

**EFFECTS OF CONSERVATION TILLAGE ON SOIL MOISTURE,
CHEMICAL PROPERTIES, MAIZE AND BEAN PHYSIOLOGICAL
PARAMETERS AND YIELDS IN EMBU COUNTY KENYA**

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UNIVERSITY.**

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DECLARATION

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

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DEDICATION

This thesis is dedicated to my mother Lucy Kanini and my wife Grace Mwangangi for their inspiration and support during the entire period of study.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
C	Carbon
CA	Conservation Agriculture
CAN	Calcium ammonium nitrate
CO ₂	Carbon dioxide
CT	Conservation tillage
CV	Coefficient of variation
CVT	Conventional tillage
DAE	Days after emergence
DAF	Days to 50 % flowering
DAP	Diammonium phosphate
DI	Deionized water
DPM	Days to 50 % physiological maturity
F/R	Furrows/Ridges
FAO	Food and Agricultural Organization
HI	Harvest index
KALRO	Kenya Agricultural and Livestock Research Organization
LA	Leaf area
LAI	Leaf area index
LR	Long rains
LSD	Least significant difference
MB	Maize and bean intercrop

N	Nitrogen
PAR	Photosynthetic active radiation
RCBD	Randomized complete block design
RCTs	Resource conserving technologies
RUE	Radiation use efficiency
SAS	Statistical analysis system
SB	Sole bean
SDW	Shoot dry weight
SEKU	South Eastern Kenya University
SFW	Shoot fresh weight
SM	Sole maize
SOC	Soil organic carbon
SOM	Soil organic matter
SPAD	Special products analysis division
SR	Short rains
SSA	Sub-Saharan Africa
SWC	Soil water content
UM	Upper midlands
WUE	Water use efficiency
ZT	Zero tillage

ABSTRACT

Production of *Zea mays* L. and *Phaseolus vulgaris* L. has been lagging at 1.8 and 0.5 t/ha respectively. Yield potentials are 6.0 and 2.5 t/ha for maize and bean respectively. This is attributed to frequent dry spells and low soil fertility. Sustainable agricultural approaches such as conservation tillage (CT) have been embraced by farmers and have contributed to improvement in chemical and physical properties of soil and crop yields. However, the physiological basis of the observed yield increase due to CT practices has not yet been reported hence the study. Objectives of the study were: to assess CT practices effects on soil moisture, soil chemical properties, maize and bean physiological parameters and yields. The study was carried out in two seasons at the Kenya Agricultural and Livestock Research Organization farm in Embu County. Experimental design was a split-plot arranged in a randomized complete block design with nine treatments replicated three times. Conservation tillage practices comprised Zero tillage (ZT) and Furrows/ridges (F/R) evaluated against conventional tillage (CVT). The test crops were maize and beans grown as intercrops or monocrops. Key data sets were: soil moisture, soil chemical properties, maize and bean physiological parameters and yields. Soil moisture was measured in each plot twice per month by the use of a PR2 moisture probe. Laboratory analysis of soil samples for organic carbon followed the Walkley and Black method, whilst Nitrogen analysis followed the Kjeldahl method. Analysis of Variance (ANOVA) was used to analyze all data sets with the Statistical Analysis System computer software (SAS). Treatment means differences were compared using Fisher's least significant difference test. The CT (ZT and F/R) practices led to increase in soil moisture content, soil organic carbon, and soil nitrogen and soil pH that was significant ($p \leq 0.05$). Significantly ($p \leq 0.05$) higher nodules, chlorophyll concentration, sugars and starch were obtained for the beans under CT plots compared to those under CVT. The beans grown under F/R plots had grain yields of 1.3 t/ha in SR 2015 and 1.4 t/ha in LR 2016 in comparison to those grown under CVT plots which had grain yields of 1.2 t/ha in SR 2015 and 1.3 t/ha in LR 2016. Maize under CT plots had significantly ($p \leq 0.05$) higher leaf area index, chlorophyll concentration, sugars and starch compared to those grown under CVT plots. Maize grain yield under ZT plots was 1.8 t/ha in SR 2015 and 2.2 t/ha in LR 2016 and that under F/R plots was 1.7 t/ha in SR 2015 and 2.1 t/ha in LR 2016. Maize grain yield under CVT plots was 1.8 t/ha in SR 2015 and 2.3 t/ha in LR 2016. It can be concluded that CT is a suitable technique for conserving soil water for plant use, improving soil health and crop physiological parameters hence the increased crop productivity. This study recommends the adoption of CT practices to enhance production of crops and ensure security of food for the studied area and other regions with comparable agro ecological conditions.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

In Sub-Saharan Africa, 65 % of the land meant for Agriculture is degraded leading to reduced crop productivity (Rockstrom *et al.*, 2009; World Bank, 2018). The degradation of land is majorly caused by intensive soil tilling coupled with the exclusion of remains from crops (Rockstrom *et al.*, 2009; Kiboi *et al.*, 2017). This exposes the soil to climatic hazards such as sun, rain and wind (Knowler and Bradshaw, 2007). Tillage manipulates the nutrient storage in soil leading to the loss of soil organic matter (SOM) (Chivenge *et al.*, 2007).

Conventional tillage (CVT) can cause the rapid release of minerals in the SOM and cause the loss of nitrogen (N) and carbon (C) from the upper layer to the lower layer of the soil away from the rooting zone of plants (Chivenge *et al.*, 2007). Numerous researches have shown that cultivation methods can change soil properties, especially soil structure (Saggar *et al.*, 2001; Roger-Estrade *et al.*, 2004), porosity and bulk density (Unger and Jones, 1998; Lampurlanés, 2003; Glsb; Kulig, 2008), water conservation and recycling (Hemmat *et al.*, 2007), growth and root yield (Shirani *et al.*, 2002; Su *et al.*, 2007).

In addition to causing soil degradation, conventional farmer agriculture can also lead to increased soil erosion (Unger and Fulton, 1990). Excessive

agriculture will lead to deterioration of the soil environment and increase production costs. Climate-smart agricultural systems such as conservation tillage (CT) have been recognized (Thierfelder *et al.*, 2017). CT benefits include better water infiltration, reduced soil water evaporation and soil erosion (Thierfelder *et al.*, 2017).

Conservation tillage (CT) has been found to be a viable method to enhance soil fertility (Peterson *et al.*, 1998). According to Twomlow and Bruneau (2008), smallholder farmers in sub-Saharan Africa are advised to implement conservation tillage (CT) to increase land productivity. By fighting the depletion of soil nutrients, this method is very important for reducing farmers' vulnerability to drought. Frequent droughts in sub-Saharan Africa have caused up to 50% of corn crop losses (Fisher *et al.*, 2015). It has been reported that the yield of small farms using CT has increased (Haggblade and Tembo, 2003; Mazvimavi *et al.*, 2009). Regardless of how much yields are produced by conservation tillage practices, smallholder farmers in sub-Saharan Africa still use traditional farming methods which account to 0.4% (Twomlow & Bruneau, 2008).

The need for food will lead to intensive agricultural practices, thereby reducing land resources, leading to a decrease in the storage and structure of soil organic matter, soil fertility, topsoil, and soil water (FAO, 2004; Wang,

2006; Banadda, 2010). In order to overcome agronomic problems, the practice of CT should be encouraged.

1.2 Statement of the problem and justification of the study

The yields of *Zea mays* L. and *Phaseolus vulgaris* L. were 1.8 and 0.5 tons/ha, respectively, compared with the expected best national yields of 6.0 and 2.5 tons/ha in this sequence (Jagtap & Abamu, 2003; Monyo *et al.*, 2013 Year; Otieno *et al.*, 2019). This is due to repeated droughts and reduced soil fertility resulting in small land areas (Ngetich *et al.*, 2012; Recha *et al.*, 2012; Otieno *et al.*, 2018). Therefore, farmers in this area need agronomic practices that can retain moisture and nutrients in the soil (Giller *et al.*, 2011; Otieno *et al.*, 2020).

According to reports, soil and crop yields in other parts of the world have improved due to conservation tillage practices (FAO, 2007; Wall *et al.*, 2013; Jug *et al.*, 2018). However; due to the practice of Conservation Tillage (CT), the physiological basis for the increase in experimental crop yield has not been reported in Embu County.

1.3 Research questions

- i) How do conservation tillage practices affect soil moisture?
- ii) What is the influence of conservation tillage practices on soil chemical properties especially nitrogen, carbon and pH?
- iii) What is the effect of conservation tillage practices on maize and bean physiological parameters, yield components and yields?

1.4 Hypotheses

- i) Conservation tillage practices do not have a significant effect on soil moisture in comparison with conventional tillage practices.
- ii) Conservation tillage practices do not have a significant effect on soil chemical properties in comparison with conventional tillage practices.
- iii) Conservation tillage practices do not have a significant effect on maize and bean physiological parameters, yield components and yields in comparison with conventional tillage practices.

1.5 Objectives

1.5.1 General objective

To assess how the various selected tillage practices affect the soil health and performance of maize and beans towards food sustainability in Embu County.

1.5.2 Specific objectives

- i) To assess the effects of conservation tillage practices on soil moisture in Embu County.

- ii) To determine the effects of conservation tillage practices on soil chemical properties; nitrogen, carbon and pH in Embu County.
- iii) To establish the effect of conservation tillage practices on maize and bean physiological parameters, yield components and yields in Embu County.

1.6 Significance of the study

The research has generated information on challenges and opportunities in adopting conservation tillage principles and practices. To the Kenyan government, this study sets a basis upon which policy formulation in regard to the improvement of agricultural practices would be based. Such policies may be targeted towards improving crop productivity especially in areas of low yields due to soil nutrient depletion and unreliable rainfall. The study will further benefit stakeholders in the management and improvement of maize and bean production in Embu County and neighboring areas with similar socio-economic and climatic conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of conservation tillage

Kassam *et al.* (2009) reported that soil conservation through crop residue retention and zero tillage have succeeded worldwide. Conservation tillage is a concept of conservation agriculture which aims at achieving high production of crops while ensuring that the environment is conserved (FAO, 2007). Conservation tillage ensures that tillage activities are minimally reduced thereby affecting biological processes (FAO, 2009).

Agricultural inputs like agrochemicals and fertilizers are applied in optimal quantities which cannot affect the biological process of the soil (FAO, 2009). Thierfelder and Wall (2010) reported greater moisture content in conservation tillage (CT) systems in comparison to conventional tillage (CVT) systems. According to Bailey *et al.* (2011), better structure of the soil is achieved after practicing CT practices such as zero tillage. The zero tillage soils have a lot of SOC compared to CVT practices particularly so at the top soil layers (Mc Carty and Meisinger, 1997; Madari *et al.*, 2015).

Soil organic matter (SOM) has a vital part in promoting productivity and improving soil structure and water retention capacity (Liu *et al.*, 2018). This makes plants to use water and nutrients effectively and uphold quality of water

through its purifying effects (Africa Conservation Tillage Network, 2008). Conservation tillage improves soil physical properties (Limon-Ortega *et al.*, 2006; Barut and Celik, 2017; Otieno *et al.*, 2017) such as hydraulic conductivity, infiltration rate and availability of water content. Burt *et al.* (2001) reported that soils low in organic matter and nutrients display greater vulnerability to degradation on being cultivated particularly in the event of poor soil management. According to Steward *et al.* (2018), CT systems are more adapted to degradation in contrast to conventionally tillage systems.

2.2 Zero tillage

Zero tillage (ZT) is a type of conservation tillage system where seeds are planted into the soil without any soil inversion to avoid the disturbance of soil. Zero tillage leads to rise in soil organic matter (SOM), prevents erosion and also restores soil fertility (Giller *et al.*, 2009). It increases soil moisture by improving water infiltration (Lopez-Bellido *et al.*, 2001). Farmers reduce labour costs, save time and cultivate more area of land with Zero tillage (Giller *et al.*, 2009).

Zero tillage results in harvest enhancements (Rockström *et al.*, 2009; Smith *et al.*, 2011). According to results from several sets of experiments by Rockström *et al.* (2009), semi-arid locations in East and Southern Africa reported increased crop yields and productivity of water when zero tillage was practised. They attributed this to its water retention. Zero tillage systems effectively increase soil and water conservation and also reduce the labour

required and the time taken for field operations (Feller and Beare, 2007). Studies conducted by Mehdi *et al.* (1999), revealed that there was greater maize yield in zero tillage compared to tilled areas, because crops under ZT are more efficient at utilising soil nitrogen (N) than crops tilled under CVT.

According to Daniel *et al.* (1999), under ZT, the surface residue enhances 25 % - 50 % infiltration of water into the soil as compared to CVT system. Hobbs *et al.* (2008) also found out that water storage by soil is more in zero tillage compared to disk tillage or where stubble mulching was done. Greater potential for nitrogen (N) stabilisation and higher grain product under zero tillage in comparison to conventional tillage has also been reported (Kong *et al.*, 2009). While the effects of zero tillage have been reported from research done somewhere else (Saharawat *et al.*, 2012; Jat *et al.*, 2013; Abagandura *et al.*, 2017; Anjum *et al.*, 2019), the effect of zero tillage combined with residue retention on soil moisture, chemical properties and crop physiological parameters has not yet been reported in Embu County.

2.3 Mulching

Mulch is any material placed on the soil surface to decrease erosion, evaporation and to control weeds (Armand *et al.*, 2009). Smallholder farmers rarely return agricultural plant remains to the soil (Hobbs *et al.*, 2008). This is as a result of little crop production in many cropping systems and the need to use the residues as fodder and fuel wood (Erenstein, 2003). Shaver, (2010)

noted that the amount of water in the soil is the most influenced parameter when residues of crop are removed from the soil.

Soil moisture is lost immediately the crop residues are removed whereas soils with mulch have higher soil moisture compared to unmulched soils (Shaver, 2010). Retaining crop residues as mulch maintains soil fertility, reduces the soil bulk density and significantly increases soil porosity (Jensen *et al.*, 2003; Watts *et al.*, 2017) by building up of organic matter hence improving soil capacity to hold water. Mulches prevent exposure of soil to drying hence reducing the loss of water from soil via evaporation. Mulches reduce surface run off, soil compaction and increases water infiltration. Mulching increases and conserves moisture in the soil (Agele *et al.*, 2000; Nasir *et al.*, 2011). Mulch contributes to weed suppression by lowering light to weeds thereby increasing yields (Mintah, 1998; Norman *et al.*, 2011).

Researches carried out by Norman *et al.* (2011) and Iftikhar *et al.* (2011) conveyed improved yield and components of yield acquired through the utilization of the organic mulches. The increased branches per plant, leaves per plant and leaf area index (LAI) led to an increased photosynthetic process and therefore contributing to the observed increased yield components and yields. Studies done by Olaoye (2002) indicated that mulching before and during the growing season affects soil erodability, soil temperature and soil moisture.

Mulching has been found to effectively make use of rainfall hence decreasing the failure of crops at the field (Batiano *et al.*, 2007). Mahboubi *et al.* (2013)

reported higher available water capacity under mulching. Erenstein (2003) reported that the benefits of mulching accumulate over time and they include reduction in degradation of soil and improvement of physical, biological and chemical properties of soil.

Studies by Erenstein (2003) found out that mulching contributed a lot in decreasing runoff and evaporation from the soil. According to Olaoye (2002), run-off is also reduced by the soil surface being rough and plant residues prevent soil crusting hence increasing infiltration. Pan *et al.* (2006) reported that mulching reduces soil wearing away by decreasing the kinetic energy of rain drops and the flowing water hydrodynamic power.

The implementation of soil protection measures, such as farming measures that retain moisture in the soil for longer periods of time, and retention of crop residues, provide a viable solution to the deterioration of SOM quality in soils in eastern Kenya, especially in the arid area of agriculture in Embu County Environment (Micheni, 2015). Organic inputs such as crop residues and their effect on soil fertility has not been widely researched. There is therefore the need to integrate mulching in investigating the significance of CT practices on soil richness and crop physiological parameters and yields in the study area.

2.4 Soil organic matter

Soil organic matter (SOM) is the material produced by living organisms in the soil and which undergo decomposition process (Bot & Benites, 2005). The

SOM increases biological, chemical and physical soil properties. A very important component of justifiable management of agronomic lands is the improvement of soil organic matter (Batiano *et al.*, 2007).

As per the Holland (2004), SOM influences many properties of soil such as moisture retention, buffering capacity, soil stability, soil structure, biological activities, nutrient reserve and its availability and ultimately determine the risk of erosion. Crop residues in different points of decomposition and mineralization include SOM, which can increase productivity of agricultural systems and soil fertility (Netherlands, 2004; Powlsen *et al.*, 2011; Mupangwa *et al.*, 2013). Adherence to the TC principle can protect soil moisture, increase soil organic matter, recycle nutrients, and increase crop productivity (FAO, 2007; Bolinder *et al.*, 2020).

Research conducted by Kong *et al.* (2009) and Giller *et al.* (2009) demonstrated the potential of no-tillage coverage to improve SOM accumulation, reduce carbon dioxide emissions, and partially solve the increasingly serious environmental problems associated with modern agricultural practices. It has been reported that SOM in agricultural systems can reduce the sensitivity to compaction during agricultural operations (Franzluebbers, 2004).

Soils with little organic matter content are more vulnerable to degradation during cultivation, especially when the soil is improperly cultivated, such as

the CVT system (Wall *et al.*, 2013). According to Lal (2004), the increase of soil organic matter is the critical problem for improving soil structure and its water retention capacity. The best way to manage soil organic matter and promote soil microbial activities is to use organic nutrient resources (such as plant debris) and inorganic nutrient resources (Bailey *et al.*, 2011). Studies that focused on SOM and its effectiveness in crop yield however did not bring out the relationship between SOM and crop physiology but only focused on how SOM enhances crop yields thus the current study sought to fill this gap.

2.5 Soil organic carbon

De Morais (2011) reported that ploughing leads to reduction of soil organic carbon (SOC) because the soil particles are exposed to microbial activity. The exclusion of plant residues from the fields leads to decline in SOC (Mann *et al.*, 2002). Soil organic carbon (SOC) is a significant contributing factor to fertility of the soil, sustainability, and productivity (Thierfelder *et al.*, 2014). It is a significant indicator of the quality of soil in agronomic systems in the tropics where nutrients in highly weather-beaten and soil are managed with minimal exterior inputs. The increase in SOC has been recorded in areas where CT is practiced in comparison to CVT (Ligowe *et al.*, 2017).

With zero tillage, soil organic carbon which is critical to crop yield, increases as a result of continued decomposition of the crop residuals (Delate *et al.*, 2012). Notably, SOC being the basis of soil fertility contributes to the best part of crop production. Soil biota and organic materials are found to be the major

contributors to the SOC. According to Halde and Entz (2016), zero tillage gives the best contribution to SOC thus making it an important aspect of consideration as much as crop production is concerned. The reviews on SOC however have not shown the relationship between SOC and crop physiology but rather focused on SOC and crop yields increases. Therefore, the current study sought to fill this gap.

2.6 Furrows and ridges

Furrows and ridges can control erosion and improve surface drainage (FAO, 2008). Their significant role in water and soil conservation hence enhancing the production of produce in areas prone to drought has been reported (Jensen *et al.*, 2003; Araya and Stroosnijder, 2010). Ridging has been practiced in Eastern Africa for quite long (Gebreegziabher *et al.*, 2009). In Kenya, the usefulness of furrows and ridges in mitigating erosion and runoff has been demonstrated (Pereira *et al.*, 1967).

Furrows and ridges are soil and water conservation measure which can substantially improve crop productivity. Studies show that maize yield under furrows and ridges in years with low rainfall were enhanced by 42 % even short of any nutrient (Jensen *et al.*, 2003). Furrows and ridges have also been reported to improve holding and infiltration of water (Giller *et al.*, 2006). Furrows and ridges have the potential benefit of rain water harvesting and improved soil fertility on maize productivity (Biazin & Stroosnijder (2012). Qin *et al.* (2018) found out that furrows and ridge tillage practices had more

soil moisture during maize growth in comparison with CVT practices and this significantly improved crop quality especially the biomass and plant height, leading to higher water use efficiency and greater yields.

Studies conducted by Gebrekidan (2003) established that in seasons when the rainfall is very low, a lot of increase in crop yields is expected above the conventional practices where furrows and ridges are used for *in-situ* harvesting of water. Greater maize grain yields are obtained under furrows and ridges tillage than in CVT in semi-arid regions of Meru south, Mbeere South and in some parts of Ghana (Akinyemi *et al.*, 2003; Miriti, 2012; Blanchart *et al.* (2012) noted that grain yield of maize response to furrows and ridging was higher in comparison to the one grown under CVT.

Despite the adequate knowledge accumulated from literature on the potential of furrows and ridges in improving crop yields, little attention has been given to it in Embu County (Okeyo *et al.*, 2014). In addition to this, combination of furrows and ridges with organic inputs such as crop residue mulch and its effect on crop physiological parameters has not yet been reported.

2.7 Cereal-legume intercropping systems

In Agriculture, intercropping entails cultivating more than two crops simultaneously in the same place (Chakraborty *et al.*, 2008). In East Africa, smallholder farmers intercrop maize (*Zea mays* L.) and leguminous plants to

promote labor utilization and land to obtain higher harvests (Mucheru-Muna *et al.*, 2010).

Smallholder farmers mainly intercrop in order to maximize profits from the harvested crops, minimize risks against crop failure, to conserve soil, enhance soil fertility and for controlling weeds (Molla *et al.*, 2018; Huang *et al.*, 2019). Thobatsi (2009) reported intercropping has the ability to increase profits and lower the fixed costs of land preparation because of a second crop in the same plot. Intercropping is associated with benefits such as alleviation of erosion and runoff, enhancement of properties of soil, enhance biodiversity and x utilization of herbicides is reduced (Celette *et al.*, 2010). Intercropping makes more efficient use of nutrients, has greater yield, control weeds in a better way, provides insurance against total crop failure and it improves quality of crops (Huang *et al.*, 2008). Cereals as a sole crop needs an enormous area for production of the similar yield as cereal in the system of an intercropping (Huang *et al.*, 2008).

Radiation interception in intercropped bean and maize is higher than sole maize, and the intercropped bean with maize has 77 % higher radiation use efficiency than single cropped beans (Tsubo *et al.*, 2001). According to Mucheru-Muna *et al.* (2010), yields are increased when intercropping is done because of higher light penetration. Notably, studies have found the number of maize stalk borer reduce when intercropped with soybean and invasion by the stalk borer is 70 % higher in mono-cropped than in intercropped maize-

soybean (Martin, 1990; Kumar *et al.*, 2012). Intercropped configurations prevent raindrops from hitting the bare soil by covering the surface pores, reducing surface runoff hence controlling soil erosion (Seran and Brintha, 2010). In the intercrops of taller cereals with legumes, the taller crops protect the shorter crops against wind (Baxevanos *et al.*, 2017). Studies done by Zougmore *et al.* (2000) stated that there is 50 % reduction in soil loss by intercropping compared with sorghum and cowpea monocultures.

Under different environmental and soil conditions, nitrogen fixation in Cereal-Legume intercropping system helps in contributing nitrogen for legume growth and grain production (Fujita and Ofusu-Budu, 1996), and also, there is replenishment of soil with nitrogen by the decomposing legume residues (Baijukya *et al.*, 2006). There is a higher cash return to smallholder farmers in intercropping system than in the growing of monocrops (Seran and Brintha, 2010). According to Beare *et al.* (2014), intercropping increases output per unit area because it entails reduced external inputs and its mix of species make better utilization of available water and nutrients in the soil. Intercropping helps farmers to maximize efficient use of water, to uphold fertility of soil and to reduce erosion which is a severe shortcoming of monocropping (Hoshikawa, 1991).

