INFLUENCE OF PLANT HEALTH CLINIC SERVICES ON POTATO (SOLANUM TUBEROSUM) PRODUCTION AMONG SMALLHOLDER FARMERS IN MOLO SUB-COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted wholly or in part for conferment of any degree in this or any other institution.

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DEDICATION

This thesis is dedicated to the Almighty God for the gift of life, strength, and guidance during my studies. I also dedicate this work to the memory of my beloved late dad Wilson Chebango, to my beloved mother Elizabeth Kosgei, to my brothers Charles and Richard, my sisters Josephine, Selina, Lucy, Nancy, Sharon, and Mercy for their support and prayers.

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ABSTRACT

Potato is one of the most important valued food and cash crop in Kenya. However, health issues which includes plant disease, pests, weed, and soil health continue to pose a major threat to potato production resulting in low yields and returns among farmers particularly the smallholder in Molo Sub-County. Plant health Clinics use innovative approach like human clinic to offer significant services to farmers in terms of crop protection advice, training, and diagnosis in the country, but research pertaining to the influence of these services on potato production in Molo Sub-County had not been studied. The purpose of this study was therefore to determine the influence of plant health clinic services on potato production among smallholder farmers in Molo Sub-County, Kenya. The study used cross-sectional survey design. The accessible population consisted of 6,000 smallholder potato farmers, and a total sample of 152 respondents were selected using proportionate and simple random sampling approach. Key informants were selected purposively via a process of theoretical sampling. Data was collected using a questionnaire and an interview guide. The questionnaire was administered to smallholder potato farmers and ten respondents for key informant interviews. A pilot study was carried out using 30 farmers in Nessuit ward of Njoro Sub-County. The reliability of the questionnaire was determined using Cronbach's alpha coefficient and it yielded a coefficient 0.726α, which was accepted. Data analysis was done using SPSS version 22 to run descriptive and inferential statistics. Multiple regression analysis was used to establish the influence of plant health clinic services on potato production among smallholder farmers in Molo Sub-County at a significance level of 0.05. It was found that plant health clinic advisory services, training services and diagnostic services had a statistically significant influence on potato production. The results showed that 61.8% ($R^2 = 0.618$), 78.1% ($R^2 = 0.781$) and 59% ($R^2 = 0.590$) of variation in the potato production were explained by advisory services, training services and diagnostic services respectively. The study concluded that plant health clinic advisory services, training services and diagnostic services have an influence on potato production among smallholder potato farmers in Molo Sub-County, Kenya. The study recommends that the County and National government enhance and strengthen the provision of plant health clinic services to potato farmers in the area. The smallholder potato farmers also need empowerment in terms of general education, capacity building and sensitization on use of plant health clinic services to improve potato production.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AAK	Agrochemicals Association of Kenya
AIR	American Institutes for Research
AKAP	Awareness-Knowledge–Adoption-Productivity
CABI	Centre for Agriculture and Bioscience International
CBOs	Community Based Organizations
CIP	International Potato Center
FAO	Food and Agricultural Organization
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
KALRO	Kenya Agricultural and Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Services
KIA	Kenya Investment Authority
KNBS	Kenya National Bureau of Statistics
MoALF	Ministry of Agriculture Livestock and Fisheries
NACOSTI	National Council of Science, Technology, and Innovation
NCIDP	Nakuru County Integrated Development Plan
NCPDP	Nakuru County Potato Development Plan
NGOs	Non-Governmental Organizations
NPCK	National Potato Council of Kenya
PCPB	Pest Control Products Board
PHS	National Plant Health system
PHCS	Plant Health Clinic Services
POMS	Plant-Wise Online Management System
PMCRP	Private Markets for Climate Resilience Project
SPSS	Statistical Package for Social Science
USAID	United States Agency for International Development
USD	United States Dollar
VIP	Vlaams Instituut Voor Biotechnologies

CHAPTER ONE

INTRODUCTION

1.1 Background Study

The potato (*Solanum tuberosum L*) is a starchy tuberous crop that develops underground (Beals, 2019). Tracing its origin in Southern Peru, South America potato domestication started about a millennium ago (Singh *et al*., 2020). Since then, the crop has been distributed widely with its production in more than 158 countries in temperate, subtropical, and tropical agro-ecology (Momčilović, 2019). This successful production in various regions demonstrates the flexibility and adaptability of this crop to a wide range of environmental conditions. Potato demand is also rising at a greater rate than any other food crop because of its high-industrial as well as nutritional value (Food and Agriculture Organization [FAO], 2019). It is a crop of major economic significance worldwide ranked fourth globally after maize, rice, wheat, and first among the non-cereal crops in terms of production and human consumption respectively (Farooq *et al*., 2020). The crop is critical in providing employment to an estimated 800 million people and food to more than 1.3 billion people globally (International Potato Center [CIP], 2020). Global output of potato is about 388 million metric tons on about 20 million hectares of land annually (Food and Agriculture Organization Corporate Statistical Database [FAOSTAT], 2020).

In Africa, potato production estimates are about 25 million metric tons per year, which accounts for 7 % of global output (Obi-Egbedi & Gulak, 2020). This is way below the increasing demand as a reliable source of income, employment, and food for many populations in the region. As a result, a bid to address sustainability on potato adequacy in the region is important especially among smallholder farmers who are predominant in the potato sector (Wasilewska-Nascimento *et al*., 2020). Smallholder farmers in Africa can be categorize depending on; the agro-ecological zones they operate in; their socio-economic status in terms of capital invested and size of land owned; or annual revenue generated from farming activities (Ochola, 2017). The potato sector can help improve the incomes of smallholder farmers who largely depend on it for their livelihoods (Mengui & Lee, 2019). Furthermore, potato sector may subsequently curb poverty by providing quick income partly because potatoes mature within short period (mostly less than 4 months) compared to major cereal crops (Tadesse *et al*., 2019).

Potato in Kenya is ranked second most important food crop after maize and a major staple food among potato growing communities (Kimathi *et al*., 2021). An estimated 800,000 farmers grow potatoes out of which 500,000 are smallholder (International Potato Center [CIP], 2019). It is mainly grown in the high-altitude areas where maize does not thrive well on about 212, 976 hectares with an average production of 2 to 3 million metric tonnes per year (Mbego, 2019). This accounts for 23.5 % of the country's economy through income generation of almost USD 500 million annually (Kenya Investment Authority [KIA], 2020). The sector also employs about 3.3 million people along the potato value chain (Bolt *et al*., 2019). Potato equally provides significant income opportunities as well as food for smallholder farmers in the country (Mburu *et al*., 2020). In addition, potato contributes to poverty alleviation through income generation in both urban and rural households (Otieno, 2019).

There are thirteen major counties in Kenya producing potato that include Bomet, Homa Bay, Bungoma, Elgeyo Marakwet, Kiambu, Meru, Nakuru, Narok, Nyandarua, Nyeri, Trans Nzoia, Uasin Gishu and West Pokot, where it acts as source of food, employment as well as cash income (Ministry of Agriculture, Livestock, and Fisheries [MoALF], 2018). Nyandarua County is the leading potato producer at 29.8 % in the country (Ruto, 2018). Nakuru County is the second largest producer with Molo Sub-County being one of the main potato's growing Sub-County in the County as well as in Kenya hence it was chosen for this study based on magnitude of potato production (Maingi *et al*., 2020). The potato industry in Nakuru has the high potential of addressing unemployment as well as food security (Mutinda, 2020). Potato production similarly is a valuable enterprise for smallholder farmers in Molo Sub County who grow various potato varieties, hence contributing positively towards their food and income levels (Kamau *et al*., 2020a).

There are more than fifty improved and local potato varieties grown in Kenya however the major varieties widely grown in the country include Kenya mpya, Asante Destiny, Asante, Dutch Robijn, Kenya Baraka, Shangi, Desiree and Tigoni (NPCK, 2021). Shangi is the most cultivated potato variety in Kenya with an estimated area under cultivation of more than 80% (NPCK, 2019). This can be attributed to the fact that shangi variety has market availability, multipurpose use as it is mainly used in; chipping, table usage, mashing, making crisps, or potato flakes (FAO, 2021). Further, Shangi mature early (≤ 3months) and has high production.

Despite the potato increasing importance in terms of consumption and income, potato production in the country have declined way below the potential as illustrated in Table 1 (FAOSTAT, 2020). The production in the country stands at average yields of between 7–10 tons/ha, much below the potential yield of 20-30 tons per hectare (Vlaams Instituut Voor Biotechnologie [VIB], 2019). This is also below that of the Tanzanian counterpart whose yields stands at 20 tons per hectare (Koome & Wanjugu, 2020a). In Nakuru county, potato average yields in the County are low at about 5.2 tons per hectare (Nakuru County Potato Development Plan [NCPDP], 2021). In the areas which are leading-producing Sub-County such as Molo production are still low with yields as low as less than 5 tons/hectare which is far below the potential yields of 20-30 tons/ha realize in many other countries (Maingi & Mbuvi, 2020).

As depicted in Table 1, potato average yields in Kenya are fluctuating downwards and from the years 2011-2019, the average yields are declining.

Table 1

Potato Yields in Kenya between 2011-2020 Tons per ha.

Year	**Production in tons/ha**
2011	19.2
2012	20.3
2013	14.4
2014	14.1
2015	14.7
2016	9.2
2017	7.9
2018	8.6
2019	9.3
2020	7.4

Source: FAOSTAT (2021)

According to Ebrahim *et al*. (2018) number of problems continue to threaten potato production leading to low yields. Among the factors attributed to low production are traditional production systems, shortage of quality seeds, decline soil fertility, poor agronomic practices, a disorganized marketing system, high incidence of pests and diseases, lack of clear policies on packaging, poor technology transfer and low use of quality inputs (Gebru *et al.,* 2017). The most contributing factors that have been cited is high incidence of pests and diseases which results in estimated 80% reduction in production therefore threatening overall yields (Centre for Agriculture and Bioscience International [CABI], 2020). The concerned stakeholders in potato sector have geared themselves towards solving most of these challenges; however, pests and diseases are still portraying worrying trend, limiting the potential yields to be realized in potato production (Komen *et al*., 2017).

Many diseases such as bacterial wilt, late blight, leaf roll virus, as well as pests such as aphids, cutworms, nematodes, and trips attack potato causing significant losses to producers and therefore restricting the potential of achieving the optimum yields (Majeed & Muhammad, 2018). According to Van der Waals and Krüger (2020), diseases especially bacterial wilt, early and late blight affect potato production negatively leading to unsustainably low yields, spread rapidly through use of farmer saved seed potato and inadequate rotation. This problem can be solved through training and advising farmers to use clean potato seed through extension services (Agutaa, 2015). In Molo Sub-County pests such as aphids, cutworms, nematodes, trips, potato tuber moth and diseases that include early blight, late blight, bacterial wilt, and leaf roll virus cause devastating destruction on potato crop (Chamedjeu, 2018; Iraboneye *et al*., 2021). According to Kamau (2019) potato farmers in Molo Sub-County encounter losses of more than 75 % due to pests and diseases.

The low yields because of losses due to pests and diseases lead to low incomes for farmers and reduce access to food and hence food insecurity (Devaux *et al*., 2020). To increase income and improve food security of potato farmers, there is a need to improve production through minimizing loses due to pests and diseases (Rana & Jhilta, 2021). As Savary *et al*. (2019) points out losses due to pests and diseases can be substantial and may be prevented or reduced, by crop protection measures. It is, therefore, important to provide farmers with options that are context-specific to their agricultural conditions and socioeconomic circumstances to address pests as well as diseases outbreaks (Heeb *et al*., 2019). This is required particularly among smallholder farmers who lack access to timely advice, diagnosis, training, and information on how to deal with crop health problems (Alwang *et al*., 2019). According to Mburu *et al*. (2018) use of effective, reliable, and practical extension services on a regular basis, more so those that enable smallholder farmers address the threats of pests and diseases is important in crop production.

Extension services act as fundamental in supporting farmers to deal with existing and new challenges in agricultural production besides enhancing information exchange, knowledge, skills among farmers as well as stakeholders (Bourne *et al*., 2017). Extension services are also effective in forecasting agricultural problems outbreaks, therefore permitting time for development and application of proper mitigation measures (Coyne *et al*., 2018). Further extension services for example plant health clinic using a demand-driven approach on a similar method to human health clinic to reach farmers are important in offering farmers with skills and knowledge such as seed selection, technologies, marketing, pests and diseases management, soil management among others (Mugambi *et al*., 2016)**.** As argued by Rajkumar and Anabel (2018) PHCS plays a vital role in providing farmers with information on how to handle crop health problems therefore assuring minimization of production losses on crops.

According to Bett (2018), plant health clinic services have been recognized as innovative in aiding farmers to deal with crop health issues by dealing with diseases and pests through responding to individual farmer’s needs. They have the capacity of offering services to farmers, that leverage best, relevant, timely and reliable recommendations on handling crop health problems (Kra *et al*., 2017). This is possible since the plant doctors offering these services are well trained, equipped with various skills and knowledge on solving crop health problems (Danielsen *et al*., 2020). Early results of plant health clinic services implementation showed that they enhanced access to information by farmers and improve pests as well as diseases vigilance by disseminating information on best crop protection (Danielsen *et al*., 2014). In Kenya, plant health clinic plays an important role in reaching out to farmers with services that promote crop health therefore reducing loses due to high incidence of pests and diseases thus translating to improve production (CABI, 2020). Specifically, they enable farmers have access to real-time, reliable, and relevant diagnostic, training and advisory services that promote crop health therefore enhancing crop production (Kansiime *et al*., 2020).

As reported in Plant-Wise Kenya final Report of 2018 plant health clinic services have been able to supplement the existing clumsy access to services promoting crop protection. They bring research knowledge through in- person interactions with plant doctors in disseminating important information on crop protection to farmers (Jowi, 2018). In Molo Sub-County, the PHCS disseminate information promoting crop protection therefore supporting farmers in addressing the threats of pests and diseases which has been cited as one of the most bottlenecks in crop production (Nakuru County Government, 2018). Though from the studies the vital roles played by plant health clinic services are highlighted, none of these studies have examined the potential of plant health clinic services in addressing potato production especially among smallholder farmers in Molo Sub-County, Kenya. Therefore, the study sought to determine the influence of PHCS on potato production among smallholder farmers in Molo Sub-County, Kenya.

1.2 Statement of the Problem

Potato is ranked second most important food crop after maize in Kenya. The crop is critical in achieving food security, employment creation, income generation, poverty reduction and economic development in the country as well as in Molo Sub County. Despite the importance, potato production has been threatened by health issues including pests and diseases resulting in low yields and returns among the smallholder farmers particularly those in Molo Sub-County. This has kept potato production in Molo Sub-County below the optimum leading to food insecurity and low incomes to farmers. To prevent these challenges, plant health clinic services have been put in place to equip farmers with knowledge and skills on crop protection consequently improving production due to reduce crop pests and diseases incidence. However, their influence on potato production in the study area have not been clarified. Past studies in the area looked at factors influencing potato production but focused on technical efficiency, farm inputs and fertilizer respectively but did not consider plant health clinic services influencing potato production. This study, thus, sought to determine the influence of plant health clinic services on potato production among smallholder potato farmers in Molo Sub County.

1.3 Purpose of the Study

The purpose of this study was to determine the influence of plant health clinic services on potato production among smallholder farmers in Molo Sub-County, Kenya.

1.4 Objectives of the Study

The following were the objectives of the study:

i. To determine the influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya.
ii. To determine the influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya.
iii. To determine the influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya.

1.5 Hypotheses of the Study

The hypotheses of the study tested were:

$H0_1$: There is no statistically significant influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya.

$H0_2$: There is no statistically significant influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya.

$H0_3$: There is no statistically significant influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya.

1.6 Significance of the Study

The findings of this study provide information to the donors, Kenyan government institutions, non-government organizations (NGOs), and other organizations for a well understanding of the influence of plant health clinic services on potato production that will guide them in making appropriate decisions, policies, interventions, and strategies aimed at increasing potato protection services for improvement in production and therefore food security. The documentation of the influence of plant health clinic services on potato production among smallholder farmers is very informative in increasing potato production. This can be achieved through extension workers applying the information, formulate extension approaches which would likely advocate for the increased utilization of crop protection information frequently during production by smallholder potato farmers and the consequent reduction of potato pests and diseases incidences therefore improve production which in the long run is likely to increased income therefore improve the livelihoods of the farmers.

1.7 Scope of the Study

The study focused on smallholder potato farmers in Molo Sub-County, Kenya. The study was restricted to analysis and documentation of the influence of plant health clinic services on potato production among smallholder potato farmers in Molo Sub County. The study centered on advisory services, training services, diagnostic services, and their influence on potato production. The selected parameters of advisory services were frequency of contact with advisor, type of advisory information access, use of advisory services and usefulness of advisory services. For the training services selected parameters were frequency of receiving training, type of training access, use of training services, relevance of training services and modes of training. While for diagnostic services include perceptions of the role of diagnostic services, frequency of receiving diagnosis and use of diagnostic services.

1.8 Assumptions of the Study

The study was guided by the following assumptions:

i. Plant health clinic services are delivered evenly across the Sub-County by extension service providers.

ii. The respondents would attend the clinics and apply the knowledge and skills received from the clinics.

iii. Extension information disseminated by plant health clinics providers in Molo Sub County contains information about potato production.

1.9 Limitations of the Study

The study was limited by the following:

i. Adverse weather conditions and other commitments of the target respondents affected their availability for data collection. To overcome this, the researcher allocated adequate time for the exercise.

ii. There was a challenge of respondents not keeping the covid-19 rules and regulations some were not wearing facemask, keeping distances, this was overcome through issuing facemasks, educating, and constantly reminding them the importance of keeping the covid-19 rules and regulations as stipulated by the ministry of health Kenya.

1.10 Definition of Terms

Advisory Services: Refer to the entire set of services that support and facilitate people engaged in agricultural production to solve problems and to obtain information, skills and technologies to improve their livelihoods (Anderson, 2008). For this study, referred to plant health clinic services assessed through frequency of contact with advisor, type of advisory information access, use of advisory services and the usefulness of the advice.

Crop Protection: Is the science and practice of managing plant diseases, pests, weeds, soil health and other pests (both vertebrate and invertebrate) that damage agricultural crops and forestry (Nishimoto, 2019). In the context of this study, crop protection meant practice of managing, controlling, and preventing pests and diseases, soil health and giving recommendations on control measures to smallholder potato farmers through plant health clinic services such as advisory, training and diagnostic.

Diagnostic Services: is defined as "the art or act of identifying a disease or a pest from its signs and symptoms and the investigation or analysis of the cause or nature of a condition, situation, or problem (Harmon, 2013). In this study referred to plant health clinic services assessed on the aspects of perceptions of diagnostic services, frequency of receiving diagnosis and use of diagnostic services.

Influence: Is to influence a particular situation and the way it develops (Oxford Advanced Learner's Dictionary 7th edition). In this study, influence meant the effect of plant health clinic services on potato production among smallholder farmers.

Key informants: These refers to those whose social positions in a research setting give them specialist knowledge about other people, processes or happenings that is more extensive, detailed or privileged than ordinary people, and who are therefore particularly valuable sources of information to a researcher (Payne & Payne, 2004). For this study, key informants meant staffs that comprised of Sub-County agricultural officers, Ward Crop development officers, and plant doctors who offer services to smallholder potato farmers directly or indirectly which helps them on potato production.

Knowledge: Facts or ideas acquired by study, investigation, observation, or experience (Oxford Advanced Learner's Dictionary 7th edition). In this study knowledge referred to the respondents 'capability to acquire information about farming practices on potato production from plant health clinic services.

Plant doctor: Staff who undergoes a standardized training program, provided with identification tools as well as reference materials that help them in making accurate diagnoses and giving effective recommendations to the farmers (Danielsen *et al.,* 2020). In this study, it referred to an extension officer who with standardized skills have been trained to provide diagnostic, advisory and training services to farmers through plant health clinic sessions.

Plant health clinic: This refers to the facility where farmers take samples of their affected plants, for problems identification and management recommendations (Koigi, 2013). For this study, plant health clinic meant the facilities and venues where potato farmers seek crop protection related services from for problems identification, advisory, diagnosis and management recommendations, and trainings on control and management recommendations.

Plant health clinic services: Are extension services provided to farmers by plant health clinic to help them manage and control pests as well as diseases (Rajkumar & Anabel, 2018). In this study, they meant extension services provided by plant health clinic that included diagnostic, training, and advisory possibly having influence on potato production among smallholder farmers in the study area.

Potato production: Refers to the quantity of potato produced in terms of yields per unit area (ha) in tons by smallholder farmers in the study area.

Skills: These are the expertise or talent needed to do a job or task (Pierce *et al*., 2017). In this study, skills meant the ability of smallholder potato farmers to comprehend and practically carry out informed practical potato pests and diseases prevention, control and management and improve production.

Smallholder Farmers: Smallholder farmers are those that cultivate less than 5 hectares of land in high potential areas, and up to 44 hectares or more in sparsely populated areas. They produce crops mainly for family consumption and income (Dixon *et al*., 2003). For this study, referred to those smallholder potato farmers who produce potato on an area of land less than five hectares either owned leased or family land.

Socio-demographic characteristics: According to Mahmudul (2011), this refers to farmer's characteristics such as education, gender, farming experience, and land ownership, access to credit, information, and technology among others. For this study, they included farmer's age, gender, potato farming experience, membership in farmer organization, educational level, and land ownership.

Training Services: Is the process of providing knowledge and skills and bringing about desired changes in attitudes to improve the competence of people being trained (Mengistu, 2009). In this context, training services referred to plant health clinic services measured in terms of frequency of receiving training, type of training, modes of training, relevance of training services and use of training services.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a literature review related to the study. It gives an overview of potato production and its economic importance. The section also discusses the constraints to potato production in Kenya. In addition, the chapter provides information on the plant health clinics concept frameworks and the services. Furthermore, this chapter provides information about influence of plant health clinic services on crop production. The theoretical framework from where the study is grounded and description of a conceptual framework of the study are also presented in this chapter.

2.2 Global Overview of Potato Production and Its Economic Importance

Potato is the world's fourth largest food crop in terms of production after maize, rice, and wheat thus the largest non-cereal food crop cultivated in the world (FAOSTAT, 2019). The crop provides more calories per cultivated area than any other crop and easily substitute's cereals for food consumption with one out of eight people in the world eating it often (Beals, 2019). The potato 's ease of production has made it an important component of agriculture which provides jobs, income, and food to approximately 1.3 billion people globally (CIP, 2020). Potato mature in 3-4 months besides can yield about 50 tons/ha and therefore ideally suited to places where land is limited with abundant labor (Tadesse *et al*., 2019). Global annual output of potato is about 388 million metric tons with yield per hectare of 20,110.8 ton/ha (FAOSTAT, 2020). Equally, in Africa annual potato outputs are about 25 million metric tons with yield of 13,215.4 tons/ha, which is way below the potential and increasing demand in the region (VIB, 2019). Nevertheless, potato production plays an important role in Africa's food security and income (Hussain, 2016).

In Eastern and Central Africa, potato is an important food and cash crop, playing a major role in national food security and nutrition, poverty alleviation, income generation, and provides employment in processing, production, and marketing Sub-Sectors (Merga & Dechassa, 2019). The developing world has witnessed a rapid expansion of potato production due to its ease of cultivation and high nutritive value (Barrett *et al*., 2020). Potatoes are rich in several essential nutrients including carbohydrates, minerals such as potassium, calcium, magnesium and phosphorus, vitamins such as vitamin C, vitamin B6, fiber, and high level of antioxidants that help heart health (Furrer *et al*., 2018). They therefore improve human food and nutrition value (Burgos *et al*., 2020). Contrary, global potato production faces relatively similar challenges like, inadequate quality seed supply, high pest and disease incidences, climatic variations among others, which has led to very low yield, averaging below 6 tons per hectare in many developing countries (Stark *et al*., 2020). However, developed countries are more robust to these shudders and have a comparative advantage in alleviating these challenges compared to the developing countries (Sawicka, 2019). Major challenges of global potato production are high pests and diseases infestation almost in all potato producing countries, Kenya being one of them leading to crop loss which translates to reduce production (CABI, 2020).

2.3 Potato Production and its Importance in Kenya

Kenya is ranked as the sixth largest producer of potato with a production of about 2 to 3 million tons per year after Algeria, Egypt, South Africa, Morocco, and Tanzania (FAOSTAT, 2019). The country enjoys the economic significance of potato crop, which is cultivated for both subsistence and commercial purposes. It is an important staple food crop in the country, with production volumes only second to maize (CIP, 2020). Beyond the farm, the industry employs about 3.3 million people as market agents, transporters, processors, vendors, and exporters (Bolt *et al*., 2019). Potato further has been identified as a significant contributor to the attainment of Sustainable Development Goal 2 on zero hunger (Hirschfeld *et al*., 2016; Kamau *et al*., 2020b). There is also an increasing concern in Kenya that potato production can significantly contribute to realizing the nationwide objectives of vision 2030 by generating employment, enhancing food security, improving nutritional security and raising incomes (Devaux *et al*., 2020).

