EVALUATION OF THREE MAIZE VARIETIES INTERCROPPED WITH COWPEA UNDER TILLAGE AND NO-TILL PRACTICES IN WESTERN KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2023

DECLARATION

This thesis is my original work and has not been submitted for an award of a degree at any other University.

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DEDICATION

This thesis is dedicated to my late father (Baribarira M.) who before leaving the life wished to see me achieve the furthest level of studies, to my mother (Mukakayihura M) and brother (Bizimana E.) who have always encouraged me morally and materially. I also dedicate this work to colleagues and workmates at International Potato Center (CIP- Rwanda).

Thank you all for your great support.

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ACKNOWLEDGMENTS

I am thankful to Almighty God for protecting and allowing me to finish this work.

My sincere appreciation and thanks go to Professor George Chemining'wa and Dr. Onesmus Kitonyo from the University of Nairobi. Out of your busy schedules, you still found time to guide and advise me. May God bless you.

My special thanks go to Dr. Leonard Rusinamhodzi, Senior Agronomist at International Maize and Wheat Improvement Centre (CIMMYT) for sacrificing your time to supervise me. You allowed me to join an ongoing experiment. Special thanks to CIMMYT for sponsoring this research study. I owe you this work. Only God can pay you back.

Much thanks to the International Potato center CIP- Rwanda especially the country manager Dr. Kirimi Sindi J. for granting me a favorable moment to pursue my studies and work on my research.

My sincere appreciation also goes to my mother and brother, for always being there for me. I cannot forget to thank my friends, schoolmates, workmates and others for your love and encouragement during this work.

May God bless you all!

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ABBREVIATIONS AND ACRONYNMS

CA	Conservation Agriculture
CT	Conventional Tillage
CIMMYT	Centro Internacional de Mejoramiento de Maíz Y Trigo
Ha	Hectare
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
ISFM	Integrated Soil Fertility Management
KALRO	Kenya Agricultural and Livestock Research Organization
LER	Land Equivalent Ratio
RT	Reduced Tillage
SSA	Sub-Saharan Africa

ABSTRACT

Over the years, mono-cropping and conventional tillage have been a hindrance to adoption of conservation agriculture (CA) in Western Kenya. Intercropping maize with legumes while practicing CA can be beneficial to improvement of maize yield. This study sought to assess and evaluate yields of maize in maize-legume inter-crop under no tillage and conventional tillage in Western Kenya. To compare the two tillage regimes, the study was carried out in Western Kenya specifically in Kisumu and Busia Counties. The experiments were conducted at KALRO Alupe and Kibos research stations and farmers' fields during 2015 short rains and 2016 long rains. The field experiments involved three varieties of maize (H12, H528 and HB505) and two cropping systems (sole establishment and inter-crops). A split plot arrangement in randomized complete block design was used to lay out the treatments. The main plot was assigned to tillage practices, the subplot was assigned to cropping systems and the sub sub plot was used for maize varieties. The land preparation was done using the hand hoe on the tilled part and by leaving the crop residues on the no tillage part. Before planting, the base fertilizer was applied at a rate of 100kg/ha. The plant spacing used was 75 cm x 30 cm for maize and 37.5 cm x 20 cm for cowpea. Plant height, number of leaves, number of plants, cob length, rows per cob, kennel per row, and grain yield for maize were among the information gathered. For the cowpea, plant height, number of leaves, number of plants and grain yield were collected. Using GenStat software, the collected data were subjected to a variance analysis, and means were separated using the least significant difference test at $P \leq 0.05$. The results showed that maize crops grown on no tilled part were significantly taller $P \leq 0.05$ in both research stations, with a higher number of kennels per row in Alupe and higher grain yield in the farmers field in Alupe and greater number of cowpeas leaves in on farm in Kibos compared to the ones grown on tillage part. The yield of maize was considerably $P \leq 0.05$ higher on tilled land than on uncultivated land. Intercropping maize and cowpea resulted in a significantly $P \leq 0.05$ higher number of plants in Alupe and plant height in Kibos on stations. Maize intercropped with cowpea had a significantly $P \leq 0.05$ higher number of rows per cob than on the sole crop. However, in cowpea, the number of plants per plot was significantly $P \leq 0.05$ higher in the sole cropped plot than in the intercropped plots. The variety H12 outperformed others in plant height, number of leaves, number of plants, cob length, number of kennels per row and grain yield on both on farm and on station sites. In addition, cowpea plant height was significantly $P \leq 0.05$ higher when intercropped with H12 maize variety than other varieties. Growing maize on no-tilled land improved the growth parameters but not the yields, intercropping maize with cowpea also affected growth than yield parameters. It is then recommendable to conduct more research studies to confirm to farmers in Western Kenya that they can plant H12 maize variety to obtain higher maize grain yield. Further research studies should be carried out to find out cowpea-intercrop growth and yield performance under conservation and conventional tillage practices. The study conducted for only two seasons thus additional studies are required to avail to farmers adoptive conservation agriculture practices for better yields.

Keywords: Tilled land, non-tilled land, intercropping, H12 variety, H528 and HB505

CHAPTER ONE: INTRODUCTION

1.1. Background Information

Most food crops in sub-Saharan African (SSA) are produced by smallholder farmers who are also the most vulnerable to food security and earn insufficient income (Harris and Orr, 2014). According to FAO (2018), close to a quarter of the SSA population was reported to be undernourished in 2017. Around 820 million people in the world are thought to be part of this demographic. More than 300 million families in SSA depend heavily on maize *(Zea mays* L.*)* (Badu-Apraku et al., 2017). In SSA maize is the most important staple food. In East and Southern Africa, over 24 million households depend on maize as their staple food crop planted annually on about 15.5 million hectares (Badu-Apraku, 2018). Despite the great importance of maize in SSA, grain yields particularly in this region are on the decline due to several factors including increase in frequency of extreme weather conditions occasioned by climate change, changes in soil nutrients, increased vulnerability to weed competition as well as pests and diseases (Eludoyin et al., 2011).

In Kenya, agricultural production is dominated by maize and legumes (dry bean) at 38.2% and 18.7%, respectively (FAOSTAT, 2014). Kenya is vulnerable to food insecurity due to the growing dependence on production of maize and dry beans. According to Kirimi et al. (2011), maize is Kenya's fourth-most valuable crop behind milk, potatoes and beef and makes up around 80% of the country's total grain production. Annual maize production in Kenya is between 37 and 40 million bags (90 kg bag) against a national requirement of approximately 42 million bags (Kirimi et al., 2011). This production is mostly dominated by an estimated 3 million smallholder farmers who account for an estimated 70% of Kenya's total maize output.

The SSA farming systems rely heavily on legumes and there is currently a growing trend and rise in demand for them due to a shift in consumer tastes towards more nutrient-dense foods (Muoni et al., 2019; Syngenta, 2017). In East Africa, common bean is regarded the most important legume under an approximate acreage of 2 million ha across Kenya, Tanzania and Ethiopia (FAO, 2018; Van Loon et al., 2018). Legumes are usually rotated with cereal crops such as maize or grown as inter-crops. In Kenya, dry bean has the highest water-limited yield potential in Southwestern part of Kenya. According to Kirimi (2011), about 58% of Kenya's smallholder farmers are net consumers of maize. According to Ownonga et al. (2014), intercropping with legumes on a variety of soil types is the main methods used in Kenya to produce maize. Legumes are important for nutrition and are common in most local dishes. Other reasons for intercropping include maximizing land use, improving soil nutrition through nitrogen fixation and spreading economic risk (Chen et al., 2014; Machado, 2009).

In order to preserve soil health, lower production costs and enhance yield over the long term, conservation agriculture (CA), a system that integrates simultaneous application of minimum soil disturbance, permanent soil cover and crop rotation has been promoted over time (Kassam et al., 2009). According to Giller et al. (2009), conservation agriculture is gaining popularity in SSA as a sustainable alternative that can improve food security and reduce environmental damage. Before the 20th century, conventional tillage practices were widely used (FAO, 2011) where the seedbed is prepared by deep ploughing and soil inversion. The adoption of CA in SSA has faced challenges that are characterized by low agricultural production. A critical analysis of the ability of unoriginal agriculture production methods to maintain their harmful effects particularly when they do not result in greater food or income production for smallholder farmers has been conducted (Cary and Wilkinson, 1997; Pannell, 1999). Some of the social and economic reasons that have made it difficult to adopt CA in SSA include family demographic elements like education, stage of development and sexual orientation (Marongwe et al. 2012; Nyathi et al., 2020). Other problems that make CA difficult to adopt in SSA include the little amount of land currently assigned to this type of farming system and the lack of implementation of practices that are essential to enhancing the procedures that are expected to increase production (Mango et al., 2017). Success in the adoption of CA has been observed in nations like Mozambique and this has been linked to the promotion of CA combined with advanced crop management practices including improved seed varieties as well as timely weeding.

Indeed, the shifting demographic of SSA where its economies are still transitioning to the middle class and the significant CA promotion campaigns present chances to boost adoption. Due to the challenge of feeding an ever-growing population in areas with widespread land degradation and low soil fertility, there is urgent demand for evidence about CA sustainability (Ayuke et al., 2019). There is great interest in CA but few data to support its use in SSA (Paul et al., 2013).

It is therefore important to assess the performance of this technology especially in Western Kenya where continuous cultivation could have worsened soil degradation. This is because according to Ayuke et al. (2019), improved productivity per unity area has been heavily credited with increasing food production in SSA. Smallholder farmers in SSA rely on strategies such as land intensification through labor cost-saving, lowering production costs and enhancing soil fertility to enhance crop yield (Ayuke et al., 2019). Therefore, it is crucial to evaluate the scope and direction of CA's effect on soil fauna, particularly in low-input sub-Saharan Africa systems like Western Kenya. Yet when it comes to changing practices and mindsets, switching from conventional to conservation agriculture offers one of the hardest obstacles (Thiombiano et al., 2007).

1.2. Problem Statement

The practice of mono-cropping by farmers and the disposal of agriculture wastes for livestock and other purposes such as fuel burning and animal paddocks during the rainy season and construction such as fencing for some farming households have been some of the major barriers to adoption of CA in Western Kenya (Wakene et al., 2011). Despite the effort farmers make to grow it, the yield of maize is continuously failing to increase due to soil fertility decline, insufficient and inappropriate fertilizer application, and variable climate, lack of improved cultivars and the resulted is poverty, soil fertility declines and others that restricted farmers opportunities to address production constraints (Sanginga et al., 2009). The recent estimates, the average maize yields in Kenya are 1.6t/ha against 2.5t/ha from Eastern Africa (Adhikari et al., 2015). The soil is intensively cultivated because conventional tillage involves ploughing two to three times until a fine seedbed is obtained. High and persistent rainfall causes high soil erosion and thus low soil fertility, and production exacerbates this practice. Furthermore, traditional tillage disrupts the soil and kills most of the microorganisms responsible for low organic matter (Dayou et al., 2017).

1.3. Problem Justification

According to research by Thierfielder et al. (2015), intercropping legumes and covering crops with maize can increase yields by improving soil fertility through nitrogen fixation. Therefore, there is need to integrate legumes such as cowpea into existing farming systems by intercropping with maize for better yields. To lower the risk of crop failure, crop diversification and better management are urgently needed (Chillinor et al., 2009). Conservation agriculture plays a critical role in ensuring that sustainability is achieved within agro-ecosystems, besides, it's also beneficial in agricultural production (Kassam et al., 2009). Most studies on maize-legume intercropping have been based mostly on conventional tillage rather than conservation tillage systems. In central Mozambique, Rusinamhodzi et al. (2012) reported some beneficial effects of ratooned pigeon-pea on maize yield under a no-till system. Some of the benefits included nitrogen fixation, which is important in low input farming systems, and improved efficiency in resource utilization. Other benefits associated with conservation agriculture under legume intercrops include minimum soil disturbance thus protecting soil from breaking down and releasing carbon to the atmosphere, reduced water and wind erosion and reduced time and cost due to reduced tillage. It is therefore necessary to do additional research to assess the outcomes of cowpea-maize intercrop systems under conventional tillage and no tillage systems to determine the optimum practices to be adopted by farmers.

1.4. Objectives

This study's main goal was to compare the productivity of cowpea and maize intercropped in western Kenya under conservation and traditional tillage techniques.

The study's specific objectives were:

1. To evaluate the impact of tillage techniques on growth and yield of maize
2. To evaluate how growth and yield of companion crops are affected by maize-cowpea intercropping.
3. To determine the interaction between tillage method and maize-cowpea intercropping on growth and yield of the companion crops

1.5. Hypotheses

1. The growth and yield of maize grown under no tillage increase.
2. Intercropping maize and cowpea increase their growth and yield.
3. Maize and cowpea intercropped under conventional tillage boosts growth and yield of both crops.

CHAPTER TWO: LITERATURE REVIEW

2.1.Ecology of maize

According to Ngome et al. (2012), maize is grown in a variety of agro-ecological zones. Depending on the kind of maize variety planted, the crop thrives well in Kenya at the elevation between 0 and 2200 m ASL. Although it can grow in a variety of soils, maize prefers loam soils that are well-drained and aerated. It grows well on soils with a pH of 5.5-8 and optimal rainfall ranges of 500-1200 mm. To help the grains dry out after harvesting, dry weather is desirable. Temperatures ranging between 18-32^{0}C are ideal for maize growth and development. When tasseling, soil temperatures between 12 ^{0} C and 30 ^{0} C are perfect because they promote germination and early seedling growth.