Walker and Ogindo (2003) and Ghanbari *et al.* (2010) reported that intercropping improves soil water content (SWC) when there is shading by the canopy cover and surface of soil is protected from impact of raindrops. Studies

by Passioura and Angus (2010) indicated that loss of water through evaporation from between the row of crops in monoculture could result to lesser content of moisture. While the effect of intercropping on crop yield increase has been reported from other research done elsewhere, the outcome of intercropping from CT practices on crop physiological parameters has not been reported adequately in Embu County.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

The research was carried out at the Kenya Agricultural and Livestock Research Organization (KALRO) farm in Embu County, Eastern Kenya. It is at $00^{\circ}33.18'S$; $037^{\circ}53.27'E$; 1420 meters above the sea level. The location is in the upper midlands (UM), which is approximately 125 kilometers North-East of Nairobi (Figure 3.1).

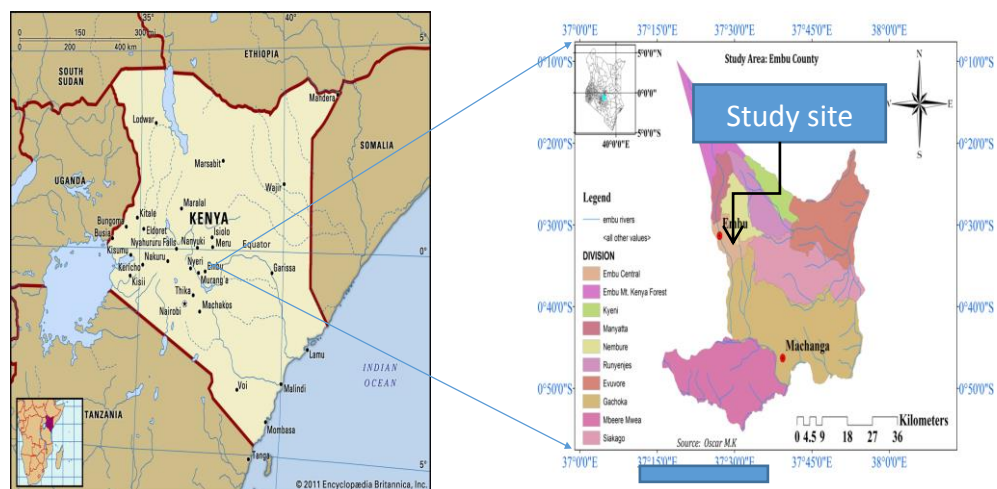


Figure 3.1: A map of Kenya showing Embu County. Source: <https://www.britannica.com/place/Kenya>.

Rainfall in the area is bi-modal and averages 1250 mm per annum. March to May forms the Long Rains (LR) and October to December the Short Rains (SR) (Nicholson, 2000). The cumulative rainfall during the short rains 2015

was 475.2 millimeters (mm) while the one received during the long rains 2016 was 562.8 mm (Figure 3.2).

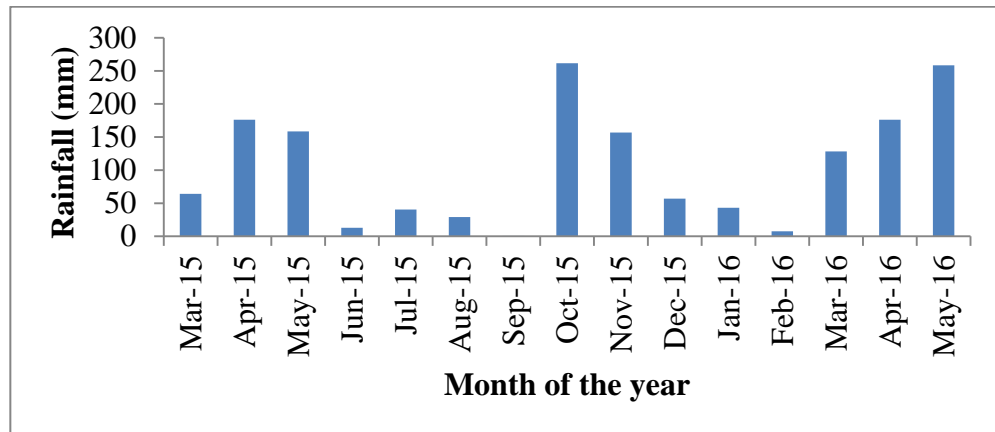


Figure 3.2: The mean rainfall per month in the study area for the period March 2015 to May 2016. Source: Embu County meteorological weather station for the period March 2015 to May 2016.

Temperatures in the study site range from 21 – 28 °C and 16 – 21 °C in terms of mean maximum and minimum in that order (Jaetzold *et al.*, 2006). Mean maximum and minimum temperatures during the short rains 2015 were 24.4 °C and 14.9 °C respectively, for the long rains 2016 they were 26.0 °C and 14.6 °C respectively (Figure 3.3).

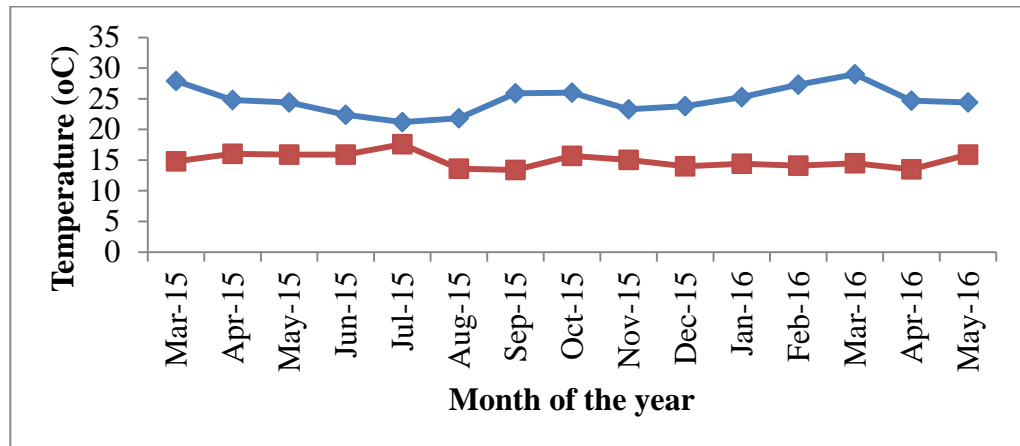


Figure 3.3: The mean monthly maximum and minimum temperatures for the study area for the period March 2015 to May 2016. Source: Embu County meteorological weather station for the period March 2015 to May 2016.

The average humidity during the short rains 2015 season was 56.7 %, during the long rains 2016 season it was 63.7 % (Figure 3.4).

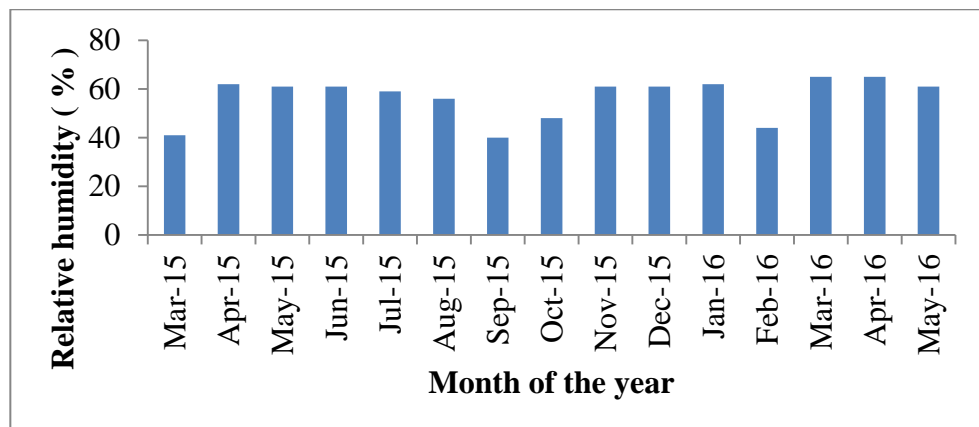


Figure 3.4: The mean monthly humidity for the study area for the period March 2015 to May 2016. Source: Embu County meteorological weather station for the period March 2015 to May 2016.

The average solar radiation during the short rains 2015 season was 19.28 MJM⁻², during the long rains 2016 season it was 21.24 MJM⁻² (Figure 3.5).

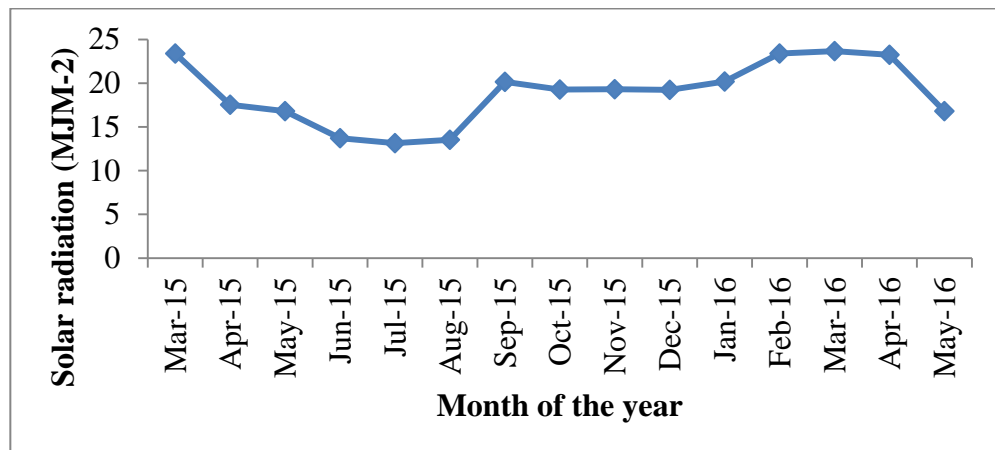


Figure 3.5: The mean monthly solar radiation for the study area for the period March 2015 to May 2016. Source: Embu County meteorological weather station for the period March 2015 to May 2016.

Humic Nitisols soils characterize the study area (WRB IUSS Working Group, 2006).

3.2 Treatments and design

The treatments involved three tillage methods namely: Furrows/Ridges (F/R), Conventional tillage (CVT) and Zero Tillage (ZT) and three cropping systems: sole maize (SM), sole bean (SB) and Maize-Bean intercrop (MB). These were compounded to give 9 treatment combinations (Table 3.1).

Table 3.1: Treatment combinations and codes

Serial no.	Tillage practice	Cropping system	Code
1	Conventional tillage	Sole maize	CVT_SM
2	Furrows / Ridges	Sole maize	F / R_SM
3	Zero tillage	Sole maize	ZT_SM
4	Conventional tillage	Sole bean	CVT_SB
5	Furrows / Ridges	Sole bean	F / R_SB
6	Zero tillage	Sole bean	ZT_SB
7	Conventional tillage	Maize - bean intercrop	CVT_MB
8	Furrows / Ridges	Maize - bean intercrop	F / R_MB
9	Zero tillage	Maize - bean intercrop	ZT_MB

Experimental design was a split-plot arranged in a randomized complete block design (RCBD) with three blocks. Tillage practices formed the main field whereas cropping systems formed the sub field (Appendix 1). Randomization of the treatments in the different plots was conducted utilizing random numbers produced from excel computer software. The treatments were reproduced multiple times giving an aggregate of 27 plots. The plot dimensions were 7.5 m x 10 m. Two meter wide paths were maintained between the blocks and also between the plots to separate them (Appendix 1). This was to prevent the effects of the various treatments from trickling between the blocks and the plots.

3.3 Land preparation and residue management

Conventional tillage involved tilling and harrowing using hoes. Furrows and ridges were made at 75 cm distant at the time of experimental establishing. They were then retained in the subsequent seasons with minimum repairs. Application of organic manure was done once at the start of the experimentation at the rate of five t/ha. For both zero tillage and furrows/ridges, 75 % of plant remains were retained on the plots. Crop residues from the maize were applied by spreading them on the soil surface between the rows at the rate of 2.5 t/ha per season (Plate 3.1).



Plate 3.1: Partially decomposed maize residue on the soil surface between the maize rows in a zero tillage plot with sole maize. Source: Author.

3.4 Crop establishment and management

The test culture was a type of maize, DK 8031 and varieties of beans in intentional-14. DK 8031 varieties have grain performance capacity 6.5 T / ha / season. Mature takes about 130 days. The Embus-14 takes 95 days to mature

with possible grain limit yields of 2.5 t / ha / season. The distance between the corn was 75 cm between rows, 50 cm in the row (Jaaetzold *et al.*, 2006). Three types of seeds were seeded and were sent on two floors after 7 days after the appearance (DAE). In this way, 53,333 plants / ha were obtained (JAAETZOLD *et al.*, 2006). Regardless of the cultivation method, 1 floor was maintained at 1 floor by group, and the only beans were distant in columns and 15 cm of 15 cm (Jaetzold *et al.*, 2006). The spacing of beans was 50 cm between rows in the row while maintaining two plants per group of 1 hills (Jaaetzold *et al.*, 2006). This gave 133,333 plants / ha, both for structured and interruption configurations (JAAETZOLD *et al.*, 2006).

3.5 Manure and fertilizer application

Diammonium phosphate (DAP) which is a source of phosphorus was applied to the maize seeds at sowing time at the rate of 20 kg / ha. Maize was top dressed with Calcium Ammonium Nitrate (C.A.N) at the rate of 60 kg / ha. For conventional tillage, fertilizers were placed on the planting hill. For Zero tillage, fertilizers were placed on top of the soil at points where planting was done. In the furrows and ridges, fertilizers were placed on the sides of the furrows for both sole maize and sole bean.

3.6 Weed and pest management

In both zero tillage and furrows/ridges plots, weeds were controlled by applying both the pre-emergence and post-emergence herbicides. Three days

after the start of the rains and maize planting, the glyphosate herbicide (rounded turbo) is actively grown in a proportion of 2.5 l / ha. After applying Round up, Dual Gold (Metolachlor) herbicide was applied at the rate of 2.5 l/ha on the wet soil before the emergence of both the crop and weeds to prevent the weeds from germinating. Basagran (Bentazon) was then applied at the rate of 1.5 l/ha on actively growing weeds as post-emergence herbicide to control weeds emerging later in the season. The application of three herbicides was performed using a knapsack hand sprayer. In conventional cultivation, the crop was plowed using a hand skin to achieve a slope of minutes without weeds. Next, two weed events were celebrated in each season. The first scored was held two weeks after the appearance of crops, and the second was carried out during half a month after the first weeding.

Chillo spp. (maize stalk borers) were controlled by applying Beta cyfluthrin, Bulldock (0.05 GR) thirty days after planting at the rate of 6.5 kg/ha. *Aphis spp.*(Aphids), *Liriomyza trifolii* (leaf miner) and *Thysanoptera spp.*(thrips)the main pests in bean were controlled casually by applying the organophosphate insecticide spray at a speed of 1.0 l / ha.

3.7 Data collection

3.7.1 Soil moisture

Soil moisture at different soil depths was measured non-destructively in each plot twice per month (during the first week and the last week of the month) throughout the growing season by the use of the soil moisture profile probe (PR2) at depths 10, 20, 30, 40, 60 and 100 centimeters (cm) below the soil

surface. For this to be realized, access channels were made by hand through drilling the soil with a soil auger and access tubes made of polyvinyl chloride (PVC) for soil humidity determination were fixed at the start of the research in the centre of each plot.

The PVC tubes were 130 cm long and their internal diameter was 5.3 cm with a waterproof lid at the bottom. The space between the access channels and the PVC tubes was cautiously fill up with soil for tight contact as a precautionary measure of air gaps. Twenty centimeters of the PVC tubes was left extended above the soil surface to avoid surface run off from entering the tubes. The PR2 moisture probe device was sunk into the tubes to determine soil moisture amount at consistent intervals of 10 cm to the depth of 100 cm. The moisture content data gotten was uploaded at the end of every season into a computer.

3.7.2 Soil chemical properties

Using the soil sampling W method (Santos et al., 2017), 10 soil samples were randomly selected from each plot to determine the chemical properties of the soil, up to a soil depth of approximately 15 cm. The initial sampling of the soil is carried out before the preparation of the experiment before the application of inputs. Sampling was also carried out after the harvest in the short rain period in 2015 and after the end of the experiment (long rain period in 2016). Use Edelman soil augers to take soil samples. They are mixed to make a composite sample. Then 200 grams were obtained and packed in small bags, then labeled

and sent to the KALRO laboratory for the determination of soil organic carbon, soil nitrogen and soil pH.

3.7.2.1 Soil organic carbon determination

Walkley and Black technique was utilized to evaluate the soil organic carbon (SOC) (Walkley & Black, 1934). Five grams of the soil was crushed to a refinement of less than 0.5 mm in mortar and a pestle and sifted through a 0.5 mm sieve. Samples of 0.5 g were then weighed and conveyed to a 500 ml conical flask, including a reference sample. Ten milliliters of potassium dichromate ($K_2Cr_2O_7$) were added by means of the burette and the flask was swirled gently for one minute to diffuse the soil in the solution. Fifteen milliliters of concentrated H_2SO_4 were quickly added in a fume cupboard and the stream was directed into the suspension. Moderate swirling was done to the flask at first until the soil and reagents mixed completely. Vigorous swirling then followed for one minute.

Thirty minutes were given for the mixture to stand, distilled water of 150 ml was added then this was allowed to settle for about 10 minutes. After that, 5 ml 85 % phosphatic acid was added and diphenylamine indicator solution of about 10 drops was added. This was done titration with 0.5 M ammonium ferrous sulphate. The end point volume was then recorded. Two blank determinations on potassium dichromate were also carried out. The percentage organic carbon

was then determined in reference to the equation below by Walkley and Black (1934);

$$\text{Percentage carbon} = \frac{(B - T) \times 0.3 \times V}{W \times B}$$

Where;

B Black titre

T Sample titre

W Weight of oven dry soil in grams.

V Volume of $K_2Cr_2O_7$

0.3 (1 ml of $K_2Cr_2O_7 = 0.003 \text{ g}$) x 100

3.7.2.2 Soil nitrogen determination

Kjeldahl method was used to determine nitrogen (Ryan *et al.*, 2001). This involved distillation and digestion. Reduction and subsequent distillation of nitrate N ($NO_3 - N$) fraction in the soil was done. A soil sample (15 mm) that was finely ground was evenly mixed and spread in a thin layer on a sheet of paper. Three grams of nitrogen was taken and this involved withdrawing 10 small lots from the sample. Weighing of the sample into 0.1 g was then done, the samples were then placed into a 250 ml digestion tube which is calibrated and then distilled water of 10 ml was added. This was exhaustively swirled so that the soil can be wet. This was then let to settle for a period of half an hour. Preparation of a blank digest was then done and a standard digest of 0.1 g EDTA was precisely weighed up to 0.1 g. ten of potassium permanganate solution of about 10 milliliters was added. This was swirled well, and left to

stand in about 30 seconds. The digestion tube was then held at an angle of 45°. Twenty ml of 50 % sulfuric acid were gradually and cautiously added so as to wash down the materials stick to the tube neck. It was left to stand for 15 minutes were given for the mixture to stand. It was then swirled. To the blank, EDTA, and sample digest tubes, a few purnice granules were added.

Add two points five grams of iron powder through a long rod funnel, and immediately place a 5 cm (internal diameter) glass funnel (without rod) on the neck of the tube. This then rotates. By pouring 5 milliliters of distilled water into a 5 cm glass funnel, excessive foaming was stopped at this stage. Let it stand overnight. The pre-digestion of samples is carried out by placing them in a cold block and heating them at 100°C for approximately 1 hour. After being removed from the block digester, 45 sample vortices were generated. Then they have time to calm down. Approximately 5 g of catalyst mixture and 25 ml of concentrated sulfuric acid were added to the long-handled funnel. Swirling then followed.

Pre-heating of the tubes to 100 °C then followed as the tubes were placed on a block-digester up to a temperature of 240 °C. Removal of the funnels then took place. Systematic arrangement of the funnels took place such that they can be returned into the digestion tube. After reaching 240 ° C at a temperature of 380 ° C, the water was boiled for 1 hour. The digestion continued for 4 hours at the same temperature. The tube was removed and 50 ml of deionized water (DI)

was added and the mixture was carried out by the use of a vortex mixture. After this is cooled, the addition of deionized water (DI) was performed at a 250 ml mark.

During distillation, the shock of the digestive tract was performed to mix the content. Then, the 50 ml of solution were then piped in a 250 ml distillation flask and distilled with the excess NaOH. 1 ml of saturated boric acid solution and 1 ml of distilled water are divided into 100 ml of Evaporation of Pyrex. Next, 10 N NaOH, including digesters, is carefully distributed to the distillation flask at an angle of 50 °. The flask is quickly attached connected to the distillation device and takes approximately 3 minutes by distillation. Then drain the distilled freely on the pan.

Deionized water (DI) was used to wash the tip of the condenser at about 4 minutes when 35 ml of the distillate had collected. Adjustment of the pH of the distillate was done to 5.0 using 0.01 N sulphuric acid (H_2SO_4) in the Auto-Titrator. When titrating was finished, washing of the Teflon covered magnetic bar, the burette tip and the combined electrode was done where disconnection was made to the distillation flasks that contained the digest sample and sodium hydroxide (NaOH), the empty distillation flask of 100 ml joined to distillation unit, and the empty beaker of 100 ml placed underneath the condenser tip. The water supply that was used for cooling was turned off and steaming out for 90 seconds was also done. Two standards and two blanks characterized each

distillation. Percentage N was then calculated using the equations below according to Ryan *et al.* (2001);

Percentage recovery of EDTA standard and Nitrogen (%) in soil;

$$\text{Percentage recovery} = \frac{(V - B) \times N \times R \times 186.1 \times 100}{Wt1 \times 1000}$$

$$\text{Percentage nitrogen} = \frac{(V - B) \times N \times R \times 14.01 \times 100}{Wt2 \times 1000}$$

Where;

- V Volume of 0.01 N H₂SO₄ titrated for the sample (ml)
- B Digested blank titration volume (ml)
- N Normality of H₂SO₄ solution
- 14.01 Atomic weight of N
- R Ratio between total volume of the digest and the digest volume used for distillation
- Wt1 Weight of EDTA (g)
- Wt2 Weight of air-dry soil (g)
- 186.1 Equivalent weight of the EDTA

3.7.2.3 Soil pH

This was done by the use of the HI 2550 bench top meter (HANNA® instruments, Mexico) in 1:2.5 soil: water suspensions according to the procedure by Thunjai *et al.* (2001).

3.7.3 Bean and maize physiological parameters, yield components and yields

3.7.3.1 Emergence stand count of beans

These data were sampled and collected in net plots (appendix 2) on the tenth day after crop emergence. The number of plants obtained in the net plot was then converted to number of plants per hectare. Emergence percentage was then determined by dividing the number of seedlings that emerged by the number of the seeds that were sown and then multiplied by 100 according to the formula outlined by Maguire (1962).

3.7.3.2 Days to 50 % flowering of beans

This parameter was determined by visual observations daily during the flowering time according to Zaidi *et al.* (2004). Recording was done when half of the beans in each plot had flowered.

3.7.3.3 Chlorophyll concentration of beans

The relative chlorophyll concentration was calculated three times per season (before flowering (30 days after emergence (DAE), at flowering and after flowering (60 DAE) using a special products analysis division (SPAD) chlorophyll meter. Ten measurements were taken on ten leaves for ten different bean plants in each plot and the average was then obtained. Data obtained were expressed in units of SPAD. The old, very young or damaged leaves in every plant were not considered for sampling.

