AGRONOMIC PRACTICES INFLUENCING SUGARCANE PRODUCTION IN WEBUYE EAST SUB-COUNTY IN BUNGOMA COUNTY, KENYA

BY

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DECLARATION

Declaration by Candidate

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

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DEDICATION

I dedicate this work to my daughter Barbra and my son Parvin who are the source of my inspiration.

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I acknowledge all persons who assisted me in one way or the other in this study. My gratitude is due to the management of Moi University, my supervisors Dr Janet Korir and Dr Fredrick Okaka not only for taking their valuable time to guide me but also for laying down the necessary foundation for me to write this thesis.

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LIST OF ABBREVIATIONS AND ACRONYMS

AID : Agency for International Development

CGB : County Government of Bungoma

CTA : Technical centre for Agriculture

DAFF : Department of Agriculture, Forestry and Fisheries

DECRM: Delegation of the European Commission Republic of Mauritius

DF : Degree of Freedom

EPA : Environment protecting agency

FAO : Food and Agriculture Organization

FAOSTAT: Food and Agricultural Organisation of the United Nation Statistics

FYM : Farm Yard Manure

GDP : Gross Domestic Product

GoK : Government of Kenya

K : Potassium

KENHA: Kenya National Highways Authority

KESREF: Kenya Sugar Research Foundation

KIIs : Key Informant Interviews

KNBS : Kenya National Bureau of Statistics

KSB : Kenya Sugar Board.

KSI : Kenya Sugar Industry

LS : Level of Significance

MAFAP: Monitoring African Food and Agricultural Policies project.

MSC : Mumias Sugar Company

N : Nitrogen

NACOSTI: National Commission for Science, Technology and Innovation

NWFP : North West Frontier Province of Pakistan

OECD : Organisation for Economic Co-operation and Development

P : Phosphorus

SRI : Sugarcane Research Institute

TRS : Theoretically Recoverable Sugar.

WADE: World Alliance for Decentralized energy

WES : Webuye East Sub-county

ABSTRACT

Sugarcane production in Kenya has been on a decline over the last two decades leading to the need for importation of sugar to meet the country's increased demand. Webuye East Sub-County is one of the important sugarcane production areas in western Kenya, but has also witnessed reduced production in sugarcane. This decline has mainly been attributed to fragmentation of land due to rapidly increasing population. However, little focus has been made on establishing the effects of agronomic practices on sugarcane production in the Sub-county. Therefore, this study was designed to assess the major agronomic factors that influence sugarcane production in Webuye East Sub-county in Kenya. The specific objectives of the study were: To assess the influence of field crop production practices on sugarcane production; To examine the influence of special purpose plant improvement practices on sugarcane production; To determine the influence of soil management practices on sugarcane production; To determine how planting season and harvesting management influences sugarcane production in Webuye East Sub-county. Through this study, it is expected that sugarcane farmers will understand effects of agronomic practices and do away with inappropriate practices in their farm, the government will achieve its goal on better distribution of rural income, sugarcane stakeholders will initiate programmes and policies geared towards improving production of sugarcane and the study contributes important knowledge and facilitate learning on sugarcane farming sub-sector. The study was anchored on Cobb Douglas (1928) production theory. Descriptive survey research design using mixed methods approach was used to elicit data from the study participants. A sample of 96 respondents based on Kothari's (2004) was systematically sampled from the target population of 6135 registered sugarcane farmers. In addition 10 farmers, 5 field officers and 8 weigh bridge workers of West Kenya Sugarcane Company in Webuye East Sub-County were purposively sampled as key informants. Questionnaires, interviews, observation and documentary analysis were the main data collection tools. Quantitative data were analyzed using percentages and frequencies and further subjected to inferential analysis using the Chi-square. Qualitative data were thematically analyzed. The study found out that a farmer could achieve on average, 23.1% more tonnage of sugarcane in an acre of land when important agronomic practices such as weeding, pest and disease control, ratooning, earthing up and raw spacing were practiced. By using the Chi-square (at 0.05 level of significance) the study established that there were a positive significant relationship between important agronomic practices and sugarcane production. It was concluded that agronomic practices significantly influenced cane production. This calls for efforts by all stakeholders to put in place intervention measures that can improve cane yield. Key among the measures includes; enhanced extension services such as information on technology of cane husbandry, harvesting technology and planting technology. This study further recommends that public meetings for sugarcane farmers be held regularly in every ward in the sub county to sensitize farmers on best sugarcane agronomy, loan services in form of materials be offered and farmers to be assisted in preparing land for planting to ensure deep tillage has been done.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

In 2012, Food and Agricultural Organization (FAO) of the United Nations estimated that sugarcane was cultivated on about 26×106 hectares (6.4×107 acres), in more than 90 countries, with a worldwide harvest of 1.83×109 tonnes (1.80×109 long tons; 2.02×109 short tons) (FAO, 2015) and was ranked as the world's largest crop production by quantity. The world's largest sugar producing countries in 2018 were Brazil, India, the European Union, China and Thailand (Food and Agricultural Organization of the United Nations Statistics FAOSTAT, 2019). About 70% of the sugar produced globally comes from S. *officinarum* and hybrids using this species. Other species of sugarcane include *Saccharum sinense, Saccharum barberi, Saccharum robustum* and *Saccharum spontaneum* (Daniels & Christian 1993; Paterson *et al.* 2012). It is noted that important sugar producing countries in Africa include Mauritius, Kenya, Sudan, Zimbabwe, Madagascar, cote D'Ivore, Ethiopia, Malawi, Zambia, Tanzania, Nigeria, Cameroon and Zaire. In general, Africa grows about 5% of world production, 30% of which comes from east Africa (Girei & Giroh, 2012).

Kenya is one of the major sugarcane producers in the East Africa region. Sugarcane is the second largest contributor to the Kenya's agricultural growth after tea (FAOSTAT, 2013). According to Sugar Research Institute SRI (2017), historically, the growing of sugarcane in Kenya started with the involvement of the Kenya Government at the turn of the century, with the establishment of experimental farms at Mazeras and Kibos, whose sole activity was to evaluate sugarcane and other crops. Subsequently, large production of sugarcane started in 1923 when a sugar factory was built at Miwani in the current Kisumu county and at Ramisi Kwale county (SRI, 2017). After independence, the Kenya Government started playing a central role in the ownership and management of the sugar industry. In addition, five more factories were established, namely Muhoroni (1966), Chemelil (1968), Mumias (1973), Nzoia (1978) and South Nyanza (1979) (SRI, 2017). Private investors have also built sugar factories in West Kenya (1981), Soin (2006), Kibos (2007), Butali (2011), Transmara (2011), Sukari (2012), Kwale international sugar company limited at Ramisi (2015) (SRI, 2023). Mbendi, (2016), notes that there are 3 sugar belts in Kenya, namely the Nyando, the western sugar belt and the south Nyanza sugar zone. Today sugarcane is grown for white sugar production in Nyando, South Nyanza, Mumias, Nzoia and Busia by small, large scale farmers and sugar factories.

In Kenya, the area under cane is 202,000 ha which gives a total production of 5.262 million tonnes of cane that is supplied to factories per year (Mati and Thomas, 2019). The sugar sub-sector consists of more than 250,000 smallholder farmers, who supply over 92% of the sugar cane processed by sugar companies while the remainder is supplied by factory owned nucleus estates (Kenya Sugar Board KSB, 2010). Kenya's annual production in 2018 was at 491,097 metric tons. This does not meet the country's annual demand which was estimated at 1,012,399 metric tons in 2018 (Kenya Sugar Directorate KSD, 2019). Consequently, sugar is imported.

The sugar sub-sector plays an important role in the country's economy. It generates an estimated KES 12 billion annually, provides about 500,000 jobs and supports livelihood of about six million people (KSI, 2009). Odenya *et al.* (2007) indicated that an estimated 25 percent of the country's population depended directly or indirectly on the sugar industry for their livelihood. It has created employment opportunities for many Kenyans in which people have been employed in the sugar estates and factories. They further indicate that the establishment of sugar mills in the growing areas has contributed to industrial developments and has contributed to the growth of towns in the growing areas such as Muhoroni, Awendo, and Mumias. Also, it has provided raw materials for other industrial plants such as those manufacturing industrial spirits.

Despite the importance of the sugar sub-sector, the sugar industry in Kenya has struggled for many years for various reasons, such as lack of accountability and transparency, poor management, excessive taxation and delayed payments to farmers to name a few (KSB, 2009). There has been a decline in cane production per given unit area and hence an increase in poverty for approximately 6 million people who depend on sugarcane farming either directly or indirectly (KSB, 2008). KSB, (2016) found out that on average, cane production stands at 60 tonnes per hectare. This concurs with a study by Wekesa *et al.*, (2015) who found a reduction of 33 percent from the 1996 level of 90 tonnes per hectare. During the year 2018, local sugar production was about 490,704 tonnes which is only 57% of the domestic demand that currently stands at 850,000 tonnes (republic of Kenya, 2020). The reasons for this low in productivity include the widespread use of low quality sugar cane varieties, poor agricultural and land management practices and delayed harvesting of mature sugarcane (KSB, 2010). Moreover, most farmers grow cane varieties that are susceptible to the major diseases such as smut, mosaic and ratoon stunting. These factors coupled with poor crop management practices leads to low yields per unit area.

Wepukhulu *et al.* (2016) observed that sugar cane production in Kenya has been on the decline mainly because of poor information flow from extension officers to the farmers. Yield declined from 71 tons per hectare to 60 tons per hectare among the out growers between 2004 and 2015 (Wepukhulu *et al.,* 2016). Like in other areas, the sugarcane yields among the farmers of Webuye East Sub-county have been on the decline while the cost of producing sugar cane have been rising resulting in losses. Webuye East Sub-county falls within the area under Nzoia and West Kenya Sugar Companies. These two companies rely on sugarcane from this area and since cane produced in the region is not enough, the region has become a conflict zone for sugarcane between the companies.

Although Engel's law (1857) suggests that relative importance of agriculture declines as economy grows, agriculture is still critical for such transformations to occur. The neglect of sugarcane growing practices by the farmer has contributed to the low productivity and profitability of the sugar industry in Kenya (Obange, 2018). This confirms the need for the farmers to implement better sugarcane production practices in their farms. Research is also needed to not only come up with high yielding breeds that do well under the conditions in Kenya but also to identify the factors that contribute to the decline in production of sugarcane. Existing studies have tended to focus on the socio-economic and physical factors affecting production yet agronomic practices have been identified as important drivers of crop production (GoK, 2008) sugarcane being included. It is against this background that this research on agronomic factors influencing sugarcane production needed to be done in Webuye East sub-county. This study aimed to establish the influence of these factors on sugarcane production and to what extent these factors influence production of sugarcane in the sub-county.

1.2 Statement of the Problem

The sugar industry plays a significant role in Kenya's economy, contributing about 15 percent to the country's agricultural Gross Domestic Product (KSI, 2009). It is estimated that 25 percent of the country's population depends directly or indirectly on the sugar industry for their livelihood (Odenya *et al.*, 2007). Kenya's annual sugar production stands at 491,097metric tons while its annual demand is 1,012,399 metric tons which has led to importation of sugar (KSD, 2019). There has been a decline in cane production per given unit area which has contributed to an increase in poverty for approximately 6 million people who depend on sugarcane farming either directly or indirectly in Kenya (KSB, 2008). Despite government investment in sugar mills, the country still has not reached self-sufficiency in sugar production. For this reason, it is unlikely that Kenya will achieve its stated goal of becoming a net exporter of raw sugar in the year 2030. In Webuye East Sub-county, there had been a decline in sugar production most often attributed to fragmented land under sugarcane production due to increase in population. Consequently, leading to reduction in the amount of cane supplied to the companies that depend on sugarcane from the area. However, although land is one of the factors of production that cannot be increased but its returns can be increased through special purpose plant improvement practices and soil management practices hence a research on agronomic practices influencing the production of sugarcane was of great benefit.

Generally, from existing literature, studies in Kenya have mainly focused on physical, socio-economic and biological factors influencing sugar production with little attention on agronomic factors. Therefore, this study was designed to address this gap in knowledge by assessing the agronomic factors influencing sugarcane production in Webuye East sub-county, Bungoma County, Kenya. Webuye East Sub-county was a high potential sugar cane production area in western Kenya, hence was the focus of this research.

1.3 Objectives of the Study

The general objective of the study was to assess the major agronomic factors that influence sugarcane production in Webuye East Sub County in Kenya. Specific objectives included:

1.3.1 Specific objectives

1. To assess the influence of field crop production practices such weeding, pests and disease control and ratooning on the sugarcane production in Webuye East Sub County, Bungoma County.
2. To examine the influences of special purpose plant improvement practices such as raw spacing, sugarcane varieties and earthing up on the sugarcane production in Webuye East Sub County, Bungoma County.
3. To determine the influence of soil management practices such as land preparation, mulching, fertilizer application and farm yard manure application on sugarcane production in Webuye East Sub County, Bungoma County.
4. To determine how planting season and harvesting management influences sugarcane production in Webuye East Sub-county, Bungoma County.

1.4 Research Hypotheses

H_1 There is no significant relationship between field crop production practices and sugarcane production in Webuye East Sub County in Kenya.

H_2 There is no significant relationship between special purpose plant improvement practices and sugarcane production in Webuye East Sub-County in Kenya.

H_3 There is no significant relationship between soil management practices and sugarcane production in Webuye East Sub County in Kenya.

1.5 Significance of the Study

From the finding of this study, the sugarcane farmers will be informed of the effects of agronomic practices, such as soil management, weeding, mulching, pests and diseases control, plant density and spacing and fertilizer application on the sugarcane production in their sub-county. The knowledge will enable sugarcane farmers to do away with inappropriate practices in their farms and increase cane production.

Sale of sugar drives the economic growth for the rural areas. The earnings from the sale of sugarcane has led to better living standards of the rural population. An improvement in sugarcane production is in the harmony with the government's goal on better distribution of rural income. This is through the government gaining a major increase in the proportion of farmers who receive a cash income from their land and for the country becoming a net exporter of sugar. This research was geared towards improving production of sugarcane so as to achieve this goal. Also the sugarcane farmers and Kenya at large are able to identify convenient ways of managing sugarcane crop in farms to reduce the impact of pests and diseases.

From the recommendations, the Webuye East Sub County officials, West Kenya sugar company and Nzoia Sugar Company through the national government will be able to initiate programmes and policies geared towards addressing the agronomics practices hence improving production of sugarcane in the county.

This study contributes to important knowledge on sugarcane farming by providing empirical evidence on agronomic practices on sugarcane production and facilitated learning on sugarcane farming sub-sector in terms of the impacts of agronomic practices on sugarcane production. This has been made possible through publication of the findings and recommendations concerning the impacts of agronomic practices on sugarcane production.

1.6 Scope of the Study

This study focused on the agronomic practices influencing sugarcane production among sugarcane farmers in Webuye East Sub County. Sugarcane is not grown in the whole study area but only in certain parts where the study was limited to. This comprised three wards namely; Ndivisi, Mihuu and Maraka in Webuye East Sub County. The study focused on both plantation and small scale sugarcane farms located within the sub county. The respondents included sugarcane farmers, field officers and weigh bridge workers of the West Kenya Company.

Sugarcane production is not only influenced by agronomic factors but also influenced by biological, socio-economic and physical factors. However, the study was centered on agronomic practices which included special purpose plant improvement practices; soil management; planting season and harvesting season.

This study utilized descriptive survey design where systematic sampling was conducted. Research tools and data collection techniques included questionnaires, observation and photography, KIIs and content analysis. The research was also based on Cobb Douglas theory of production.

1.7 Area of Toe Study

1.7.1 Geographical location

Webuye East Sub County is located in Bungoma County in Western Kenya. It is one of the sub counties in Bungoma County with three wards, Mihuu, Ndivisi and Maraka. The sub county lies within the coordinates $34^0$40'E to $34^0$48'E and $0^0$35'N to $0^0$45'N and covers an area of 161.8km^2.

1.7.2 Economic activities

Agriculture is the main economic activity in the sub county with sugar cane and maize the major crops grown. Most farming activities take place during the long rains. However, with the introduction of short season variety seeds, most farmers plant food crops during both long and short season rains. This accounts for a large part of the sub-county's income. Due to mismanagement of potentially lucrative industries, disillusioned farmers have resorted to subsistence farming to put food on the table, and selling their land to real estate developers. Sugarcane is the main cash crop that is grown in the region due to favourable physical conditions such as high rains that is well distributed throughout the year and high temperature which supports faster growth of sugarcane in the farm.

1.7.3 Population

Webuye East Sub County has a total population of 114,548 people (Government of Kenya GoK, 2019a) that comprises of 55775 male, 58771 female and 2 intersex. The sub county has a growing population with varying demographics, which include fertility, mortality, birth rates, migrations, immigrations among others. The high population pressure in the County has led to encroachment on wetlands, riverbanks and protected forests for farming purposes (GoK, 2009a).

The capacity to increase agricultural production through the expansion of land under cultivation has reduced in many parts of the Webuye East Sub County. Many hectares of land that were once known as ‘land surplus’ have been converted into what is known as ‘labour surplus’ as the countryside population in the area continues to rise significantly. Due to the limited availability of land in Webuye East Sub County, land has been continuously overused leading to degradation. There is a demand to adopt the ‘science based’ method in order to achieve better yield. This involves the utilization of modern agronomic practices that provide the maximum production which can be achieved per hectares as opposed to resource-based.

1.7.4 Relief

The major relief feature in the sub-county is Chetambe hills. River Nzoia and Kibisi traverse the sub-county and Nabuyole falls is the magnificent waterfall within Webuye East sub-county. The sub-county is underlain by granite which forms the basement system. The sub county is well drained due to the gentle topography. The gentle topography of the area has favored mechanization to be carried out on sugarcane growing in the area. The drainage pattern is radial to parallel on the upper and mid-slopes respectively (County Government of Bungoma (CGB), 2013).

1.7.5 Climate

The Sub County experiences two rainy seasons, the long and short rains. The long rains are received from March to July, while the short rains are expected from August and continue up to October. The annual rainfall in the sub county ranges from 400mm (lowest) to 1,800mm (highest). Webuye East Sub-county has an average temperature of 20.3^0 C which is suitable for sugarcane farming.

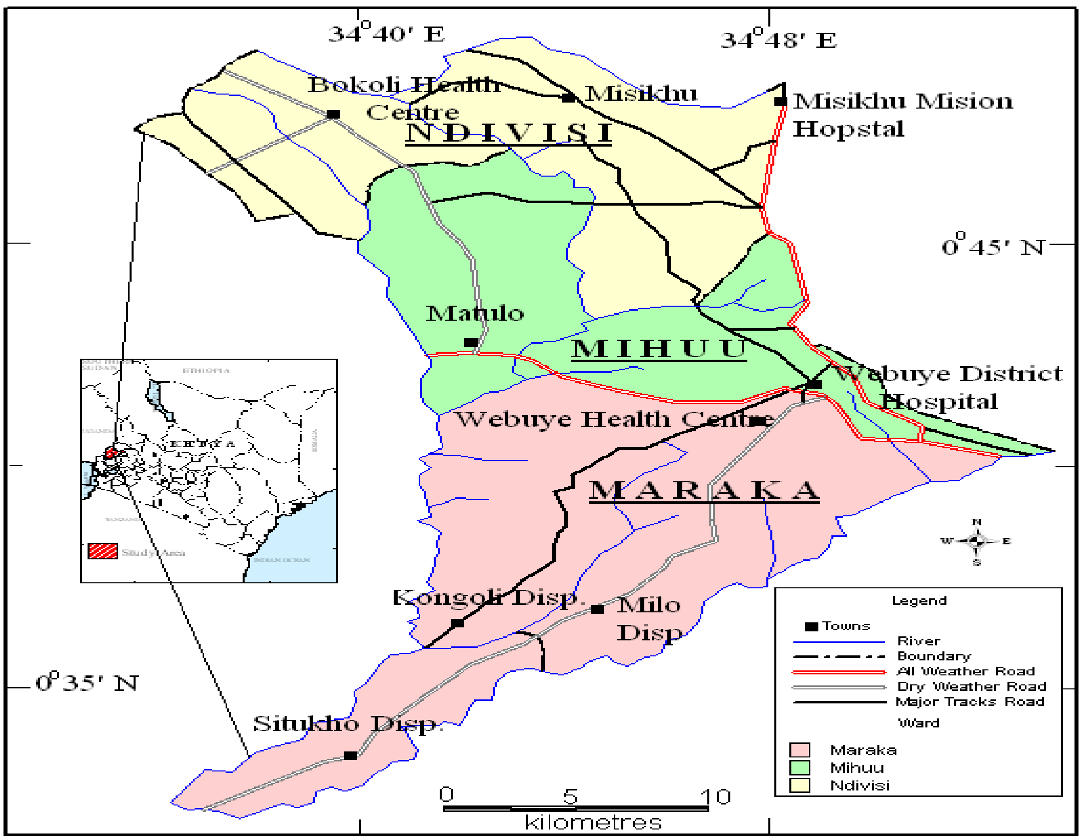

Figure 0.1: Map of Webuye East Sub-county

Source: *Moi University Department of Geography and Environment Studies GIS Lab, 2019.*

1.8 Operational Definitions of Significant Terms

Agronomic practices

This study defined agronomic practices as a scientific management process involved in sugarcane production and soil management for the attainment of better yield. Agronomic practices included soil management, weeding, mulching, pests and diseases control, plant density and spacing, fertilizer application, sugarcane varieties, land preparation, farm yard manure, harvesting and ratooning.

Field crop production practices

This study referred to field crop production practices as principles and practices of general field management to enhance productivity and quality. These practices include weeding, pests and disease control and ratooning.

General field management

General field management refers to In-field management practices such as weeding, pests and disease control and ratooning.

Harvesting management

Harvesting management refers to the system of handling and transporting sugarcane during and after harvesting to reduce wastage of agricultural produces.

Soil management

This study referred to soil management as the agronomic practice meant to improve soil condition and needs such as mulching fertilizer and manure application and land preparation so as to enhance its performance.

Special purpose plant improvement practices

These are specific agronomic practices that are performed on a specific plant in the field to improve the quality of the plant thereby increasing the production of the crop.

Sugarcane Production

In this study sugarcane production referred to quantity of sugarcane harvested per acre plot expressed in tonnes as recorded at the weigh bridge.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter indicates the link between the study objectives and the major theories upon which literature review has been done. It integrates and summarizes ideas related to agronomic practices that influence sugarcane production from scholars. This chapter also looks at the theoretical and conceptual framework related to the area of study.