Vision 2030 is a long-standing national plan that targets at transforming Kenya into middle-income and industrial Country by 2030 (ElMassah & Mohieldin, 2020). For instance, potato contributes to economic development and industrial growth through income of about 50 billion Kenya shillings annually towards the Gross Domestic Product of Kenya, and therefore it is acknowledged as one of the pillars that will significantly contribute to achievement of Kenya vision 2030 because of its substantial contribution to food availability in the country (KIA, 2020). Congruently potato production is important acting as source of food, employment, and cash crop among smallholder farmers in Molo Sub-County (Maingi *et al*., 2020). Despite potato contributions, the production in the country is low with yields per hectare as low as below 5 tones/ha which is far below the potential yields of 20 – 30 tons/ha (Auma & Shimon, 2019). Hence, to maintain the importance of potato and arrest the decline in potato yield in Kenya, there is need to remove the bottlenecks on its production like high incidence of pests and diseases (Sigrid *et al*., 2016).

The low potato production compared to its potentials and importance has therefore attracted the attention of policy makers and researchers to find out and mitigate the causes of this low production (NPCK, 2021). Government and other non-government organizations such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), United States Agency for International Development (USAID), International Potato Council (CIP), and NPCK have focused much of their efforts in developing various potato seeds (NPCK, 2019). These concerned stakeholders have also geared themselves towards potato production technologies focused on developing commercial potato varieties, new clear packing policies, marketing prices, certified seeds, correct seed size and good agricultural practices. Still, unless farmers combine efficient use of the available resources with services minimizing pests and diseases, enhancement in production is not a guarantee (Stark *et al*., 2020). Pests and diseases have been proven to contribute a devastating damage on potato crop by reducing the tuber growth as well as quantity, and therefore the output (AIR, 2018).

A study carried out in Molo Sub-County by Kamau (2019), have shown that pests and diseases are among the main potato constraints to many potato farmers, which cause an estimated 75% reduction in production a situation that hinders potential maximum production therefore threatening overall yields among them. The situation therefore calls for efforts to bridge this gap to address the issue of low potato production and improve production (Momanyi, 2021). Thus, managing pests and diseases threats affecting potato production among smallholder farmers especially in Molo Sub-County whose vulnerability and susceptibility to pests plus diseases have increased is important in approaching and reducing these risks (Kamai, 2021).

2.4 Constraints to Potato Production in Kenya

Despite potato being the second most important crop after maize in Kenya and playing a major role in national food production and security, potato production is constrained by several factors (Gebru *et al*., 2017). These constraining elements include high pests and diseases incidence, unavailability of quality and certified seeds, lack of packaging facilities and poor agronomic practices (Muthoni *et al*., 2017). The other factors are traditional production systems, disorganized marketing system, lack of proper storage, decline soil fertility, lack of clear policies on packaging, poor technology transfer and low use of quality farm inputs (Devaux *et al*., 2020; Mumia *et al*., 2018; Wasilewska-Nascimento *et al*., 2020). These production constrictions have led to reduced potato harvest quantity and quality, which in turn reduce the yields, incomes, and market potential to potato farmers (Okello *et al*., 2017). As identified by Private Markets for Climate Resilience Project [PMCRP] (2020), potato sector in Kenya is faced also by poor market infrastructure, weak research-extension-farmer linkages, disintegration of actors in the value chain and a lack of value-add and new product development.

Furthermore, factors like poor enforcement of produce and products standards, inadequate credit services, lack of cold storage facilities and proper on farm storage facilities at farm level and at the marketing centers, prolonged droughts, and lack of market-oriented production among farmers affect potato production (MoALF, 2019; Mosota, 2018; Musita, *et al*., 2019; PMCRP, 2020). This leads to instability of supply and therefore low prices, which translates to low income, enormous losses therefore reduced produce among potato farmers. The low yields prevent commercialization of potato production and keeps smallholder farmers in subsistence production that primes to slow development of the smallholder potato sector (Devaux *et al*., 2021). Nevertheless, high incidence of pests and diseases are among the major yield-reducing factors in potato production in Kenya (CABI, 2020). Potato is susceptible to numerous pests and diseases reducing its capabilities of providing food and cash crop (Savary *et al*., 2019).

According to Kamau *et al*. (2019) diseases such as those caused by bacteria are a major biotic production constraint on potato production. A study by Mburu *et al*. (2020), found out that emergence of new pests and diseases, such as the recently detected potato cyst nematodes (PCNs), Globodera rostochiensis and G. pallida are globally considered as the most important pests and diseases threatening potato production. This are however, too often overlooked in less developed countries such as Kenya (Niere & Karuri, 2018). Early detection of pests and diseases problems associated with potato production can greatly help in reducing the loss and reaching the targeted yields (Moore *et al*., 2020). Otieno (2019), noted that for farmers to sustainably manage pests and diseases constraints the control must begin right from the initial stage of selection of fields and planting materials- all these must be free of pests and diseases. Maingi and Mbuvi (2020) further suggest that it is important to not only determine the cause but also the corrective measures necessary to unlock the immense potential a region possesses in the production of potato in the quest to attaining food and food security.

Plant health clinic extension services such as advisory, training, and diagnostic services that promote crop protection consequently helping reduce and minimize high pests and diseases incidence, henceforward enhance production, income, and improve the livelihoods of farmers are essential (Rajkumar & Anabel, 2018). Conferring to Murithi *et al*. (2013) advisory, trainings and diagnostic services are important sources of innovations in helping farmers to detect, identify, manage, and control pests and diseases. Furthermore, Otieno *et al*. (2020) found out that diagnostic services like, accurate pests and diseases diagnosis, is a key determinant of the effectiveness of recommendations for managing pests and diseases in any cropping system. As a result, there is a need of this diagnostics services, advisory services, and training services that promote minimization of pests and diseases destruction on crop production such as in potato (Bett *et al*., 2018). Sophie (2018) in her study establishes that by understanding the pests and diseases risks affecting potato production, it leads to better understanding of how to deal with them. In addition, it is vital to comprehend dynamics surrounding the potato production in line with the influence of these services especially among smallholder farmers dominant in potato production to improve diseases and pests' resilience for eventual increase in yields, incomes and improve livelihoods (NPCK, 2019).

2.5 The Plant Health Clinics Concept Frameworks

Plant health clinics concepts evolved as scientists were in the trial of exploring ways of giving support to farmers who were looking for advice on crop health problems (Danielsen *et al*., 2013). Since then, the plant health clinics have extended rapidly to over 34 countries across Asia, America, and Africa (CABI, 2020). They are usually position in public places frequently visited by farmers in movable shelters and indicated through a banner (Danielsen & Matsiko, 2016). In addition, they are set up with a few chairs and tables to ease operation in the clinics and operated by trained extension personnel referred to as plant doctors on specific days for about half a day once every one or two weeks. The particulars of the farmer name, the crop grown, gender, symptoms detected, recommendations given by the plant doctor are recorded and kept (Mugambi *et al*., 2016). These records are important as they play a role of being a source of information about prevalent pests and diseases and how to handle them efficiently. Data recorded by paper are also digitized, cleaned, and uploaded to the Plant-Wise online management system database to be retrieve any time needed (Finegold *et al*., 2014). In addition, farmers can access them online and making phone calls and sending their queries to officers offering them (Chege *et al*., 2020).

In Kenya, plant health clinics began operating in 2010 and since then they have been convened to address challenges within agriculture such as those concerning crop health problems (Sluijs *et al*., 2017). The MoALF through the Extension and Training directorate is leading in running plant health clinics in close partnership with relevant players in the plant health system. Among these players include agencies like (Kenya Plant Health Inspectorate Services (KEPHIS) and Pest Control Products Board (PCPB), agricultural research and learning institutions, (Kenya Agricultural and Livestock Research Organization (KALRO), agro-input providers (Agrochemicals Association of Kenya (AAK), Non-Governmental Organizations (NGOs), Community Based Organizations (CBOs) and Private sectors (MOALF, 2012). There are about 300 plant health clinics distributed across over 23 counties with more than 550 plant doctors trained to operate the clinics in Kenya (Kansiime *et al*., 2020).

The plant health clinics in Nakuru County are over 20 with over 64 plant doctors across the Sub-Counties (NCPDP, 2021). On the other hand, in Molo Sub-County, in each ward there exist more than one plant health clinic offering services to farmers with the clinics operating in open areas such as markets often visited by farmers and the plant doctors reaching out to various farmers by accepting all types of crops across the Sub-County (County Government of Nakuru, 2020). In addition, farmers receive PHCS in farmers' meeting sites such as field days, farmer groups meetings, agricultural exhibitions, field demonstrations, village meetings, and barazas. Further farmers seek for plant health clinic services anytime they need through making a phone call or even sending their queries through WhatsApp or via message to plant doctor. Yet, despite this substantial distribution of the plant health clinics concept framework in the Sub-County there is still limited information existing on concept framework of plant health clinic in potato production among smallholder farmers.

2.6 Plant Health Clinics Services

Plant health clinic services are extension services using demand-driven approach with expectation that the farmers will benefit in terms of obtaining knowledge and skills on handling crop health problems leading to improved production, therefore transforming to livelihoods improvement (Silvestri, 2019). Plant health clinic offer services to farmers on one-on-one guidance in reaction to individual farmers' demands (Danielsen *et al*., 2013). They strengthen the National Plant Health system (PHS) enabling countries to avail the knowledge that will give farmers solutions to the crop health problems they face (Davis *et al*., 2018). They are vital constituent, which targets to reinforce connection between research and extension in delivering services to farmers to deal with issues such as unpredicted emerging pests and diseases (Khaila *et al*., 2015). This enhances institutional linkages and networks by bringing together different service providers with different capabilities, experience and therefore providing quality services to harmonize smarter responses to farmers (Mugambi *et al*., 2016).

Additionally, plant health clinic services play a vital role in assuring crop production and prosperity by providing timely recommendations to farmers for managing pests and diseases problems (Cameron *et al*., 2016). Plant health clinic services also aim at improving people's lives by providing information and applying scientific expertise to solve crop health problems in agriculture consequently improving crop production and well-being of the people (Tambo *et al*., 2021). The activities of PHCS extend beyond with emphasis on extension, working more closely with farmers and organizations involved in promoting production of crops (Danielsen & Matsiko, 2016). Study by Musebe *et al*. (2018) stated that plant health clinics focus primarily on services such as diagnostic, advisory, and training that disseminate information to farmers on crop protection. Farmers receive diagnostic services on identification, examination, and detection of pests along with diseases on the samples of the infected crops (Powell, 2017). The plant doctor offers these services by identifying and examining infested samples of crops along with giving recommendations of control and management to farmers (Danielsen *et al*., 2013).

Furthermore, farmers can send images of diseased or affected crops to plant doctors through online platform where they receive responses on their phones (Ghiasi *et al*., 2017). In the field, plant doctors offer diagnostic services to farmers by carrying out the laboratory tests for diseases and pests' detection afterwards give recommendation feedback to farmers on how to manage and control (Danielsen *et al*., 2013). According to Ghaiwat and Arora (2014), diagnosis of plant disease is very essential at an earlier stage to cure and control them. Early and accurate detection of plant diseases are key factors in crop production and the reduction of both qualitative as well as quantitative losses in crop (Toroitich, 2017). Pests and diseases forecasts through diagnosis play an important role in determining when to use pesticides, how to use it and the amount to use (Abadi, 2018). This saves farmer waste of resources and helps minimize costs alongside protection of environment.

The training services provided by plant health clinics include; plant doctor educating farmers on pests and diseases signs as well as symptoms and selection of quality farm inputs (Vakilian, 2017). This service help them in detecting, identfying any emerging pests and diseases themselves for early control and management. They also educate them on how to monitor pests and diseases outbreak for timely prevention (Rajkumar & Anabel, 2018). They include training on improved quality seed varieties, improved fertilizer, soil health, chemicals use, harvesting and storage techologies all aiming to mitigate pest and disease infestation and subsequently improving production (Silvestri, 2019). It has also been observed that farmers are trained on different types of control and management measures such as chemical, cultural and biological applications methods and how to relate pests and diseases damages (Danielsen & Matsiko, 2016).

Plant health clinics further offer advisory services on best types of measures and practices on handling pests as well as diseases problems (Negussie *et al*., 2018). These measures and practices on advisory services include; rotation of crops, selection of seeds, soil management, soil fertility, intercropping, handling diseased crops, choosing clean seeds, proper fertilizer application, timely planting of crops and intervals of weeding among others (Brubaker *et al*., 2013). According to

Majuga *et al*.(2018), services obtained from plant health clinics aid farmers in decision-making process on crop protection from pests and diseases incidence leading to reduction of loss in crop production consequently increasing yields. Studies in Kenya have shown how the plant doctors through the diagnostic services offer farmers information on symptoms, signs, detection, identification, examination, monitoring of pests and diseases (Jowi, 2018). According to Kansiime *et al*. (2020), plant health clinics train farmers on how to carry out control, management and monitor occurrence of pests and diseases through training packages such as chemicals use, harvesting techologies, improved quality seed varieties and storage techologies.

Jowi (2018) also pointed out that farmers receive training on how to relate pests and diseases damages and crop production technologies. Besides, farmers receive advisory services on new approaches of pests and diseases management as well as control. In Molo Sub-County, the PHCS such as diagnostic, advisory, and training services are providing a platform where farmers and extension agents interact easily with minimal facilitation (Nakuru County Government, 2018). Even though the services have been outline reaching and benefiting farmers in the Sub-County, the information existing on these services and potato production among smallholder farmers is still lacking. Therefore, focused to inaugurate PHCS on potato production among smallholder farmers in Molo Sub-County, Kenya was important.

2.7 Influence of plant Health Clinics Services on Crop Production

Several studies suggest that global food production will need to increase by nearly 50 % by 2050 (FAO, 2020). Meeting these food production requirements will rely in large part on the world's smallholder producers (Bizikova *et al*., 2020). Smallholder farmers manage nearly 500 million farms worldwide and contribute an appreciable share of agricultural production and poverty alleviation in many regions of the world (Giordano *et al.,* 2019). Investments in smallholder productivity, therefore, is the best option to accelerate economic growth, reduce rural poverty, and support global food security needs (Tinta *et al*., 2018). Despite the importance of the agriculture sector to the economy and the contributions of smallholder farmers, limited access to agricultural extension information has resulted in poor decisions on agricultural production and related activities thus, affecting achievement of food security (Kamara *et al*., 2019). Policy interventions associated with agricultural development have lagged compared to other sectors particularly in empowering smallholder farmers through agricultural extension (Kalimba & Culas, 2020).

Smallholder farmers increasingly face barriers that prevent them from producing enough to fully meet market demand or generating enough income to keep their households out of poverty (Alwang *et al*., 2019). The limited accessibility to resources, information, technology, capital, and assets by smallholder farmers continue to restrict them from achieving full potentials in production as much as there are regular government budget allocations for agricultural development (De Janvry & Sadoulet, 2020). An extension system that does not significantly contribute to improving the lives of its target group is inappropriate (Takahashi *et al*., 2020). Thus, agricultural extension has been reformed into a system that is cost effective, responsive to farmers ‘needs, broad-based in-service delivery, participatory, accountable, and sustainable (Cheruiyot, 2020). Smallholder farmers not only require advice to increase farm production, but also advice on how to do it and training on how to implement (Kos & Kloppenburg, 2019).

As indicated by Nelson *et al*. (2019) in their study diverse range of rural development options including improve crop production promotion, value addition, and diversified income opportunities are required among farmers for management of devastating pests and diseases. The vulnerability along with susceptibility to diseases and pests has emerge to constraint crop production among farmers (Savary *et al*., 2019). Yearly, an estimated 40% of crops grown worldwide are lost to pests and diseases causing both direct and indirect losses on crop production leading to mass disruption in food supply and income (Tambo *et al*., 2020). It is, therefore, necessary to reduce crop losses by keeping pests and diseases at bay in the process of crop production. Having plant health clinic services such as diagnostic, training, and advisory in place to provide preventive action from pests and diseases on crop is important (Vennila *et al*., 2016). Managing crop health is key in reducing the effects of pests and diseases in crop production (Otieno, 2019). They reduce the level of loss which is critical in enhancing production thus increasing yields by offering protection against pests and diseases (Nolte *et al*., 2020). Therefore, it is necessary to use these reliable and concrete services that promote crop protection on consistent basis (Coyne *et al*., 2018).

Utilizing of plant health clinic services is important in communicating quality information to farmers to meet their crop protection needs (Jowi, 2018). Various studies carried out in Nepal, Costa Rica, and Malawi revealed that farmers were able to receive the services from plant health clinics and thereafter-applied recommendations given on pests as well as diseases handling, which eventually led to enhancement of crop production consequently increase in yields (Rica, 2018). Each farmer-received message tailored to his or her problem, also obtained a written prescription just for her or him, which help them in dealing with devastating pests and diseases. A study carried out in Malawi on impact of plant health clinics on disease and pest management among tomato farmers highlighted increased in tomato yields among farmers who used plant health clinics services (Bett *et al*., 2018). They found out that plant health clinics services influence crop production by equipping farmers with skills and knowledge on management and control of pests and diseases.

Earlier study by Hussain *et al*. (2016) in Vietnam, Sri Lanka, Malawi and Zambia did show that farmers often use PHCS and were afterwards able to apply recommendations to handle pests and diseases, which led to improvement of production thus increase their yields. Magesa *et al*. (2014) also asserts that contact with advisor, receiving diagnosis and trainings from plant health clinics enable farmers to access guidance and instruction guidance on how to handle developing or prevailing crop health problems which is a requisite in meeting pests and diseases threats. As discovered by a study carried out in Rwanda by Tambo *et al.* (2020) among maize farmers, those who used plant health clinics services had a higher maize yields compared to those who never used after they applied the recommendations given through plant health clinic services. These services significantly increased the use of recommended pests' management practices to control devastating maize pests, such as fall armyworm and maize stalk borer, which eventually reduced losses and hence improve production (Ghiasi *et al*., 2017).

Additionally lessons from the counties of Embu, Kirinyaga, Kiambu, Bungoma and West Pokot households in Kenya, showed a higher chance of increased proper use of pesticides as recommended by plant health clinic services which led to minimization and prevention of pests consequently improve crop production for those farmers who received these services (Musebe *et al*., 2018). Receiving services such as training has also shown to play an important role in educating farmers on signs besides symptoms of pests and diseases thus enable farmers to timely apply correct control and management measures (Danielsen *et al*., 2020). A study by Hussain *et al*. (2016) also found that plant health clinics offered advisory services on pests and diseases management to attendees of plant health clinics in Malawi, Zambia, Sri Lanka, and Vietnam which had a positive influence on the crop production among farmers. In link with this, Hampson *et al*. (2017) discovered that farmers value information disseminated by PHCS on crop protection since they could easily relate to in terms of timely and accurate information. The farmers who had received and contacted PHCS were able to obtain a larger amount of information on pests and diseases from plant health clinics than those who never received nor use these services (Mur & Kleijn, 2017).

In divergence to the negative correlation of receiving PHCS and production, Danielsen and Matsiko (2016) argued that receiving and using plant health clinic services can either, positively or negatively correlate with production depending on the circumstances such as consistency on giving out accurate services. Different studies have also emphasized positive impact of plant health clinics on increased access to quality services and consequently increased on crop yields through improve production (Vakilian, 2017). Some of these studies conducted to establish outcomes for plant health clinic services include plant health clinics in Bolivia, Bangladesh on major crops such as rice, brinjal, mango and coconut (Rajendran & Islam 2017), Uganda on cassava crop (Brubaker *et al*., 2013), and Rwanda on maize (Nsabimana *et al.*, 2015). Most of these studies highlight increased harvest for those who had accessed and utilize plant health clinic services. Yet, in Kenya, limited information is available on the literature on PHCS on crop production especially on potato production which is important in the country (NPCK, 2019).

Potato has been identified as one of the crops playing a major role in food security in Kenya contributing to poverty alleviation through income generation and employment creation (Kimathi *et al*., 2021). Potato production in the country is however characterized by extremely low yields compared to developed countries (Koome & Wanjugu, 2020a). Kenya's potato sector is still underdeveloped and is faced with low production of 7-10 t/ha, against the attainable yield of 20-30 t/ha under normal field conditions (Gitari *et al*., 2018; Muthoni *et al*., 2013). This decline in yield is attributed to high incidences of pests and diseases infestation, unavailability of quality and certified seeds, lack of packaging facilities, poor agronomic practices, traditional production systems, disorganized marketing system, lack of proper storage, decline soil fertility, lack of clear policies on packaging, poor technology transfer and low use of agro-inputs (Devaux *et al.*, 2020; Mumia *et al.*, 2018; Muthoni *et al.*, 2017; Wasilewska-Nascimento *et al.*, 2020). Having potato farmers especially the smallholder who are predominant in potato sector access and utilize services that equip them with corrective measures necessary to unlock the immense potential of potato production has the capacity to improve production and contribute to food security in the country (Maingi & Mbuvi,2020).

Evidence has shown that expansion of smallholder potato farming can lead to a faster poverty alleviation through raising the incomes of smallholder potato farmers and reduction in food expenditure hence leading to a faster rate of poverty reduction (Moore *et al.*, 2020). The potato production of smallholder farmers and its contribution to the economy, food security in addition to poverty reduction depends on a supportive agricultural sector, which include effective extension service (Otieno, (2019). Therefore, is vital to use extension services by farmers such as advisory, training, and diagnostic services that promote crop protection and hence help them reduce and minimize high pests and diseases incidence, hence boost production, income, and improve their livelihoods (Rajkumar & Anabel, 2018). However, with limited allocation of budget to agricultural extension services it has been left to thrive on survival (Toroitich, 2021). This has left many smallholder potato farmers unattended or unexposed to new farming technologies. Moreover, ineffective agricultural extension services have limited access, use, availability, and technology adoption by smallholder potato farmers (Devaux *et al*., 2021).

Potato has a big bearing on extension services that allow technology adoption due to emerging crises such as pests and diseases (Devaux *et al*., 2020). As indicated in CABI surveillance report of 2020 high pests and diseases infestations have been reported to be majorly affecting potato production, hence require demand-driven services by farmers to help them handle on time. Adoption of technologies and better practices being central in extension interventions are valuable for improving production and increasing smallholder potato farmers' incomes (Ogola & Ouko, 2021). It is therefore becoming incumbent to identify, document the contribution of extension services in production that can help smallholder farmers attain the twin goal of improve crop production (De Janvry & Sadoulet, 2020).

While it is clear many studies have shown the positive contributions of plant health clinic services, there are no studies yet showing the link between the plant health clinic extension services and potato production among smallholder farmers in Kenya particularly in Molo Sub County, which is one of the major potato-producing Sub County in Kenya (NPCK, 2019). Therefore, it is not clear whether these extension services are influencing potato production among smallholder farmers, thus the study objectives. In this study, the aim was to determine influence of plant health clinic services on potato production among smallholder farmers in Molo Sub-County.

2.8 Theoretical Framework

This study draws its basis from the Awareness-Knowledge–Adoption-Productivity (AKAP) theory by Swanson, Bentz and Sofranko (1998) and Sustainable Livelihood Approach theory by Ashley and Carney (1999).

The theory of AKAP envisions extension services as accomplishing its ultimate economic impact by providing training services, advisory services, technical services, information or educational to induce the four sequence that include farmer awareness of technology or practices, farmer gain skills and knowledge through testing and demonstrating, farmer adoption of technology or practices and changes in farmer's production (Swanson *et al*., 1998). The theory suggests that changes in farmer behavior will be reflected in quantities of goods produced. These in turn, can be measured as economic impact, which is benefit of goods produced made possible by the extension services activities (Raza *et al*., 2019). Studies of extension impacts have measured farmer awareness and their sources of awareness, knowledge, testing of practices on adoption, and production (Muddassir *et al*., 2019). Studies have shown statistical relationship between the role, capacity, quantity, and type of extension services made available to farmers and increases in awareness, knowledge, adoption, and production (Fisher *et al*., 2018). The theory gives an insight into why farmers engage in extension services. The theory was important in the study as it touched on the areas of how extension services influences crop production.

The AKAP sequence has a natural organization whereby real resources in the form of skills, knowledge, and activities by both extension staff and farmers are required to move along the sequence (Swanson *et al*., 1998). Production depends on not only the adoption of technically efficient practices but also role of the service, capacity of the service, type of the service, frequency of the service, type of information, knowledge, usefulness and relevance of the service, and skills acquired and the available market institutions. Extension services affect each part of the sequence hence complementing the attained skills for their clientele, the farmers (Kassem *et al*., 2019). The knowledge and skills acquisition through extension services is envisaged that the farmers may adopt them, who would in turn put into practice the same at their own farms. Adoption and use of the innovations, recommendation and technologies obtained through the extension services acquired would sharpen the farmers' crop husbandry skills, which would in turn translate to changes in farm production, hence improve household yields, therefore translate to food surplus, income, and finally improve livelihoods.