3.7.3.4 Leaf sugar and starch content of beans

Both parameters were measured three times per crop growing season (three weeks after planting, at 50 % flowering and at physiological maturity) on bean leaves. The leaves were cut from the plants and mixed together to make a composite sample. A smaller sub-sample was put in paper bags separately per plot, labeled and then delivered to the KARLO, Embu laboratories for drying at room temperature for a period of one month. Once the materials were dry, they were packaged into smaller well labeled bags for sugar and starch analysis at the University of Nairobi, Upper Kabete campus laboratories.

For total sugar determination, weighing of 100 mg of defatted flour was made into a boiling tube then 30 ml of hot ethanol (80 %) was added into the boiling tube and shaken on a vortex mixer. Settling of the material was allowed for 30 minutes then filtration done into a beaker through a Whatman No. 41 filter paper. Repetition of the procedure was done for three times. A hot sand bath was used to evaporate the extract until the ethanol had vaporized. About 10 ml water was added; the contents were dissolved and transferred into a 100 ml volumetric flask.

The contents in the beaker were rinsed 3 times and added to the volumetric flask, then topped to 100 ml with water. 1ml aliquot from the above was taken with 1ml water as blank into a test tube. Phenol (1ml 5 %) was added and shaken. Sulphuric acid (5 ml 96 %) was added and shaken strongly on a vortex mixer and water was used to cool the tubes. Golden yellow color absorbance

obtained at 490 nm was read against a blank. The standards were run with different concentrations (i.e. 10, 20, 30, 40, and 50 grams of glucose standard) besides the working standard, keeping the volume to 1 ml with water. The total sugar was then calculated according to the equation by Hedge and Hofreiter (1962);

$$\text{Total soluble sugars (\%)} = \frac{A \times B \times C}{100000 \times D \times E} \times 100$$

Where;

- A concentration of the standard
- B absorbance of the standard
- C absorbance of 1ml sample extract
- D Volume made up (100 ml)
- E sample weight

For starch determination, a dry sample (1.0 g) containing 300 mg total available starch was weighed. This was transferred to a graduated 100 ml stoppered measuring cylinder. Water (10 ml) was then added and stirring was done with a glass rod to scatter the sample thoroughly. Thirteen milliliters of 52 % perchloric acid reagent was then added by measuring cylinder. This was stirred frequently with the glass rod for 20 minutes. The rod was then washed with distilled water and the contents of the flask were diluted to 100 ml. They were then mixed and filtered into a 250 ml graduated flask. This was diluted to 250 ml mark with distilled water and mixed thoroughly.

Ten milliliters of the sample extract was then diluted to 100 ml with water. One milliliter of diluted filtrate was pipetted into a test tube. Duplicate blanks were then pipetted using 1 ml of water. Duplicate standards were pipetted using 1 ml of dilute glucose. Five milliliters of freshly prepared anthrone reagent was pipetted rapidly to all the test tubes. Stoppering of all tubes was done and the contents thoroughly mixed. A boiling water bath was used to heat the tubes for exactly 12 minutes and then cooling of the tubes was done to room temperature. One cm long glass cuvettes were then used to hold the solutions. The samples absorbance and standards was then read and recorded at 630 nm of the reagent blanks. The total starch was then calculated according to the equation below by Hedge and Hofreiter (1962).

$$\text{Total available starch} = \frac{25 \times B}{A \times W}$$

Where:

Weight (g) of sample W

Absorbance of dilute standard A

Absorbance of dilute sample B

3.7.3.5 Days to 50 % physiological maturity of beans

This parameter was measured daily by visual observations on the bean plants after the 50 % flowering period. This was documented when half of the bean plants in each plot had turned brown, bean pods dried and when the seeds rattled when shaken.

3.7.3.6 Number of nodules per bean plant

This was ascertained at the 50 % flowering of the bean plants on wet soils. Four plants in the net plots were carefully uprooted (Plate 3.2) and the samples for each plot put separately into clean bags. They were then instantaneously delivered to the KALRO, Embu laboratory where they were washed carefully with tap water to eliminate the particulate matter. Only the pink root nodules were counted manually and recorded. The average nodules per root was calculated and then recorded.



Plate 3.2: The researcher sampling the bean plants for nodule determination in a zero tillage maize bean intercrop plot. Source: Author.

3.7.3.7 Number of branches per bean plant

This was determined at harvesting by physically counting the number of branches per plant. Five plants were selected at random in the net plots and their mean was calculated and recorded.

3.7.3.8 Number of pods per bean plant

This was ascertained at reaping time by physically counting the number of bean pods per plant in the net plot. The plants that were selected for the

number of branches per plant were also selected for the number of pods per plant.

3.7.3.9 Number of seeds per bean pod

This was determined at reaping by physically counting the number of bean seeds per pod per plant. The plants that were selected for the number of branches per plant were also selected for the number of pods per plant.

3.7.3.10 Shoot biomass of beans

This parameter was determined at harvesting in the net plots. Twenty randomly selected bean plants in each net plot were obtained, cut into small pieces with a machete and mixed thoroughly. The samples were weighed in the field to provide shoot fresh weight (FW) per plot, and then transported to the KARLO, Embu laboratories. The samples were then oven dried at 105 °c until a constant weight i.e. the shoot dry weight (DW) was obtained .The shoot biomass per hectare was then calculated by having the net plot shoot biomass weight (kg) multiplied by 10000, divided by the net plot area (Appendix 2) and then divided by 1000 according to the formulae outlined by Otieno *et al.* (2018).

3.7.3.11 Grain yield of beans

The remaining bean in the net plot are uprooted. The bean pods are manually separated from the residue, dried in the sun and packed in gunny bags, and then threshed from the residue. The beans are then dried to a moisture content of approximately 12.5%, and measured with a Soybean Moisture Meter

(Farmex Moisture Meter) before weighing the final weight. Then calculate the total bean yield per hectare by multiplying the net dry weight of beans (kg) by 10,000, dividing by the net area of the plot (Appendix 2), and then dividing by 1,000 according to the formula described Fageria *et al.* (2009).

3.7.3.12 Harvest index of beans

The harvest index was determined by dividing the grain yield (t /ha) by the total shoot biomass (t/ha) then multiplied by 100 to get the percentage as described by Wnuk *et al.* (2013).

3.7.3.13 Emergence stand count of maize

This set of data was sampled and collected in each plot by the use of a net plot (Appendix 2) on the 10th day after seedling emergence. The number of plants obtained in the net plot was then converted to number of plants per hectare. The maize emergence percentage was then calculated using the procedure outlined in section 3.7.3.1.

3.7.3.14 Days to 50 % tasseling of maize

This parameter was determined by visual observations each day during the flowering period as described by Zaidi *et al.* (2004). This was determined when half of the maize plants in each plot had undergone tasseling.

3.7.3.15 Number of leaves of maize per plant at anthesis

This parameter was determined by physical counting of all the green leaves from the ground level to the uppermost leaf in each plant. This was done on five randomly selected maize plants in the net plot and the average was then obtained.

3.7.3.16 Leaf area index of maize

This was determined before anthesis and after anthesis on five random chosen maize plants utilized to calculate the number of corn numbers on the number of plants. The measuring tape was used to measure the length of the leaf blade's collar seal sheet to the sheath chip. The width of the rim was measured from the end to the end with the widest part of the sheet with a tape measure. This was then multiplied by 0.75 which is the maize calibration factor (Elings, 2000). From the data obtained, the Leaf Area Index (LAI) was then calculated by dividing the total leaf area of a maize plant stand by the total land area occupied by the single stand according to Mauro et al. (2001).

3.7.3.17 Stem diameter of maize

Stem diameter of maize was measured at anthesis with a digital vernier caliper from the internode just below the maize ear. A sample of five plants was considered in the net plots. The average stem diameter per plant was then calculated.

3.7.3.18 Plant height of maize

This parameter was measured two times per crop growing season (before anthesis and after anthesis). This was determined on five randomly selected maize plants in the net plots used to calculate the maize number of leaves per plant. The maize plant height was measured by a measuring tape which was stretched between the plant base at the soil surface and the arch of the uppermost fully developed leaf. The average plant height per plant was then calculated.

3.7.3.19 Internode number and internode length of maize

These parameters were determined after anthesis and involved counting the number of internodes from below the ear to the ground level then measuring their individual lengths with a tape measure. This was too determined on the five randomly selected maize plants in the net plots used to calculate the maize number of leaves per plant. The means were then taken to represent the internode number and internode length per treatment respectively.

3.7.3.20 Leaf chlorophyll concentration of maize

The relative chlorophyll concentration was determined three times per season (before flowering (45th DAE), at flowering and after flowering (at the 100th DAE) using the procedure described in section 3.7.3.3.

3.7.3.21 Leaf sugar and starch content of maize

Both parameters were measured three times per crop growing season (four weeks after planting, at 50 % flowering and at 50 % physiological maturity) on maize leaves using the procedure described in Section 3.7.3.4.

3.7.3.22 Days to 50 % physiological maturity (DPM) of maize

This parameter was recorded by visual observation on the maize plants daily after the 50 % flowering period. Physiological maturity was reached when a black layer of silk was observed between the maize ear surface and ear grains (Plate 3.3).



Plate 3.3: A maize ear at physiological maturity showing the black silk at the ear tip in a zero tillage sole maize plot. Source: Author.

3.7.3.23 Number of ears per maize plant

This parameter was determined at the maize physiological maturity stage on the five randomly selected maize plants in the net plots used to calculate the maize number of leaves per plant by the use of a measuring tape. The results

obtained were averaged to give the average number of ears per plant in each plot.

3.7.3.24 Ear length per maize plant

This parameter was too determined at the plant physiological maturity. This was too determined on the five randomly selected maize plants in the net plots used to calculate the maize number of leaves per plant. Their average length was then calculated.

3.7.3.25 Root length of maize plant

This parameter was determined at the crop harvesting stage. It involved carefully digging out the five randomly selected maize plants in the net plots. Then the excavated soil blocks containing corn plants were soaked in water for 24 hours. Then carefully separate the roots from the adhered organic matter and soil particles, and then spread them on paper. Then use a tape measure to measure the length in centimeters from the base of the stem to the tip of the root.

3.7.3.26 Harvest stand count of maize

This was done at harvesting and was determined from the net plot. The number of plants obtained in the net plot was then converted to number of plants per hectare. This was done by having the number of plants obtained in the net plot multiplied by 10000, divided by the net plot area and then divided by 1000 as described by Otieno *et al.* (2018).

3.7.3.27 Shoot biomass of maize

This parameter was also evaluated at reaping stage. Five maize plants in the net plot were randomly selected, cut from the ground level, macerated into small pieces and mixed thoroughly. The sample was then weighed in the field to provide shoot fresh weight (FW) per plot, and then transported to the KALRO, Embu laboratories. The samples were then dried in the sun to a constant weight; the shoot dry weight (DW) was obtained. The shoot biomass per hectare was then calculated by having the net plot shoot weight (kg) multiplied by 10000, divided by the net plot area and then divided by 1000 as described by Otieno *et al.* (2018).

3.7.3.28 Grain yield of maize

All corn plants in the clean plot are harvested by cutting them on the ground after they are 50% physiologically mature. The ears of corn are separated from the husks manually and dried in the sun. Subsequently, the corn kernels were separated from the maize by hand. Then, after adding the grains, dry the grains in an oven for 48 hours, adjust the amount of water particles to 12.5%, and measure with a water meter (agricultural moisture meter). The total performance of corn particles (kg) per hectare is then multiplied by 10000 and then divided into a pure plot region and then Fageria *et al.* (2009).

3.7.3.29 Harvest index of maize

The harvest index (HI) of maize was determined using the procedure outlined in section 3.7.3.12.

3.8 Data analysis

Data sets were subjected to analysis of variance (ANOVA) using SAS 9.1.3 (SAS Institute Inc, 2003), to test the levels of significance due to treatments, means were separated using Fisher's least significant difference (LSD) test at $p \leq 0.05$.

CHAPTER FOUR

RESULTS

4.1 Effect of tillage practices and cropping systems on the soil moisture content

Tillage practices significantly ($p \leq 0.05$) affected the soil moisture content during the short rains (SR) 2015 and long rains (LR) 2016 growing seasons following an increasing trend of $CVT < ZT < F/R$ (Figure 4.1). Furrows and ridges (F/R) tillage practices recorded significantly ($p \leq 0.05$) the highest soil moisture content during the SR 2015 and LR 2016 crop growing seasons whilst the conventional tillage practices (CVT) practices recorded significantly ($p \leq 0.05$) the lowest moisture content throughout the cropping season (Figure 4.1).

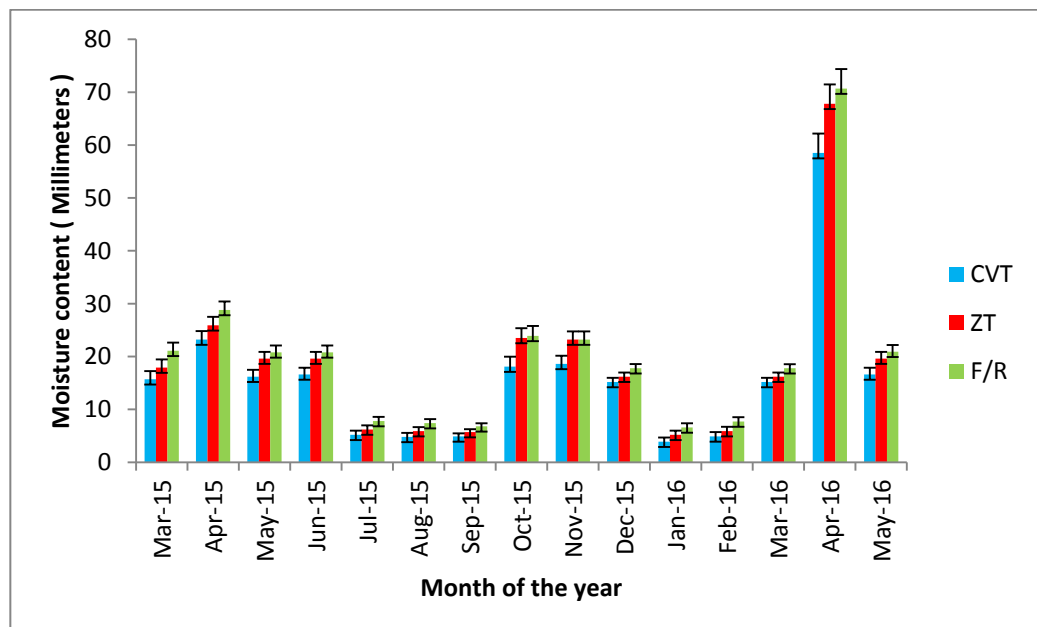


Figure 4.1: Effect of tillage practices on soil moisture content during SR 2015 and LR 2016 cropping seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/T, Furrows and ridges tillage. 15, year 2015;16, year 2016.

The soil moisture content was not significantly ($p > 0.05$) affected by cropping systems during the SR 2015 and LR 2016 cropping seasons (Figure 4.2). Interaction between tillage practices and cropping systems did not significantly ($P > 0.05$) affect the soil moisture content in both SR 2015 and LR 2016 seasons.

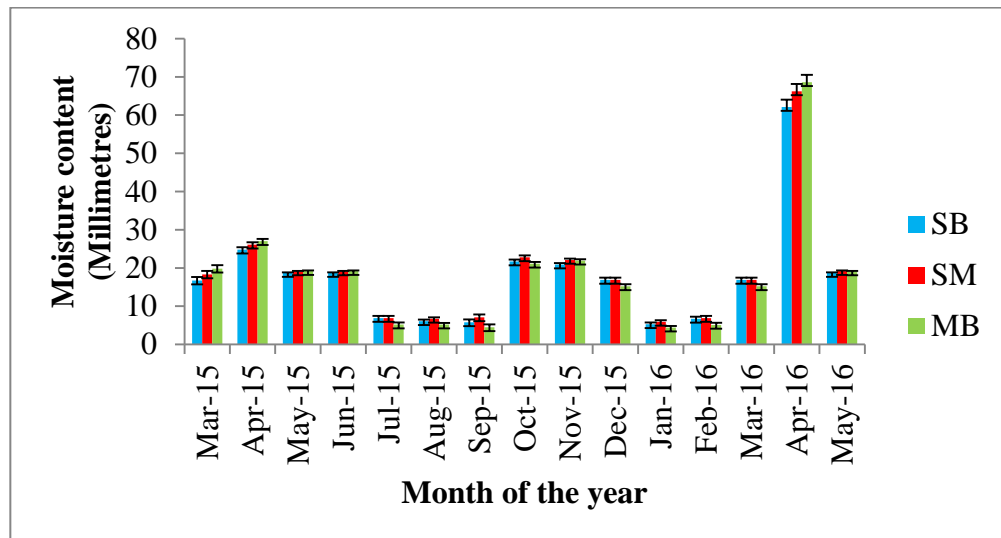


Figure 4.2: Effect of cropping systems on soil moisture content during SR 2015 and LR 2016 cropping seasons in Embu County, Kenya. Error bars represent standard error. SB, sole beans; SM, sole maize; MB, maize bean intercrop. 15, year 2015; 16, year 2016.

The soil moisture content at different soil depths due to the tillage practices differed significantly ($p \leq 0.05$) only at the 10 cm and 20 cm soil depths during the SR 2015 and LR 2016 with a decreasing trend of $F/R > ZT > CVT$ (Figure 4.3). At 10 cm depth, the soil moisture content in the F/R plots was 20.0 millimeters (mm) while the soil moisture content in the ZT plots was 18.5 mm in comparison to the soil moisture content in the CVT plots which was 15.5 mm. At 20 cm depth, the soil moisture content in the F/R plots was 24.4 mm

while the soil moisture content in the ZT plots was 22.3 mm in comparison to the soil moisture content in the CVT plots which was 22.1 mm (Figure 4.3).

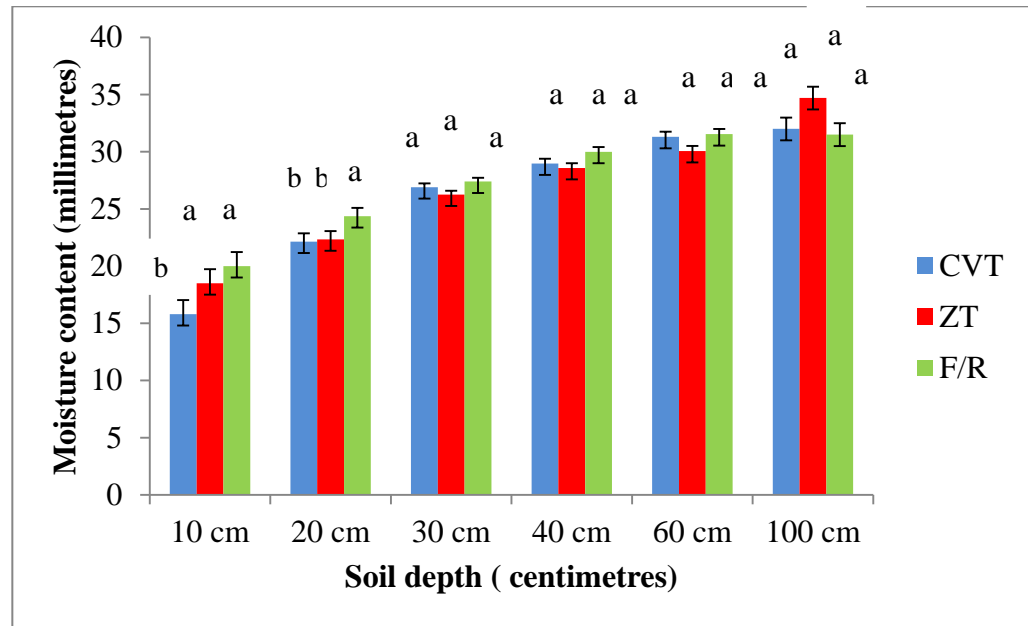


Figure 4.3: Effect of tillage practices on soil moisture content during SR 2015 and LR 2016 cropping seasons in Embu County, Kenya at 10 , 20 , 30 , 40 , 60 and 100 centimeters soil depths. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/T, Furrows and ridges tillage. Bars followed by different letters are significantly different ($p \leq 0.05$) according to Fisher's LSD. LSD, Least significant difference.

Cropping systems only significantly affected ($p \leq 0.05$) the soil moisture content over the various depths at 30 cm and 100 cm depths (Table 4.1). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the soil moisture content at 20 cm, 30 cm and 60 cm soil depths in both SR 2015 and LR 2016 seasons (Table 4.1).

Table 4.1: Effect of cropping systems on soil moisture content (mm) during SR 2015 and LR 2016 cropping seasons at 10-100 cm soil depths in Embu County, Kenya

Cropping Systems (C)	Soil depth					
	10 cm	20 cm	30 cm	40 cm	60 cm	100 cm
Sole maize	18.5 a	23.8 a	28.1 a	28.8 a	30.2 a	36.4 a
Sole bean	17.8 a	22.2 a	26.8 a	29.9 a	31.4 a	29.9 b
Intercrop	17.9 a	22.9 a	25.6 b	28.8 a	31.4 a	31.9 a b
Mean	18.1	22.9	26.9	29.2	30.9	32.8
CV (%)	11.1	7.1	6.6	6.6	12.5	15.3
LSD (0.05)	2.01	1.6	1.8	1.9	3.9	5.0
Significance levels						
P Cropping (C)	0.68	0.13	0.03	0.4	0.8	0.03
P T × C	0.108	0.008	0.04	0.4	0.05	0.3

Values followed by the same letters within the column are not significantly different $p > 0.05$ according to Fisher's LSD, CV, Coefficient of variation; LSD, Least significant difference.

4.2 Effect of tillage practices and cropping systems on soil chemical properties

4.2.1 Effect of tillage practices and cropping systems on soil organic carbon

Tillage practices significantly affected ($p \leq 0.05$) the percentage soil organic carbon in both cropping seasons (Table 4.2). The trend in the soil organic carbon due to tillage practices increased in the order of CVT < ZT < F/R (Table 4.2). The percentage soil organic carbon in the plots under F/R tillage practices was 1.6 % in SR 2015 and 2.3 % in LR 2016 while the one for plots under ZT

practices was 1.5 % in SR 2015 and 2.2 % in LR 2016 in comparison to the soil organic carbon for the plots under CVT practices which was 0.7 % in SR 2015 and 1.6 % in LR 2016 (Table 4.2). Cropping systems did not significantly affect ($p > 0.05$) the soil organic carbon in both seasons (Table 4.2). Interaction between tillage practices and cropping systems had a significant effect ($p \leq 0.05$) on the soil organic carbon only during the SR 2015 season (Table 4.2).

Table 4.2: Effect of tillage practices and cropping systems on the soil organic carbon at the end of SR 2015 and LR 2016 cropping seasons in Embu County, Kenya

Tillage practices (T)	Organic carbon (%)		
	Initial	End of SR 2015	End of LR 2016
Conventional tillage	1.6 a	0.7 b	1.6 b
Zero tillage	1.6 a	1.5 a	2.2 a
Furrows/ridges	1.6 a	1.6 a	2.3 a
Mean	1.6	1.3	2.0
CV (%)	2.5	20.6	11.7
LSD (0.05)	0.04	0.3	0.2
Cropping systems (C)			
Sole maize	1.6 a	1.2 a	1.9 a
Sole bean	1.6 a	1.2 a	2.0 a
Intercrop	1.6 a	1.3 a	2.0 a
Mean	1.6	1.3	2.0
CV (%)	2.5	20.6	11.7
LSD (0.05)	0.03	0.3	0.2
Significance levels			
P Tillage (T)	0.2	0.0001	0.0001
P Cropping (C)	0.2	0.46	0.42
P T × C	0.07	0.001	0.418

Values followed by the same letters within the column are not significantly different $p > 0.05$ according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference.