2.2.Importance of maize

In SSA, 30% of the daily calories that people consume are from maize, and when it is unavailable or limited, hunger and starvation follow. According to projections made by CIMMYT and IITA (2010), maize is expected to overtake all other crops in terms of production in developing nations and the rest of the world by 2025 and its consumption would be more than double in 2050. The availability of maize in Kenya impacts whether the nation has enough food. There are various uses for maize in both food and business whereby none of the other major grains can even come closer to matching maize's production capacity. Maize is the primary food and nutritious source of energy to majority of households. It provides a variety of food and produce in the places where other crops fail (Cassman and Grassini, 2012).

The use of maize varies from country to country and the most popular products are maize meal and flour (Ranum et al., 2014). In various cultures, maize meal is cooked into a thick porridge that is referred to as 'meali pap' in South Africa or 'ugali' in the other regions of Africa. Ranum et al. (2014) reported that maize can be used as green maize that has been roasted or cooked. The various forms in which maize is utilized play a key role in filling the hunger gaps during droughts (Nyandiko et al., 2015).

Majority of the concentrated feed for farm animals is comprised of grains and maize is the most important and preferred one due to its low cost (compared to other crops) low fiber content and high starch content which contains concentrated energy food that gives highest conversion of dry substance to meat, milk and eggs. Maize used as silage for animals plays a key role in improving production. Maize stovers, the plant residues after the ear has been removed is the most important and preferred (Grujcic et al., 2021). The entire plant is cut and chopped to make two types of animal feeds: the silage made from cut green forage maize fodder stored in anaerobic condition for fermentation; and the hay that is made from grass cut and dried to use as animal fodder. Both are stored as is crucial feed in temperate regions (the United States, Canada and Europe). From 42% of the maize produced in the United States in 2005, 58% was used for animal feed (FAO, 2006).

2.3.Maize production trends in Kenya

In order to meet future food demands, maize, the second most produced grain in the world and in Sub-Saharan Africa, is likely to be grown on an increasing amount of land (Santpoort, 2020). For instance, in a period of a decade (2007-2017), the area under maize production increased by 60% in SSA. This trend of expansion is unsustainable with more than two-thirds of maize produced in sub-Saharan Africa being grown for human consumption. Since the 1970s, Kenyan agricultural production fails to keep up with growing population needs. The Kenyan population increased from 10.9 million in 1969 to 36.6 million in 2009 and 45 million in 2019. It is predicted that by 2030 the population would reach 65.9 million. Although the population is increasing, agricultural productivity is decreasing. Most Kenyans live in rural areas, with agriculture as the main source of income (FAO, 2011). As the main staple food crop in Kenya, maize production trend is an important concern in relation to the agricultural policy, food security and the overall development of the economy. Production of maize in Kenya is majorly by small-scale farmers, with an average Kenyan consuming 98 kg of maize annually. According to Santpoort, (2020), in comparison to the rest of sub-Saharan Africa, maize prices in Kenya are among the highest (43.06Kesh - 58.33Kesh) the poorest quarter of the population spending 28% of their income on maize. Samtpoort (2020) noted stagnation in maize production and productivity, a trend that has led to widening of gap between production and consumption, thereby increasing frequency of food crop supply shortages.

2.4.Constraints to maize production in Kenya

Production of maize, a main staple food in many African countries including Kenya, cannot meet the demand of growing population in sub-Saharan Africa due to many constraints. Among these are low soil fertility, drought and variable weather patterns, diseases, insect pests, weeds, prohibitively expensive farm inputs, poor agricultural extension services and limited access to inputs and markets (Odendo et al., 2001). Other climate smart technologies like conservation agriculture have faced low adoption among smallholder farmers due to competing effects of livestock production and other conventional practices like tillage.

Around 80% of these farms are on land areas of less than two hectares and are rain-fed, just like most of the smallholder African agriculture. Growth in food production and decrease of poverty in Africa is linked with growth in productivity of small-scale farmers. There is needed for development programs to increase the capacity of small-scale farmers to become more productive, to reduce their risks and vulnerability to extreme weather events (FAO, 2009). More research work needs to be done on the management practices to increase maize yield in drought vulnerable zones.

2.5.Intercropping systems

Intercropping has been practiced in Kenya by small-scale farmers in particular cereal and legume intercropping (Ndiso, 2015). Maize and cowpea plants play critical role in Kenya’s food production sector; despite their importance, their yields are still low (Miriti et al., 2012). This is so because the small-scale farmers are depended on rain fed agriculture which in dry and semi-arid areas is characterized by low and irregular rainfall. In order to supply the expanding need for in deficit areas, intercropping has become a popular farming technique in Kenya among small-scale farmers. In the face of climatic uncertainties, small-scale farmers do intercrop to stabilize crop yields. For instance, intercropping cereals and legume ensures efficient use of environmental resources, boosts financial returns, lowers agronomic risks, improves soil fertility and reduces weed growth and pest damage (Miriti et al., 2012).

According to special organization there are at least four different types of intercropping (Sullivan, 2003). Row intercropping is when two or more crops are grown simultaneously with at least one crop planted in a row; strip intercropping is when two or more crops are grown simultaneously in strips wide enough to allow separate production of crops using mechanical implements close enough for the crop to interact; mixed intercropping is when two or more crops are grown simultaneously with no clearly define raw arrangement; and relay intercropping is when a second crop is grown into an existing crop but after it has flowered. Further research needs to be conducted on the effects of the various intercropping systems. Due to issues with food insecurity, intercropping is used in small farms in Africa as part of traditional farming methods. It is less common in the mechanized agriculture sectors of Europe, North America and some regions of Asia. This is because intensive mono-cropping methods have become increasingly popular in modern agriculture as a result of a shift in emphasis toward a more market-related economy (Horwith, 1985).

Intercrops are set up in many ways in Kenya with the traditional arrangement being 1:1 intercropping scheme advised by the Ministry of Agriculture (Mutuku et al., 2020). In this arrangement a row of maize is followed by a row of legume. MBILI, which stands for ‘‘Managing Beneficial Interactions in Legume Intercrops,’’ is another improved intercropping technique that alternates two maize rows with two legume rows. Increased light penetration for under-story legume is made possible by the intercropping system MBILI (Means ‘’Two’’ in Kiswahili) without affecting plant densities (Tungani et al., 2002). The MBILI crop arrangement has been shown to be effective in Western Kenya where it has been demonstrated to increase light penetration by 50% as mentioned in (Woomer et al., 2007). In addition to enhance root spread and reducing below ground competition, MBILI intercropping system has been linked to significantly increased light penetration for the under-story legume (Mucheru-Muna et al. 2010; Woomer et al. 2007).

2.5.1. Effect of intercropping systems on maize yield

Intercropping systems based on cereals and legumes have been demonstrated to yield several advantages generated from facilitation and complementarity between species (Zhang and Li, 2003). According to Gou et al. (2017), intercropping of maize and wheat demonstrated that farmers achieved a high yield advantage. On smallholder farmlands, intercropping maize and common beans results in the intensification of sustainable systems (Nassary et al., 2020). Due to land shortage, intercropping remains a preferred and prominent cultivation system and is associated with farming practices that avert the risks of total failure (Giller, 2001; Lunze et al., 2012). Intercropping of maize with common beans has been shown to render benefits such as controlling insect pests and diseases (Chen et al., 2004). Intercropping the two crops ensures effective use of the available plant growth resources which boosts total productivity on a given plot of land Bharucha and Pretty (2014). The changes in the acquisition and utilization of growth resources including nutrients, moisture, and light are to blame for the overall increase in maize yields associated with intercropping legume like common beans (Giller, 2001; Yu et al. 2016). Increased nitrogen nutrition for maize when planted alongside grain legume has been linked to the increase in maize yield (Bedoussac et al., 2015; Ndakidemi et al., 2006). Nevertheless, there is limited information on the contribution of leguminous crops to the soil in maize-legume intercrop systems. Further research needs to be conducted on the effect of leguminous crops such as cowpea in maize-intercrop with other green manure crops like cowpea.

2.6.Conservation agriculture

Intensified tillage is sometimes useful for controlling weeds, but it makes soil erosion worse. Frequent tillage can exacerbate soil erosion, land degradation and compact which are all significant obstacles to smallholder farmers ‘ability to produce crops according to Hamza and Anderson (2005). The necessity to improve the use of conservation tillage among South Africa smallholder farmers is evident as a result of the rise in soil degradation. The agricultural system that practices crop rotation, a permanent soil cover and causes little soil disturbance is known as conservation agriculture (Hobbs et al., 2007). The no-tillage farming practice in CA promotes soil organic matter due to the use of cover crops that leads to control of soil erosion and has beneficial agricultural effects such as reduced use of chemical fertilizers and weed problems (Roldan, 2003). The reduction in labor inputs and drudgery is cited by small farmers with limited resources as one of the reasons they embraced conservation tillage methods (Johansen et al., 2012).

Sustainable and environmentally friendly conservation farming techniques result in soil with greater bioactivity and biodiversity and the use of fewer pesticides promotes biodegradation (Bhan and Behera, 2014). The principles of CA are founded on making the land use more sustainable through enhancement of resource use efficiency and crop productivity (Behera, et al., 2010; Bhan and Behera, 2014; Lal, 2013; Wassmann et al., 2009). According to Kassam and Friedrich (2009), the first concept of CA is minimal mechanical soil disturbance which enables soil biological activity to build very stable aggregates and enhances the extent of water and air infiltration. To ensure the rooting zone has the ideal amount of respiration gases, there is porosity for water circulation and restricts their-exposure of weeds to encourage their germination minimal mechanical soil disturbance is necessary (Kassam and Friedrich, 2009).

The permanent organic soil cover used in CA practices aids in defending soil against harmful sun and rains effects that could change the soil's microclimate and inhibit the growth of plants and other soil organisms (Ghosh et al., 2010). The organic cover assists in improving soil aggregation and enhancing soil biodiversity and biological activity as well as enhancing carbon sequestration (Ghosh et al., 2010). Conservation agriculture farming practice increases the diversity of the soil microorganisms. The legumes are used to break up the life cycles of the pest species while biologically fixing nitrogen which serves to reduce the accumulation of pest species (Dumanski et al., 2006; Kassam and Friedrich, 2009). For crops grown under CA, Giller et al. (2009) observed increased crop yields, decreased soil erosion, increased soil fertility and reduced labor requirements.

Smallholder farmers can utilize cover crops particularly the spreading varieties as an alternative to applying herbicides. By enhancing the biological chemical and physical qualities of the soil such as its organic matter content, cover crops are crucial for generation of sustainable crop yields. Cover crops made of legumes aid in increasing soil fertility (Sharma et al., 2018). Compared to cereal cover crops which make substantial use of nitrogen, legume cover crops have the potential to use less of the available nutrients. Legumes can be used as cover crops by smallholder farmers since they provide high yields of maize while using little fertilizers (Murungu, 2012). Many legumes have undergone weed-suppression testing and can be used by smallholder farmers who practice conservation agriculture. The spreading variety of cowpea is noted for its ability to effectively control weed growth and can be utilized to produce maize (Hani, 2015). Its growth habit affects its capacity to control weeds. Weed biomass and density may decrease as a result of lower light interception as cowpea grows over ground runners. According to Zaviehmaradat et al. (2013), cowpea is effective at controlling amaranths weed species. It is also well recognized that grazing vetch effectively reduces the diversity of weed species. According to a South African study, grazing vetch significantly lowers weed density by 80% (Murungu et al., 2010). Despite the many benefits associated with CA, its adoption in Kenya is still low. Increased e extension services on the importance of CA need to be given to farmers Also, more research is needed to be conducted on the causes of low adoption of conservation Agriculture.

2.7.Effect of conservation agriculture on maize-based farming system

Most of the time, greater yields and profits have been observed from CA systems compared to traditional tillage systems (Thierfelder et al., 2013). This is due to labor savings in the land preparation and weeding processes. However, several studies have shown that crop yields did not change, nor decreased over the first few years of using the CA tillage system (Paul et al. 2013). Low crop yields in CA systems emanate from rainfall variability and declining soil fertility (Mutuku et al., 2020). Low use of fertilizers including both inorganic and organic additions exacerbate the low yields. According to Nyamangara et al. (2014), the usage of chemical fertilizers in Zimbabwe's CA production methods let to a higher maize output. (Grabowski, 2013) came to an additional conclusion that a CA system without automation was only profitable on small parcels of land with low worker opportunity costs. According to Giller et al. (2009), not all smallholder farmers using subsistence farming methods should use the CA tillage approach. They argued that CA has the potential to increase smallholders' production over the long term and lower their level of poverty.

There has been evidence that increasing the use of CA and integrated soil fertility management (ISFM) techniques will increase maize output (Sommer et al., 2018). In Kenya like the rest of other African settings, the farming practice has been challenged by low biomass production and ineffective weed management (Mutuku et al., 2020). According to studies (Farooq et al. 2011; Thierfelder et al. 2018), the optimal use of mineral fertilizer and effective weed control are key components of raising CA. The weather varies over time and space in Kenya where CA used in smallholder farming systems that are characterized by a wide range in soil qualities and reliance on rainfall (Mutuku et al., 2020). It should be noted that CA farming system can be advantageous to maize production in areas experiencing low rainfall. No tillage practice enhances soil moisture by reducing evaporation aided by soil surface cover (Kiboi et al., 2019; Mutuku et al., 2020). Further research needs to be conducted on the effect of conservation agriculture in both drought and humid conditions. Information on the effects of various cover crops especially the green manure cover crops on maize production is still scanty.

