterpretation by the respondents.

3.8 Data Analysis

The data was cleaned and then subjected to statistical analysis using Statistical Package for Social Sciences (SPSS). To assess the extent of adoption of recommended technologies along the banana value chain, descriptive statistics including means, frequencies and percentages were conducted and the results were presented using tables. To determine the effect of adoption of recommended technologies on banana productivity, the log-linearized Cobb-Douglas production function was applied. This production function was the most suitable for this study because it provides parameters that are easy to estimate and interpret (Tadesse & Krishnamoorthy, 1997). The general stochastic Cobb-Douglas production function is specified as follows:

$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 ... + \beta_n \ln X_n + \alpha_1 z_1 + \cdots \alpha_1 z_n + \varepsilon$ ....(3.3)

Where Y is the output, β_0 is the vertical intercept showing values of Y when variables X_1 to X_n are quantities of inputs used. β_1 to β_n are the inputs co-efficient of the regressor or multiplier that describes the size of the effect of the inputs have on the dependent variable Y. α_1 is the coefficient for factors and z_1 to z_n are the factors. ε is natural logarithm and ε is the composite error term.

To determine the effect of socio-economic and institutional factors on the adoption of recommended technologies along the banana value chain among smallholder farmers, the multinomial logit regression model was used. Assuming the utility of household i choosing a recommended technology j is given by U_{ij} is a linear stochastic function of exogenous household characteristics X and endogenous household choices Z:

Uij =α X + β Z + ε .... (3.4)

The parameter estimates of the multinomial logit regression model only provide the direction of the effect of the independent variables on the dependent (choice) variable; thus the estimates represent neither the actual magnitude of change nor the probabilities. Marginal effects are used to measure the expected change in probability of a particular recommended technology being chosen with respect to a unit change in an independent variable from the mean (Greene, 2002). The end results of the above equation were as shown;

$Y = \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + \varepsilon$ ....(3.5)

Where: Y is the dependent variable (the recommended technologies), β_1 , β_2 ... β_n are the coefficients of the explanatory variables while X_1, X_2 … X_n are the explanatory variables (selected socio-economic and institutional factors) and ε is the error term.

3.9 Operationalization of the Study Variables

The variables used in the study, its descriptions and the respective measurement is presented in Table 3.2 in the next page

Table 3.2: Operationalization of variables

Variable	Descriptions	Measurements
Extent of adoption	The extent of adoption of recommended banana technologies	Descriptive statistics e.g. mean, percentages
Effects of adoption	The effect of adoption on banana productivity	Output per acre
Adoption	Adoption of the banana recommended technologies	1= Adopters, 0=non-adopters
Farm size	Farm acreage	Number of acreage
Farmers education	Education level attained by the respondent	1) Primary, 2) Secondary 3) College, 4) University
Farmers experience	The period when the sampled farmer has been practicing banana farming	Number of years
Extension services	Accessibility	Frequency of access (extension contact)
Access to credit	Access or not	Amount of credit accessed in Kenyan shillings
Household income	Respondents monthly income	Income in Kenyan shillings
Farmers groups	Membership to a group	Member of a group or not
Labour availability	Extent of labour availability based on requirement	Man days per acre per year

CHAPTER FOUR

RESULTS

4.1 Overview

This chapter presents the results from the descriptive and inferential statistical analysis of the data collected. Descriptive results on socio-economic and institutional characteristics of the respondents are presented. Descriptive analysis regarding rate of adoption of recommended banana production technologies among smallholder farmers are explained. The chapter also presents the results on the extent of adoption of the recommended banana production technologies among the small-scale farmers in the study area. The Cobb-Douglas production function results on the effects of adoption of the selected recommended technologies along banana value chain on banana productivity have been presented. Further, the results of multinomial logit regression analysis on the effects of socio-economic and institutional factors on adoption of selected recommended technologies along banana value chain are presented.

4.1 Reliability and Validity Analysis

A sample of 15 interview schedules for the pre-test helped in assessing the accuracy of the data collection instrument. Items found ambiguous and inadequate were correctly worded and re-modified to avoid misinterpretation by the respondents. The Pearson product linear correlation coefficient results show that the instruments yielded a correlation coefficient, r of 0.745 for the full instrument. Since reliability is assumed to be stronger for r values approaching 1, the reliability coefficient of 0.745 implies that the data collection instrument was adequately reliable.

4.2 Farm and Farmers' Characteristics of the Sampled Banana Farmers

This section presents the results on the socio-economic and institutional characteristics of the sampled banana farmers in the study area. Socio-economic factors that related to the characteristics of the household head include age, gender, education, household size, farming experience among others. The economic factors included household income, both total and off-farm income, and household assets such as land among others. The institutional factors consist of credit access, government policy, market access, and road infrastructure, extension support and technology development.

4.2.1 Socio-Demographic Characteristics of the Sampled Farmers

The study determined the frequency and the percentage of respondents for the selected socio-demographic factors. The results are given in Table 4.1. Majority (72.66%) of the households interviewed were male-headed while the rest (27.34%) were female-headed. This implies that banana farming in Embu West Sub-County is mainly dominated by male-headed households.

The results on the marital status indicated that majority (75.52%) of the respondents were married, 13.02% were widows, 6.25% were widowers and 5.21% were unmarried (Table 4.1). In terms of age, only 7.81% of the respondents were within the youthful age bracket of 18-30 years. Majority (54.69%) of the respondents were aged between 41-50 years while 15.63% of the respondents ranged between 31-40 years of age. Those within the age bracket of 51-60 years constituted 13.02% while 8.85% of the respondents were above 60 years of age (Table 4.1).

Majority of the sampled famers (79.6%) had acquired formal basic education but only 12.6% had attained tertiary level of education while 7.8% of the sampled farmers had no formal education (Table 4.1). This implies that most farmers were capable of adopting and applying the recommended banana production technologies. Banana farming experience among the sampled farmers averaged 16.96 years (Table 4.1), implying that most of the sampled farmers had a substantial experience in banana farming. In terms of family sizes, 53.6% of the sampled households had between 1-5 family members while the rest had more than 5 family members (Table 4.1).

Table 4.1: Socio-demographic characteristics of the sampled banana farmers

Variable	Frequency (Number)	Percentages (%)
Gender of the Farmer		
Male	279	72.66
Female	105	27.34
	Mean = 0.73, Std. Dev = 0.23	Max = 1, Min = 0
Marital Status		
Married	290	75.52
Window	50	13.02
Widower	24	6.25
Single	20	5.21
Age of the household head		
18 – 30 (years)	30	7.81
31-40	60	15.63
41-50	210	54.69
51-60	50	13.02
61 and above	34	8.85
	Mean = 55.32, Std. Dev = 13.52	Max= 80, Min=30
Level of education		
Primary	180	46.8
Secondary	126	32.8
Post-secondary	48	12.6
Non-formal education	30	7.8
Banana farming experience (years)		
< 10	112	29.1
10 – 20	154	40.1
21 – 30	73	19.0
> 30	45	11.8
	Mean =16.96, Std. Dev=10.88	Max=30, Min= 10
Household size		
1 – 5	206	53.6
6 – 10	144	37.5
> 10	34	8.9
	Mean=5.60, Std. Dev=0.35	Max=8, Min=3

4.2.2 Economic Characteristics of the Sampled Farmers

The means, frequencies and percentage of respondents for the selected economic characteristics were as presented in Table 4.2. The results indicate that the 20.83% of the respondents had a household income of between Kes 10,000 and 20,000. Majority had a household income of between Kes 21,000 and 30,000. In addition, 13.02% of the respondents had household income ranging between Kes 31,000 and 40,000 while 10.16% of the respondents had household income of above Kes 40,000. The mean household income per year was Kes 28,028.65.