2.2. Sugarcane Growing

Daniel and Roach (1987), defines sugarcane as the various species of tall perennial true grasses that belong to the genus saccharum, tribe Andropogonea, native to the warm temperate tropical regions of South Asia and Melanesia which is used for sugar production. In addition, sugarcane has stout, jointed and fibrous stalks which contain sucrose that accumulate in the internodes. Sugarcane is two to six meters tall when mature. All sugarcane species interbreed but the main commercial cultivars are complex hybrids. They further indicate that the plant belongs to the grass family poaceae which is an economically significant seed plant family that includes rice, maize, sorghum, wheat and many forage crops.

Although sugarcane has its roots in tropical South and South East Asia, different species originated from various locations, with *Saccharum edule* and *S. officinarum* having their roots in New Guinea and *S. barberi* in India (Sharpe, 1998). Ellen (2004) notes that Northern India is known to be the earliest production of crystalline sugar though the exact date is unclear. She adds that Arab traders and Muslims introduced sugar from South Asia to other areas of the Abbasid Caliphate within the Mediterranean, Mesopotamia, Egypt, North Africa and Andalusia at around 8th century. By around 10th century no village in Mesopotamia did not grow sugarcane. Ellen (2004) further indicates that sugarcane is one of the crops that was introduced in America by the Spanish majorly Andulasians from the fields in Canary Islands and from Madeira Islands by the Portuguese.

Currently, cultivated sugarcane varieties are hybrids derived from breeding the species of commercial importance. The effects of this breeding is development of hybrid sugarcane varieties that incorporate hardness and vigour of *S. sinense* and *S. spontaneum* with high sugar content of *S. barberi* and *S. officinarum* (Ogarnization for Economic Co-operation and Development OECD, 2002). Modern stem cutting is the commonly used reproduction method although some sugarcane produces seeds (Nasir, 2010). Once planted, sugarcane can be harvested a number of times and after each harvest, new stalks known as ratoons are send up.

Perez (1997) says that farming of sugarcane in Kenya has provided sugar for domestic consumption hence saving foreign exchange which would have been used for importation of sugar. She adds that farmers earn a living through the sale of sugarcane hence raising their living standards. Moreover, sucrose is used as raw material in food industry and fermented to produce ethanol. Sugarcane gives rise to products such as sugar, falernum, rum, molasses, bagasse and ethanol. In addition, sugarcane reeds are used to make screens, pens, thatch and mats. Apart from being a cash crop, sugarcane is also a livestock fodder. Dried filter cake is used as a supplement to animal feeds, source of sugarcane wax and fertilizer. Bagasse is used as fuel for the boilers and kilns, paper production, reconstitutes panel board, production of chemicals, agricultural mulch and paperboard products (Environment Protecting Agency EPA, 2005). Further, Sugarcane is one of the plants that has highest bioconversion efficiency. Sugarcane can fix solar energy hence give rise to around 55 tons of dry matter per hectare of land per year.

The worldwide energy potential from baggase is over 100 000 Gwh with a total global harvest of over one billion tonnes of sugarcane annually (World Alliance for Decentralized Energy WADE, 2004). An annual of 10 000Gwh of extra electricity can be produced throughout Africa when Mauritius is used as a reference point (Pollan, 2003).

To add on, Pollan (2003) notes that sugarcane can solve challenges that confront the government officials and worldwide leaders because the plant has the capacity to create jobs, help provide a healthier cleaner planet, reduce carbon dioxide emissions and reduce petroleum use. Sugarcane ethanol when compared with gasoline cuts carbon dioxide emission by 90% hence reduces the level of greenhouse gases in the atmosphere. In addition, WADE (2004) indicates that when diesel and gasoline are replaced with ethanol, it will reduce hospital admissions, save life and improve air quality. These benefits, necessitates a research on agronomic factors influencing sugarcane production so as to increase the production of sugarcane and maximize the importance that can be derived from the crop.

2.3 Field crop production Practices

2.3.1 Weeding

Sugar Research Institute [SRI] (2015), defines weeds as a plant which is considered undesirable or troublesome or unattractive growing where it is not wanted. Therefore, they are unwanted intruders into agro-ecosystems that compete for limited resources. Linda (2005) observed that weeds are the main factor that sets back sugarcane production in Louisiana. The competition for light, space, water and nutrients between the crop and weeds can lower sugarcane stalk population and yield (Linda, 2005). Weeds emerging with the crop may lower tillering of cane and hinder growth hence resulting in low yields during harvest. Nazir *et al.* (2013), indicates that weeds restrict moisture, nutrients, light and serve as alternative hosts for insect pests to sugarcane crop. SRI (2015) further indicates that presence of weeds in cane field at the age of 3-4 months of cane growth affect tiller growth, number and development of millable stalks and will compete with sugarcane for sunlight and plant nutrients.

Sugarcane weeds that are perennial and most problematic are Johnson grass and Bermuda grass that survives from year to year through production of an underground network of fleshy stems called rhizomes (Linda, 2005). In Kenya, there are two types of sugarcane weeds classified as grasses and grass-like that are found in most sugarcane farms, though there are 150 species that have been seen in fields of sugarcane in various zones within the country (SRI, 2015).

Nazir *et al.* (2013) noted that a key factor for controlling weeds is proper land management and recommend the use of Gesapax combi at 1.4 kg per acre in medium textured soils and 1.8 per acre in heavy soil in 100 to 120 liters of water. They further indicated that generally three weedings are carried out in Pakistan sugarcane fields which are done manually by hoeing and by use of tractor before cane matures. On the other hand, Linda (2005) suggests that weeds can be controlled through fallowing and planting early - maturing glyphosate - resistant soybeans on sugarcane farms and apply glyphosate to control weeds. Department of Agriculture, Forestry and Fisheries DAFF (2014) of South Africa adds that it is important to spray herbicides so as to prevent competition of weeds and decrease in production of sugarcane. SRI (2015) adds that though weeds may be present in any sugarcane farm, these weeds differ from location to location due to variations in agro-chemical conditions and management practices. SRI (2015) adds that depending on weather conditions, four or more hand weeding is needed to achieve good crop yield during the first 3-4 months of cane or active tillering stage. Control of weeds is done culturally by intercropping, crop rotation and mulching, mechanically by hoeing with hand and chemically by spraying using chemicals like glyphosate (SRI, 2015). The negligence towards weed management in the cane industry is a big problem under various agro-chemical situations. Therefore, a study on weed control and how they influence sugarcane production in different locations is essential.

2.3.2 Pests and disease control

SRI (2015) indicates that pests and diseases on sugarcane are among the important factors affecting the productivity of cane. It adds that in Kenya, 30 diseases including major and minor diseases caused by fungi, bacteria, viruses and phytoplasma were recorded on commercially cultivated sugarcane varieties. The diseases identified by SRI (2015) include sugarcane smut , ratoon stunting, red rot, pineapple, sugarcane rust, and sugarcane mosaic virus. DAFF (2014) argues that pests such as eldana borer cause severe loss in cane quality and reduce cane weight. These pests are controlled through natural control by parasites, biological control such as varietal resistance and chemical control by using recommended insecticides. Further, it adds that, diseases such as eye spot, brown spot, pokkah boeng, gumming, red rot, rust, leaf scald, mosaic, smut and ratoon stunting attack sugarcane and reduce yield. These diseases are controlled through use of healthy seed cane, sterilizing cane knives and harvesters' blades, use of resistant varieties, eradication of volunteers before replanting and use of approved chemicals.

Sugarcane crop is protected from a variety of pests, diseases and weeds by use of agricultural chemicals. Herbicides constitute 90% of the pesticides that are used in sugarcane farms in Australia (Christiansen, 2000). Herbicides are applied within the crop and in other parts of the farm to reduce nesting places and sources of food for rats. In addition, fungicides and rodenticides are used to control fungal diseases and rodent pests respectively. Also, insecticides are used to control pests. These involve controlled release of chlorpyrifos and imidacloprid to reduce cane grubs in Australia (Allsopp, 2010) or carbofuran to control borders in Florida (Hall *et al.*, 2007).

Garside and Bell (2007) point out that the alternation of sugarcane with a different crop may assist to reduce the development of disease, avail nitrogen for the upcoming sugarcane crop and give ground cover to curb soil erosion. They add that, experiments have shown that planting a legume crop to break monoculture of sugarcane crop increases the yield of the following sugarcane plant crop and the subsequent ratoon crops in Australia. This may be attributed to a drop in soil nematodes which damage feeder roots and root hairs, further reducing a plant's effective extraction of water and nutrients from the soil. Research in South Africa proved that certain type of green manure crops reduces the number of nematode species whereas others resulted in increased nematode population (Berry and Rhodes, 2006). In Zimbabwe, research by Shoko and Zhou (2009) noted that there was a decrease in the number of nematodes in sugarcane field following a soybean rotation.

Santo *et al*. (2000) notes that during the last two decades, the three sugarcane insect pests were the yellow sugarcane aphid, the New Guinea sugarcane weevil and the lesser cornstalk borer. However, modification of cultural practices, selection of insect tolerant cultivars and bio-control of the insect pests are some of the control methods that can be utilized. Because of the potential harm to the insects that are beneficial, insecticides are not used. They add that the major diseases of sugarcane in Hawaii are pineapple disease, rust, eyespot, smut, ratoon stunting, yellow leaf syndrome and leaf scald. The sucrose level can be interfered by: white scale pest, cane premature harvesting, smut disease, harvesting cane during the short rainy season and delays between burning and crushing the cane. This study is designed to look at how diseases and pests control affect sugarcane production in Webuye East Sub-county

2.3.3 Ratooning

Ratoon cropping which is a form of farming where the base of the sugarcane plant is left to regenerate the next season. This has demonstrated to be cost effective for most sugarcane growers (Nazir *et al*., 2013). Despite the fact that the yield of the ratoon crop diminishes after each cutting, ratoon cropping allows sugarcane farmers to harvest their cane several times before replanting. Ratoon cropping farmers have the capacity to generate higher margins than those who use traditional methods since ratoon farmers do not pay for preparation of land and seed every growing season (KSB, 2012). Mumias and Nzoia are the only sugar companies that produce ratoon crop in Kenya. Nazir *et al.* (2013) indicate that production costs when using ratoon cropping are significantly lower than when traditional methods are applied.

Shukla *et al.* (2013), reports that ratoon in sugarcane saves seedbed preparation cost, materials for seeds and planting operations. Though ratoon crop yields are lower when compared to plant crop. Malik (1997) reports that more than half of total sugarcane grown is kept as ratoon crop in the province of Punjab. On the other hand, he argues that in excess of 35% of ratoon sugarcane production is lost as a result of improper attention of the sugarcane farmers towards ratoons.

Generally, the productivity of ratoon is 10 to 30 percent below the plant crop of sugarcane. Low yield of ratoon crop is majorly as a result of low and differential ratooning capabilities of cultivars and sub-optimal crop management (Aamer *et al.*, 2017). They further suggest that the underlying reasons for low yield of ratoon cane crop are low fertility of soil, improper planting methods, sub-optimal plant population density and poor management. In addition, Myeni and Malaza (2009) argue that there is an inverse relationship between the age of the ratoon and the yield of the crop. This necessitates the adoption of suitable agronomic practices for harvesting good yield of ratoon crop. Ratooning is practiced in

Webuye East Sub-county; however, its effect on sugarcane yield and the reasons for practicing it need to be known.

Obange (2018) focused his study on socio-economic determinants of sugarcane production among small scale farmers in Nyando Sugar belt of Kenya. Obange (2018) concluded that the variable input costs such as weeding and weed control cost, seed cane, planting cost, land preparation cost and fertilizer application cost significantly affected sugarcane production in Nyando sugar belt. However, he did not consider the agronomic practices that should be done in sugarcane field to improve production of the sugarcane crop.

2.4 Special purpose plant improvement Practices

2.4.1 Row spacing

The yield of sugarcane is affected by the spacing between the rows (Garside *et al.,* 2009). Studies have been developed to determine the ideal spacing between sugarcane rows with results found to be specific to local climatic conditions and soil as well as to sugarcane varieties and use of inputs (Omoto *et al.,* 2013). In South Africa, closer spacing tends to result in higher yields provided there is adequate moisture in the soil. Row and plant spacing for manual planting is 1.0m to 1.3m by 0.5m. For normal mechanical operations, the best row spacing is between 1.4m and 1.6m (DAFF, 2014). In Kenya, sugarcane is planted in wider row spacing of 1.2m to 1.5m; however, many growers are reluctant to widen row spacing for fear of yield penalties (SRI, 2015). On the other hand, Omoto *et al.* (2013) indicates that the production of seed cane yield grown at a row spacing of 0.4m, 0.5m and 0.6m greatly exceeded that grown at the standard 1.2m row spacing. They further indicated that seed cane grown at row spacing of 0.5m to 0.6m is of more value to farmers than that grown at row spacing of 1.2m. This study intends to establish the types of sugarcane row spacing adopted by farmers in Webuye East and the impact they have on sugarcane yield.

2.4.2 Sugarcane varieties

Commercial sugarcane hybrid cultivars have emerged through intensive selective breeding of species in the Saccharum genus, mainly encompassing crosses between *Saccarum officinarum* and *Saccharum spontaneum*. *Saccharum officinarum* stores very high amounts of sucrose in the stem but is highly vulnerable to diseases (Lakshmanan *et al.,* 2005). *S. spontaneum* has thinner stalks, accumulates small amount of sucrose and has higher fibre content but it is tolerant to many diseases and pests (Jackson, 2005). Presently, commercial hybrid cultivars of sugarcane are majorly descended from trispecific hybridization between *S. officinarum*, *S. barberi* and *S. spontaneum* (Babu *et al*. 2009). The primary breeding concept involves the merging of fast growth, ability of ratooning and endurance to biotic stresses and disease resistance from *S. spontaneum* and high level of sucrose content from *S. officinarum* (Berding *et al.,* 2007).

Nazir *et al.* (2013) analysed sugarcane varieties in Sindh, NWFP and Punjab and found out that the sugarcane varieties THATTA-10, HSF-240 and CP-77-400 were the dominant varieties in the three areas. These varieties were adopted and recommended because of accumulating high sucrose content. On the other hand, KESREF (2006), observed that production of sugarcane in Kenya is dependent on a few sugarcane varieties, particularly CO 421 which accounts for over 60% of the total acreage. Despite this information, it was still not clear which varieties of sugarcane were recommended by sugarcane companies to Webuye sugarcane farmers, which varieties were adopted by the farmers and how they influenced the yield of sugarcane crop in the Sub-county.

2.4.3 Earthing up

Bilal (2010) in his study on effects of earthing up and fertilizer level on growth and yield of spring planted sugarcane (*Saccharum officinarum*) in Punjab found out that earthing up resulted into significantly more cane yields. Bilal's (2010) results were similar with Aslam's *et al.* (2005) in which earthing up using ridger and spade raised cane yield by 18 and 19.20 percent respectively over no earthing up. Minhas *et al*. (2004) reported that earthing up using tractor mounted cane ridger is effective for increase in yield. Different scholars have made significant contribution on how earthing up influences sugarcane yield in different areas of the world. Therefore, this study was intended to find out whether sugarcane farmers in Webuye East practice earthing up and its effect on sugarcane yield.

2.5 Soil Management Practices

According to Azam & Khan (2010), agricultural productivity is greatly affected by a number of inputs such as land, labour, capital, seed, fertilizers, irrigation and soil.

2.5.1 Land preparation

Cane fields are most vulnerable to soil erosion when they are ploughed and fallowed before a plant crop has formed a complete leaf canopy. When preparing land for planting, deep tillage of soil is unnecessary in most soils of the natural sugar belt (Moberly and Turner, 1977). On highly erodible and poorly drained soils, minimum tillage system results in minimal soil erosion and improved cane yield when compared to the convectional system of preparing land (Moberly and Turner, 1977). In Mauritius, Mcintyre *et al.* (1983) showed that cane yields increased where minimum tillage was practiced in four trials on gentle sloping land. Minimum tillage is recommended for erodible soils and steeply sloping fields in rain fed regions of sugar industry.

Nazir *et al.* (2013) add that in order to get good germination and excellent crop stand, a good seed preparation is required which can be achieved by use of different equipment other than simple cultivator. They further found out that for one to arrive at optimal growth of sugarcane crop, adequate land preparation is important as it plays a role in development of sugarcane root system. It is important to utilize more effective equipment other than use of simple cultivator. Farmlink (2017) suggests that land should be prepared deeply to remove obstacles and plant debris and that tractor drawn implements are more preferable especially the disc plough as it helps in the achievement of required tilth. He further suggests that land preparation should be done during the dry spell to avoid formation of hard pans which affect drainage and root penetration into the soil.

In his study on socio-economic factors influencing sugarcane production in Nyando sugar belt, Owiti *et al.* (2018) found out that 51.6 percent increase in cane output is associated with unit change in land preparation cost. Solomon *et al.* (2016) also adds that land preparation cost has a positive relation to that of cane production and an increase in the cost of land preparation results in an increase of 18.6% sugarcane production by individual farmers. They suggest that land has to be prepared taking into account irrigation methods to be used and it should enhance proper water movement. The current study was designed to find out the kinds of land tillage used by sugarcane farmers in Webuye East and their effect on sugar cane yield.

2.5.2 Farm Yard Manure (FYM)

Nazir *et al.* (2013) argue that farmers use some amount of farmyard manure on sugarcane crop so as to improve the fertility of soil for better yield as compared with other crops. They add that farmyard manure should be applied before land is prepared. The overall average usage of farm yard manure in Pakistan was recorded as 3.8 to 5.7 tons per acre. Khanzada (1992) showed that use of FYM was negligible and irregular giving negative impact on sugarcane production. Munyabarenzi (2014), notes that the combined application of organic and inorganic fertilisers in maize crop produced yields which were significantly higher than organic or inorganic alone. This is further indicated by Gana and Busari (2001) that cane treated with cowdung and inorganic fertilizer significantly produced better cane in terms of height, vigour and yield. This study aimed at establishing the extent of the use of FYM by farmers in Webuye East Sub-county and how it affected sugarcane yield.

2.5.3 Fertilizer Application

DAFF (2014) notes that fertilizer is added in the soil to promote the development of the plant. Therefore, for producing higher cane and sugar yields on a sustainable basis, application of adequate amounts of fertilizer such as Nitrogen (N), Phosphorus (P) and Potassium (K) is essential. It further indicates that N requirement of sugarcane is greatest during the tillering phase while P need of sugarcane is greater in the formative phase of the crop in South Africa. It adds that the optimum time of P application is during initial stages of crop growth and K application is usually done along with N application. It further indicates that late application of K at around six months improves sugar recovery and so nitrogen is applied before six months, P before four months and K before seven months. Nazir *et al*. (2013) adds that optimum yield of sugarcane is obtained when fertilizer is applied although the use of chemical fertilizer is inadequate and unbalanced in Pakistan since large numbers of growers use only nitrogenous fertilizers whereas others use an unbalanced combination of N and P. They further note that the use of K is nearly neglected in cane crop by most farmers in Pakistan. Olwande *et al*. (2009) in their study revealed that fertilizer use was higher in major cash crops such as sugarcane, tea and coffee due to organized input credit schemes which allow farmers to acquire inputs on credit and repay through deductions made on deliveries of the produce.

FAO (2016) noted that it is very weighty to use proper amount of balanced fertilizers to achieve the maximum yield of sugarcane crop and recommends that cane fields should be assessed for N, P and K levels of the soil. Therefore, a quarter of N, all potash and phosphorus have to be applied during planting. It further indicates that K and P may be applied in furrows in which sets of seeds are placed while the remaining fertilizer can be applied thrice in equal splits. Nazir *et al.* (2013) adds that it will be beneficial if nitrogen is applied four times in equal splits to sugarcane crop that is planted in September besides the one fifth which is applied during planting. Sugarcane crop that is planted in September may be given an additional amount of 20 to 40 kg N (one to two bags of urea) per acre.

Sugarcane cultivation depends on extensive use of pesticides and fertilizers. Nitrogen is widely used because it is lost to the atmosphere, soil storage, surface runoff and ground water (Macdonald *et al.* 2001). In Japan, potassium is applied at 50-120 kg per ha, nitrogen at 200-300 kg per ha and phosphorus at 80-120 kg per ha (Matsuoka, 2006). Sugarcane is grown with low nitrogen inputs of 50 kg per ha in Brazil (Boddey *et al.* 1991), which has led to the proposal that a few cultivars of sugarcane can acquire nitrogen through biological nitrogen fixation. Lal and Singh (2008) says that sugarcane crop is an exhaustive crop which has a higher imposition for nitrogenous fertilizer as a result of sprouting of stubble buds, shallow root system, immobilization of nitrogen and decay, old roots. It is advisable to use 20% to 25% extra nitrogenous fertilizer above the recommended amount of nitrogen for ratoon crop. Solomon *et al* (2016) adds that 1% rise in DAP fertilizer will increase the sugarcane yield by 65%. On similar lines Khan *et al.* (2002; 2005) found that balanced and optimal use of fertilizers improved sugarcane yield and enhanced maximum economic benefit to farmers.

Khattak and Hussain (2008) studied the economics of sugarcane production and found that the area under sugarcane, total fertilizer used, human labor, tractor labor and total seedcane used were the main factors affecting sugarcane production. Narayan (2004) assessed a sugarcane production model in Fiji and indicated that the size of sugarcane field harvested and fertilizer, labor force and prices paid to sugarcane farmers had positive impact on sugarcane productivity and profitability. In addition, Malaza and Myeni (2009) identified seed, fertilization, irrigation, transport costs and ratoon management as the key elements to be managed for efficient production. They further note that the major determinant of sugarcane yield is the timely and adequate application of inputs throughout the crop life cycle. Webuye East Sub-county being a sub-county with its own soil type, this study intended to investigate the type of fertilizers used by sugarcane farmers in the sub-county, extent of use and their effect on sugarcane yield in the sub-county.

2.5.4 Mulching

In the study on evaluation of organic mulch on the growth and yield of sugarcane in Southern Guinea Savannah of Nigeria Ahmed *et al.* (2001) reported that organic mulch rate had significant impact on the production of sugarcane. They further agreed that application of organic mulch has to be recommended and encouraged for effective production of sugarcane hence maximum yield. In addition, Mui *et al.* (1996) suggests that leaving the dead leaves on the surface of the soil increases biomass production of soil living micro-organisms. It also raises the amount of carbon sequestered in soil and improves soil fertility. This study aimed at finding out the extent at which mulching is performed, mulching material that is used and its effect on the production of sugarcane in Webuye East sub-county.