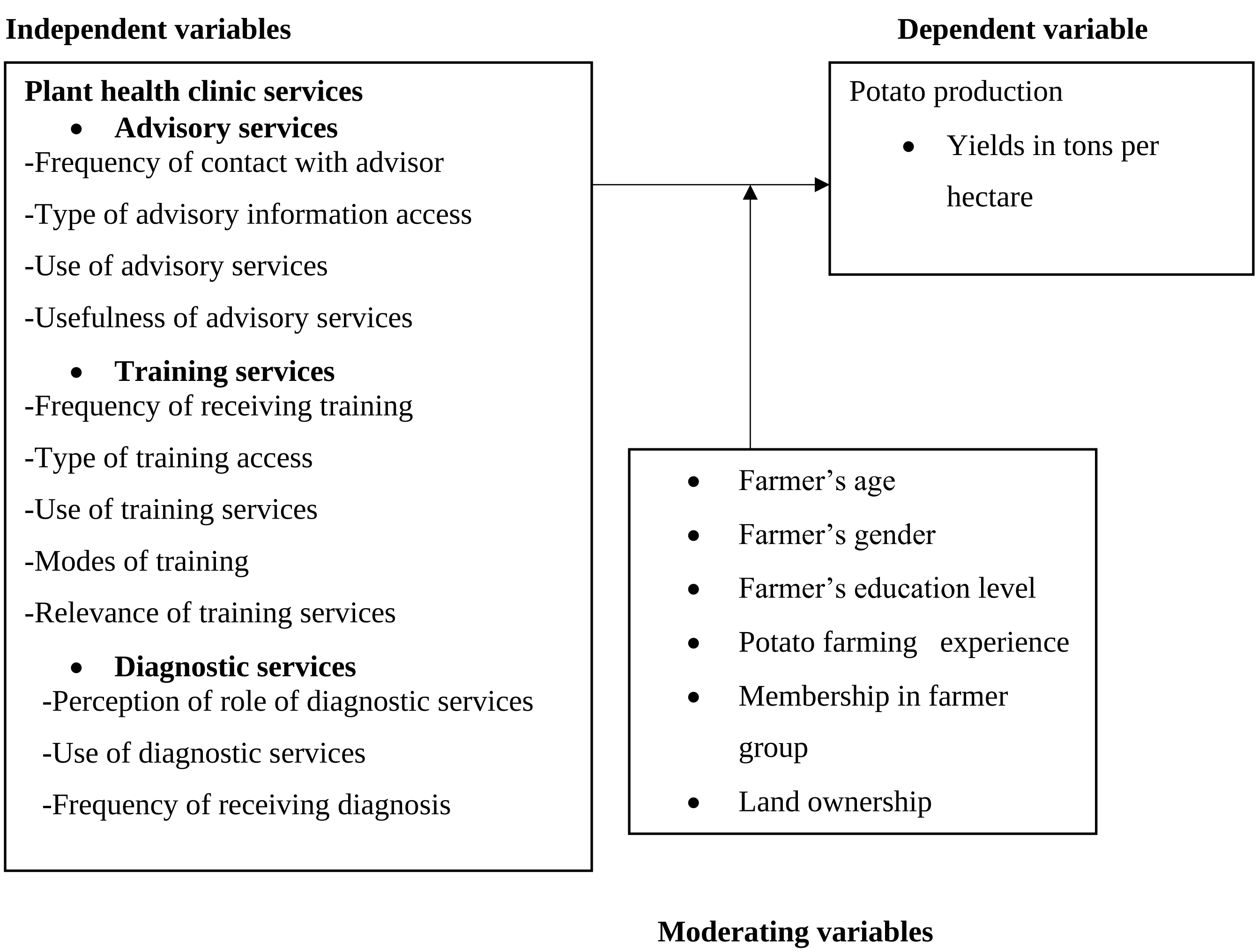
The Sustainable Livelihood Approach theory do focuses on sustainability, productivity, and people's livelihoods, which comprises of people's situation, needs, and interests (Ashley & Carney, 1999). For sustainability to occur there should be an inclusive involvement of all in addressing identified needs (Scoones, 1998). Any external support should be flexible to changes in people's situations. The framework provides an important insight and a strong starting point to understanding the dynamics of Molo Sub-County smallholder potato farmers' livelihoods as it places emphasis on potato production. This theory seeks to analyze potential factors influencing farmers' ability to make decisions to improve their potato production. This analysis framework shows how livelihood resources and services combine to achieve different livelihood strategies such as agricultural production (Morse & McNamara, 2013). The theory shows how services such as extension by farmers influence their farm output in terms of equipping them with skills and knowledge on how to carry out farming activities. The main idea about the analysis of the range of formal and informal organizational and institutional factors that influences sustainable livelihood outcomes. In this study, receiving and using plant health clinic services is link to the smallholder farmers' ability to attain increase potato yields by improving their potato production through receiving, using and perception of services such as diagnostic, training and advisory that help them boost and address potato health problems. The potato production among smallholder farmers was studied with respect to these services.

2.9 Conceptual Framework

The conceptual framework (Figure 1) presents the independent variables of this research, which are the plant health clinic services that predict potato production among smallholder farmers and the moderating variables.

Figure 1

Conceptual Framework of the Study



The independent variables for this study were the diagnostic services, training services, and advisory services. The dependent variable of this study was the potato production. This was measured by looking at the yields in tons per hectare. The moderating variables were farmer's age, education level, land ownership, gender, membership in farmer group, and potato farming experience. These were built into the study and were controlled statistically during data analysis and their potential moderating effect on the relationship between independent and dependent variables recorded and analyzed.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses in detailed the methods that were used in sampling, data collection and analysis. The chapter begins with the following order: research design, the study location, the target population, the sampling procedures, and sample size, instrumentation, validity, reliability, data collection procedures and data analysis. Ethical considerations are also presented in this chapter.

3.2 Research Design

Abutabenjeh and Jaradat (2018) defines a research design as the arrangement of conditions for collection and analysis of data in a method that aims to combine relevance to the research purpose with the economy to the process. In this study, a cross-sectional survey design that captures information based on data gathered for a specific point in time was used. A cross-sectional survey design is a present oriented methodology used to investigate populations by selecting samples to analyze and discover occurrences (Bhattacherjee, 2012). This design was most suitable because it enabled the researcher to describe, analyze, and interpret conditions that exist in variables under study without manipulating the environment of the study. Moreover, a cross-sectional survey design was considered suitable for the study, as it is the best method that enables obtaining data from different sources at a single point in time without repetition from the representative population (Zheng, 2015). Kothari (2004) asserts that in a cross-sectional survey design, the researcher describes the situation as it exists at present and does not manipulate the variables. In addition, this research design was applied to validate qualitative findings with quantitative statistical results in understanding the existing situation relating to influence of plant health clinic services on potato production among smallholder potato farmers in Molo Sub County, Kenya.

3.3 Location of the Study

The study was conducted in Molo Sub-County, which is one of the eleven Sub-Counties making up Nakuru County among others namely, Nakuru East, Nakuru West, Naivasha, Gilgil, Rongai, Nakuru North, Subukia, Njoro, Kuresoi South, Kuresoi North, (Nakuru County Government, 2018). Administratively, Molo Sub County has four wards namely, Mariashoni, Elburgon, Turi and Molo as shown in Appendix C. The Sub County covers a total area of 478.79 KM^2 and a population of 156,732 (Kenya National Bureau of Statistics [KNBS], 2019). Molo is in the Rift Valley along the Mau Forest, which runs along the Mau escarpment. It is situated at 0.25° South latitude, 35.73° East longitude and 2534 meters above sea level. The area is categorized as cold with the average temperatures of 14.1°C and an average rainfall of 1131 millimeters. Its geographical position makes it a suitable place for growing potatoes among other crops. Generally, the main economic activities in this area include crop farming [main crops are maize, pyrethrum, potato, and barley], dairy, and sheep rearing (Kamau *et al*., 2020b). The main cash crops are potatoes, barley, maize, and pyrethrum. The Sub County was chosen for the study because it is the leading potato producer in Nakuru County and among the major producers of potato in Kenya (NPCK, 2019).

3.4 Target Population

The target population for this study was smallholder potato farmers in Molo Sub-County from the wards of Molo, Elburgon, Mariashoni and Turi. There are about 17,312-smallholder potato farmers in Molo Sub-County (KNBS, 2019). Therefore, the target population of the study was 17,312 smallholder potato farmers in Molo Sub County. The Accessible population was 6000 smallholder potato farmers who are in Elburgon, Mariashoni, Molo and Turi Ward (Molo Sub-County Agricultural Officer, 2021 personal communication).

3.5 Sampling Procedures and Sample Size

The study used a multi-stage sampling procedure in which Molo Sub-County was purposively selected based on the magnitude of potato production. Additionally, the Sub-County has embraced the use of plant health clinic services. All the four wards were selected owning to their importance in potato production. The sample size for the smallholder potato farmers was determined using the formula recommended by Nassiuma (2000). Sample size is the number of units, or items in the sample and it determines the precision for the accuracy of the inferences made from the sample to be generalized to the population (Borg & Gall, 2003). The Nassiuma formula is used to determine a study sample for the known population in a survey study. The formula is given by.

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where:

***n*=** sample size,

N= population

C= Coefficient of variation,

E= Standard error

Nassiuma (2000) declares that in most surveys or experiments, a coefficient of variation is in the range of 21% ≤ C ≤ 30% and standard error in the range of 2 % ≤ e ≤ 5 % is usually acceptable. Therefore, a coefficient of variation of 25 % and standard error of 2 % was used for this study. The lower limit of the standard error is selected to ensure low variability in the sample and minimize the degree or error. For this study N = 6,000 smallholder potato farmers C =25 % and e =2 %.

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

$$n = \frac{6000 \times (0.25)^2}{(0.25)^2 + (6000-1)(0.02)^2} = 152$$

The wards extension officers helped in coming up with the list of all the potato smallholder farmers in the study area. Proportionate random sampling was used in determining the number of respondents for the four wards (Table 2), and simple random sampling was be used in obtaining the actual respondents from the wards.

Table 2

Proportion of Sample Size Per Ward

Ward	Number of Potato Farmers	Proportion (%)	Sample size
Elburgon	1000	16.67	25
Mariashoni	2500	41.67	63
Molo	500	8.33	13
Turi	2,000	33.33	51
Total	**6,000**	**100**	**152**

The study sample size for key informants was 10, which comprised of two Sub-County agricultural officers, four Ward Crop development officers, and four plant doctors who oversee crop development in the four wards, and plant doctors involved in coordinating and offering plant health clinic services. Key informants were selected purposively via a process of theoretical sampling (Glaser & Strauss, 1967) based on their potential to offer distinct and important perspectives on potato production and recent issues regarding farmers' potato production and plant health clinic services. Table 3 presents a summary of all the participants in the study.

Table 3

Summary of the Respondents

Target Group	**Number of the Respondents**
Smallholder farmers	152
Sub-County Agricultural officers	2
Ward Crop development officers	4
Plant Doctors	4
Total	**162**

From Table 3 it shows that 152 smallholder potato farmers were the respondents involved in the study, while 2 Sub-County officers, 4 ward crop development officers and 4 plant doctors were also the respondents involved in the study which gave a total sample size of 162 of the respondents.

3.6 Instrumentation

The study used a researcher-constructed questionnaire and an interview guide to collect required data in line with the objectives.

3.6.1 Questionnaire

The study used a structured questionnaire containing a combination both closed and open-ended questions to collect the data in line with the study objectives. The questionnaire had five sections as fellow.

Section A of the questionnaire collected data about the socio-demographic characteristics information of the respondents. Gender, age, education level, farmer experience in potato farming, land ownership, and membership in farmer groups. Respondents experience in potato farming, educational level and age were treated as continuous variable while, land ownership were scored as polytomous and gender of the farmer, membership in farmer groups was dichotomous (female= 0 and male= 1, Yes =1 and No= 0).

Section B collected information on plant health clinic advisory services where 4-point scale was created and the respondents rated the usefulness of plant health clinic advisory services in potato production (Not useful=1, Moderate = 2, Useful =3, Very Useful = 4). Frequency of contact with advisor was treated as continuous variable. The respondents were requested to indicate the frequency of contact with advisor during the previous one year they had planted potatoes, while type of advisory information access was scored as polytomous, and use of advisory services was treated as dichotomous (Yes=1 and No=0)

Section C collected information on plant health clinic training services. The respondents were asked to indicate the frequency of receiving training on potato production in the previous one year they had grown potatoes. Type of training access modes of training were scored as polytomous, while use of training services was treated as dichotomous (Yes=1 and No=0). A 4-point scale was created where the respondents rated the relevance of plant health clinic training services in potato production. On the scale 1= Not relevant, 2 = Moderate, 3 = Relevant, 4 = Very relevant)

Section D collected information on plant health clinic diagnostic services. Variables of interest on diagnostic services included perceptions of the role of diagnostic services, frequency of receiving diagnosis, and use of diagnostic services. The frequency of receiving diagnosis was scored as continuous. While use of diagnostic services was treated as dichotomous (Yes=1 and No=0). Perception of the role of diagnostic services was measured in 5-Point scale. On the scale 1= strongly disagree, 2 = disagree, 3 =neutral, 4 = agree, 5 = strongly agree)

Section E collected information on potato production practices like size of land used for potato production, purpose for growing potatoes, number of bags harvested, variety of potato grown, number of times of potato grown. Variables like Size of land used for potato production and number of bags harvested were treated as continuous data while variety of potato grown and reasons for growing potato were scored as polytomous.

3.6.2 Key Informant interviews

These interviews were used to gather expert knowledge from agricultural extension officers, Sub County Agricultural officers, and plant doctors on notable changes in roles and responsibilities, impact of challenges on smallholder farmers' involvement in potato production and intervention put in place by the ministry to address the challenges. The interaction involved sharing their experience on the role of plant health clinic services and potato production among smallholder potato farmers in Molo Sub County.

A total of (10) interviews were carried out with the informants who were purposively selected. These informants were drawn from the Sub County offices and ward offices based at Molo Sub County Agricultural headquarters respectively. An interview guide (Appendix B) was used to gather the relevant information.

3.6.3 Validity of the Instrument

The instruments were developed in line with the objectives of the study to guarantee content validity of research instrument. The research instruments were also given to experts in Department of Agricultural Education and Extension, and Department of Curriculum Instruction and Educational Management under the Faculty of Education and Community Studies for review and advice and the researcher made correction as was advised. They checked the degree to which the expected results from the data analysis represented the reality of the studied phenomenon. This was achieved by assessing the accuracy of the instruments in providing representative data relating to the variables of the study.

Face validity assessment checked to ascertain whether the instruments would logically measure what it was designed to measure (Kimberlin & Winterstein, 2008). This was to ensure that the items were concise, complete, clear, comprehensive, well organized, and non-ambiguous before being used in the field. Face validity was done by subjecting the instrument and the objectives of the study to scrutiny by the specialists, their comments were used to improve the validity of the instrument. In addition, the instruments were also examined for external and internal validity. Internal validity helps determine the extent to which extraneous variables are controlled in a study (Mugenda & Mugenda, 2003). This ascertain whether the effects on a criterion variable is due to predictor variables or extraneous variables. External validity tests assisted in determining the degree to which the results obtained after the administration of instruments could be generalized to populations and wider environments. The instruments were also subjected to content validity scrutiny to determine whether the data collected realistically and fully reflected the content or indicators of the concept relevant to the study. According to Mugenda and Mugenda (2003) the suitability and complexity of the items checking helps in reframing of where it is necessary.

3.6.4 Reliability of the Instrument

Reliability of the questionnaire was determined through pilot testing and analysis of the results. The questionnaire was pilot tested with 30 smallholder potato farmers from Neissuit ward, Njoro Sub-County, Nakuru-County, Kenya. This assessment was conducted to determine the degree of the internal consistency of the instrument in which the research instruments are expected to yield the same results with repeated trials under similar conditions. Connelly (2008) stated that at least 20 % of the sample size is considered acceptable for a pilot study. According to McMillian and Schumacher (2004) to determine the consistency of the measuring instrument to return the same results when used at different times data collected from the piloting is analyzed to estimate the reliability. The questions that could be unrelated to the study objectives and vague are adjusted accordingly, before commencing on data collection exercise (Kimberlin & Winetrstein, 2008). The questionnaire was considered reliable upon attaining a Cronbach's alpha coefficient of 0.726 ($\geq$ .7) which was greater than the threshold reliability of 0.70 for social science research.

3.7 Data Collection Procedure

The researcher sought a clearance letter from the Board of Post Graduate Studies of Egerton University, which facilitated application for a permit to conduct research from the National Commission for Science, Technology, and Innovation (NACOSTI). After obtaining the permit, the researcher sought clearance from Molo Sub-County authorities that allowed the collection of data from Molo Sub-County. From the list of smallholder potato farmers, a sample was drawn following the earlier stated procedure. Thereafter, visits to the sampled smallholder potato farmers were arranged with the assistance of agricultural Field Officers and plant doctors in all the four wards. The researcher administered the questionnaires herself and recorded the answers given by the respondents for those respondents who were not able to answer by themselves to improve accuracy. The interviews were administered to the key informants in their respective places of work. To avoid risk of the Coronavirus pandemic the researcher implemented recommended basic protective measures that include sanitizing, wearing masks and maintain the social distancing rule to avoid coming into physical contact with the respondents and avoiding shaking hands with the respondents.

3.8 Data Analysis

The completed questionnaires were serialized, organized, and coded according to study objectives. Summarized data was then entered in *Statistical Package for Social Sciences (SPSS)* data management software and analyzed. Descriptive and inferential statistics were used to analyze data. The qualitative data from the interviews and the open-ended questions were organized along key thematic areas processed and analyzed using thematic analysis technique. Inferential statistics were used to examine the relationships between the potato production and the plant health clinic services. Multiple regression analysis was used in analyzing the influence of plant health clinic services on potato production.

3.8.1 Multiple Regression Model Equation

Multiple regression analysis was used to test whether there was a significant influence of plant health clinic services on potato production at $\alpha = 0.05$ level of significant. As define by Hayes and Montoya (2017), multiple Regression is a statistical tool used to examine how multiple independent variables are related to a dependent variable. It helps in understanding how much the dependent variable will change when the independent variables change (Keith, 2019). Specifically, it considers whether there is linear relationship between the independent variables and the dependent variable in a multiple regression model, then further determines the magnitude of relationship i.e., the strength of the effect that each independent variables have on a dependent variable (Azadi & Karimi-Jashni, 2016). According to Plonsky and Ghanbar (2018) multiple regression determines the overall fit (variance explained) of the model and the relative contribution of each of the predictors to the total variance explained. Selected parameters of each of the three independent variables were tested against the potato production. The potato yields in tons per hectare was used as the dependent variable Y.

$H0_1$

Multiple regression model used to show the influence of plant health clinic advisory services on potato production.

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$, where.

Y = dependent variable potato production

b_0 = Predictor Constant or axis y intercept of the multiple regression model equation

b_1X_1, b_2X_2, b_3X_3 and b_4X_4, are coefficients of plant health clinic advisory services selected parameters.

X_1 = Use of advisory services, X_2 = Frequency of contact with advisor, X_3 = Type of advisory information access, X_4 = Usefulness of advisory services

$H0_2$

Multiple regression model used to show the influence of plant health clinic training services on potato production.

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$, where.

Y = dependent variable potato production

b_0 = Predictor Constant or axis y intercept of the multiple regression model equation

b_1X_1, b_2X_2, b_3X_3, b_4X_4 and b_5X_5, are coefficients of plant health clinic training services selected parameters

X_1 = Relevance of training services, X_2 = Frequency of receiving training, X_3 = Use of training services, X_4 = Modes of training, X_5 = Type of training access

$H0_3$

Multiple regression model used to show the influence of plant health clinic diagnostic services on potato production.

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ where.

Y= dependent variable potato production

b_0 = Predictor Constant or axis y intercept of the multiple regression model equation

b_1X_1, b_2X_2, and b_3X_3, are coefficients of plant health clinic diagnostic services selected parameters.

X_1 = Frequency of receiving diagnosis, X_2 = Use of diagnostic services, X_3 = Perceptions of the role of diagnostic services

The data analysis summary of the study is presented in Table 4.

Table 4

Summary of Data Analysis Matrix

Objectives	**Independent Variables**	**Dependent Variable**	**Statistical Tools**
To establish the influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya.	Advisory services • Use of advisory services • Frequency of contact with advisor • Type of advisory information access • Usefulness of advisory services	Potato production • Yields in tons per hectare	Descriptive Statistics Multiple regression analysis
To determine the influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya.	Training services • Frequency of receiving training • Use of training services • Type of training access • Modes of training • Relevance of training services	Potato production • Yields in tons per hectare	Descriptive statistics Multiple regression analysis
To establish the influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya.	Diagnostic services • Perception of the role of diagnostic services • Use of diagnostic services • Frequency of receiving diagnosis	Potato production • Yields in tons per hectare	Descriptive statistics Multiple regression analysis

3.9 Ethical Considerations

Research ethics that were observed in this study are informed consent, confidentiality, and data Handling. The participants were informed about the purpose of the research and the procedures of the study, and they gave their consent to participate in the research before data collection began. The respondents were guaranteed that the research is for academic purposes only and participation will be voluntary. They were assured of confidentiality of the information they give and asked to feel free to withdraw from participation without fear of penalization. The openness regarding the purpose and nature of the research were observed. The data collection process was undertaken while observing the covid-19 regulations as set by the government of Kenya. The researcher also obtained university authorization letter and research permit from NACOSTI before carrying out the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussions of the findings based on the objectives and hypotheses of the study. The study was carried out to determine the influence of plant health clinic services on potato production among smallholder potato farmers in Molo Sub County, Kenya. The chapter presents socio-demographic characteristics of the respondents, influence of advisory, training, and diagnostic services, testing of hypothesis and potato production. Testing of hypotheses was presented concurrently with the study objectives. The results are presented in form of Tables and Figures.

4.2 Socio-Demographic Characteristics of the Respondents

This section presents a description of the socio-demographic characteristics of smallholder potato farmers at Molo Sub-County. Socio-demographic characteristics refer to attributes that describe the status of the people (Cevik *et al.*, 2020). The demographic characteristics of respondents were perceived as significant to the study on the basis that variations on such orientations would prompt individual smallholder potato farmer to engage in different potato farming activities for their livelihoods (Kamara *et al*., 2019). In the light of this reality, the study investigated smallholder farmers' socio-demographic characteristics such as age, gender, education level, potato farming experience, membership in farmer group and land ownership.

4.2.1 Age of the Respondents

Determining the age of the respondents was very crucial in the study as it provided information on whether those involved in potato production are the youth, middle aged or the elderly as it has been found to affect farm level decisions and activities.

The distribution of the respondents according to the age is presented in Table 5.

Table 5

Age Distribution of the Respondents

Age distribution	**Percent**
Below 35 years (Youth farmers)	22
35-60 years (Middle aged farmers)	41
Above 61 years (Elderly farmers)	37
Total	**100**

Table 5 reveal that averagely, the largest percentage (41 %) of the respondents were age between 35 and 60 years. This indicates that most of the respondents involved in potato production fall in the age between 35 and 60 years. This implies that most of the smallholder potato farmers in Molo Sub-County were middle aged which may affect farm level decisions and participation in potato farming activities. This assertion commensurate Dhraief *et al*. (2021) findings that revealed age is a key latent characteristic in making decisions on adoption practices, production and predisposes a farmer to better farming techniques through learning and better management skills. According to Kimaru-Muchai *et al*. (2020) middle aged and young farmers have proved to be active and ready to try new innovations and can provide the needed labor during crop production. Similarly, Relf-Eckstein *et al*. (2019) reported that elderly farmers have more experience, resources and authority that would give them more possibilities for trying new innovations, however receptiveness to new ideas and technologies typically decreases with age because of an increase in risk aversion and a decreased interest in farming.

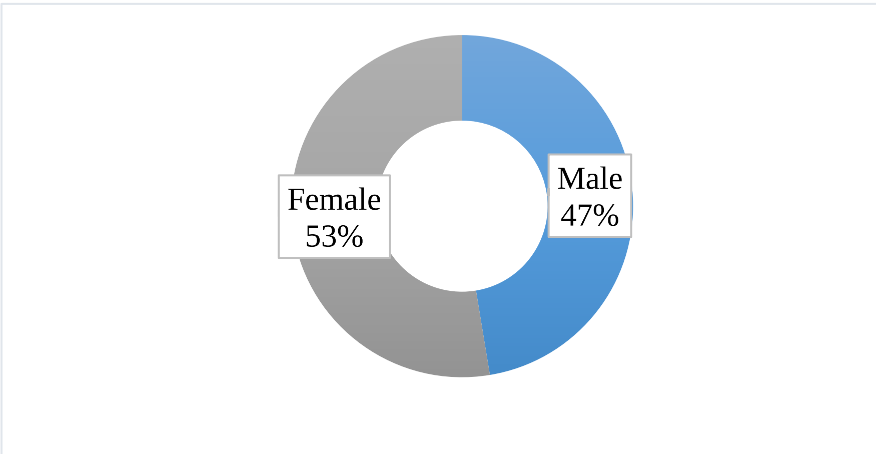
4.2.2 Gender of the Respondents

Gender remains one of the key factors in agricultural production hence the need for collection of gender data in the study to have representation in both males and female groups.