4.2.2 Effect of tillage practices and cropping systems on soil nitrogen

The percentage soil nitrogen was significantly affected ($p \leq 0.05$) by tillage practices in both cropping seasons with an increasing trend of CVT < F/R < ZT

in the SR 2015 and CVT < ZT < F/R in LR 2016 (Table 4.3). The soils from ZT plots had the highest percentage nitrogen content in SR 2015 season (0.3 %) while F/R tillage plots had the highest soil nitrogen in LR 2016 (0.4 %) in comparison to the soils under CVT plots which had a percentage nitrogen content of 0.1 % in SR 2015 and 0.2 % in LR 2016 (Table 4.3). Cropping systems did not significantly affect ($p > 0.05$) the soil nitrogen content in both seasons (Table 4.3). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the percentage soil nitrogen content in both seasons (Table 4.3).

Table 4.3: Effect of tillage practices and cropping systems on the soil nitrogen at the end of SR 2015 and LR 2016 cropping seasons in Embu County, Kenya

Tillage practices (T)	Soil nitrogen (%)		
	Initial	End of SR 2015	End of LR 2016
Conventional tillage	0.1 a	0.1 c	0.2 c
Zero tillage	0.1 a	0.3 a	0.3 b
Furrows/ridges	0.1 a	0.2 b	0.4 a
Mean	0.1	0.2	0.3
CV (%)	-	18.9	10.7
LSD (0.05)	0	0.04	0.03
Cropping systems (C)			
Sole maize	0.12 a	0.2 a	0.3 a
Sole bean	0.12 a	0.2 a	0.3 a
Intercrop	0.12 a	0.2 a	0.3 a
Mean	0.1	0.2	0.3
CV (%)	0	18.9	10.7
LSD (0.05)	0	0.04	0.03
Significance levels			
P Tillage (T)	-	0.0001	0.0001
P Cropping (C)	-	0.58	1.00
P T × C	-	0.37	0.44

Values followed by the same letters within the column are not significantly different $p > 0.05$ according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference. The CV and the p value for Nitrogen could not be generated because the measurements observed were the same for all the tillage practices.

4.2.3 Effect of tillage practices and cropping systems on soil pH

Tillage practices significantly affected ($p \leq 0.05$) the soil pH in both SR 2015 and LR 2016 cropping seasons (Table 4.4). The trend in the increase in soil pH due to tillage practices was in the order of CVT < F/R < ZT in SR 2015 and CVT < ZT < F/R in the LR 2016 (Table 4.4). The soil pH in the plots under F/R tillage practices increased from 4.5 in SR 2015 to 5.3 in LR 2016 while the one for the plots under ZT practices increased from 4.6 in SR 2015 to 5.2 in LR 2016 in comparison to the soil pH in the plots under CVT practices which increased from 4.2 in the SR 2015 to 4.3 in the LR 2016 (Table 4.4). There was no significant difference ($p > 0.05$) in the soil pH in both cropping seasons due to the cropping systems (Table 4.4). Interaction between tillage practices and cropping systems resulted in a significant difference ($p \leq 0.05$) in the pH of the soil only in LR 2016 (Table 4.4).

Table 4.4: Effect of tillage practices and cropping systems on the soil pH at the end of SR 2015 and LR 2016 cropping seasons in Embu County, Kenya

Tillage practices (T)	Soil pH		
	Initial	End of SR 2015	End of LR 2016
Conventional tillage	1.6 a	4.2 b	4.3 b
Zero tillage	1.6 a	4.6 a	5.2 a
Furrows/ridges	1.6 a	4.5 a	5.3 a
Mean	1.6	4.4	4.9
CV (%)	2.5	2.7	2.8
LSD (0.05)	0.04	0.1	0.1
Cropping systems (C)			
Sole maize	1.6 a	4.3 a	5.0 a
Sole bean	1.6 a	4.5 a	4.9 a
Intercrop	1.6 a	4.4 a	5.0 a
Mean	1.6	4.4	4.9
CV (%)	2.5	2.7	2.8
LSD (0.05)	0.03	0.11	0.14
Significance levels			
P Tillage (T)	0.2	0.0001	0.0001
P Cropping (C)	0.2	0.06	0.08
P T × C	0.07	0.105	0.01

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3 Effect of tillage practices and cropping systems on bean and maize performance

4.3.1 Effect of tillage practices and cropping systems on the emergence stand count of bean

The emergence stand count of bean was significantly affected by tillage practices ($p \leq 0.05$) in both seasons following a decreasing trend of $ZT > F/R > CVT$ (Table 4.5). The percentage emergence stand count of beans in the plots under F/R tillage practices was 87.6 % in the SR 2015 and 88.9 % in the LR 2016. The one for the beans under ZT practices was 91.8 % in the SR 2015 and 93 % in the LR 2016. The lowest emergence stand count of bean plants was for the beans under CVT which was 84.9 % in the SR 2015 and 86.3 % in the LR 2016 (Table 4.5). The emergence stand count of bean was not affected significantly ($p > 0.05$) by cropping systems in both the crop growing seasons (Table 4.5). Interaction between tillage practices and cropping systems did not produce a significant effect ($p > 0.05$) on the emergence stand count of beans in both cropping seasons (Table 4.5).

Table 4.5: Effect of tillage practices and cropping systems on percentage emergence stand count of bean during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Emergence Stand count (%)	
	SR 2015	LR 2016
Conventional tillage	84.9 b	86.3 b
Zero tillage	91.8 a	93.0 a
Furrows/ridges	87.6 a b	88.9 a b
Mean	88.1	89.4
CV (%)	5.2	4.8
LSD (0.05)	5.9	5.5
Cropping systems (C)		
Sole bean	87.1 a	88.4 a
Intercrop	89.2 a	90.4 a
Mean	88.1	89.4
CV (%)	5.2	4.8
LSD (0.05)	4.9	4.5
Significance levels		
P Tillage (T)	0.04	0.05
P Cropping (C)	0.07	0.4
P T × C	0.8	0.8

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.2 Effect of tillage practices and cropping systems on bean nodulation

Tillage practices significantly affected ($p \leq 0.05$) the nodules on bean plant in both cropping seasons (Table 4.6). The trend for number of nodules per bean plant observed across the tillage practices was decreasing in the order of ZT > F/R > CVT. Cropping systems significantly affected ($p \leq 0.05$) the bean number of nodules per plant in both SR 2015 and LR 2016 seasons. The intercropped beans had more nodules per plant (50.2 nodules per plant in both SR 2015 and LR 2016) in comparison to the monocropped beans which had 12.3 nodules per plant in SR 2015 and 11.7 nodules per plant in LR 2016 (Table 4.6). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the number of nodules per bean plant in both seasons (Table 4.6).

Table 4.6: Effect of tillage practices and cropping systems on nodule per bean plant during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Average nodule / plant	
	SR 2015	LR 2016
Conventional tillage	13.9 b	13.8 b
Zero tillage	57.5 a	57.6 a
Furrows/ridges	22.3 a b	21.3 a b
Mean	31.2	30.9
CV (%)	91.9	90.7
LSD (0.05)	40.6	39.6
Cropping systems (C)		
Sole bean	12.3 b	11.7 b
Intercrop	50.2 a	50.2 a
Mean	31.2	30.9
CV (%)	91.9	90.7
LSD (0.05)	33.1	32.3
Significance levels		
P Tillage (T)	0.05	0.05
P Cropping (C)	0.03	0.03
P T × C	0.2	0.2

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.3 Effect of tillage practices and cropping systems on number of days to 50 % flowering of bean

The mean number of days to bean 50 % flowering was 36.8 days in SR 2015 and 42.1 days in LR 2016 (Table 4.7). Tillage practices significantly affected ($p \leq 0.05$) bean number of days to 50 % flowering in both seasons with an increasing trend of ZT < CVT < FR in SR 2015 and ZT < F/R < CVT in LR 2016 (Table 4.7). The beans planted under the ZT practices flowered earlier while the ones under F/R their flowering was delayed by two days in SR 2015 (Table 4.7). Cropping systems did not significantly affect ($P > 0.05$) the number of days to 50 % flowering per bean plant in both seasons. Interaction between tillage practices and cropping systems had a significant effect ($p \leq 0.05$) on the number of days to 50 % flowering only in the LR 2016 cropping season (Table 4.7).

Table 4.7: Effect of tillage practices and cropping systems on days to 50 % flowering of bean during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	Days to 50 % flowering	
	SR 2015	LR 2016
Conventional tillage	37.3 a	44.3 a
Zero tillage	35.5 b	41.0 b
Furrows/ridges	37.5 a	41.0 b
Mean	36.8	42.1
CV (%)	2.6	1.6
LSD (0.05)	1.3	0.9
Cropping systems (C)		
Sole bean	36.9 a	42.4 a
Intercrop	36.7 a	41.8 a
Mean	36.8	42.1
CV (%)	2.6	1.6
LSD (0.05)	1.09	0.8
Significance levels		
P Tillage (T)	0.02	0.0002
P Cropping (C)	0.6	0.08
P T × C	0.2	0.01

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.4 Effect of tillage practices and cropping systems on leaf chlorophyll content of bean

Tillage practices had a significant effect ($p \leq 0.05$) on the chlorophyll concentration of beans in all the seasons (Table 4.8). The highest chlorophyll concentration in all the seasons was recorded at the flowering stage (Table 4.8). The lowest chlorophyll concentration was recorded after flowering stage (Table 4.8). The chlorophyll concentration after anthesis followed the sequence of CVT < ZT < F/R in SR 2015 and CVT < F/R < ZT in LR 2016 (Table 4.8).

Cropping systems only significantly affected ($p \leq 0.05$) the chlorophyll concentration of beans after flowering in both seasons with the intercropped beans having a higher chlorophyll concentration (31.6 in SR 2015 and 32.6 in LR 2016) in comparison to the monocropped beans (25.5 in SR 2015 and 26.2 in LR 2016) (Table 4.8). At all stages of growth, interaction between tillage practices and cropping systems had no significant effect ($p > 0.05$) on bean chlorophyll concentration in both seasons (Table 4.8).

Table 4.8: Effect of tillage practices and cropping systems on leaf chlorophyll content of beans (units of SPAD) taken before, at and after flowering during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BF	AT	AF	BF	AT	AF
Conventional tillage	35.8 a b	38.0 b	22.4 b	36.3 a b	38.3 b	22.7 b
Zero tillage	38.7 a	41.7 a	31.3 a	40.3 a	41.4 a	32.9 a
Furrows/ridges	32.4 b	35.4 b	32.0 a	32.1 b	35.4 c	32.6 a
Mean	35.6	38.4	28.6	36.3	38.4	29.4
CV (%)	6.9	6.5	12.5	8.2	5.1	10.9
LSD (0.05)	3.5	3.5	5.04	4.2	2.7	4.6
Cropping systems (C)						
Sole bean	35.5 a	38.1 a	25.5 b	36.3 a	38.0 a	26.2 b
Intercrop	35.7 a	38.6 a	31.6 a	36.2 a	38.8 a	32.6 a
Mean	35.6	38.4	28.6	36.3	38.4	29.4
CV (%)	6.9	6.5	12.5	8.2	5.1	10.9
LSD (0.05)	2.9	2.9	4.1	3.4	2.2	3.7
Significance levels						
P Tillage (T)	0.01	0.013	0.005	0.009	0.006	0.002
P Cropping (C)	0.9	0.7	0.01	0.9	0.4	0.002
p T × C	0.9	0.4	0.4	0.4	0.06	0.4

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains. BF, before flowering; AT, at flowering, AF, after flowering.

4.3.5 Effect of tillage practices and cropping systems on leaf sugar content of bean

Tillage practices did not significantly affect ($p > 0.05$) the bean sugar content in both seasons at all crop growth stages (Table 4.9). The percentage sugars in beans were the highest at the flowering stage for both seasons (Table 4.9). The amount of sugars was the lowest after flowering (Table 4.9). Cropping systems significantly affected ($p \leq 0.05$) the leaf sugar content of bean only before flowering during the LR 2016 cropping season (Table 4.9). Interaction between tillage practices and cropping systems on bean sugar content differed significantly ($p \leq 0.05$) only after flowering in the SR 2015 cropping season (Table 4.9).

Table 4.9: Effect of tillage practices and cropping systems on the percentage leaf sugar content of bean in during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BF	AT	AF	BF	AT	AF
Conventional tillage	1.9 a	3.2 a	1.5 a	2.0 a	3.3 a	1.6 a
Zero tillage	2.3 a	2.9 a	1.5 a	2.2 a	3.1 a	1.3 a
Furrows/ridges	2.2 a	3.2 a	1.7 a	2.2 a	3.3 a	1.7 a
Mean	2.1	3.1	1.6	2.2	3.2	1.5
CV (%)	21.2	11.1	24.4	17.4	11.5	29.2
LSD (0.05)	0.6	0.5	0.5	0.5	0.5	0.6
Cropping systems (C)						
Sole bean	2.3 a	3.2 a	1.7 a	2.4 a	3.2 a	1.6 a
Intercrop	1.9 a	3.0 a	1.4 a	1.9 b	3.3 a	1.4 a
Mean	2.1	3.1	1.6	2.2	3.2	1.5
CV (%)	21.2	11.1	24.4	17.4	11.5	29.2
LSD (0.05)	0.4	0.4	0.4	0.4	0.4	0.5
Significance levels						
P Tillage (T)	0.3	0.4	0.2	0.5	0.5	0.4
P Cropping (C)	0.07	0.2	0.2	0.03	0.4	0.4
p T × C	0.07	0.06	0.05	0.09	0.2	0.1

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains. BF, before flowering; AT, at flowering; AF, after flowering.

4.3.6: Effect of tillage practices and cropping systems on leaf starch content of bean

Tillage practices significantly affected ($p \leq 0.05$) the percentage leaf starch content of beans before flowering only in the LR 2016 season following an

increasing sequence of F/R < CVT < ZT (Table 4.10). The percentage starch content was highest at flowering stage while the amount of starch was the lowest after flowering in both seasons (Table 4.10). Cropping systems did not significantly affect ($p > 0.05$) the bean leaf starch content in both seasons (Tables 4.10). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the bean starch content only before flowering in the LR 2016 season (Table 4.10).

Table 4.10: Effect of tillage practices and cropping systems on percentage leaf starch content of bean during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BF	AT	AF	BF	AT	AF
Conventional tillage	8.7 ab	13.3 a	5.08 a	8.9 a b	13.8 a	5.0 a
Zero tillage	10.3 a	13.9 a	5.1 a	10.7 a	14.4 a	5.0 a
Furrows/ridges	5.8 b	12.8 a	6.7 a	7.3 b	13.0 a	5.5 a
Mean	8.3	13.4	5.6	8.9	13.7	5.2
CV (%)	28.5	10.3	34.5	25.8	8.04	27.8
LSD (0.05)	3.0	1.7	2.5	2.9	1.4	1.9
Cropping systems (C)						
Sole bean	8.2 a	13.0 a	5.6 a	8.8 a	13.4 a	5.3 a
Intercrop	8.4 a	13.7 a	5.6 a	9.2 a	13.9 a	5.0 a
Mean	8.3	13.4	5.6	8.9	13.7	5.2
CV (%)	28.5	10.3	34.5	25.8	8.04	27.8
LSD (0.05)	2.5	1.4	2.0	2.4	1.2	1.5
Significance levels						
P Tillage (T)	0.9	0.35	0.29	0.007	0.2	0.8
P Cropping (C)	0.9	0.4	0.9	0.7	0.4	0.7
P T × C	0.1	0.8	0.4	0.04	0.9	0.4

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference.

4.3.7 Effect of tillage practices and cropping systems on the number of branches per bean plant

The mean number of branches per bean plant due to tillage practices ranged from 9.7 in the SR 2015 to 14.4 in the LR 2016 (Table 4.11). Due to the tillage

practices, the number of branches per bean plant differed significantly ($p \leq 0.05$) in the two crop growing seasons following an increasing trend of CVT < ZT < F/R in SR 2015 and F/R < ZT < CVT in LR 2016 (Table 4.11). Cropping systems significantly affected ($p \leq 0.05$) the number of branches per bean plant only during the LR 2016 season with the intercropped beans having a higher number of branches (18 branches) in comparison to the monocropped beans which had 10.8 branches (Table 4.11). Interaction between tillage practices and cropping systems did not have a significant effect ($p > 0.05$) on the number of branches per bean plant in both seasons (Table 4.11).

Table 4.11: Effect of tillage practices and cropping systems on the number of branches per bean plant during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	No. branches / plant	
	SR 2015	LR 2016
Conventional tillage	6.5 c	18.7 a
Zero tillage	9.2 b	15.3 a
Furrows/ridges	13.3 a	9.2 b
Mean	9.7	14.4
CV (%)	14.8	27.2
LSD (0.05)	2.03	5.5
P tillage	0.0005	0.01
Cropping systems (C)		
Sole bean	10.7 a	10.8 b
Intercrop	8.9 a	18.0 a
Mean	9.7	14.4
CV (%)	14.8	27.2
LSD (0.05)	1.7	4.5
Significance levels		
P Tillage (T)	0.0005	0.01
P Cropping (C)	0.06	0.008
p T × C	0.3	0.3

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.8 Effect of tillage practices and cropping systems on the number of pods per bean plant

Tillage practices significantly affected ($p \leq 0.05$) the number of pods per bean plant only in the LR 2016 season with an increasing trend of F/R < ZT < CVT (Table 4.12). Furrows / ridges tillage practice which is a form of CT had the highest number of pods per bean plant (9.2 pods) in the SR 2015 crop growing season while CVT method had the lowest pods per plant (7.0 pods). (Table 4.12). Cropping systems significantly affected ($p \leq 0.05$) the number of pods per bean plant during the LR 2016 season only with the intercropped beans having a higher number of pods per plant (16.9 pods) in comparison to the monocropped beans (9.6 pods) (Table 4.12). Interaction between tillage practices and cropping systems did not have a significant effect ($p > 0.05$) on bean number of pods per plant in both seasons (Table 4.12).

Table 4.12: Effect of tillage practices and cropping systems on the number of pods per bean plant during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	No. pods / plant	
	SR 2015	LR 2016
Conventional tillage	7.0 a	17.7 a
Zero tillage	8.0 a	13.0 a b
Furrows/ridges	9.2 a	9.0 b
Mean	8.1	13.2
CV (%)	35.4	35.7
LSD (0.05)	4.02	6.7
Cropping systems (C)		
Sole bean	9.0 a	9.6 b
Intercrop	7.1 a	16.9 a
Mean	8.1	13.2
CV (%)	35.4	35.7
LSD (0.05)	3.3	5.5
Significance levels		
P Tillage (T)	0.5	0.05
P Cropping (C)	0.2	0.05
p T × C	0.5	0.4

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.9 Effect of tillage practices and cropping systems on the number of seeds per bean pod

The mean number of seeds per bean pod due to tillage practices ranged from 4.1 seeds in SR 2015 to 4.4 seeds in the LR 2016 (Table 4.13). The number of

seeds due to tillage differed significantly ($p \leq 0.05$) only in the LR 2016 season with an increasing trend of $CVT < ZT < F/R$ (Table 4.13). The number of seeds per bean pod in the plots under F/R tillage practices was 5.2 in LR 2016 while the one for the plots under ZT practices was 4.7 in the LR 2016 in comparison to that of beans in the plots under CVT practices which was 3.5 in the LR 2016 (Table 4.13). Cropping systems significantly affected ($p \leq 0.05$) the number of seeds per bean pod only in the LR 2016 (Table 4.13). The number of seeds per bean pod of the intercropped beans was 4.9 in the LR 2016 while that of the monocropped bean was 4.0 during the LR 2016 season (Table 4.13). There was a significant interaction effect ($p \leq 0.05$) due to tillage practices and cropping systems on the bean number of seeds per pod only in LR 2016 cropping season (Table 4.13).

Table 4.13: Effect of tillage practices and cropping systems on number of seeds per bean pod during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	Seeds per bean pod	
	SR 2015	LR 2016
Conventional tillage	3.5 a	3.5 b
Zero tillage	4.2 a	4.7 a
Furrows/ridges	4.5 a	5.2 a
Mean	4.1	4.4
CV (%)	20.9	15.9
LSD (0.05)	1.2	0.9
Cropping systems (C)		
Sole bean	3.8 a	4.0 b
Intercrop	4.3 a	4.9 a
Mean	4.1	4.4
CV (%)	20.9	15.9
LSD (0.05)	0.9	0.8
Significance levels		
P Tillage (T)	0.2	0.01
P Cropping (C)	0.2	0.02
p T × C	0.4	0.04

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.10 Effect of tillage practices and cropping systems on number of days to 50 % physiological maturity of beans

The mean number of days to 50 % physiological maturity of beans due to tillage practices was 69.2 days in the SR 2015 and 72.6 days in the LR 2016

(Table 4.14). Tillage practices significantly affected ($p \leq 0.05$) bean number of days to 50 % physiological maturity in both seasons following an increasing trend of CVT < ZT < F/R (Table 4.14). The beans planted under the ZT practice reached 50 % physiological maturity later (2.7 more days in SR 2015 and 3 more days in LR 2016) compared to the ones grown under CVT practices (Table 4.14). The bean plants grown under F/R tillage system took the longest number of days to reach 50 % physiological maturity (4.4 more days in SR 2015 and 3.7 more days in LR 2016) in comparison to those grown under CVT practices (Table 4.14). The intercropped beans took more days to reach physiological maturity (2.1 more days in SR 2015 and 1.7 days in LR 2016) in comparison with the monocropped beans (Table 4.14). Interaction between tillage practices and cropping systems had no significant effect ($p > 0.05$) on the number of days to 50 % physiological maturity in both cropping seasons (Table 4.14).

Table 4.14: Effect of tillage practices and cropping systems on days to 50 % physiological maturity of bean during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	Days to 50 % physiological maturity	
	SR 2015	LR 2016
Conventional tillage	66.8 c	70.3 b
Zero tillage	69.5 b	73.3 a
Furrows/ridges	71.2 a	74.0 a
Mean	69.2	72.6
CV (%)	1.3	1.1
LSD (0.05)	1.3	1.1
Cropping systems (C)		
Sole bean	68.1 b	71.7 b
Intercrop	70.2 a	73.4 a
Mean	69.2	72.6
CV (%)	1.3	1.1
LSD (0.05)	1.02	0.9
Significance levels		
P Tillage (T)	0.0004	0.0004
P Cropping (C)	0.002	0.0004
P T × C	0.4	0.06

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.11 Effect of tillage practices and cropping systems on the harvest stand count of bean

Tillage practices significantly affected the harvest stand count of bean ($p \leq 0.05$) in both seasons following an increasing trend of CVT < F/R < ZT (Table 4.15). The harvest stand count of beans under the ZT practices was 90.3 % in SR 2015 and 91.7 % in LR 2016 while that of the beans under F/R was 86.1 % in SR 2015 and 87.4 % in LR 2016 in comparison to that of beans under CVT practices which was 83.1 % in SR 2015 and 84.3 % in LR 2016 (Table 4.15). Cropping systems did not significantly affect ($p > 0.05$) the harvest stand count of bean in both seasons (Table 4.15). Interaction between tillage practices and cropping systems did not significant effect ($p > 0.05$) the harvest stand count of beans in both seasons (Table 4.15).