Further analysis indicated that majority (47.09%) of the respondents had an off-farm income of above Kes 40,0000. Those who had attained an off-farm income of between Kes 31,000 and 40,000 constituted 26.04% while 15.63% had off-farm income of between Kes 21,000 and 30,000. Only 10.42% of the respondents had an off-farm income of between Kes 10,000 and 20,000. In addition, the mean off-farm income per annum was KES 65,739.58. With regard to the various sources of off-farm income, 62.72% of the farmers obtained off-farm income through self-employment, 33.85% through formal employments, 3.91% through pensions and 0.52% through wages. The results further indicated that, 72.9% of the respondents owned land with title deeds, while 27.1% had leased the land for banana production.

Majority of the farmers (45.6%) had land sizes ranging between 0.5 acres and 2 acres, implying that the land have been fragmented into small parcels probably due to increasing population pressure. Consequently, majority (56%) of the sampled farmers had apportioned less than an acre of the total land to banana farming. In terms of labour, majority (56.5%) of the sampled banana farmers were using family labour in the production activities while 27.6% were using hired labour. The rest (15.9%) combined both family and hired labour. In terms of labour requirement, the majority (71.9%) were engaging between 50 and 100 man days per acre per year on banana farming operations while 27.1% were using more than100 man days per acre per year. Only 1% of the respondents were managing with less than 50 man days per acre per year.

Table 4.2: Economic characteristics of the sampled farmers

Variables	Frequency	Percentage
	Household income per year (Kes)	
10000- 20000	80	20.83
21000-30000	215	55.99
31000-40000	50	13.02
40000 and above	39	10.16
	Mean=28028.65, Std.Dev=16593.49	Min=10000, Max=70000
	Off-farm income per year	
10000- 20000	40	10.42
21000-30000	60	15.63
31000-40000	100	26.04
40000 and above	184	47.09
	Mean=65739.58, Std.Dev 20357.89	Min=15000, Max=120000
Sources of off-farm income		
Self-employment	237	61.72
Formal employment	130	33.85
Pensions	15	3.91
Wages	2	0.52
	Types of land ownership	
Owned with title deed	280	72.9
Lease	104	27.1
	Total farm size (acres)	
< 0.5	30	7.8
0.5 -0.99	127	33.0
1- 2	175	45.6
> 2	52	13.6
	Mean = 2.00; Std. Dev =1.44	Max = 8, Min = 0.25
	Acreage under banana	
< 0.5	96	25
0.5 -0.99	215	56
1- 2	48	12.5
> 2	25	6.5
	Mean=0.7, Std. Dev=0.52	Max = 3, Min = 0.125
	Type of Labour	
Family	217	56.5
Hired	106	27.6
Both family and hired	61	15.9
	Labour use (man days/acre/ year)	
< 50	2	1.0
50 -100	143	71.9
> 100	54	27.1
	Mean = 70.56; Std. Dev =2.56	Max = 120, Min = 20

4.2.3 Institutional Characteristics of the Sampled Banana Farmers

The frequency and percentage of respondents for the selected institutional factors are given in Table 4.3. The results show that 83.33% of the respondents sold their bananas to vendors, 12.50% sold their produce to the nearby local markets and 4.17% to the cooperatives. The results further indicate that 66.41% of the farmers obtained market information through mobile phones through text messages, 28.91% from neighbors, 2.86% obtained information through radio and 1.92% through extension officers. In terms of proximity to the road, 22.1% of the farmers reported that their farms were less than one kilometer from the nearest tarmac road, 44.8% were located between 1-2 kilometers, 27.6% between 3-4 km and 5.5% above 4 km (Table 4.3).

With respect to distance to the nearest market, 26.6% of farmers were located less than 1 km from the nearest market, 45.1% were located between 1-2 km while 22.1% of the respondents were located between 3-4 km from the nearest market. Only 6.2% of farmers were located more than 4 km from the nearest market. This implies that the sampled farmers were incurring varying transport cost to access the market. With regard to time taken to get to the nearest market, majority (75.5%) of the respondents took less that one hour to reach the market, 18.2% took between one to two hours and 6.3% of the respondents took more than two hours to reach the market.

The largest segment of the households sampled (59.7%) had not received any extension support before the interview. In addition, majority (51.6%) of the respondents received extension contact once in a year, 32.3% twice in a year and 16.1% thrice a year. Furthermore, 12.9% of the farmers indicated that County Government was their main source of extension services while 38.7% obtained extension services from non-governmental organizations operating in the study area. Those who obtained extension services from farmer groups constituted 22.5% while 19.4% of the respondents received extension services from electronic media.

In terms of access to credit, majority (74.7%) of the sampled households did not have access to farm credit. Those who had access to credit (25.3%) obtained the facility from various sources. For instance, 20.4% indicated that they obtained credit from banks, 30.6% from Sacco’s and 49% non-governmental organizations such as One-Acre Fund. Regarding affiliation to farmers’ groups, only 32% of the farmers belonged to farmer groups. From the farmers who belonged to groups, 59.3% indicated they obtained training through those groups, 16.3% indicated that the groups were their main sources of credit, while 24.4 % indicated that groups were crucial for both credit access and savings

Table 4.3: Institutional characteristics of the sampled farmers

Variables	Frequency	Percentage
Main markets for bananas		
Vendors	320	83.33
Local markets	48	12.50
Cooperatives	16	4.17
Sources of market information		
Buyers	255	66.41
Neighbours	111	28.91
Media	11	2.86
Extension officers	7	1.92
Distance to road (km)		
< 1	85	22.1
1-2	172	44.8
3-4	106	27.6
> 4	21	5.5
Market distance (km)		
< 1	102	26.6
1-2	173	45.1
3 – 4	85	22.1
> 4	24	6.2
Time taken to the markets		
<1 hour	290	75.5
1-2 hours	70	18.2
>2 hours	24	6.3
Extension services		
No	229	59.7
Yes	155	40.3
Frequency of extension services		
Once a year	80	51.6
Twice a year	50	32.3
Thrice a year	25	16.1
Sources of extension services		
County government	20	12.9
Non-governmental organizations	60	38.7
Farmers group	35	22.5
Media	40	19.4
Access to credit		
No	286	74.7
Yes	98	25.3
Sources of credit		
Bank	20	20.4
Sacco	30	30.6
One acre fund	48	49.0
Group membership		
No	261	68
Yes	123	32
Services offered by group membership		
Credit only	20	16.3
Training	73	59.3
Saving and credit	30	24.4

4.3 The Extent of Adoption of Recommended banana production Technologies

4.3.1 Descriptive Statistics for the Adopted Banana Production Technologies

The results presented in Table 4.4 shows the descriptive statistics of the adopted recommended banana technologies. The results indicate that only 19.53% of the sampled farmers were growing tissue culture bananas. Among the adopters, 66.67% indicated that they preferred tissue culture bananas because of higher returns obtained after harvest while, 33.33% preferred tissue culture bananas because they are free from pests and diseases. The results further show that 72.92% of the farmers bought banana plantlets from private nurseries, 15.63% obtained plantlets from government agencies while 11.45% from non-governmental organizations (Table 4.4).

In terms of fertilizer application, 69.77% of the farmers applied Triple Super Phosphate (TSP) whereas 30.23% applied Di-Ammonium Phosphate (DAP). With respect to manure application, 49.48% of the respondents indicated that they used cattle manure, 20.83% applied poultry manure, 15.63% used goat manure and 14.06% of the respondents used composite manure. Besides farmers practiced various pest and disease management practices. For instance, 12.5% of the farmers sprayed their bananas against various pests and diseases, 8.33% of the farmers practiced fumigation, 25% practiced bagging as one of the pest management practice while 54.17% of the respondents practiced other cultural practices such as deleafing and debudding (Table 4.4).