Figure 2 shows the distribution of the respondents according to their gender

Figure 2

Gender of the Respondents



Results on gender indicated that, there was a higher percentage of women respondents than men in the study area. Out of 152 respondents studied 53 percent were women while 47 percent were men as shown in Figure 2**.** These findings implies that the number of women involved in potato production was higher compared to men. This may have been contributed by the fact that most women are involved in agricultural activities while their male counterparts seek for employment opportunities in the formal sector. Besides, men and women may have different perceptions of making decisions on crop production owing to differences in access to productive resources and extension services (Bello *et al*., 2021). These results are consistent with those of Nyasulu *et al*. (2019) who conducted a study in the same area documenting participation of small-scale farmers in collective marketing and observed that there were more women respondents than men. In this study, gender was considered significant owing to the fact that engagement in life activities also vary on the basis of gender, with males normally take preference on seeking for employment opportunities away from home and women generally remain performing local assignments (Chete, 2019). According to Doss (2018) gender has been known to influence agricultural production through issues and concerns that surround access and control of resources for production. Women especially in the developing countries reside in rural areas and are greatly involved in the agricultural production (Sachs, 2018). This may explain the high percent of female smallholder farmers in potato production in Molo Sub County.

4.2.3 Education Level of the Respondents

Formal education attained is an important determinant in livelihood pursuit. It is on this account that respondents' level of education was considered an important profile for analysis in this study. The respondents were asked to state the level of formal education they had attained, and the results are given in Table 6.

Table 6

Education Level of the Respondents

Education level	**Percent**
No formal education	7.2
Primary	32.9
Secondary	38.2
Post-secondary education	21.7
Total	**100.0**

From the results presented in Table 6 it shows that 32.9 % of the respondents completed primary level of education while 38.2% of the respondents completed secondary school education, 21.7 % attained post-secondary education and only 7.2% of the respondents never attended any formal education. The findings prove that the smallholder potato farmers had at least basic education which could make them understand basic concepts about plant health clinics, new production methods, access marketing information and linkages in potato production. It would help farmers get exposed to more knowledge and skills on changing innovations and ideas meant for improving potato production, proper use of chemical fertilizers and pesticides, adoption of improved potato varieties leading to increase potato production (Mgema, 2021). The results agree with the findings by Kangogo *et al*. (2021) who reported that most of the smallholder potato farmers had primary education level in Kenya enabling them to read, write and understand basic crop production ideas. According to Adhikari *et al*. (2016) literate farmers are more likely to understand the recommendations given to them by plant doctors, they would be expected to make more demand for the services after realizing their benefits.

4.2.4 Potato Farming Experience

In order to establish the experience farmers', have in potato farming the respondents were asked to provide information about the years they have grown potatoes and the results are tabulated in Table 7.

Table 7

Potato Farming Experience

Farming experience (Years)	Percent
0-5 years	48.0
6-10 years	28.3
11-15 years	7.2
over 16 years	16.4
Total	**100.0**

As shown in Table 7 majority of respondents (48 %) had spent up to five years in farming potato, 28.3% had spent 6-10 years in farming potato, 7.2% had spent 11-15 years in farming potato while 16.4 % had spent over 16 years in farming potato. Therefore, it indicates that more households are taking up potato farming in this area as one of their sources of livelihoods. Further the results imply that with farming experience smallholder potato farmers would enhance their knowledge and skills in potato production practices, therefore potato farming experience is most likely to improve potato production hence improve livelihoods of smallholder potato farmers. Francis *et al*. (2020) supports the results by stating that as a farmer gain farming experience they can increase proficiency in the processes of farm production due to skills and knowledge gained and, therefore, increased productivity. According to Barasa (2019), improvement in livelihood can be realized effectively through taking in farming production in the relevant field of operation, since individuals often grow with the growth of a venture.

4.2.5 Membership in Farmer Group

The study aimed at establishing membership to farmer groups and main activities carried out within those groups.

The results of belonging to a farmer group and the activities carried in a group are given in Figure 3 and Figure 4

Figure 3

Membership in Farmer Group

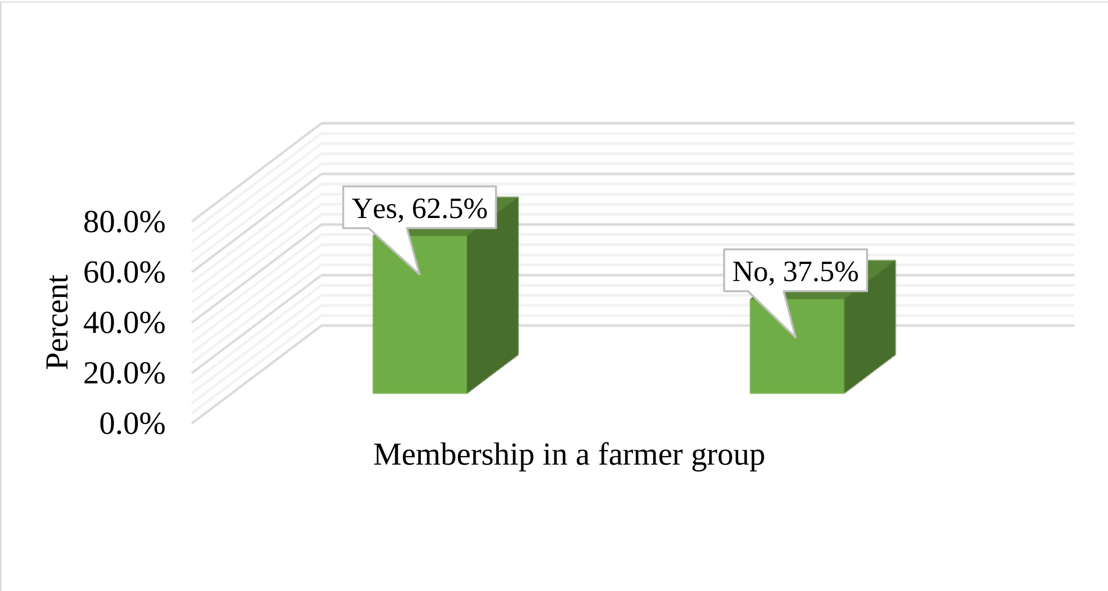
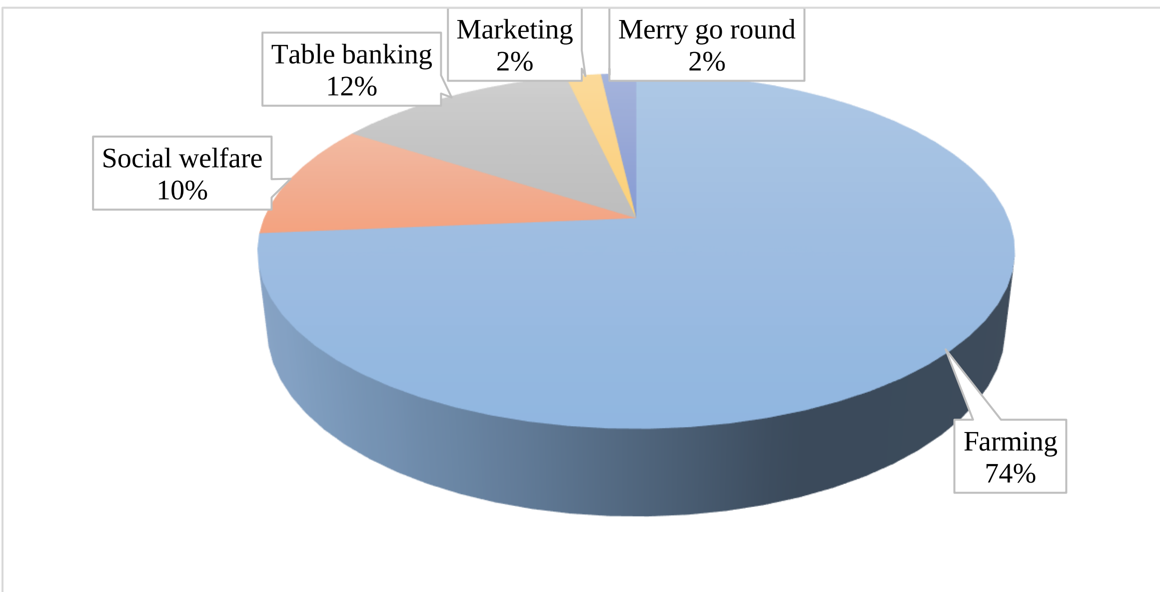


Figure 3 reveal that 62.5 % of the smallholder potato farmers belonged to farmer groups whereas 37.5 % of the respondents did not belong to any farmer group in the region. This implies that majority of the smallholder potato farmers belong to a farmer group. Belonging to a group is most likely to enable them receive training on potato production, adoption of modern production methods innovations and use of certified potato seed varieties, accessed farm credits and purchased farm inputs at subsided prices and linked them to potato markets resulting in the improvement of their potato production therefore improved livelihoods (Okello *et al*.,2017). These results are consistent with those of Devaux (2020) who stated that belonging to farmer groups have the potential to enhance information sharing, networking, exchange of new ideas and increased access to production and marketing information among potato producers due to collective action.

Tolno *et al*. (2016) found that membership in a farmer group is likely to increase producers 'income earning capabilities due to skills and joint learning among them as opposed to individual farmers who do not belong to a farmer group. Bourne *et al*. (2021) argued that the Kenya government through the county government, Non- Governmental Organizations, private sectors use farmer groups as a strategy to maximize efficiency in agricultural production by spreading newly developed technologies to farmers, training farmers and information dissemination through extension services. These bodies find it easy to work and conduct activities like training, advisory services with farmers who are already organized in groups compared to individuals (Eidt *et al*., 2020).

Figure 4

Activities done in the Farmer Groups



There were five group activities in the study area which include farming, social welfare, table banking, marketing and merry go round as indicated in Figure 4. According to the findings farming was the most cited activity by various groups at a frequency of 74%, whereas 10% of smallholder potato farmers indicated social welfare, 12% of the smallholder potato farmers indicated table banking, 2% of the smallholder potato farmers indicated marketing as the activity and merry go round respectively. This implies that smallholder potato farmers belonging to a group could be able to gain knowledge and skills through group activities therefore promoting their potato production. This result agrees with those of Kimathi *et al*. (2021) who opined that farmer groups carrying out various group activities with majority conducting farming that is drive towards farming improvement and development. Suswati *et al*. (2020) noted that merry go round and table banking for example are strategic activities that enable farmers save, access finances and other contributions in terms of pool of funds through loans. According to Wulanjari *et al*. (2021) collective marketing enables potato farmers to costs share the fee for additional storage, processing, or packaging among themselves, in a collective potato marketing, a select farmer, mainly the group leader can do transactions on behalf of the group thus saving time and resources of others. Similarly, through collective marketing in group potato farmers are empowered to achieve the required quantities of the potato produce and can negotiate on their prices. Further Ingutia and Sumelius (2021) stated that farming, social welfare, and marketing activities leverage collective action to access certain services, including the exchange of information, providing representation and voice to members, the marketing of produce and the buying of farm inputs.

4.2.6 Land Ownership

The status of land ownership may determine type of land management practice and ultimately farm production. The findings on the land ownership status by the respondents in the study area are shown in Table 8.

Table 8

Ownership of land

	Percent	
Type of land ownership	**Male**	**Female**
Self-owned	34	12
Family	15	2
Rented	27	10

Table 8 reveals that 34 %, 15 % and 27% of respondents who owned the land used in potato production, used family land, and rented land for potato production respectively were male, while 12%, 2% and 10% of the women self-owned the land used in potato production, used family land, and rented land from elsewhere for potato production, respectively. The results imply that male respondents are mostly accessing land more than women thus gives them a free hand in choice of investment and control. Access to land for cultivation may be dictated by communal rules on land ownership in an area which mostly favor males, with a well-defined property right structure, individuals' farmers who own land will use their resource efficiently while operating on the land because a decline in the value of the resource use in the land represents a personal loss (Coulibaly & Li, 2020). This agrees with the findings by Alban and Willem (2020) on land tenure and agricultural productivity who asserted that land ownership have an influence on crop production. According to Sylvester (2013), the nature of land ownership has an important contribution to how a farmer utilizes and makes investments on land and intensification of agricultural production in his/her land. This is because according to Tolno *et al*. (2016) effective use of land for instance the use of appropriate farm practices and quality inputs can improve productivity.

4.2.7 Purpose for Growing Potatoes

The study sought to establish the purpose for growing potatoes by the respondents in the study area. The findings on the purpose for growing potato by the respondents are indicated in Table 9.

Table 9

Purpose for Growing Potatoes by the Respondents

Purpose for growing potato	**Percent**
Sale	51.3
Home consumption	1.3
Both	47.4
Total	**100.0**

The study found that potato is grown for food as well as for income generation in Molo Sub-County. The results in Table 9 indicate that most of the respondents 51.3 % grow potato for sale, 47.4% grow potato for both sale and home consumption while only 1.3 % grow potato for home consumption. Thus, this implies that most of the respondents designate that potato contributes towards food and income generation. Reasons for growing potatoes could indicate the role of the potato crop in food security and economy in the study area. Maingi *et al*. (2020) supports the results by stating that in Molo Sub-County and other counties in Kenya potato production is done mainly by smallholder farmers as a key food and cash crop. Additionally, results by FAO (2019) confirm that potato is a valuable and nutritious staple crop, driving both food security and Growth Domestic Product (GDP) growth globally.

4.2.8 Types of Potato Variety Grown by Respondents

The respondents were asked to indicate the potato variety they grow to establish types of potato variety grown in the study area. The findings of the potato variety grown by the respondents in the study area are presented in Figure 5.

Figure 5

Types of Potato Variety Grown by respondents.

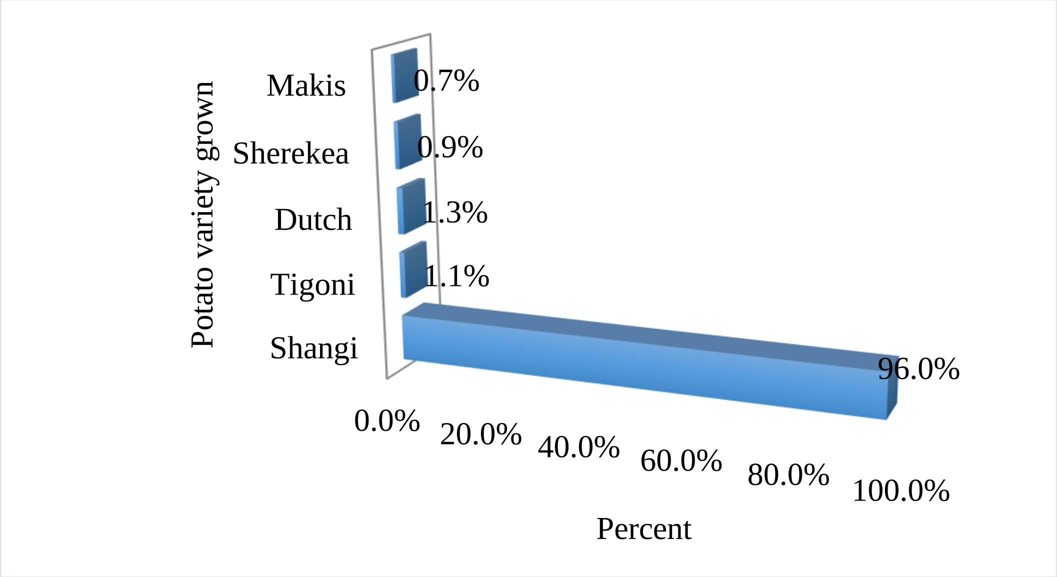


Figure 5 shows that majority (96 %) of the respondents grow Shangi, 1.3 % grow Dutch, 1.1 % grow Tigoni, 0.9 % grow Sheherekea, while 0.7% grow Makis. These results imply that majority of the respondents preferred growing shangi. Though different varieties of potatoes are popular for specific uses, as they vary in attributes such as shape, color, size, and rate of maturity the high preference of shangi variety by the smallholder potato farmers may be because of the minimal dormancy since farmers can replant it within three weeks, its monopolistic force in the market and early maturity (FAO, 2019), which possibly explains the higher number of smallholder potato farmers growing it. According to Okello *et al.* (2016) use of potato varieties which are quality has the potential to increase outputs, food security and income of the farmers. CIP (2020) confirms the results by indicating that Shangi is the most cultivated potato variety in Kenya with an estimated area under cultivation of more than 85%.

4.2.9 Number of Times Potatoes are Grown in a Year by the Respondents

The number respondent grow potato in a year determines the pattern of the crop production. The study therefore collected data on the number of times respondents grow potato in a year to determine the potato production pattern in the study area. The results are presented in figure 6.

Figure 6

Number of Times the Respondents Grow Potatoes in a Year

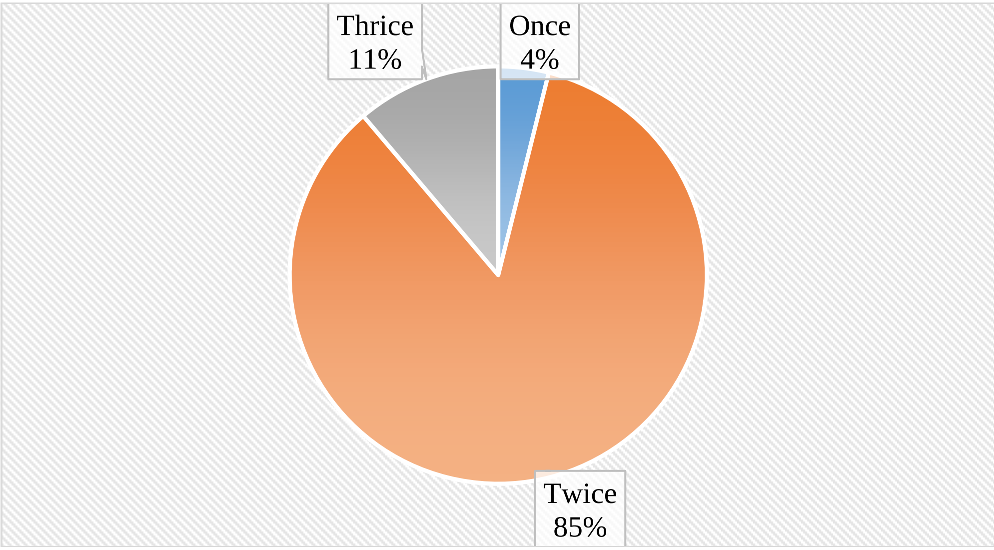


Figure 6 indicates that potato was mainly grown twice a year in the study area as the majority (85%) of the respondents reported to grow potato twice in a year, while 11 % grow it thrice in a year and 4% grow it once in a year. This imply that the potatoes are grown majorly twice a year in the study area with few of the smallholder potato farmers producing more than once. This could be attributed by the fact that the respondents depended mostly on rain to grow their potatoes. Majority of the farmers further, due to maybe fear of unknown and uncertainty trust the long rains only to grow their potatoes hence end up growing them once a year with some going beyond and doing it in the long and short rain seasons, others because of the correct timing and maybe added advantage of the practice of irrigation and water retention practices grow the potatoes thrice a year (Agong *et al*., 2021). According to Ndegwa (2021), potato production in Kenya by smallholder is mainly rainfed, the bi-modal rainfall pattern determines potato production, however with well timing by farmers and irrigation farmers can grow potatoes twice and three times per year since potato crop has a short cropping cycles per year. These results conform Maingi *et al*. (2020) who revealed that potato has a short and highly flexible vegetative cycle averaging between 3-5 months therefore allowing farmers to have up to 3 cropping cycles per year.

4.2.10 Size of the Farm Use for Potato Production in Acres by the Respondents

Farm size is an important factor as it determines the scale of operation that can be utilized by the farmers. The study anticipated that by taking advantage of economies of scale potato farmers would exploit available agricultural extension services and improve potato production. The respondents were asked to indicate the total size of the land they use to grow potato. The responses provided on size of the farm within which they use for potato production are indicated in Figure 7.

Figure 7

Distribution of Potato Farm Size of the Respondents

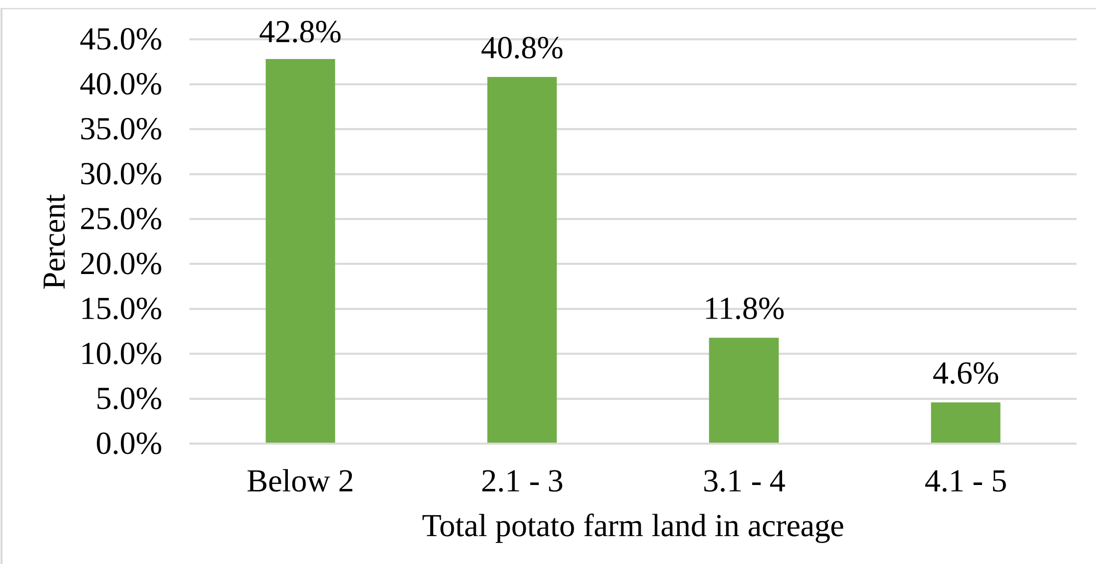


Figure 7 shows that 42.8% of the respondents farmed their potatoes on land below 2.0 acres, 40.8 % farmed potatoes on a land ranging between 2.1- 3 acres, while 11.8% farmed their potatoes on a land ranging between 3.1 - 4 acres. Only 4.6 % farmed their potatoes on a land ranging between

4.1 - 5.0 acres. The study therefore established that most respondents grow potatoes on land less than five acres. This confirms the general observation that most potato in Kenya are predominantly grown by smallholder farmers whose farm size is less than five acres (MoALF, 2016). With the less than five acres of land dedicated by the smallholder potato farmers to produce potatoes this attract the intention and possibility of them to adopt intensification measures such as use of quality inputs and extension services to produce optimum production in smaller land sizes (Franke & Sekoboane, 2021).

4.2.11 Potato Yield

Results in Table 10 provides the distribution of potato yields per ha in year 2020/21 by the respondents in the study area.

Table 10

Distribution of Potato Yields in Year 2020/21 Production Seasons by the Respondents

Potato Yields per ha	**Frequency**	**Percent**
< 5tons/ha	119	78.3
5-10 tons/ha	27	17.8
Above >10 tons/ha	6	3.9
Total	**152**	**100.0**

The findings on the potato yields (Table 10) among the respondents show that majority of them 119 (78.3%) had potato yields less than 5tons/ha and 27 (17.8%) of the respondents had potato yields of between 5 and 10 tons/ha and only 6 (3.9 %) among the smallholder potato farmers produced above 10 tons/ha as shown. This indicates that potato yields are still low in the area as compared with optimum potential yield of 20-30 tons/ha (VIB., 2019).

4.4 Influence of Plant Health Clinic Advisory Services on Potato Production

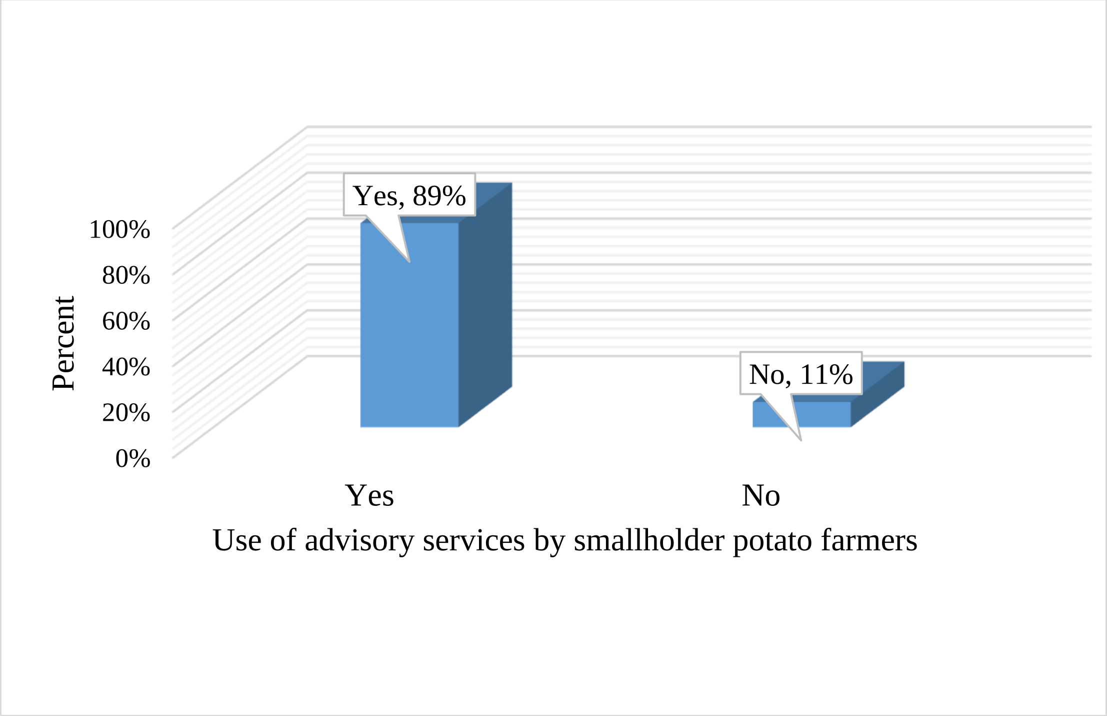
The first objective sought to determine the influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya. The following were investigated in this study, use of advisory services, frequency of contact with advisor, type of advisory information access and usefulness of the advisory services. The findings about the influence of plant health clinic advisory services on potato production were as presented in Figure 8, 9 and Table 11,12 13, 14 and 15.