2.8. **Tillage and crop residue impact on cereal and legumes yield**

Reduced Tillage (RT) and mulching the soil's surface have been recommended as effective conservation agriculture practices. In order to prevent the harmful effect of continuous tillage, reduced tillage systems ask for the least amount of soil disturbance during crop production (Masvaya et al. 2017). Many farmers in Africa are still engaging in season and mid-season tillage practices while CA is still in the experimental stage. Through exposure to disruptive pressures and the distribution of plant residues in the plough layers, continuous tillage has an impact on soil processes (Khalif et al., 2015). This has an impact on the physical, chemical and biological characteristics of the soil as well as the retention or loss of soil organic matter and water. In contrast, conservation methods like reduced tillage have been shown to improve soil quality compared to traditional tillage methods according to (Wander and Yang, 2000).

In Africa's smallholder agriculture system, legumes are an essential component that significantly contributes to root biomass and litter fall. These legumes can lessen the RT-related crusting and hard setting issues. Furthermore, according to Giller et al. (2009), legumes have a significant residual nitrogen influence on succeeding grain crops. In Africa, legumes are grown either as intercropped pure plots in rotation or with cereals and tubers. There is a shortage of research that has evaluated continuous and rotation system simultaneously and most of the tillage research in Africa and worldwide has concentrated on either continuous cereals or rotation system separately. Legume can supply additional crop residues and improve cropping performance when used as intercrop and rotation crop. One of the greatest approaches to enable comparisons is to test tillage techniques in various agriculture systems that concurrently represent farmers' practices.

Research findings are frequently confined by a short repetition period, especially in Africa where most studies only present data from one or two seasons. However, this study was carried out throughout in two seasons the 2016 short rains and 2016 long rains. Research on tillage needs enough time to produce reliable results and numerous seasonal assessments are required to account for changing environmental circumstances. It should be noted that the rainfall regime has significant influence on performance of RT due to the reaction of the soil, albeit other facts could also influence the performance of RT. To make reliable comparisons, it is necessary to carry out this type of research about tillage systems over several seasons.

2.9.Cowpea productivity in Kenya

A significant staple food crop particularly in the dry savanna regions of west Africa is the cowpea. The crop provides both humans and animals with protein and vitamins as well as serving as source of revenue. According to Ekhuemelo et al. (2019), its immature pods and young leaves are consumed as vegetables. The report from Nkomo et al. (2021) stated that the world's annual cowpea production is roughly 7.56 million tons grown on approximately 12.76 million ha. The SSA contributes 84% of this production with Nigeria ranking as the top producer and consumer of cowpea (2.92 million of metric tons) followed by Niger at nearly 1.1 million metric tons. After beans, cowpea is the second most significant grain legume in Kenya. The entire area under cowpea production in Kenya was projected to be 24,432 ha in 2014. Kitui county produced the most cowpea in 2014 with the remaining production coming from Siaya, Kilifi, Migori, Bungoma, Kakamega, Makueni, Tharaka Nithi and Machakos (Koile, 2018). Numerous farmers have embraced and produced cowpea as a drought tolerant crop increasing production in Africa. The yield of cowpea is estimated between 50 and 300 kg per hectare in farmer's fields whereas cowpea can give up to 2000 kg per hectare in the research stations (Bationo et al., 2000). The yield of cowpea is very low in the farmer's fields, because of low fertility, low planting densities, mixed cropping which brings shading on the cowpea, pest and diseases attack among other factors (Singh and Tarawali, 1997).

2.10. The role of legume in the cereal-intercrop systems

In dry areas, cowpea is commonly used grown in a cereal-legume intercrop system. When it is in the intercrop system with other crops, cowpea is the main source of the large amount of nitrogen used by the other crops (Nyasasi and Kisetu, 2014). Like other legumes cowpea has the capacity to fix atmosphere nitrogen and transmit it to the soil; and is it is associated with increasing the yield of subsequent cereal in association (Sanginga, 2003). In Kenya, maize is commonly intercropped or rotated with a variety of legumes such as cowpeas and dry beans. These legumes have been demonstrated to be viable and a preferable alternative to maize-maize sequences and weedy fallows (Cheruiyot et al., 2001). Cereal-legume intercropping has been shown to be a sustainable intensification practice that results to improved yields and reduced variability implying that the smallholder farmer has low risk exposure (Kiwi et al., 2019). However, decrease in land productivity continues to be a major issue for smallholder farmers in SSA and in Kenya. The decline has been linked to reduction in soil fertility (Mucheru-Muna et al., 2011). In systems based on maize, agronomic practices that use grain legumes can increase production. Numerous studies have shown that intercropping maize with legumes like beans increases maize output (Mucheru-Muna et al., 2011). However, its only poorly understood how cowpea would affect growth and yield of different varieties of maize. Maize varieties present significant differences in phenology and morphology that could markedly affect its interaction with cowpea in an intercrop system.

CHAPTER THREE: MATERIALS AND METHODS

3.1. Study Sites

Field tests were carried out in two counties located in western Kenya specifically in Kenya Agricultural and Livestock Research Organization's (KALRO) Alupe in Busia County and Kibos in Kisumu County. In total, seven sites were used namely on-stations at Kibos and Alupe and five on farm sites two in Kibos and three in Alupe. KALRO Alupe is located 34.12051 S and 0.501197 E, and 1154m above sea level. Three on farm stations located in Angorom, Amogoro and Asopopoip places are nearing the research station and sharing the same characteristics. Bimodally distributed yearly rainfall at this location is 1700 mm. Between March and May, there are long rains and from August to November, there are short rains. Mean maximum and minimum daily temperature in this area is 22.8 °C and 21.1°C, respectively. Soils of Alupe are Ferro-orthic acrisols, sandy clay, well drained Mariuki and Macharia (2022).

KALRO Kibos is located 34.815922 S, 0.051197 E and 1135m above sea level and two on farm sites located in Guba and Nyahera places nearing the research station. The 1900mm of rain that falls on this location each year is split into two phases. Between April and May there are long rains whereas between July and December there are brief rains. In this region, the daily high and low temperatures are 20.6 °C and 18.7°C respectively.

3.2. Treatments and experiment design

A split plot layout was reproduced twice as part of the randomized complete block design (RCBD) used to arrange the treatments. Treatments consisted of two-tillage methods (no tillage and conventional tillage) and two cropping systems (sole-crop and inter-crop of maize and cowpea). Tillage system (Conventional tillage vs. no till) was allocated to the main plots, the intercropping system (sole crop vs. inter-crop) was assigned to the subplot while maize varieties formed the sub-sub plots. No till plots were prepared by leaving the crop residues after harvesting intact and then manual seeding and fertilizer application were done.

The conservation treatment involved direct seeding with a dibble stick, and all the residues were retained in situ after grain harvesting. In the conventional tillage (CT) treatment plots, crop residues were removed after harvesting, land was prepared using hand hoe, manual seeding and fertilizer application was done in the tilled seedbed after ploughing.

The maize varieties used were a local hybrid (HB505), a striga-resistant variety (H528) and an MLN resistant variety (H12). The varieties (H528) and (H12) were chosen because of their superior traits that can withstand effects of MLN and Striga and still give considerable yield to the farmers. One cowpea variety (KK1) was intercropped with the three maize varieties. Cowpea (KK1) variety was used since it is well adapted to the climatic conditions in KALRO Alupe and KALRO Kibos and is tolerant to cowpea mosaic virus.

3.2.1. On station experiments

In the KALRO Alupe on-station site, the trial consisted of 64 plots divided into two parts 32 plots under conventional practice and 32 plots under conservation agriculture. Two cropping systems (sole-crop and intercrop of maize and cowpea) were planted for each tillage method, each of which was duplicated twice. Each cropping system was established in 16 plots whereby each plot was 7.5m by 3.9m in size.

The 56 plots that made up the KALRO-Kibos on-station sites were divided into two sections with 28 plots each for the convention practices and conservation agriculture tillage systems. In 14 plots, each measuring 7.5m by 3.9m, two cropping systems were established under each tillage system and the treatment was repeated twice.

3.2.2. On-farm experiments

The on-farm experiment was planted on five farms, two in Kibos (Nyahera and Guba) and three in Alupe (Doris, Charles and Francis) Farmers. The farms for experiment were obtained from five farmers who were CIMMYT beneficiaries. Two main treatments were conducted: tillage systems and maize varieties. Three different maize types intercropped with cowpeas were tested using both traditional and no-tillage methods. Six plots each measuring 7.5m by 3.9m made up each farm.

3.2.3. Experiment Management

The study was carried out between November 2015 and February 2016 (short rains) and March and July 2016 (long rains). The same growth seasons were used for the on-station and on-farm tests. For traditional tillage, the land was prepared manually with a hoe whereas for no tillage, crops leftovers were cut and left on the field on a rate of 3t/ha. For sole and intercrop maize planting holes were cut with a short hoe at intervals of 75 cm between rows and 30 cm between stations (hills). Prior to planting, base fertilizer was equally used on maize at the rate of 100kg/ ha (18:46) it means 5g per hole with two seeds, and well incorporated into the soil then two seeds were inserted into each hole. Between each two rows of maize on the intercropped plots, one cowpea row was planted at 37.5 cm from maize and two cowpea stands were separated by 20 cm. For both the on-farm and on-station studies, weeding was done three times. Under conventional tillage, weeding was done manually using a hoe, while those under no tillage, uprooting was done to ensure there were no weeds.

3.3. Data collection

Plant height, leaf number, plant number, cob length, rows per cob and kennels per row count and grain yield were all measured for maize. Plant height, leaf and plant count as well as grain yield were measured for cowpeas.

For ongoing data collection, the middle row of five plants in each plot were labelled. In a similar way, five plants each of cowpea and maize were randomly chosen from the inter-crops and tagged to collect data.

3.3.1 Maize

After the germination, on bi-weekly basis up to harvesting, data on plant height was measured, using a meter ruler by measuring the distance from the ground to the tip of the first tassel branch; and the number of leaves was counted. The number of plants that had reached physiological maturity (between 105-120) days after planting, was counted by excluding the first plant on each side of the row before harvesting. The sampled plants that had reached physiological maturity were harvested. The maize yield components were determined from the harvested cobs. A 30 cm ruler was used to measure the entire length of the cob to establish its length. The number of rows per cob and the number of kernels per row were counted. After the corn had dried in the sun, it was shelled by hand. The grains were then weighed using a weighing balance. The grain yield was then converted to t. ha^{-1} using the following formula (Carangal et al., 1971).

Equation 1:

$$x = (y \times t \times 10000) \div (z \times q)$$

Whereby: x = yield per hectare at 12.5%, y = yield per plot in kg, t = grain moisture content in %, z = standard dry matter content in %, q = the area of the plot in m^2. Where grain moisture is the standard moisture content of the maize grains when they are dry, yield per plot is the field weight, 12.5% is the standard moisture content of dry maize grain. Grain yield was converted in t ha^{1}.

3.3.1. Cowpea

For cowpea, plant height and number of leaves were obtained on bi-weekly basis whereby the height of the plant was gauged using a meter ruler by measuring the distance in centimeters from the ground to the central shoot. By counting the leaves, it was possible to establish how many there were. At physiological maturity, when the cowpea plants had turned yellow and dried off, the number of plants harvested was counted. Grains from the harvested pods were sun dried, threshed and winnowed, thereafter, they were weighed using a weighing balance. The grain yield was then converted to t/ha^{-1} using the following formula (Carangal et al., 1971).

Equation 2

$$x = (y \times t \times 10000) \div (z \times q)$$

Whereby: x = yield per hectare at 12.5%, y = yield per plot in kg, t = grain moisture content in %, z = standard dry matter content in%, q = the area of the plot in m^2. Where grain moisture is the standard moisture content of the grain when they are dry, yield per plot is the field weight, 12.5% is the standard moisture content of dry cowpea grain. Grain yield was converted in t ha^{1}.

3.4. Data analysis

Gen Stat Version (15^{th} edition) was used to perform an analysis of variance (ANOVA) on the collected data. Fisher's least significant difference (LSD) test with a p-value of at $p \leq 0.05$ was used to separate means where the difference was significant.

CHAPTER FOUR: RESULTS

4.1. On-station experiment results

4.1.1. Effects of two tillage systems, cropping system and maize variety on maize plant height, number of leaves and number of plants

The cropping system and maize variety treatment significantly (P≤0.05) affected plant height in the short rains and variety in both seasons as well as the number of plants per plot in KALRO Alupe (Table 1) whereas the treatments had a significant impact on plant height, number of leaves per plant and the number of plants per plot in KALRO Kibos (Table 2).

Table 1: Plant height, number of leaves per plant and number of plants per plot of three maize varieties grown under two tillage methods and two crop systems at KALRO Alupe during 2015 short rains and 2016 long rains.

	2015 short rains			2016 long rains		
	P.H (cm)	No. L	No. P	P.H (cm)	No. L	No. P
Tillage method						
No-till	130.6	13.9	65.5	139.6	13.1	71.8
Tilled	97.1	14.0	64.0	112.7	14.2	54.1
P-value	0.026	0.8	0.313	0.101	0.759	0.59
LSD	85.9	11.2	10.5	7.3	0.4	35.58
Cropping system						
Inter-crop	114.9	14.2	68.0	128.2	13.8	58.1
Sole	112.7	13.7	61.5	124.1	14.2	67.8
P-value	0.495	0.073	0.045	0.137	0.904	0.416
LSD	14.4	0.6	6.1	7.3	0.4	35.4
Variety						
H12	124.4	14.3	74.5	138.5	13.8	63.4
H528	101.5	13.6	57.4	112.3	13.4	77.5
HB505	115.6	13.9	62.4	127.7	13.8	47.9
P-value	<.001	0.066	0.02	<.001	0.235	0.383
LSD	7.8	0.5	11.2	8.9	0.5	43.3
CV%	5.9	3.2	15.0	9.6	5.2	94.1

P.H=plant height, No. L = number of leaves per plant, No P=number of plants per plot, NS= Not significant; LSD= least significant difference; CV=coefficient of variation

Table 2: Plant height, number of leaves per plant and number of plants per plot for three maize varieties under two tillage methods and two cropping systems at KALRO Kibos during the 2015 short rains and 2016 long rains.