Table 4.15: Effect of tillage practices and cropping systems on percentage harvest stand count of bean during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Harvest stand count (%)	
	SR 2015	LR 2016
Conventional tillage	83.1 b	84.3 b
Zero tillage	90.3 a	91.7 a
Furrows/ridges	86.1 a b	87.4 a b
Mean	86.5	87.3
CV (%)	5.4	5.4
LSD (0.05)	5.9	5.9
Cropping systems (C)		
Sole bean	85.4 a	86.9 a
Intercrop	87.5 a	88.8 a
Mean	86.5	87.3
CV (%)	5.4	5.4
LSD (0.05)	4.9	4.8
Significance levels		
P Tillage (T)	0.04	0.05
P Cropping (C)	0.07	0.4
P T × C	0.6	0.8

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.12 Effect of tillage practices and cropping systems on the shoot biomass of beans

Tillage practices did not significantly affect ($p > 0.05$) the shoot biomass of beans in both SR 2015 and LR 2016 seasons (Figure 4.4). The shoot biomass of beans under the F/R practices was 2.4 t/ha in SR 2015 and 2.2 t/ha in LR 2016 while that of the beans under ZT was 2.4 t/ha in SR 2015 and 2.2 t/ha

during LR 2016 in comparison to the shoot biomass of beans under CVT practices which was 2.1 t/ha in SR 2015 and 1.9 t/ha during LR 2016 (Figure 4.4).

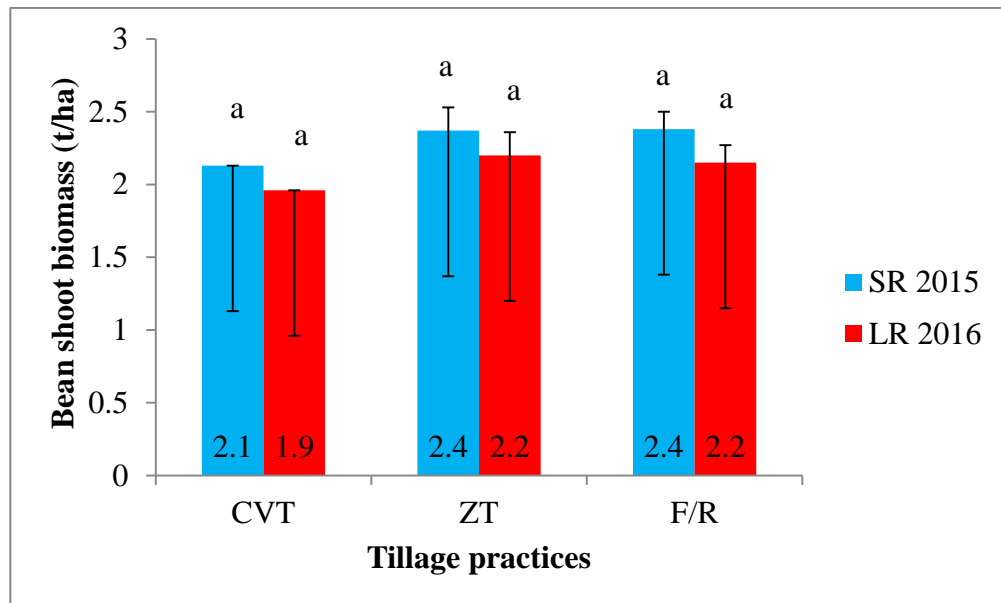


Figure 4.4: Effect of tillage practices on bean shoot biomass during short rains 2015 and long rains 2016. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by the same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

Cropping systems significantly affected ($p \leq 0.05$) the shoot biomass of beans only during the LR 2016 cropping seasons (Table 4.16). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the shoot biomass of beans during SR 2015 and LR 2016 cropping seasons (Table 4.16).

Table 4.16: Effect of cropping systems on shoot biomass of beans during short rains 2015 and long rains 2016 in Embu County, Kenya

Cropping systems (C)	Shoot biomass (t /ha)	
	SR 2015	LR 2016
Sole bean	2.3 a	2.4 a
Intercrop	2.3 a	1.8 b
Mean	2.3	2.1
CV (%)	10.7	20.2
LSD (0.05)	0.3	0.5
Significance levels		
P Cropping (C)	0.9	0.02
P T × C	0.3	0.2

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.13 Effect of tillage practices and cropping systems on the grain yield of beans

Tillage practices did not significantly affect ($p > 0.05$) the grain yield of beans in both the SR 2015 and LR 2016 seasons (Figure 4.5). The grain yield of beans under the F/R practices was 1.3 t/ha in SR 2015 and 1.4 t/ha in LR 2016 while that of the beans under ZT was 1.3 t/ha in SR 2015 and 1.5 t/ha in LR 2016 in comparison to the grain yields of beans under CVT practices which was 1.2 t/ha in SR 2015 and 1.3 t/ha in LR 2016 (Figure 4.5).

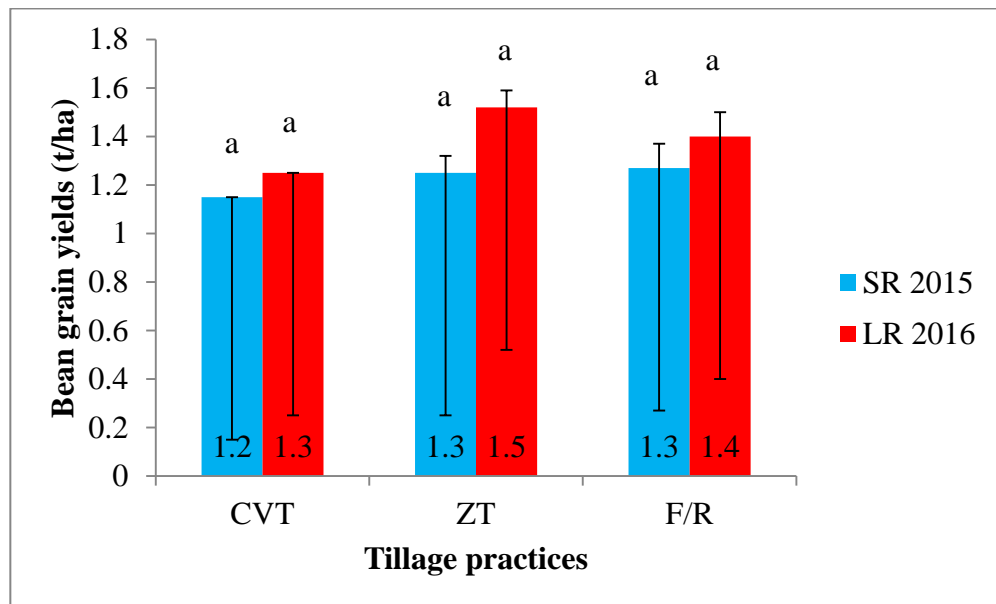


Figure 4.5: Effect of tillage practices on bean grain yields during short rains 2015 and long rains 2016 seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by the same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

Cropping systems did not significantly affect ($p > 0.05$) the grain yield of beans during both the SR 2015 and the LR 2016 seasons (Table 4.17). The grain yields of intercropped beans in LR 2016 was 1.3 t/ha in comparison with that of the monocropped beans which was 1.5 t/ha (Table 4.17). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the grain yield of beans during SR 2015 and LR 2016 cropping seasons (Table 4.17).

Table 4.17: Effect of cropping systems on grain yields of beans during short rains 2015 and long rains 2016 in Embu County, Kenya

Cropping systems (C)	Grain yield (t /ha)	
	SR 2015	LR 2016
Sole bean	1.2 a	1.5 a
Intercrop	1.2 a	1.3 a
Mean	1.2	1.4
CV (%)	11.3	19.1
LSD (0.05)	0.2	0.3
Significance levels		
P Cropping (C)	0.7	0.3
P T × C	0.7	0.2

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.14 Effect of tillage practices and cropping systems on harvest index of beans

Tillage practices did not significantly affect ($p > 0.05$) the harvest index of beans in both the SR 2015 and LR 2016 seasons (Figure 4.6). The harvest index of beans under the F/R practices was 52.9 % in the SR 2015 and 66.1 % in the LR 2016 season while that of the beans grown under ZT was 52.7 % in SR 2015 and 68.8 % in LR 2016 compared to the harvest index of beans grown under CVT practices which was 53.5 % in SR 2015 and 63.6 % in LR 2016 (Figure 4.6).

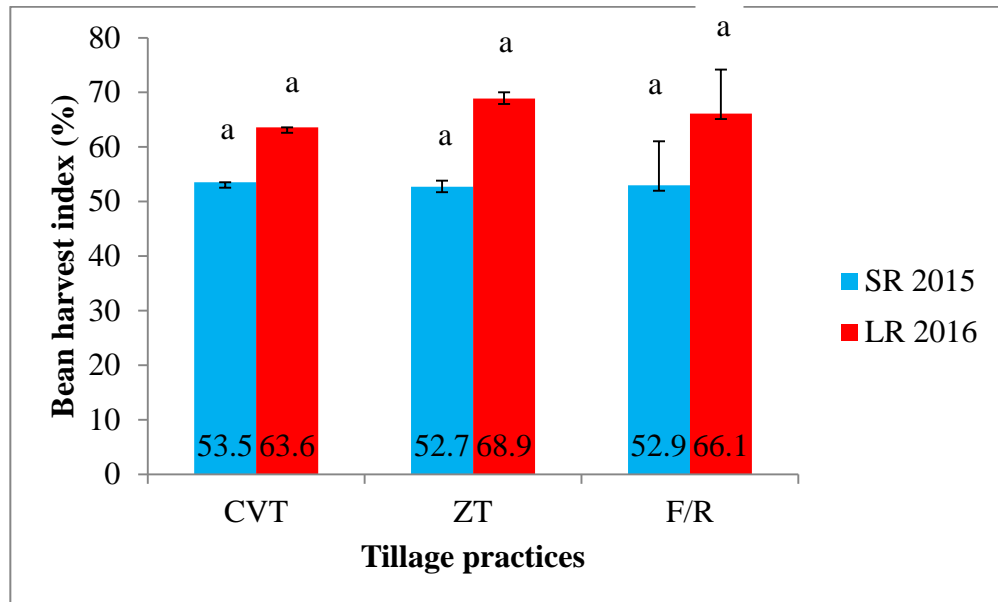


Figure 4.6: Effect of tillage practices on bean harvest index during short rains 2015 and long rains 2016 seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by the same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

Cropping systems did not significantly affect ($p > 0.05$) the harvest index of beans during SR 2015 and LR 2016 cropping seasons (Table 4.18). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the harvest index of beans during SR 2015 and LR 2016 cropping seasons (Table 4.18).

Table 4.18: Effect of cropping systems on harvest index of beans during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Cropping systems (C)	Harvest index (%)	
	SR 2015	LR 2016
Sole bean	53.5 a	63.1 a
Intercrop	52.6 a	69.2 a
Mean	53.1	66.2
CV (%)	7.5	10.2
LSD (0.05)	4.6	7.8
Significance levels		
P cropping (C)	0.6	0.1
P T × C	0.1	0.5

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.15 Effect of tillage practices and cropping systems on the emergence stand count of maize

Tillage practices significantly ($p \leq 0.05$) affected the percentage emergence stand counts of maize plants for both SR 2015 and LR 2016 seasons following an increasing sequence of ZT < CVT < F/R (Table 4.19). The emergence stand count of maize grown under the F/R plots was 89.7 % in SR 2015 and 90.0 % in LR 2016 while the emergence stand count of maize grown under CVT plots was 88.4 % in SR 2015 and 89.1 % in the LR 2016 season (Table 4.19). Cropping systems did not significantly affect ($p > 0.05$) the emergence stand count of maize in both cropping seasons (Table 4.19). Interaction between

tillage practices and cropping systems had no significant effect ($p > 0.05$) on the emergence stand count of maize in both cropping seasons (Table 4.19).

Table 4.19: Effect of tillage practices and cropping systems on emergence stand count of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Emergence stand count (%)	
	SR 2015	LR 2016
Conventional tillage	88.4 ab	89.1 ab
Zero tillage	83.5 b	84.6 b
Furrows/ridges	89.7 a	90.0 a
Mean	87.2	87.9
CV (%)	4.7	4.4
LSD (0.05)	5.3	4.9
Cropping systems (C)		
Sole maize	87.7 a	88.2 a
Intercrop	86.68 a	87.5 a
Mean	87.2	87.9
CV (%)	4.7	4.4
LSD (0.05)	4.3	4.1
Significance levels		
P Tillage (T)	0.05	0.03
P Cropping (C)	0.06	0.7
P T × C	0.2	0.2

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.16 Effect of tillage practices and cropping systems on leaf chlorophyll concentration of maize

Tillage practices significantly affected ($p \leq 0.05$) the leaf chlorophyll concentration of maize only after anthesis in SR 2015 following a sequence of CVT < F/R < ZT (Table 4.20). In the LR 2016, tillage practices significantly affected the chlorophyll concentration before anthesis and after anthesis (Table 4.20). The highest chlorophyll concentration was recorded at anthesis while the lowest chlorophyll concentration was observed after anthesis (Table 4.20). Cropping systems significantly affected ($p \leq 0.05$) the chlorophyll concentration only at anthesis in the LR 2016 with the intercropped maize plant recording a higher (58.1) chlorophyll concentration in comparison to the monocropped beans which was 55.4 (Table 4.20). Interaction between tillage practices and cropping systems had no significant effect ($p > 0.05$) on maize chlorophyll concentration in both seasons (Table 4.20).

Table 4.20: Effect of tillage practices and cropping systems on leaf chlorophyll concentration of maize at different stages of crop development during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BA	AT	AF	BA	AT	AF
Conventional tillage	56.2 a	57.9 a	45.7 b	51.2 a b	61.3 a	45.7 a
Zero tillage	52.5 a	58.1 a	54.1 a	53.2 a	58.0 b	52.1 a
Furrows/ridges	53.0 a	56.1 a	53.6 a	44.9 b	50.9 c	46.7 a
Mean	53.9	57.4	51.1	49.8	56.7	48.2
CV (%)	6.3	2.7	7.3	10.3	3.6	10.3
LSD (0.05)	4.8	2.2	5.3	7.3	2.9	6.9
Cropping systems (C)						
Sole maize	55.0 a	57.1 a	51.4 a	47.2 a	55.4 b	46.7 a
Intercrop	52.7 a	57.6 a	50.9 a	52.4 a	58.1 a	49.6 a
Mean	53.9	57.4	51.1	49.8	56.7	48.2
CV (%)	6.3	2.7	7.3	10.3	3.6	10.3
LSD (0.05)	3.9	1.8	4.3	5.9	2.3	5.7
Significance levels						
P Tillage (T)	0.2	0.1	0.01	0.04	0.0003	0.1
P Cropping (C)	0.2	0.5	0.8	0.08	0.03	0.3
P T × C	0.3	0.3	0.8	0.3	0.9	0.2

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference. BA, before anthesis; AT, at anthesis; AF, after anthesis; SR, short rains; LR long rains.

4.3.17 Effect of tillage practices and cropping seasons on leaf area index (LAI) of maize

Tillage practices significantly affected ($p \leq 0.05$) the LAI of maize only after anthesis in the two crop growing seasons following a trend of CVT < ZT, F/R (Table 4.21). Among the tillage practices, the maize plants grown in the plots under F/R practices and ZT practices had a higher LAI of $0.6 \text{ M}^2\text{M}^{-2}$ while the ones grown under CVT plots had a lower LAI of $0.5 \text{ M}^2\text{M}^{-2}$ in both SR 2015 and LR 2016 seasons after anthesis (Table 4.21). Cropping systems did not significantly affect ($p > 0.05$) the LAI of maize in both seasons (Table 4.21). Interaction between tillage practices and cropping systems did not significantly ($p > 0.05$) affect the LAI of maize in both seasons (Table 4.21).

Table 4.21: Effect of tillage practices and cropping systems on leaf area index (LAI) of maize before and after anthesis during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	LAI before anthesis (M ² M ⁻²)		LAI after anthesis (M ² M ⁻²)	
	SR 2015	LR 2016	SR 2015	LR 2016
Conventional tillage	1.1 a	0.5 a	0.5 b	0.5 b
Zero tillage	1.1 a	0.5 a	0.6 a	0.6 a
Furrows/ridges	1.1 a	0.5 a	0.6 a	0.6 a
Mean	1.1	0.5	0.5	0.5
CV (%)	7.1	6.5	3.6	3.5
LSD (0.05)	0.1	0.03	0.03	0.03
Cropping systems (C)				
Sole maize	0.5 a	0.5 a	0.5 a	0.5 a
Intercrop	0.5 a	0.5 a	0.5 a	0.6 a
Mean	0.5	0.5	0.5	0.5
CV (%)	7.1	6.5	3.6	3.5
LSD (0.05)	0.03	0.03	0.03	0.02
Significance levels				
P Tillage (T)	0.3	0.2	0.001	0.03
P Cropping (C)	0.3	0.16	0.1	0.0004
P T × C	0.09	0.9	0.7	0.07

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.18 Effect of tillage practices and cropping systems on the number of leaves per maize plant

Tillage practices significantly affected ($p \leq 0.05$) the number of leaves per maize plant in both seasons following a sequence of CVT < ZT < F/R (Table

4.22). The mean number of leaves per maize plant due to tillage practices ranged from 13.3 leaves to 14.9 leaves in both seasons (Table 4.22). The number of leaves of maize plants grown under the F/R practices plots was 16.2 in SR 2015 and 14.3 in LR 2016 while those of maize plants grown under ZT plots was 15.4 in SR 2015 and 13.7 in LR 2016 in comparison with those grown under CVT practices plots which was 13.1 in SR 2015 and 13.0 in LR 2016 (Table 4.22). The number of leaves of maize at anthesis differed significantly ($p \leq 0.05$) only in the LR 2016 season due to cropping systems (Table 4.22). The number of leaves of the intercropped maize in the LR 2016 were significantly ($p \leq 0.05$) higher (13.7 leaves) in compared to those grown under sole configuration which were 13.0 leaves (Table 4.22). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the number of leaves per maize plant only in the LR 2016 (Table 4.22).

Table 4.22: Effect of tillage practices and cropping systems on the number of leaves per maize plant at anthesis during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	No. leaves at anthesis	
	SR 2015	LR2 2016
Conventional tillage	13.1 b	13.0 b
Zero tillage	15.4 a	13.7 a
Furrows/ridges	16.2 a	14.3 a
Mean	14.9	13.3
CV (%)	5.9	3.1
LSD (0.05)	1.0	0.5
Cropping systems (C)		
Sole maize	14.8 a	13.0 b
Intercrop	14.9 a	13.7 a
Mean	14.9	13.3
CV (%)	5.9	3.1
LSD (0.05)	1.02	0.5
Significance levels		
P Tillage (T)	0.002	0.0009
P Cropping (C)	0.562	0.01
P T × C	0.6	0.008

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.19 Effect of tillage practices and cropping systems on the leaf sugar content of maize

Tillage practices significantly affected ($p \leq 0.05$) the maize leaf sugar content at all crop growth stages following the increasing trend of CVT < ZT < F/R

(Table 4.23). The leaf sugar content of maize was the highest at anthesis stage while it was the lowest after anthesis in both SR 2015 and LR 2016 seasons (Table 4.23). Cropping systems significantly affected ($p \leq 0.05$) the leaf sugar content of maize only after anthesis in the LR 2016 (Table 4.23). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the maize leaf sugar content at anthesis and after anthesis in the SR 2015 and before anthesis and after anthesis in the LR 2016 (Table 4.23).

Table 4.23: Effect of tillage practices and cropping systems on the percentage leaf sugar content of maize during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BA	AT	AF	BA	AT	AF
Conventional tillage	1.7 b	2.6 b	1.3 b	2.1 b	2.7 b	1.4 b
Zero tillage	2.4 a	2.9 a	1.6 b	2.4 a	3.3 a	1.3 b
Furrows/ridges	2.4 a	3.4 a	1.9 a	2.6 a	3.6 a	2.0 a
Mean	2.1	2.9	1.6	2.3	3.2	1.6
CV (%)	14.0	9.5	12.6	10.9	11.8	7.8
LSD (0.05)	0.4	0.4	0.3	0.3	0.5	0.2
Cropping systems (C)						
Sole bean	2.0 a	2.9 a	1.5 a	2.3 a	3.1 a	1.5 b
Intercrop	2.3 a	3.1 a	1.7 a	2.4 a	3.4 a	1.7 a
Mean	2.1	2.9	1.6	2.3	3.2	1.6
CV (%)	14.0	9.5	12.6	10.9	11.8	7.8
LSD (0.05)	0.3	0.3	0.2	0.3	0.3	0.13
Significance levels						
P Tillage (T)	0.005	0.004	0.0005	0.02	0.01	0.0001
P Cropping (C)	0.2	0.08	0.08	0.4	0.11	0.003
p T × C	0.3	0.03	0.001	0.001	0.07	0.0001

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains. BA, before anthesis; AT, at anthesis; AF, after anthesis.

4. 3.20 Effect of tillage practices on leaf starch content of maize

Tillage practices significantly affected ($p \leq 0.05$) the leaf starch content of maize before anthesis and at anthesis in both SR 2015 and LR 2016 seasons.

(Table 4.24). For all the tillage practices, the leaf starch content of maize was the highest at anthesis stage in SR 2015 season (Table 4.24). Among the tillage practices, the maize plants grown under the F/R tillage recorded the highest leaf starch content in comparison to the maize plants grown under the CVT practices in the SR 2015 (Table 4.24). Cropping systems significantly affected ($p \leq 0.05$) the leaf starch content of maize only during SR 2015 cropping season (Table 4.24). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the maize leaf starch content at anthesis and after anthesis in both the SR 2015 and LR 2016 seasons (Table 4.24).

Table 4.24: Effect of tillage practices and cropping systems on leaf starch content of maize during short rains 2015 and long rains 2016 in Embu County, Kenya

Tillage practices (T)	SR 2015			LR 2016		
	BA	AT	AF	BA	AT	AF
Conventional tillage	6.6 b	8.2 c	4.03 a	6.9 b	9.6 c	4.9 a
Zero tillage	7.4 a	10.2 b	4.8 a	8.1 a	10.8 a	4.8 a
Furrows/ridges	7.6 a	11.3 a	4.8 a	8.3 a	12.3 b	4.2 a
Mean	7.2	9.9	4.5	7.8	10.9	4.6
CV (%)	4.1	5.8	1.03	8.3	4.9	15.3
LSD (0.05)	0.4	0.7	1.04	0.83	0.7	0.9
Cropping systems (C)						
Sole bean	7.1 b	8.9 b	5.2 a	7.6 a	10.1 a	4.7 a
Intercrop	7.4 a	10.8 a	3.9 b	8.0 a	11.7 a	4.6 a
Mean	7.2	9.9	4.5	7.8	10.9	4.6
CV (%)	4.1	5.8	17.8	8.3	4.9	15.3
LSD (0.05)	0.3	0.6	0.8	0.7	0.6	0.7
Significance levels						
P Tillage (T)	0.0004	<0.0001	0.21	0.006	<0.0001	0.3
P Cropping (C)	0.03	0.001	0.006	0.2	0.0001	0.8
p T × C	0.3	0.0002	0.008	0.1	0.0006	0.02

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains. BA, before anthesis; AT, at anthesis; AF, after anthesis.