4.4.1 Use of Advisory Services by the Respondents

The smallholder potato farmers were asked to indicate their plant health clinic advisory services usage in potato production. Their responses are illustrated in Figure 8.

Figure 8

Use of Advisory Services by the Respondents



The results in Figure 8 indicate that 89 % of smallholder potato farmers use advisory services from plant health clinic for potato production purposes while 11 % of the smallholder potato farmers did not use advisory services for potato production purposes. While agreeing with these sentiments, key informants further stated that plant doctors disseminate the advisory information on crop health in the area. These results imply that majority of the smallholder potato farmers have access to plant health clinic advisory services for potato production purposes. The results further imply that plant health clinic advisory services are most likely to enable smallholder potato farmers have access to better knowledge and practices regarding proper use of pesticides, mix of substitute management options (including non-chemical options) for instance Integrated Pest Management approaches such as improved potato seed varieties and non-chemical pest management options, correct input application (Bentley *et al*., 2018). This contention is supported by previous study by Tambo *et al*. (2020) which found that advisory services can play important role in supporting farmers to address the threats of pests and diseases through offering quality advice on crop production and therefore enhancing productivity and food security.

Plant doctors give advice and recommendations to farmers based on quality standard and available information to address multiple plant health problems that farmers present therefore supporting them to address the threats of pests and diseases through adopting the recommendations given (Bett *et al*., 2018). Ghosh *et al*. (2019) further confirms these results by indicating that if farmers adopt the recommendations provided at plant health clinics, they obtain greater yields than farmers growing the same crops who do not use plant health clinic advisory services. These results in addition agree with the findings of Musebe *et al*. (2018) who found out that plant health clinic advisory services offer information on crop health to farmers in Kenya therefore enabling them to improve crop production.

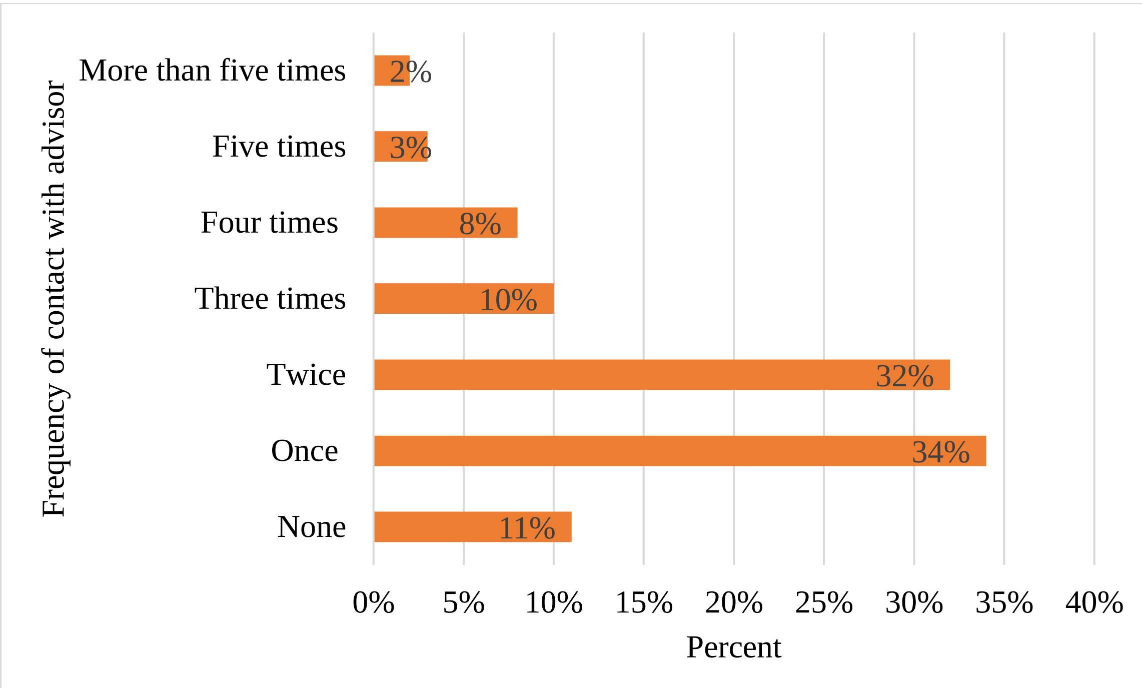
4.4.2 Frequency of Contact with Advisor by Smallholder Potato Farmers

The study sought to determine the number of times smallholder potato farmers had contact with advisor from plant health clinic in the previous one year they planted potato. One year period was used as it gives an opportunity to smallholder potato farmers enough time to utilize the plant health clinic advisory services in potato production by possibly fully implementing advisory recommendations which may take one or a few seasons to have the full impact on potato yield.

The results on frequency of contact with advisor by smallholder potato farmers were as presented in Figure 9.

Figure 9

Frequency of Contact with advisor by Smallholder Potato Farmers



As shown in the results presented in Figure 9, 34% of the respondents contacted advisor once, 32% contacted twice, while 10 %, 8 %, 3 %, and 2% contacted it thrice, four, five and more than five times, respectively. Only 11% had no contact with the advisor. The study established that mainly the frequency of contact with advisor was once and twice during the one-year period they produce potato. However, having once and twice frequency contact with advisor from the plant health clinic is a bit low as compared to the much attention potato production require as they are vulnerable and susceptible to pests and diseases (CABI, 2020). Farmers contacting plant doctor on regular basis for advisory services access is important as it enable them gain knowledge on crop production, explore new equipment and other farm related items like fertilizers, chemicals, pesticides, and insecticides (Beverley & Thakur, 2021). This is the conception that being frequent in contacting plant health clinic advisor in farming, the farmers would be receiving more advice on different ventures of crop farming. Danielsen and Matsiko (2016) also stated that the frequency of contact with plant health clinic advisor by farmers create an awareness among them of the presence of a problem and knowledge of suitable interventions, which is a major pre-requisite for adoption of interventions. According to Srivastava (2013) frequency of contacting plant health clinic advisor leads to changes in knowledge and practices for pest and disease management and ultimately to food security and livelihood improvement of farmers.

4.4.3 Access to Advisory Information

The smallholder potato farmers were further asked to indicate the type of advisory information on potato health they had access to from plant health clinic. The results were as presented in Table 11.

Table 11

Advisory Information on Potato Health Access to by Smallholder Potato Farmers

Type of Advisory information	Percent
Proper chemical application	77
Selecting appropriate pests and diseases resistant potato varieties	80
Proper weeding and intervals	66
Removing and destroying infected potato plants	61
Early potato planting	65
Monitoring pests and diseases emergence	70
Planting certified seed potatoes	73
Practicing field hygiene	69
Growing potato tubers in rotation with other crops	76

Table 11 shows that 77% and 80% of the smallholder potato farmers had access to advisory information on proper chemical application and selecting appropriate pests as well as diseases resistant potato varieties. 66% had access to advisory information on proper weeding and intervals, while 61% and 65% had access to advisory information on removing and destroying infected potato plants and early potato planting. It was also established that 70% had access to advisory information on monitoring pests and diseases emergence and 73% to advisory information on planting certified seed varieties. Further 69% of the respondents had access to advisory information on practicing field hygiene, while 76% to advisory information on growing potato tubers in rotation with other crops. This implies that over 60 percent of the respondents were able to access various types of advisory information on potato health from plant health clinic. As noted in key informant interviews smallholder potato farmers had access to knowledge and skills on guidance about the cultural and agronomic aspects of farming seed treatment, required seed rate, technical advice on sowing time and seed bed preparation, management of insects, pests, and diseases infestation, use of soil according to its nature and capacity to accelerate productivity and balanced application of fertilizers to improve the production of potato by sustaining the soil health. These results are consistent with those of Gurmessa and Bundi (2021) who in their study found out that farmers access preventive advice that include selecting appropriate disease-resistant crop varieties, sourcing clean planting material, proper mulching, removing infected plants to mitigate future disease pressure and pests therefore improving crop production.

Farmers are advised about the post-harvest handling, cultural, chemical, and biological control and management, Integrated Pest Management technique to yield desired output, control the risk leading to a positive change in knowledge on season of disease, pest occurrence among attendant farmers (Boa, 2016). These results are further in line with those of a study in Ethiopia by Bundi (2021), who found out that farmers access to various types of advisory information from plant health clinic to improve crop production. They noted that these types of advisory information have the needed knowledge and skills required for crop protection measures.

4.4.4 Usefulness of Advisory Services

The study sought to determine the usefulness of advisory services in improving smallholder potato production. The results summary on usefulness of advisory services was as presented in Table12.

Table 12

Usefulness of Plant Health Clinic Advisory Services

Usefulness	**Percent**
Not useful	11
Moderate	3
Useful	6
Very useful	80

Table 12 shows that majority (80%) of the smallholder potato farmers indicated the plant health clinic advisory services as very useful in potato production, 6% as useful, 3% as moderate, while about 6 % indicated the plant health clinic advisory services as not useful. From these findings it can be disguised that there is high percentage of respondents indicating that the advisory services are very useful in potato production in the study area. Key informant interviews provided information that plant health clinic advisory services are very useful to smallholder potato farmers as they are very significant in helping them improve production through providing them with advisory information that promote potato production that include selection of quality potato varieties and other valuable quality inputs that can help in improving potato health and vitality, crop protection services, marketing information and harvesting services. This implies that smallholder potato farmers can access technical advisory services from the plant doctors on multiple avenues regarded necessary for the potential outcomes among various aspects include agronomic and plant protection related contents (Okeke *et al*., 2020).

Talib *et al*. (2017) confirms the results by indicating that plant doctors recommend good agronomic practices and plant protection related strategies advices to farmers which can curb the cost of production and increase the output of the farmers, this is because it enable the farmers to benefit in terms of changes in knowledge and management of pests and diseases and improve production as they significantly increased the adoption of crop protection technologies to control devastating potato pests and diseases. Negussie *et al*. (2017) added that providing smallholders with plant health advisory services via plant clinics is worthwhile in terms of improved management of crop pests and diseases, increased productivity and achieving household food security, therefore, interventions such as plant health clinics advisory services may guide farmers towards more sustainable production through their impact to increase the accuracy of knowledge and skills to identify the cause of plant health problems. According to Kansiime *et al*. (2020) plant health clinic advisory services enhanced the awareness and knowledge of crop pests and diseases among farmers, which improved the adoption of interventions and improve production.

Test of Hypothesis one

$H0_1$ *The null hypothesis stated that there is no statistically significant influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya.*

Multiple regression analysis was applied to test the influence of the plant health clinic advisory services on potato production. To predict the influence of plant health clinic advisory services on potato production a stepwise multiple regression of the form $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$ was used to evaluate whether they could predict potato production, Y = potato production, X_1 = use of advisory services, X_2 = frequency of contact with advisor, X_3 = type of advisory information access, X_4 = usefulness of advisory services. The results are illustrated in Table 13, 14 and 15 as follows:

Model summary illustrating a measure of proportion of the variation of potato production as explained by plant health clinic advisory services was as shown in Table 13.

Table 13

Model Summary for Plant Health Clinic Advisory Services and Potato Production

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.789[a]	.622	.618	0.9238	.622	30.396	4	147	.000

As indicated in Table 13, four independent variables (frequency of contact with advisor, use of advisory services, usefulness of advisory services and type of advisory information access) that were studied explain 61.8 % of the potato production as represented by R^2. This therefore means that 61.8 % of the variation of amount of potato produced is explained by the factors in the regression model.

Results of analysis of variance on frequency of contact with advisor, use of advisory services, perception of usefulness of advisory services, type of advisory information access and potato production were as presented in Table 14.

Table 14

Analysis of Variance between Plant Health Clinic Advisory Services and Potato Production

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	798.433	4	199.608	30.396	.000[b]
	Residual	965.347	147	6.567		
	Total	1763.78	151			

From Table 14, F (4, 147) = 30.396, p = 0.000. The overall regression model was significant at p = 0.000. This indicates that the model was fit for looking into the influence of plant health clinic advisory services on potato production. Therefore, factors (frequency of contact with advisor, use of advisory services, usefulness of advisory services and type of advisory information access) successfully predicted the outcome variable (potato production).

The results of multiple regression analysis obtained from fitted regression using plant health clinic advisory services and potato production were as illustrated in Table 15

Table 15

Coefficients for Regression between Plant Health Clinic Advisory Services and Potato Production

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.781	.867		6.426	.000
Frequency of contact with advisor	.881	.260	.284	3.721	.000
Usefulness of advisory services	.427	.132	.130	1.443	.007
Type of advisory information access	.751	.051	.754	8.952	.000
Use of advisory services	.573	.517	.131	1.240	.000

a. Dependent Variable: Potato production
b. Predictors: (Constant), Frequency of contact with advisor, Usefulness of advisory services, Type of advisory information access, Use of advisory services

The regression coefficients result in Table 15 show that frequency of contact with advisor, use of advisory services, usefulness of advisory services and type of advisory information access had a positive contribution on potato production at 0.881, 0.573, 0.427 and 0.751 respectively. Frequency of contact with advisor, use of advisory services, usefulness of advisory services and type of advisory information access were significant at 0.05 significance level ($p = 0.000$, $p = 0.000$, $p = 0.007$ and $p = 0.000$).

Multiple regression model equation below explains the interaction of factors:

$Y = b_0 + b_1X_1 + b_2X_2 + bX_3 + b_4X_4$

Where: Y = potato production; X_1 = use of advisory services, X_2 = frequency of contact with advisor, X_3 = type of advisory information access, X_4 = usefulness of advisory services

In this case therefore:

$Y = 3.781 + 0.573X_1 + 0.881X_2 + 0.751X_3 + 0.427X_4$

Table 15 indicates that the intercept (b_0) = 3.781 is the estimated average potato produced when no predictor variable is considered in the model. Frequency of contact with advisor coefficient b_2 = 0.881, implies that when frequency of contact with advisor is increased by one unit, then potato production is increased by 0.881 tons per hectare if all other variables are fixed. Further type of advisory information access coefficient b_3 = 0.751 implies that when farmers access various types of advisory information then potato production is increased by 0.751 tons per hectare keeping all other variables constant. Frequency of contact with advisor, use of advisory services, usefulness of advisory services and type of advisory information access were at 5 % significance (p-values, p =0.000, p = 0.000, p = 0. 007 and p = 0.000) respectively which were less than level of significance 0.05 ($p \leq 0.05$). Therefore, the null hypothesis that there was no statistically significant influence of plant health clinic advisory services on potato production among smallholder potato farmers was rejected. This implies that plant health clinic advisory services had statistically significant influence on potato production in Molo Sub-County.

In support of these results, Bundi (2021) found out a significant increase in tomato production after farmers had several contacts with advisor and receiving advice including pests and diseases management in Shashemene, Fogera and Seharti Samre districts of Ethopia. Gurmessa and Bundi (2021) also found that frequency of contact with plant health clinic advisor was important and statistically significant in crop yields produce by farmers.These findings similarly agree with those of Musebe *et al.* (2018) who found out that frequency of contact by farmers with plant health clinic advisor significantly influence the farmer’s crop production in Kuti, Kibugu, and Matumbei of Kenya. This they argued that more frequent visits enable farmers to gain more knowledge and skills on areas such as efficient use of agricultural productivity enhancing inputs including fertilizer, improved seed, pesticides, cultural methods of diseases and pests’ management and control.

The results similarly are congruent with those of Negussie *et al*. (2017) who found out that access to various types of advisory information from plant health clinics favorably influence farmers access and utilization of advice therefore get equip on how to manage the pests and diseases problems in Ethiopia. According to Rebecca (2012) farmers access to advisory service strongly suggests that most of the respondents are likely working in conjunction with an extension agent therefore utilizing advisory services that improve crop production. These results are also steady with the findings of Bundi (2021) who found out that type of information access from plant health clinic advisory services favorably influence potato, maize, and tomato production in Ethiopia. He stated that farmers who access this advisory information had more knowledge related to pests and diseases management and knew more about new technologies in crop production. Knowledge gained through advisory information exposes farmers to the advantages of learning different measures that improve production (Majuga *et al*., 2018). Farmers who have access to various advisory information from plant health clinic display better knowledge and practices regarding proper use of pesticides to manage and control pests therefore reduce loss and improve production, therefore increase yields (Bundi, 2021).

Further the results indicate that usefulness of advisory services positively contributed to potato production at 0.427 and had a significant influence on potato production, since the p-value was (p = 0.007) at 5 % significance level. This finding agrees with those of Uzayisenga *et al*. (2015) who found that advisory services are significant in explaining the improvement of plant health, vitality and helps mitigate losses therefore improve production. Further the results are in line with those of Rajendran and Islam (2015) who found out that usefulness of plant health clinic advisory services to farmers was statistically significantly in influencing crop yields among sampled farmers in Bangladesh. They explained that usefulness drive the ability of farmers to utilize the service and therefore gain knowledge and skills to identify, thus address crop health problems. According to Silvestri *et al*. (2019) usefulness of plant health clinic advisory services stimulates farmers uptake of crop protection technologies, and this reduce crop losses, therefore increase production.

4.5 Influence of Plant Health Clinic Training Services on Potato Production

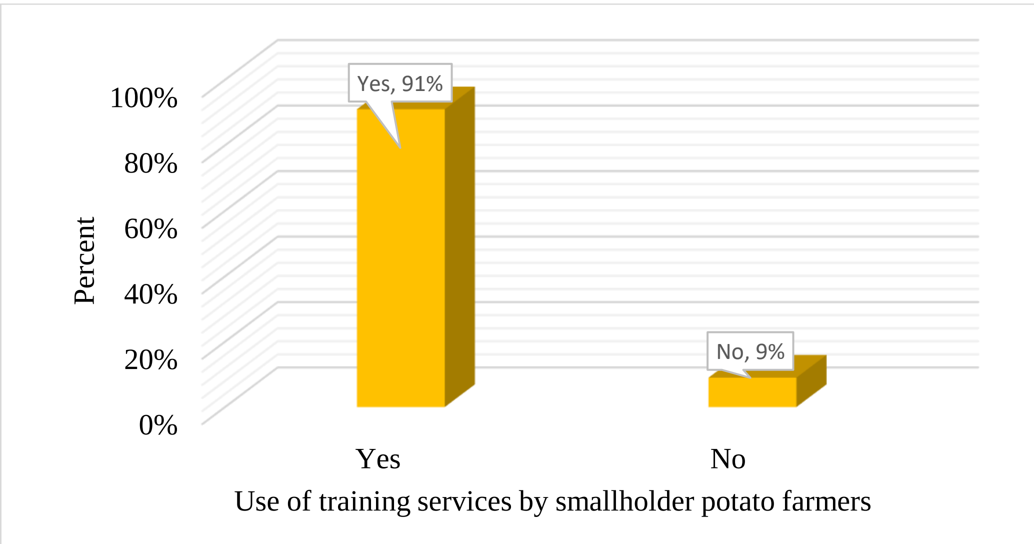
The second objective sought to determine the influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya. To fulfill this objective the following indicators were measured; use of training services, frequency of receiving training, modes of training session, type of training access and relevance of training services.

4.5.1 Use of Training Services by the Respondents

The smallholder potato farmers were asked to indicate their plant health clinic training services usage in potato production. The results are provided in Figure 10.

Figure 10

Use of Training Services by Smallholder Potato Farmers in Potato Production



As shown in Figure 10, 91 % of the smallholder potato farmers use training services from plant health clinic, while 9 % of the smallholder potato farmers did not use the training services. This means that the smallholder potato farmers were able to utilize the plant health clinic training services in potato production hence access efficient and effective solutions on crop health problems which enable them to have a greater array of information about intervention options. Supporting this, the key informants agreed that use of plant health clinic training services offer pests and diseases recommendations practices, integrated pest management promotion and pest and disease surveillance to smallholder potato farmers which is important and innovative solutions to farmers' problems on improving potato production. These findings agree with that of Silvestri (2019) which noted that training of farmers in the new approaches is essential as they equip farmers with skills and knowledge on disease symptom recognition and management, pest management, and record keeping as well as better technical backstopping to solve unknown problems in crop production. Further, Bett *et al.* (2018) added that use of plant health clinic trainings helps farmers to get practical information on pest and diseases they faced and their management by equipping them with the most recommendations for disease and pest management with a combination of monitoring, cultural practices, and pesticides, in line with Integrated Pest Management (IPM) principles.

4.5.2 Frequency of Receiving Training by the Respondents

The study also sought to determine how frequent the respondents in the study area received training on potato production from plant health clinic. This was achieved by asking the respondents to indicate the frequency of receiving training in the previous one year they had planted potatoes. Results are presented in Table 16.

Table 16

Frequency of Receiving Training by the Smallholder Potato Farmers

Number of times	Percent
None	9
Once	32
Twice	30
Thrice	10
Four	8
More than 5 times	11

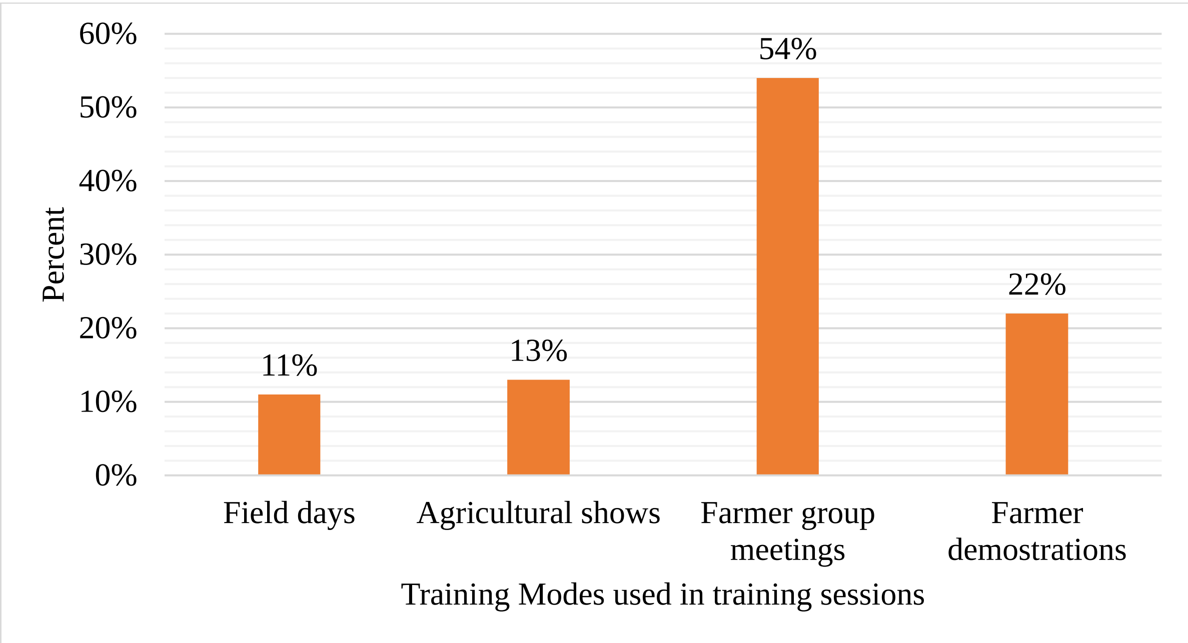
The results in Table 16 indicate that 32 % of smallholder potato farmers received training once, as the highest followed by 30 % who received twice. This implies that most of the smallholder potato farmers received plant health clinic training services majorly once and twice in the previous one year they had planted potato. Key informants in the interviews supported the fact that smallholder potato farmers receiving training on various innovations to improve potato production once or twice most of time during potato production. This conforms to the findings by Gurmessa *et al*. (2021) who indicated that frequency of receiving training services enable smallholder potato farmers to often receive training on fertilizer application during potato production, potato planting methods and other management methods like chemical and pesticide application for the potato variety planted. As documented by Kumar (2014) the success in crop production on handling and managing disease and pests hinge on disease identification and management and crop production practices which are achieve through receiving right training services frequently through various training methods. He further argued that the key tool for diseases and pests' management is knowledge and having knowledge gives confidence which is obtain through receiving trainings on how to solve it.