2015 short rains				2016 long rains		
	P.H (cm)	No.L	No.P	P.H (cm)	No.L	No.P
Tillage method						
No-till	136.5	14.1	81.5	147.1	14.733	80.9
Tilled	130.0	14.5	88.7	148.5	14.725	85.5
P-value	0.033	0.787	0.861	0.98	0.061	0.954
LSD	49.1	0.6	80.9	9.7	0.339	9.39
Cropping system						
Inter crop	139.1	14.5	85.6	153.1	14.608	75.9
Sole	127.4	14.1	84.6	142.6	14.85	90.4
P-value	0.033	0.556	0.939	0.104	0.499	0.169
LSD	23.5	0.8018	8.3	9.7	0.34	9.42
Variety						
H12	135.9	14.5	86.3	167.4	14.825	78.1
H528	128.0	14.0	75.0	136.5	14.775	88.1
HB505	135.9	14.4	94.0	139.6	14.588	83.3
P-value	0.072	0.017	0.003	<.001	0.471	0.216
LSD	7.7	0.3	8.8	11.87	0.415	11.5
CV%	5.0	1.9	8.8	11.0	3.9	18.9

P.H= plant height, No. L=number of leaves per plant, No. P=number of plants per plot NS= Not significant; LSD= least significant difference; CV=coefficient of variation

During 2015 short rains, maize plants established in no-tilled land were significantly (P≤0.05) taller than those established in tilled land for both fields in KALRO Alupe and KALRO Kibos (Table 1 and 2).

Maize plants inter-cropped with cowpea in KALRO Alupe during the 2015 short rains had significantly (P≤0.05) more plants than those under sole establishment (Table 1). On the contrary, maize plants inter-cropped with cowpea in KALRO Kibos during the 2015 short rains cause plants to grow significantly (P≤0.05) taller than plants grown under single cropping system (Table 2).

For both seasons in KALRO Alupe, maize variety (H12) had significantly (P≤0.05) taller plants than HB505 which, in turn, were taller than H528. During the 2015 short rains, variety H12 significantly ($P \leq 0.05$) outperformed the other varieties (H528 and HB505) which were statistically similar in number of plants (Table 1).

There was no significant ($P \leq 0.05$) difference in the number of leaves between HB505 and H12for maize crops planted KALRO Kibos during the 2015 short rains although H12 had significantly ($P \leq 0.05$) more leaves (Table 2). Like this, maize variety H12 and HB505 produced significantly ($P \leq 0.05$) more of plants than H528 maize variety over the same growing season in KALRO Kibos, but there was no difference between the two varieties (Table 2).

The maize variety (H12) planted KALRO Kibos had significantly ($P \leq 0.05$) taller plants than varieties HB505 and H528 during the 2016 long rains although there was no significant difference between variety HB505 and H528 (Table 2).

4.1.2. Effects of two tillage systems, cropping system and maize variety on maize cob length, rows per cob, number of kernels and grain yield

Cob length, number of rows per cob, number of kernels per row and grain yield in KALRO Alupe were significantly influenced by the tillage strategy, cropping system and maize variety (Table 3) The tillage system and cropping system had no significant ($P \leq 0.05$) impact on the maize production characteristics in KALRO Kibos (Table 4). On the other hand, cob length, number of rows per cob, number of kernels per row and grain yield were significantly ($P \leq 0.05$) influenced by maize variety (Table 4)

In KALRO Alupe, maize plants exposed to tilled soil had significantly ($P \leq 0.05$) less kernels per row than those grown on untilled land during the 2016 long rains (Table 3). In contrast, maize planted on tilled ground had a grain yield that was significantly ($P \leq 0.05$) higher than maize cultivated on untilled soil (Table 3).

Table 3: Cob length, number of rows per cob, number of kernels per raw and grain yield of three maize varieties grown under two tillage methods and two cropping systems at KALRO Alupe during 2015 short rains and 2016 long rains.

2015 short rains					2016 long rains			
	C.L (cm)	R/cob	No.K	GY (kg/ha)	C.L (cm)	R/cob	No.K	GY (kg/ha)
Tillage method								
No-till	11.2	12.4	25.5	1723.0	11.3	12.8	30.1	2121.0
Tilled	10.2	12.3	24.6	1659.0	10.9	12.6	26.1	2423.0
P-value	0.166	0.85	0.83	0.889	0.195	0.42	0.01	0.007
LSD	3.5	7.6	41	460.7	2.3	1.3	3.3	132.9
Cropping system								
Inter crop	11.1	12.6	25.8	1681.0	11.2	12.3	27.8	2292.0
Sole	10.3	12.2	24.3	1701.0	11	13.1	28.3	2251.0
P-value	0.102	0.09	0.04	0.686	0.873	0.85	0.68	0.737
LSD	1.2	0.3	0.8	189.7	2.2	1.3	3.3	432.9
Variety								
H12	12.0	12.0	27.7	2078.0	12.1	12.7	30.2	2759.0
H528	10.9	13.3	25.8	1484.0	11.2	13.3	29.6	2133.0
HB505	9.2	11.9	21.6	1511.0	10.0	12	24.2	1924.0
P-value	<.001	0.06	0.04	0.03	0.321	0.29	0.02	0.009
LSD	0.8	1.2	4.1	463.4	2.75	1.7	4	530.2
CV%	6.4	8.5	14.1	23.8	33.8	18.0	19.7	31.9

C.L= cob length, R/cob= number of rows per cob, No. K= number of kernels per row, GY= grain yield; NS- Not significant; LSD= least significant difference; CV=coefficient of variation

Table 4: Cob length, number of rows per cob, number of kernels per raw and grain yield of three maize varieties grown under two tillage methods and two cropping systems at KALRO Kibos during the 2015 short rains and 2016 long rains.

2015 short rains					2016 long rains			
	C.L (cm)	R/cob	No.K	GY (kg/ha)	C.L (cm)	R/cob	No. K	GY (kg/ha)
Tillage method								
No-till	22.7	13.4	28.7	3465.0	14.9	13.7	29.5	1128.0
Tilled	13.6	13.2	27.2	1339.0	15.0	13.6	28.8	1199.0
P-value	0.394	0.867	0.88	0.178	0.658	0.652	0.67	0.464
LSD	102.0	2.0	4.8	2988.8	1.0	0.7	2.5	263.5
Cropping system								
Inter crop	14.0	13.6	28.3	1998.0	16.1	13.7	31.5	1346.0
Sole	22.3	12.9	27.6	2806.0	13.8	13.6	26.9	980.0
P-value	0.402	0.999	0.84	0.383	0.315	0.743	0.13	0.325
LSD	38.6	1.0	4.8	4089.9	1.0	0.6	2.6	267.2
Variety								
H12	27.1	12.0	28.6	1833.0	16.3	13.4	33.6	1509.0
H528	13.5	13.6	28.9	1742.0	14.3	13.7	26.6	947.0
HB505	13.8	14.1	26.4	3631.0	14.3	13.9	27.3	1034.0
P-value	0.396	<.001	0.25	0.205	0.002	0.62	<.001	0.003
LSD	24.9	0.8	3.5	2493.4	1.2	0.9	3.0	456.4
CV%	118.9	5.4	10.7	90.0	11.1	8,9	14.2	37.9

C.L= cob length, R/cob= number of rows per cob, No. K= number of kernels per row, GY= grain yield; NS- not significant; LSD= least significant difference; CV=coefficient of variation

In KALRO Alupe, maize inter-crop produced a significantly (P≤0.05) higher number of rows per cob than maize in sole crop during the 2015 short rains (Table 3). During the brief rains of 2015 in KALRO Alupe, maize cultivars significantly (P≤0.05) affected cob length. In comparison to H528, which in turn had a longer cob length than HB505, maize variety H12 had a significantly (P≤0.05) longer cob length (Table 3). The number of rows per cob in KALRO Kibos was significantly (P≤0.05) influenced by the maize variety (Table 4). There was no significant ((P≤0.05) difference between the number of rows per cob in the maize variety HB505 and H528 but they had significantly (P≤0.05) more rows per cob than H12 (Table 4)

In KALRO Alupe, maize varieties significantly ($P \leq 0.05$) affected the number of kernels per row and grain yield for both seasons (Table 3). In terms of Kernels per row, maize varieties H12 and H528 significantly ($P \leq 0.05$) outperformed HB505 in both seasons (Table 3) although there was no significant difference in kernel count between H12 and H528 for any season. Variety H12 had significantly ($P \leq 0.05$) better grain yield than the other two types in both seasons. There was no difference between the grain yield of varieties H528 and HB505 (Table 3).

In KALRO Kibos, maize varieties significantly ($P \leq 0.05$) affected cob length number of kernels and grain yield during the 2016 long rains (Table 4). In Comparison to H528 and HB505, the variety H12 had significantly ($P \leq 0.05$) longer cobs, a higher density of kennels per row and a higher grain yield (Table 4). The quantity of kernels, cob length and grain yield did not significantly differ between the two varieties.

4.1.3. Effects of two tillage systems and cowpea-maize inter-cropping on cowpea plant height, number of leaves, number of plants and grain yield

In KALRO Alupe, research results showed that cowpea-maize intercropping had significant effects on the number of cowpea plants per plot only during the 2016 long rains (Tables 5), treatment effects on all other measured parameters were not significant during either season in KALRO Kibos.

Table 5: Influence of two tillage methods, and three maize varieties on cowpea plant height, number of leaves per plant, number of plants per plot and grain yield in KALRO Alupe during 2015 short rains and 2016 long rains.

2015 short rains					2016 long rains			
	P.H (cm)	No.L	No. P	GY (kg/ha)	P.H (cm)	No.L	No. P	GY (kg/ha)
Tillage								
No-till	75.8	121.2	85.1	915.0	87.2	112.2	111.0	886..0
Tilled	84.0	134.4	101.5	745.0	107.8	86.7	156.4	547.0
P-value	0.512	0.796	0.364	0.097	0.118	0.399	0.168	0.421
LSD	107.2	504.9	133.6	332.7	49.24	54.7	155.7	3359.0
Variety								
KK1+H12	88.2	139.9	116.1	945.0	87.8	108.6	84.9	864.0
KK1+H528	71.4	123.8	84.0	749.0	105.8	93.4	113.4	553.0
KK1+HB505	88.2	126.3	89.3	825.0	92.6	102.3	88.2	422.0
KK1	71.7	121.1	83.9	802.0	103.8	93.5	248.2	1027.0
P-value	0.062	0.668	0.334	0.305	0.117	0.67	<.001	0.305
LSD	16.1	39.2	45.3	234.3	17.28	34.68	50.94	782.7
CV%	11.6	17.7	28.0	16.3	10.2	20.2	22.0	63.2

P.H=plant height, No. L=number of leaves per plant No. P=number of plants per plot GY=grain yield; NS- Not significant; LSD= least significant difference; CV=coefficient of variation

Table 6: Influence of two tillage methods and three maize varieties on cowpea plant height, number of leaves per plant, number of plants per plot and grain yield in KALRO Kibos during the 2015 short rains and 2016 long rains.

	2015 short rains				2016 long rains			
	P.H (cm)	No.L	No. P	GY (kg/ha)	P.H (cm)	No.L	No. P	GY (kg/ha)
Tillage								
No-till	89.9	116.2	118.2	865.0	109.6	91.5	168.0	525.0
Tilled	95.8	95.1	97.0	781.0	117.2	66.2	199.0	331.0
P-value	0.282	0.091	0.5	0.326	0.518	0.18	0.272	0.221
LSD	35.6	38.5	276	602.4	102.33	93.55	181.9	889.1
Variety								
KK1+H12	92.0	91.2	98.8	823.0	110.4	76.9	218.0	558.0
KK1+H528	96.9	106.9	116.2	778.0	110.1	69.0	177.0	347.0
KK1+HB505	91.9	90.6	105.7	779.0	111.3	82.3	171.0	386.0
KK1	90.5	133.8	109.6	912.0	121.6	87.0	168.0	423.0
P-value	0.668	0.087	0.26	0.428	0.369	0.296	0.791	0.308
LSD	13.1	37.2	19.2	209.5	17.1	21.5	135.8	259.0
CV%	8.2	20.3	10.3	14.7	8.7	15.8	42.8	34.9

P.H=plant height, No. L=number of leaves per plant No. P=number of plants per plot GY=grain yield, N. S= Not significant LSD= least significant difference; CV=coefficient of variation;

4.2. On-farm experiment results

4.2.1. Effects of maize varieties, cropping patterns and tillage practices on grain yield, cob length, the number of rows per cob, number of kernels per row

In the 2015 short rains, the tillage strategy and maize variety used by farmers in Alupe had significant (P≤0.05) effects on grain yield and cob length respectively (Table 7). In the 2016 long rains, the effects of tillage and maize variety on grain yield, cob length, number of rows per cob and number of kernels per row were not significant (Table 7). The maize variety had a significant (P≤0.05) impact on the number of rows per cob and grain yield in the 2015 short rains as well as the number of kernels per row in the 2016 long rains in the fields of Kibos farmers (Table 8).

During the 2015 short rains from farmers' fields in Alupe, in comparison to maize grown in tilled soil, no-till maize produced significantly (P≤0.05) higher grain yields (Table 5). Besides, maize variety (HB505) resulted to significantly (P≤0.05) longer cobs than H12, which in turn, had longer cobs than H528 (Table 5).

Table 7: Cob length, number of rows per cob, number of kernels per raw and grain yield of three maize varieties grown under two tillage methods at farmer's field in Alupe during 2015 short rains (Weather data D) and 2016 long rains (Weather data C).