2.6 Planting Season and Harvesting Management

2.6.1 Planting season

Fauconnier (1993) argues that planting dates for sugarcane largely rely on whether it is to be irrigated or not. Linda (2005) reported that sugarcane is planted during winter in August and September by use of cut stalk (billets) and whole stalk in Louisiana. However, DAFF (2014) advised that the ideal time for planting sugarcane is from mid-February to April which is under irrigation conditions, when enough water is present in the soil for faster canopy and maximum use of summer conditions in South Africa. It adds that planting of sugarcane is done from September to November under rain fed conditions and once rains have socked the soil in South Africa. Therefore, in South Africa, in Midlands planting of sugarcane does not go beyond October as mosaic vector is active and thereafter there may occur rapid spread of the disease. In addition Nazir *et al.* (2013) noted that planting of sugarcane in Pakistan is carried out in autumn and spring. Nazir et al. (2013) added that planting sugarcane in autumn results in high sugar recovery and high yields when compared to spring season of planting. They further add that planting of sugarcane in October results in very luxuriant growth till June - July but is vulnerable to lodging in July or before July if excessive rain or windstorm is experienced.

Fauconnier (1993) reported that timing of the rain determines planting of rain fed sugarcane. He adds that in India, sugarcane that is planted at the beginning of the wet season is harvested 12 months later while sugarcane that is planted at the end of the wet season is harvested after 16-18 months. Dindi (2013) discussed the managerial factors influencing sugarcane production by farmers of Mayoni Division, in Kenya which focused on how bureaucratic management, management of extension services, financial management and food security affected sugarcane production. In her study, she did not consider agronomic factors influencing the yield of sugarcane. Though different research had highlighted the different seasons when planting of sugarcane took place, Webuye East Sub-county has its own ecological conditions hence this study was designed to establish the season when sugarcane is planted and its effect on the yield.

2.6.2 Harvesting

Nazir *et al.* (2013) indicated that sugarcane is harvested by cutting the cane stick at the base level using special type of knife and the cane is stripped, topped and placed in bundles of 10-15kg for loading. DAFF (2014) indicates that sugarcane is harvested after 12 to 16 months when it is 2m to 4m tall and is harvested between April and December when rainfall is less frequent and the plants' sugar content is at its highest in South Africa. It further adds that in South Africa, sugarcane is harvested when it is green rather than burnt to increase yield and harvesting is mostly by hand and sometimes mechanically.

According to Nazir *et al.* (2013), most farmers conduct their harvest with no regards to modern techniques. Sugarcane farmers in Pakistan suffer from high costs of sugarcane production and reduced yields due to inadequate modernization. Harvesting of cane in Pakistan is by hand which is labor intensive. The appropriate time of harvesting sugarcane is when it has attained 12-14 months. KESREF (2006) indicates that in Kenya the optimal age for harvesting April planted cane is 21 months after planting; June planted sugarcane should be harvested after 21 months while October planted cane should be harvested after 17 to 25 months after planting. The variation in harvesting period between Pakistan and Kenya is due to different ecological conditions and soil characteristics. Nazir *et al.* (2013), added that harvested cane has sugar content of around 10% and should be transported to the factory in 24-48 hours of cutting to reduce lose of sugar. In Kenya, sugarcane is harvested when it is 14-18months depending on rainfall, variety and crop cycle (Mulianga *et al*. 2015). Hagos, (2014) showed that temperature, solar radiation, relative humidity and total rainfall are climatic variables that account for a significant difference in harvest age among sugarcane growing countries. This study aimed at establishing the period, age and nature of sugarcane when harvesting was done in Webuye East Sub-county. In addition, it established the length of stay that cut cane stayed in the field before it was transported to the factory and how it affected the yield.

2.7 Impacts of Government Policies, Credit Facilities, Extension Services and Farmers Education on Agronomic Practices.

Alila, (2006) indicates that policies for agriculture consists of government decisions that influence the level and stability of input and output prices, public investments affecting agricultural production, costs and revenues and allocation of resources. These policies affect agriculture either directly or indirectly. Although agriculture has over the years contributed more than proportionately to GDP growth in comparison to other sectors, this has been partly due to infrastructure established through efforts made for specific commodities. Some of these include provision and maintenance of rural access roads to facilitate the movement of agricultural produce to market, establishment of agro-based industries to increase the value of agricultural produce, education, training and extension services to enhance the adoption of modern farming techniques.

Jimi *et al*., (2019) notes that lack of capital has been identified as one of the constraints that face small scale farmers and provision of agricultural credit at a subsidized interest rate can be an effective tool for enhancing the production of rural farms. Relaxing the credit constraints for farming enterprises could lead to greater adoption of modern inputs and improved ability to turn inputs into outputs, both of which boost productivity. Extension services play the critical role in enhancing farm productivity and household income.

Agricultural extension services delivery should be boosted through timely recruitment, periodic training of agents and provision of adequate logistics (Abbeam *et al*., 2018).

It is noted that scholarly farmers achieve the highest social position while farmers with only junior high school background having the lowest social position. The less educated farmers are less able to absorb information and make innovations. Scholarly farmers are more successful and become role models for other farmers. Therefore, educational institutions should educate and motivate scholars to return to their villages as agents of change (Paramith, *et al*., 2018)

These factors in the current study are treated to be the mediating factors on the impacts of agronomic factors on sugarcane production in Webuye East Sub-county in Kenya.

2.8 Summary of Knowledge Gaps

Different scholars have made significant contributions to the study of sugarcane as a crop. Studies have been made on economics of sugarcane production where area under sugarcane, total fertilizer used, human labour, tractor labour and total seed cane used were main factors affecting sugarcane production. Other researchers have identified seed, fertilization, irrigation, transport costs and ratoon management as key elements to be managed for efficient production. Some scholars have concluded that major determinants of sugarcane yield were timely and adequate application of inputs throughout the crop life cycle. Also, studies have been made on managerial factors influencing sugarcane production where bureaucratic management, management of extension services, financial management and food security were identified to affect sugarcane production. In addition, studies on socio-economic determinants of sugarcane production among small scale farmers have been made where variable input costs such as weeding and weed control cost, seed cane, planting cost, land preparation cost and fertilizer application cost significantly affected sugarcane production. Nazir *et al.* (2013), made a significant study on the agronomic factors influencing sugarcane production in Pakistan. Weeding, pests and disease control, ratooning, sugarcane varieties, land preparation, farm yard manure, fertilizer application, irrigation, planting season and harvesting. Though Nazir *et al.* (2013) focused on agronomic factors influencing sugarcane production; Pakistan and Kenya are two different areas with different climates, socio-economic developments, cultural practices and soil characteristics. Therefore, based on Nazir *et al.* (2013) research, this study focused on agronomic factors influencing sugarcane production in Webuye East Sub-county, Bungoma County.

2.9 Theoretical Framework

The study relied on Production theory propounded by Cobb Douglas 1928. The theory shows the correlation between the input factors and output factors in production. It provides an explanation on the principles that a firm considers when making decisions on the amount of products it produces and sells and the amount of raw materials it will utilize to reach a specification level of output. Cobb Douglas' production theory comprises of economic and technical efficiencies analysis and production function. The highest quantity of production that can be produced from a given set of inputs can be explained by production function. Production function may be expressed in the form Q=f (L, K) (where Q is total production, L is labour input, K is capital input and f is total factor productivity. Some factor input determines output in the short run. In the long run, all factors are assumed variables within the confines of the technology and therefore determine output. Technical efficiency is achieved when maximum output is produced with a given set of inputs whereas economic efficiency is achieved when a firm is producing a given output at the lowest possible cost (Mishra, 2008). The main concern of the firm in production theory is to maximize profits and reduce costs (Cobb & Douglas, 1928). Production theory has been criticized by Dana & Jaromir (2006) on the ground that production function is not derived from observation, it is oversimplified and assumes variations in the rest of the economy, it assumes variations in techniques of production and does not pay attention to uncertainties which revolves around all decisions in a firm. However, the Cobb Douglas production theory is considered as conditions of an economy that leans towards rather than conditions that are always instantaneously achieved (Dorfman *et al*. 1987). Therefore, this research was based on Cobb Douglas' production theory.

The researcher gained a deeper understanding of the agronomic factors of sugarcane production since the analysis of sugarcane input and output was done in mathematical form. These factors are interlinked within the sugarcane production system. Production hazards can be counterbalanced if a sugarcane farmer improves soil management practices and special purpose plant improvement practices. The agronomic factors are the input variables and included, weeding, mulching, pests and disease control, fertilizer application, planting and harvesting season, plant density and spacing, ratooning, and earthing up. These factors tend to affect sugarcane production in different ways if all other factors are kept constant since they comprise the input factors in sugarcane production: just like in production theory where the input determines the output.

In his study on socio economic determinants on sugarcane production, Obange (2018) anchored his study on Cobb Douglas 1928 Production Theory which turned out to be successful. Also, Odhiambo & Nyangito (2003) in Measuring and analyzing Agricultural productivity in Kenya based on this theory which was a success. In addition, Nyakora *et al.,* (2022) in their study on Determinants of maize production and its supply response in Kenya used cob Douglas Production Theory to arrive at their findings and conclusion. Therefore, this study was also based on this theory.

2.10 Conceptual Framework

Sugarcane production which was the dependent variable in this study is influenced by a variety of agronomic practices, the independent variables. These factors are interlinked and if not considered can adversely affect the yield of sugarcane crop. These factors were categorized into those that are concerned with soil management and those that concern plant improvement and management. This study classified the agronomic practices into three: special purpose plant improvement practices such as weeding, pests and disease control, row spacing, ratooning, sugarcane varieties and earthing up; soil management practices such as land preparation, farm yard manure, fertilizer application, mulching and planting season and harvesting management. These factors can be mediated/intervened by government policies, credit facilities, farmer's educational level, holding farmers public meetings and provision of extension services to farmers. These are in the form of inadequate finance and skills to institute the agronomic practices. Failure to provide appropriate guidance to the farmers on the right agronomic practices and to execute agricultural policies.

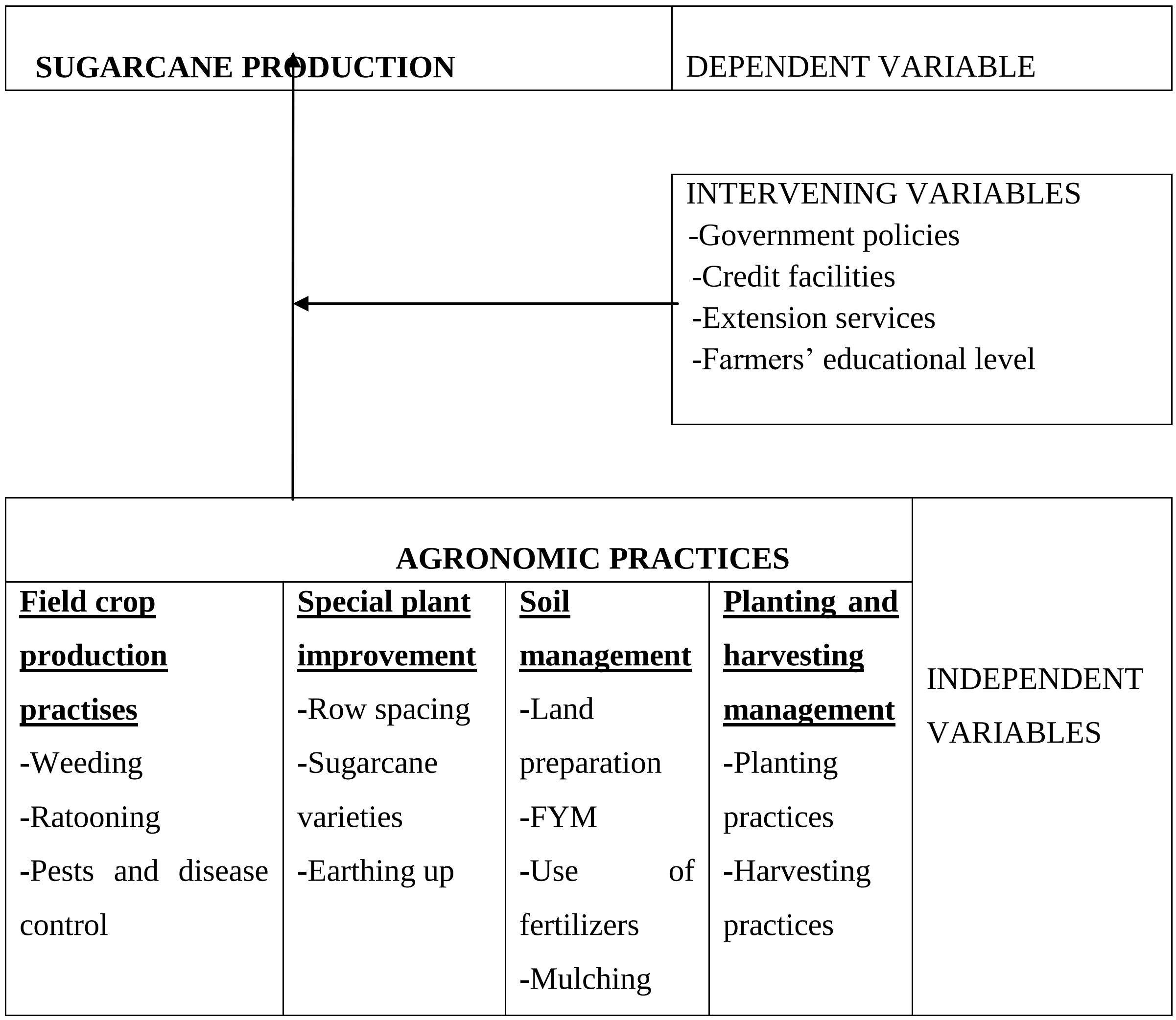

Figure 0.1: A simplified conceptual framework of factors influencing sugarcane production

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents research design adopted, sampling design, sample size, target population, data collection tools and procedure, data analysis and data presentation. The area of this study is Webuye East Sub County. The sub-county is in Bungoma County in Western Kenya. It is one of the sub counties in Bungoma County with three wards, Mihuu, Ndivisi and Maraka. It lies within the coordinates $34^0$40'E to $34^0$48'E and $0^0$35'N to $0^0$45'N and covers an area of 161.8km^2. The Sub County has a total population of 114,548 people (Government of Kenya GoK, 2019a) that comprises of 55775 male, 58771 female and 2 intersex. The Sub County experiences two rainy seasons, the long and short rains. The annual rainfall in the sub county ranges from 400mm (lowest) to 1,800mm (highest). The long rains are received from March to July, while the short rains are expected from August and continue up to October. Agriculture is the main economic activity in the sub county with sugar cane and maize the major crops grown. Most farming activities take place during the long rains. Webuye East Sub-county has an average temperature of 20.3^0 C which is suitable for sugarcane farming.

3.2 Research Design

This study drew on the descriptive survey research design using mixed methods approach to elicit data from the study participants. The researcher chose descriptive survey research design for this study basing on the kind of data that was required to answer the research questions. Bayat & Fox (2006) notes that descriptive survey research is aimed at casting light on current issues or problems through a process of data collection that enables them to describe the situation more completely. It is the best method for collecting information to demonstrate relationships and describe the world as it exists (Bickman & Rog, 1998). Descriptive survey research minimizes bias and maximizes the reliability of the evidence collected by providing all the participants with a standardized stimulus.

Descriptive survey research was used because it is effective in analyzing non-quantified topics and issues which will lead to statistically significant results (Dudovskiy, 2018). It also makes it possible to observe the phenomenon in a completely natural and unchanged environment and provides the opportunity to integrate the qualitative and quantitative methods of data collection (Travers, 1978). In general, descriptive survey research was employed in this research as a result of it having high representativeness, low costs, convenient data gathering and precise results. Similar studies have utilized this research design to generate very informative data. Nasir *et al.* (2013) utilised descriptive survey research design to gather information on the factors affecting sugarcane production in Pakistan. Damrong (1986) also, employed descriptive survey research design to study the socio-economic factors affecting small scale farmers in South East Asia. This study therefore found it convenient in acquiring data on agronomic practices influencing sugarcane production in Webuye East Sub-County.

3.3 Target Population

This research targeted a population of 6135 farmers in WES who were registered with West Kenya Sugarcane Company. West Kenya Sugarcane Company was preferred because it was the company that most farmers in the region preferred compared to Nzoia Sugarcane Company. This was due to the company paying farmers promptly after a period of two weeks of cane harvesting. The target population per ward was as follows; Maraka ward with 1250 farmers, Ndivisi ward with 1355 farmers and Mihuu ward with 3530 farmers (GOK, 2019b). The three wards were purposively selected because sugarcane farmers are distributed in all of them which made a correct sample for this study from whose findings and conclusions could be generalized for the entire Webuye East Sub-county. The study also targeted 5 field officers and 8 weighbridge workers of West Kenya Sugarcane Company as key informants to this research.

3.4 Sampling Design and Sample Size

This research utilized systematic sampling design to select the study sample which is a probability sampling technique. Systematic sampling was preferred because it was operationally more convenient, cost effective and ensured that each farmer had equal probability of inclusion in the sample. Also, it ensured that no large part of the population failed to be represented in the sample.

The sample size was 96 sugarcane farmers in the entire Webuye East Sub-County and was calculated based on the Kothari (2004) formulae for determining sample size. Obange (2018) used Kothari's formulae for determining sample size in his study on socio-economic determinants of sugarcane production. The sample size turned out to be adequate which led to successful findings and conclusions.

The sample size for sugarcane farmers was calculated as illustrated below.

$$n = \frac{Z^2PQ}{e^2}$$

$$n = \frac{1.96^2(0.5)(0.50)}{0.1^2}$$

$n = 96\ sugarcane\ farmers$

Where:

n is the sample size the researcher wants

e is the desired level of precision (i.e the margin of error) which in this case is 10%, equivalent to 0.1(10/100)

p is the estimated proportion of the population which has the attribute in question. (Sample proportion of successes) which is 0.5

q is 1-p which is 1-0.5=0.5

z- Value is found in a z table which is 1.96

e is 10% which translates into 0.1

The sample size for each ward was derived proportionately as illustrated in table 3.1. Therefore, the sample size for Ndivisi ward was 21 farmers, Maraka ward 20 farmers and Mihuu ward 55 farmers.

Table 0.1: Sample size of each ward

Ward	Number of Farmers	Sample size
Mihuu	3530	$\left(\frac{3530}{6135}\right)96 = 55$
Ndivisi	1355	$\left(\frac{1355}{6135}\right)96 = 21$
Maraka	1250	$\left(\frac{1250}{6135}\right)96 = 20$
Total	6135	96

Source; *GoK 2019*

A list of all farmers in each ward was taken and each farmer was assigned a number in their respective wards. The first farmer on the list in each ward was randomly selected and the subsequent farmers were systematically picked so that farmers were picked after every 65th

farmer in the list from Ndivisi ward, from Maraka ward farmers were picked after every 63rd farmer in the list and from Mihuu ward, farmers were picked after every 64th farmer in the list. Also, 5 field officers in charge of the three wards i.e., one from Maraka ward, two from Ndivisi ward and two from Mihuu ward and 8 weigh bridge workers at the sugarcane collection point in charge of the weighbridge at Misikhu in Ndivisi ward were purposively selected for interview because it had been determined that they were at a position to provide deeper insight on the topic being investigated due to their expertise. In addition, 10 farmers were purposively selected to be interviewed during collection of the questionnaires to give more explanation on what they had indicated in the questionnaires. The 10 farmers had sugarcane as their major crop that was grown. The 5 field officers, 8 weigh bridge workers and 10 farmers were considered as key informant interviewees in this study.

3.5 Data Collection Techniques and Research Tools

Data collection tools that were employed in this study included questionnaires, interviews, observation and document analysis.

3.5.1 Primary Data Collection

Primary data on agronomic factors influencing sugarcane production were collected by use of questionnaires, field observation and by interviewing key informants.

Questionnaire

Each item in the questionnaire was developed to address a specific objective or research question of the study (Mugenda & Mugenda, 2003). Questionnaire was used because large amount of information was collected from a large number of people spread over a wide geographical area in a short period of time and in a relatively cost effective way. The questionnaire was administered to 96 respondents. This questionnaire was short with clear questions that were systematically arranged from simple to difficult and used simple language without touching on the privacy of the sugarcane farmers (appendix 1). The questionnaire was given to individual farmers to be filled. Those farmers who had difficulty in reading and writing were assisted to fill the questionnaire by the researcher during collection of questionnaires. Data collected through questionnaire included general information about the farmer, land preparation, planting season, sugarcane varieties, application of fertilizers and farm yard manure, pests and disease control, row spacing, weeding and earthing up (appendix 1).

Observation

Direct field observation was employed to capture data. Observation on the current state of the sugarcane farm was made and descriptive notes and photographs were taken. Data on pests and diseases that were present in the farm, weeds present, earthing up, mulching, soil erosion, plant density and spacing and intercropping within the sugarcane farm was collected. Observation as a tool of data collection was used in this study as it allows one to directly see what people do rather than relying on what people say they do. Furthermore, observation does not rely on people’s willingness or ability to provide information. This method of data collection was made possible by the use of observation checklist (appendix III).

Key informant interviews

These key informants were purposively selected because it had been determined that they were at a position to provide deeper insight on the topic being investigated due to their experience. Interviews were used to collect data because they allow collection of data that cannot be obtained through other settings (Krishna 1989). Interviews enabled the researcher to get full range of information and explore the actual reasons behind the problem. Interview guides which listed the topics and issues that were covered during the session were used. The researcher framed the actual questions in the course of the interview and the atmosphere in the interview was informal. Interviews were used to elicit information such as; sugarcane varieties, ratooning, harvesting and average quantity of sugarcane harvested per year. Key informants who were interviewed included 5 field officers, 8 weigh bridge workers of West Kenya Sugarcane Company and 10 farmers.

3.5.2 Secondary Data Collection

Secondary data was collected by reviewing sub-county farmers' records, West Kenya Sugarcane Farmers Records, sub county agricultural and demographic records and KSB reports. Data collected from secondary sources included the number of sugarcane farmers in Webuye East Sub-county from West Kenya Sugarcane Farmers Records, sugarcane varieties, population of Webuye East Sub-county from sub-county agricultural and demographic records and climatic data from KSB reports. Document review was a good source of background information; brought up information that were not noted by other means, provided a behind the scenes look at a theme that was not directly observed and helped to digitize the map of the study area.