4.5.3 Modes of training

The study further sought to determine modes of training used during training sessions of smallholder potato farmers in the study area. The results were as shown in Figure 11.

Figure 11

Modes of Training Used in Training Sessions of Smallholder Potato Farmers



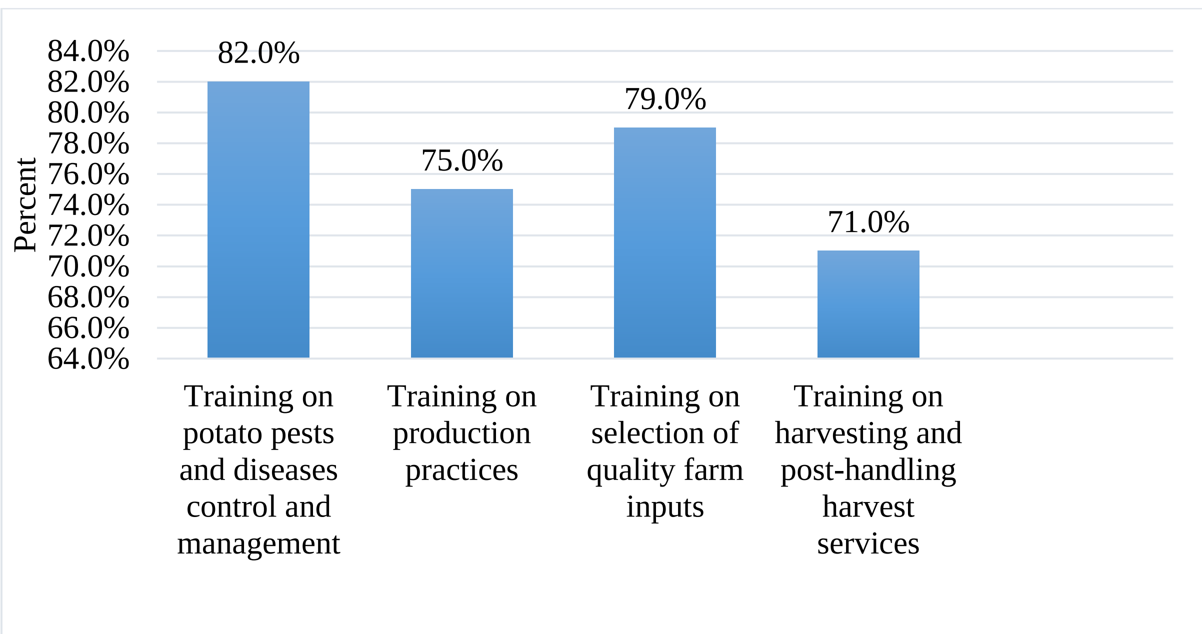
As indicated in Figure 11, a higher proportion (54 %) of the smallholder potato farmers indicated that the mode of training used was farmer group meetings. This was closely followed by 22 % of the smallholder potato farmers indicating farmer demonstrations while a low proportion (13%) and (11%) of the smallholder potato farmers indicated agricultural shows and field days. Information gathered from key informants' interviews agreed with the results as they stated that farmer groups are a strategy used mostly to deliver extension services to maximize the efficiency of agricultural production by spreading newly developed technologies, knowledge, and skills to farmers. This implies that the use of farmer group meetings during plant health clinic training sessions was the most method used as 54 % of smallholder potato farmers reported to have received training through this method. The smallholder potato farmers are therefore able to acquire skills and knowledge on how to handle problems arising from plant health which affects their farm production output. Maina (2014) confirms the results by indicating that modes of training used during training sessions determined the intensive of the training among the farmers which subsequently affect their utilizations of skills and knowledge received during training therefore affecting their farm production.

4.5.4 Type of Training Access by the Smallholder Potato Farmers

The study sought to find out the type of training access from plant health clinic on potato production by the smallholder potato farmers. Their responses on type of training access were as indicated in Figure 12.

Figure 12

Type of Training Access on Potato Production by Smallholder Potato Farmers



From Figure 12, the majority (an average of over 70%) of smallholder potato farmers had access to training on potato pests and diseases control and management, production practices, selection of quality farm and harvesting and post-harvest handling services. As agreed by the information gathered from key informants' interviews majority of smallholder potato farmers had access training on various crop protection practices, potato production practices, quality farm inputs and further on how to do harvesting and handle potato after harvesting. This implies that many respondents have access to various type(s) of training on potato production therefore enable smallholder potato farmer acquire skills and knowledge on how to handle potato health issues which is likely to boost potato production. Negussie *et al*. (2017) supports the results by stating that farmers access trainings on approaches to disease treatment such as crop rotation, use of resistant varieties, intercropping with disgusting crops, and the use of commercial sprays boosted awareness and best use of pest management practices. This contributed to increased knowledge of managing potato health, which is likely to increased production and thus productivity (Devaux, 2021).

The type of training access from plant health clinic increases smallholder potato farmers access information to specific and knowledge-intensive agronomic solutions, compared to non-users who relied on local and more general trainings on pest and disease management information (Ghiasi *et al*., 2017). This results further conform to Bett *et al*. (2018) who indicated that the various type(s) of training concerning potato production access by a farmer portrays the capability of a farmer to handle emerging issues such as pests and diseases, selection of quality inputs to use, and handling potato during harvesting and post-harvest handling practices which affect the overall output of the crop.

4.5.5 Relevance of Training Services

The study sought to establish the relevance of plant health clinic training services on potato production to smallholder potato famers. The results regarding the relevance of training services on improving potato production by the respondents are summarized in Table 17.

Table 17

Relevance of Training Services

Response	Percent
Not relevant	9
Moderate	3
Relevant	5
Very relevant	83

The findings in Table 17 reveals that majority (83 %) of the smallholder potato farmers indicated that the plant health clinic training services are very relevant, whereas 5% indicated that are relevant, 3% indicated that are moderate, while 9 % indicated that are not relevant implying that plant health clinic training services is relevant to majority of smallholder potato farmers in potato production and irrelevant to a very few farmers. As noted in key informant interviews plant health clinic training services are very relevant to smallholder potato farmers as they provide a range of technological solutions including cultural practices trainings such as weeding to reduce harborage, and crop rotation, biological for instance use of pheromone and light traps) and chemical methods. Further the plant health clinic training services recommend a realistic combination of cultural controls and limited use of insecticide early in the season to potato farmers, thus allowing dramatic increases in production with slight decrease in plant protection costs (Kansiime *et al*., 2020). These findings agree with those of Nsabimana *et al*. (2015) who conducted a study on the analysis of relevance of plant health clinic training services on farmer’s crop production and found out that more than 90% of farmers interviewed indicated that the plant health clinic training services are relevant in agricultural production and referred to plant health clinics as their main source of crop health information.

Additionally, Mur *et al*. (2015) established that plant health clinic training services are relevant strategy to equip farmers with crop protection measures in which when properly positioned can act as a tool for improvement in crop production. Plant health clinic training services provide quality agricultural information and skill training to farmers with the intention of enhancing farmers' ability to increase agricultural output through equipping them with skills and knowledge in addition to innovations that lead to crop protection and improvement of production (Danielsen *et al*., 2020).

Test of Hypothesis Two

The following null hypothesis was tested:

$H0_2$ *There is no statistically significant influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya.*

Multiple regression analysis was applied to test the hypothesis. A stepwise multiple regression of the form $Y= b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$, where; X_1= relevance of training services, X_2 = frequency of receiving training, X_3 = use of training services, X_4 = modes of training X_5 = type of training access, was used to evaluate whether the factors could predict potato production. The results of multiple regression analysis were as tabulated in Table 18, 19 and 20.

The model summary basically shows how far the independent variables (factors) explain the variation in the dependent variable. From the study results of the model summary the coefficient of determination for the relationship between (independent variables) plant health clinic training services (factors) and potato production (dependent variable) was as shown in Table 18.

Table 18 presents model summary of the coefficient of determination for plant health training services variables and potato production.

Table 18

Model Summary for Plant Health Clinic Training Services and Potato Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.893[a]	.797	.781	0.7321	.797	86.85	5	146	.000

The results in Table 18 indicates that the R-squared for the relationship between plant health clinic training services and potato production in Molo Sub-County, Kenya was 0.781. This implies that the factors that were studied (frequency of receiving training, type of training access, modes of training, relevance of training services, and use of training services) explained 78.1 % variation in amount of potato produced.

Analysis of variance was used to assess whether the model was fit for the prediction. Table 19 present the results of analysis of variance (ANOVA) and the usefulness of the regression model in predicting how factors (frequency of receiving training, type of training access, modes of training, relevance of training services, and use of training services) in the model could predict the outcome which is potato production.

Table 19

Analysis of Variance between Plant Health Clinic Training Services and Potato Production

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1230.415	5	246.083	86.85	.000[b]
	Residual	413.721	146	2.8336		
	Total	1644.136	151			

From Table 19, the F (5, 146) = 86.85, P = 0.000 which is less than 0.05 thus the model was statistically significant in predicting how the factors (frequency of receiving training, type of training access, modes of training, relevance of training services, and use of training services) influence the outcome variable which was potato production.

Table 20 illustrates the results obtained from fitted regression model and fitted regression coefficient using plant health clinic training services on potato production

Table 20

Coefficients for Regression between Plant Health Clinic Training Services and Potato Production

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	2.351	.500		3.120	.000
	Type of training access	0.156	.124	.093	1.403	.000
	Relevance of training services	2.742	.300	.593	10.370	.000
	Frequency of receiving training	0.121	.124	.035	0.332	.009
	Modes of training	0.342	.037	.381	7.201	.000
	Use of training services	0.153	.461	.014	0.311	.000

a. Dependent Variable: Potato production
b. Predictors: (Constant), Type training access, Relevance of training services, Modes of training, Frequency of receiving training, Use of training services,

The multiple regression model equation used to show the influence of plant health clinic training services on potato production is illustrated below:

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$

Where:

b_0 is the regression intercept, Y = potato production; X_1 = relevance of training services, X_2 = frequency of receiving training, X_3 = use of training services, X_4 = modes of training, X_5 = type of training access

Hence, $Y = 2.351 + 2.742X_1 + 0.121X_2 + 0.153X_3 + 0.342X_4 + 0.156X_5$

The results in Table 20 show that the frequency of receiving training with p- value = 0.009 was statistically significant factor of potato production. This implies that as frequency of receiving training by smallholder potato farmer increase, potato production also increases. A unit increase in frequency of receiving training will lead to an increase in potato production by 0.121 tons per hectare keeping all other variables constant. Type of training access was found as a significant predictor variable influencing the potato production at 0.05 significant level (p = 0.000). Type of training access slope b_5 = 0.156, indicates that when the type of training is access, then the potato production is increase by 0.156 tons per hectare. This infer that the frequency of receiving training and the type of training access by smallholder potato farmers influence the outcome that is potato production. This is because farmers can acquire knowledge and skills that guide them in improving potato production leading to better yields (Devaux, 2021). Moreover, with the skills and knowledge acquired, farmers can recognize the presence of pests, diseases and their damage more readily therefore eradicating them earlier before causing damage.

The results similarly indicates that the five predictor variables; type of training access, relevance of training services, frequency of receiving training, modes of training and use of training services were found as significant predictors variable influencing the potato production at 0.05 significant level (p = 0.000, p = 0.000, p = 0.009, p = 0.000 and p = 0.000 respectively). Thus, the null hypothesis that there was no statistically significant influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya was rejected. This implies that plant health clinic training services had statistically significant influence on potato production in Molo Sub-County. These findings are in line with those of Adhikari *et al*. (2020) who found out that frequency of receiving plant health clinic training services result in skills and knowledge enhancement which is likely to increase uptake of recommendations on how to handle issues such as pests and diseases therefore likelihood of crop production improvement in Nepal. Mur *et al*. (2015) noted that since plant health clinic training services offer type of training services such as management of pests and diseases and production practices farmers can maximize production through use of acquired skills and knowledge therefore increase yields.

Negussie *et al.* (2018) in their study showed that farmers can learn advance practices on protection measures therefore are able to recognize symptoms of pests and diseases thus prevent and manage them before causing damage to crops. Review study by Kansiime *et al*. (2020) in Kikuyu Kenya revealed that type of trainings such as proper use of pesticides enable farmers to employee various methods for management of observed pest problem. Bentley *et al*. (2011) argued that due to the most farmers adopting a functional pragmatic blend of cultural controls recommendations and therefore limiting use of insecticide early in the season, thus allowing dramatic increase in production with slight decrease in plant protection costs. Equally, Kansiime *et al*.(2020) found out that frequency of training farmers on crop protection measures statistically and significantly influenced household crop production in Kenya.

Further the results in Table 20 reveals that relevance of training services, use of training services and modes of training had a positive contribution on potato production at unstandardized coefficients of 2.742, 0.153 and 0.342 respectively. These findings are in an agreement with a study by Maina (2014) in Kenya which found out that modes of training during training sessions of farmers determined the response of the farmers. He expounds that modes of training subsequently affect the uptake of skills and knowledge and hence their extent of level of utilization by farmers therefore handling problems arising from plant health which affects farms production output. According to Ghosh *et al*. (2019) relevance of a service has impact on how farmers view and accept it and therefore have significant influence on crop production. The significance result on use of training services also concurs with that of Uzayisenga *et al.* (2015) who reported a statistically significant relationship between plant health clinic training services use and crop production among maize farmers in provinces of Kigali city, Northern, Southern, and Western of Rwanda.

4.6. Influence of Plant Health Clinic Diagnostic Services on Potato Production

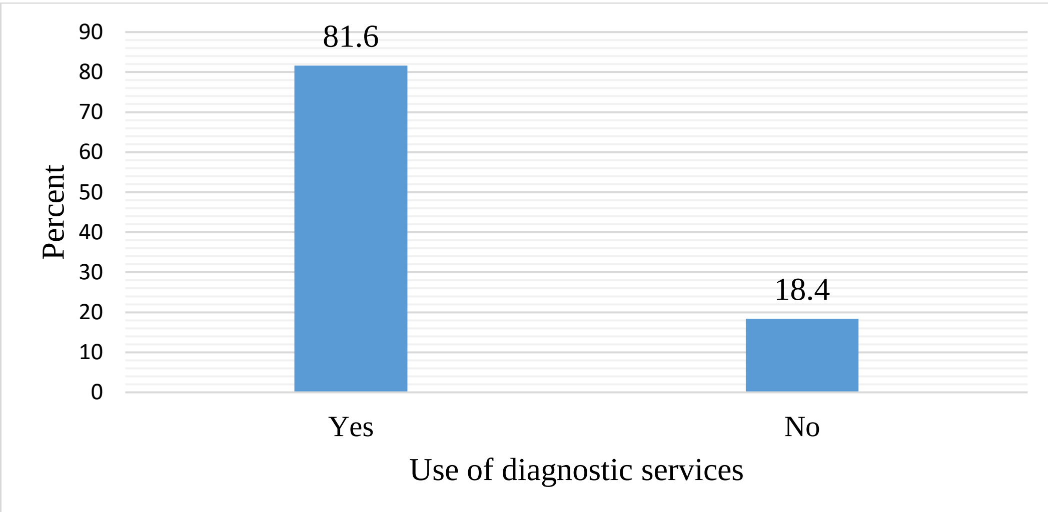
The third objective of the study sought to determine the influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya. This section provides information on diagnostic services in Molo Sub County. To achieve this, the study investigated; the use of plant health clinic diagnostic services, frequency of receiving diagnosis by the respondents and the perception of the role of advisory services by the respondents.

4.6.1 Use of Diagnostic Services by the Respondents

The smallholder potato farmers were asked to indicate their use of plant health clinic diagnostic services in potato production. Their responses noted as illustrated in Figure 13.

Figure 13

Use of Diagnostic Services by Smallholder Potato Farmers in Potato Production



Majority of the smallholder potato farmers (81.6%) indicated that they use plant health clinic diagnostic services while 18.4 % did not use plant health clinic diagnostic services in potato production. In the interviews, key informants 'responses were in line with the findings by smallholder potato farmers majorly using diagnostic information in the area from plant health clinic in potato production. This implies that majority of the smallholder potato farmers use diagnostic services from plant health clinics thus are likely to obtain information on potato production practices which includes information on crop diseases, pests' management, production practices, quality inputs for instance certified potato varieties and field management practices boosting potato production. As well, farmers could get right diagnostic and mitigatory in time through diagnostic services from plant health clinic which promote potato production (Negussie *et al*., 2013).

Additionally, plant health clinic services provide need-based mitigatory prescription, with greater reliance on integrated holistic approach which is environment-friendly, with least impact on biodiversity and is also easily affordable therefore addressing the problems of efficient and effective diagnostic and management strategies to combat yield loss due to pests and diseases among farmers which are important aspects in potato production (Tambo *et al*., 2020).These findings are consistent with those of Rajendran and Islam (2015) who conducted a study documenting the impact of plant health clinic in Bangladesh among farmers and observed that majority of farmers obtained plant health diagnostic information from plant health clinic facilitating a capable disease as well as pest diagnostic system which is fundamental pillar to the maintenance of a plant health care service. According to Lugman *et al*. (2020), diagnoses must be combined with constant scrutiny that includes homogenous and measurable estimates of authentic and probable impacts of disease to prioritize those necessitating urgent attention.

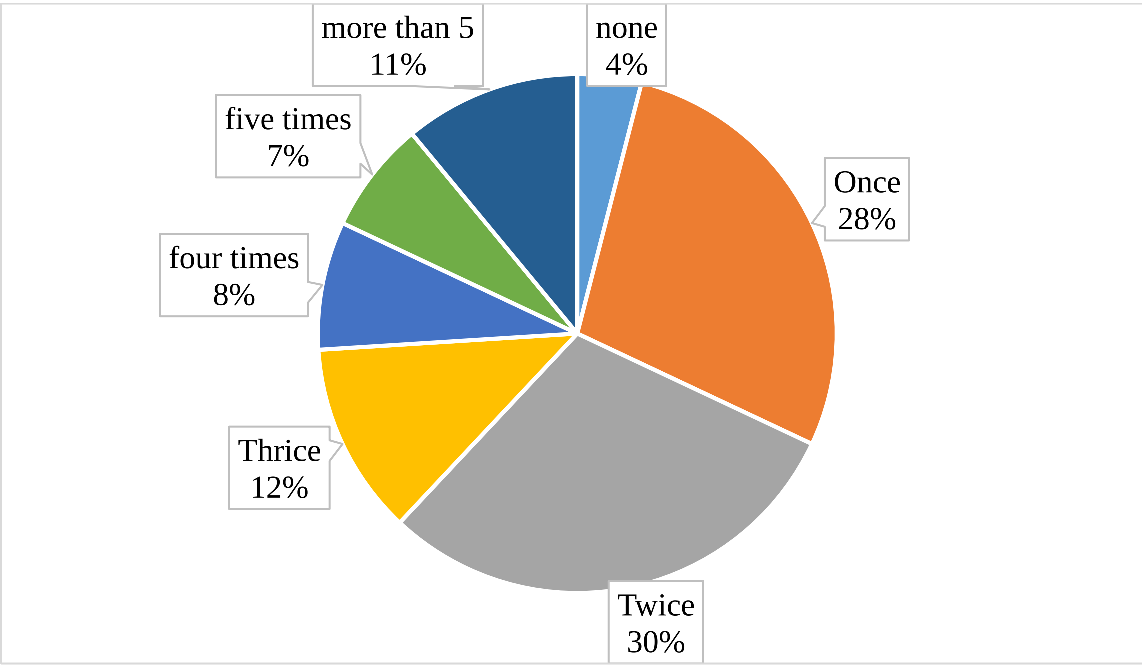
4.6.2 Frequency of Receiving Diagnosis by the Respondents

The study further sought to determine the extent to which respondents received diagnostic services from plant health clinic. The respondents were asked to indicate the frequency of receiving diagnosis in the previous one year they had planted potato. Results are given in Figure 14.

Responses by respondents on frequency of receiving diagnosis was as presented in Figure 14.

Figure 14

Frequency of Receiving diagnosis by the respondents



The results in Figure 14 reveal that 28 % of the smallholder potato farmers in the study area received plant health clinic diagnosis once and 30 % received it twice while a smaller percentage (4 %) reported no diagnosis received. The results further revealed that 11% of smallholder potato farmers received plant health clinic diagnosis more than 5 times. Information gathered from the key informant interviews agreed with these findings as they stated that farmers seek diagnosis once and twice mostly per year in potato production. This implies that mostly smallholder potato farmers access plant health clinic diagnosis once and twice annually in production of potato which is a bit low compared to the needed diagnosis attention that potato require since is majorly susceptible to pests and diseases. The reason of low frequency diagnosis may most likely be because the farmers visit them mostly during potato production season which is majorly once or twice a year. This means that the smallholder potato farmers might be missing out on very important information and recommendations on potato health diagnosis issued during more frequency potato diagnosis that can help improve their potato production activities.

Uzayisenga *et al.* (2015) conform to the results by stating that, routine monitoring of crop allows one to catch a problem early, when it is relatively simple and inexpensive to treat and before extensive damage occurs. In addition, this supports findings by Murithi *et al.* (2013) who found that most farmers receive training once and twice during the annual year they carry out crop production. Ghaiwat and Arora (2014) points out that knowledge and skills on crop health symptoms is crucial which is attain through receiving diagnosis frequently by farmers, therefore before any potential causes can be evaluated, however, it is necessary to do a thorough examination of both individual crop and all area under production in general.

4.6.3 Perception of the Role of Diagnosis on Potato Production by the Respondents

In line to get to know the role played by plant health clinic diagnosis in potato production in the study area as perceived by the respondents, they were asked to rate their perception towards the role of diagnosis on potato production. Closed ended Likert scale questions were given to the respondents on which they were to rate their perception. Neutral meant that the respondent is not sure (neither disagree nor agree). Strongly Agree meant that the respondent strongly agree with the statement. Agree meant that the respondent somehow agree to the statement. Strongly Disagree meant that the respondent strongly disagrees with the statement, while disagree meant that the respondent somehow disagrees with the statement. The results are shown in Table 21.

Perception of the Role of Diagnosis on Potato Production by the smallholder potato farmers was as illustrated in Table 21

Table 21

Perception Towards the Role of Diagnosis on Potato Production

Perception	**Strongly disagree**		**Disagree**		**Neutral**		**Agree**		**Strongly agree**	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
Enable farmers to detect and identify pests	5	3	4	9	41	27	52	34	40	26
Enable farmers to describe the condition and damage of pests	4	3	8	5	43	28	62	41	35	23
Enable farmers to monitor and manage pests	5	3	3	2	38	25	66	43	40	26
Enable farmers to detect and identify diseases	3	2	1	0.7	41	27	65	42	42	28
Enable farmers to describe the condition and damage of diseases	3	2	7	5	42	28	66	43	34	22
Enable farmers to monitor and manage diseases	2	1	4	3	35	23	67	44	44	29

The results in Table 21 revealed that majority of the smallholder potato farmers agree and strongly agree with most of the statements with very low percentage strongly disagreeing with all the statements. Information gathered from key informants' interviews agreed with the results findings that diagnostic services assist farmers in developing their own abilities to improve their potato productivity. This implies that there is high perception of the great role played by diagnostic services in improving potato production among smallholder potato farmers. Results by Uzayisenga *et al*. (2020) confirm that Plant health clinic diagnostic services offer one-on-one personalized diagnostic services in response to farmers' queries on plant health, therefore provide critical access to the knowledge, information, and technology that farmers require to improve the productivity in potato production and thus improve the quality of their levels of livelihood.

Danielsen *et al.* (2014) in their study revealed that plant health clinic diagnostic services influence crop production as they facilitate farmers access to knowledge and skills that aimed at reducing crop losses and improving production. According to Wright *et al.* (2016) the plant doctors make diagnosis and give recommendations to farmers on practices and standards that are nationally and internationally accepted on how to improve crop production. Therefore, significantly increasing the ability of farmers to identify and address crop health problems, increasing their knowledge and ability to communicate crop problems and address them which boost crop production (Rajendran & Islam, 2017).

Test of Hypothesis Three

$H0_3$* *There is no statistically significant influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya.

Multiple regression analysis was applied to test the influence of the plant health clinic diagnostic services on potato production. Multiple regression in the form of $Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ where X_1 = frequency of receiving diagnosis, X_2 = use of diagnostic services, X_3= perception of the role of diagnostic services, was used to evaluate whether these variables could predict potato production. The findings are tabulated in Table 22, 23 and 24.

The study results of coefficient of determination explaining the extent to which changes in predicted variable (potato production) is explained by the change in the predictor variables (plant health clinic diagnostic services) is shown in Table 22

Table 22

Model Summary for Plant Health Clinic Diagnostic Services and Potato Production

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.769[a]	.591	.590	0.8092	.591	71.335	3	148	.000

a. Predictors: (Constant), Perception of the role of diagnostic services, Use of diagnostic services, Frequency of receiving diagnosis

From Table 22, a coefficient of determination (R^2) = 0.590 indicated that 59.0 % of variation in the potato production is explained by the predictors (perception of the role of diagnostic services, frequency of receiving diagnosis and use of diagnostic services). This implies that 59.0 % of potato produced could be explained by plant health clinic diagnostic services.