The average prices for the raw banana per bunch was KES 250 and only 73.44% of the farmers practiced banana value addition. Majority 53.19% of the respondents practiced ripening as a form of banana value addition, 10.64% made banana flour, 28.37% of the respondents practiced both banana flour making and ripening while 7.8% made banana crisps. In terms of the prices, the average price of a ripened banana per bunch was KES 600. In addition, the average price of banana flour per kilogram was KES 80 and the average price of banana crisps per 500g packet was KES 40 (Table 4.4).

Table 4.4: Descriptive statistics for adopted banana technologies

Variable Description	Variable	Frequency	Percentages
Adoption of tissue culture bananas	Yes	75	19.53
	No	309	80.47
Why prefer tissue culture banana variety	Highly profitable	50	66.67
	Diseases resistance	25	33.33
Why not prefer TC banana	Not Available	200	53.76
	Expensive	172	46.24
Sources of banana plantlets	Private nurseries	280	72.92
	Government agencies	60	15.63
	NGOs	44	11.45
Types of fertilisers applied	TSP	30	69.77
	DAP	13	30.23
Type of manure used	Cattle manure	190	49.48
	Poultry manure	80	20.83
	Goat manure	60	15.63
	Composite	54	14.06
Pest and disease control	Yes	120	31.25
	No	264	68.75
Pest and disease management practices	Spraying	15	12.50
	Fumigation	10	8.33
	Bagging	30	25
	others	65	54.17
Average prices of raw banana per bunch (Kes)	100-200	80	20.83
	200-300	200	52.08
	>300	104	28.08
Practicing banana value addition	Yes	282	73.44
	No	102	26.56
Banana value addition practices	Ripening	150	53.19
	Banana flour	30	10.64
	Flour and ripening	80	28.37
	Banana Crisps	22	7.8
Average price of ripened banana per bunch (Kes)	500-700	100	66.67
	>700	50	33.33
Average price of banana flour per kg (Kes)	50-100	25	83.33
	>100	5	16.37
Average price of banana crisps per 500g (Kes)	50-100	18	81.82
	>100	4	17.18

In this study an adopter was defined as a farmer who was found to be practicing any of the 12 selected recommended banana production technologies. The farmers' opinion on the extent to which he or she has adopted each of the recommended technologies was assessed by using three-point Likert rating scale. The scale was as follows: High = 3, Medium = 2 and Low = 1. In order to estimate the extent of adoption, the farmers' adoption of the recommended technologies were classified into three categories.

Farmers who had adopted zero to four of the recommended banana technologies were classified as the low adopters. Those who had adopted between 5 - 8 of the recommended banana technologies were considered as medium adopters while those who had adopted 9 to 12 of the recommended banana technologies were categorized as the high adopters. Majority (63%) of farmers sampled were found to be low adopters while 25% were found to be medium adopters. Only 12% of the sampled farmers were high adopters (Table 4.5). These findings implied that the extent of adoption of recommended technologies along the banana value chain in the study area was still low.

Table 4.5: Adoption levels of recommended banana production technologies

Adopted Technologies	Adoption level	Frequency	%
0 - 4	Low	243	63
5 - 8	Medium	97	25
10 -12	High	44	12

The rate of adoption for each recommended technology was determined using Spearman rank correlation. Table 4.6 shows the recommended banana technologies adopted by the farmers, the mean threshold of adoption, the standard deviation and the level of adoption of the recommended technology. Deleafing was the most adopted (95.3%) technology followed by debudding (94.6%), desuckering (91%), manure application (89.8%), banana ripening (53.19%), mattacking (22.2%), tissue culture (19.5%), irrigation (18.5%), fertilizer application (11.2%), banana flour (10.64%), pest and disease management (9.08%) and banana crisp (7.8%).

Table 4.6: Spearman rank correlation results

Variable of adoption	Mean threshold	Standard Deviation	Rate of adoption (%)
Deleafing	2.91	1.50	95.3
Debudding	2.51	0.54	94.6
Desuckering	2.45	0.65	91.0
Manure application	1.98	0.52	89.8
Mattacking	1.71	0.93	22.2
Tissue culture	1.45	1.08	19.5
Irrigation	1.30	1.01	18.5
Pest and disease management	2.51	0.86	9.08
Fertilizer application	0.86	0.67	11.2
Banana ripening	1.91	1.11	53.19
Banana flour	1.72	1.23	10.64
Banana crisps	1.67	1.81	7.8

4.4 Effects of Adoption of Recommended Technologies on Banana Productivity

4.4.1 Descriptive Analysis of Banana Production

The results in table 4.7 shows the descriptive statistics of banana production and inputs used in production among smallholder farmers in Embu-West Sub-County. The results showed that the mean size of land allocated to banana production (farm size) was 2 acres. The small farm sizes were attributed to land fragmentation resulting from the ever swelling population growth in the study area (Murimi *et al*., 2019). The results further showed that majority of the respondents engaged about 80 man-days per year in banana production. The respondents apportioned a range of KES 15,000 to 80,000 of credit per year in banana production which averaged KES 30,000 per year. The yields per acre per year ranged from 2500 – 10,000 Kg which averaged 6,500 Kg. The income per acre ranged from KES 25,000 to 180,000 which averaged KES 80,000. The income was low compared to the yield and the plausible explanation of this is that some bananas were consumed at the household level while some went to waste along the value chain before they reached the end consumer. The farmers maintained an average of 4 suckers per stool with a minimum of 3 and a maximum of 7 suckers per banana stool.

Table 4. 1: Descriptive analysis of banana production

Variable	Minimum	Maximum	Mean	σ
Farm size (acres)	0.5	3	2	1.265
Labour (Man-days /year)	30	120	80	26
Credit (KES/ year)	15000	80000	30000	3500
Yield/acre (Kg)	2500	10000	6500	1250
Income/Acre (KES)	25000	180000	80000	4036
Suckers per stool	3	7	4	2.76

σ = Standard Deviation

4.4.2 The effects of inputs used on banana productivity

In order to assess the effects of adoption of selected recommended banana production technologies on productivity along the value chain among small-scale farmers in Embu West Sub-County, it was necessary to conduct an input-output analysis. In economics, given available inputs at a constant level of technology, some producers achieve higher yields while others produce less due to differences in their levels of efficiency. Estimation of the stochastic frontier requires that a particular form of production function be executed.

The commonly used production function is log linearized Cobb-Douglas production function. This production function was preferred as it is generally considered higher on theoretical and econometric grounds for determining the effects of inputs on the expected output (Ndirangu *et al*., 2018). Effects of different inputs, namely, labour (man-days), farm size (acres), amount of credit accessed (KES) and cost of the various banana varieties (KES) were analyzed using Cobb-Douglas Production function. The estimated coefficients and related statistics of the Cobb-Douglas production function are presented in Table 4.8.

From the results given in Table 4.8, the coefficient of multiple determination was 0.826 denoting that approximately 83% of the variation in banana output was explained by the independent variables included in the model. Besides, the remaining 17% was accounted for by the error term and variables not considered in the model. The F-value was 90.34 which was positive and significant at 1% level. The rule of thumb states that F-statistics greater than 10 signifies that all variables in the model explain the variation of banana productivity (Woodridge, 2010). Therefore, the study revealed that the small-scale banana farmers during survey had not optimally utilized their inputs and were at the initial stage of the production function i.e. increasing returns to scale. The return to scale of 1.062 shows that there exist some potential to increase gross income by increasing input use.