3.6 Data Collection Procedure

Research permit (appendix 6) was obtained NACOSTI. The research permit authorized the researcher to carry out a research on agronomic factors influencing sugarcane production in Webuye East Sub-county.

Questionnaires were piloted on sugarcane farmers in Webuye West Sub-county to ensure that the questionnaires did not fail as a result of not being understood. During piloting 10 questionnaires were randomly distributed to sugarcane farmers in Webuye West Sub-county and detailed notes on how farmers reacted to specific questions and how long farmers took to fill the questionnaires were taken. Piloting aided the researcher to delete questions that didn't make sense to farmers, replace some difficulty terms in the questionnaires with simpler terms and problems with the questionnaire that could have led to collection of biased data. These numbers of farmers were cost efficient, time efficient and energy efficient because the number was large enough that many will note the similar problems with the survey question.

Data was collected in three wards of Webuye East sub-county i.e. Mihuu, Ndivisi, and Maraka during the year 2020. Questionnaires were administered to 96 sugarcane farmers in person and at their homes. A period of 5 days was given to each farmer to fill in the questionnaires then the questionnaires were collected. In addition, first contact with the 5 field officers and the 8 weigh bridge workers was made where each of these key informants scheduled a convenient place and time for the interview. Interviews lasted 20-30 minutes for every interviewee and notes were taken during the interview. Topics in the interview tool were used to guide the researcher during the interview process (Appendix 2).

3.7 Data Analysis

Quantitative data in questionnaires was coded and a master sheet prepared at the beginning of the data collection. After data collection, data pieces were screened and codes marked on the different variables to make data ready for entry into the master sheet using SPSS programme. Data analysis was performed using SPSS when all codes had been entered into the master sheet where cross tabulation was made and descriptive and inferential statistics generated between relevant variables where applicable. Descriptive statistics generated included frequency, percentage and totals.

While inferential statistics involved analysis using the chi-square. Chi-square analysis is a technique used for measuring statistical significance between observed frequencies and the expected frequencies. The formula for calculating chi-square is as follows:

$$X^2 = \sum(O_i - E_i)^2/E_i$$

Where, X^2 is the chi-square value

O_i is the observed frequency

E_i is the expected frequency

The value of x^2 is large when there are large differences between observed and expected frequencies which indicate a poor experimental agreement between the two values. The value of X^2 depends on the degrees of freedom (DF), this is, the maximum number of expected frequencies.

$$DF=(R-1) \times (C-1)$$

Where, DF is degrees of freedom

R is the number of rows

C is the number of columns

Where there was one row or one column with n number of values then the formula for calculating the DF took the form of n-1. A calculated X^2 value was compared to a theoretical or critical value of X^2 with a given level of significance and degrees of freedom in the chi-square distribution table. In this study, 0.05 or 5% level of significance was used was. Conclusions were made when the calculated value of chi-square was greater or less than the critical or theoretical value at five percent level of significance. The output that was deduced from chi-square and SPSS was used to discuss the findings of this study. Chi-square analysis was used to test for the relationship between soil management and sugarcane production. After the analyses, results were then presented using tables, graphs and charts.

To add on, qualitative data from key informant interviews was edited to get the correct transcription of the accounts of interviewees. Notes were then typed where emerging themes were identified and categorization of the themes done. Thereafter the researcher discussed the findings with regard to the objectives of the study.

3.8 Data Presentation

The data was presented by use of tables, charts and plates. Qualitative data was presented using notes.

3.9 Ethical Consideration

The researcher obtained a research permit from NACOSTI that provided the permission to carry on with the research. The researcher maintained the highest level of objectivity in discussion and analyses throughout the research. Also works of other authors that were used in the research were acknowledged within the text and in the reference. Privacy and anonymity of the respondents was observed where personally identifiable data was not collected. Moreover, respondents participated on the basis of informed consent. This involved provision of sufficient information and assurances about taking part to allow the respondents to understand the implication of participation.

3.10 Validity and Reliability of Research Instruments

Reliability of research instrument refers to how consistently a method measures something. The instrument is considered reliable if the same results can be consistently achieved by using the same method under the same circumstances. Validity of the research instrument refers to how accurately a method measures what it is intended to measure. In this study, validity was measured where an expert in the department of Geography in Moi University went through the questionnaire which the researcher had designed and recommended that the questionnaire was valid. In addition, reliability was measured by piloting 10 questionnaires in Webuye West Sub-county. The farmers in the pilot area responded to the questions in the questionnaire without difficulty and the questionnaire contained all aspects of agronomic practices that influence sugarcane production.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents a qualitative and quantitative analysis of study results and discusses them in relation to research objectives. The chapter is divided into sections based on the research objectives.

4.2 Response Rate

The study targeted a sample of 96 farmers, 5 field officers and 8 weigh bridge workers. From a sample of 96 farmers that were chosen to participate in the study, a total of 96 questionnaires were returned representing 100% response rate. The questionnaires were then checked for completeness and all were found to be complete. Data was then subjected to further quantitative analysis.

4.3 Demographic Characteristics of Farmers

Demographic characteristics of the respondents were analysed by use of three aspects; gender, educational level and age as illustrated in table 4.1.

Table 0.1: Demographic characteristics of the farmer

Characteristics	n=96	Frequency	Percentage
Gender	Male	72	75.0
	Female	24	25.0
Educational Level	Primary	12	12.5
	Secondary	64	66.7
	Tertiary	20	20.8
Age	20-40years	50	52.1
	41-60years	28	29.2
	61 and above	18	18.8
Total		**96**	**100.0**

Source: *Survey data 2020*

Out of 96 sampled sugarcane farmers, 75 percent were male and 25percent were female. In terms of education, 12.5 percent of farmers had primary education, 66.7 of farmers had secondary education and 20.8 percent of farmers had their education up to tertiary level. In terms of age, 52.1 percent of farmers were aged between 20-40 years, 29.2 percent aged 41-60 years and 18.8 percent of farmers were 61 and above of age. This implied that majority of sugarcane farmers were male, most of the farmers had secondary education and were aged between 20-40 years. This was supported by the sentiments of the field officers that men were the ones allowed to inherit land in the sub-county hence many had their own land unlike women. In addition, most sugarcane farmers were middle aged because these were the people who were aggressive and still had higher hopes of creating wealth and developing. Also, it was explained by the field officers that 20-40 years were the age when men who depended on family wealth could be allowed to own land within the sub-county. Most farmers had secondary education because most families could not afford tertiary education due to inability to pay school fees and those who went up to tertiary level engaged themselves in white color jobs and tended to neglect agriculture.

4.4 Influence of field crop Production Practices on Sugarcane Production

This section addresses objective one of this study where level of field crop production practices were assessed and their impact on sugarcane production. Weeding, ratooning, pest and diseases control were field crop production practices on sugarcane production that were assessed. The researcher looked at weeds present in sugarcane farm, how the weeds were controlled, how weeding affected sugarcane yield, pest that were commonly found in sugarcane field, diseases that affected the sugarcane crop, how pest and diseases were controlled in the sugarcane farm and how pest and diseases affected the sugarcane production. The researcher also looked at ratoon cropping, in terms of whether the farmers practice ratoon cropping, the number of times the ratoon cropping was practiced before sugarcane plant was uprooted, how ratoon crop affected production of sugarcane crop and the reasons that motivated farmers to practice ratoon cropping. The results were as presented below.

4.4.1 Control of weeds by farmers

Weeds which were observed to be present in the sugarcane farm included oxalis, pig weed, leave me not, wandering jew, mexican marigold, couch grass and black jack (plate 4.1).

Although these weeds were observed to be present in sugarcane farms, the most commonly observed weeds in the sugarcane fields were the black jack and couch grass. Contrary to the findings of this research, Linda (2005) in her study on '*weed control'* in Louisiana found out that the major weeds in the sugarcane field were Johnson grass and Bermuda grass. SRI (2015), indicates that weeds differ from location to location due to variation in agro-ecological conditions and management.

Plate 0.1: Sugarcane field with weeds in Ndivisi ward

Source: *Author 2020*

The study sought to establish how the sugarcane farmers controlled weeds in their farms. The findings of the study presented in Table 4.2 show that majority of the farmers (51.0%) controlled weeds by spraying and hoeing, followed by hoeing alone (46.8%), and only 2.1% used spraying alone. This information was supported by field officers who indicated that most farmers used both hoeing and spraying because spraying completely eradicated the weeds that could have survived after hoeing. They also explained that spraying reduced the number of times of hoeing before the sugarcane plant attained maturity. They also added that the farmers who used hoeing only could not afford the purchase of chemicals because hoeing labor is from family. Further, they stated that some farmers intercrop sugarcane with beans and spraying could interfere with the survival of beans. The field officers added that those farmers who used spraying alone considered the method appropriate because of the inadequate and expensive human labour. To this group of farmers, spraying was faster and easier way of weed control.

Table 0.2: Methods of weed control

Weed control methods	Frequency	Percent	Cumulative Percent
Hoeing	45	46.8	46.8
Spraying and hoeing	49	51.0	97.8
Spraying	2	2.1	99.9
Total	96	100.0	

Source: *Survey data 2020*

These weeds had been controlled mechanically by hoeing as indicated in plate 4.2 and chemically by spraying in some sugarcane fields. These findings agree with those of SRI (2015) which indicated that sugarcane farmers controlled weeds mechanically by hoeing and chemically by spraying using glyphosate. However, SRI (2015) also found that apart from these two methods, farmers also used other methods like intercropping, crop rotation and mulching. In addition, Linda (2005) explained that control of the weeds in Louisiana was by fallowing and planting early maturing resistant soybeans on sugarcane farms.

Plate 0.2: Weeded sugarcane field in Mihuu ward

Source: *Author 2020*

Concerning the effect of weed on sugarcane yield, most of the farmers (81.0%) strongly agreed that weeds should be controlled for cane production to be high, few (18%) agreed that weeds should be controlled for cane yield to be high and very few (1%) of farmers disagreed that weed control determined cane production. The proportion of farmers who agreed that weeds should be controlled for cane yield to be high in fig 4.1 is large compared to the farmers who disagreed with the same statement. In-depth interview with one of the field officers indicated that weed control highly increase sugarcane yield. He observed that:

> "farmers who totally failed to control weeds ended up harvesting sugarcane in an acre of land whose weight does not exceed 8 tones while farmers who partially control weeds would harvest cane that does not exceed a total weight of 18 tones in an acre of land,".

This was in agreement with sentiments by key informants who said that sugarcane farmers who controlled weeds in their sugarcane fields harvested cane whose average tonnage was 55 tonnes in an acre of sugarcane plot. This implied that farmers who failed to control weeds in sugarcane fields harvest low yield.

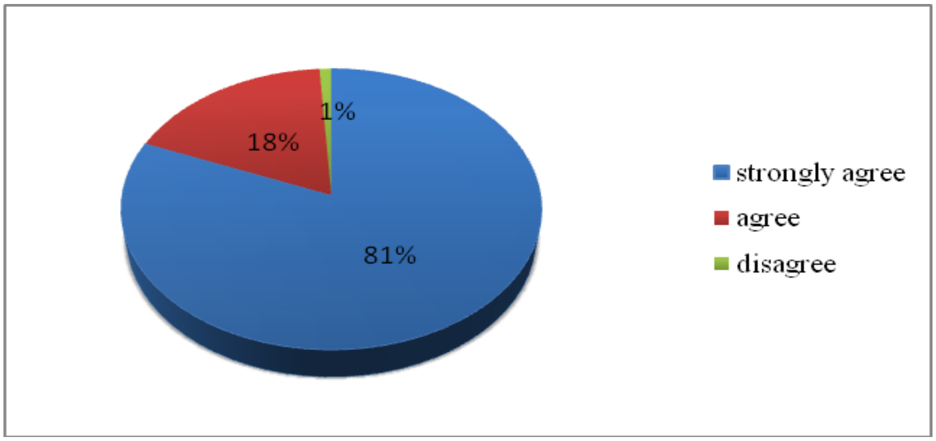

Figure 0.1: View of farmers on weed control and cane yield

Source: *Survey data 2020*

In addition, 82% of farmers indicated that they have ever experienced variation in cane output based on the level at which weeds were controlled. Farmers (44%) who fail to control weeds harvest an average yield of 18 tones in an acre of sugarcane farm while 51% of farmers who manage to control weeds harvest an average yield of 50 tones in acre of cane field. Farmers (5%) who totally did not control the weeds had an average yield of 8 tones in one acre of cane plot as illustrated in table 4.3. This implies that farmers who successfully controlled weeds harvested 58.2% more tonnage than those who unsuccessfully controlled weeds and 76.4% more tonnage than those who did not control weeds. These findings concur with that of Linda (2005) who notes that the competition for light, space, water and nutrients between the crop and weeds can lower sugarcane stalk population and yield. She adds that weeds emerging with the crop may lower tillering of cane and hinder growth hence resulting in low yields during harvest. Nazir *et al.* (2013), also indicates that weeds restrict moisture, nutrients, light and serve as alternative hosts for insect pests to sugarcane crop.

Table 0.3: Effects of weed control on sugarcane production.

Level of control	**Frequency**	**Percentage of farmers**	**Amount of yield in tonnes**
Successful control	49	51	50
Unsuccessful control of weeds	42	44	18
Did not control	5	5	8
Total	**96**	**100.0**	

Source: *Survey data 2022*

4.4.2 Control of pests and diseases

It was indicated by farmers that pests such as sugarcane borers, yellow sugarcane aphids, wireworms, ants, moles, army worms, termites and rodents are found in sugarcane field within Webuye East Sub County the most common being; Sugarcane borers, yellow sugarcane Aphids, moles and termites as indicated in table 4.4. This finding compare to the conclusion made by Santo *et al.* (2000) in their study on sugarcane where due to different agro-ecological zones only three insects, yellow sugarcane aphid, new guinea sugarcane weevil and the lesser cornstalk borer were identified by sugarcane farmers in Hawaii as the most common pests.

Table 0.4:Types of pest present in WES

Pest	**Frequency**	**Percentage**	**Cumulative percent**
Termites	31	32.3	32.3
Moles	25	26.0	58.3
Sugarcane borers	17	17.7	76.0
Yellow sugarcane aphid	13	13.5	89.5
Rodents	4	4.2	93.7
Ants	3	3.1	96.8
Wireworms	2	2.1	98.9
Armyworms	1	1.0	99.9
Total	**96**	**99.9**	

Source: *Survey data 2020*

Diseases that were identified to affect sugarcane production included; smut, ratoon stunting and yellow orange leave. Smut and ratoon stunting diseases were observed to be the most common diseases that affected sugarcane production as indicated in table 4.5. Ratoon stunting disease was as a result of mismanagement of the first and subsequent ratoons while smut disease was a viral disease as explained by one of the field officers.

Table 0.5: Diseases that affect cane yield in WES

Disease	**Frequency**	**Percentage**	**Cumulative percent**
Ratoon stunting	45	46.9	46.9
Smut	38	39.6	86.5
Yellow orange leave	13	13.5	100.0
Total	**96**	**100.0**	

Source: *Survey data 2020*

The pests and diseases control measures showed that, 19.7% controlled pests and diseases by use of chemicals, 17.8% controlled the pest and diseases culturally, 1.0% controlled pest and diseases biologically and 61.5% controlled pest and diseases mechanically as indicated in the table 4.6. cultural control of pests involved the use of resistant variety of cane crop which was CO421 and detrashing. This was in agreement with the sentiments by the field officers who said that most farmers controlled pests mechanically though these pests are not yet fully managed. The field officers added that moles had been identified to be notorious pests in sugarcane crop. The field officers further indicated that moles attacked the cane crop from the roots hence caused drying up and subsequently death of the cane crop. They further noted that moles had been controlled mechanically through trapping and killing them.

Table 0.6: Methods of Pests and Disease Control

Pests and disease control methods	**Frequency**	**Percent**	**Cumulative Percent**
Chemical	19	19.7	19.7
Cultural	17	17.8	37.5
Biological	1	1.0	38.5
Mechanical	59	61.5	100.0
Total	**96**	**100.0**	

Source: *Survey data 2020*

Moreover, the field officers noted that chemical control of pests involved the use of synthetic chemicals to manage pest population and diseases. This method was highly effective and gave quick results though non targeted species were affected and its continued use made pests develop resistance. Famers also use cultural method to control pests. This involved the use of timings and a combination of agronomic practices which made the environment less favourable for development of pests and diseases. Cultural pest and disease control included, crop rotation, destruction of sugarcane crop residue, use of CO-421 variety which was a resistant variety, earthing up of sugarcane that checked up emergence of borers and thrush mulching. Though this method was effective for single pests only, no extra cost was incurred. Mechanical control of pests and diseases involved manual killing or hand picking the pests such moles. These methods of controlling pests and diseases were in line with the findings by Santo *et al.* (2000) in Hawaii where pests and diseases were controlled through modification of cultural practices, selection of the insect tolerant cultivars and bio-control of the insect pests. However, the chemical control method was in contrast with his conclusion that insecticides were not used because of the potential harm to the insects that were beneficial. Although different methods of pest and disease control were employed, cultural method was the best though more involving and partially used while mechanical control of pests and disease was not involving and was widely used by farmers in the sub-county.

It was explained by the field officers that pests negatively affected sugarcane in terms of weight and quality. The field officers explained that termites were controlled chemically by use of chemicals supplied to farmers on credit by the Nzoia sugar company and mechanically by removing the queen and killing it. They added that Moles were controlled mechanically by digging and applying plenty of water in the path of the mole which choked it and forced it to come out. The field officers indicated that rust disease was controlled by planting resistant variety of CO-421. They explained that sugarcane borers were controlled by detrashing the cane and trash mulching to promote growth of beneficial organisms though some farmers burned sugarcane crop residue after they had harvested and practiced crop rotation. The field officers mentioned that although pest and diseases were controlled by sugarcane farmers, it was not a hundred percent managed because the methods that were mostly applied were mechanical which was overwhelming to farmers. They advised that farmers should incorporate detrashing, trash mulching and chemicals to control the menace caused by pests and diseases in order to achieve maximum yield of 55 tonnes per acre of sugarcane plot.

When asked whether control of pests and diseases affected sugarcane yield, 50% of farmers strongly agreed that control of pests and diseases resulted in high cane production, 47.9% agreed, 1% disagreed and 1% strongly disagreed with the statement as illustrated in table

4.7. This finding compares with that of DAFF (2014) in South Africa where it was found that pests such as eldana borer cause severe loss in cane quality and reduce cane weight whereas diseases such as eye spot, brown spot, pokkahboeng, gumming, red rot, rust, leaf scald, mosaic, smut and ratoon stunting attack sugarcane and reduce yield.

Table 0.7: Response rate on control of pests and diseases on cane yield

Response rate	Frequency	Percent	Cumulative Percent
Strongly agree	48	50.0	50
Agree	46	47.9	97.9
Disagree	1	1.0	98.9
Strongly disagree	1	1.0	100.0
Total	**96**	**100.0**	

Source: *Survey data 2020*

Moreover, 38% of farmers who had a successful pests and disease control in their sugarcane farm harvested 36 tonnes in an acre of sugarcane field as opposed to maximum yield of 55 tonnes in an acre while 62% of farmers who did not control pests successfully had an average sugarcane yield of 28 tonnes in an acre of land as indicated in figure 4.2. This implied that farmers who controlled pests and diseases successfully harvested 14.5% more tonnage than those who controlled diseases and pests unsuccessfully in their sugarcane plot. Though farmers who controlled pests successfully harvested more, these farmers did not attain the maximum yield of 55 tonnes per acre because of failure to practice successfully other agronomic practices as explained the field officers.

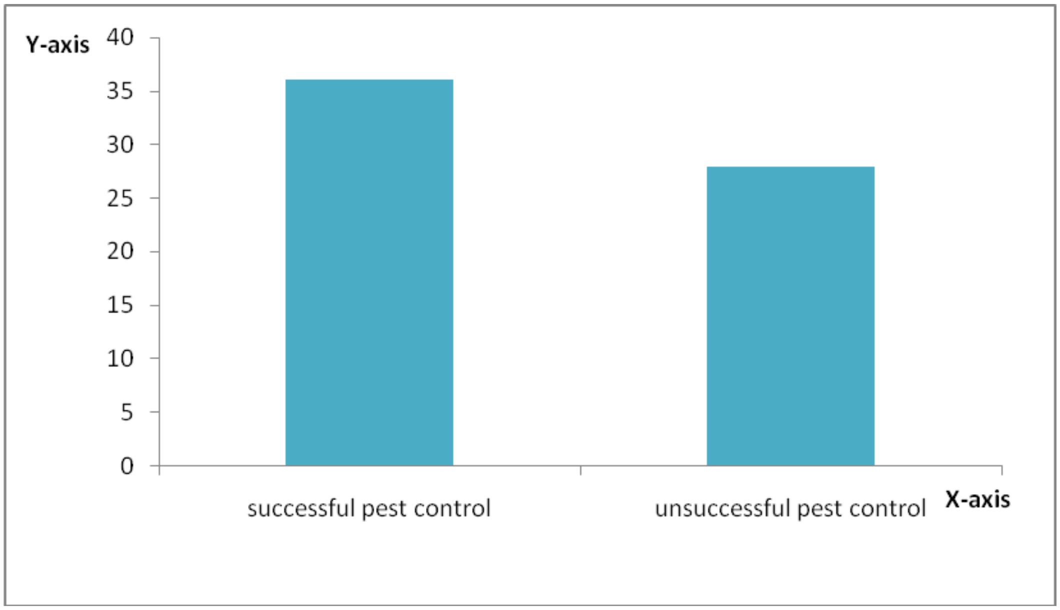

Figure 0.2: Control of pest and sugarcane production

Source: *Survey data 2020*

4.4.3 Ratooning

The practice of ratooning results show and it was found that most (91.7%) sugarcane farmers in the sub-county practiced ratooning while few (8.3%) indicated that they did not practice ratooning as illustrated in the table 4.8. The 91.7% of sugarcane farmers indicated that they practiced ratooning two to three times before the sugarcane plant crop was uprooted.