4.3.21 Effect of tillage practices and cropping systems on the number of internodes of maize

Tillage practices significantly affected ($p \leq 0.05$) the number of internodes of maize plants in both SR 2015 and LR 2016 cropping seasons following an increasing sequence of CVT < ZT < F/R in SR 2015 and ZT, F/R < CVT in LR 2016 (Table 4.25). The number of internodes of maize plants grown under the F/R practices was 6.3 in SR 2015 and 5.5 in LR 2016 while those of maize plants under ZT was 6.2 in SR 2015 and 5.5 in LR 2016. Those under CVT practices were 5.6 in SR 2015 and 6.0 in LR 2016 (Table 4.25). The number of internodes differed significantly ($p \leq 0.05$) due to cropping systems only during LR 2016 season (Table 4.25). The intercropped maize had 6.0 internodes in comparison with the monocropped maize which had 5.3 internodes in the LR 2016. Interaction between tillage practices and cropping systems did not significantly ($p > 0.05$) affect the maize number of internodes per plant in both cropping seasons (Table 4.25).

Table 4.25: Effect of tillage practices and cropping systems on number of internodes of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Number of internodes	
	SR 2015	LR 2016
Conventional tillage	5.6 b	6.0 a
Zero tillage	6.2 ab	5.5 b
Furrows/ridges	6.3 a	5.5 b
Mean	6.0	5.7
CV (%)	5.5	5.9
LSD (0.05)	0.7	0.5
Cropping systems (C)		
Sole maize	5.9 a	5.3 b
Intercrop	6.2 a	6.0 a
Mean	6.0	5.7
CV (%)	5.5	5.9
LSD (0.05)	0.6	0.4
Significance levels		
P Tillage (T)	0.05	0.05
P Cropping (C)	0.3	0.005
P T × C	0.2	0.3

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.22 Effect of tillage practices and cropping systems on internode length of maize

Tillage practices significantly affected ($p \leq 0.05$) the maize internode length in both SR 2015 and LR 2016 cropping season following an increasing trend of

CVT < F/R < ZT in the SR 2015 season (Table 4.26). The mean internode length of the maize plants for all the tillage practice for the two cropping seasons was 16.7 cm (Table 4.26). The internode length of the maize plants under ZT plots was the highest (17.5 cm) while that of F/R plots was 16.5 cm and the lowest was 15.8 cm for the maize plants grown under the CVT plots in the SR 2015. Cropping systems significantly affected ($p \leq 0.05$) the internode length of maize plants only during the LR 2016 cropping season (Table 4.26). Interaction between tillage practices and cropping systems did not significantly ($p > 0.05$) affect the maize internode length in both seasons (Table 4.26).

Table 4.26: Effect of tillage practices and cropping systems on internode length of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Internode length (cm)	
	SR 2015	LR 2016
Conventional tillage	15.8 b	17.1 a
Zero tillage	17.5 a	16.7 b
Furrows/ridges	16.5 ab	16.3 b
Mean	16.7	16.7
CV (%)	5.8	1.9
LSD (0.05)	0.02	0.005
Cropping systems (C)		
Sole maize	17.0 a	16.3 b
Intercrop	16.3 a	17.1 a
Mean	16.7	16.7
CV (%)	5.8	1.9
LSD (0.05)	0.01	0.004
Significance levels		
P Tillage (T)	0.05	0.01
P Cropping (C)	0.15	0.003
p T × C	0.3	0.6

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.23 Effect of tillage practices and cropping systems on the stem diameter of maize

Tillage practices significantly affected ($p \leq 0.05$) the stem diameter of maize plants only in SR 2015 season with the decreasing sequence of ZT > F/R > CVT (Table 4.27). Cropping systems did not significantly affect ($p > 0.05$) the stem diameter of maize plants in both seasons (Table 4.27). Interaction

between tillage practices and cropping systems did not significantly affect ($p > 0.05$) maize stem diameter in both cropping seasons (Table 4.27).

Table 4.27: Effect of tillage practices and cropping systems on stem diameter of maize at anthesis during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Stem diameter (mm)	
	SR 2015	LR 2016
Conventional tillage	22.2 b	23.5 a
Zero tillage	29.0 a	24.7 a
Furrows and ridges	27.7 a	24.7 a
Mean	26.3	24.3
CV	8.9	10.3
LSD (0.05)	3.0	3.2
Cropping systems (C)		
Sole maize	26.4 a	25.3 a
Maize bean intercrop	26.1 a	23.2 a
Mean	26.3	24.3
CV	8.9	10.3
LSD (0.05)	2.5	2.6
Significance levels		
P Tillage (T)	0.002	0.7
P Cropping (C)	0.8	0.1
P T × C	0.3	0.6

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.24 Effect of tillage practices and cropping systems on the plant height of maize

The mean height of the maize plants due to tillage practices ranged from 212.3 cm to 292.8 cm for both cropping seasons (Table 4.28). Tillage practices significantly affected ($p \leq 0.05$) the height of maize plants in both seasons following an increasing sequence of CVT < F/R < ZT in SR 2015 and ZT, F/R < CVT in LR 2016 (Table 4.28). The plant height of the maize plants grown under the F/R plots was 310.5 cm in SR 2015 and 207.2 cm in LR 2016 while that of the maize plants under ZT plots was 323.8 cm in SR 2015 and 207.2 cm in the LR 2016. The plant height of the maize under CVT practices was 244.2 cm in the SR 2015 and 222.5 cm in the LR 2016 (Table 4.28). Plant height was only significantly affected ($p \leq 0.05$) by cropping systems in the LR 2016 (Table 4.28) with the intercropped maize plants being 221.4 cm tall and the monocropped maize plants being 203.1 cm tall (Table 4.28). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the maize heights in both cropping seasons (Table 4.28).

Table 4.28: Effect of tillage practices and cropping systems on plant height of maize at physiological maturity during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Maize height (cm)	
	SR 2015	LR 2016
Conventional tillage	244.2 b	222.5 a
Zero tillage	323.8 a	207.2 b
Furrows/ridges	310.5 a	207.2 b
Mean	292.8	212.3
CV (%)	4.9	4.6
LSD (0.05)	18.8	12.5
Cropping systems (C)		
Sole maize	295.7 a	203.1 b
Intercrop	290.0 a	221.4 a
Mean	292.8	212.3
CV (%)	4.9	4.6
LSD (0.05)	15.4	10.2
Significance levels		
P Tillage (T)	0.0001	0.03
P Cropping (C)	0.4	0.002
P T × C	0.5	0.2

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.25 Effect of tillage practices and cropping systems on number of ears per maize plant

Among the tillage practices, the mean number of ears per maize plant ranged from 1.0 to 1.9 in both cropping seasons (Table 4.29). Tillage practices significantly affected ($p \leq 0.05$) the number of ears only in the LR 2016 with an increasing trend of CVT < ZT < F/R (Table 4.29). The number of ears of the maize plants grown under the F/R practices was 2.5 in LR 2016 while that of maize plants grown under ZT practices was 2.0 in LR 2016 in comparison with those under CVT practices which was 1.2 ears (Table 4.29). Cropping systems significantly affected ($p \leq 0.05$) the number of ears per maize plant only during the LR 2016 season (Table 4.29). The maize plants grown under intercropped configuration had higher number of ears per plant (2.1 ears) in comparison with the maize plants grown under sole configuration which had 1.7 ears in the LR 2016 (Table 4.29). Interaction between tillage practices and cropping systems significantly affected ($p \leq 0.05$) the maize number of ears only in the LR 2016 season (Table 4.29).

Table 4.29: Effect of tillage practices and cropping systems on number of ears per maize plant during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	No. of ears / plant	
	SR 2015	LR 2016
Conventional tillage	0.9 a	1.2 c
Zero tillage	1.0 a	2.0 b
Furrows/ridges	1.0 a	2.5 a
Mean	1.0	1.9
CV (%)	3.7	11.9
LSD (0.05)	0.1	0.3
Cropping systems (C)		
Sole maize	1.0 a	1.7 b
Intercrop	1.0 a	2.1 a
Mean	1.0	1.9
CV (%)	3.7	11.9
LSD (0.05)	0.04	0.3
Significance levels		
P tillage (T)	0.2	0.0002
P cropping (C)	0.7	0.005
P T × C	0.2	0.02

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.26 Effect of tillage practices and cropping systems on the ear length of maize

Tillage practices did not significantly affect ($p \geq 0.05$) the ear length per maize plant in the two cropping seasons (Table 4.30). Cropping systems did not significantly affect ($p > 0.05$) the ear lengths of maize in both cropping systems (Table 4.30). Interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) ear length of maize plants in both seasons (Table 4.30).

Table 4.30: Effect of tillage practices and cropping systems on ear length of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Ear length (cm)	
	SR 2015	LR 2016
Conventional tillage	12.0 a	12.4 a
Zero tillage	12.0 a	12.3 a
Furrows/ridges	12.2 a	12.2 a
Mean	12.1	12.3
CV (%)	12.7	12.5
LSD (0.05)	1.9	1.9
Cropping systems (C)		
Sole maize	12.7 a	12.8 a
Intercrop	11.4 a	11.8 a
Mean	12.1	12.3
CV (%)	12.7	12.5
LSD (0.05)	1.6	1.6
Significance levels		
P Tillage (T)	0.9	0.9
P Cropping (C)	0.1	0.2
P T × C	0.2	0.5

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.27 Effect of tillage practices and cropping systems on the days to 50 % tasseling of maize

In all the tillage practices, the number of days to 50 % tasseling of maize ranged from 54.3 days in the SR 2015 to 64.4 days in the LR 2016 (Table 4.31). Tillage practices significantly affected ($p \leq 0.05$) the number of days to

50 % tasseling in the two seasons following the increasing sequence of CVT < ZT < F/R (Table 4.31). In all the tillage practices, the maize plants grown under the F/R tillage practices took significantly the longest number of days to 50 % tasseling (56.3 days in SR 2015 and 66.3 days in LR 2016) while those grown under ZT practices took (54.2 days in SR 2015 and 64.3 days in the LR 2016) The maize plants grown under the CVT plots took the fewest number of days to 50 % tasseling (52.3 days in SR 2015 and 62.7 days in LR 2016) (Table 4.31). Cropping systems did not significantly affect ($p > 0.05$) the number of days to 50 % tasseling of maize plants (Table 4.31). The interaction between tillage practices and cropping systems did not significantly affect ($p > 0.05$) the maize number of days to 50 % tasseling in both cropping seasons (Table 4.31).

Table 4.31: Effect of tillage practices and cropping systems on number of days to 50 % tasselling of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Days to 50 % tasseling	
	SR 2015	LR 2016
Conventional tillage	52.3 c	62.7 c
Zero tillage	54.2 b	64.3 b
Furrows/ridges	56.3 a	66.3 a
Mean	54.3	64.4
CV (%)	1.6	1.2
LSD (0.05)	1.2	1.1
Cropping systems (C)		
Sole maize	54.3 a	64.4 a
Intercrop	54.2 a	64.4 a
Mean	54.3	64.4
CV (%)	1.6	1.2
LSD (0.05)	0.9	0.9
Significance levels		
P Tillage (T)	0.0006	0.0006
P Cropping (C)	0.0006	1.000
P T × C	0.4	0.3

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.28 Effect of tillage practices and cropping systems on the number of days to 50 % physiological maturity of maize

In all the tillage practices, the maize number of days to 50 % physiological maturity ranged from 104.9 days in the SR 2015 to 108.7 days in the LR 2016 respectively (Table 4.32). The number of days to 50 % physiological maturity in the two crop growing seasons was significantly affected ($p \leq 0.05$) by the

tillage practices following an increasing trend of CVT < ZT < F/R (Table 4.32). The maize plants grown under F/R tillage practices took significantly the longest number of days to reach 50 % physiological maturity (106.3 days in the SR 2015 and 110.7 days in the LR 2016), while those grown under ZT practices took (105.5 days in the SR 2015 and 109.7 days in the LR 2016) (Table 4.32). The maize plants grown under CVT took significantly the fewest days to reach 50 % physiological maturity (103.0 days in SR 2015 and 105.8 days in LR 2016) (Table 4.32). Cropping systems significantly affected ($p \leq 0.05$) the maize number of days to 50 % physiological maturity only in SR 2015 season. (Table 4.32). The interaction between tillage practices and cropping systems only significantly affected ($p \leq 0.05$) the maize number of days to 50 % physiological maturity in the LR 2016 season (Table 4.32).

Table 4.32: Effect of tillage practices and cropping systems on number of days to 50 % physiological maturity of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Days to 50 % physiological maturity	
	SR 2015	LR 2016
Conventional tillage	103.0 c	105.8 b
Zero tillage	105.5 b	109.7 a
Furrows/ridges	106.3 a	110.7 a
Mean	104.9	108.7
CV (%)	0.4	0.9
LSD (0.05)	0.6	1.4
Cropping systems (C)		
Sole maize	104.7b	108.1 b
Intercrop	105.2 a	109.3 a
Mean	104.9	108.7
CV (%)	0.4	0.9
LSD (0.05)	0.5	1.1
Significance levels		
P tillage (T)	0.0001	0.0003
P cropping (C)	0.0006	1.000
P T × C	0.4	0.03

Values followed by different letters within the column are significantly different ($p \leq 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.29 Effect of tillage practices and cropping systems on the root length of maize

Tillage practices significantly affected ($p \leq 0.05$) the root length of the maize plants in both cropping seasons in the increasing sequence of F/R < ZT < CVT (Table 4.33). In all the tillage practices, the mean root length of the maize plants ranged from 35.6 cm to 36.2 cm in both cropping seasons (Table 4.33).

The root length of the maize plants grown under F/R plots was 30.7 cm in SR 2015 and 30.0 cm in LR 2016 while those of maize plants under ZT plots was 35.8 cm in SR 2015 and 35.5 in LR 2016. The root length of the maize grown under CVT was 42.0 cm in the SR 2015 and 41.2 cm in the LR 2016 (Table 4.33). Cropping systems did not significantly affect ($p > 0.05$) the root length of the maize plants in both seasons (Table 4.33). Interaction between tillage practices and cropping systems produced a significant difference ($p \leq 0.05$) in the root length of maize only in the LR 2016 season (Table 4.33).

Table 4.33: Effect of tillage practices and cropping systems on root length of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Root length (cm)	
	LR 2015	SR 2016
Conventional tillage	42.0 a	41.2 a
Zero tillage	35.8 b	35.5 b
Furrows/ridges	30.7 c	30.0 c
Mean	36.2	35.6
C.V	4.2	1.7
LSD (0.05)	1.9	0.8
Cropping systems (C)		
Sole maize	36.3 a	35.3 a
Intercrop	36.0 a	35.8 a
Mean	36.2	35.6
CV (%)	4.2	1.7
LSD (0.05)	1.6	0.6
Significance levels		
P Tillage (T)	0.0001	0.0001
P Cropping (C)	0.6	0.2
P T × C	0.4	0.0001

Values followed by different letters within the column are significantly different at ($p \leq 0.05$) according to Fisher's LSD; CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.30 Effect of tillage practices and cropping systems on harvest stand count of maize

Tillage practices significantly affected ($p \leq 0.05$) the percentage harvest stand count of maize plants only in the SR 2015 season following an increasing trend of ZT < CVT < F/R (Table 4.34). Cropping systems did not significantly affect ($p > 0.05$) the harvest stand count of maize in both cropping seasons

(Table 4.34). Interaction between tillage practices and cropping systems had no significant effect ($p > 0.05$) on the maize harvest stand count in both seasons (Table 4.34).

Table 4.34: Effect of tillage practices and cropping systems on harvest stand count of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Tillage practices (T)	Harvest stand count (%)	
	SR 2015	LR 2016
Conventional tillage	86.8 a b	87.1 a
Zero tillage	82.2 b	83.5 a
Furrows/ridges	88.4 a	88.3 a
Mean	85.8	86.3
CV (%)	4.5	4.4
LSD (0.05)	4.9	4.9
Cropping systems (C)		
Sole maize	86.1 a	87.1 a
Intercrop	85.5 a	85.6 a
Mean	85.8	86.3
CV (%)	4.5	4.4
LSD (0.05)	4.1	3.9
Significance levels		
P Tillage (T)	0.04	0.3
P Cropping (C)	0.7	0.4
P T × C	0.2	0.3

Values followed by the same letters within the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.31 Effect of tillage practices and cropping systems on shoot biomass of maize

Tillage practices did not significantly affect ($p > 0.05$) the shoot biomass of maize in both the SR 2015 and LR 2016 seasons (Figure 4.7). The shoot biomass of maize plants grown under the F/R plots was 3.4 t/ha in SR 2015 and 4.4 t/ha in LR 2016 while that of the maize plants grown under ZT was 3.6 t/ha in SR 2015 and 4.7 t/ha in LR 2016. The shoot biomass of the maize plants grown under CVT plots was 3.4 t/ha in SR 2015 and 4.5 t/ha in LR 2016 (Figure 4.7).

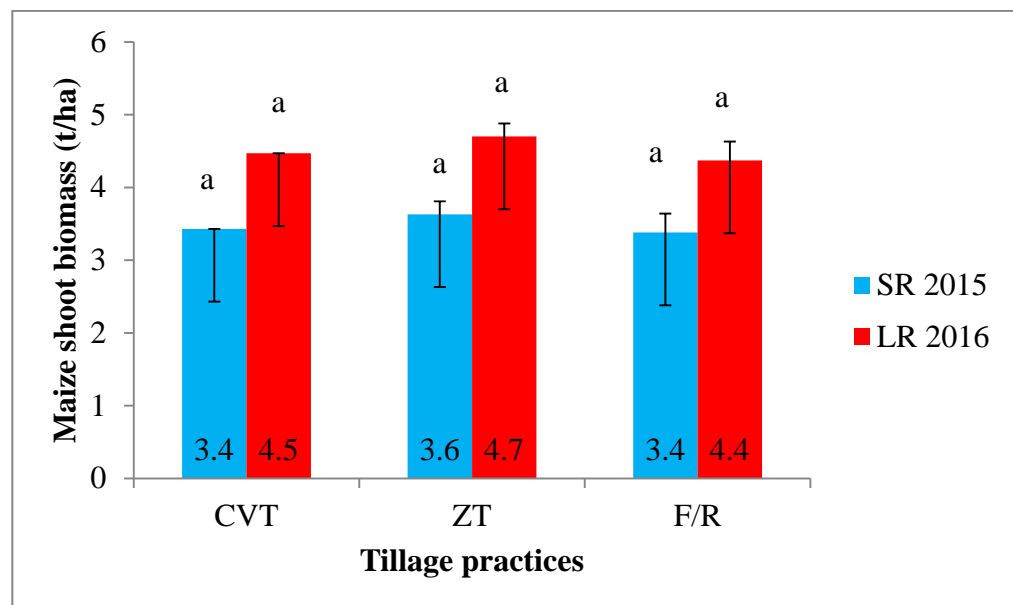


Figure 4.7: Effect of tillage practices on maize shoot biomass during short rains 2015 and long rains 2016 seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by the same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

The shoot biomass of maize was not significantly affected ($p > 0.05$) due to cropping systems (Table 4.35). There was no significant interactive effect ($P > 0.05$) between tillage practices and cropping systems on maize shoot biomass in both seasons (Table 4.35).

Table 4.35: Effect of cropping systems on shoot biomass of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Cropping Systems (C)	Shoot biomass (t/ha)	
	SR 2015	LR 2016
Sole maize	3.5 a	4.5 a
Intercrop	3.5 a	4.5 a
Mean	3.5	4.5
CV (%)	9.3	9.6
LSD (0.05)	0.4	0.5
Significance levels		
P Cropping (C)	0.9	0.8
P T × C	0.3	0.6

Values followed by the same letters along the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.32 Effect of tillage practices and cropping systems on grain yields of maize

Tillage practices did not significantly affect ($p > 0.05$) the grain yield of maize in both the SR 2015 and LR 2016 cropping seasons (Figure 4.8). The grain yield of maize plants grown under the F/R plots was 1.7 t/ha in SR 2015 and 2.1 t/ha in LR 2016 while that of maize plants grown under ZT plots was 1.9 t/ha in SR 2015 and 2.2 t/ha in LR 2016 in comparison with those grown under

CVT plots which was 1.8 t/ha in the SR 2015 and 2.3 t/ha in LR 2016 (Figure 4.8).

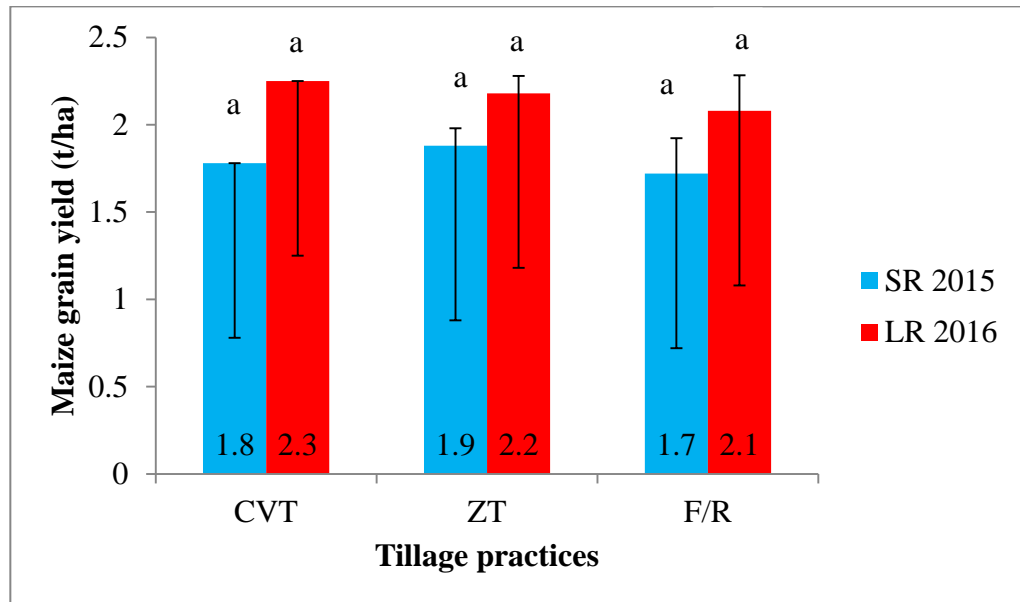


Figure 4.8: Effect of tillage practices on maize grain yield during short rains 2015 and long rains 2016 seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

Cropping systems did not significantly affect ($p > 0.05$) the grain yield of maize in both seasons (Table 4.36). There was no significant interactive effect ($p > 0.05$) of tillage practices and cropping systems on grain yields of maize in both seasons (Table 4.36).

Table 4.36: Effect of cropping systems on grain yields of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Cropping Systems (C)	Grain yield (t /ha)	
	SR 2015	LR 2016
Sole maize	1.8 a	2.1 a
Intercrop	1.8 a	2.2 a
Mean	1.8	2.2
CV (%)	8.7	17.7
LSD (0.05)	0.2	0.4
Significance levels		
P Cropping (C)	0.7	0.8
P T × C	0.4	0.3

Values followed by the same letters along the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

4.3.33 Effect of tillage practices and cropping systems on harvest index of maize

Tillage practices did not significantly affect ($p > 0.05$) the harvest index of maize in both the SR 2015 and LR 2016 seasons (Figure 4.9). The harvest index of the maize plants grown under the F/R plots was 50.8 % in SR 2015 and 47.7 % in LR 2016 while that of the maize plants grown under ZT plots was 51.7 % in SR 2015 and 46.1 % in LR 2016 in comparison with those grown under CVT plots which was 52.1 % in SR 2015 and 50.1 % in LR 2016 (Figure 4.9).