In regards to the amount of credit obtained by farmers for banana farming activities, the coefficient was positive and significant at 5% level. The results indicate that an increase in the amount of credit by one shilling increases banana productivity by 0.37%. Furthermore, the cost of banana plantlets had a negative coefficient that was significant at 1% level. The results show that an increase in the cost of banana varieties by one shilling would reduce the amount of banana output by 0.35%. Fertilizer application had a positive and significant effect on banana productivity. The results indicated that an increase in fertilizer application by one kilogram increased banana output by 0.34%. In addition, manure application had a positive and significant influence on banana productivity. An increase in manure application by one debe (20 kg) would increase the banana output by 0.65%

Table 4.8: The effects of input use on banana productivity

Variable	Parameter	Coefficient	Std.error	z	P>/z/
Constant	β_0	6.3244	0.5023	10.56	0.000**
Labour (Man-day)	β_2	0.5623	0.1318	0.52	0.479
Farm size (acres)	β_3	0.8104	0.0501	1.62	0.126
Amount of credit	β_4	0.3764	0.1463	2.57	0.010*
Cost of plantlets	β_5	-0.3578	0.0890	-3.78	0.000**
Fertilizer (Kg)	β_6	0.3467	0.7650	1.43	0.036*
Manure (Debe)	β_7	0.6534	0.4573	2.67	0.000**
R^2		0.826			
Return to scale		1.062			
F-value		90.34**			

**significance at 1%, *significance at 5%

4.4.3 Effect of Recommended Production Technologies on Banana Productivity

Banana productivity is not only affected by the inputs used in the process but is also affected by various recommended banana production technologies adopted by the farmers. The selected recommended banana production technologies were included in the Cobb Douglas production function and the model analyzed in a single step other than a two-step procedure. This is because the single step generates estimates which are not biased compared to the two-step method. Results of the analysis of selected recommended banana production technologies affecting banana productivity are presented in Table 4.9.

The Variance Inflation Factor (VIF) was used to test the presence of Multicollinearity between the independent variables. Multicollinearity exists when the VIF of an independent variable exceeds 10 or less than 1. In this case, none of the independent variables had a VIF value less than 1 or greater than 10, implying that there was no Multicollinearity problem. From the results, banana tissue culture adoption had a positive coefficient and was significant at 1% level. The results indicate that an increase in the adoption of tissue culture bananas would increase productivity by 56.94%. The positive coefficient of adoption of irrigation was 0.1120 indicating that an increase in adoption of irrigation as a recommended banana production technology increase the level of output by 11.2%.

The regression coefficient of adoption of deleafing was 0.2919 indicating that 1% increase in deleafing as a recommended banana production technology led to an increase in banana productivity by 29.19%. Adoption of debudding had a positive and significant influence on banana productivity. The results show that an increase in farmers' adoption of debudding as a recommended technology increase the level of output by 21.43%. Adoption of desuckering had a positive and significant influence on banana productivity at 5% level of significance. Therefore, increased adoption of desuckering as a recommended technology increases banana productivity by 20.5%. Adoption of various banana value addition practices was found to influence the level of banana output at 5% level of significance. The results were that an increase in the adoption of banana value addition as a recommended technology increased banana productivity by 9.44%.

Table 4.9: Effects of recommended technologies on banana productivity

Variables	Coef.	Std. Error	t-value	P-value	VIF
Tissue culture	0.5694	0.1362	2.715	0.007**	1.546
Deleafing	0.2919	0.1121	2.604	0.003**	1.667
Mattacking	0.0391	0.0949	0.413	0.680	1.036
Irrigation	0.1120	0.0098	1.223	0.046*	1.092
Debudding	0.2143	0.0022	6.757	0.000**	1.153
Desuckering	0.2050	0.0065	1.443	0.035*	1.062
Mulching	0.0686	0.0365	1.4154	0.178	1.084
Pest and disease management	-0.1741	0.1974	-0.882	0.378	2.689
Banana value addition	0.0944	0.0504	1.874	0.024*	2.702

(**, * shows 1% and 5% significance levels respectively)

4.5 Factors Affecting Adoption of Recommended Banana Production Technologies

Multinomial Logit model was used to determine the factors affecting the adoption of the selected recommended banana production technologies among small-scale banana farmers in Embu West Sub-County. The categories of adoption described in section 4.3 were used as dependent variables in the Multinomial Logit regression. The categories were low, medium and high adopters. High adopter's category which was the preferred category of adoption was used as a reference in the analysis. The results of the Multinomial regression analysis are given in Table 4.10.

Table 4.10: Factors affecting adoption of recommended production technologies

Variable	Low adopter (0-4)			Medium adopter (5-9)		
	Marginal effects	Std Error	P-Values	Marginal effects	Std Error	P-Values
Age	0.1034	0.0708	0.0000**	0.1398	0.0765	0.1245
Gender	1.1345	1.532	0.434	0.7829	-1.3650	0.1236
Farming experience	-0.7865	0.2564	0.0435*	0.2347	0.0067	0.0645
Farm size	1.2376	0.0654	1.3567	3.7865	0.6754	0.7856
Labour	0.6789	0.1267	0.2354	-0.0672	0.4634	0.0325*
Household income	-0.3467	0.0012	0.3367	-0.0657	-0.0574	0.0876
Off-farm income	2.6756	1.8965	0.3452	1.7865	0.2453	0.1254
Extension contact	-0.0564	0.5437	0.0154*	-0.0167	0.0654	0.0454*
Access to credit	-3.4567	0.4532	1.438	-0.0674	0.2360	0.0000**
Market access	2.5674	0.4567	1.6754	3.9876	0.0654	1.6754
Farmers groups	-0.0654	0.0542	0.0143*	4.5460	0.2365	1.2456

Asterisks ** and * indicate significance at 1% and 5% level respectively. LR chi^2 =541.72, Prob > chi^2 = 0.0000, (χ^2) =370.47, Pseudo R^2 =0.6252.

From the results in Table 4.10, the likelihood ratio (χ^2) value was 370.47 and significant at 1% level. The likelihood ratio test confirms that all the variable coefficients are significantly different from zero (Ojo *et al.*, 2013). The pseudo R^2 was 0.6252 indicating that the factors significantly explained approximately 62% of the observed variations in the adoption of the selected recommended banana production technologies. The coefficients from multinomial logit can be difficult to interpret because they are interpreted relative to the base outcome. To better evaluate the effect of a unit, change in covariates on the dependent variable, the marginal effects are examined (Greene, 2003).

The age of then household head had a negative and significant effect on adoption of recommended banana production technologies at 1% level of significance. The results indicate that an increase in the age of household head by one year increases the likelihood of the farmer being in low adoption level of recommended banana production technologies by 10.34% in favor of the preferred category. The results further indicate that an increase in farming experience by one year decreases the likelihood of a farmer being in low adoption level of recommended banana production technology by 78.65% in favor of the preferred category (high adoption level). In addition, an increase in labour availability by one man-day decreases the likelihood of a banana farmer being in medium level of adoption of recommended technologies by 6.72% in favor of the preferred category. In addition, an increase in the household income by one unit was found to decrease the probability of the sampled banana farmers being in the low level of adoption of recommended technologies by 34.67% in favor of the preferred category.

The results further indicate that an increase in the extension contact between the farmers and extension officers had positive effect on the adoption of recommended banana production technologies at 1% and 5% for low and medium adopter respectively. The results indicate that an increase in extension contact by one visit decreases the likelihood of a farmer being in low level of adoption by 5.64% and medium level of adoption by 1.67% in favor of the preferred category. An increase in farmers' access to credit by one unit decreases the probability of farmer being in medium level of adoption of recommended banana production technologies by 6.74% in favor of the preferred category. Farmer's membership to a group had a positive and significant effect on adoption of the selected recommended banana production technologies. The results indicate that been a member of farmers group decreased the likelihood of a farmer being in the low level of adoption of the recommended banana production technologies by 6.54% in favor of the preferred category.

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter gives discussion of the results of the current study and explores the findings of the previous studies compared with those of the current study. Conclusions have been made based on the findings of this study. Recommendations to the policy makers and the farmers have also been highlighted in this chapter.