Table 0.8:Farmers who practice ratooning

Whether ratooning is practiced or not	Frequency	Percent	Cumulative percent
Yes	88	91.7	91.7
No	8	8.3	100.0
Total	**96**	**100.0**	

Source: *Survey data 2020*

The weigh bridge workers indicated that some sugarcane farmers went up to five times of cutting sugarcane before uprooting their plant crop. Information elicited from field officers reported that cane variety CO-421 could go up to 9 ratoons before the cane crop was uprooted although most ratoons went up to 3 times of cutting before the crop was uprooted. However, the number of times that sugarcane crop was cut before it was uprooted depended on how the farmers had maintained the cane crop in the field. It was observed by the researcher that the plant crop was healthier than ratoon crop as indicated in plate 4.3 and plate 4.4 respectively. The field officers added that;

> "*The production of ratoon crop was lower than the plant crop but farmers considered practicing ratooning.*"

The reasons cited by the field officers as to why ratooning was practiced were: Ratoon crop was easy to maintain and matured faster than the plant crop. Also, there was inadequacy of the planting material, the need by the farmer to save on the initial costs of establishing the new sugarcane plant and because of the lease agreement of harvesting cane three times before uprooting the crop.

Plate 0.3: Sugarcane plant crop in Maraka ward

Source: *Author 2020*

Plate 0.4: Sugarcane ratoon crop in Maraka ward

Source: *Author 2020*

Ratooning was highly practiced by cane farmers though the yield of the cane crop decreased with the subsequent ratoon as indicated by 77% of farmers who agreed (figure 4.3). Aamer *et al.* (2017) noted the same on productivity of ratoon crop in Faisalabad in Pakistan. The major reason for ratoon cropping as was indicated by farmers was to reduce cost that could have been incurred during replanting and ease management. This was in agreement with Shukla *et al.* (2013) in India who argued that ratooning in sugarcane saved seedbed preparation cost and planting operations.

Out of 96 responses on whether or not cane production decreased with the increase in the number of ratoons, 43.0% of the farmers strongly agreed that production of cane went down with the increase in number of ratoons, 34.0% agreed and 23.0% disagreed as illustrated in figure 4.3. The number of farmers who agreed that cane yield decreases with the number of ratoons was higher (77%) compared to the number of farmers who disagreed (23%) from figure 4.3. This finding implied that the tonnage of sugarcane decreased when the number of ratoons increased.

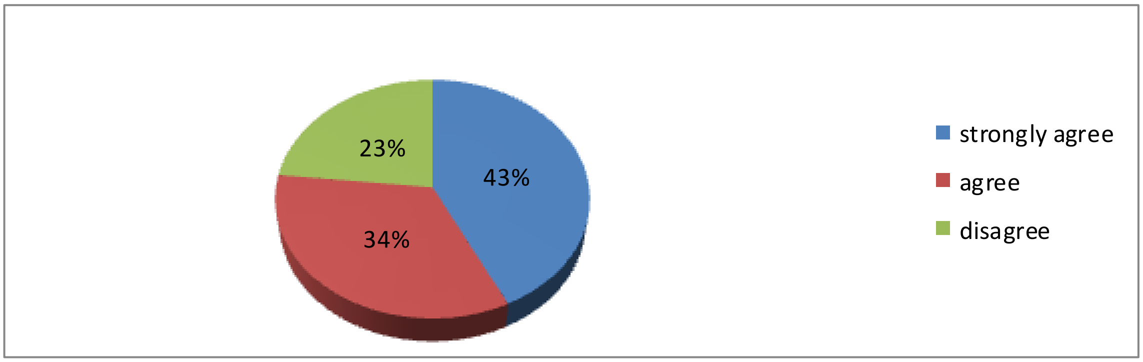

Figure 0.3: Response rate on cane yield decreases with the number of ratoons

Source: *Survey data 2020*

It was also indicated by farmers that on average, sugarcane plant crop gave 35 tonnes in an acre, first ratoon had an average yield of 41 tonnes in an acre and second ratoon had 30 tonnes while the third ratoon had a yield of 21 tonnes in an acre of land as indicated in figure 4.4. First ratoon gave higher yield than the plant crop. The first ratoon had 14.9% more tonnage than the plant crop. Sugarcane crop plant yield was lower than the first ratoon because after the first harvest sugarcane plant formed more buds which led to increased number of cane stalks hence increase in yield. Though the second and third ratoon had less tonnage than the plant crop, farmers did not incur extra costs of preparing land, seed cane and planting. This finding compares with the findings of Aamer *et al.* (2017) who note that the productivity of ratoon is 10 to 30 percent below the plant crop of sugarcane which can be attributed to the low and differential ratooning capabilities of cultivars and sub-optimal crop management. Malaza & Myeni (2009) also found out that there is an inverse relationship between the age of the ratoon and the yield of the crop.

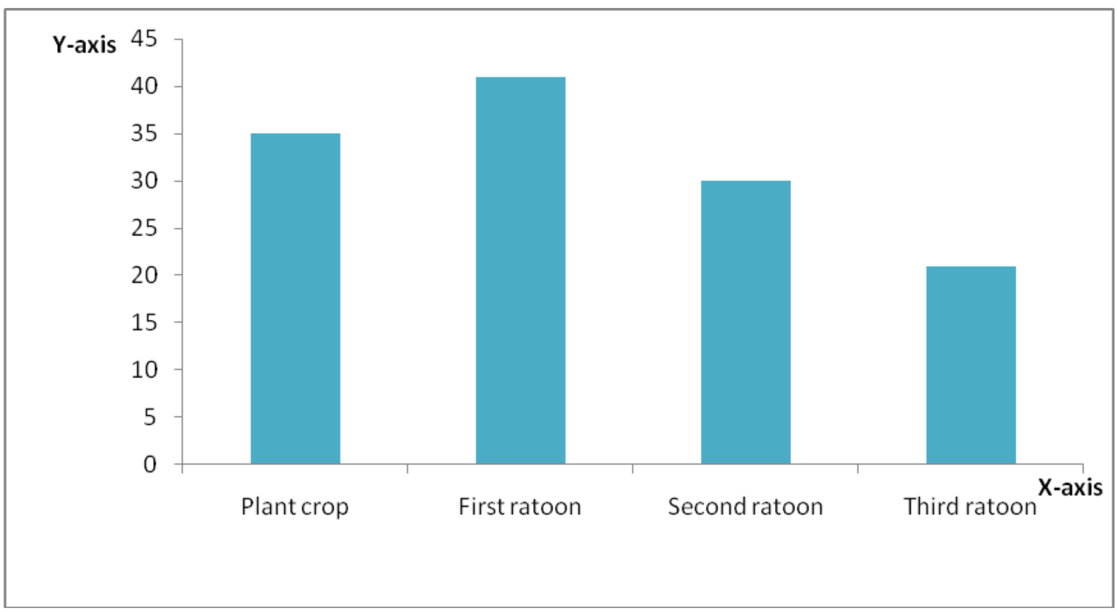

Figure 0.4: Ratooning and sugarcane production

Source: *Survey data 2020*

The weigh bridge workers indicated that;

> *"The production of the plant crop was normally higher than the ratoon crop though in some cases, the production of the first ratoon could be higher when compared to plant crop."*

The weigh bridge workers added that the production of the first ratoon was higher than the subsequent ratoons though the returns for ratoon crops were higher than the plant crop because there were no planting costs in ratoon crops. Variations in the output of ratoon crop was attributed to soil degeneration as a result of monocropping and continuous cropping and sub optimal ratoon sugarcane crop management as explained the field officers.

In general, field crop production practices have impact on cane production where farmers who adequately practised field crop production practices had on average 29.2% more tonnage of the total expected production in an acre of sugarcane farm than those farmers who partially implemented these practices.

4.5 Influence of Special Purpose Plant Improvement Practices Sugarcane Production

This section addresses the second objective of this study which was to examine the influence of special purpose plant improvement practices on sugarcane production. The special purpose plant improvement practices that this study investigated included; row spacing, sugarcane varieties and earthing up.

4.5.1 Row Spacing and Sugarcane production

In table 4.9, it was observed by the researcher that 21.9% of farmers practiced 1.5-2.0m wide row spacing while 78.1% of sugarcane farmers practiced a row spacing of 0.5m to 1.0m which impacted negatively on their sugarcane production. Sugarcane farmers with plots as small as half an acre practiced a row spacing of 0.5m wide which normally led to overcrowding in sugarcane field leading to tiny stalks of cane hence low tonnage. Those with large parcels of land preferred the 2m recommended row spacing. This implied that most farmers practiced a row spacing of 0.5m to 1.0m which was considered in this study as a narrow spacing that makes tonnage to be low and overall low cane production as depicted in table 4.9.

Table 0.9: Effect of row spacing on sugarcane production

Row spacing practiced	**Frequency**	**Percentage**	**Cumulative percent**	**Yield in tonnes**
1.5-2.0 meters	21	21.9	21.9	35
0.5-1.0 meters	75	78.1	100.0	18
Total	**96**	**100**		

Source: *Survey data 2020*

This was supported by the sentiments from the field officers who indicated that most sugarcane farmers would prefer a wide spacing of 2m which would result in increased sugarcane output when compared to close spacing of 1-1.5m but because of the small parcels of land most of the farmers practiced a close row spacing which impacts negatively on the general sugarcane production.

This study sought to determine the experience that farmers had on row spacing and sugarcane production where majority (52%) of farmers agreed that wide spacing increased cane production, 45% strongly agreed and few (3%) farmers disagreed as shown in the figure 4.5. From this finding, it follows that farmers had knowledge on the effect of row spacing on sugarcane yield though most of those farmers (78.1%) did not practice the 2m wide row spacing which could have increased the yield of sugarcane had it been practiced.

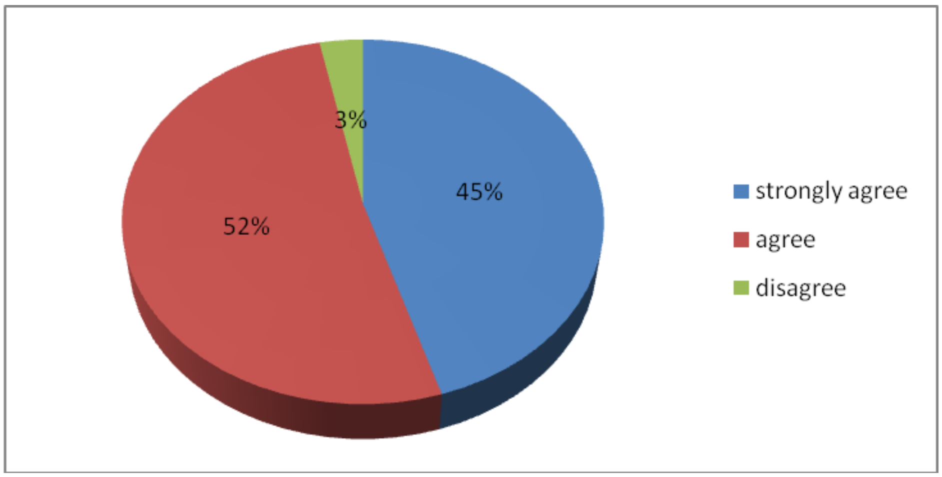

Figure 0.5: Response rate on wide spacing increased cane production

Source: *Survey data 2020*

This was supported by the fact that the 78% of farmers who practiced a row spacing of 0.5 to 1.0m had an average yield of 18 tonnes in an acre of land while those farmers who practiced a row spacing of 1.5-2.0m had an average yield of 31 tonnes in an acre of sugarcane farm as illustrated in figure 4.6. This implies that farmers who practised row spacing of 2m harvested 23.6% more tonnage than those farmers who practised a row spacing of 1.5m.

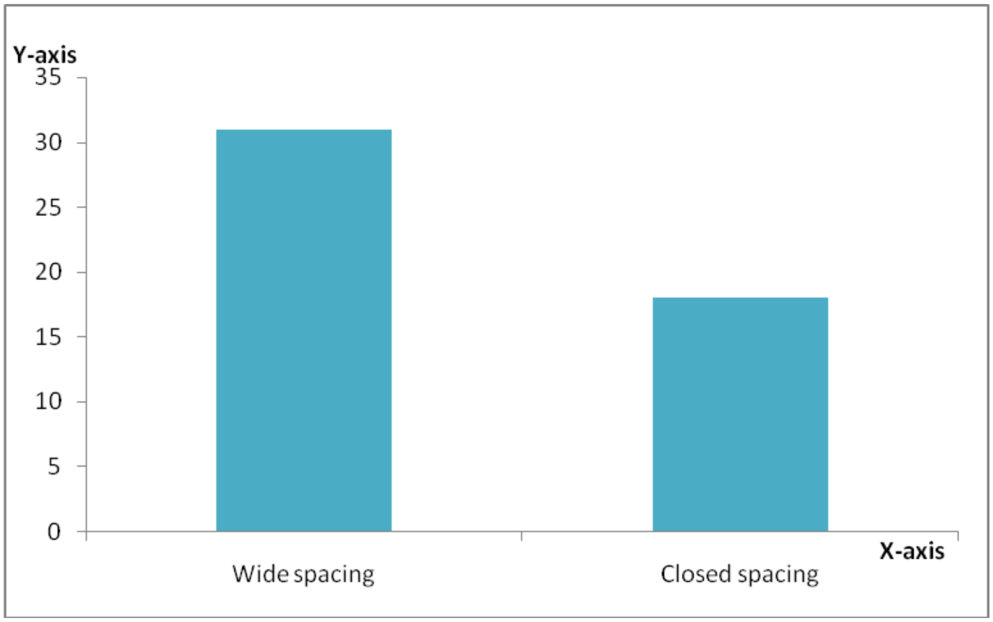

Figure 0.6: Row spacing and sugarcane production

Source: *Survey data 2020*

DAFF (2014) in South Africa indicated that closer spacing tended to result in higher yields provided there was adequate moisture in the soil. In addition, Omoto *et al.* (2013) noted that the production of seed cane yield grown at a row spacing of 0.4m, 0.5m and 0.6m greatly exceeded that grown at the standard 1.2m row spacing. They add that seed cane grown at row spacing of 0.5m to 0.6m is of more value to farmers than that grown at row spacing of 1.2m. This was in contrast with the findings of row spacing because farmers practiced a close spacing not because of availability of moisture in the soil but because of the small farm sizes and the need to harvest more without knowing that that could only increase the number of stalks of cane harvested but not weight. This was affirmed by the field officers who indicated that;

"*Closed row spacing led to tiny stalks of cane which were less weighty*."

4.5.2 Sugarcane varieties and production

This study found that majority (86.5) of sugarcane farmers planted '*Nyundo*' cane variety in their field which had average sucrose content of 12% and 15% fiber (FAO, 2023), 10% of farmers planted N14 variety and only 3.7% planted D8484 variety as illustrated in table 4.10.

Table 0.10: Variety of Sugarcane and tonnage produced

Variety	**Frequency**	**Percentage**	**Tonnage**
Nyundo	83	86.5	43.0
N14	10	10.4	37.5
D8484	3	3.1	33.1
Total	**96**	**100**	

Source: *Survey data 2020*

High number of farmers used the 'Nyundo' cane variety because the variety was strong, accumulated more weight and grew bigger and tall as illustrated in table 4.11. This was supported by the sentiments of the field officers, who indicated that,

> *"Nyundo cane variety was weighty and produced more buds hence gave rise to more ratoons."*

This finding implied that there were a variety of sugarcane species that were planted but Nyundo variety was the most preferred and utilized by farmers.

Table0.11: Reasons why 'Nyundo' variety is preferred

Reason	Frequency	Percent
Strong	29	34.9
Weighty	33	39.8
Grow bigger	21	25.3
Total	**83**	**100**

Source: *Survey data 2020*

This study looked at the experience that farmers had concerning the impact of cane variety CO-421 and production where 24.9% of the farmers strongly agreed with the statement that adopted sugarcane variety CO-421(Nyundo) increased cane production, 54.1% agreed with the statement and 21% disagreed with the statement as indicated in the figure 4.7. This was confirmed by information from farmers that Nyundo variety gave the highest average tonnage of 43.0 tonnes per acre followed by N 14 with 37.5 tonnes per acre and D8484 which gave 33.1 tonnes per acre (table 4.12. Farmers who used sugarcane variety Co 421 had more tonnage of 10% and 9.9% than those who used N 14 and D 8484 varieties respectively. This finding means that the variety CO421 gave more return than other varieties of sugarcane such as D8484 and N14 that were grown by farmers.

Table 0.12: Variety of Sugarcane and tonnage produced

Variety	Frequency	Percentage	Tonnage
Nyundo	83	86.5	43.0
N14	10	10.4	37.5
D8484	3	3.1	33.1
Total	**96**	**100**	

Source: *Survey data 2020*

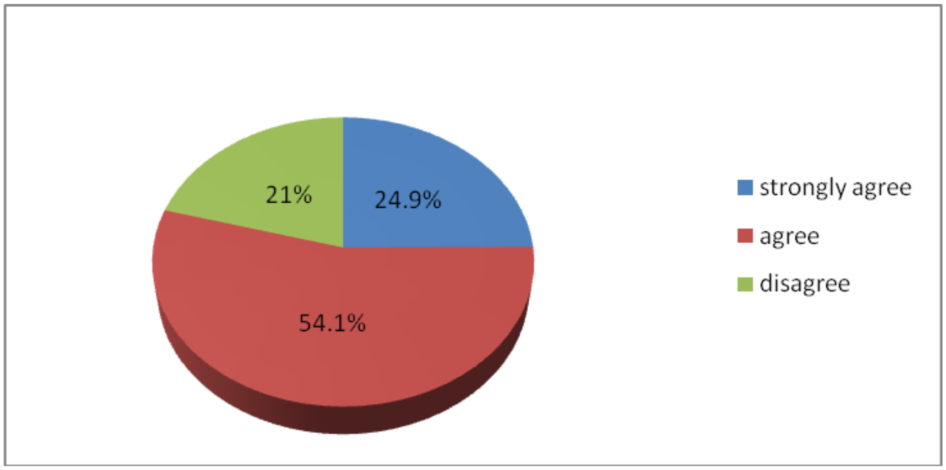

Figure 0.7: Response rate on sugarcane varieties on cane production

Source: *Survey data 2020*

Field officers, indicated that,

> *"Sugarcane varieties supplied by the West Kenya Sugar Company to sugarcane farmers in Webuye East Sub-County include; CO-421, N14 and D8484 but most sugarcane farmers preferred CO-421 variety, commonly known as 'Nyundo' variety."*

Reasons that were given by the field officers as to why CO-421 cane variety was preferred included; the variety was resistant to diseases, gave rise to more ratoons as more buds were formed and produced more sugar. This was also confirmed field officers who added that;

> *"Maintenance cost of this variety to the farmers is low; however, output of this variety depends on how the farmer has managed the crop as far as other agronomic practices are concerned."*

Moreover, field officers reported that sugarcane variety D-8484 was less supplied and less adopted because it gave less number of ratoons, formed little number of buds and it was vulnerable to human pest because it was soft and sweet. In addition, the variety D-8484 was light hence gave less tonnage to the farmer thus was not preferred.

The weigh bridge workers indicated that the commonly supplied cane variety in the sub county was CO-421, which is locally known as 'Nyundo'. This variety of cane was one of the recommended varieties and had been adopted by cane farmers because it was resistant to diseases and pests, it was weighty and it was an old variety. These findings compares with that of Nazir *et al* (2013) in Pakistan where sugarcane varieties THATTA-10, HSF-240 and CP 77-400 varieties were adopted because of accumulating high sucrose content. The findings were in line with Kaiser and Ndimande (1978) in Kenya where CO-421 cane variety accounted for over 60% of total acreage in Kenya.

4.5.3 Earthing up

It was found out that most farmers (90.5%) practiced earthing up in sugarcane while few farmers (9.5%) did not practice earthing up as shown in the table 4.13.

Table0.13: Farmers who practiced earthing up in sugarcane

Do you practice earthing up?	Frequency	Percent	Cumulative Percent
Yes	86	90.5	90.5
No	9	9.5	100.0
Total	**96**	**100**	

Source: *Survey data 2020*

The field officers explained that earthing up was mostly done in ratoon sugarcane crop when the plant was one month old after cutting and was done using oxen at that stage. They added that the practice was repeated when the cane was seven to twelve months old and was meant to provide support to the sugarcane plant so as to prevent it from falling when the plant was mature. Earthing up that was done when cane crop was one month after cutting was meant to cut the roots of the crop so that they remain confined within their line. Farmers who practiced earthing up harvested an average yield of 37.2 tonnes in an acre while those who did not practice it harvested an average yield of 33.1 tonnes in an acre as illustrated in figure 4.8. Earthing up yielded 4.1 more tonnage than where earthing up was not done. These findings imply that those farmers who practiced earthing up had 7.5% tonnes more than those who did not practice earthing up.

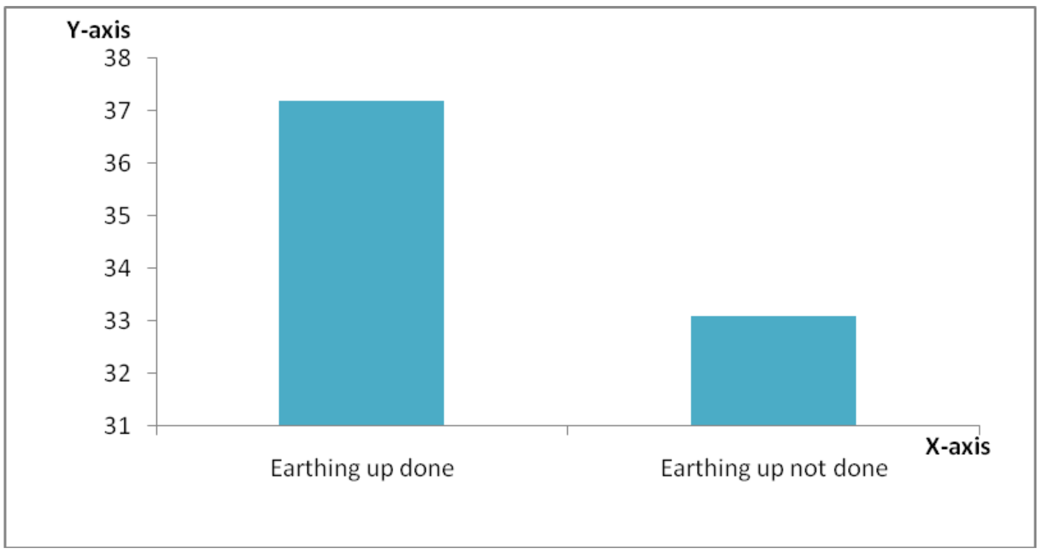

Figure 0.8: Earthing up and sugarcane yield

Source: *Survey data 2020*

This was supported by the high number of farmers who agreed when they were asked to rate their experience with earthing up in sugarcane where 33.3% of farmers strongly agreed that earthing up led to high sugarcane production, 54.2% agreed, 9.4% disagreed and 3.1% strongly disagreed as illustrated in the table 4.14. Earthing up significantly increased cane production where 86.8% of farmers agreed that indeed it affected cane yield (table 4.14). These sentiments compares with the study by Bilal (2010) on effects of earthing up and fertilizer level on growth and yield of spring planted sugarcane (*Sacchairuan officinarum*)' in Punjab who concluded that earthing up significantly increased cane yields.