	2015 short rains				2016 long rains			
	C.L(cm)	R/Cob	No.K	GY (kg/ha)	C.L(cm)	R/Cob	No.K	GY (kg/ha)
Tillage								
No-till	12.1	13.1	25.8	1768.0	13.5	13.1	31.3	1132.0
Tilled	11.5	13.3	24.5	1383.0	15.0	13.3	31.8	2003.0
Pvalue	0.484	0.511	8	0.012	0.08	0.708	3	0.235
LSD	3.3	1.1	7.2	183.5	1.9	1.3	1.9	2228.4
Variety								
H12	11.9	12.9	25.4	1571.0	14.0	12.9	30.1	1485.0
H528	11.2	13.2	24.6	1492.0	14.3	13.5	32.4	1766.0
HB505	12.3	13.4	25.5	1662.0	14.5	13.3	32.0	1452.0
P-value	0.005	0.562	1	0.358	0.744	0.72	7	0.565
LSD	0.6	1.0	3.9	256.5	1.9	1.7	8.7	717.7
CV%	3.6	5.7	8.7	12.2	7.9	9.7	20.8	34.4

C.L= cob length, R/cob= number of rows per cob, No.K= number of kernels per row, GY= grain yield; NS- Not significant ;LSD= least significant difference; CV=coefficient of variation

Table 8: Cob length, number of rows per cob, number of kernels per raw and grain yield of three maize varieties grown under two tillage methods at farmer's field in Kibos during the 2015 short rains and 2016 long rains

	2015 short rains				2016 long rains			
	C.L (cm)	R/cob	No.K	GY (kg/ha)	C.L (cm)	R/cob	No.K	GY (kg/ha)
Tillage								
No-till	35.0	13.1	42.2	1892.0	15.5	13.3	30.0	1802.0
Tilled	30.0	12.9	34.1	1401.0	12.8	13.2	25.9	1207.0
P-value	0.394	0.862	0.192	0.388	0.241	0.842	0.397	0.211
LSD	44.6	10.1	32.1	4355.4	13.5	6.2	37.9	2608.1
Variety								
H12	33.0	13.0	37.8	2231.0	14.4	12.8	29.1	1696.0
H528	32.5	13.0	39.1	1447.0	14.3	13.4	28.8	1332.0
HB505	31.9	13.4	37.5	1261.0	13.6	13.7	26.0	1486.0
P-value	0.85	0.024	0.795	0.021	0.141	0.088	<.001	0.194
LSD	4.3	0.3	5.6	657.6	0.9	0.8	1.3	418.0
CV%	11.4	5.7	12.8	34.6	5.5	5.2	3.9	24.1

C.L= cob length, R/cob= number of rows per cob, No. K= number of kernels per row, GY= grain yield; NS=Not significant; LSD= least significant difference; CV=coefficient of variation

From the farmers' field in Kibos, during 2015 short rains, maize variety H12 gave significantly ($P \leq 0.05$) higher grain yields than H528 and HB505 (Table 8). Between the H528 and HB505 maize varieties, the grain yield did not significantly change. In comparison to HB505 maize varieties H12 and H528 had a significant ($P \leq 0.05$) larger quantity of kernels per row during the 2016 rains. Between the cultivars H12 and H528, there was no discernible change in the number of kernels per row (Table 8).

4.2.2. Effects of two tillage strategies and intercropping of cowpea and maize varieties on height, number of leaves, plant count and grain production of cowpea in farmer's fields

In a farmer's field in Alupe, intercropping cowpea and maize only had a substantial impact on plant height during the short rains and no effect during the 2016 long rains (Table 9). The quantity of leaves per plant was significantly influenced by the tillage system according to the findings from the farmer's field in Kibos (Table 10).

Table 9: Plant height, number of leaves, number of plants and grain yield of cowpea grown under two tillage methods and intercropped with three maize varieties in a farmer's field in Alupe during the 2015 short rains and 2016 long rains

	2015 short rains				2016 long rains			
	P.H (cm)	No.L	No. P	GY (kg/ha)	P.H (cm)	No.L	No. P	GY (kg/ha)
Tillage								
No-till	59.6	111.4	56.6	489a	86.5	99.1	109.8	407
Tilled	55.7	117.1	52.3	410a	102.2	94	115.1	405
P-value	0.85	0.716	0.277	0.08	0.285	0.346	0.676	0.972
LSD	79.0	58.4	12.5	102.9	95.51	38.75		679.8
Variety								
KK1+H12	65.6	123.0	55.0	431a	82.6	97.5	108.4	351
KK1+H528	58.4	117.9	51.8	484a	107.7	102.4	117	407
KK1+HB505	49.0	101.9	56.4	434a	92.6	89.8	112	461
P-value	0.05	0.254	0.807	0.51	0.075	0.268	0.417	0.357
LSD	12.9	28.0	16.4	113.7	21.62	18.31	16.22	185.8
CV%	16.8	18.4	22.7	19	11.7	9.7	7.3	23.3

P.H=plant height, No. L=number of leaves per plant No. P=number of plants per plot GY=grain yield, NS= Not significant; LSD= least significant difference; CV=coefficient of variation

Table 10: Plant height, number of leaves, number of plants and grain yield of cowpea grown under two tillage methods and intercropped with three maize varieties in a farmers' fields in Kibos during the 2015 short rains and 2016 long rains

	2015 short rains				2016 long rains			
	P.H (cm)	No.L	No. P	GY (kg/ha)	P.H (cm)	No.L	No. P	GY (kg/ha)
Tillage								
No-till	86.5	99.1	109.8	407	96.5	122.0	119.7	308.9
Tilled	102.2	94	115.1	405	94.2	112.5	133.7	304.7
P-value	0.285	0.346	0.676	0.972	0.866	0.046	0.5	0.953
LSD	95.51	38.75	119.65	679.8	133.1	8.7	177.9	723.2
Variety								
KK1+H12	82.6	97.5	108.4	351	97.7	112.7	126.1	276.7a
KK1+H528	107.7	102.4	117	407	90.9	129.5	124.1	340.9a
KK1+HB505	92.6	89.8	112	461	97.5	109.5	129.8	302.8a
P-value	0.075	0.268	0.417	0.357	0.62	0.394	0.659	0.075
LSD	21.6	18.3	16.2	185.8	20.8	38.8	16.5	54.9
CV%	11.7	9.7	7.3	23.3	11.1	16.8	6.6	9.1

P.H=plant height, No. L=number of leaves per plant, No. P=number of plants per plot GY=grain yield, NS= Not significant; LSD= least significant difference; CV=coefficient of variation

Cowpea intercropped with maize variety H12 had a significantly ($P \leq 0.05$) taller plants than cowpea intercropped with maize variety HB505 during the 2015 short rains in a farmer's field in Alupe (Table 10). The number of leaves per plant for cowpea plants grown on no-tilled soil during the 2016 long rains was considerably higher than for plants grown on taller land (Table 10)

CHAPTER FIVE: DISCUSSION

5.1. Effects of two tillage systems, cropping methods and maize varieties on height, number of leaves and number of plants of maize

The results of the study indicated that plants established in non-tilled fields were significantly taller than those established in tilled lands at both Alupe and Kibos research stations. Perhaps, the timely control of weeds through uprooting and retention of plant residue helped to conserve moisture during the dry periods at the critical plant growth stage (Weather data provided), thus favoring crop growth rates. Tillage scheme had no noticeable impact on the height of maize according to (Aikins et al., 2012). Wasaya et al. (2011) and Borghei et al. (2008) reported in earlier studies that conventional tillage boosted maize plant height in comparison to no tillage.

Intercropping maize with cowpea in Alupe research station resulted in an increased number of plants per plot while in Kibos research station it increased plant height. The results of this finding may be attributed to fast growth of the maize varieties that later provided shade to cowpea without compromising on their plant height and number of plants. However, more long-term studies are needed on cropping systems and tillage systems since the effects can always take years or more time to manifest themselves. The general observation of a rise in plant height and plant number though not always considerable and consistent, aligns with the research by Masvaya et al. (2017) who concluded that maize-cowpea inter-crops may either not affect or improve growth/yield components depending on the pattern of arrangement and date of inter-crop establishment.

In maize plant height, number of leaves and number of plants at both research stations Maize variety H12 outperformed all the maize varieties (H528 and HB505). This can be attributed to the ability of the H12 maize variety to withstand positively different environmental conditions compared to the other remaining maize varieties. Similar observations have been made by other researchers (BK and Shrestha, 2014; Rusinamhodzi et al., 2020), who reported that maize varieties by environment interaction performed differently when tested under a combination of tillage and cropping systems.

5.2. Effects of two tillage systems, cropping methods and maize variety on maize cob length, number of rows per cob, number of kernels per row and grain yield of maize

The higher number of kernels per row was recorded on maize under no tillage at Alupe research station than under conventional tillage. However, at Alupe research station during the 2016 long rains (Weather data C) maize under conventional tillage outperformed those under no tillage in grain yield. The reduced maize yields in no-tilled farms may be caused by soil surface crusting which would harm soil nutrients, increase surface runoff and decrease water infiltration resulting in higher plant water pressure than in tilled lands. Similar observations were made by Rusinamhodzi et al. (2020) in maize established under conventional tillage which outperformed that established under no tillage. Previous researchers (Shae et al., 2016) reported higher maize yield in conventional tillage than in no tillage. Dinnes et al. (2002) reported that soil disturbance usually improves the aeration and mineralization of organic matter, thus increasing nitrogen availability. Additionally, according to Rusinamhodzi et al. (2011), other factors such as invasive grass species, increased weed competition, strong root penetration resistance and reduced porosity may also contribute to lower grain yields with no tillage than conventional tillage.

In contrast, during the short rains of 2016 (Weather data D), maize grown without tillage in a farmer’s field in Alupe produced higher yields than maize grown with traditional treatment. The results obtained in this study may be probably due to improved soil water conservation, with more plant water held at plant available soil water tension during critical growth stage experienced during the short rains when there was minimal rainfall. Quotes from the weather data are available (weather data is provided). In comparison to conventional tillage, which lost a lot of water during weeding and plowing, it’s probable that no tillage enhanced water conservation. Weeding was done thrice by uprooting under conservation agriculture as compared to five times under conventional tillage. In their research, Buah et al. (2017) found that under an extended drought, untilled land produced better corn yields. Simic et al. (2019) found that reduced tillage conditions increased maize grain yield relative to conventional tillage in some dry regions. In contrast, conventional tillage had a greater mean maize yield than a conservation tillage according to (Bongomin et al., 2020).

At the Alupe study site, maize intercropped with cowpea had a higher number of rows per cob than the sole maize. This might be explained by the cowpea canopy which decreased the soil moisture loss and promoted plant development and yield-related factors. These findings are in line with those Belel et al. (2014) who noted that increasing the number of rows per cob resulted in higher maize yields when intercropping as opposed to solitary production particularly when the environment was moisture stressed. According to earlier research by Rusinamhodzi et al. (2012), intercropping with different planting arrangements can also increase the primary crop's yields. However, other researchers Masvaya et al. (2017) have reported reduced yields under maize cowpea intercrops due to competition for resources such as nutrients, water and light. Similarly, findings by Poigne et al. (2015) on maize intercrop with alfalfa under no tillage resulted to low yield components of maize due to competition of resources brought by the legume intercrop.

In both Alupe and Kibos research stations, maize variety H12 outperformed the varieties H528 and HB505 in cob length, number of kernels and grain yields. However, variety HB505 out-yielded varieties H528 and H12 in number of rows per cob in both the farmer's field and research stations during the 2015 short rains. The general observations made in this study have been made by other researchers Rusinamhodzi et al. (2020), who reported that maize variety by environment interaction performed differently when tested under a combination of tillage and cropping systems.

5.3. Effects of tillage systems and maize variety inter crop on plant height, number of leaves, number of plants and grain yield of cowpea.

Cowpea plants established under sole production resulted in a higher number of plants during the 2016 long rains than those established as inter-crops in Alupe research station. The inter-specific conflict between the intercrop components for water, light and nutrients may be the cause of the low number of cowpea plants grown in conjunction with maize. These results coincide with those of Masvaya et al. (2017), who found that cowpea under lonely establishment had higher growth and yield components than those under inter-crop. According to Mucheru-Muna et al. (2021), legumes are less competitive than cereals because they have shallow and short root systems which makes them less able to compete for mineral nitrogen.

The number of leaves under no tillage was higher than those under conventional tillage at farmer's field in Kibos. Similar findings were reported on maize. It could be possible the soils under no tillage had higher aggregate stability and organic matter content thus increasing water holding capacity and improving water infiltration. This, consequently, may have resulted in increase in number of leaves per plant.

Cowpea plant height was higher under maize H12 variety inter crop at a farmer's field in Alupe as compared to variety H528 and HB505. Throughout this research studies, maize variety H12 has maintained higher yields in both growth parameters and yield attributes, irrespective of the treatment subjected to which was attributed to the positive reaction from the H12 variety regarding the environmental conditions.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

In this study, maize plants established in the research stations and subjected to conventional tillage resulted to higher grain yields than conservation tillage. However, maize plants established in farmers' fields and subjected to conservation agriculture resulted in higher grain yields compared to those subjected to conventional tillage. In comparison to cultivation of a single crop, maize-cowpea intercropping increased the number of maize plants per plot, the number of rows per cob and the height of the maize plant. On the other hand, cowpea grown as a single crop produced more plants per plot. In comparison to variety H528 and HB505, maize variety H12 substantially produced taller plants, higher number of plants per plot, more kernels per row more leaves and greater grain yields. Variety HB505 resulted in a significantly higher number of rows per cob as compared to variety H12 and H528.