5.1 Extent of Adoption of Recommended Banana Production Technologies

Smallholder farmers in Kenya have been cultivating bananas among other crops such as coffee since the pre-colonial times (Indimuli, 2013). Bananas were grown to provide rural households with food. Unlike in other countries where banana is considered a typical export crop, in Kenya banana is grown by peasant farmers for home consumption and for the domestic market. The Kenya Agricultural Research Institute (KALRO) launched a tissue culture project in but some farmers have pegged the decision of discontinuance on technical factors including pests, crop diseases, costs of plantlets and labor requirements; the second reason for discontinuance is the socio-economic factors including things like inaccessibility to credit and information, poor infrastructure and access to markets. The study recommended that farmers be educated to understand and appreciate the benefits of tissue culture technology as a tool for crop propagation.

The spearman rank correlation results on the adoption of the recommended banana production technologies indicated that majority (95.3%) of the small-scale banana farmers had adopted deleafing. The reason behind this is because farmers in the study area were using the deleafed leaves as a source of animal feeds. In addition, deleafing as a recommended banana production technology is used as a management practice towards black sigatoka disease. These results are in line with Nfor *et al*. (2011) and Muthee *et al*. (2019) who also reported that deleafing is an important practice in banana farming as it acts as a preventive measure of various diseases.

The results indicated that 94.6% of the farmers had adopted debudding as a recommended banana production technology. Debudding involves the removal of the male bud by twisting with a forked stick as soon as the last cluster is formed (Nakakawa *et al*., 2017). This method prevents contact between the tool and the potentially infected tissues. Debudding is a practice that act as a preventive measure towards banana infection by the bacterial diseases. This is done three weeks after flowering to prevent insect vector from transmitting the disease. Debudding was found to be one of the recommended banana production technologies that was used by the farmers to prevent their bananas from Xanthomonas wilt disease (Kwach, 2014).

The results further indicated that 91% of the farmers had adopted desuckering as a recommended technology in banana farming. Desuckering involves the removal of suckers from the banana stool. Suckers are removed from the mother either by cutting the suckers at the ground level or by destroying the heart of the suckers without detaching the suckers from the plant (Kamuyaka et al., 2019) Two bearing plants and two suckers per clump are considered as the optimum and the rest are desuckered. Majority of the farmers in the study area indicated that desuckering was a good management practice as it leads to increased banana output though some farmers reported lack of adequate work force to carry out this activity. Muthee *et al*. (2019) found that desuckering as a recommended banana production technology increased yield among small-scale farmers in Embu County.

Manure application as a recommended banana production technology was practiced by 89.8% of the small-scale farmers in the study area. Majority of farmers in the study used farm yard manure which is majorly prepared using cow dug and urine, waste straw and other dairy wastes. A large portion of nitrogen is made available as and when the farm yard manure decomposes hence balanced nutrition is made available to the plant. Availability of phosphorous and potassium from farm yard manure is similar to that in inorganic sources (Tadesse et al., 2013). Information obtained from small-scale banana farmers in the study area is that manure increases soil fertility and conserves soil moisture which in turn reflects to high yield and output of high quality. This report concur with Meya *et al*. (2020) who reported that manure and fertilizer application were the most preferred soil management strategies by the small-scale banana farmers.

The study also revealed that 73.44% of the small-scale farmers in the study area practiced banana value addition. Value adding is the process of changing or transforming a product from its original state to a more valuable state (Boland, 2009). Value addition can therefore be said is a process of enhancing a product to gain more from it. In agriculture the role of value addition is to maximize production and economic value of a produce. There are several products that can be made from bananas, such include wine, flour, yoghurt and crisp which are by-products once the bananas have been processed. In this case, then it can be noted that agriculture can be profitable and alleviate poverty in rural areas through value addition of the farm produce (Kumar *et al*, 2006). The banana value addition practices by the small-scale farmers in the study include ripening, banana flour and banana crisps. The information obtained from the respondents was that banana value addition improves their income and thus enables them to access the basic necessities. The respondents also pointed out that the additional income obtained through banana value addition enabled the farmers to increase their assets as well as improve the household welfare. These results are in agreement with Obaga and Mwaura (2018) that farmers' participation in banana value addition increases the farmers' income. Kirimi et al., (2021) found that banana value addition had a positive and significant effect on farmers' income among smallholder famers in Meru and Tharaka Nithi Counties respectively. In addition, the results revealed that factors such as extension services, cropping system and gender of the farmer influence farmers to add value to their produced banana. These farmers added value to their banana to produce the following products; banana local brews such as *tonto, waragi, Crisps, banana flour, yellows and roasted gonja*. The main challenge was the lack of capital and limited extension work that affected the level of adoption in banana value addition. Providing extension services about banana value addition to farmers would improve its shelf life and ensure banana product quality which fetches better prices in the market that leads to better farmers' livelihood

The results further indicated that 22.2% of the small-scale banana farmers in the study area had adopted mattacking as one of the recommended banana production technologies. This reflects low adoption of this technology among the small-scale farmers due to lack of knowhow as there was inadequate extension services and training on how mattacking should be practiced. Mattacking is recommended to be practiced after harvesting and involves cutting the pseudostem leaving a stump of about 0.6 m in height. The food material stored in the left out stump continues to nourish the daughter suckers until the stump withers and dries up (Nyandika, 2016). Although the majority of the respondents in this study attributed low adoption of mattacking as a banana recommended technology, this was as a result of inadequate access to extension services, some famers reported that they were aware of these practices but they lacked manpower to implement them. Wachira et al. (2013) reported that some banana farmers demonstrated adequate awareness of the banana recommended technologies but were reluctant to adopt them, due to high cost implication and lack of technical know-how.

Adoption of tissue culture bananas as a recommended technology was found to be low among the sampled small-scale farmers in the study area. Majority of farmers in the study area were yet to adopt tissue culture bananas and they reported the high cost of tissue culture plantlets as the major hindrance. Some farmers also argued that tissue culture bananas were more prone to pests and diseases. However, this study observed that there was an extension gap and most farmers did not know the importance of tissue culture bananas as compared to the conventional ones. Similarly, Thuo (2018) assessed the adoption of tissue culture bananas in the semi-arid areas of lower Eastern region of Kenya and found that there was low adoption of this technology due to low level of extension services.

The rate of adoption of irrigation among the sampled banana farmers was also found to be low as only 18.5% of the sampled farmers had adopted the technology. The farmers reported that water stress was becoming a major production constraint and needed to be addressed. This was due to increasing rainfall variability and competition for the available water from the available water sources. Water stress induce yield losses due to loss in bunch weight even in moderate to low rainfall areas (Raderschall *et al*., 2021). Furthermore, Panigrahi *et al*. (2020) found that practicing irrigation in banana production is one of the easiest ways of improving the management of water stress. In addition, Salazar, & Rand, (2016) found that more educated farmers, and with credit access and receiving extension services are likely to adopt the use of modern irrigation techniques. Moreover, production risk is often associated with adoption of traditional irrigation, and this risk undermines a shift to more modern irrigation systems. Controlling for pre-conditions that determines irrigation choices clearly improves understanding for small-scale farmers' irrigation adoption decisions

The results further indicated that 9.08% of the respondents had adopted various pest and disease management practices as one of the recommended banana production technologies. The information obtained from the small-scale banana farmers in the study area indicated that spraying, fumigation and bagging helped to control pest and diseases that might cause a huge damage to the banana fruit as well as decreasing the yield. This observation concurred with Wachira *et al*. (2013) who reported that nematodes, banana weevil and thrips are among the major pests limiting banana production in many growing regions in Kenya. Nematodes, particularly R. similis, damages the feeder roots of secondary and tertiary banana roots thus reducing the yields by more than 50% and significantly reducing the productive life of banana fields (Isaac *et al*., 2012). Heavy nematode infestation may also cause severe necrosis and toppling of banana plants. The banana weevil is an important pest of bananas in all production regions in the Kenya with associated yield losses ranging from 40% to 100% (Wachira *et al*., 2013). This study further established that only 20% of farmers had adopted chemical pest control with majority of them applying traditional methods like application of ash to control nematodes.