The results obtained from analysis of variance for the plant health clinic diagnostic services on potato production were as presented in Table 23

Table 23

Analysis of variance for Plant Health Clinic Diagnostic Services and Potato Production

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	857.311	3	285.770	71.335	.000[b]
	Residual	592.894	148	4.006		
	Total	1450.205	151			

From the results of the ANOVA presented in Table 23, it shows that the model was significant at p = 0.000. This is a prove that the model used was reliable in determining how the independent variable, plant health clinic diagnostic services influence potato production in Molo Sub-County, Kenya. Further, the F (3, 148) = 71.335, P = 0.000 thus this indicates that the model was fit for looking into the influence of plant health clinic diagnostic services on potato production.

Table 24 presents the multiple regression analysis results between potato production, frequency of receiving diagnosis, use of diagnostic services and perception of the role diagnostic services.

Table 24

Coefficients for Regression Between Plant Health Clinic Diagnostic Services and Potato Production

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.177	.499		2.356	.000
	Frequency of receiving diagnosis	0.144	.108	.085	1.337	.018
	Use of diagnostic services	1.114	.456	.144	2.444	.016
	Perception of the role of diagnostic services	4.038	.347	.679	11.639	.000

a. Dependent Variable: Potato production
b. Predictors: (Constant), Perception of the role of diagnostic services, Frequency of receiving diagnosis, Use of diagnostic services

As indicated in Table 24 frequency of receiving diagnosis, use of diagnostic services and perception of the role of diagnostic services had an influence on potato production at p = 0.018, p = 0.016 and p = 0.000 respectively which were less than level of significance 5%. The unstandardized coefficients frequency of receiving diagnosis, use of diagnostic services and perception of the role of diagnostic services had a positive contribution on potato production at 0.144, 1.114 and 4.038 respectively. Further noted from the findings, if all the other variables are kept constant, a unit increase in frequency of receiving diagnosis will lead to an increase in potato production by 0.144 tons per hectare. Moreover, use of diagnostic services would lead to an increase in potato production by1.114 tons per hectare taking all other variables constant while a perception of the role of diagnostic services will lead to an increase in potato production by 4.038 tons per hectare.

The multiple regression model equation below explains the interaction of factors:

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$

Where:

Y = potato production; X_1 = frequency of receiving diagnosis; X_2 = use of diagnostic services; X_3 = perception of the role of diagnostic services.

Therefore

$Y = 1.177 + 0.144X_1 + 1.114X_2 + 4.038X_3$

At 5% level of significance, frequency of receiving diagnosis, use of diagnostic services and perception of the role of diagnostic services had a $p = 0.018$, $p = 0.016$ and $p = 0.000$ respectively. Therefore, the null hypothesis that there was no statistically significant influence of plant health clinic diagnostic services on potato production in Molo Sub-County was rejected. These findings concur with other studies that found out that frequency of diagnosis and use of diagnostic services among farmers statistically and significantly relate with production. For example, Tambo *et al.* (2021) found that frequency of diagnosis received by the farmers significantly influenced maize production in Rwanda. They are also in agreement with a study done in Bolivia by Bentley *et al.* (2011) that confirmed that frequency of diagnosis make an appreciable contribution to crop production. Further the findings are in support of a study by Uzayisenga *et al*. (2015) that found out that use of plant health clinic diagnostic services impact on farmers' production. The findings also are in line with that of Srivastava (2013), that farmers production is related to use of plant health clinic diagnostic services which enable farmers manage and control diseases and pests. With this they argue that when farmers use diagnostic services from plant health clinics they are equip with skills and knowledge that guide them in detecting pests and diseases and manage them leading to production improvement.

The findings also conform to those of Murithi *et al*. (2013) who also found that use of plant health clinic diagnostic services is important in diagnosing disease and pest for early management and control to avoid yield loss by farmers in Embu County, Eastern Kenya. According to Rajendran and Islam (2017) use of diagnostic services significantly increase farmers ability to detect, identify and address crop problems which effectively improve production due to crop protection. Danielsen and Matsiko (2016) proclaims that plant health clinic diagnostic services are effective key contributor to improving production among farmers through helping farmers in handling crop health problems and crop management practices. Additionally, Srivastava (2014) reported that through plant health clinic diagnostic services farmers get timely diagnosis of their crops and are well placed to cope with the crop loss early before distressing loss.

The study finding on the perception of the role of diagnostic services in Table 24 is in line with findings by Mangini (2012), who noted that the degree of perception of role of diagnostic services of the farmer significantly affect their degree of seeking for these services therefore learning how to improve crop production. They explained that perception of role of diagnosis is a determinant for tendency to seek for these services which help them gain skills and knowledge for them to manage a problem early when it is relatively simple and inexpensive to treat and before extensive damage occurs.

4.7 Effects of Moderating Variables between Independent and Dependent Variables

The relationship between independent and dependent variables in the study was regulated by moderating variables which are socio-demographic characteristics composed of age, gender, educational level, potato farming experience, membership in farmer group and land ownership. Respondents were asked to indicate their age, if they belong to a farmer group, their gender, education level completed, the nature of the land they have for potato production and their experience in potato production. These variables were tested for their potential moderating influence of the relationship between the independent and dependent variables by use of simple regression analysis. The results are presented in Table 25.

Table 25 illustrate the results of the effects of moderating variables between independent and dependent variables

Table 25

Results of Effects of Moderating Variables on Relationship between Independent and Dependent Variables

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.969	.276		3.507	.001
	Gender	.065	.082	.062	.788	.432
	Age	-.029	.038	-.068	-.753	.453
	Education level	.084	.042	.164	1.988	.049
	Potato farming experience	.012	.042	.026	.298	.766
	Land ownership	-.037	.046	-.065	-.806	.421
	Membership in a farmer group	.273	.088	.255	3.109	.002

The moderation analysis reveals that variable namely: gender, age, ownership of land and potato farming experience had no significant influence, while level of education and membership to a farmer group were the only moderator variables found to have significant influence, at 5% level of significance ($p = 0.049$ and $p = 0.002$ respectively) as shown in Table 25. This implies that smallholder potato farmers' education level and membership in a farmer group is a crucial component in contributing and addressing potato production in Molo Sub-County. Farmers' capacity to produce and sell more in a market to improve their livelihood positively relate to their education levels (O'Hara & Low, 2020), therefore would likely influence the ability of the farmer to access knowledge and skills from plant health clinic in potato production and their perception towards these services in improving potato production. From the literature reviews and findings of this study revealed that smallholder potato farmers in Molo Sub-County grow potato for both income and food therefore for sustainability output for their livelihoods these farmers are driven and motivated to access extension services such as plant health clinics to improve potato production. These are driven by likely factors such as education, results from the study findings by Rahman and Sujan (2021), proved this by stating that the farmers had at least basic education which could make them to read and understand basic concepts about plant health clinics, new production methods, access marketing information flyers and linkages.

Hassan *et al*. (2021) conforms to the results by stating that Education keeps farmers well-informed with changing innovations and ideas meant for improving potato production because most educated farmers stand high chances of making better decisions as well as quickly implementing new technologies and innovations in farming. Education helps a person to effectively understand the production requirements and implement the knowledge correctly (Gilbertson *et al*., 2022), with the attainment of formal education farmers become aware of information on skills and knowledge on improving potato production from the plant health clinics.

Abera *et al*. (2020) observed that farmers with higher level of education tend to be more efficient in crop production since education equips them with capacity to perceive, interpret and respond to new information and improved know-how in crop production much faster than their counterparts. Adoption of strategies in farming such as crop protection, use of improved potato varieties (insect and disease resistant varieties), crop rotation, weeding, intercropping, and mulching, comes from accessing skills and knowledge attained which are driven by the education level of the farmer (Edwards, 2020). Basch *et al*. (2020) revealed that better educated farmers tend to use pesticides, chemicals cautiously and are careful to follow the recommended guidelines to the latter, proper application of inputs such as fertilizer, seeds unlike less educated farmers, because of awareness of the ill effects associated with misusing pesticides, poor quality inputs since they have access to that information. Correspondingly, Gebremariam (2021) reported existence of a link between education level of the farmer possession of appropriate information and making informed choices on adoption of agricultural innovations that promote crop productivity because education level is an important parameter since the activities related to learning, sharing and uptake of technologies requires some level of comprehension. Education enables the individual farmer to know how to seek for and apply information on improved farm practices form extension services platforms

(Krell *et al*., 2021). This suggests that education enabled farmers to access and interpret agricultural information correctly.

Similarly, belonging to farmer group play an essential role in the use of plant health clinic services since they constitute of farmers who come together and pool resources that may be necessary to access and use plant health clinic services in potato production. Being a member of farmer group could provide easy and quick access to relevant information on crop protection measures, purchase of essential agricultural certified farm inputs, access to the steady market, monitoring of production activities by the members at a lower cost (Zeweld, 2020). Bartova and Fandel (2020) noted that farmers belonging to a group can participate in multiple networks and hence are likely to be most empowered and are more inclined to seek greater decision-making roles to improve crop production through access of extension services frequently. Like the latter in the result findings, majority of the smallholder potato farmers received training through farmer group meetings which might be explained by the fact that meetings are done most of the times twice, or once a month therefore inferences of how frequent the farmer receive training services. With the intensive of the training, methods used during the training sessions might be influence on the attraction of the training and the capacity of farmers to acquire knowledge and skills through training which is likely to affect their frequency of receiving the trainings. Additionally, group-setting provides links with other farmers which enables the exchange of new ideas, information, and experiences, which shape farmers` behaviors, attitude, and practices leading to improvement of crop production (Sabillón *et al*,.2022).

According to Yanakittkul (2020) belonging to a farmer group enables farmer to access formal research-based acquaintance, innovative experiences, knowledge, and financial resources and opinioned opportunities for varying forms of production which lead to improvement in productivity. This means that by facilitating farmer group, smallholder potato farmers would come together to interact and innovate and provide a platform to direct efforts in ensuring the efficiency of the tactic in enhancing potato productivity through accessing plant health clinic services thereby improving the welfare of farmers.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary, conclusions and recommendations of the study that was carried out to determine the influence of plant health clinic services on potato production in Molo Sub-County, Kenya. Suggestions for further research are also provided in this chapter.

5.2 Summary of the Study

The purpose of the study was to determine the influence of plant health clinic services on potato production among smallholder potato farmers in Molo Sub-County, Kenya. The objectives of the study were to determine the influence of plant health clinic advisory, training, and diagnostic services on potato production among smallholder potato farmers in Molo Sub-County.

The following is a summary of the study findings based on the objectives.

i. Objective one sought to determine the influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya.

It was found that majority 89% of the respondents use plant health advisory services in the area during potato production. Similarly, around 34% and 32 % of the respondents contacted plant health clinic advisor once and twice for the previous one year they had grown potato, respectively. Over 60 percent of the respondents were able to access various advisory information on potato health. The majority 80 % of the respondents indicated that plant health clinics advisory services were useful in improving potato production in the area. An analysis of the plant health clinic advisory variables (frequency of contact with advisor, use of plant health clinic advisory services, usefulness of advisory services and type of advisory information access) were found to have a statistically significant influence on potato production. Therefore, the null hypothesis that stated, there is no statistically significant influence of plant health clinic advisory services on potato production among smallholder farmers in Molo Sub-County, Kenya was rejected. This meant that the frequency of contact, using advisory services, usefulness of advisory services and type of advisory information access had an influence on potato production.

ii. Objective two sought to determine the influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya.

Results indicate that the majority 91 % of the respondents use plant health clinic training services in the area during potato production. Similarly, frequency of receiving training was once and twice for the previous one year they had grown potato for most of the respondents. Respondents' modes training sessions were through farmer group. Over 80 % of respondents indicated that plant health clinic training services were very relevant in improving potato production. It further revealed that the five variables; type of training access, frequency of receiving training, use of training services, modes of training and relevance of training services were found to have a statistically significance influence on potato production at 0.05 level of significance. Therefore, the null hypothesis that stated, there is no statistically significant influence of plant health clinic training services on potato production among smallholder farmers in Molo Sub-County, Kenya was rejected. Therefore, necessitating that type of training access, frequency of receiving training, use of training services, modes of training and relevance of training services is thought to produce favorable fundamentals skills and knowledge for potato farming activities that lead to improvement in production.

iii. Objective three sought to determine the influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya.

Results revealed that most of the respondents had a positive perception towards plant health clinic diagnostic services with most agreeing and strongly agreeing on their role in improving potato production. Study results indicated that with respect to frequency of receiving diagnosis by the respondents, over 25 per cent of the respondents indicated having received plant health clinic diagnostic services once and thrice. Majority of the respondents 81.6 % use advisory services in potato production. The variables for plant health clinic diagnostic services; frequency of receiving diagnosis, use of diagnostic services and perception of role of diagnostic services had a statistically significance influence on potato production. Therefore, the null hypothesis that stated, there is no statistically significant influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya was rejected. Thus, imposing frequency of receiving diagnosis, use of diagnostic services and perception of role of diagnostic services is thought to produce fortunate essentials for potato farming methods for improving production through skills and knowledge gain by farmers from plant health clinics.

5.3 Conclusions

The following conclusions were made based on the study findings which were guided by three objectives.

i. There was a statically significant influence of plant health clinic advisory services on potato production among smallholder potato farmers in Molo Sub County. Overall use of plant health clinic by the respondents was high with respondents receiving various advisory services on potato production and further the majority indicated that advisory services were useful in potato production and that using plant health clinic advisory services, frequency of contact with advisor, usefulness of advisory services and type of advisory information access, by the respondents would improve the potato production.

ii. There was a statistically significant influence of plant health clinic training services on potato production. This therefore means improving farmers frequency of receiving training, type of training access from plant health clinic, use of training services, modes of training and the relevance of training services would improve the potato production.

iii. The plant health clinic training services had a statistically significant influence on potato production. The more the frequency of diagnosis increase, high the perception of the role of diagnostic services and use of diagnostic services the more they engaged in many, farming activities in potato production. This thus means improving frequency of diagnosis, perception of the role of diagnostic services and use of diagnostic services would improve potato production in Molo Sub County.

5.4 Recommendation of the Study

Based on the findings and conclusions presented, the study recommends the following:

i. The County and national government should create more awareness on plant health clinics services, establish more plant health clinics sites within easy reach of the farmers. Provision of plant health clinic sites on lower administrative units such as villages would considerably improve coverage, hence more access therefore further use of the plant health clinic services by farmers. Additional farmers should be encouraged to come together in groups which will allow collective group activity with the benefits like reduced costs in purchase of farm inputs and easy access to plant health clinic services. With groups farmers can access and use these services easily.

ii. Agricultural extension service providers should educate the farmers more on the importance of accessing and using plant health clinic services more often during crop production. Sensitize them on the importance of seeking these services frequently and adapting the recommendations given to utilize skills and knowledge that improve potato production.

iii. Smallholder potato farmers should utilize plant health clinic services to obtain agricultural knowledge and skills more often to increase their potato production. The access and use of plant health clinic services are necessary for the achievement of crop production. The more farmers access and use them, the more productive farmers benefit from an increase potato production therefore improvement on their livelihoods.

5.5 Suggestions for Further Research

i. The study was conducted in Molo Sub-County, it would be necessary to carry out similar research in other areas with different social economic environments to find out if similar results would be obtained.

ii. The influence of plant health clinic services delivery on the livelihood outcomes of all categories of farmers

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APPENDICES

Appendix A: Questionnaire for Smallholder Potato Farmers

Introduction

I am Beatrice Chepkoech, a student pursuing a Master of Science (MSc) Degree in Agricultural Extension in the Faculty of Education and Community Studies Department of Agricultural Education and Extension at Egerton University. I am carrying out a research project on ***Influence of plant health clinic services on potato production among smallholder farmers in Molo sub-county, Kenya***. The purpose of this questionnaire is to collect the information required for the study, whose findings will inform government and other stakeholders on how plant health clinic services, can be improved and made to benefit more farmers in potato production. You are among the selected farmers to participate in the study. I would like to assure you that all the information you give will be treated with confidentiality and will be used only for purposes of this study. I therefore request you to provide relevant responses voluntarily and sincerely to questions in an honest manner.

SECTION A. SOCIO-DEMOGRAPHIC CHARACTERISTICS

Sub County	**Ward**	**Village**

1. Gender (Tick as appropriate) Male [ ] Female [ ]
2. Age in Years (Specify)..
3. Education level (Tick as appropriate)

   None [ ] Primary [ ] Secondary [ ] Post-secondary education [ ]
4. How long have you been growing potatoes in years(specify) ………………………………
5. Land ownership……………………………………………………………………………
6. Are you a member of any farmer group? Yes [ ] No [ ]
7. If yes, how often do you meet? ………………………………………………………
8. What type of the activity is carried out when you meet………………………

SECTION B: PLANT HEALTH CLINIC ADVIOSRY SERVICES

9. Did you use advisory services from plant health clinic in the last one year you planted potato

   Yes [ ] No [ ]

10. How many times did you contact plant health clinic advisor in the previous one year you planted potato?..

11. Tick the advisory information you access from plant health clinic in the previous one year you planted potato (Tick as appropriate)

Advisory information access	**Yes**	**No**
Proper chemical application		
Selecting appropriate pests and diseases resistant potato varieties		
Proper weeding and intervals		
Removing and destroying infected potato plants		
Early potato planting		
Monitoring pests and diseases emergence		
Planting certified seed potatoes		
Practicing field hygiene		
Growing potato tubers in rotation with other crops		

12. Rate the usefulness of plant health clinic advisory services in improving potato production?

    Not useful [ ] Moderate [ ] Useful [ ] Very useful [ ]

SECTION C: PLANT HEALTH CLINIC TRAINING SERVICES

13. Did you use training services from plant health clinic in the last one year you planted potato?

    Yes [ ] No [ ]

14. How many times did you receive training from plant health clinic in the previous one year you planted potato…………………………………………………………………?

15. Tick the type(s) of training you receive from plant health clinics in the previous one year you planted potato (Tick as appropriate)

	Type of training	**Yes**	**No**
a	Training on pests and diseases control and management		
b	Training on production practices		
c	Training on selection of certified farm inputs		
d	Training on harvesting and post-harvest handling services		

16. Which of the following modes of training was used during the training sessions?
    Field days [ ] Farm demonstration [ ] Agricultural shows [ ] Farmer group meeting [ ]

17. Rate the relevance of plant health clinic training services in improving potato production?

Not relevant [ ] Moderate [ ] Relevant [ ] Very relevant [ ]

SECTION D: PLANT HEALTH CLINIC DIAGNOSTIC SERVICES

18. Did you use diagnostic services from plant health clinic in the last one year you planted potato

    Yes [ ] No [ ]

19. How many times did you receive plant health clinic diagnosis in the previous one year you planted potato ……………………………………………………………………………………?

20. The statements below focus on the perception of the role of plant health clinic diagnostic services on potato production scaled on a five-point Likert scale. Rate your perception

    SA= Strongly agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly disagree

Role of diagnostic services	**Pests**				
	SA	**A**	**N**	**D**	**SD**
a) Enable farmers to detect and identify pests					
b) Enable farmers to describe the condition and damage of pests					
c) Enable farmers to monitor and manage pests					
	Diseases				
	SA	**A**	**N**	**D**	**SD**
d) Enable farmers to detect and identify diseases					
e) Enable farmers to describe the condition and damage of diseases					
f) Enable farmers to monitor and manage diseases					

SECTION E: POTATO FARMING PRACTICES

21. Reasons for growing potato Sell [ ] Home consumption [ ] Both [ ]
22. How many times do you grow potatoes in a year? ....
23. What potato variety do you grow? ………………………………………………………
24. How many acres do you use for potato production? ....
25. How many bags of potato did you produce in the last one year?

    (a)Short-season [ ] (b) Long-season [ ]

END

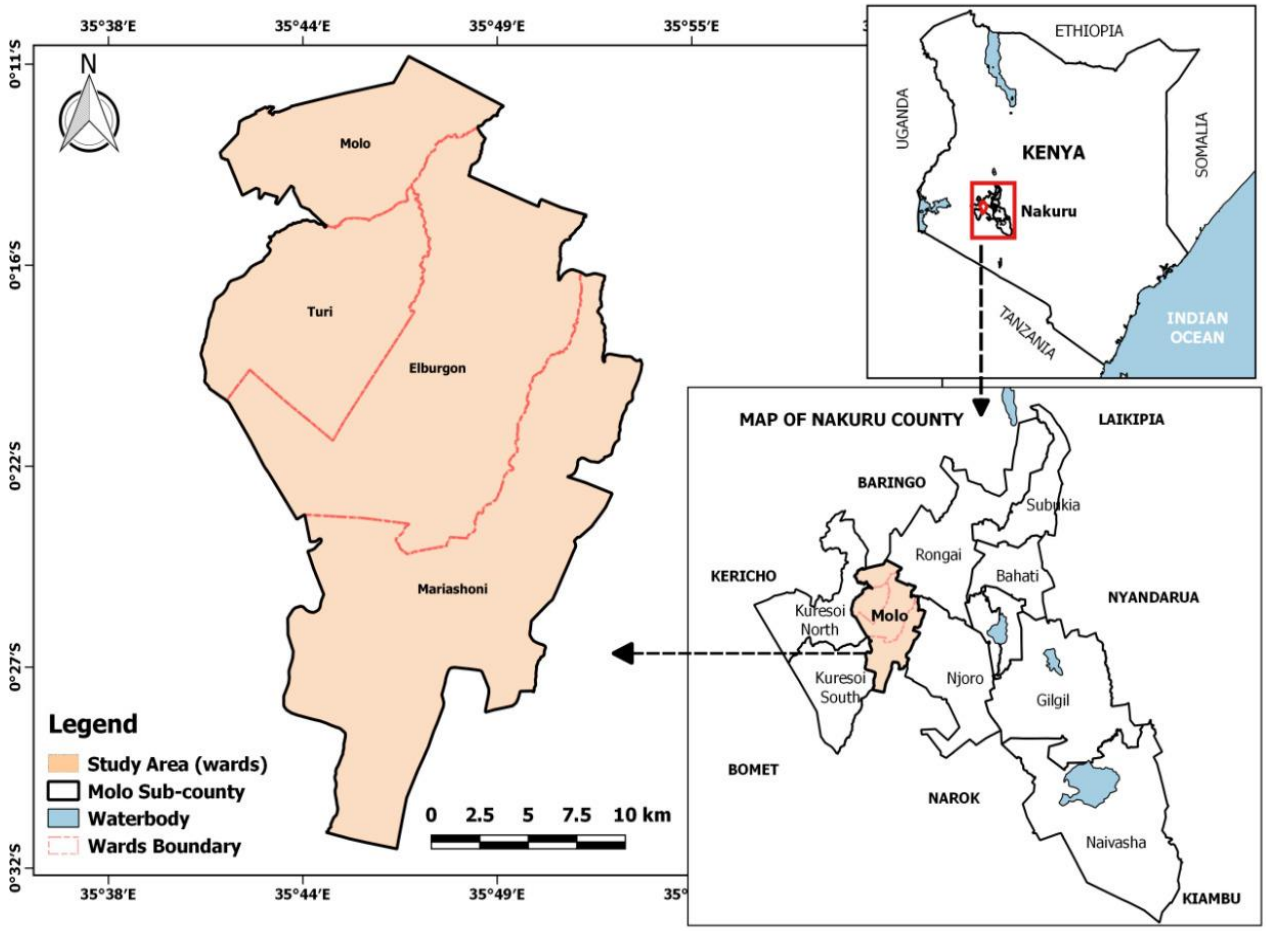
Thank you for your cooperation

Appendix B: Interview Guide for Key Informants

Name____________________________ Position_____________________

1. For how long have you been working in this area?
2. Are smallholder potato farmers using plant health clinic services in your area? Explain.
3. Do smallholder potato farmers access services from plant health clinics in your area? Explain.
4. Comment on the coverage of plant doctors in terms of plant health clinic services,
5. Comment on the capacity of plant health clinics services in disseminating information on pests and diseases mitigation measures and meeting needs of smallholder potato farmers
6. Which information do you communicate to farmers on the potato farming?
7. How do plant health clinics services influence potato production among smallholder farmers
8. How is the production of potato among smallholder farmers in this area?
9. What kinds of problems exist in respect to accessing/using plant health clinics services by smallholder farmers?
10. Which challenges do staffs face in delivering plant health clinics services?
11. What do you think can be done to improve the operations services of plant health clinics to improve potato production
12. What are the challenges facing potato production?
13. What should be done to overcome these challenges facing potato production?

Appendix C: Map of Molo Sub-County



Appendix D: Letter of Research Authorization

EGERTON *UNIVERSITY*

Tel: Pilot: 254-51-2217620
254-51-2217877
254-51-2217631
Dir.line/Fax: 254-51-2217847
Cell Phone

P.O. Box 536 - 20115
Egerton, Njoro, Kenya
Email: bpgs@egerton.ac.ke
www.egerton.ac.ke

OFFICE OF THE DIRECTOR GRADUATE SCHOOL

Ref: EM12/13624/19 **Date: 9th August, 2021**

The Director General
National Commission for Science Technology and Innovation,
P. O. Box 30623-00100
NAIROBI.