6.2. Recommendations

Following are suggested actions based on the study:

1. From the three studied maize varieties H12, HB505 and H528, it is advisable to conduct more research studies to confirm to farmers in Western Kenya that they can plant H12 maize variety to obtain higher maize grain yield.

2. Further research studies should be conducted to find out cowpea-intercrop growth and yield performance under conservation and conventional tillage practices.

3. The study was conducted for only two seasons thus additional studies are required to avail to farmers encouraging conservation agriculture practices for better yields.

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APPENDICES

Appendix 1: Plant height (cm) of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3655.6	3655.6	13.34	
Tillage	1	6743.55	6743.55	24.61	0.127
Residual	1	274.05	274.05	4.07	
Cropping	1	30.38	30.38	0.45	0.571
Tillage, Cropping	1	56.73	56.73	0.84	0.456
Residual	2	134.82	67.41	1.49	
Variety	2	2131.04	1065.52	23.56	<.001
Tillage, Variety	2	540.99	270.5	5.98	0.026
Cropping Variety	2	69.63	34.82	0.77	0.495
Tillage Cropping,Variety	2	65.03	32.51	0.72	0.516
Residual	8	361.8	45.22		
Total	23	14063.63			

Appendix 2: Number of leaves of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	1.7604	1.7604	0.38	
Tillage	1	0.375	0.375	0.08	0.824
Residual	1	4.6817	4.6817	37.14	
Cropping	1	1.5504	1.5504	12.3	0.073
Tillage.Cropping	1	0.135	0.135	1.07	0.409
Residual	2	0.2521	0.126	0.63	
Variety	2	1.5475	0.7737	3.9	0.066
Tillage.Variety	2	0.0175	0.0087	0.04	0.957
Cropping.Variety	2	0.8258	0.4129	2.08	0.187
Tillage.Cropping.Variety	2	0.0475	0.0238	0.12	0.889
Residual	8	1.5883	0.1985		
Total	23	12.7812			

Appendix 3: Number of plants of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	2414.02	2414.02	591.13	
Tillage	1	14.26	14.26	3.49	0.313
Residual	1	4.08	4.08	0.34	
Cropping	1	250.91	250.91	20.88	0.045
Tillage.Cropping	1	8.88	8.88	0.74	0.481
Residual	2	24.03	12.01	0.13	
Variety	2	1245.6	622.8	6.63	0.02
Tillage.Variety	2	45.26	22.63	0.24	0.791
Cropping.Variety	2	36.81	18.4	0.2	0.826
Tillage.Cropping.Variety	2	159.12	79.56	0.85	0.464
Residual	8	751.65	93.96		
Total	23	4954.61			

Appendix 4: Cob length (cm) of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	1.495	1.495	3.31	
Tillage	1	6.314	6.314	14	0.166
Residual	1	0.451	0.451	1.02	
Cropping	1	3.6738	3.6738	8.3	0.102
Tillage.Cropping	1	0.1855	0.1855	0.42	0.584
Residual	2	0.885	0.4425	0.96	
Variety	2	31.7224	15.8612	34.38	<.001
Tillage.Variety	2	9.5374	4.7687	10.34	0.006
Cropping.Variety	2	0.0266	0.0133	0.03	0.972
Tillage.Cropping.Variety	2	0.1609	0.0805	0.17	0.843
Residual	8	3.6906	0.4613		
Total	23	58.1423			

Appendix 5: Number of rows per cob of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	2.282	2.282	1.06	
Tillage	1	0.06	0.06	0.03	0.895
Residual	1	2.16	2.16	70.05	
Cropping	1	0.735	0.735	23.84	0.039
Tillage.Cropping	1	0.027	0.027	0.86	0.451
Residual	2	0.062	0.031	0.03	
Variety	2	9.426	4.713	4.21	0.056
Tillage.Variety	2	0.728	0.364	0.32	0.732
Cropping.Variety	2	0.157	0.079	0.07	0.933
Tillage.Cropping.Variety	2	0.126	0.063	0.06	0.946
Residual	8	8.957	1.12		
Total	23	24.718			

Appendix 6: Number of kennel and Yield (kg ha -1) of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	101.68	101.68	1.63	
Tillage	1	5.7	5.7	0.09	0.813
Residual	1	62.4	62.4	318.32	
Cropping	1	14.11	14.11	71.96	0.014
Tillage.Cropping	1	0.18	0.18	0.94	0.435
Residual	2	0.39	0.2	0.02	
Variety	2	153.33	76.66	6.15	0.024
Tillage.Variety	2	9.27	4.64	0.37	0.701
Cropping.Variety	2	1.03	0.52	0.04	0.96
Tillage.Cropping.Variety	2	0.32	0.16	0.01	0.987
Residual	8	99.74	12.47		
Total	23	448.16			

Appendix 7: Yield (kg ha -1) of three varieties of maize, planted on station – Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	8098327	8098327	10.03	
Tillage	1	24955	24955	0.03	0.889
Residual	1	807290	807290	69.2	
Cropping	1	2544	2544	0.22	0.686
Tillage.Cropping	1	9271	9271	0.79	0.467
Residual	2	23331	11665	0.07	
Variety	2	1800709	900355	5.57	0.03
Tillage.Variety	2	1646506	823253	5.1	0.037
Cropping.Variety	2	96079	48040	0.3	0.751
Tillage.Cropping.Variety	2	765698	382849	2.37	0.155
Residual	8	1292257	161532		
Total	23	14566966			

Appendix 8: Plant height (cm) of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	2839.8	1419.9	4.18	
Tillage	1	128	128	0.38	0.602
Residual	2	678.8	339.4	1.45	
Variety	2	247	123.5	0.53	0.609
Tillage.Variety	2	765.3	382.6	1.64	0.254
Residual	8	1871	233.9		
Total	17	6529.9			

Appendix 9: Number of leaves of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	2.8078	1.4039	17.19	
Tillage	1	0.045	0.045	0.55	0.535
Residual	2	0.1633	0.0817	0.14	
Variety	2	0.3211	0.1606	0.28	0.761
Tillage.Variety	2	2.4033	1.2017	2.12	0.183
Residual	8	4.5422	0.5678		
Total	17	10.2828			

Appendix 10: Number of plants of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	275.4	137.7	1.44	
Tillage	1	14.2	14.2	0.15	0.737
Residual	2	191.4	95.7	0.78	
Variety	2	648.1	324.1	2.63	0.133
Tillage.Variety	2	2818.1	1409.1	11.42	0.005
Residual	8	987.1	123.4		
Total	17	4934.4			

Appendix 11: Cob length (cm) of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	18.7778	9.3889	3.65	
Tillage	1	1.8689	1.8689	0.73	0.484
Residual	2	5.1378	2.5689	14.1	
Variety	2	3.9644	1.9822	10.88	0.005
Tillage.Variety	2	4.0711	2.0356	11.17	0.005
Residual	8	1.4578	0.1822		
Total	17	35.2778			

Appendix 12: Number of rows per cob of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.0933	0.0467	0.16	
Tillage	1	0.18	0.18	0.63	0.511
Residual	2	0.5733	0.2867	0.51	
Variety	2	0.6933	0.3467	0.62	0.562
Tillage.Variety	2	2.08	1.04	1.86	0.218
Residual	8	4.48	0.56		
Total	17	8.1			

Appendix 13: Number of kennel and Yield (kg ha -1) of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	98.671	49.336	3.95	
Tillage	1	8	8	0.64	0.508
Residual	2	25	12.5	1.43	
Variety	2	3.308	1.654	0.19	0.831
Tillage.Variety	2	9.523	4.762	0.55	0.599
Residual	8	69.742	8.718		
Total	17	214.244			

Appendix 14: Yield (kg ha -1) of three varieties of maize, planted on farm - Alupe, 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	2185650	1092825	133.57	
Tillage	1	668245	668245	81.68	0.012
Residual	2	16363	8181	0.22	
Variety	2	86907	43453	1.17	0.358
Tillage.Variety	2	31370	15685	0.42	0.669
Residual	8	296836	37105		
Total	17	3285372			

Appendix 15: Plant height (cm) of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	9.2	4.6	0.01	
Tillage	1	872.2	872.2	1.63	0.33
Residual	2	1072.7	536.4	1.98	
Variety	2	148	74	0.27	0.768
Tillage.Variety	2	1177.2	588.6	2.17	0.177
Residual	8	2168.7	271.1		
Total	17	5448			

Appendix 16: Number of leaves of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	914.59	457.3	0.96	
Tillage	1	474.32	474.32	0.99	0.424
Residual	2	954.81	477.41	14.17	
Variety	2	91.19	45.6	1.35	0.312
Tillage.Variety	2	62.23	31.12	0.92	0.436
Residual	8	269.45	33.68		
Total	17	2766.6			

Appendix 17: Number of plants of three varieties of maize, planted on farm - Alupe, 2016B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	902.3	451.2	0.29	
Tillage	1	1.4	1.4	0	0.979
Residual	2	3104.1	1552.1	9.92	
Variety	2	54.2	27.1	0.17	0.844
Tillage.Variety	2	641.7	320.8	2.05	0.191
Residual	8	1251.2	156.4		
Total	17	5955			

Appendix 18: Cob length (cm) of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	3.653	1.826	2	
Tillage	1	10.05	10.05	11	0.08
Residual	2	1.827	0.914	0.71	
Variety	2	0.785	0.393	0.31	0.744
Tillage.Variety	2	0.155	0.077	0.06	0.942
Residual	8	10.229	1.279		
Total	17	26.698			

Appendix 19: Number of rows per cob of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.0933	0.0467	0.16	
Tillage	1	0.18	0.18	0.63	0.511
Residual	2	0.5733	0.2867	0.51	
Variety	2	0.6933	0.3467	0.62	0.562
Tillage.Variety	2	2.08	1.04	1.86	0.218
Residual	8	4.48	0.56		
Total	17	8.1			

Appendix 20: Number of kennel and Yield (kg ha -1) of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	588.97	294.49	321.65	
Tillage	1	1.39	1.39	1.52	0.343
Residual	2	1.83	0.92	0.02	
Variety	2	17.83	8.92	0.21	0.817
Tillage.Variety	2	73.92	36.96	0.86	0.458
Residual	8	343.36	42.92		
Total	17	1027.3			

Appendix 21: Yield (kg ha -1) of three varieties of maize, planted on farm - Alupe, 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	483396	241698	0.2	
Tillage	1	3412578	3412578	2.83	0.235
Residual	2	2414181	1207091	4.15	
Variety	2	356100	178050	0.61	0.565
Tillage.Variety	2	1525187	762594	2.62	0.133
Residual	8	2324630	290579		
Total	17	10516072			

Appendix 22: Plant height of cowpea on station - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3984.77	3984.77	13.99	
Tillage	1	264.88	264.88	0.93	0.512
Residual	1	284.77	284.77	3.3	
Variety	3	1107.38	369.13	4.28	0.062
Tillage.Variety	3	118.19	39.4	0.46	0.722
Residual	6	517.64	86.27		
Total	15	6277.62			

Appendix 23: Number of leaves of cowpea on station - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	13392.3	13392.3	2.12	
Tillage	1	693	693	0.11	0.796
Residual	1	6316.3	6316.3	12.33	
Variety	3	839.5	279.8	0.55	0.668
Tillage.Variety	3	1400	466.7	0.91	0.489
Residual	6	3072.6	512.1		
Total	15	25713.7			

Appendix 24: Number of plants of cowpea on station - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3326.4	3326.4	7.52	
Tillage	1	1070.9	1070.9	2.42	0.364
Residual	1	442.1	442.1	0.65	
Variety	3	2850	950	1.39	0.334
Tillage.Variety	3	131	43.7	0.06	0.977
Residual	6	4107.3	684.5		
Total	15	11927.7			

Appendix 25: Yield of cowpea on station - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	1791	1791	0.65	
Tillage	1	115719	115719	42.18	0.097
Residual	1	2743	2743	0.15	
Variety	3	83001	27667	1.51	0.305
Tillage.Variety	3	5869	1956	0.11	0.953
Residual	6	110007	18334		
Total	15	319131			

Appendix 26: Plant height of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	721.19	360.59	0.24	
Tillage	1	69.62	69.62	0.05	0.85
Residual	2	3033.24	1516.62	16.1	
Variety	2	838.47	419.24	4.45	0.05
Tillage.Variety	2	187.96	93.98	1	0.41
Residual	8	753.67	94.21		
Total	17	5604.15			

Appendix 27: Number of leaves of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	695.8	347.9	0.42	
Tillage	1	145.1	145.1	0.18	0.716
Residual	2	1655.4	827.7	1.87	
Variety	2	1445.7	722.9	1.64	0.254
Tillage.Variety	2	1039.5	519.7	1.18	0.357
Residual	8	3533.8	441.7		
Total	17	8515.2			

Appendix 28: Number of plants of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1642	821	21.66	
Tillage	1	83.2	83.2	2.2	0.277
Residual	2	75.8	37.9	0.25	
Variety	2	67.2	33.6	0.22	0.807
Tillage.Variety	2	15.6	7.8	0.05	0.95
Residual	8	1217.1	152.1		
Total	17	3100.9			

Appendix 29: Yield of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1322995	661498	256.83	
Tillage	1	28425	28425	11.04	0.08
Residual	2	5151	2576	0.35	
Variety	2	10704	5352	0.73	0.51
Tillage.Variety	2	16115	8057	1.11	0.377
Residual	8	58324	7290		
Total	17	1441714			

Appendix 30: Plant height of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	670.5	335.2	0.08	
Tillage	1	2257.9	2257.9	0.56	0.531
Residual	2	7999.4	3999.7	10.21	
Variety	2	997.1	498.5	1.27	0.331
Tillage.Variety	2	1929.8	964.9	2.46	0.147
Residual	8	3134.5	391.8		
Total	17	16989.2			