5.2 Effect of Selected Recommended Technologies on Banana Productivity

In terms of inputs used in banana productivity, an increase in the amount of credit accessed for banana farming was found to positively and significantly influence banana productivity. Regarding the amount of credit accessed, large number of respondents agreed that it was one of the main factors that influenced credit accessibility for them and hence the performance of the banana farms. A plausible explanation for this is that access to credit is critical in the financing of inputs such as manure, fertilizers, pesticides, and herbicides thus increasing the chances of high productivity. Similarly, access to farm credits was among the essential factors needed for agricultural production, and with it, farmers were able to secure farm inputs such as farm equipment, fertilizer, and hired labour thus increasing the level of agricultural output per acre among small-scale farmers (Mohammed *et al*., 2016; Udoka *et al*., 2016).

As expected the cost of banana plantlets had a negative influence on banana productivity. An increase in the cost of banana plantlets by one unit reduced the amount of banana output per acre by 0.36 units. The study found that the cost of banana plantlets was higher than what farmers can afford to buy and this deprived farmers willigness to adopt high yielding varieties leading to reduced levels of production. Similar observation was made by Tumuhimbise & Talengera, (2018) who concluded that the high cost of tissue culture banana plantlets deprived farmers the capacity to adopt improved banana varieties thus contributing to reduced yields.

Fertilizer and manure applied had a positive and significant influence on banana productivity. Banana farmers in the study area apply fertilizer and manure to improve soil fertility, which in turn leads to improved quality and production. According to Gichimu et al. (2020), banana production has a high requirement of macro and micro nutrients especially nitrogen, phosphorous, potassium, calcium, magnesium and Sulphur. Fertility enhancement through addition of organic and inorganic fertilizers is necessary because banana crops extract large quantities of nutrients from the soil. This study agrees with the findings by Ntakayo *et al.* (2013) and Hussen and Yimer (2013) that the amount of organic fertilizer (manure) influences apple and mango production among small-scale farmers respectively.

Use of Irrigation on banana production had a positive and significant influence on the yields. Water is very crucial in banana farming as it facilitates the growth as well as the ripening of banana fruits thus increasing the yield and farmers' income. According to Panigrahi et al. (2021) practicing irrigation in banana production is one of the easiest ways of managing the water stress thus improving production during dry periods.

The results indicate that adoption of banana tissue culture improved productivity by 56.94%. Only 19.53% of the sampled farmers embraced the use of tissue culture (TC) planting materials. This is a very low adoption rate, considering the benefits associated with TC technology which includes the production of pest and disease-free planting materials, and increased productivity (Wasala, 2014). Tissue culture plantlets are also more vigorous, are able to multiply faster and also lead to faster maturition. Low adoption of TC technology was also reported Indimuli (2013) and Wasala (2014). Wasala (2014) recommended the provision of affordable TC plantlets to smallholder farmers, to reduce their reliance on the use of conventional suckers which are more prone to pest and disease attacks, and hence contribute to the decline in banana production. According to Muyanga (Indimuli, 2013), adoption of TC technology increases farmer income, due to a reduction in the cost of controlling pests and diseases. The information obtained from the small-scale banana farmers who had already adopted the technology in the study area was that tissue culture banana plantlets were disease free and had high yield hence this increased the productivity level. 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 (Nguluu and Kisangau, 2017). This results are in line with Wanyana *et al*. (2019) that the adoption of banana tissue culture technology increased banana productivity among the small-scale farmers.

Deleafing had a positive and significant effect on banana productivity among small-scale farmers in the study area. Deleafing involves the removal of excess leaves from banana stools and this reduces the chances of pest infestation, disease infection and competition for the food resources thus increasing the yields. Wanda (2009) reported that promotion of deleafing as a recommended technology in banana farming would enable farmers to achieve stable yield levels. Practicing debudding also had a positive and significant effect on banana productivity. These results are in line with Jogo *et al*. (2013) that debudding was one of the recommended banana technologies among small-scale farmers as it helped in controlling pest and disease infection hence this lead to increased level of output.

Desuckering had a positive and significant effect on banana productivity among small-scale farmers. Desuckering involves the removal of excess suckers from the banana stool. Majority of the farmers in the study area indicated that desuckering was a good management practice as it leads to increased banana output. Muthee *et al*. (2019) also found that desuckering as a recommended banana production technology increased yield among small-scale farmers in Embu County. Deleafing is the hygienic removal of banana leaves that are infected with the black-leaf-streak disease (black sigatoka) (Chillet *et al*., 2013). However, even a few farmers who were reported of practicing deleafing, did not associate the practice with the management of this disease. This is an extensive gap that needs to be addressed. Deleafing does not only contribute to the management of black sigatoka disease, but also the cutting of leaves helps in moisture conservation

At postharvest level, adoption of various banana value addition practices was found to have a significant ($p \leq 0.05$) influence on banana productivity. Value addition is the process of converting a product from its original form to a more valuable form that is convenient to the user or consumer (Musyoka, Isaboke, & Ndirangu, 2020). The results indicated that adoption of banana value addition increased banana productivity by 9.44%. These results were in agreement with Obaga and Mwaura (2018) that adoption of banana value addition helps in boosting the farmers' income. The small-scale farmers in the study area were found to have embraced various value addition practices including banana ripening, making banana flour and crisps, hence increasing their farming income. From the results obtained the average prices for the raw banana per bunch was KES 250 compared average price of KES 600 per ripened bunch which was the most commonly practiced banana value addition technology in the area. The information obtained from the farmers as to why they largely practiced banana value addition is because of the higher income they obtained from the practice with the lowest cost incurred for the process.

5.3 Factors Affecting Adoption of Recommended Banana Production Technologies

The age of the household head had a negative and significant effect on adoption of recommended banana production technologies at 1% level of significance. The results indicate that an increase in the age of household head by one year increases the likelihood of the farmer being in low adoption level of recommended banana production technologies by 10.34% in favor of the preferred category. The plausible explanation to this is that older people are conservative and resistant to change. A study by Kinyagi (2014) found that age had a negative and significant effect on the adoption of recommended agricultural technologies among small-scale farmers. Furthermore, a study by Chuchird *et al*. (2017) to determine the factors affecting adopting of agricultural technologies found that age had a negative effect on the adoption of various technologies such as use of irrigation in farming. The reason behind this was that older farmers were receptive to agricultural technologies due to its ease of use while the younger counterparts preferred the agricultural technologies probably due to their familiarity.

The results further indicate that an increase in farming experience by one year decreased the likelihood of a farmer being in low adoption level of recommended banana production technologies by 78.65% in favor of the preferred category (high adoption level). This show that farmers who had engaged in banana farming for a longer period had higher adoption of the recommended technologies in banana farming. Shaw (2017) found that farming experience had a positive and significant effect on the adoption of various recommended agricultural technologies among smallholder farmers.