Table 0.14: Response on earthing up on Cane production

Level	**Frequency**	**Percent**	**Cumulative Percent**
Strongly agree	32	33.3	33.3
Agree	52	54.2	87.5
Disagree	9	9.4	96.9
Strongly disagree	3	3.1	100.0
Total	**96**	**100.0**	

Source: *Survey data 2020*

Special purpose plant improvement practices such as row spacing, sugarcane varieties and earthing up have impact on cane production where farmers who observed these practices had increased cane yield of 12.8% than those who failed to follow these practices.

4.6 Effects of Soil Management Practices on Sugarcane Production

This section addresses the third objective which was to determine the influence of soil management practices on sugarcane production. Soil management practices in sugarcane production that were researched on included, land preparation, application of farm yard manure, application of fertilizer and mulching.

4.6.1 Land Preparation

Data collected on land preparation was analysed and out of a sample of 96 farmers, it was found out that 61.5% of farmers ploughed their sugarcane field twice before planting the cane crop, 35.4% of the farmers ploughed thrice before planting their sugarcane crop and

3.1% of the farmers ploughed their cane field once before planting the cane crop. Table 4.15 is a summary of the response in terms of the number of times the sugarcane field was ploughed before planting. These findings imply that a majority of farmers ploughed their cane fields twice before they could plant their cane crop.

Table0.15: Number of times the cane field is ploughed before planting cane crop

Number of times	Frequency	Percent	Cumulative Percent
1	3	3.1	3.1
2	59	61.5	64.6
3	34	35.4	100
Total	**96**	**100.0**	

Source: *Survey data 2020*

Study on instruments that were used to prepare sugarcane field in the sub county indicated that 68.8% of farmers used oxen plough, 30.2% used tractors and 1.0% of farmers used hoe to prepare the field for planting the sugarcane crop, as illustrated in the table 4.16. This finding implied that a majority of the farmers utilized oxen plough while preparing land in the sub-county while few used the hoe. The reason highlighted by the farmers for using oxen plough was due to its availability and less expensive when compared to tractors. The field officers reiterated that most farmers who used tractors to prepare land got credit on land preparation from West Kenya Company. The reason highlighted by the field officers as to why the company gives credit facilities on land preparation was because most farmers had less access to capital needed to hire tractor plough and it was to help them overcome the problem of weeds during early stages of cane growth. In addition, field officers said that;

> *"The way land is prepared is important in sugarcane crop management as it determines the level at which weeds may colonize the sugarcane field after planting."*

Table 0.16: Instruments used to prepare land

Instrument	**Frequency**	**Percent**	**Cumulative percent**
Oxen plough	66	68.8	68.8
Tractor	29	30.2	99.0
Hoe	1	1.0	100
Total	**96**	**100.0**	

Source: *Survey data 2020*

Farmers who used tractors to prepare land had an average yield of 40 tonnes; those who used oxen plough had an average yield of 36 tonnes while those who used hoe had an average yield of 17 tonnes in an acre of land of sugarcane as illustrated in figure 4.9. Farmers who used tractors to prepare land harvested 32.4% and 14.2% more tonnage than those who used hoe and oxen respectively. This finding implies that those farmers who used tractors to prepare land harvested more tonnage when compared to those who used oxen plough and hoe to prepare land. This is because tractors perform deep tillage compared to oxen and hoe where shallow tillage is done hence weeds are controlled earlier in tractor plough which could interfere with sugarcane growth than in oxen and hoe plough. Also, in tractor plough soil colloids are broken down maximally hence easing root penetration, aeration and water movement which is key to healthy and strong sugarcane growth.

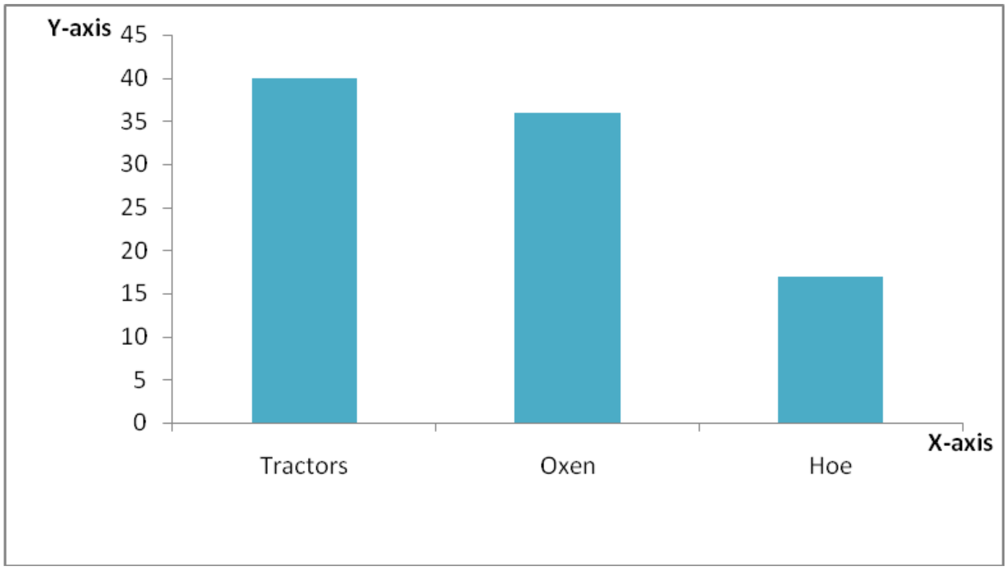

Figure 0.9: Instrument used to prepare land and cane production

Source: *Survey data 2020*

Though from the field officers' sentiments, most farmers preferred deep tillage using tractors, this did not happen due to poverty among some cane farmers as noted by farmers. Thus 68.8% of farmers in the region ploughed their sugarcane fields twice using oxen plough before planting the cane crop. Other reasons cited by farmers for the use of oxen plough were: because oxen were available and were cheaper compared to tractors. Moberly (1972) indicated that deep tillage was unnecessary in most soils of natural sugar belt while Nasir *et al.* (2013) in Pakistan found out that the main use of modern equipment for ploughing was found present in Punjab which was tractor. However the main instrument that was used to prepare land was found to be oxen plough which had 68.8 percent of farmers in the sub-county (table 4.17) and the reason given by farmers as to why oxen plough was commonly used was because it was more available and cheap when compared to the tractor.

This study sought to determine the effect of land preparation on cane production and found out that 61.5% of farmers who ploughed their sugarcane field thrice before planting had an average yield of 44.8 tonnes in an acre of land, those who ploughed their field twice before planting cane had an average yield of 37 tonnes while farmers who ploughed once had an average yield of 27 tonnes in an acre of land as indicated in figure 4.10.

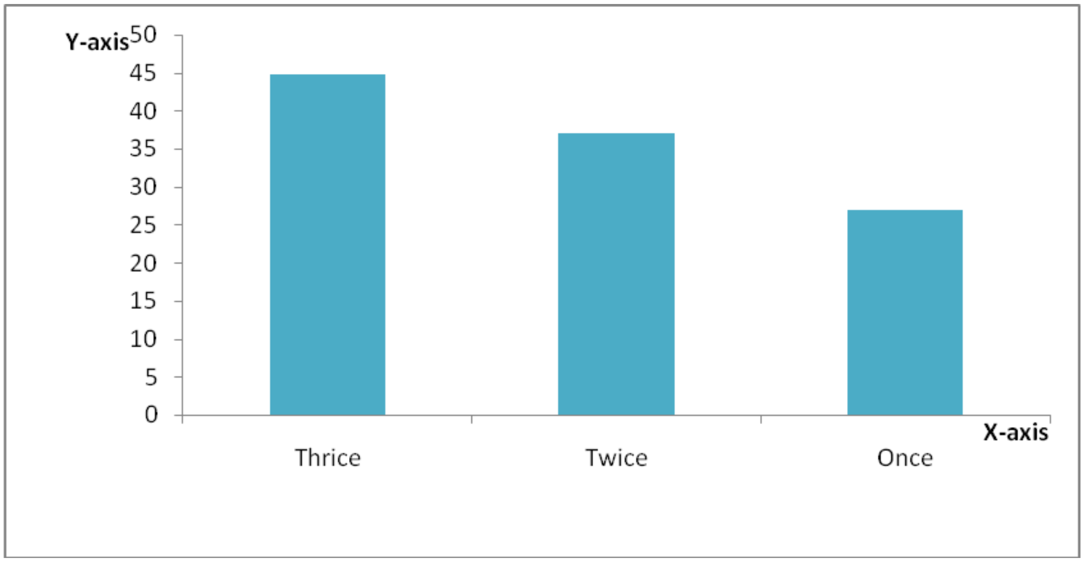

Figure 0.10: Land preparation and sugarcane yield

Source: *Survey data 2020*

Those farmers who prepared land thrice had 73% and 41.8% more tonnage than those who ploughed once and twice respectively. This was explained by one of the field officers that ploughing the land thrice helped to control weeds that could colonize sugarcane field during early stages of cane growth and to further break the soil for easy root penetration and development. In addition, when the farmers were asked to give their view on their experience on land preparation, 70.8% of farmers agreed that deep tillage resulted in high sugarcane production, whereas 29.2% strongly agreed as shown in table 4.17. This finding partly compares with that of Solomon *et al* (2016) who found out that land preparation cost had a positive relation to that of cane production and an increase in the cost of land preparation results in an increase of 18.6% sugarcane production by individual farmers.

Table0.17: Responses on effect of Deep Tillage on Cane Production

Level of agreement or disagreement that deep tillage increases production	**Frequency**	**Percent**	**Cumulative percent**
Agree	68	70.8	100
Strongly agree	28	29.2	29.2
Total	**96**	**100.0**	

Source: *Survey data 2020*

4.6.2 Application of Farm Yard Manure and Sugarcane Yield

The results of the study indicated that majority of the farmers (82.0%) in WES did not utilize farmyard manure (FYM). Only 18.0% of the farmers utilized farm yard manure in their sugarcane plots as illustrated in table 4.18. Farmers who did not utilize farm yard manure in their sugarcane farms indicated that it was due to unavailability of FYM, the high prices of FYM and inadequate information on the general knowledge on the agronomy of the cane plant. Field officers indicated that most farmers would use FYM on crops like maize and beans but not on sugarcane because famers had a notion that sugarcane was one of the crops that was not so much demanding when it came to manure and fertilizer application in general. These findings on the usage of FYM compares with that of Khanzada (1992) who found out that use of FYM was negligible and irregular.

Table 0.18: Use of FYM in WES

Manure application	Number of farmers	Percentage number	Cumulative %
Did not apply manure	79	82	82
Applied manure	17	18	100
Total	96	100	

Source: *Survey data 2020*

Farmers who utilized FYM used a mixture of plant wastes such as maize and sunflower remains and animal wastes such as cow dung. This mixture was allowed to decompose for at least six months before it was applied in sugarcane furrows during planting and along sugarcane lines during growth stage. This study found out that 24% of farmers who used FYM applied 2-3 tonnes (one trailer) of this manure in an acre of land, 35% of farmers applied 4-6 tonnes (two trailers) per acre and 41% applied 7-9 tonnes (three trailers) per acre of sugarcane field as illustrated in table 4.19. Those farmers who applied 2-3 tonnes of FYM in an acre of land harvested an average yield of 30 tonnes per acre; those who applied 4-6 tonnes per acre harvested an average yield of 33 tonnes per acre while those who applied 7-9 tonnes in an acre harvested an average yield of 38 tonnes per acre as illustrated in table 4.19. Though farmers who applied three trailers of FYM per acre had a higher yield of 9.5% and 14.5% than those who applied two trailers and one trailer per acre respectively, most farmers in the sub-county did not use farm yard manure. These findings compares with that of Nazir *et al.* (2013) where the overall average usage of farm yard manure in Pakistan was recorded as 3.8-5.7 tonnes (1.9 tractor trolleys) per acre which meant that FYM was underutilized. From these findings, it can be noted that those farmers who used more trailers of FYM in their cane plot harvest more tonnage of sugarcane than those who use less number of trailers of FYM to their sugarcane crop.

Table 0.19: Application of FYM and cane yield

Amount of FYM	Frequency	Percentage	Yield (in tonnes/acre)
One trailer (2-3 tonnes)	4	24	30
Two trailers (4-6 tonnes)	6	35	33
Three trailers (7-9 tonnes)	7	41	38
Total	17	100	

Source: *Survey data 2020*

These findings were supported by the large number of farmers (63.5%) who strongly agreed that application of farm yard manure led to increased cane yields and 33.3% of farmers who agreed despite only 3.1% of farmers who strongly disagreed with the statement that application of farm yard manure in sugarcane farm led to a high sugarcane production as illustrated in the table 4.20. These findings compares with that of Gana *et al*. (2001) who notes that cane treated with cow dung and inorganic fertilizer significantly produced better cane in terms of height, vigour and yield.

Table 0.20: Response rate on effect of farm yard manure on sugarcane yield.

Level of agreement or disagreement	Frequency	Percent	Cumulative percent
Strongly agree	61	63.5	63.5
Agree	32	33.3	96.8
Strongly disagree	3	3.1	100
Total	96	100.0	

Source: *Survey data 2020*

4.6.3 Application of Fertilizer and Sugarcane Production

Farmers were questioned about the type of fertilizer they applied to their sugarcane plot, the amount they applied per acre, the number of times the fertilizer was applied, the stages of sugarcane growth when the fertilizer was applied and whether fertilizer application influenced sugarcane growth based on their experience. The results in table 4.21 showed that 93.7% of the farmers applied 50 kg of the fertilizer in an acre while 6.3% of the farmers applied 100 kg in an acre of cane plot. These findings imply that there are more farmers who used 50 kg fertilizer in an acre of sugarcane farm than those who use 100 kg of fertilizer per acre.

Table 0.21: Amounts of fertilizer (kg) applied per acre of cane plot

Amount of fertilizer	Frequency	Percent	Cumulative percent
50kg	90	93.7	93.7
100kg	6	6.3	100.0
Total	96	100.0	

Source: *Survey data 2020*

This study sought to determine the level of impact of fertilizer application on the yield of sugarcane crop and it was found out that 93.7% of farmers (table 4.21) who applied 50 kg of fertilizer in an acre of land harvested an average yield of 26 tonnes (figure 4.11) in an acre of sugarcane plot while 6.3% of farmers who applied 100kg of fertilizer in an acre of land harvested an average yield of 35.3 tonnes in an acre of sugarcane farm as illustrated in figure 4.11. However, the 100 kg fertilizer was split into two halves and applied twice while the 50 kg fertilizer was applied once. From this finding, it can be explained that farmers who used 100 kg of fertilizer per acre of sugarcane harvested 9.3% more tonnage of sugarcane than those farmers who used 50 kg of fertilizer per acre of cane field hence the more the amount of fertilizer used the more the harvest.

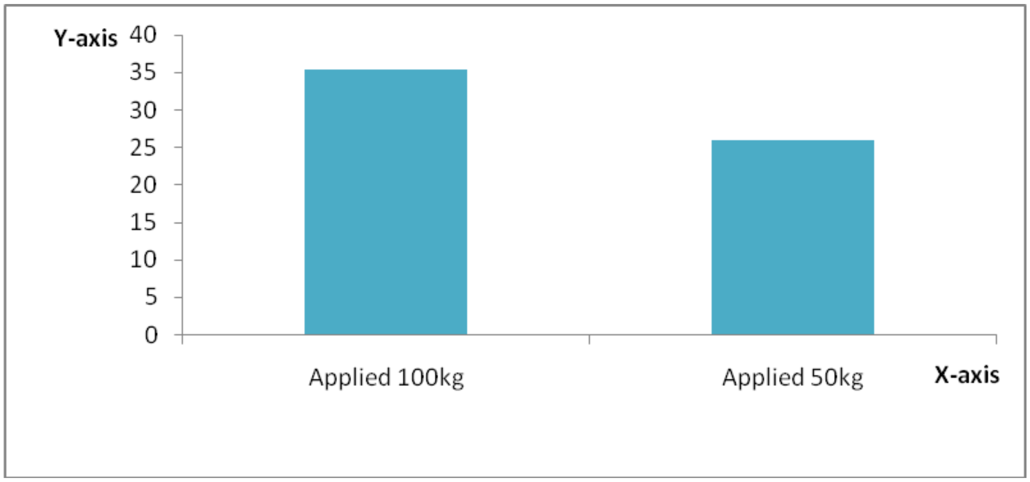

Figure 0.11: Effect of application of fertilizer and sugarcane production

Source: *Survey data 2020*

Farmers indicated that they applied DAP, CAN and Urea fertilizers to their sugarcane crop and this fertilizer was applied during the growing stage of sugarcane after germination. Field officers elaborated this by explaining that:

> "*Most farmers did not apply DAP to their sugarcane crop during planting time but utilized a mixture of DAP and urea during the sugarcane growing stage. This mixture is applied once during the growing period of sugarcane crop.*

This was in contrast with the findings by Nasir *et al.* (2013) in Pakistan where a quarter of N, all potash and phosphorus had to be applied during planting. They recommended that K and P may be applied in furrows in which sets of seeds were placed. The remaining Fertilizer was to be applied thrice in equal splits. The reason given by farmers who applied fertilizer once was due to inadequate finances to purchase the fertilizers. However, field officers indicated that some farmers who received fertilizer on credit preferred utilizing it on growing maize than in sugarcane due to the notion that sugarcane can grow without fertilizer unlike maize.

From the above findings, it is evident that sugarcane farmers who applied 100 kg of fertilizer in an acre harvested more tonnage than those who applied 50 kg in an acre. This was supported by the high percentage of farmers who agreed that fertilizer application increased cane yield where

67.8% of farmers strongly agreed with the statement that application of fertilizer increased cane production and 32.2% of farmers agreed as illustrated in the figure 4.12. More salient from field officers was that there was inappropriate application of fertilizers thus affecting the yield. They observed that:

> "F*armers within WES use unbalanced and less amount of fertilizers in their sugarcane plots despite them having knowledge that fertilizer use improves sugarcane yield. Proper and adequate use of fertilizers on cane crop can result to maximum yield of 55 tonnes per acre if all other agronomic practices are done.*"

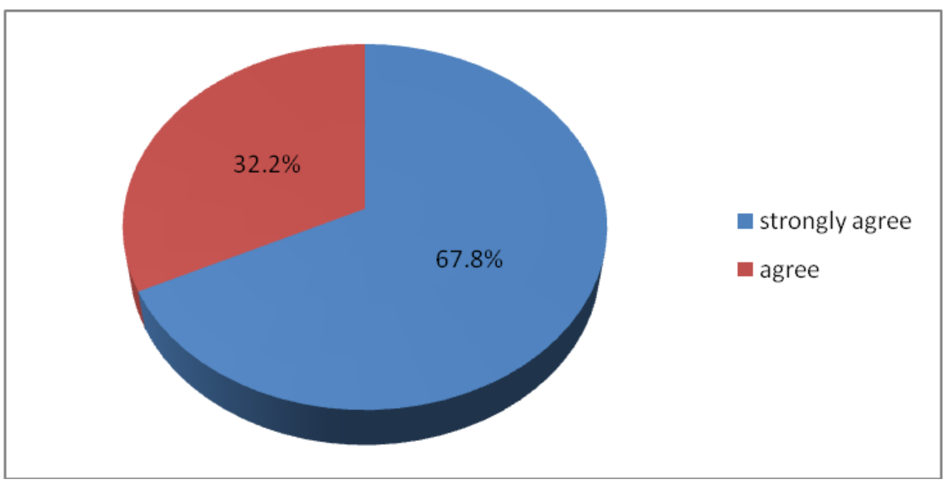

Figure 0.12: Response on effect of application of fertilizer on cane yield

Source: *Survey data 2020*

4.6.4 Mulching and Sugarcane Growth

It was observed that farmers did mulching after the first cutting of sugarcane plant crop as shown in plate 4.5. Sugarcane thrashes were used as mulching material in ratoon crop while in sugarcane plant crop, there were no materials (sugarcane thrash) to be used for mulching hence intercropping was done. Farmers carried out intercropping during the early stages of sugarcane plant growth as shown in plate 4.6. Crops that were observed to be intercropped with sugarcane included beans, cow peas and lentils. Though there were no observable signs of soil erosion within the sugarcane field, mulching was meant to majorly control the rate at which weeds grew and partly to preserve moisture in the soil.

Plate 0.5: Mulched Sugarcane in Mihuu Ward

Source: *Author 2020*

Plate 0.6: Plot of Intercropped Sugarcane in Ndivisi Ward

Source: *Author 2020*

Sugarcane thrash was used to mulch the first ratoon crop which indicated an increased cane output averaging to 41 tonnes per acre compared to the unmulched sugarcane plant crop which gave an average yield of 35 tonnes in an acre of land as illustrated in figure 4.13. This meant that those farmers who mulched their cane crop had 10.9% more tonnage in an acre of cane crop than those who did not mulch their crop. Mulching added organic matter and helped to check weeds in the sugarcane crop as explained by the field officers. This was supported by the large number of farmers who agreed that mulching increased cane yield. Out of 96 respondents, 19.3% of farmers in the sub county strongly agreed with the statement that mulching increased sugarcane production, 73.9% agreed with the statement and 6.8% of farmers disagreed with the statement as illustrated in figure 4.14.