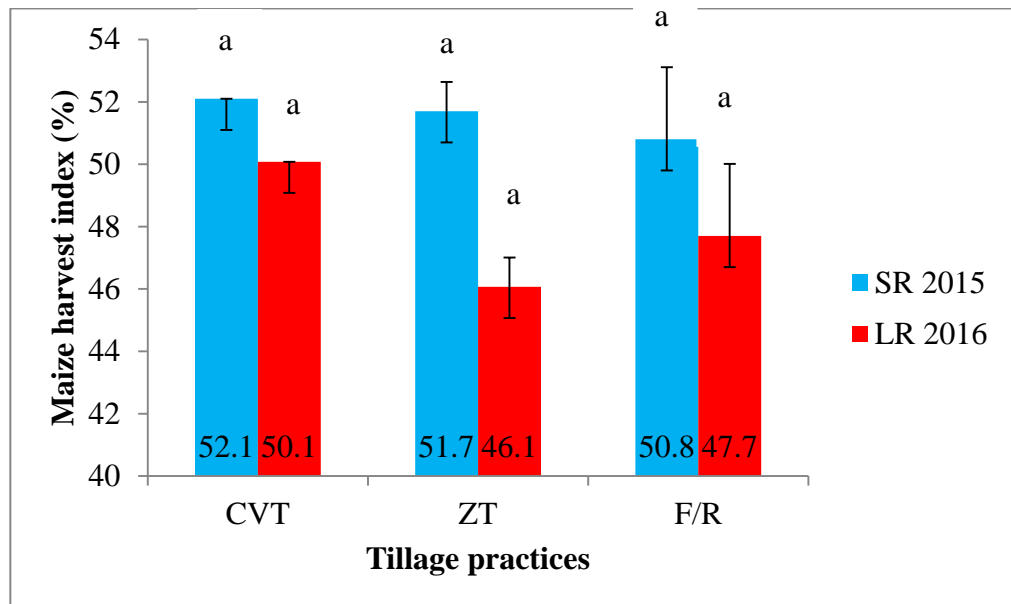


Figure 4.9: Effect of tillage practices on harvest index of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya. Error bars represent standard error. CVT, Conventional tillage; ZT, Zero tillage; F/R, Furrows and ridges tillage. Bars followed by the same letters are not significantly different ($p > 0.05$) according to Fisher's LSD.

Cropping systems did not significantly affect ($p > 0.05$) the harvest index of maize during SR 2015 and LR 2016 cropping seasons (Table 4.37). There were no significant interactive effects ($p > 0.05$) of tillage practices and cropping systems on the harvest index of maize during SR 2015 and LR 2016 cropping seasons (Table 4.37).

Table 4.37: Effect of cropping systems on harvest index of maize during short rains 2015 and long rains 2016 seasons in Embu County, Kenya

Cropping Systems (C)	Harvest index (HI %)	
	SR 2015	LR 2016
Sole maize	51.1 a	47.5 a
Intercrop	52.0 a	48.4 a
Mean	51.5	47.9
CV (%)	3.3	9.9
LSD (0.05)	1.9	5.5
Significance levels		
P Cropping (C)	0.3	0.7
P T × C	0.4	0.2

Values followed by the same letters along the column are not significantly different ($p > 0.05$) according to Fisher's LSD. CV, Coefficient of variation; LSD, Least significant difference; LR, long rains; SR, short rains.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Effect of tillage practices and cropping systems on the soil moisture content

The significant content of soil water recorded on the F / R plot can allow the slots to harvest and store more rainwater than the CVT plot where the slots do not have slots. It also reduces the loss of evaporation of the soil, and can also promote water infiltration when confined rainwater on the surface. This can have many waters in the root area of the plant. Similar results were obtained by Govaerts *et al.* (2007a), Giller *et al.* (2006) and Pereira *et al.* (1967). They were attributed to the thermal insulation effect of the remaining crop residue on the soil surface that reduces evaporation and steam transfer near the soil surface.

The results of this study are concurring with the results of Verhulst *et al.* (2010) was observed to improve the infiltration of soil moisture due to storage cultivation compared to the use of a conventional crop. These results are consistent with Wang *et al.* (2015) ZT treatment discovered that the soil moisture content on the ground is high due to the reduction of surface evaporation.

The proper use of soil moisture is reflected in a higher yield of corn (Blevins, 1971). The results of the current survey ensure that the culture system plays an important role in the availability of soil water. The nutrients of the plants are

absorbed from the floor by diffusion, working as well as solvent and serve as a nutrient carrier for the growth of plants. Water is a raw material for photosynthetic process, so plants with appropriate water increased levels of nutrients and photosynthesis and increased in final performance (Peters *et al.*, 2019).

It has been found that Mrabet (1997) has been found that soil moisture can be maintained above the wilting in the paramount area for up to 5 weeks in a zero crop combined with the crop residue cover during the CVT plot. This is only 15 days. It has been shown that a permanent floor cover with a practical culture residue F / R reduces surface runoff (Pereira *et al.*, 1967). This often leads to the availability of water and crops in the root zone (Bismonnais, 1996, Govaerts *et al.*, 2007b, Govaerts *et al.*, 2009).

This study consistent with Mrabet (2007), reported that the influence of culture and residue coverage to water penetration is caused by the change in soil texture. The discovery of this study is consistent with Bismonnais (1996) reported that the crop residue harvested on the surface of the soil was avoided directly with raindrops. And it is due to the wetting and fast drying of the soil. The aggregates are more stable by virtue of CT practices with residues of crop retained compared to CVT without residual retention (Verhulst *et al.*, 2010). Therefore, the practice of cultivation F / R plays an important role in preserving soil moisture from raw water excrement, especially during the dry season.

The higher ground water content registered under the plot where small and medium projections can be obtained can be attributed to the culture canopy protection effect and the reduction of the loss of evaporation of the surface. The result is consistent with the and Willy (1990) and Ghanbari *et al.* (2010). However, they are different from Karuma *et al.* (2014) and Steward *et al.* (2018) The interval cultures are growing and indicated that more water is transported as the canopy cover increases. The results of this study are similar to the results of Thierfelder and Wall (2009) studied in Zimbabwe in 2005/2006 and 2006/2007, and then established that TREATA with CT has an infiltration rate of 49% and 45% higher after an artificial rainfall in both seasons.

5.1.2 Effect of tillage practices and cropping systems on soil chemical properties

5.1.2.1 Effect of tillage practices and cropping systems on soil organic carbon

Compared to the CVT plot, the significant increase in soil organic carbon (SOC) observed in the ZT plot and the F / R plot due to agricultural practices in both seasons can be attributed to the retention of organic matter from soil. The impact of the crop Residues (SOM) in the soil are compared with plots where crop residues are not retained under CVT practice. Soil organic carbon is important for soil fertility because it affects the chemical and biological

activities of the soil that stimulate primary production (Micheni *et al.*, 2016; Zhang *et al.*, 2018). The increase in COS increases the cation exchange capacity of the soil, which means that the soil retains more cations for use by plants.

This study agrees with the argument of Dolan *et al.* (2006) and Engel *et al.* (2017) The SOC in CT is higher than CVT because crop residues remain in the soil. Zero tillage can lead to carbon sequestration (Bessam and Mrabet, 2003). The results obtained are consistent with those of Kassam *et al.* (2009) Who reported that keeping the residue on the soil surface helps the accumulation of SOM.

Jobbagy and Jackson (2000) also reported similar results. The results of this study are also consistent with those of Verhulst *et al.* (2010) Who has observed that no-tillage promotes SOC protection, the SOC concentration in the soil depends on the retained crop residues. The results of this study are also consistent with the results of Giller *et al.* (2009); Kong *et al.* (2009) and Zhang *et al.* (2018) Who determines that no-tillage and mulching will increase SOM, leading to COS accumulation Soil organic carbon plays a fundamental role in ensuring the availability of soil nutrients and stabilizing soil aggregates, because good management of organic matter is essential for sustainable agriculture (Foster *et al.*, 2018).

5.1.2.2 Effect of tillage practices and cropping systems on soil nitrogen

The observed percentage of soil nitrogen in the ZT and F / R plots increased significantly compared to the plots under the CVT practice, which can be attributed to the decomposition and decomposition of the crop residues incorporated in the F / R plots and ZT Mineralization. Nitrogen is an important mineral element and plant nutrition requires a large amount of nitrogen (Zhang *et al.*, 2018). The increase in nitrogen content is closely related to the increase in the photosynthesis process, which in turn increases crop yields (Sandhu *et al.*, 2019). The results of this study are consistent with those of Kong *et al.* (2009) found that compared to CVT, no-tillage contributes more to nitrogen stability and grain yield.

Wright *et al.* (2008) and Alam *et al.* (2018) Who reported that in a soil profile of 0 to 5 cm, ZT increased soil nitrogen by 27% compared to CVT. The addition of crop residues is characterized by an increase in the total nitrogen content of the soil (Dendooven and Deckers, 2009). Tillage and residue management have a significant impact on the transformation and distribution of nutrients in the soil (Gilliam and Fraser, 1987; Verhulst *et al.*, 2010). Conservation tillage practices contribute to the availability of nitrogen in the soil and influence the mineralization of nitrogen and soil organic carbon (Bradford and Peterson, 2000).

The significantly higher soil nitrogen observed in the maize-bean intercropping compared to single-crop beans during the 2015 SR can be attributed to the fact that intercropped legumes fix atmospheric nitrogen for plant use. Current research agrees with Fujita and Ofusu-Budu (1996); Kaluma *et al.* (2016) Who reported that the grain-lung intercropping system resulted in the growth of legumes and grain production to obtain higher nitrogen in different environmental conditions.

5.1.2.3 Effect of tillage practices and cropping systems on soil pH

Compared to CVT plots, the significant increase in soil pH observed in F / R and ZT plots can be attributed to the effects of retained crop residues, which reduce soil acidification and lower the pH value. corn and beans, thus helping to improve soil health. Most plant nutrients are available to plants in the pH range of 5.5 to 7.0, which is the optimal pH condition established for beans and corn (Allen and Edje, 1990; Yadav *et al.*, 2017; Opola *et al.*, 2018). Soil pH affects many plant characteristics, such as plant height, lateral plant distribution, and shoot biomass (Allen and Edje, 1990; Jiang *et al.*, 2017).

The results of the present study are similar to those of Van Eerd *et al.* (2014) and Zhang *et al.* (2018) Who reported that after 14 years of agricultural production, the soil pH of the Conservation Tillage (CT) plot was significantly higher than that of the CVT plot. The results of this study are also consistent

with Karuma *et al.* (2016) and Agegnehu *et al.* (2016) Who found that when the soil was corrected by crop residues, the soil pH increased from 4.97 to 5.63 instead of being corrected by applying crop residues.

5.1.3 Effect of tillage practices and cropping systems on bean and maize performance

5.1.3.1 Effect of tillage practices and cropping systems on emergence stand count of beans

The significantly higher bean emergence stand counts under F/R plots and ZT plots in comparison to those grown under CVT plots could be as a result of the better soil health, greater soil water storage capability and improved available water in the root zone. Hilel (1998) and Adeux *et al.* (2017) also found out that soils under CT practices have more moisture and heats up more slowly than soils under CVT practices.

The results of this study are in agreement with those of Belfield and Brown (2008) and Lenssen *et al.* (2018) who reported that crops establish better in CT systems where residue is retained on the soil surface than in the CVT systems where no crop residue is retained. They also noted that crop residues provide a good microclimate for the establishment of crops. The results of this study are also in agreement with those of Moraru *et al.* (2013) and Rodriguez, (1997) who found out that CT plots which were mulched had more moisture

accumulation and higher germination percentage of crops than unmulched CVT plots.

5.1.3.2 Effect of tillage practices and cropping systems on nodules per bean plant

The observed significantly higher root nodules of the bean plants under ZT plots and F/R plots in comparison to those under CVT plots can be attributed to the effect of crop residues left on the soil surface which conserved the soil water, moderated the soil temperatures and thus promoted biological activities especially those of the *Rhizobium spp.* The bean plants grown under the CVT plots had no crop residues retained on the soil surface and therefore less moisture was conserved. The soil temperatures were therefore not moderated hence less biological activities in the CVT plots.

Soil water content in the rooting zone has been reported to enhance nodule development and nodule activity (Liu *et al.*, 2012). For instance, studies have shown that soil water shortage results in decreased nodule number in common beans and the effects of the water shortage on the nodule number and activity depends on the severity of the water stress (Buttery *et al.*, 1998). The results of this study are in agreement with those of Ramos *et al.* (2003); Bedadi *et al.* (2018); Mulinge, (2018); Pataczek *et al.*, 2018 and Allemann, (2019) who reported that a decrease in soil water potential retards nodule growth and the fixation of nitrogen .

The more nodules per plant of the intercropped bean in comparison to the monocropped ones could be attributed to more moisture content because of the shading effect of the maize plants in the intercropped configuration which reduced evaporative water losses. The soil temperatures were therefore moderated creating a favorable environment for biological activities of the *Rhizobium spp.* The monocropped beans had few nodules per plant in both seasons in comparison with the intercropped beans and this could be because of less biological activity taking place from the uncovered inter rows (Willey, 1990; Mulinge, 2018; Allemann, 2019).

5.1.3.3 Effect of tillage practices and cropping systems on days to 50 % flowering of bean

The more number of days taken by bean plants to 50 % flowering under the F/R plots in comparison to those under CVT plots could be attributed to enhanced soil water content and better soil health in the CT practices which enhanced prolonged vegetative growth. Similar studies were conducted by Micheni *et al.* (2016) who reported increased mean number of days to 50 % flowering of beans in CT plots in comparison to those grown under CVT plots. The findings of this study differ with the findings of Onyari *et al.* (2010) and Corbeels *et al.* (2016) who found out that the method of tillage used did not significantly change the time required for the beans to attain 50 % flowering.

5.1.3.4 Effect of tillage practices and cropping systems on leaf chlorophyll concentration of bean plants

The highest chlorophyll content in all the seasons recorded at the flowering stage could be attributed to the synergistic effect of the conserved moisture by the crop residues and the fact that the bean crop residues which were applied as mulch could have undergone decomposition and mineralization thereby contributing some extra nitrogen which is essential to chlorophyll formation.

Also, significantly higher chlorophyll concentration for the bean plants grown under F/R plots and ZT plots after anthesis in comparison to those under CVT plots could be due to the conserved moisture by the crop residues and the fact that the bean crop residues which were applied as mulch could have undergone decomposition and mineralization thereby contributing some extra nitrogen which is essential to chlorophyll formation (Micheni, 2015). According to Jat *et al.* (2015), residue decomposition can release mineral nitrogen which is useful for plant growth.

The results of this study concur with those of Agamy *et al.* (2012) who detailed that improved plant supplements emphatically affect the plant's development and yield factors remembering chlorophyll for leaf cells. The consequences of this investigation are additionally in concurrence with those

of Pramanik (1999) who detailed that the spoiling of harvest deposits on the outside of the dirt contributes additional nitrogen which is fundamental mineral component in chlorophyll development. Yamori *et al.* (2016) announced that leaf photosynthesis was the main factor for grain yield and biomass.

Chlorophyll is a significant part of the Calvin–Benson cycle, and it is answerable for reaping light during photosynthesis, which brings about the excitation of electrons that are utilized to drive the creation of nicotinamide adenine dinucleotide phosphate and compound energy as adenosine triphosphate (Croft *et al.*, 2017). Leaf chlorophyll content is decidedly connected with the degree of photosynthesis in plant leaves (Xiao *et al.*, 2012). Photosynthesis is the essential determinant of harvest yield, and the proficiency by which a harvest catches light and converts it into biomass over the developing season is a critical determinant of conclusive yield (Long *et al.*, 2006).

5.1.3.5 Effect of tillage practices and cropping systems on leaf sugar content of bean

The significantly high rate sugars in bean plants at the blossoming stage in the two seasons could be credited to the way that the chlorophyll content was at its greatest and subsequently the plants were effectively engaged with the union of photosynthetic acclimatizes in anticipation of grain filling. This brought

about expanded photosynthetic action bringing about higher measures of sugars (Jahanzad *et al.*, 2016; Valadares *et al.*, 2016).

The lessening in sugar content in the leaves subsequent to blossoming might have been because of movement of the photosynthetic absorbs from the leaves to the grains during grain filling. This could likewise be credited to the way that the plant leaves had arrived at senescence henceforth the chloroplasts had begun maturing and subsequently minimal photosynthetic action was occurring (Pataczeck *et al.*, 2018). The outcomes got in this investigation are like the exploration consequences of Elzbieta and Malgorzata (2007), Patil *et al.* (1996) and Ibrahim *et al.* (2009) who noticed an expansion in bean sugar and starch content in mulched CT plots in contrast with unmulched CVT plots. In spite of this discovering, Wilkes *et al.* (2010) detailed that culturing rehearses had no impact on bean sugar content.

5.1.3.6 Effect of tillage practices and cropping systems on leaf starch content of bean

The significant higher rate starch content in bean plants at the blooming stage in the two seasons could be credited to the way that the chlorophyll content was at its most extreme and the plants were effectively engaged with the combination of photosynthetic absorbs in anticipation of grain filling. The noticed higher starch content for the bean plants developed under CT plots in contrast with those become under CVT plots could be credited to the more

chlorophyll content at all development stages. This brought about expanded photosynthetic movement bringing about higher measures of starch (Jahanzad *et al.*, 2016; Valadares *et al.*, 2016).

The decline in starch content in the leaves in the wake of blossoming might have been because of movement of the photosynthetic absorbs from the leaves to the grains during grain filling. This could likewise be credited to the way that the plant leaves had arrived at senescence henceforth the chloroplasts had begun maturing and subsequently minimal photosynthetic action was occurring (Pataczeck *et al.*, 2018).

Comparative outcomes were acquired by Elzbieta and Malgorzata (2007), Patil *et al.* (1996) and Ibrahim *et al.* (2009) who noticed an increment in bean starch content in mulched CT plots in contrast with unmulched CVT plots. Wilkes *et al.* (2010) actually revealed that culturing rehearses had no impact on bean starch content.

5.1.3.7 Effect of tillage practices and cropping systems on number of branches per bean plant

The observed significantly higher number of branches per plant due to tillage practices for the bean plants grown under the ZT plots and F/R plots in the SR

2015 in comparison to those under CVT plots could be as a result of better soil health as denoted by the improved soil moisture, soil organic carbon, nitrogen and pH conditions under the CT plots. Yield deposition preserves and deteriorates soil moisture, provides minerals to increase soil productivity, and promotes crop development by expanding cell division and cell elongation. The results obtained in this investigation are consistent with those of Amanullah *et al.* (2010) Who finds that the number of branches per plant varies greatly due to good agronomic harvesting practices and better soil welfare. Sadras and Rodríguez (2010) and Foster *et al.* (2018) reveal that crop yield is affected by crop physiological characteristics, soil, climatic conditions and agronomic practices.

Compared to bean monoculture, the higher number of branches per plant in intercropping may be due to improvement in soil moisture, soil nitrogen, and pH under the intercropping design (Micheni *et al.*, 2016). The number of branches per plant varies greatly due to the persistence of intercropping rather than individual crops. (2010). The yield of the crop is affected by the physiological properties of the crop, the soil, the climatic conditions and the agronomic practices (Sadras & Rodríguez, 2010).

5.1.3.8 Effect of tillage practices and cropping systems on number of pods per bean plant

Significantly high number of pods per plant due to tillage practices for the bean plants grown under the ZT plots and F/R plots in the SR 2015 in

comparison to those under CVT plots could be as a result of better soil health as denoted by the improved soil moisture, nitrogen and pH conditions under the CT plots. Yield deposition relieves soil moisture, just as decomposition provides minerals to increase soil richness and enhance crop development. The results obtained in this investigation are consistent with those of Amanullah et al. (2010) Who finds that due to good agronomic harvesting practices and better soil health, there are critical changes in the number of units per plant. Research by Sadras and Rodríguez (2010) and Foster et al. (2018) revealed that the crop yield is affected by the physiological quality of the crop, the soil, the climatic conditions and the agronomic practices.

Compared to monoculture beans, the higher number of cases per plant in intercropped beans may be due to better soil health, as evidenced by improvements in soil moisture, soil nitrogen, and pH in intercropping environments. There are critical changes in the number of units per plant due to the persistence of intercropping rather than monocultures. (2010). Sadras and Rodríguez (2010) announced that the number of cases per legume plant is affected by the physiological properties of the harvest, the soil, climatic conditions and agronomic practices.

5.1.3.9 Effect of tillage practices and cropping systems on number of seeds per bean pod

Significantly high number of seeds per bean pod obtained under the ZT plots and F/R plots in the SR 2015 in comparison to those under CVT plots could be attributed to better soil health under the CT plots. The applied crop residues conserved soil moisture and also underwent decomposition to release minerals. This improved the soil fertility and enhanced the growth of the bean crops hence more number of seeds per pod under the CT plots.

Similar results were obtained by Amanullah *et al.* (2010) who found out that there was a significant variation in the number of seeds per bean pod due to good crop agronomic practices and better soil health. The crop's physiological characteristics, soil, weather conditions and the agronomic practices have an influence on the crop yield as reported by Sadras and Rodriguez (2010) and Foster *et al.* (2018).

Significantly high number of seeds per pod in the intercropped beans in comparison with the monocropped beans could be attributed to the improved soil moisture, soil nitrogen and pH under the intercropped configuration. There is a significant variation in the number of seeds per pod due to adherence to intercropping than monocropping as reported by Amanullah *et al.* (2010).

5.1.3.10 Effect of tillage practices and cropping systems on days to 50 % physiological maturity of bean

The more number of days taken by bean plants to 50 % physiological maturity under the F/R plots in comparison to those under CVT plots could be attributed to high soil water content and better soil health. This enabled the bean chlorophyll integrity to last longer hence delaying the senescence of the leaves. The bean plants grown under CVT plots grew rapidly and reached 50 % physiological maturity earlier to utilize the little available water. Zhang *et al.* (2015) and Singh *et al.* (2015) observed that crop phenology depends on water and nutrient availability. The higher soil moisture content and increased availability of nutrients due to better soil health in the CT plots regulates the soil temperatures (Gosh *et al.*, 2006) and causes increased vegetative growth of the plants in CT plots and the cause of delayed phenology of crops (Wang *et al.*, 2012; Bowles *et al.*, 2014).

The findings of this study are in agreement with those of Van Donk *et al.* (2011) who reported delay in bean flowering under mulched CT practices as compared to unmulched CVT practices. The findings of this study contradict those of Onyari *et al.* (2010) and Corbeels *et al.* (2016) who found out that the method of tillage used did not significantly change the time for the beans to attain 50 % physiological maturity.

5.1.3.11 Effect of tillage practices and cropping systems on harvest stand count of beans

The significantly higher harvest stand count recorded for bean plants under ZT plots and F/R plots in comparison to those grown under CVT plots could be as a result of the higher emergence rates, higher soil moisture content and the better soil health in the these plots that helped to maintain a higher plant population throughout the season.