The results further indicate that an increase in the extension contact between the farmers and extension officers increased the probability of farmers being in low and medium level of adoption of recommended banana production technologies by 5.64% and 1.67% in favor of the preferred category. The positive impact signifies that effective and efficient extension contact between farmers and extension officers is very crucial in the adoption of recommeded agricultural technologies as it determines how efficient these technologies will be delivered to the farmers within their location and how these practices shall be adopted by the targeted farmers. This results are line with the findings of Kanyamuka (2017) that extension contact had a positive significant effect on adoption of the recommended agricultural technologies by smallholder farmers. Farmers' contact with extension agents is expected to have a positive effect on adoption based on innovation-diffusion theory (Sani et al., 2014). Therefore, such contacts expose farmers to availability of information that is expected to stimulate adoption; and a positive relationship is hypothesized between extension visits and the probability of adoption of a new technology. Contact with government extension agents enhanced adoption of banana recommended technologies. This is true given that government extension agents are represented up to sub-location level. They also play a lead role in promoting banana recommended technologies in partnership with other agents along the banana value chain. Similar results of the positive impact of extension contact with farmers growing cowpea varieties have been reported by Adesina *et al*. (2019). However, it is recognized that despite the mobile phone not being significant as an extension source of information, it has been shown that perceived ease of its use, usefulness, relative advantage, compatibility and attitude, were found to be direct predictors of agricultural technology adoption behavior

Access to the agricultural extension and advisory services plays an important role in enhancing the adoption of agricultural innovations and techniques critical to agricultural production (Chowdhury *et al*., 2014). Onyeneke *et al.* (2018) opined that extension services are essential sources of information for adoption of agricultural recommended technologies. Contact with agricultural extension workers is anticipated to positively correlate with the level of adoption of the recommended agricultural technologies. The adoption is influenced by the access to the information (Kassem *et al*.,2019). Sapkota *et al*. (2018) noted that farmers with better exposure to farm-related information have better deposition to the adoption of innovations or practices. Although farmers could obtain information from different sources, they typically make use of farm related information which could be of benefit to their production. Exposure to media was also predetermined to drive adoption of recommended banana production technologies in this study.

An increase in the household income by one unit was found to decrease the probability of farmers being at low level of adoption of the recommended banana technologies by 34.67% in favor of the preferred category. The income from the farming activities tend to increase the level of adoption of the recommended banana technologies by the small-scale farmers. This finding could be because farmers with higher household income are less risk averse and have better exposure to information regarding adoption of the recommended agricultural technologies (Onyeneke *et al*., 2018). This result is in line with the conclusion of Onyeneke *et al*. (2018) who established that there is an increased likelihood for the adjustment of the agricultural production systems with an increase in farm income. Vera *et al*. (2017) and Katengeza *et al*. (2012) also confirmed a statistically significant positive influence of farm income on the intensity of adoption of agricultural technologies. With an increase in income from farming activities, farmers would be able to acquire resources needed for the adoption of recommended practices or newly obtained information either from extension services, colleagues, social platforms or the media. Farmers need to be financially capable to adopt some agricultural practices or innovations successfully. Hence, financial empowerment is crucial to mainstream adoption of agricultural technologies.

Farmers' membership to group had a positive and significant effect on adoption of the recommended banana production technologies. The results indicate that group membership decreased the likelihood of a farmer being at low level of adoption of the recommended banana production technologies by 6.54% in favor of the preferred category. A plausible explanation for this is that membership in groups, help farmers obtain information and understand more on the need of adopting the recommended banana production technologies. In addition, farmers in groups can easily receive training on recommended banana production technologies. These findings agree with those of Donker *et al*. (2018) and Nadhika *et al*. (2018) that group membership has a positive influence on farmers' adoption of agricultural recommended technologies among the small-scale farmers. Membership to a group is part of the build-up of the social capital of farmers, since it influences access to public spheres, particularly in rural areas (Aryal *et al*., 2013). Membership of agricultural groups plays crucial roles in the enlightenment of their members (Ojoko *et al*., 2017). Agricultural associations or groups present a platform for farmers to discuss their challenges with their colleagues, thereby benefitting from counsel on how to cope with problems. Farmers with membership to an agricultural-related groups could enjoy better access to information and resources (Ojoko *et al*., 2017). A strong social network among farmers could also enhance adoption of recommended banana production technologies.

An increase in labour availability by one man-day decreases the likelihood of a banana farmer's being in medium level of adoption of recommended banana production technologies by 6.72% in favor of the preferred category. This can be explained by the fact that banana farming activity is labor-intensive and requires intensive management which requires available labour. These findings are consistent with Dessale (2018) that availability of labour significantly influences adoption of agricultural recommended technologies among the small-scale farmers. Narayana (2016); Kamau *et al.* (2016) and Beck et al. (2016) also found labour to have the greatest and significant impact on yields. Labour availability facilitates farm operations such as weeding, fertilizer application, disease control and harvesting. Increase in labour supply accompanied by static labour demand, would decrease wage rate and subsequently increase agricultural production per unit area of land given the scale of production. Labour availability would be key in banana production given the intensity of farm operations. Mburu *et al*., (2014) found negative coefficient for family labour and wheat productivity.

An increase in farmers' access to credit by one shilling decreased the probability of farmer being in medium level of adoption of recommended banana production technologies by 6.74% in favor of the preferred category. A reasonable explanation for this is that access to credit is critical in financing investments as well as acquiring inputs such as manure and fertilizers. Likewise, an increase in the amount of credit accessed positively increased the probability of farmers' adoption of mango recommended technologies among small-scale farmers (Sarma *et al*., 2016). Access to credit had a positive and significant elasticity in explaining variations in coffee yield. Studies by Akudugu *et al*. (2012); Musaba & Bwacha, (2014) reported similar findings on the effect of credit on farm productivity. Credit would enable banana farmers to purchase key farm inputs for increased productivity and also cushion them against random shocks and market failures. Access to credit would also finance investment in capital intensive technologies for increased production efficiency and productivity per unit area to avoid diseconomies of scale.

5.4 Conclusions

This study purposed to determine the selected factors affecting adoption of recommended banana production technologies, the extent of adoption of recommended banana production technologies and the effects of recommended banana production technologies on productivity among small-scale farmers in Embu West Sub-County. The study found that there is low adoption of recommended production technologies among the banana farmers in Embu County. The study established that some important production technologies were very poorly adopted by farmers in the County which include mattacking, the use of tissue culture planting materials, use of irrigation, fertilizer application, banana value addition and use of recommended pest and disease management practices. The Low adoption of technologies was associated with lack of technical know-how among farmers due to lack of adequate modern extension services. However, some farmers were well aware of these practices, but they lacked the ability to implement them due to the high cost implications. On the other hand, adoption of the recommended banana production technologies was found to have positive effects on banana productivity. Therefore, high adoption of the recommended technologies would play a big role in improving food security and livelihoods among banana farming communities.

The amount of credit, fertilizers and manure were the inputs that had a positive significant effect on banana productivity while, cost of banana varieties precipitated a negative effect on banana productivity. Tissue culture had a positive and significant influence on banana productivity. Tissue culture is a major scientific milestone widely accepted as a means of increasing productivity at household level, with surpluses reaching the market to generate the much needed income by small-scale farmers. Deleafing and debudding had a positive and significant effect on banana productivity. Deleafing and debudding reduces the chances pest and disease as well as increasing the yield. Water is very crucial in banana farming as it facilitates the growth as well as the ripening of banana fruits thus increasing the yield and farmers' income thus had positive and significant influence on banana productivity. The value addition practices embraced by the farmers in the study area include banana ripening, making banana flour and crisps and had a positive and significant effect on banana productivity.

Adoption of the selected recommended banana production technologies among small-scale farmers is influenced by many factors. These factors differ with different farmers living in different geographical environment and different social-cultural point of view and in different economic environment with different farming investment capital. This study established that farming experience, access to extension, farmers' membership to groups, availability of labour and access to credit decreases have positive effects on adoption of recommended banana production technologies. On the other hand, the advanced age of the farmer has a negative effect on adoption of recommended banana production technologies.

5.5 Recommendations

Based on the findings from this study several recommendations were drawn and proposed to various stakeholders as summarized in the following sections.

5.5.1 The Extent of Adoption of Recommended banana production Technologies

The study established that the extent of adoption of recommended technologies along the banana value chain in the study area was low. The study therefore recommends as follows:

- There is need to enhance extension services to promote various recommended technologies among the small-scale banana farmers to enable them make informed decisions. This would boost the level of adoption of the recommended banana technologies among the small-scale farmers.
- The National and County governments in Kenya should generally motivate farmers to embrace recommended banana production technologies by providing an enabling environment including subsidizing of farming inputs and provision of farming resources such as water for irrigation and access to credit.
- The National and County governments in Kenya should support farmers to adopt banana value addition through provision of capital to set up processing factories for production of value added products such as flour and crisps.