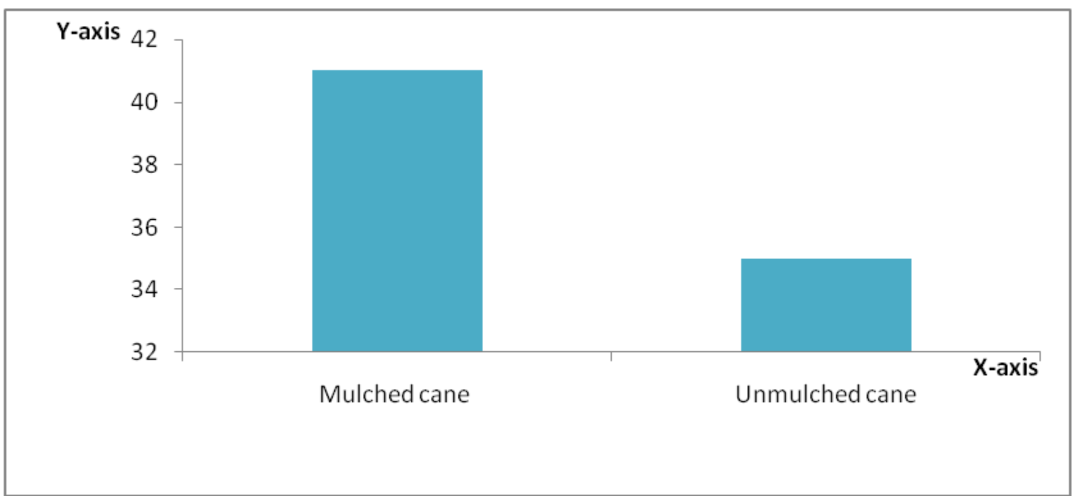

Figure 0.13: Mulching and sugarcane production.

Source: *Survey data 2020*

Farmers indicated that mulching was majorly done to control weeds hence significantly affected the production of cane plant especially the ratoon crop. This was in line with the study by Ahmed *et al.* (2001) on evaluation of organic mulch on the growth and yield of sugarcane in Southern Guinea Savannah of Nigeria where they found out that organic mulch rate had significant impact on the production of sugarcane. They agreed that application of organic mulch had to be recommended and encouraged for effective production of sugarcane hence maximum production.

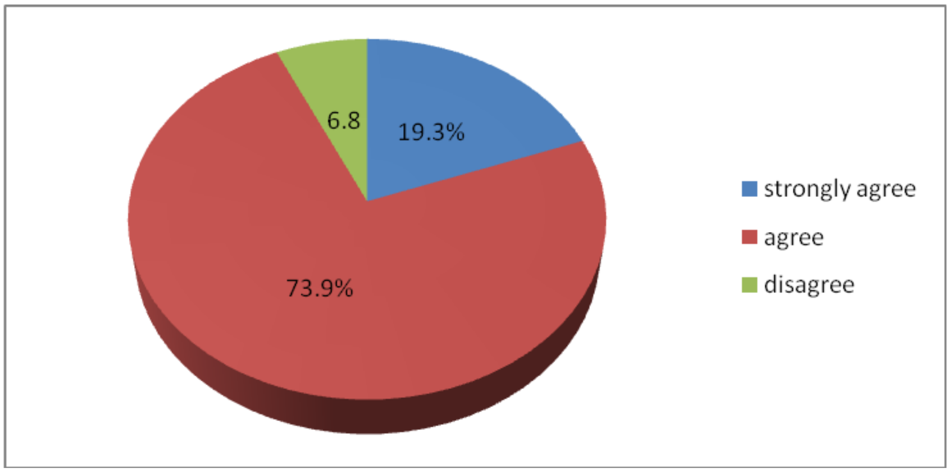

Figure 0.14: Response rate on effects of Mulching on Cane Production

Source: *Survey data 2020*

In general, soil management practices gave an increased yield of 25.7% in cane crops where these practices were observed.

4.7 Influence of Planting Season and Harvesting Management on Sugarcane yield

This section addresses the fourth objective which was to determine how planting season and harvesting management influence sugarcane production.

4.7.1 Planting management and cane production

The study sought information on the planting season of sugarcane crop and found out that it took place in two seasons; between April and June and between August and September. Most farmers (72%) noted that they planted their cane during April and June while 28% indicated that they planted in August and September as illustrated in table 4.22. These findings partly compare with that of Linda (2005) who notes that sugarcane is planted in August and September by use of cut stalk (billets) and whole stalk in Louisiana. Farmers who planted their cane crop in April and June cited reasons that the season was of long rain which enhanced germination, sprouting of buds and growth of healthy cane for a longer period before the onset of a dry spell and sugarcane would be planted together with maize at intervals since it was the season for growing maize. Farmers who planted their cane between August and September explained that during that time the land was free of other crops like maize and so sugarcane could occupy the field instead of the land remaining fallow. The April-June planted sugarcane crop had an average yield of 45 tonnes while the August-September crop gave an average yield of 39 tonnes in an acre of sugarcane farm as indicated in table 4.22. This shows that farmers who plant their cane crop in April-June season harvested 6 more tonnages which translate into 10.9% than those farmers who planted their sugarcane in August-September as evidenced by the higher tonnage in April-June planted crop compared to August-September planted crop.

Table0.22: Planting season and cane yield

Planting season	Number of farmers	percentage	Cumulative percentage	Yield per acre
April-June	69	72.0	72	45 tonnes
August-September	27	28.0	100	39 tonnes
Total	96	100.0		

Source: *Survey data 2020*

Sugarcane farmers preferred planting sugarcane during two rainy seasons when the rain was at its peak. Most farmers planted their cane crop in April-June season compared to August-September season. April-June season was a season of long rains. Confirming the period, the field officers noted that;

> “April-June season is the period when the company supplies seed cane to most farmers because it’s the season when the rains are higher and long. The rain enhances maximum germination of the sugarcane plant crop due to the ideal moisture in the soil hence luxuriant growth of the plant. In addition, rain enhanced development of strong stalks in sugarcane hence high tonnage. This helps the company and the farmers not to suffer lose as a result of poor germination.”

4.7.2 Harvesting Management and cane Production

Most sugarcane farmers (99%) noted that they harvested their cane at the age of 18 months after planting and only 1% noted that they harvested cane when it was less than 18 months as illustrated in table 4.23. The reason given by the farmers for harvesting sugarcane before the attainment of maturity period of 18 months was due to urgent need of money for paying school fees, medical emergency and to pay for funeral arrangements of their loved one. Information elicited from one of the field officers indicated that sugarcane plant crop was harvested for the first time when it was between 16-18 months while the sugarcane ratoon crop was harvested at 14-18 months.

Table0.23: Period when sugarcane was harvested

Period of harvesting	Frequency	Percentage	Cumulative percentage
18 months	95	99.0	99
Less than 18 months	1	1.0	100
Total	96	100.0	

Source: *Survey Data 2020*

Field officers noted that:

> *"Harvesting of cane crop depends on whether the crop was a plant crop or it was a ratoon crop. Ratoon crop matures faster than the plant crop. During harvesting, dry season or wet season was not considered but cane maturity was considered."*

This meant that sugarcane was harvested any time as long as it had attained maturity and not based on whether it was a dry season or wet season. This was in contrast with Nazir *et al.* (2013) in Pakistan who concluded that sugarcane was harvested when rainfall was less and the plant sugar content was at its highest.

There is a slight variation on the period that sugarcane takes in farm before it is harvested in different regions of the world. DAFF (2014) noted that sugarcane was harvested after 12 to 16 months in South Africa while Nasir *et al.* (2013) indicated that sugarcane was harvested at 12-14 months in Pakistan which can be attributed to variation in climate and soil characteristics.

The state in which sugarcane was harvested refers to whether sugarcane was harvested green or when burnt. The study found out that most farmers (98%) harvested their cane while green without burning and only 2% of the farmers harvested cane when burnt as shown in table 4.24. This was attributed to the fact that cane took 3-4 days in the farm before it was transported to the factory hence tended to reduce weight and when cane was burnt before cutting, weight reduced drastically as noted by farmers in WES. The 98% of farmers who harvested their cane when green had an average yield of 46 tonnes in an acre while the 2% (table 4.24) of farmers who harvested their cane when burnt had 25 tonnes in an acre. This implies that harvesting green sugarcane gave a higher yield of 38.2% than harvesting burnt cane. The reasons given by farmers for harvesting green cane was to prevent drastic weight lose and to use thrash in mulching. Those farmers who practiced harvesting burnt cane indicated that they wanted ease of harvesting cane and to chase away some dangerous animals like snake that could be present in the sugarcane farm. These finding agrees with that of DAFF (2014) who notes that it is necessary to harvest green sugarcane to increase yield.

Table 0.24: Nature of harvested Cane

Nature of cane during harvesting	Frequency	Percent	Cumulative percent	Average Yield per acre
Burnt then cut	2	2.0	2.0	25 tonnes
Cut when green	94	98.0	100.0	46 tonnes
Total	96	100.0		

Source: *Survey data 2020*

Farmers were questioned on the length of stay of harvested sugarcane in the farm before transportation and most farmers (88%) indicated that sugarcane was transported to the factory after two to three days of cutting, 7% of farmers indicated four days and only 5% of farmers indicated more than four days as illustrated in table 4.25. Farmers also noted that there were incidents when sugarcane could be delayed in the farm before it was transported to the factory. Reasons that were cited for this delay included muddy roads that were impassable during heavy rains and when the company had much sugarcane in its weighbridge yard. This was supported by the weigh bridge workers who said that:

> *"The crop has to be transported to the factory within 48 hours after harvesting. However, during rainy season, transportation of the harvested cane crop may delay as a result of poor feeder roads. When cane is transported to the factory within 48 hours of harvest it can give up to 55 tonnes in an acre that has been properly managed."*

The sentiments of the weigh bridge workers were supported by the field officers who reiterated that when cane was delayed in the farm it attracted human pest and much of the tonnage could get lost through theft. This finding compares with that of Nasir *et al.* (2013) who indicates that harvested cane has sugar content of around 10% and should be transported to the factory in 24-48 hours of cutting to reduce weight lose. These findings imply that production of cane reduces when cane is delayed in the farm for a longer period before harvesting and when cane is delayed in the farm after harvesting before it is delivered to the factory.

Table 0.25: Period that cut cane take in farm before transportation

Days	Frequency	Percentage	Cumulative percentage
2-3	84	88	88
4	7	7	95
More than 4 days	5	5	100

Source: *Survey data 2020*

When farmers were asked whether harvesting green sugarcane led to high yields, 40.6% strongly agreed, 57.3% agreed and 2.1% disagreed with the statement as indicated in figure 4.15. This was further supported by the field officers who indicated that cane reduced in weight depending on the state in which it was harvested and so most farmers preferred harvesting green sugarcane.

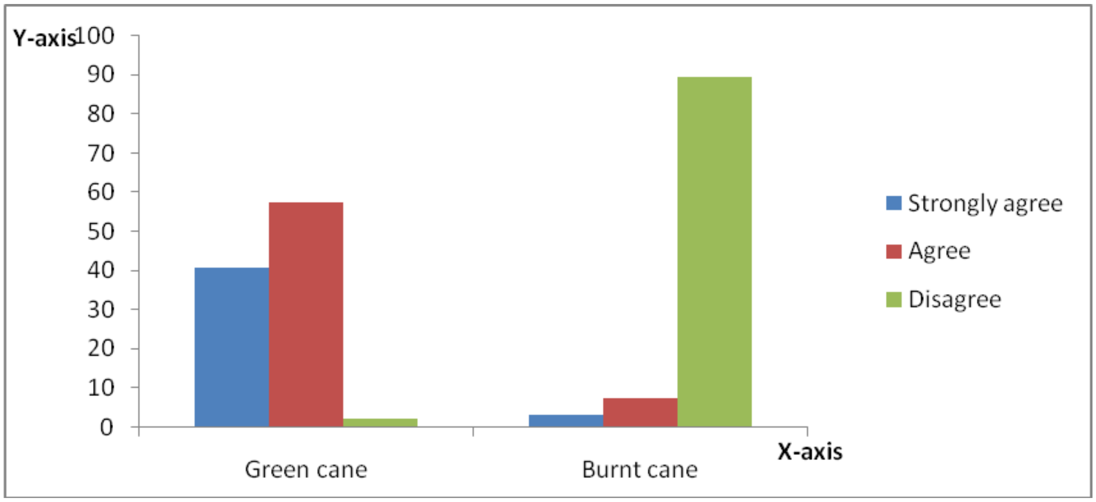

Figure 0.15: Response rate on state of sugarcane harvested

Source: *Survey data 2020*

From a sample of 96 respondents, 89.6% of farmers disagreed that harvesting burnt sugarcane led to high cane yields, 7.3% of farmers agreed and 3.1% of farmers strongly agreed. This implied that farmers preferred harvesting green sugarcane than burnt sugarcane because harvesting green sugarcane would be beneficial than burnt sugarcane as seen from the high tonnage posted by those farmers who harvested their cane while green.

Planting season and harvesting management practices have impact on cane production where when these practices are fully managed a farmer would harvest average yield of 24.6% more tonnage than those who did not observe these practices.

4.8 Inferential analysis of the results using Chi-Square

The summary of the raw data from questionnaires were presented as illustrated in the tables below and chi-square analysis done on each set of data based on the objectives of the study.

4.8.1 Influence of field crop production practices on sugarcane production

The overall hypothesis that guided the analysis in this section under several crop production practices was: $\mathbf{H_1}$ There is no significant relationship between field crop production practices and sugarcane production in Webuye East Sub County in Kenya.

Control of weeds and sugarcane production

Table 4.26 shows the quantity yield in tons harvested with respect to how weeds were controlled in the sugarcane farm. The results were subjected to Chi-square analysis to test the hypothesis that there is no significant relationship between control of weeds and sugarcane production. The critical X^2 value was 5.99 at 0.05 level of significance and 2 degrees of freedom. This was less than the calculated Chi-square value of 65.5, implying a positive significant relationship between control of weeds and sugarcane production. Therefore the null hypothesis is rejected and alternative hypothesis is accepted.

Table0.26: Control of weeds and sugarcane production

Variable	Observed tonnage	Expected tonnage
Successful control weeds	50	55
Unsuccessful control of weeds	18	55
Did not control	08	55

Source: *Survey data 2020*

Control of pests and diseases and sugarcane production

Table 4.27 indicates the amount of tonnage harvested with respect to how pests and diseases were controlled in the sugarcane farm. The results were subjected to chi-square analysis to test the hypothesis that there is no significant relationship between control of pests and diseases and sugarcane production and the critical X^2 value was 3.84 at 0.05 level of significance and 1 degrees of freedom. This was lower than the calculated Chi-square value of 19.9 implying that method of pests and disease significantly affected cane production.

Table0.27: Control of pests and diseases and sugarcane production

Variable	Observed tonnage	Expected tonnage
Successful pest and disease control	36	55
Unsuccessful pest and disease control	28	55

Source: *Survey data 2020*

Ratooning and sugarcane production

Results on ratooning and sugarcane production were subjected to Chi-square analysis to test the hypothesis that there is no significant relationship between ratooning and sugarcane production. Results show that the critical X^2 value was 7.81 at 0.05 level of significance and 3 degrees of freedom. The calculated chi-square value was 43.3 was higher than the critical or theoretical value of chi-square. This indicated that ratooning positively influenced cane production hence alternative hypothesis is accepted and null hypothesis is rejected.

Table 0.28: Ratooning and sugarcane production

Variable	Observed tonnage	Expected tonnage
Plant crop	35	55
First ratoon	41	55
Second ratoon	30	55
Third ratoon	21	55

Source: *Survey data 2020*

4.8.2 Influence of special purpose plant improvement practices on sugarcane production

The overall hypothesis that guided the analysis in this section under various special purpose plant improvement practices was: $\mathbf{H_2}$ There is no significant relationship between special purpose plant improvement practices and sugarcane production in Webuye East Sub-County in Kenya.

Row spacing and sugarcane production

Results on row spacing and sugarcane production were subjected Chi-square analysis in order to test the hypothesis that there is no significant relationship between row spacing and sugarcane production. Results show that the critical X^2 value was 3.84 at 0.05 level of significance and 1 degrees of freedom which was lower than the calculated Chi-square value of 35.4, implying significant influence of row spacing on sugarcane production. When row spacing was increased, sugarcane production increased hence null hypothesis is rejected and alternative hypothesis is accepted.

Table 0.29: Row spacing and sugarcane production

Variable	Observed tonnage	Expected tonnage
0.5-1.0M	18	55
1.5-2.0M	31	55

Source: *Survey data 2020*

Sugarcane varieties and production

The results for sugarcane varieties and production were subjected to Chi-square analysis in order to test the hypothesis that there is no significant relationship between sugarcane varieties and sugarcane production. This resulted in the critical X^2 value of 5.99 at 0.05 level of significance and 2 degrees of freedom. This value was lower than the calculated Chi-square value 16.9 implying a significant influence of sugarcane varieties and sugarcane yield.

Table0.30: Sugarcane varieties and production

Variable	Observed tonnage	Expected tonnage
CO-421	43	55
N-14	37.5	55
D-8484	33.1	55

Source: *Survey data 2020*

Earthing up and sugarcane production

Table 4.31 indicates the amount of tonnage harvested with respect to earthing up in the sugarcane farm. The results were subjected to chi-square analysis in order to test the hypothesis that there is no significant relationship between earthing up and sugarcane production. The critical X^2 value was 3.84 at 0.05 level of significance and1 degrees of freedom which was low than the calculated Chi-square value of 14.5. This implied that earthing up had significant impact on cane yield. This was explained partly by the fact that sugarcane in which earthing up had been done were held firm in the soil, did not fall and were stronger hence increase in weight.

Table0.31: Earthing up and sugarcane production

Variable	Observed tonnage	Expected tonnage
Did earthing up	37.2	55
Did not earth up	33.1	55

Source: *Survey data 2020*

4.8.3 Effects of soil management practices on sugarcane production

The relationship between soil management and sugarcane production was statistically analysed under various soil management practices and the results were indicated as below.

Land preparation and sugarcane production

Results on instruments that were used to prepare land and sugarcane production were subjected to Chi-square to test the hypothesis that there is no significant relationship between land preparation methods and sugarcane production. The critical X^2 value was 5.99 at 0.05 level of significance and 2 degrees of freedom which was lower than the calculated chi-square value of 37 denoting a positive significant relationship between instruments used to prepare land and cane yield. Instruments such as tractors broke the soil colloids which made it easy for root penetration, aeration and water movement.

Table0.32: Land Preparation Methods and sugarcane production

Variable	Observed tonnage	Expected tonnage
Tractor	40	55
Oxen	36	55
Hoe	17	55

Source: *Survey data 2020*

Table 4.33 indicates the amount of tonnage harvested with respect to number of times the cane field is ploughed before planting the cane. The results were subjected to Chi-square analysis to test the hypothesis that there is no significant relationship between the number of times the cane field was ploughed and sugarcane production Results show that the critical X^2 value was 5.99 at 0.05 level of significance and 2 degrees of freedom. The critical Chi-square value of 5.99 was below the calculated Chi-square value of 22.1. This indicated that the number of times the cane field was ploughed determined the amount of tonnage that farmer could realize in a given cane plot. The higher the number of ploughing the higher the cane production. This was because weeds were controlled maximally during early stages of cane germination and the soil was made looser to ease root penetration and shooting.

Table0.33: Number of times the cane field is ploughed and sugarcane production

Variable	Observed tonnage	Expected tonnage
Thrice	44.8	55
Twice	37	55
Once	27	55

Source: *Survey data 2020*

Application of FYM and sugarcane production

Table 4.34 indicates the amount of tonnage harvested with respect to application of FYM in the sugarcane farm. The results were subjected to Chi-square analysis to test the hypothesis that there is no significant relationship between application of FYM and sugarcane production. The output shows that the critical X^2 value was 5.99 at 0.05 level of significance and 2 degrees of freedom. This critical value was below the calculated value of Chi-square of 65.5. This implied that application of FYM affected the production of sugarcane positively. FYM improved soil water retention capacity, soil structure and soil mineral content which were key to the growth of sugarcane as explained earlier by the field officers.

Table0.34: Application of FYM and Sugarcane Production

Variable	Observed tonnage	Expected tonnage
One trailer	30	55
Two trailers	33	55
Three trailers	38	55

Source: *Survey data 2020*

Application of fertilizer and sugarcane production

Table 4.35 indicates the amount of tonnage harvested with respect to the amount of fertilizer that was applied in the sugarcane farm. The results were subjected to Chi-square analysis to test the hypothesis that there is no significant relationship between application of fertilizer and sugarcane production. The results show that the critical X^2 value was 3.84 at 0.05 level of significance and1 degrees of freedom. When this value was compared to that of the calculated Chi-square value of 22.4, it was way below it. This implied that application of fertilizer to sugarcane significantly affected cane growth. Fertilizer has inorganic mineral contents which improves soil fertility hence support plant growth as supported by one of the field officers.

Table0.35: Application of fertilizer and sugarcane production

Variable	Observed tonnage	Expected tonnage
100kg per acre	35.3	55
50kg per acre	26	55

Source: *Survey data 2020*

Mulching

The results for mulching and sugarcane production in table 4.36 below were analysed to test the hypothesis that there is no significant relationship between mulching and sugarcane production. It was divulged that the critical X^2 value was 3.84 at 0.05 level of significance and 1 degrees of freedom whereas the calculated chi-square value was 10.9. The critical Chi-square value was less than the calculated value of Chi-square which meant that mulching of sugarcane plant had a significant impact on the production of sugarcane. Mulching improved the soil fertility through the decomposition of organic matter hence improved soil structure and water retention as explained by the field officers.

Table0.36: Mulching and sugarcane production

Variable	Observed tonnage	Expected tonnage
Mulched cane	41	55
Unmulched cane	35	55

Source: *Survey data 2020*

Field crop production practices such as weeding, pests and disease control and ratooning which the study examined influenced sugarcane production in WES. Where farmers who adequately implemented field crop production practices harvested on average 29.2% more yield of the total expected production in an acre of sugarcane farm. Common weeds in the sugarcane field were the black jack and couch grass which were controlled mechanically by hoeing and chemically by spraying. Sugarcane borers, yellow sugarcane, Aphids, moles and termites were the common pests in sugarcane fields while smut and ratoon stunting diseases were the common diseases that affecting sugarcane yield. Most farmers controlled pests mechanically though these pests were not fully managed. Ratooning was highly practiced though the yield decreased with the subsequent ratoon. The major reason for ratoon cropping was to reduce cost that could be incurred during replanting and ease management.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents summary of the research findings on agronomic factors influencing sugarcane production, conclusion and recommendations of the study and suggestions for further research.