Appendix 31: Number of leaves of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	917.7	458.8	1.97	
Tillage	1	62.7	62.7	0.27	0.656
Residual	2	466.1	233.1	2	
Variety	2	289.1	144.6	1.24	0.339
Tillage.Variety	2	78.4	39.2	0.34	0.724
Residual	8	932.1	116.5		
Total	17	2746.1			

Appendix 32: Number of plants of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1962.5	981.3	1.07	
Tillage	1	260.7	260.7	0.28	0.647
Residual	2	1834.2	917.1	3.56	
Variety	2	688.4	344.2	1.34	0.316
Tillage.Variety	2	1525.7	762.8	2.96	0.109
Residual	8	2062.4	257.8		
Total	17	8333.9			

Appendix 33: Yield of cowpea on farm - Alupe intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1568279	784139	12.34	
Tillage	1	104364	104364	1.64	0.329
Residual	2	127123	63561	0.5	
Variety	2	407974	203987	1.6	0.261
Tillage.Variety	2	408748	204374	1.6	0.26
Residual	8	1022464	127808		
Total	17	3638951			

Appendix 34: Plant height (cm) of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	5060.51	5060.51	56.41	
Tillage	1	257.42	257.42	2.87	0.339
Residual	1	89.71	89.71	0.5	
Cropping	1	817.83	817.83	4.58	0.166
Tillage.Cropping	1	1526.42	1526.42	8.54	0.1
Residual	2	357.46	178.73	4.04	
Variety	2	329.98	164.99	3.73	0.072
Tillage.Variety	2	477.59	238.8	5.4	0.033
Cropping.Variety	2	476	238	5.38	0.033
Tillage.Cropping.Variety	2	24.58	12.29	0.28	0.764
Residual	8	353.99	44.25		
Total	23	9771.48			

Appendix 35: Number of leaves of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3.375	3.375	225	
Tillage	1	0.80667	0.80667	53.78	0.086
Residual	1	0.015	0.015	0.07	
Cropping	1	1.30667	1.30667	6.27	0.129
Tillage.Cropping	1	0.08167	0.08167	0.39	0.595
Residual	2	0.41667	0.20833	2.92	
Variety	2	1.00771	0.50385	7.06	0.017
Tillage.Variety	2	0.03521	0.0176	0.25	0.787
Cropping.Variety	2	0.09021	0.0451	0.63	0.556
Tillage.Cropping.Variety	2	0.11271	0.05635	0.79	0.486
Residual	8	0.57083	0.07135		
Total	23	7.81833			

Appendix 36: Number of plants of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	52.22	52.22	0.21	
Tillage	1	308.17	308.17	1.27	0.462
Residual	1	243.21	243.21	10.87	
Cropping	1	5.42	5.42	0.24	0.672
Tillage.Cropping	1	0.88	0.88	0.04	0.861
Residual	2	44.77	22.38	0.4	
Variety	2	1449.38	724.69	12.83	0.003
Tillage.Variety	2	17.22	8.61	0.15	0.861
Cropping.Variety	2	7.15	3.58	0.06	0.939
Tillage.Cropping.Variety	2	13.31	6.66	0.12	0.89
Residual	8	451.84	56.48		
Total	23	2593.56			

Appendix 37: Cob length (cm) of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	213.6	213.6	0.55	
Tillage	1	495.6	495.6	1.28	0.461
Residual	1	386.7	386.7	0.8	
Cropping	1	411.7	411.7	0.85	0.453
Tillage.Cropping	1	424.5	424.5	0.88	0.447
Residual	2	964.2	482.1	1.04	
Variety	2	968.3	484.1	1.04	0.396
Tillage.Variety	2	973.5	486.8	1.05	0.394
Cropping.Variety	2	951.1	475.5	1.02	0.402
Tillage.Cropping.Variety	2	970.8	485.4	1.04	0.395
Residual	8	3718.5	464.8		
Total	23	10478.5			

Appendix 38: Number of rows per cob of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	0.5859	0.5859	4.11	
Tillage	1	0.2709	0.2709	1.9	0.4
Residual	1	0.1426	0.1426	0.48	
Cropping	1	2.6334	2.6334	8.8	0.097
Tillage.Cropping	1	0.2501	0.2501	0.84	0.457
Residual	2	0.5985	0.2993	0.59	
Variety	2	19.1631	9.5816	18.84	<.001
Tillage.Variety	2	0.1481	0.0741	0.15	0.867
Cropping.Variety	2	0.0006	0.0003	0	0.999
Tillage.Cropping.Variety	2	0.184	0.092	0.18	0.838
Residual	8	4.0692	0.5086		
Total	23	28.0466			

Appendix 39: Number of kennel and Yield (kg ha -1) of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	56.273	56.273	65.24	
Tillage	1	13.878	13.878	16.09	0.156
Residual	1	0.863	0.863	0.11	
Cropping	1	3.338	3.338	0.44	0.576
Tillage.Cropping	1	1.105	1.105	0.15	0.74
Residual	2	15.234	7.617	0.85	
Variety	2	30.191	15.096	1.69	0.245
Tillage.Variety	2	2.795	1.398	0.16	0.858
Cropping.Variety	2	3.791	1.896	0.21	0.814
Tillage.Cropping.Variety	2	2.57	1.285	0.14	0.868
Residual	8	71.638	8.955		
Total	23	201.677			

Appendix 40: Yield (kg ha -1) of three varieties of maize, planted on station (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	1392739	1392739	4.2	
Tillage	1	27134778	27134778	81.74	0.07
Residual	1	331985	331985	0.06	
Cropping	1	3914357	3914357	0.72	0.485
Tillage.Cropping	1	10803503	10803503	1.99	0.294
Residual	2	10842387	5421193	1.16	
Variety	2	18154221	9077110	1.94	0.205
Tillage.Variety	2	20204106	10102053	2.16	0.178
Cropping.Variety	2	10153612	5076806	1.09	0.383
Tillage.Cropping.Variety	2	12828980	6414490	1.37	0.307
Residual	8	37412257	4676532		
Total	23	153172923			

Appendix 41: Plant height (cm) of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	4701.2	4701.2	8.17	
Tillage	1	3026.3	3026.3	5.26	0.262
Residual	1	575.3	575.3	40.77	
Cropping	1	1839.3	1839.3	130.35	0.008
Tillage.Cropping	1	271.4	271.4	19.23	0.048
Residual	2	28.2	14.1	0.12	
Variety	2	888.9	444.5	3.74	0.071
Tillage.Variety	2	202.9	101.4	0.85	0.461
Cropping.Variety	2	1252	626	5.27	0.035
Tillage.Cropping.Variety	2	602	301	2.54	0.14
Residual	8	949.5	118.7		
Total	23	14336.8			

Appendix 42: Number of leaves of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	0.427	0.427	0.27	
Tillage	1	2.535	2.535	1.58	0.428
Residual	1	1.602	1.602	0.44	
Cropping	1	6.202	6.202	1.71	0.321
Tillage.Cropping	1	7.26	7.26	2	0.293
Residual	2	7.268	3.634	0.69	
Variety	2	9.116	4.558	0.86	0.459
Tillage.Variety	2	7.832	3.916	0.74	0.507
Cropping.Variety	2	8.981	4.49	0.85	0.464
Tillage.Cropping.Variety	2	7.668	3.834	0.72	0.514
Residual	8	42.383	5.298		
Total	23	101.273			

Appendix 43: Number of plants of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	28.17	28.17	0.02	
Tillage	1	9.37	9.37	0.01	0.946
Residual	1	1305.38	1305.38	53.78	
Cropping	1	10.67	10.67	0.44	0.576
Tillage.Cropping	1	1.04	1.04	0.04	0.855
Residual	2	48.54	24.27	0.26	
Variety	2	660.9	330.45	3.48	0.082
Tillage.Variety	2	25.19	12.59	0.13	0.878
Cropping.Variety	2	85.15	42.57	0.45	0.653
Tillage.Cropping.Variety	2	0.77	0.39	0	0.996
Residual	8	758.67	94.83		
Total	23	2933.83			

Appendix 44: Cob length (cm) of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	8092.72	8092.72	109.53	
Tillage	1	145.48	145.48	1.97	0.394
Residual	1	73.89	73.89	7.41	
Cropping	1	6.52	6.52	0.65	0.504
Tillage.Cropping	1	1.46	1.46	0.15	0.739
Residual	2	19.94	9.97	0.72	
Variety	2	4.58	2.29	0.17	0.85
Tillage.Variety	2	52.65	26.32	1.9	0.211
Cropping.Variety	2	0.15	0.07	0.01	0.995
Tillage.Cropping.Variety	2	5.67	2.83	0.2	0.819
Residual	8	110.66	13.83		
Total	23	8513.71			

Appendix 45: Number of rows per cob of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	6.5104	6.5104	1.73	
Tillage	1	0.1838	0.1838	0.05	0.862
Residual	1	3.7604	3.7604	77.14	
Cropping	1	0.0104	0.0104	0.21	0.689
Tillage.Cropping	1	0.0337	0.0337	0.69	0.493
Residual	2	0.0975	0.0487	0.09	
Variety	2	6.7508	3.3754	6.14	0.024
Tillage.Variety	2	0.3225	0.1613	0.29	0.753
Cropping.Variety	2	0.2258	0.1129	0.21	0.818
Tillage.Cropping.Variety	2	0.0175	0.0088	0.02	0.984
Residual	8	4.3967	0.5496		
Total	23	22.3096			

Appendix 46: Number of kennel and Yield (kg ha -1) of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	2314.77	2314.77	60.51	
Tillage	1	396.09	396.09	10.35	0.192
Residual	1	38.25	38.25	192.47	
Cropping	1	19.62	19.62	98.72	0.01
Tillage.Cropping	1	0.05	0.05	0.25	0.665
Residual	2	0.4	0.2	0.01	
Variety	2	11.32	5.66	0.24	0.795
Tillage.Variety	2	193.87	96.93	4.05	0.061
Cropping.Variety	2	4.13	2.07	0.09	0.918
Tillage.Cropping.Variety	2	7.16	3.58	0.15	0.864
Residual	8	191.56	23.95		
Total	23	3177.22			

Appendix 47: Yield (kg ha $^{-1}$) of three varieties of maize, planted on farm (Kibos) 2016 A with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3303310	3303310	4.69	
Tillage	1	1446633	1446633	2.05	0.388
Residual	1	704968	704968	2.53	
Cropping	1	12362	12362	0.04	0.853
Tillage.Cropping	1	41792	41792	0.15	0.736
Residual	2	557109	278554	0.86	
Variety	2	4237882	2118941	6.51	0.021
Tillage.Variety	2	2890921	1445460	4.44	0.05
Cropping.Variety	2	115747	57873	0.18	0.84
Tillage.Cropping.Variety	2	32067	16033	0.05	0.952
Residual	8	2602594	325324		
Total	23	15945384			

Appendix 48: Plant height (cm) of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	133	133	0.08	
Tillage	1	5969.3	5969.3	3.43	0.315
Residual	1	1742.5	1742.5	8.87	
Cropping	1	0	0	0	0.995
Tillage.Cropping	1	55.5	55.5	0.28	0.648
Residual	2	392.9	196.4	1.77	
Variety	2	567	283.5	2.56	0.138
Tillage.Variety	2	560.3	280.2	2.53	0.141
Cropping.Variety	2	670.6	335.3	3.03	0.105
Tillage.Cropping.Variety	2	115.6	57.8	0.52	0.612
Residual	8	885.5	110.7		
Total	23	11092.2			

Appendix 49: Number of leaves of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	6.7204	6.7204	133.3	
Tillage	1	2.1004	2.1004	41.66	0.098
Residual	1	0.0504	0.0504	1.86	
Cropping	1	0.0204	0.0204	0.75	0.477
Tillage.Cropping	1	0.1204	0.1204	4.45	0.169
Residual	2	0.0542	0.0271	0.14	
Variety	2	0.2275	0.1138	0.59	0.578
Tillage.Variety	2	0.0758	0.0379	0.2	0.826
Cropping.Variety	2	0.2408	0.1204	0.62	0.561
Tillage.Cropping.Variety	2	0.0858	0.0429	0.22	0.806
Residual	8	1.55	0.1938		
Total	23	11.2462			

Appendix 50: Number of plants of three varieties of maize, planted on farm (Kibos) 2016B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	51.04	51.04	0.27	
Tillage	1	57.04	57.04	0.3	0.679
Residual	1	187.04	187.04	1.2	
Cropping	1	204.17	204.17	1.31	0.372
Tillage.Cropping	1	42.67	42.67	0.27	0.654
Residual	2	312.83	156.42	3.24	
Variety	2	345.06	172.53	3.58	0.078
Tillage.Variety	2	194.02	97.01	2.01	0.196
Cropping.Variety	2	72.27	36.14	0.75	0.503
Tillage.Cropping.Variety	2	72.4	36.2	0.75	0.503
Residual	8	386.08	48.26		
Total	23	1924.62			

Appendix 51: Cob length (cm) of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	32.3176	32.3176	4.76	
Tillage	1	43.1212	43.1212	6.35	0.241
Residual	1	6.7947	6.7947	9.92	
Cropping	1	0.0176	0.0176	0.03	0.887
Tillage.Cropping	1	0.8177	0.8177	1.19	0.389
Residual	2	1.3693	0.6847	1.12	
Variety	2	3.0944	1.5472	2.52	0.141
Tillage.Variety	2	0.6609	0.3304	0.54	0.603
Cropping.Variety	2	0.2527	0.1264	0.21	0.818
Tillage.Cropping.Variety	2	1.5439	0.7719	1.26	0.335
Residual	8	4.9051	0.6131		
Total	23	94.8951			