5.5.2 Effect of Selected Recommended Technologies on Banana Productivity

This study established that adoption of recommended crop husbandry practices including soil fertility management techniques, pests and disease management, adequate water utilization and the use of clean planting materials will effectively improve the yields of bananas. Therefore, this study makes the following recommendations:

- There should be enhanced sensitization of small-scale banana farmers on the importance of adopting the recommended banana technologies for improved banana yields per unit area.
- The County and National Government should support farmers with subsidized farm inputs, including easy and affordable access of tissue culture bananas and availability of farming resources such as water. This would result into increased banana output per unit area and subsequently increased farm income.
- Banana farmers need to be equipped with skills on the proper management of soil fertility, proper and timely identification of pests and diseases. National and County Governments should therefore, ensure adequate extension services are made available to the farmers. This can be easily achieved if farmers are organized into groups.

5.5.3 Factors Affecting Adoption Recommended Banana Production Technologies

The study found that the age of the farmer had a negative effect on adoption of recommended banana production technologies while the farming experience, labour availability, extension contact, access to credit and membership to farmers' groups had positive effects. Therefore, this study makes the following recommendations:

- The government together with other stakeholders should create an enabling environment for banana farming to be more attractive and lucrative. This would encourage more youths to venture into banana farming thus increasing adoption of recommended technologies since the youths are more responsive than the aged.
- Banana farmers should be supported with the necessary resources to enable them remain in the farming business for a longer time thus building their farming experience which would in turn increase their rate of adoption of recommended technologies.
- Extension services should be enhanced to boost the farmers' understanding and technical knowhow for adoption of recommended banana production technologies.
- The national and county governments should promote formation of farmers' groups and associations and encourage the farmers to join these groups.
- Access to farm credit should be improved by strengthening financing institutions that

offer cheaper loans like the Agricultural Finance Corporation (AFC).

5.6 Areas for Further Research

This study examined the extent of adoption of recommended banana production technologies, the effect of recommended banana production technologies on productivity and the factors affecting adoption of recommended banana production technologies among small-scale farmers in Embu West Sub-County. However, there is an urgent need to assess the influence of the County Government on adoption of the recommended banana production technologies, the factors affecting the intensity of adoption of recommended banana production technologies and the effect of adoption of recommended banana production technologies on farmers’ income.

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Appendix 1: Study Questionnaire

Introduction

This interview schedule aims to collect data on technology adoption along banana value chain and its effects on productivity among small-scale farmers in Embu west sub-county. The information provided herein was treated with the utmost confidentiality.

Questionnaire No:

General Information

Enumerator:	Sub-County:
Date:	Ward:

A: Socio-Economic Information

This section will record information on socio-demographic information of small-scale banana farmers.

A1 Household head gender	1=male 2=female
A2 Marital status of the household head	1= married 2=window 3=single 4 widower
A3 Household head age in years	
A4 Education level of the household head	1= primary 2=secondary 3=college 4= university
A5 Household head occupation	1= farming 2= business 3= employment
A6. Household income per year in KES	
A7 Off-farm income per year in KES	
A8 Sources of off-farm income	1= self-employment 2= salaried jobs 3= pension 4=wages 5= others (specify)……………………
A9 No. of years spent in banana farming	
A10 Total Farming Land (Acres)	
A11 Type of land ownership	1 = Owned with title 2 = Owned without title 3 = Lease

12) Do you grow banana in your farm? (1= Yes 2= NO)

13) If Yes, what is the total farm size under banana production (Acres)

14) What is the amount of output per acre during harvesting?..............

15) What is the source of labour for your farm? (1 = Family labour 2 = Hired labour 3 = Both family and hired labour)

16) The number of Mandays involved in banana farming practices...........................

B) Adoption of recommended technologies along banana value chain

1) Which Banana variety do you grow in your farm? ....

2) Why do you prefer that variety over others? ………………………………………

3) Which type of banana plant do you grow in your farm (1= tissue culture 2= conventional)

   If tissue culture, what made you prefer tissue culture? (1= Highly profitable 2= Disease resistant 3=reliable income 4=others (specify)……………………………

   If conventional, why do you prefer them………………………………………

4) What is your source of tissue culture plantlets? (1=Buying from pre-hardened nursery 2=From Government Agencies 3= From NGOs 4= Other (specify)……………………

5) Do you practice deleafing to your banana plants? (1= Yes, 0=No)

   If no, why?..

6) Do you practice mattacking to your banana plants? (1= Yes, 0=No)

   If no, why……………………………………………………………

7) Do you practice irrigation to your banana plants? (1= Yes, 0=No)

   If no, why?..

   If yes what type of irrigation do you practice 1=sprinkler irrigation, 2= drip irrigation 3= open land irrigation 4= others specify…………………

   How many times do you irrigate your bananas in a day? 1= Once, 2= Twice 3=Thrice)

8) Do you apply fertilizer in your banana plants? (1= Yes, 0=No)

   If no, why? …………………………………………………..

   If yes, which type of fertilizer do you apply to your banana plants ……

   At what rate do you apply fertilizer to your banana plants……………….

9) Do you apply manure to your banana plants? 1= Yes, 0=No)

   If no, why………………………………………………………………

   If yes, what amount of manure do you apply per year? (1= half debe per stool 2= one debe per stool 3= two debes per stool 4= None)

10) Are there any other soil fertility management measures that you practice in your banana farm? 1= Yes, 0=No)

11) Do you practice debudding (denaveling) to your banana plants? (1=Yes, 0=No) If no, why?..

12) Do you practice desuckering to your banana stools? (1=Yes, 0=No)

If yes, how many suckers do you allow per stool? ……………………..

13) Which strategies do you use to manage pests and diseases to your banana?

14) Do you practice value addition on your banana fruits? 1= Yes, 0=No)

If yes, what type of value addition? (1= ripening, 2 = banana crisps, 3= banana juices, 4= banana flour 5= making wine, 6 = others (specify)…………

What is the average price for the value added products?

Type of banana value addition	**Average prices for unit products**
Ripened	
Crisps	
Juices	
Wine	
Flour	
Others specify	

C) Institutional Factors affecting adoption of recommended banana production technologies

1) Do you receive agricultural extension service or information? (1= YES 0 = NO)

If YES, from where do you get the extension information? (1 = County extension officer 2 = Farmer Groups 3 = Non-Governmental Organization 4 = Television 5 = Radio 6 = Newspapers/ magazine 7 = Others (specify)…………………

How often do you receive extension support? (1 = once a year; 2 = Twice a year; 3 = Thrice a year; 4 = Others (specify)……………

2) What is your main market for your bananas?..............................

3) Which is your main source of marketing information? (1 = Radio 2= Neighbors 3 = Extension officer 4= Others (specify)……………………

4) Distance to the nearest market…………...

5) Time taken to the nearest market…………

6) Do you or any member of your household belong to any social or community Organization /Association (1=YES, 2=NO)

If Yes, which social group do you belong to? (1 = Co-operative society 2 = Microfinance 3 = Women Group 4 = Producer Group 5 = Farmers Association 6 = Community/Village Group 7= Community Marketing Group 8= Others (specify)……………

What services do you get from the organization/association? (1= Credit only 2 = Training/ Information sharing 3 = Savings and Credit 4 = Others)

7) Do you have access to any credit? (1= Yes 2= NO)

If YES, provide the information required in the table below;

i) Sources of credit	1=Banks 2= SACCO 3= Government 4= Merry go round 5=Others specify…………………..
ii) Amount of credit borrowed	KES………………………
iii) Purpose of credit	1= banana farming 2=school fees 3= medical 4=others (specify)…………..
iv) Activities carried out	1= banana farming 2= school fees 3= medical 4= others specify……….
v) Constraints in obtaining credit	1= fear of risk 2= high-interest rate 3=lack of collateral 4= others (specify)…………

Thank you