5.2 Summary

This study aimed at shading light on the agronomic practices influencing sugarcane production in Webuye East Sub-County in Bungoma. The agronomic practices that were studied include: field crop production practices such as weeding, pests and disease control and rationing; special purpose plant improvement practices such as raw spacing, sugarcane varieties and earthing; soil management practices such as land preparation, application of farm yard manure, mulching, planting season and harvesting management.

Influence of field crop production practices and sugarcane production

It was found out that most common weeds in sugarcane fields were black jack and couch grass. These weeds were controlled by hoeing and spraying. Farmers who failed to control these weeds ended up incurring losses in cane yield. The common pests that were found in cane fields included Aphids, moles and termites. These pests were controlled mechanically by farmers which included manual killing of the moles. Diseases that were mostly observed included rust disease which was controlled by use of resistant variety co 421. Pests and diseases were not fully managed as farmers employed mechanical methods. Farmers practiced ratooning two to three times before sugarcane plant was uprooted though ratoon crop produced less yields with the subsequent ratoon. Variation in the output of ratoon crop was attributed to soil degeneration as a result of mono cropping and continuous cropping and sub optimal ratoon sugarcane management. The Chi-square analysis that was performed on field crop production practices at 0.05 level of significance ranged between 19.5-65.5 which was higher than the critical Chi-square of 3.84-7.8 implying a significant positive relationship between field crop production practices and sugarcane production.

Influence of special purpose plant improvement practices on sugarcane production

Special purpose plant improvement practices that were addressed included raw spacing, sugarcane varieties and earthing up. Farmers practiced a narrow raw spacing of 0.5m to 1.0m which resulted to overcrowding and tiny stalks hence low yield. Closed spacing was as a result of fragmented plots of sugarcane crop. The sugarcane varieties that were supplied in the sub-county by the companies included Co421, N14 and D8484. Sugarcane variety Co421 was the most preferred variety because it was resistant to diseases, weight, produced more buds and grew bigger and taller. Earthing up was done in ratoon sugarcane crop using oxen. Farmers who observed special purpose plant improvement practices had higher yields per acre than those who partially observed these practices. Chi-square analysis on special purpose plant improvement practices indicated a calculated value of 16.9-35 at 0.05 level of significance. This value was higher than the critical value of Chi-square indicating a positive significant relationship between special purpose plant improvement practices and sugarcane production.

Influence of soil Management practices on sugarcane production on sugarcane production

The soil management practices that were addressed include; land preparation, application of farm yard manure, application of fertilizers and mulching. Farmers ploughed their cane fields twice using oxen plough before they could plant. Higher number of ploughing resulted into increased yields as it helped to control weeds during early stages of growth and to break the soil for easy root penetration. However, farmers who used tractors to prepare their cane fields harvested higher yields than those who used oxen and hoe. Farm yard manure was partially applied in sugarcane fields due to inadequate knowledge on the agronomy of the cane crop and the notion that sugarcane crop is not demanding in terms of manure application. Farmers applied DAP, CAN and Urea during the growing stage of sugarcane. However farmers applied 50 Kg per acre of fertilizer once during the growth period of sugarcane cycle as a result of inadequate finances. Moreover, farmers practiced mulching in their sugarcane plots using sugarcane thrashes. Where sugarcane thrushes were not available, intercropping using beans, cow peas and lentils was done. Mulching controlled the rate at which weeds grew and preserved moisture in the soil. There was higher yield in sugarcane crops where mulching was undertaken than where it was not practiced. The calculated Chi-square on soil management practices and sugarcane production ranged between 22.1-65.5 at 0.05 level of significance. This value was higher than the critical Chi-square value of 3.84-5.99. This implied that there is a significant positive relationship between soil management and sugarcane production.

Influence of planting season and harvesting management on sugarcane production

Farmers planted their sugarcane crop between April and June when the rains had socked the soil. April-June season was preferred because it was the season of long rains which enhanced germination, sprouting of buds and growth of healthy cane for a longer period before the onset of a dry spell and sugarcane could be planted together with maize at intervals since it was the season for growing maize. There were higher yields when cane was planted in April-June season. In terms of harvesting management, farmers harvested cane at 18 months after harvesting. During harvesting maturity of the sugarcane was considered. Cane was harvested while green to reduce drastic weight lose and to use sugarcane thrash in mulching.

5.3 Conclusion

It was concluded that special purpose plant improvement practices such as row spacing, sugarcane varieties and earthing up significantly affected sugarcane yield. Farmers who observed these practices had increased cane yield of 11.9% than those who did not. Wide spacing of 2m increased cane yields while closed spacing of 0.5-1.5m resulted to low yields. However, most sugarcane farmers practiced closed spacing of 0.5-1.5m due to reduced plots which resulted in overcrowding and tiny stalks hence low yield of sugarcane. The commonly supplied cane variety in the sub county was CO-421, locally known as ‘Nyundo’. This variety of cane was one of the recommended varieties by sugarcane companies and had been widely adopted by cane farmers. This was because it was resistant to diseases and pests, weighty hence resulted into high yield at the factory, its ratoon produced more buds and it was the old variety.

In addition, soil management practices such as land preparation, fertilizer application, application of farm yard manure and mulching significantly influenced the production of sugarcane in WES Soil management practices gave an increased yield of 25.7% in cane crops where these practices were observed. Most farmers in the region ploughed their sugarcane fields twice using oxen plough before planting. Though most farmers preferred deep tillage using tractors, this did not happen due to the high costs involved. Farmers applied a mixture of urea and DAP to their sugarcane once after five months of planting. Farmers used 50 kg of fertilizer once in an acre of land which affected cane yield. Mulching was done using sugarcane thrash after harvesting cane crop. In addition, intercropping was done in sugarcane plant crop where mulching material was not found. Mulching was majorly done to control weeds hence significantly affecting the production of cane plant.

It is also concluded that planting and harvesting management positively influenced production of sugarcane where when these practices are fully managed, a farmer would harvest average yield of 24.6% more tonnage than those who did not. Harvesting of cane was done when the plant crop was between 16 to 18 months while the ratoon crop was between 14 to 18 months. However, during cane harvesting maturity of the cane crop was considered. Sugarcane was harvested while green because by harvesting burnt cane one could incur a loss of about 21 tonnes per acre. Cane was transported to the factory within 48 hours after cutting though there were delays that were experienced between the farm and the factory due to impassable roads during the rainy season resulting in decreased weight.

In general, farmers who observed agronomic practices on their sugarcane farm had an average increased sugarcane yield of 23.1% per acre. Although these agronomic practices affected cane yield, they were partially practiced farmers in the sub-county due to inadequate information and poverty.

5.4 Recommendation

In order to augment the productivity of sugarcane crop within Webuye East Sub County and the country at large, government and other related stakeholders should aid sugarcane farmers solve the problems of growers such as poverty, inadequate information and inadequate extension services that hinder agronomic practices within the sugarcane field so as to produce more sugarcane and earn higher net return. These problems can be solved through sugarcane companies offering extension services such as information on technology of good cane husbandry, harvesting technology and planting technology. This can be done through holding farmers public meetings for every ward in the sub county in order to sensitize farmers on the proper agronomy of the sugarcane crop. The West Kenya Sugar Company and Nzoia Sugar Company should offer loan services in form of materials to include high quality seed cane, fertilizes for planting and top dressing and preparing land for planting to ensure deep tillage has been done. In addition, the sugar companies in partnership with the county government should improve the state of feeder roads so that they can be passable during times of heavy rains. These initiatives are essential for quality and quantity cane production in the country and satisfactory return to all the stakeholders.

5.5 Recommendation for further studies

It is recommended that a research on effects of zoning in sugarcane growing areas be done for necessary step to be carried by sugarcane stakeholders.

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APPENDICES

APPENDIX 1: FARM SURVEY QUESTIONNAIRE

I. GENERAL INFORMATION ABOUT THE FARMER

a) Farmers

Ward.____

b) Farmer's age.____

c) Farmer's gender.____

d) Farmer's educational level._______________________________________

II. FIELD CROP PRODUCTION PRACTICES

1. a) Which types of weeds are present in your sugarcane farm?

   b) How do you control these weeds?

   A) Spraying B) hoeing C) spraying and hoeing D) others (specify)

   c) Does weeding affect sugarcane yield?

   A) Yes B) No

2. What is your experience on sugarcane field weed control?

   A) Successful B) Unsuccessful

3. What was your approximate yield in tonnes based on the answer in (2) above?

   A) Below 20 (specify) B) 21-30 C) 31-40 D) 41-50 E) 51 and above

4. a) Which pests are commonly found in your sugarcane field?

   b) Which diseases affect your sugarcane?

   c) How do you control pests and diseases in your sugarcane farm?

   A) Mechanical B) Cultural C) Biological D) Chemical

   d) How do pests and diseases affect the production of sugarcane?

   A) Increase yield B) Decrease yield

5. What experience do you have in pest and disease control in your sugarcane field?

   A) Successful B) Unsuccessful

6. What was the total tonnage in an acre based on the answer in (5) above?

   A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

7. a) Do you practice ratooning?

A) Yes. B) No

b) If yes, how many times do you practice ratooning before the cane crop is uprooted?

A) 2times. B) 3times. C) 4times. D) Others (specify)

c) What was the total tonnage per acre in the following sugarcane crops?

A) Sugarcane plant crop

B) First ratoon

C) Second ratoon

D) Third ratoon

d) How does the ratoon crop affect yield?

A) Yield is higher than the plant crop.

B) Yield is lower than the plant crop.

e) If the yield is lower than the plant crop, give reasons for practicing ratoon farming in sugarcane.

III. SPECIAL PURPOSE PLANT IMPROVEMENT PRACTICES

1. a) What is the approximate row spacing in your sugarcane farm?

A) 2m B) 1.5m C) 1m D) 0.5m E) others (specify)

b) Which row spacing would you prefer in your sugarcane farm?

A) 2m B) 1-1.5m C) Others (specify)

c) What was the total tonnage harvested in an acre based on the row spacing indicated in (c) above?

A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

d) Does row spacing affect sugarcane yield?

A) Yes. B) No.

e) If yes, how does it affect cane yield?

A) Close spacing results in high yields.

B) Close spacing results in low yields.

C) Wide spacing results in high yield.

D) Wide spacing results in low yields.

2. a) Which sugarcane varieties do you plant?

A) Co-421 B) N-14 C) D-8484 D) Others (specify)

b) Give reasons for the varieties selected.

A) Recommended variety and give high yield.

B) Recommended variety and give low yield.

C) Non recommended variety and give high yield.

D) None recommended variety and give low yield.

3. What was the total tonnage in an acre of land of the variety indicated in 2a above?

   A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

4. a) Do you practice earthing up?

   A) Yes. B) No.

   b) If yes, at what stage of cane growth do you perform earthing up?

   A) 1 to 6 months B) 7 to 12 months C) 13 to 18 months D) Others (specify)

   c) How many times do you perform earthing up?

   A) Once B) Twice C) Thrice D) others (specify)

   d) Give reasons for earthing up.

   A) Provide more support

   B) Prevent falling

   C) All of the above

   D) Others (specify)

   e) Based on your experience, does earthing up affect sugarcane yield?

   A) Yes, it results in high yield.

   B) Yes, it results in low yield.

   C) No, it does not affect cane yield.

   f) What was the tonnage per acre when earthing up was done?

   A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

   g) What was the tonnage per acre when earthing up was not done?

   A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

5. How do you agree or disagree with the following statements? (tick where appropriate)

Statement	Strongly agree	Agree	Disagree	Strongly Disagree
Weeds should be controlled for cane yield to be high.				
Control of pests and diseases result in high cane yield.				
Wide spacing increases cane production				
Cane yield decreases with the number of ratoons.				
Adopted sugarcane varieties increase cane production.				
Earthing up leads to high sugarcane yield.				

IV. SOIL MANAGEMENT

1. a) How many times do you plough your cane field before planting?

   A) 1. B) 2. C) 3. D) Others (specify)

   b) What was the total tonnage when land was prepared the number of times indicated in a) above?

   A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

   c) Which equipment do you use when preparing sugarcane farm for planting?

   A) Hoe. B) Oxen plough. C) Tractor. D) Others (specify)

   d) Give reasons for your answer in (b) above.

   A) Readily available

   B) Cheap

   C) Poverty

   D) All of the above

   E) Others (specify)

   e) Which instrument would you prefer to use when preparing land?

   A) Hoe. B) Oxen plough. C) Tractor. D) Others (specify)

   f) Does land preparation affect sugarcane production?

A) Yes. B) No.

g) If yes, how does it affect sugarcane yield?

A) Deep ploughing results in low yield.

B) Deep ploughing results in high yield.

C) Shallow ploughing results in low yield.

D) Shallow ploughing results in high yield.

2. a) Do you apply farm yard manure in the sugarcane production?

A) Yes. B) No.

b) When do you apply FYM?

A) Planting stage B) Growing stage

c) How do you apply the farm yard manure?

A) In furrows B) sugarcane lines

d) What material do you use to prepare FYM?

e) How long does it take to prepare FYM?

A) 1 year B) 6 months C) 3months D) Others (specify)

f) What amount of FYM do you apply in an acre of land?

A) 1 Trailer B) 2 Trailers C) 3 Trailers D) Others (Specify)

g) What was the total tonnage in an acre based on your answer in 2f) above?

A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

h) If yes, how does application of farm yard manure affect sugarcane production?

A) Results in lower yield.

B) Results in higher yield.

3. a) Do you apply fertilizer to sugarcane farm?

A) Yes. B) No.

b) If yes, which type of fertilizer do you apply?

A) CAN B) DAP C) Urea D) Others (specify)

c) i) How many kilograms of fertilizer do you apply in an acre of sugarcane plot?

A) 25kg. B) 50 kg. C) 100kg. D) Others (specify)

ii) What was the total tonnage based on your answer in c) i) above?

A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

d) How many times do you apply fertilizer to sugarcane farm before harvesting?

A) Once. B) Twice. C) Thrice. D) Others (specify)

e) At what stage of sugarcane growth do you apply Fertilizer?

A) Planting stage

B) Growth stage (specify by months)

C) Others (specify)

f) Does fertilizer application affect sugarcane yield?

A) Yes, it results in high yields.

B) Yes, it results in low yields.

C) No, it does not affect sugarcane yield.

g) What was your yield in tonnage when you applied fertilizer?

A) 21-30 B) 31-40 C) 41-50 D) 51 and above

4. a) Do you mulch your sugarcane farm?

A) Yes. B) No.

b) If yes, which type of mulching material do you use?

A) Sugarcane thrashes. B) Others (specify)

c) How does mulching affect sugarcane yield?

A) Mulching leads to high yield.

B) Mulching leads to low yield.

C) Mulching does not affect sugarcane yield.

d) What was the total tonnage in an acre based on your answer in 4a) above?

A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

5. How do you agree or disagree with the following statements? (tick where appropriate)

	Strongly agree	Agree	Disagree	Strongly Disagree
Deep tillage results in high sugarcane production.				
Application of farm yard manure leads to increased yield.				
Application of fertilizer increases cane yield.				
Mulching increases cane production.				

V. PLANTING SEASON AND HARVESTING MANAGEMENT

1. a) When do you plant sugarcane?

    A) Between April and June

    B) Between August and September.

    C) Others (specify)

    b) Give reasons for your answer in (a) above.

    A) Long rain season

    B) Land is devoid of other crops

    C) Sugarcane can be planted alongside maize

    D) All of the above

    E) Others (specify)

    c) What was the approximate yield of your sugarcane crop in tonnes per acre when planted during the season above?

    A) Below 30 B) 31-40 C) 41-50 D) 51 and above

    d) How does planting season affect sugarcane yield?

    A) Rainy season results in low yield.

    B) Rainy season results in high yields.

    C) Dry season results in high yield.

2. a) Sugarcane is harvested after how many months of growth?

    b) Give reasons for your answer in a) above.

    c) How do you harvest cane?

    A) Burnt then cut.

    B) Cut while green without burning.

    d) Give reasons for your answer above)

    e) What was the total tonnage in an acre when cane was harvested in the state indicated above?

    A) 0-20 B) 21-30 C) 31-40 D) 41-50 E) 51 and above

    f) If sugarcane is harvested while green, how is yield affected?

    A) Yield is low.

B) Yield is high.

C) Can yield is not affected.

g) How many days can sugarcane stay in the farm before it is transported to the factory?

A) 1 day. B) 2 days. C) 3 days. D) 4 days. e) Others (specify)

h) What was the tonnage based on your answer in (f) above?

3. How do you agree or disagree with the following statements? (tick where appropriate)

	Strongly agree	Agree	Disagree	Strongly Disagree
Planting season affects cane production.				
Planting cane during rainy season leads to high sugarcane yield.				
Harvesting green sugarcane leads to high yields.				
Harvesting burnt cane leads to high yields.				

APPENDIX II: INTERVIEW GUIDE TO FIELD OFFICERS AND WEIGH BRIDGE WORKERS

1. Sugarcane varieties
    - Varieties supplied by the company
    - Varieties farmers wish to be supplied with
    - Reasons for the varieties supplied
    - Varieties that farmers grow on their own
    - Output per variety when compared
2. Ratooning
    - Number of times sugarcane is cut before uprooting
    - Output of cane per cutting
    - Increase or decrease of cane tonnage per cutting
    - Whether ratooning is encouraged
3. Harvesting of sugarcane
    - Time (month) that is preferred for harvesting
    - Period that sugarcane matures for harvesting
    - Whether harvesting season influences sugarcane production
4. Trend on quantity of sugarcane harvested.
    - Variation on cane output for the last four years
    - Reasons for variation in output per year.

APPENDIX III: INTERVIEW GUIDE TO FARMERS

- Methods preferred in weed control
- Reasons for the choice of the method of weed control
- Production when weeds were fully controlled and when they were partially controlled.
- Preferred method of pests and disease control
- Reasons for the choice of the method of pests and disease control
- Explanation on variations in cane out based on the number of cuttings
- Reasons for the raw spacing specified and the most preferred raw spacing
- Reasons for the variety of cane preferred by the farmer
- Reasons for performing earthing up
- Reasons for the choice of instrument used to prepare land
- How farm yard manure is prepared.
- Reasons the choice of fertilizer and amount applied in an acre of cane plot
- Reasons for mulching sugarcane farm
- Reasons for planting cane during a given season

APPENDIX IV: OBSERVATION CHECKLIST

Observation on current state of the farm

FARM INSPECTION ITEM	YES	NO	COMMENT
Is the plot weeded?			
Are there pests within the farm?			
Are there indicators of diseases within the farm?			
Are weeds present in the farm?			
Has the farmer carried out earthing up?			
Is mulching practiced by the farmer?			
Are there signs of soil erosion within the farm?			
Is intercropping practiced within the sugarcane crop?			
Has the farmer considered plant density and spacing?			

APPENDIX V: RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 691227

Date of Issue: 26/August/2020

RESEARCH LICENSE

This is to Certify that Ms.. Joan Khaoma of Moi University, has been licensed to conduct research in Bungoma on the topic: ASSESSMENT AGRONOMIC PRACTICES INFLUENCING SUGARCANE PRODUCTION AMONG SUGARCANE FARMERS IN WEBUYE EAST SUBCOUNTY IN BUNGOMA, KENYA for the period ending : 26/August/2021.

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APPENDIX VI: CHI-SQUARE DISTRIBUTION TABLE

Chi-square Distribution Table

d.f.	.995	.99	.975	.95	.9	.1	.05	.025	.01
1	0.00	0.00	0.00	0.00	0.02	2.71	3.84	5.02	6.63
2	0.01	0.02	0.05	0.10	0.21	4.61	5.99	7.38	9.21
3	0.07	0.11	0.22	0.35	0.58	6.25	7.81	9.35	11.34
4	0.21	0.30	0.48	0.71	1.06	7.78	9.49	11.14	13.28
5	0.41	0.55	0.83	1.15	1.61	9.24	11.07	12.83	15.09
6	0.68	0.87	1.24	1.64	2.20	10.64	12.59	14.45	16.81
7	0.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21
11	2.60	3.05	3.82	4.57	5.58	17.28	19.68	21.92	24.72
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22
13	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69
14	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14
15	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00
17	5.70	6.41	7.56	8.67	10.09	24.77	27.59	30.19	33.41
18	6.26	7.01	8.23	9.39	10.86	25.99	28.87	31.53	34.81
19	6.84	7.63	8.91	10.12	11.65	27.20	30.14	32.85	36.19
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57
22	8.64	9.54	10.98	12.34	14.04	30.81	33.92	36.78	40.29
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98
26	11.16	12.20	13.84	15.38	17.29	35.56	38.89	41.92	45.64
28	12.46	13.56	15.31	16.93	18.94	37.92	41.34	44.46	48.28
30	13.79	14.95	16.79	18.49	20.60	40.26	43.77	46.98	50.89
32	15.13	16.36	18.29	20.07	22.27	42.58	46.19	49.48	53.49
34	16.50	17.79	19.81	21.66	23.95	44.90	48.60	51.97	56.06
38	19.29	20.69	22.88	24.88	27.34	49.51	53.38	56.90	61.16
42	22.14	23.65	26.00	28.14	30.77	54.09	58.12	61.78	66.21
46	25.04	26.66	29.16	31.44	34.22	58.64	62.83	66.62	71.20
50	27.99	29.71	32.36	34.76	37.69	63.17	67.50	71.42	76.15
55	31.73	33.57	36.40	38.96	42.06	68.80	73.31	77.38	82.29
60	35.53	37.48	40.48	43.19	46.46	74.40	79.08	83.30	88.38
65	39.38	41.44	44.60	47.45	50.88	79.97	84.82	89.18	94.42
70	43.28	45.44	48.76	51.74	55.33	85.53	90.53	95.02	100.43
75	47.21	49.48	52.94	56.05	59.79	91.06	96.22	100.84	106.39
80	51.17	53.54	57.15	60.39	64.28	96.58	101.88	106.63	112.33
85	55.17	57.63	61.39	64.75	68.78	102.08	107.52	112.39	118.24
90	59.20	61.75	65.65	69.13	73.29	107.57	113.15	118.14	124.12
95	63.25	65.90	69.92	73.52	77.82	113.04	118.75	123.86	129.97
100	67.33	70.06	74.22	77.93	82.36	118.50	124.34	129.56	135.81

APPENDIX VII: Z-TABLE

STANDARD NORMAL DISTRIBUTION: Table Values Represent AREA to the LEFT of the Z score.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07215	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15151	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414