Dear Sir,

RE: REQUEST FOR RESEARCH PERMIT– MS. BEATRICE CHEPKOECH REG. NO. EM12/13624/19

This is to introduce and confirm to you that the above named student is in the Department of Agricultural Education & Extension, Faculty of Education and Community Studies, Egerton University.

She is a bona-fide registered M.Sc. student in this University. Her research topic is **"Influence of Plant Health Clinic Services on Potato Production Among Smallholder Farmers in Molo Sub-County, Kenya".**

She is at the stage of collecting field data. Please issue her with a research permit to enable her undertake the studies.

Your kind assistance to her will be highly appreciated.

Yours faithfully,

DIRECTOR, BOARD OF POST GRADUATE STUDIES
12 AUG 2021
EGERTON UNIVERSITY, P.O. Box 536-20115 EGERTON

Prof. Nzula Kitaka
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

NK/en

"Transforming Lives Through Quality Education"

Appendix E: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **390734**

Date of Issue: **23/August/2021**

RESEARCH LICENSE

This is to Certify that Miss... Beatrice n/a chepkoech of Egerton University, has been licensed to conduct research in Nakuru on the topic: INFLUENCE OF PLANT HEALTH CLINIC SERVICES ON POTATO PRODUCTION AMONG SMALLHOLDER FARMERS IN MOLO SUB-COUNTY, KENYA for the period ending: 23/August/2022.

License No: **NACOSTI/P/21/12456**

390734

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix F: List of Publications

International Journal of Agricultural Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 12, Issue 1, Jun 2022, 133–144

INFLUENCE OF PLANT HEALTH CLINIC DIAGNOSTIC SERVICES ON POTATO PRODUCTION AMONG SMALLHOLDER FARMERS OF MOLO SUB-COUNTY, KENYA

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[2]Department of Agricultural Education and Extension Egerton University, P.O Box 536-20115, Kenya

[3]Department of Curriculum, Instruction and Educational Management, Egerton University, P.O Box 536 -20115, Kenya

ABSTRACT

Plant health clinics are primarily responsible for diagnosing plant ailments and providing remedial measure to reduce crop losses and improving food security through diagnostic services among farmers. Globally pests and diseases cause massive losses among farmers. It is believed that by reducing crop losses and increasing yields millions of people can be fed. The objective of this study was to determine the influence of plant health clinic diagnostic services on potato production among smallholder farmers in Molo Sub-County, Kenya. The study engaged 152 smallholder potato farmers randomly sampled from Mariashoni, Molo, Elburgon and Turi wards of Molo Sub County and 10 key informants, mainly officers of agriculture in the area. Data was gathered through administration of questionnaires and key informant interviews. The data was analyzed using both qualitative and quantitative techniques. The hypotheses were tested using multiple regression analysis. The findings indicated that frequency of receiving diagnosis, use of diagnostic services and perception of the role of diagnostic services significantly influence potato production among smallholder farmers [$p = 0.018$, $p = 0.016$ and $p = 0.000$] with adjusted $R^2 = 0.590$. The study concluded that frequency of receiving diagnosis, perception of the role of diagnostic services and use of diagnostic services are vital services in potato production. The study therefore recommends that plant health clinic diagnostic services on potato production should be put more emphasis on. This ensures sustainability of potato production efforts in smallholder potato production.

***KEYWORDS:** Use of Diagnostic Services, Frequency of Receiving Diagnosis, Multiple Regression Analysis & Potato Production*

Received: Jan 19, 2022; **Accepted**: Feb 09, 2022; **Published**: Apr 28, 2022; **Paper Id.**: IJASRJUN202214

INTRODUCTION

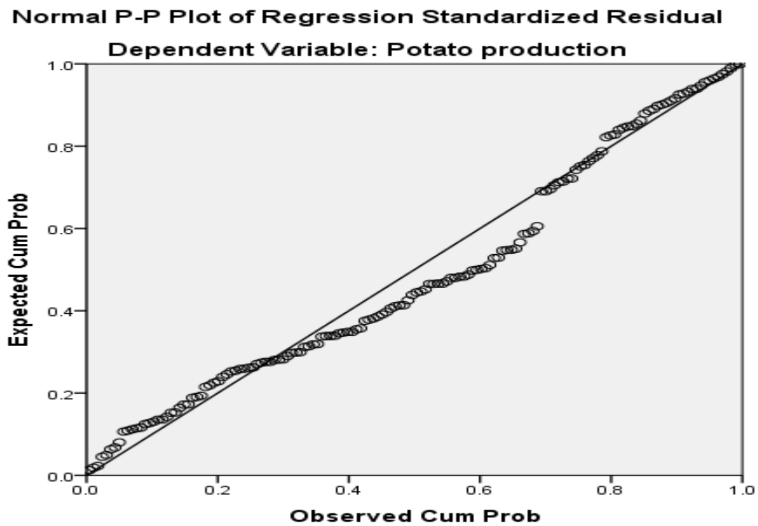
Globally crop pests and diseases are common and important threats to agricultural production (Trebicki & Finlay, 2019). Similarly, in Sub-Saharan Africa crop pests and diseases are major limiting factor of growth in agricultural production thus threatening the livelihoods of farmers in the region (Savary et al., 2019). It is estimated that crop losses due to pests and diseases are about 50 % across Sub-Saharan Africa (Ratnadass, 2020). Therefore, any loss on their crops caused by pests and diseases can have distressing effects on the livelihoods of the people who largely depends on it for food and income. As Gehen et al. (2019) points out losses due to pests and diseases can be substantial and may be prevented, or reduced, by crop protection measures. It is hence, important to provide extension services to farmers with options that are context-specific to their agricultural conditions and socioeconomic circumstances to address pests as well as diseases outbreaks (Heeb et al., 2019).

Appendix G: Multiple Regression Tests Results for Plant Health Clinic Services and Model Adequacy Check

PLANT HEALTH CLINIC ADVISORY SERVICES

Model Adequacy Check

Linearity:



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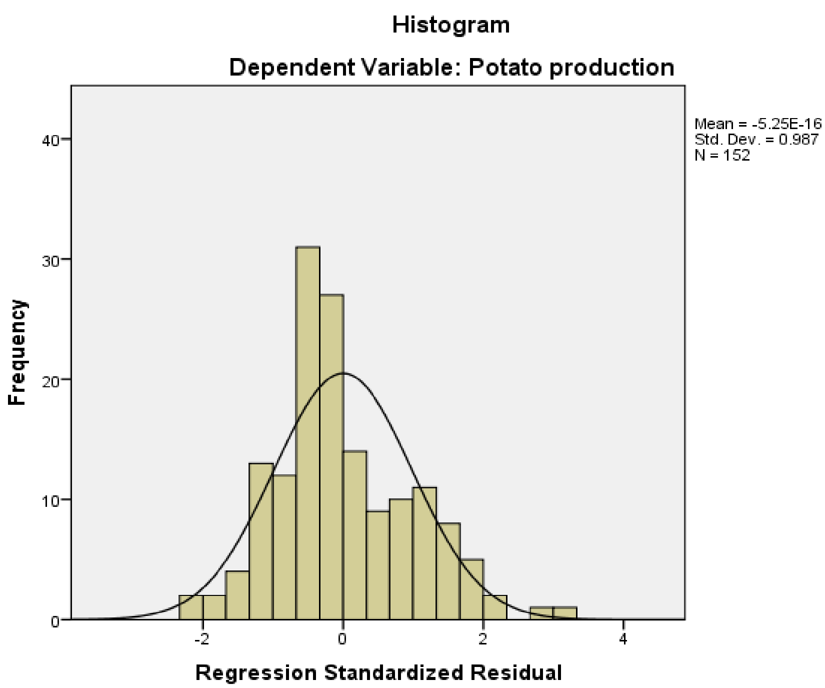
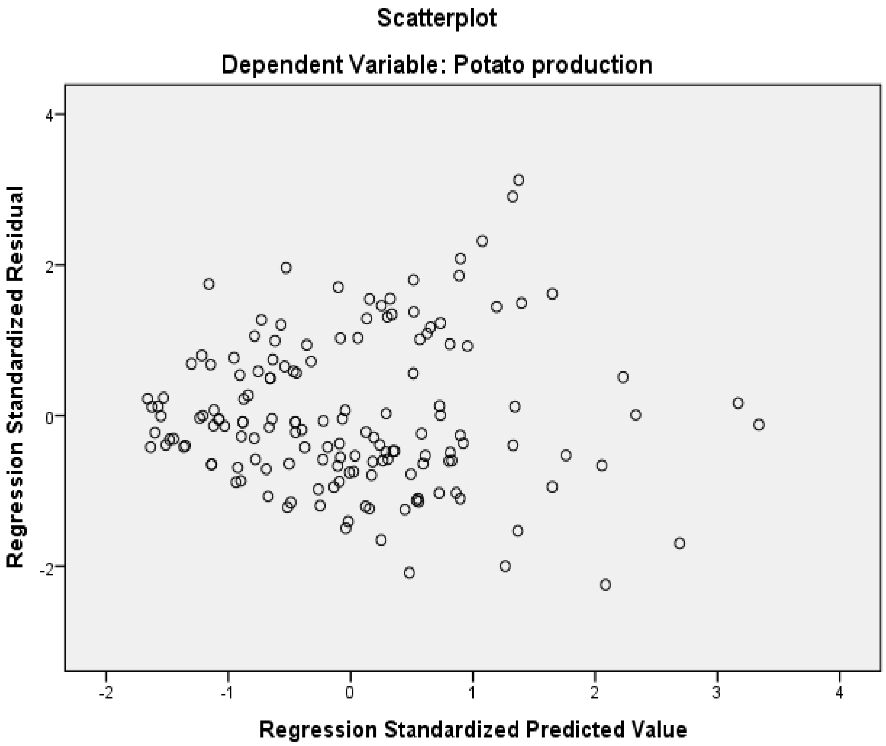


Homoscedasticity:



Multicollinearity

Variables		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Frequency of contact with advisor	.961	1.052
	Perception of usefulness of advisory services	.780	1.254
	Type of advisory information access	.926	1.179
	Use of advisory services	.825	1.251

Multiple regression analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.789[a]	.622	.618	0.9238	.622	30.396	4	147	.000

a. Predictors: (Constant), Use of advisory services, Type of advisory information access, Frequency of contact with advisor, usefulness of advisory services

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	798.433	4	199.608	30.396	.000[b]
	Residual	965.347	147	6.567		
	Total	1763.78	151			

a. Dependent Variable: Potato production

b. Predictors: (Constant), Use of advisory services, Type of advisory information access, Frequency of contact with advisor, usefulness of advisory services

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.781	.867		6.426	.000
	Frequency of contact with advisor	.881	.260	.284	3.731	.000
	Usefulness of advisory services	.427	.132	.130	1.443	.007
	Type of advisory information access	.751	.051	.754	8.952	.000
	Use of advisory services	.573	.517	.131	1.240	.000

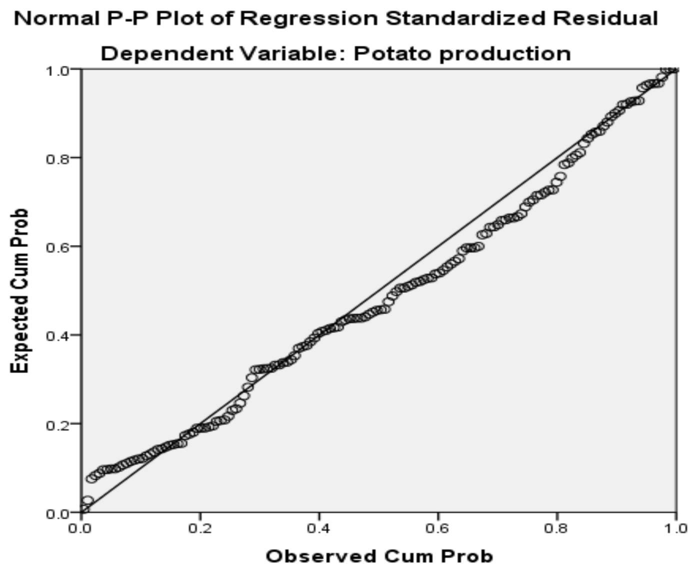
a. Dependent Variable: Potato production

b. Predictors: (Constant), Use of advisory services, Type of advisory information access, Frequency of contact with advisor, usefulness of advisory services

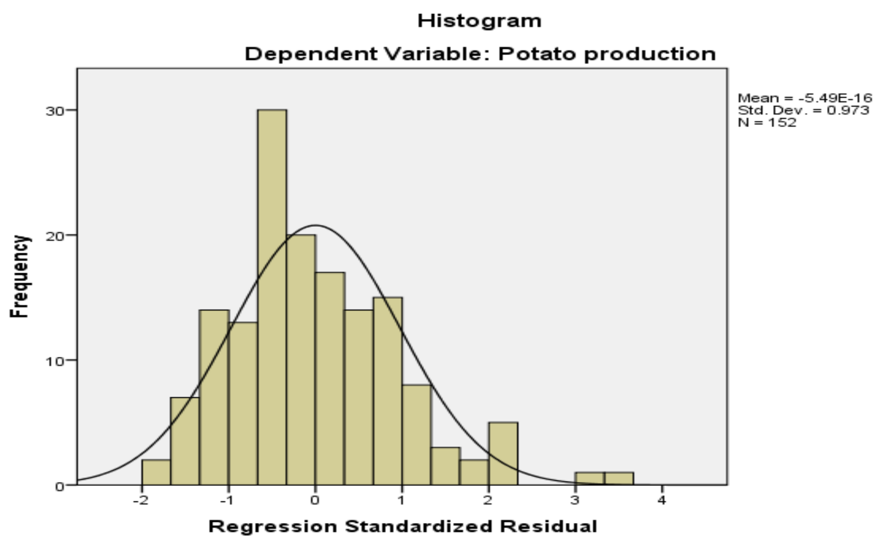
SELECTED PLANT HEALTH CLINIC TRAINING SERVICES

Model Adequacy Check

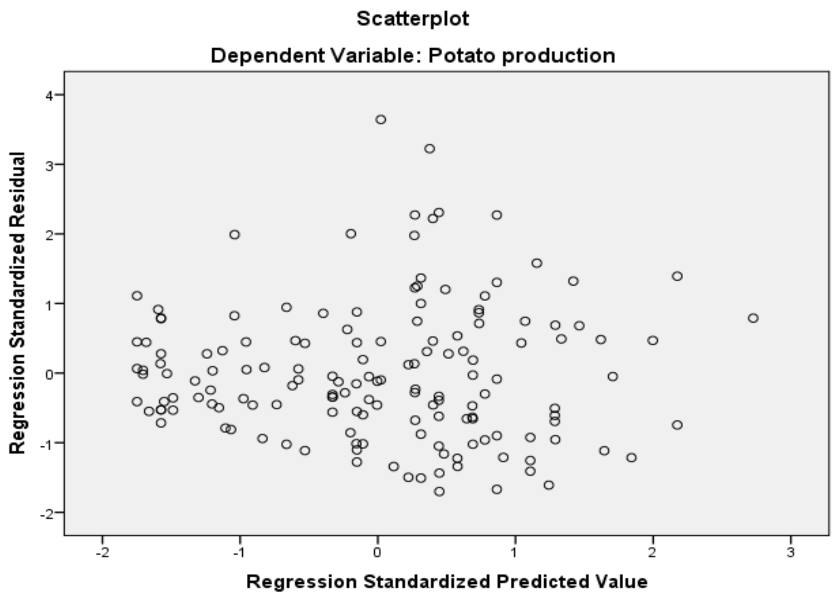
Linearity:



Normality



Homoscedasticity:



Multicollinearity:

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Type training access	.797	1.255
	Relevance of training services	.889	1.125
	Frequency of receiving training	.723	1.383
	Method of training undertaken	.864	1.157
	Use of training services	.852	1.174

Multiple regression analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.893[a]	.797	.781	0.7321	.797	86.85	5	146	.000

a. Predictors: (Constant), Use of training services, relevance of training services, modes of training, Type training access, Frequency of receiving training

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1230.415	5	246.083	86.85	.000[b]
	Residual	413.721	146	8.8336		
	Total	1644.136	151			

a. Dependent Variable: Potato production

b. Predictors: (Constant), Use of training services, relevance of training services, modes of training, Type training access, Frequency of receiving training

Coefficients

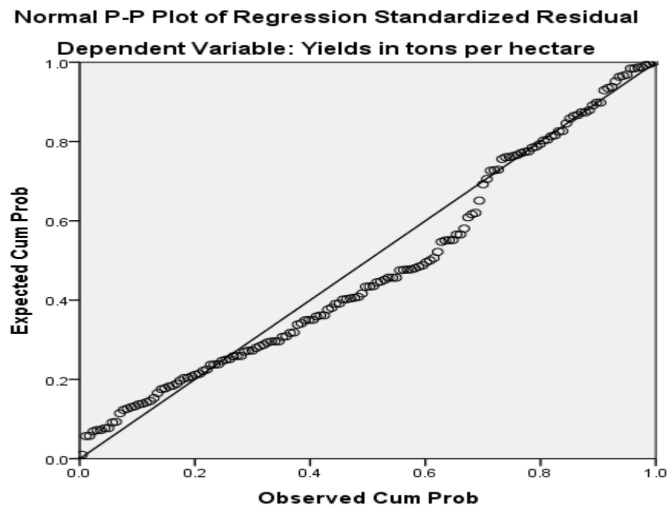
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.351	.500		3.201	.000
	Type of training access	.156	.124	.093	1.403	.003
	Relevance of training services	2.742	.300	.593	10.370	.000
	Frequency of receiving training	.121	.124	.035	.332	.009
	Modes of training	.342	.037	.381	7.201	.000
	Use of training services	.153	.461	.014	.311	.000

a. Dependent Variable: Potato production

PLANT HEALTH CLINIC DIAGNOSTIC SERVICES

Model Adequacy Check

Linearity:



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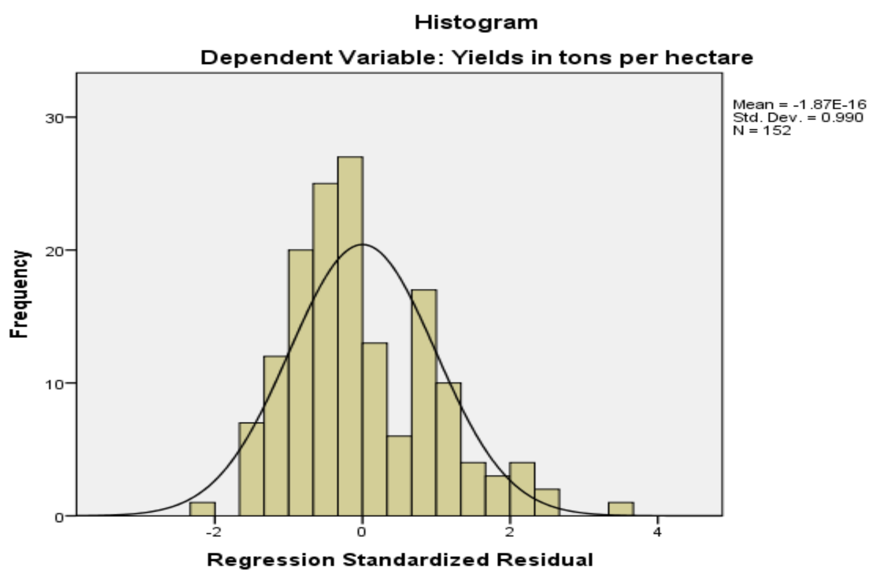
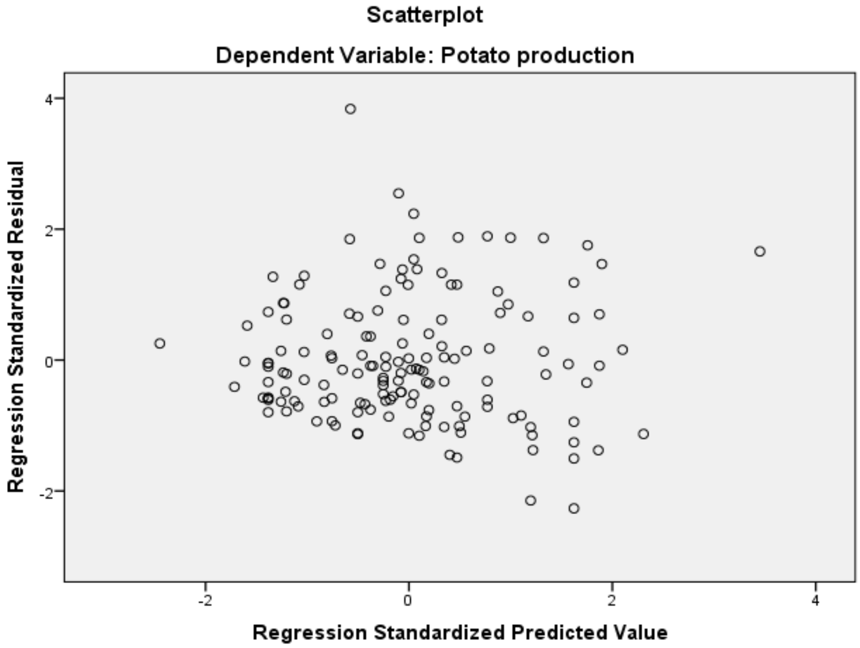


Homoscedasticity:



Multicollinearity

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Frequency of receiving diagnosis	.632	1.581
	Use of diagnostic services	.426	2.348
	Perception of the role diagnostic services	.336	2.975

Results from multiple regression on plant health clinic services

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.769[a]	.591	.590	0.809151	.591	71.335	3	148	.000

a. Predictors: (Constant), Perception of the role diagnostic services, Frequency of receiving diagnosis, Use of diagnostic services

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	857.311	3	285.770	71.335	.000[b]
	Residual	592.894	148	4.006		
	Total	1450.205	151			

a. Dependent Variable: Potato production

b. Predictors: (Constant), Perception of the role diagnostic services, Frequency of receiving diagnosis, Use of diagnostic services

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.177	.499		2.356	.000
	Frequency of receiving diagnosis	.144	.108	.085	1.337	.018
	Use of diagnostic services	1.114	.456	.144	2.444	.016
	Perception of the role of diagnostic services	4.038	.347	.679	11.639	.000

a. Dependent Variable: Yields in tons per hectare

Appendix H: The Qualitative analysis from Key Informant Interviews

Thematic analysis for interview responses from key informants on plant health clinic services and potato production

Themes	Sub-themes	Responses
Use of plant health clinic services	Are plant health clinic services use by smallholder potato farmers in your area?	Farmers prefer to use them because they are free and, they get quality services anytime they need. However, the weakness is that you find most using it once and twice per potato production season. This is low turnover compared to high demand of them to have proper skills and knowledge in improving production through crop protection.
Access plant health clinic services	Do smallholder potato farmers access services from plant health clinics in your area	Farmers access the services in plant health clinic venues, during field days, agricultural exhibitions farm demonstration, group meeting, agricultural shows, online on the Plant wise Online Management System, Farmers also call to seek for services through their cell phones.
Capacity of plant health clinic services	Comment on the capacity of plant health clinics services in disseminating services and meeting needs of potato smallholder farmers	Farmers are train and advice on how to prevent and manage pests and diseases, advice on when to plant potato, spacing, fertilization application, weeding, proper use of pesticides and chemicals, value addition, storage and harvesting technologies marketing and also importance of using certified farm inputs. Farmers receive diagnosis on insightful ways of identifying and detecting diseases and pests through diagnosis.
Challenges of potato production	What are the challenges facing potato production	Farmers practice rainfed potato production which becomes a challenge when the climate issues arise. Market prices fluctuations also is another challenge. High pests and disease infestation. Emergence of new diseases e.g., cyst is a challenge especially when these farmers don't access more frequently services such as plant health clinic that help them learn how to deal with them. High cost of quality inputs because the agro-input suppliers aren't control so they decide the prices which discourage farmers. Lack storage facilities, poor feeder roads which delay delivery to market that reduce the quality and cause losses
Improving potato production	What should be done to overcome these challenges facing potato production?	Organized markets e.g., farmers marketing potato together for a market power. Improve feeder roads to make them passable for transporting potato to the market. The government should set up subsides inputs for the farmers and enforce laws on packaging. Facilitate building storage facilities such as cold storage through the development program me plans. Encourage farmers to use quality inputs and educate farmers on the importance of seeking and demanding extension services in improvement of potato production frequently.
Challenges on plant health clinic service delivery, use and access	What kinds of problems exist in respect to accessing, using and delivery of plant health clinics	Insufficient logistics and delays in release of funds affecting timelines and few number of plant doctors are overwhelmed by work. Farmers lack bundles and airtime for online services and communication to plant doctors limiting accessibility, delivery, and utilization of the services
Improving plant health clinics	What should be done to improve the operations of plant health clinic	Increase the number of plant doctors and allocate more facilitation to increase the percentage of farmers they reach.