Appendix 52: Number of rows per cob of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	0.1204	0.1204	0.08	
Tillage	1	0.0938	0.0938	0.06	0.842
Residual	1	1.4504	1.4504	1.8	
Cropping	1	0.0104	0.0104	0.01	0.92
Tillage.Cropping	1	0.0704	0.0704	0.09	0.795
Residual	2	1.6108	0.8054	1.7	
Variety	2	3.1633	1.5817	3.34	0.088
Tillage.Variety	2	0.19	0.095	0.2	0.822
Cropping.Variety	2	3.0833	1.5417	3.25	0.093
Tillage.Cropping.Variety	2	0.2633	0.1317	0.28	0.765
Residual	8	3.7933	0.4742		
Total	23	13.8496			

Appendix 53: Number of kennels of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3.375	3.375	0.06	
Tillage	1	103.335	103.335	1.94	0.397
Residual	1	53.402	53.402	33.59	
Cropping	1	4.507	4.507	2.83	0.234
Tillage.Cropping	1	2.16	2.16	1.36	0.364
Residual	2	3.18	1.59	1.32	
Variety	2	46.903	23.452	19.44	<.001
Tillage.Variety	2	21.81	10.905	9.04	0.009
Cropping.Variety	2	0.763	0.382	0.32	0.738
Tillage.Cropping.Variety	2	4.41	2.205	1.83	0.222
Residual	8	9.653	1.207		
Total	23	253.498			

Appendix 54: Yield (kg ha -1) of three varieties of maize, planted on farm (Kibos) 2016 B with: tilled and no-till; intercropped and sole cropping.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	490690	490690	1.94	
Tillage	1	2126828	2126828	8.41	0.211
Residual	1	252786	252786	4.65	
Cropping	1	58519	58519	1.08	0.409
Tillage.Cropping	1	29547	29547	0.54	0.538
Residual	2	108760	54380	0.41	
Variety	2	532926	266463	2.03	0.194
Tillage.Variety	2	268649	134325	1.02	0.402
Cropping.Variety	2	218239	109119	0.83	0.47
Tillage.Cropping.Variety	2	98965	49483	0.38	0.698
Residual	8	1051202	131400		
Total	23	5237111			

Appendix 55: Plant height of cowpea on station - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	7111.55	7111.55	227.18	
Tillage	1	139.12	139.12	4.44	0.282
Residual	1	31.3	31.3	0.54	
Variety	3	94.37	31.46	0.55	0.668
Tillage.Variety	3	670.09	223.36	3.89	0.074
Residual	6	344.77	57.46		
Total	15	8391.22			

Appendix 56: Number of leaves of cowpea on station - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	11011.9	11011.9	299.61	
Tillage	1	1777.7	1777.7	48.37	0.091
Residual	1	36.8	36.8	0.08	
Variety	3	4925.9	1642	3.56	0.087
Tillage.Variety	3	113.7	37.9	0.08	0.967
Residual	6	2767.9	461.3		
Total	15	20633.8			

Appendix 57: Number of plants of cowpea on station - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	22.1	22.1	0.01	
Tillage	1	1801.8	1801.8	0.95	0.507
Residual	1	1887.7	1887.7	15.32	
Variety	3	638.7	212.9	1.73	0.26
Tillage.Variety	3	240.7	80.2	0.65	0.611
Residual	6	739.3	123.2		
Total	15	5330.3			

Appendix 58: Yield of cowpea on station - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	224	224	0.02	
Tillage	1	28502	28502	3.17	0.326
Residual	1	8992	8992	0.61	
Variety	3	47238	15746	1.07	0.428
Tillage. Variety	3	55644	18548	1.27	0.367
Residual	6	87950	14658		
Total	15	228550			

Appendix 59: Plant height of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	6802	6802	40.13	
Tillage	1	737.9	737.9	4.35	0.285
Residual	1	169.5	169.5	1.4	
Variety	2	1284.4	642.2	5.3	0.075
Tillage.Variety	2	432	216	1.78	0.28
Residual	4	485.1	121.3		
Total	11	9910.9			

Appendix 60: Number of leaves of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	3211.14	3211.14	115.06	
Tillage	1	76.51	76.51	2.74	0.346
Residual	1	27.91	27.91	0.32	
Variety	2	324.29	162.15	1.86	0.268
Tillage.Variety	2	389.5	194.75	2.24	0.223
Residual	4	348.09	87.02		
Total	11	4377.43			

Appendix 61: Number of plants of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	196.02	196.02	0.74	
Tillage	1	82.69	82.69	0.31	0.676
Residual	1	266.02	266.02	3.9	
Variety	2	150.04	75.02	1.1	0.417
Tillage.Variety	2	18.88	9.44	0.14	0.875
Residual	4	273.08	68.27		
Total	11	986.73			

Appendix 62: Yield of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 A

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	426010	426010	49.61	
Tillage	1	16	16	0	0.972
Residual	1	8587	8587	0.96	
Variety	2	24153	12077	1.35	0.357
Tillage.Variety	2	102	51	0.01	0.994
Residual	4	35811	8953		
Total	11	494679			

Appendix 63: Plant height of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 AND HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	9000.9	9000.9	27.34	
Tillage	1	15.1	15.1	0.05	0.866
Residual	1	329.2	329.2	2.93	
Variety	2	121.3	60.7	0.54	0.62
Tillage.Variety	2	1442.8	721.4	6.43	0.056
Residual	4	448.8	112.2		
Total	11	11358.1			

Appendix 64: Number of leaves of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 and HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	6603.5	6603.5	4713.99	
Tillage	1	271.7	271.7	193.96	0.046
Residual	1	1.4	1.4	0	
Variety	2	924.9	462.4	1.19	0.394
Tillage.Variety	2	385.5	192.7	0.49	0.643
Residual	4	1560	390		
Total	11	9746.9			

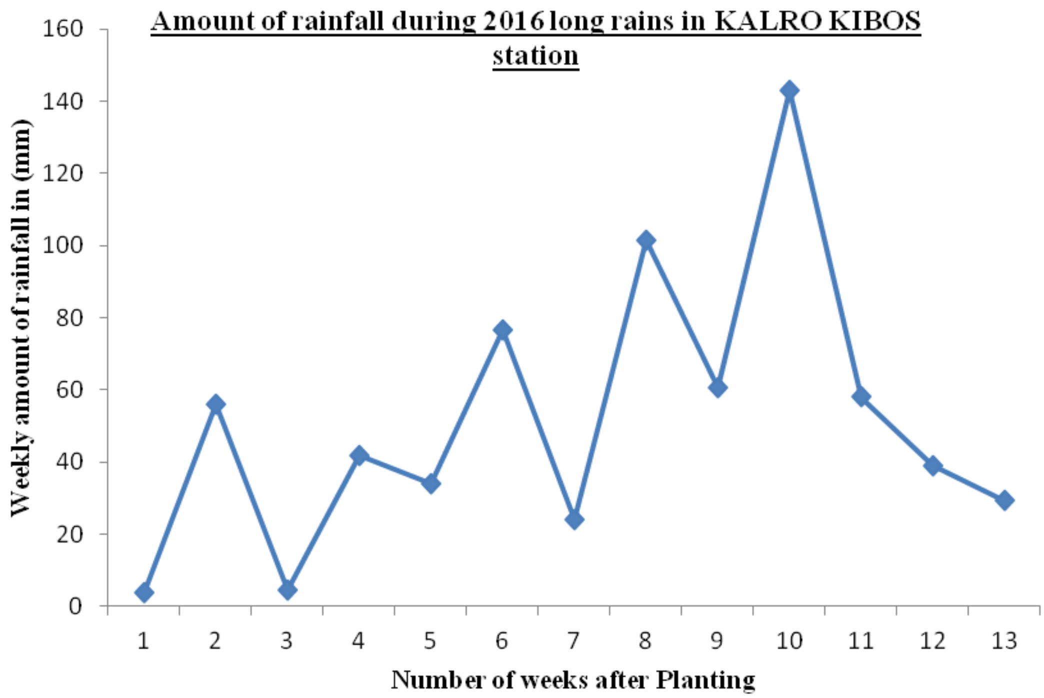
Appendix 65: Number of plants of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 and HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	18408.33	18408.33	31.31	
Tillage	1	588	588	1	0.5
Residual	1	588	588	8.37	
Variety	2	65.04	32.52	0.46	0.659
Tillage.Variety	2	956.38	478.19	6.81	0.052
Residual	4	280.92	70.23		
Total	11	20886.67			

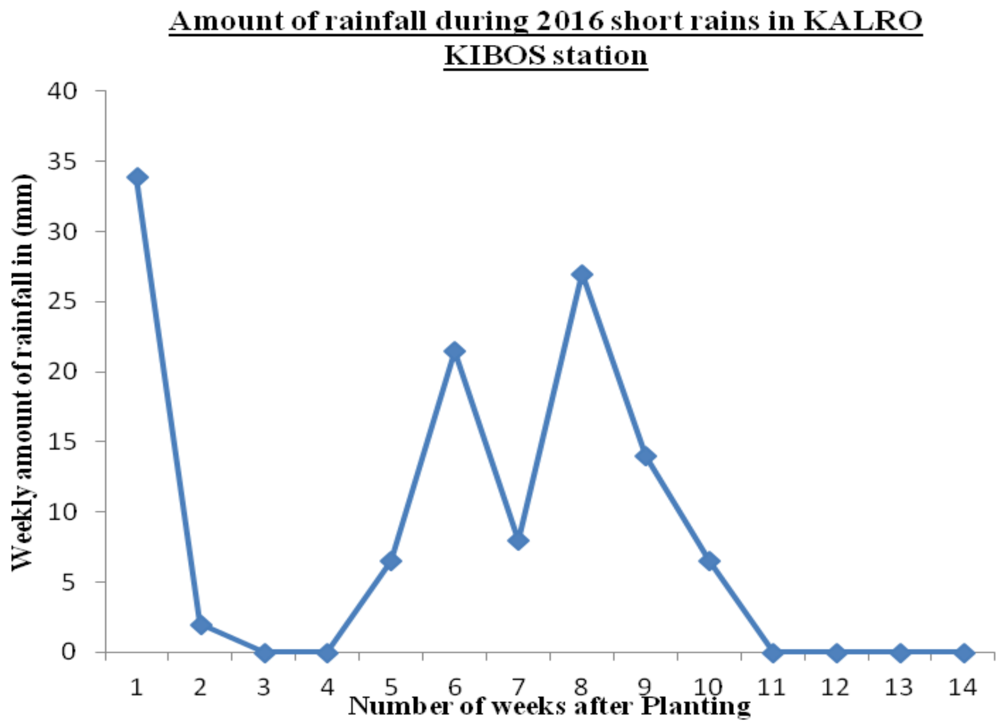
Appendix 66: Yield of cowpea on farm - Kibos intercropped with maize under no-till and tilled; sole crop and intercrop systems of varieties H12, H528 and HB505 during 2016 B

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	1	85227.3	85227.3	8.77	
Tillage	1	53.3	53.3	0.01	0.953
Residual	1	9718.5	9718.5	12.44	
Variety	2	8320.4	4160.2	5.33	0.075
Tillage.Variety	2	871.1	435.6	0.56	0.612
Residual	4	3124.6	781.2		
Total	11	107315.4			

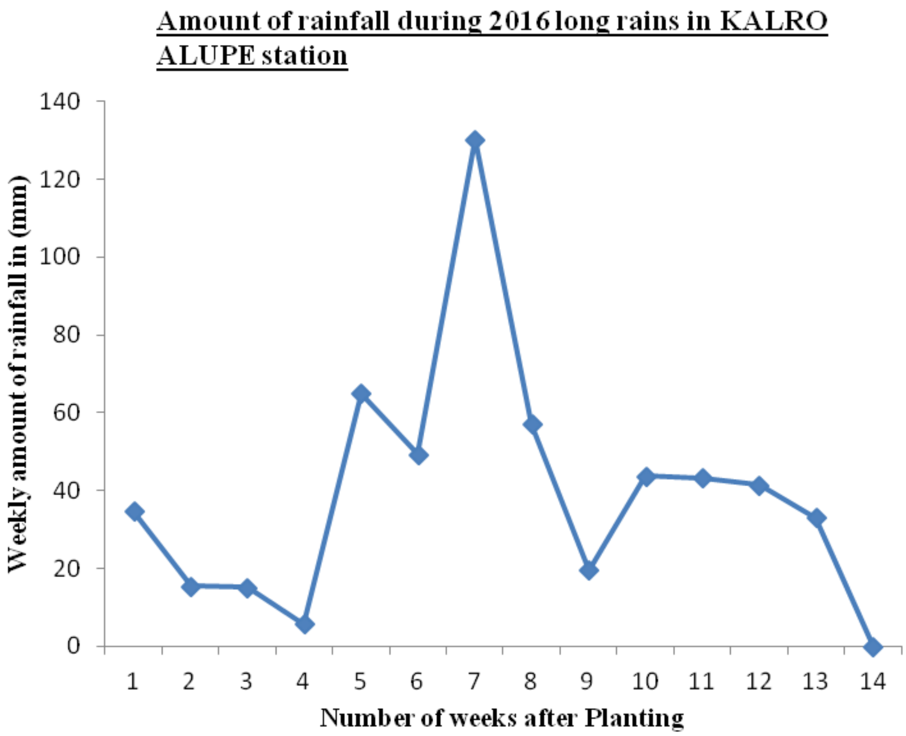
Appendix 67: Weather Data A



Appendix 68: Weather Data B



Appendix 69: Weather Data C



Appendix 70: Weather Data D