The findings of this study are in line with those of Zhang *et al.* (2015); Berti *et al.* (2017) and West, (2018) who reported a higher harvest stand count for bean plants under CT practices in comparison with those grown under CVT practices . Chen *et al.* (2019) reported that plant population depends on the soil properties and environmental conditions. On the other hand, the low soil moisture levels and low levels of nutrients under CVT plots might have resulted to plant mortality leading to a low plant population (Mc Dowell, 2011). The results of this study differ from those of Kutu (2012); Kumar *et al.* (2012) and West (2018) who found out that neither cropping system nor tillage had any significant effect on maize plant population .

5.1.3.12 Effect of tillage practices and cropping systems on shoot biomass of bean

The non-significant results on bean shoot biomass due to tillage practices obtained in this study are contrary to those of Ngwira *et al.* (2012) and Boysdston *et al.* (2018) who found out the highest shoot biomass of beans was in CT practices in comparison to those under CVT practices. Similar to the

findings of the present study, Giller *et al.* (2009) observed non-significant difference in the shoot biomass of the bean plants under CT and those under CVT. These observations are also consistent with the findings from Kiboi *et al.* (2019) who reported that CT practices would require a longer period to increase a plant's shoot biomass yields significantly.

The lower shoot biomass for the bean plants under intercropped configuration in comparison with the ones under sole configuration might have been attributed to the competition between the intercrops for light, water, nutrients and also due to the aggressive effects of maize on bean (Matusso *et al.*, 2014). Crops with C₄ (maize) photosynthetic pathways are dominant when intercropped with C₃ species (bean).

The low shoot biomass of the intercropped beans could also have been due to the shading effect of the beans by the taller maize plants (Belel *et al.*, 2014; Karanja *et al.*, 2014). This study concurs with Mucheru–Muna *et al.* (2011) that the low competitive capacity of the legumes compared to the cereals is due to its short root system and its shallow root distribution. This study also agrees with Belel *et al.* (2014) and Karuma *et al.* (2016) who argue that the yield reductions due to intercropping are due to competition for nutrients, solar radiation and moisture.

5.1.3.13 Effect of tillage practices and cropping systems on grain yield of bean

The non-significant difference in the results of grain yields of beans obtained in this study was also obtained by other researchers (Maltas *et al.*, 2013; Paul *et al.*, 2013). They reported that CT practices require a longer period of implementation to increase crop yields significantly. Similarly, non-significant difference in bean grain yields between CT plots and CVT plots was also obtained by Thiefelder *et al.* (2013) in a study conducted for eight seasons in Zimbabwe.

Findings from the present study are contrary to those of Ngwira *et al.* (2012) and Boydston *et al.* (2018) who found out that the significantly high grain yield of beans was in CT practices in comparison to CVT practices. On the other hand, Marwat *et al.* (2007), Abagandura *et al.* (2017) and Khorami *et al.* (2018) reported that beans under conventional tillage systems are more productive than beans under conservation tillage systems. They attributed the increase in grain yields under CVT plots to better root development that allows better nitrogen utilization, assimilation and remobilization. Contrary to the present findings, Moraru and Rusu (2012) also recorded a significant increase in bean yields under conservation tillage compared to conventional tillage. They attributed the increase in the bean yields to higher water accumulation in the CT soils caused by lower evaporation and changes in soil water permeability under the CT conditions.

5.1.3.14 Effect of tillage practices and cropping systems on harvest index of bean

The non-significant results on harvest index of the beans on conventionally tilled plots and conservation tillage plots obtained from this study are in line with the research findings of Patil and Sheelavantar (2009) and those of Anjum *et al.* (2019). Harvest index shows how efficiently plant assimilates stored in the stems are partitioned to the grains (Passioura and Angus, 2010).

The findings from the present study are contrary to those of Bakht *et al.* (2011) and Rasheed *et al.* (2003) who reported significantly high harvest index of beans in conservation tilled plots compared to conventionally tilled plots. The current study's findings also contradict the research findings of Amanullah *et al.* (2015) who observed significantly high harvest index of bean due to more favorable ecological conditions and improved crop husbandry in CT plots in comparison with the CVT plots.

5.1.3.15 Effect of tillage practices and cropping systems on emergence stand count of maize

Significantly high emergence stand counts of maize grown under F/R plots in comparison with those grown under CVT practices could be as a result of the better soil health in the plots, greater soil water storage capability and improved available water in the root zone.

The findings of this study are consistent with those of Zhang *et al.* (2015); Berti *et al.* (2017) and West, (2018) who reported higher percentage emergence rates for maize plants under CT practices in comparison with those grown under CVT practices. Hilel (1998) and Adeux *et al.* (2017) also found out that the soils under CT practices have more moisture and heats up more slowly than the soils under CVT practices. The results of this study are in agreement with those of Belfield and Brown (2008) and Lenssen *et al.* (2018) who noted that maize establishes better in CT systems where residue is retained on the soil surface.

The results of this study are also in conformity to those of Altuntas and Dede, (2009) that reported an increase in maize emergence under CT practices in comparison to CVT practices and attributed this to favourable soil properties for maize seedling emergence in the CT plots. Moraru *et al.* (2013) and Rodriquez, (1997) also found out that CT plots which were mulched had more moisture accumulation and more germination percentage in comparison with unmulched CVT plots.

5.1.3.16 Effect of tillage practices and cropping systems on the leaf chlorophyll concentration of maize

The chlorophyll concentration of the corn plants in the ZT plot and the correlation between the F / R plot and the CVT plot after flowering may be due to the way that the corn crop deposits applied as mulch maintain the humidity of the soil in the CT plot. it may have undergone decomposition and mineralization, thus providing additional nitrogen to the soil for use by the

corn plants. The most notable chlorophyll content in the two editing seasons during the flowering period may be due to the expansion and progress of chloroplasts, which expanded the rate of photosynthesis. The lower chlorophyll content after flowering can be attributed to the way the plant reaches senescence.

The chlorophyll content of leaves is closely related to the degree of photosynthesis of plant leaves (Xiao *et al.*, 2012). Photosynthetic rate determines crop yield, and the effectiveness of crops to capture light and convert it into biomass during the growing season is a key determinant of final yield (Long *et al.*, 2006). Yamori *et al.* (2016) also introduced in detail that leaf photosynthesis is the main factor in food production and biomass collection. Chlorophyll is an important part of the Calvin-Benson cycle, and its function is to harvest light in the process of photosynthetic interaction.

Namuko *et al.* (2009), Egli and Rucker (2012) revealed that high chlorophyll content indicates high harvest performance and high expected yield. The low chlorophyll content observed during the physiological development of crops can be attributed to the fact that the leaves of corn plants have senescence.

The conservation tillage test provided better soil welfare and higher soil moisture content in the CVT test (Barut *et al.*, 2017; Otieno *et al.*, 2017). According to Mehdi *et al.* (1999), under the higher soil water content in the CT practices, there is efficient absorption and utilization of nutrients such as soil nitrogen as compared to CVT systems. Therefore the increase of nitrogen uptake under the CT practices in comparison to CVT practices resulted in the

increase in maize leaf chlorophyll concentrations. The results obtained in this study are similar to those of Pandey *et al.* (2000), Rui *et al.* (2009), Rambo *et al.* (2010) and Munyao *et al.*(2019) who found out that the high soil water content in CT plots leads to an efficient nutrient uptake and utilization hence high chlorophyll concentration .

5.1.3.17 Effect of tillage practices and cropping systems on leaf area index of maize

Significantly high leaf area index (LAI) for the maize plants grown under ZT plots and F/R plots in comparison with those grown under CVT plots could be attributed to the higher soil moisture content and better soil health. This meant that the maize plants grown under F/R and ZT plots had a higher capacity to intercept photosynthetically active radiation and this led to higher rates of photosynthesis (Marek *et al.*, 2017). The findings of this study are likewise to those of Onyari *et al.* (2010) who established that the leaf area list of corn plants under CT test is fundamentally higher than that of corn grown under conventional crops 91 days after sowing.

The findings of this study are contrary to those of Carlesso *et al.* (2002) who reported higher LAI values for maize plants under CVT in comparison to those grown under CVT. According to Sanipan *et al.* (2010), there exists a strong relationship between LAI and the number of leaves per plant. This is because the more leaves per plant the more the canopy cover and the more the

interception of photosynthetic active radiation (PAR) and therefore increased photosynthetic activity (Karuma *et al.*, 2016). A higher LAI in a plant results in a better ground cover for lesser soil water evaporation (Sullivan, 2003). Higher soil moisture status under the CT plots stimulated more leaf growth as reported by Thobatsi (2009) and Mounce *et al.* (2016) who found a high LAI of 2.23 under maize intercropped with cowpea due to higher moisture status than monocropped maize.

5.1.3.18 Effect of tillage practices and cropping systems on number of leaves per maize plant

The higher number of leaves per plant for the maize plants grown under F/R plots and ZT plots in comparison with those grown under CVT plots could be attributed to the increased soil moisture retained because of the crop residues and better soil health which stimulated more leaf growth.

The results of this survey are consistent with those of Jean du Plessis (2003) and Colbach *et al.* (2017) and Sandhu *et al.* (2019) Who revealed that the number of leaves on a corn plant depends on ecological factors, such as soil moisture, temperature, and available soil supplements. The findings of this research cannot help but contradict the findings of Kutu (2012), who revealed that the number of leaves per plant in the CVT practices was greater than the number of leaves developed under the CT practices. According to Dolan *et al.* (2006) photosynthesis takes place in the leaves where biomass is produced, partitioned and stored for crop productivity.

5.1.3.19 Effect of tillage practices and cropping systems on the leaf sugar content of maize

The observed high percentage sugars in maize plants at the flowering stage in both seasons could be attributed to the fact that the chlorophyll content was at its maximum. The observed higher sugar content for the maize plants grown under F/R plots and ZT plots in comparison with those grown under CVT plots could be attributed to the more chlorophyll content.

The decrease in leaf sugar content in leaves after flowering may be due to the movement of photosynthetic acclimation agents from leaves to grains during grain filling. This can also be attributed to the way plant leaves reach senescence, whereby chloroplasts begin to mature and minimal photosynthetic movement occurs in this regard.

The results obtained in this study are similar to those of Elzbieta and Malgorzata (2007), Patil *et al.* (1996) and Ibrahim *et al.* (2009) who observed an increase in maize sugar content in mulched CT plots in comparison to unmulched CVT plots. Contrary to this finding, Wilkes *et al.* (2010) reported that tillage practices had no effect on maize sugar content.

5.1.3.20 Effect of tillage practices and cropping systems on the leaf starch content of maize

The observed high percentage of starch content in maize plants at the flowering stage in both seasons could be attributed to the fact that the

chlorophyll content was at its maximum and therefore the plants were actively involved in the manufacture of photosynthetic assimilates. Higher starch content for the maize plants grown under ZT and F/R plots in comparison to those under CVT plots could be attributed to the more chlorophyll content at all crop growth stages. This resulted in increased photosynthetic activity resulting in higher amounts of starch.

According to Sanipan *et al.* (2010) there exists a strong relationship between LAI, the number of leaves per plant, chlorophyll content and starch content. This is because the more number of leaves a plant has, the more the canopy cover. This results in a greater interception of photosynthetically active radiation (PAR) and therefore an increased photosynthetic activity (Sathish *et al.*, 2018). The decrease of starch content in leaves after flowering may be due to the movement of photosynthetic absorption from leaves to grains during grain filling. This can also be attributed to the way the leaves of plants reach senescence, that is, the chloroplasts begin to mature and the subsequent photosynthesis is very small.

Similar findings were obtained by Elzbieta and Malgorzata (2007), Patil *et al.* (1996) and Ibrahim *et al.* (2009) who observed an increase in maize starch content in mulched CT plots in comparison to unmulched CVT plots. Contrary to this finding, Wilkes *et al.* (2010) reported that tillage practices had no effect on maize starch content.

5.1.3.21 Effect of tillage practices and cropping systems on the number of internodes of maize

The significantly more internodes of maize plants grown under F/R plots during the SR 2015 in comparison with those of the maize plants grown under CVT plots could be attributed to the improved soil moisture content and better soil health in comparison to those of maize grown under CVT plots. Similar findings were also observed by Wall (2007), Nyawade *et al.* (2018) and Muoni *et al.* (2020), who reported that some of the benefits accrued from short to medium term of practicing CT farming methods over CVT practices are the increasing trends in the maize growth parameters.

5.1.3.22 Effect of tillage practices and cropping systems on the internode length of maize

The significantly long internodes of maize plants grown under F/R tillage plots in comparison with those of the maize plants grown under CVT plots could be attributed to the improved soil moisture and better soil health in comparison to those of the maize grown under CVT plots.

The results of this study are supported by the findings of Pervaiz *et al.* (2009) who reported that maize had longer internodes under CT tillage practices with greater mulch levels in comparison with those grown under CVT practices. They attributed this increase in internode length to the availability of more moisture content for plant growth and better soil health under the CT practices. The results obtained in this study differ with those of Verhulst *et al.* (2010),

Memon *et al.* (2012) and those of Kiboi *et al.* (2019) who reported taller maize plants with longer internodes in plots under CVT practices compared to those under CT practices.

5.1.3.23 Effect of tillage practices and cropping systems on the stem diameter of maize

The altogether higher stem breadth of the maize plants developed under F/R plots during the SR 2015 in correlation with those of the maize plants become under CVT plots could be because of the improved soil dampness and better soil wellbeing in contrast with those of maize become under CVT plots.

Comparative results were likewise seen by Wall (2007), Nyawade *et al.* (2018) and Muoni *et al.* (2019) who detailed expanding patterns in the maize development boundaries like expansion in stem measurement because of rehearsing CT. Despite what might be expected, the outcomes acquired in this investigation were not viable with those gotten by Aikins *et al.* (2012) and Anjum *et al.* (2014) who expressed that maize stem distance across was not altogether influenced in both CT and CVT plowed plots.

5.1.3.24 Effect of tillage practices and cropping systems on the plant height of maize

The significant plant height observed of the maize plants grown under F/R plots in comparison with the maize plants grown under CVT plots could be attributed to higher soil moisture conditions and better soil health. The results of this study are in conformity with those of Nandwa (1995) who observed increased maize height grown under CT plots in humic Nitisols soils of the central highlands of Kenya in comparison to the maize plants grown under CVT plots. Pervaiz *et al.* (2009) reported taller maize plants under mulched CT plots than in unmulched CVT plots and they attributed this phenomenon to more moisture contents available for plant growth under the CT plots than in the CVT plots. Similar results were obtained by Yi *et al.* (2017) who observed that mulched CT plots resulted to increased plant height of maize than unmulched CVT plots.

According to Nyawade *et al.* (2018) and Muoni *et al.* (2019), some of the benefits accrued from short to medium term of practicing CT farming methods are the increasing trends in the maize growth parameters. Higher plant height under the CT systems could be attributed to the soil organic matter which improved soil physical and chemical properties according to Lal (1976). These improved soil properties enabled the maize plants to maximize the use of water and nutrients (Zhao *et al.*, 2018).

The results of this study differ with those of Kutu (2012) who reported a higher plant height under conventional tillage than under zero tillage. The results obtained in this study also differ with those of Verhulst *et al.* (2011), Memon *et al.* (2012) and those of Kiboi *et al.* (2019) who reported taller maize plants in plots under CVT practices compared to those under CT practices.

5.1.3.25 Effect of tillage practices and cropping systems on number of ears per maize plant

Compared with CVT plots, the higher number of ears of corn plants saw in F/R plots can be ascribed to the way that corn plants under F/R cultivating rehearses advantage from higher maintenance mugginess and can be utilized for plants.

The consequences of this examination are reliable with those acquired by Belfield and Brown (2008); Tan *et al.* (2019) and Zhang *et al.* (2019) It was tracked down that the mulch in TC practice gives a decent microclimate to the foundation of harvests. Yi *et al.* They saw that contrasted and the CVT plot, the quantity of ears per corn plant in the CT plot was higher. (2017) He Wang *et al.* (2011). They credited this to the higher soil dampness content in the CT plot contrasted with the CVT plot.

5.1.3.26 Effect of tillage practices and cropping systems on ear length of maize

Compared to CVT practice, the greater corn ear length observed in F / R agricultural practice can be attributed to the fact that corn plants under F / R agricultural practice benefit from greater water conservation and provide it to the rooting area. Belfield and Brown (2008) also obtained similar results; Tan *et al.* (2019) and Zhang *et al.* (2019) Who finds that the coverage in TC practice provides a good microclimate for growing crops.

As per the Yi *et al.* (2017) Wang *et al.* (2011) the increase in the length of the maize ears in the CT plots is attributed to the high water content of the soil. The results of this study contradict the results of Anjum *et al.* (2019) compared with conservation tillage plots, longer ears of corn were obtained in conventional tillage plots. They attribute this to the maximum vegetative growth of corn, which captures sunlight and food reserves in conventional agriculture than in conservation agriculture.

5.1.3.27 Effect of tillage practices and cropping systems on days to 50 % tasseling of maize

Compared to maize grown in CVT plots, the longer it takes for corn maize to reach 50% tassels in F / R plots, which may be due to better soil health, crop residues, and furrows. Collect rainwater to get more soil moisture provided by plants.

The results of this study are consistent with those of Belfield and Brown (2008) and Musyoka *et al.* (2019) It was found that the coverage of the CT plots provided a good microclimate for the growth of the crops. Such a system allows greater infiltration and storage of rain in the soil profile throughout the season for crop use (Chen *et al.*, 2019). The research by Shinoto *et al.* (2019) also pointed out that 50% of panicle removal in CT plots was delayed by days compared to those planted in CVT plots. Therefore, the results of this study are consistent with the results of Singh *et al.* (2016) Who finds the phenology of corn depends on the availability of nutrients, soil conditions and the availability of water.

5.1.3.28 Effect of tillage practices and cropping systems on days to 50 % physiological maturity of maize

The more number of days taken by maize plants to reach 50 % physiological maturity under F/R plots in comparison to those grown under the CVT plots could be attributed to the higher soil moisture content and the better soil health with enhanced nutrients in the F/R plots in comparison with the CVT plots. The conserved soil moisture by the crop residues in the F/R plots led to high water content in the maize leaves enhancing longer chlorophyll integrity and delayed the senescence of the maize leaves.

The results obtained in this study are in conformity with those of Belfield and Brown (2008) and Musyoka *et al.* (2019) who found out that mulching in CT

practices provides a good microclimate for crop establishment hence delaying their days to 50 % physiological maturity. Therefore, such a system allows greater rainfall infiltration for more water storage in the soil profile for crop use throughout the season (Chen *et al.*, 2019).

5.1.3.29 Effect of tillage practices and cropping systems on the root length of maize

The shorter root for the maize plants grown under F/R and ZT plots in comparison to those grown under CVT plots could be attributed to the fact that more soil moisture and nutrients were on the top soil profile. The plants therefore did not sink their roots deeper in the soil in search for water and mineral nutrients unlike the maize plants grown under CVT plots.

The findings of this study are in agreement with those of Varsa *et al.* (1997); Hiel *et al.* (2016) and Sun *et al.* (2018) who reported that maize grown under the CVT plots had longer roots than the maize plants grown under CT plots. The shorter root length of the intercropped maize compared to maize grown under sole configuration could have been due to competition and obstruction between the maize and beans (Jiang *et al.*, 2017).

5.1.3.30 Effect of tillage practices and cropping systems on harvest stand count of maize

The significantly high harvest stand count of the maize plants recorded under F/R plots in comparison to those grown under CVT plots could be as a result of the higher soil moisture content, higher maize emergence stand count and

the better soil health. These factors worked synergistically to maintain a high plant population in the F/R plots in comparison to the CVT plots.

The findings of this study are consistent with those of Zhang *et al.* (2015) , Berti *et al.* (2017) and West, (2018) who reported a higher percentage harvest stand count for maize plants under CT practices in comparison with those grown under CVT practices . Chen *et al.* (2011) reported that plant population depends on soil properties and environmental conditions and therefore the improved soil moisture content and better soil health in the CT plots might have resulted in the maintaining a high plant population. On the other hand, the low soil moisture levels and low levels of nutrients under CVT plots might have resulted to plant mortality leading to a low plant population (Mc Dowell, 2011).

5.1.3.31 Effect of tillage practices and cropping systems on shoot biomass of maize

Compared with the CVT plot, the higher biomass conversion of maize plant buds in the ZT plot may be attributed to higher soil water content and better soil welfare, which synergistically expands LAI and increases yield. Corn plant. In the sense of a high fixed content of chlorophyll, sugar and starch, the photosynthetic rate expands. As Nelson *et al.* (2010), the most significant biomass development is attributed to more prominent interference from solar energy and expanded photosynthesis. Finally, the most prominent LAI and the most prominent photosynthesis result in a more prominent corn biomass yield.

The results obtained from this study are consistent with those of Khan *et al.* (2001); Mc Williams (2003) and Zhao *et al.* (2018).

As pointed out by Sarkar (2005), higher humidity levels produce root reproduction and increase the availability of mineral supplements for root editing. Ngome *et al.* (2011) found that acceptable soil conditions improved the performance of corn, thereby providing better soil for managers when handling Ferralsol, Acrisol and Nitisols in western Kenya. The sequels of this research also apply to the studies by Ozpinar (2009) and Sandhu *et al.* (2019) Simultaneously reduce the ZT chart.

The equivalent biomass of maize buds was observed both in intercropping and in monocultures. The results of this inspection could not help but contradict the results of Dahmardeh (2010), Ngwira and others. (2012) Lai *et al.* (2017) who noticed that the corn bud biomass expanded under the intercropping framework in contrast to corn plants in a single environment.

5.1.3.32 Effect of tillage practices and cropping systems on grain yield of maize

Compared with corn plants grown under CVT plots, the non-significant grain yield of corn plants grown under CT plots can be attributed to the fact that the high soil moisture content and better soil moisture content in CT plots Soil health does not necessarily translate into corn grain yield. They reported similar non-significant corn yield results by Rockstrom *et al.* (2009). Engaged

in conservation and conventional farming plots in Kenya and Tanzania at the same time. Gwenz *et al.* (2008) when working in the semi-arid area of Zimbabwe, it was observed that the yield of maize kernels depends more on the maize genotype than the farming system.

The results obtained from this study contradict the results of Khan *et al.* (2001); McWilliams (2003); Buah *et al.* (2017) and Zhao *et al.* (2018) The report indicated that compared to the CVT plot, the corn production in the CT plot has increased significantly. They attribute the significant increase in corn production to the better water savings of the CT plot compared to the CVT plot. Several other researchers reported that compared to CVT plots, grain yield in CT plots increased significantly (Aflakpui *et al.*, 1993; Buah *et al.*, 2000; Miriti *et al.*, 2012; Zheng *et al.*, 2014; Thierfelder *et al.*, 2017).

Compared to the monoculture configuration, the higher grain yield of maize plants in the intercropping configuration can be attributed to the higher soil water content and additional nitrogen fixed by intercropping legumes. Murungu *et al.* (2011) and Tsubo *et al.* (2003) reported that the grain-legume intercropping system is more productive than a simple maize configuration. Working simultaneously in several areas in South Africa. Intercropping allows crops to make better use of growth resources (Gitonga *et al.*, 2008; Lelei *et al.*, 2009 and Odendo *et al.*, 2011). Intercropping maize plants are more

competitive as C4 plants than legumes (C3) (Belel *et al.*, 2014; Karanja *et al.*, 2014 and Matusso *et al.*, 2014).

It is reported that compared with monoculture, intercropping can increase crop growth because it can efficiently use natural resources (Ghanbari *et al.*, 2010). The results of this study are consistent with those of Nielsen *et al.* (2010) and Singh *et al.* (2016) who reported that higher LAI is associated with higher interception of photosynthetically active radiation, therefore higher rate of photosynthesis and ultimately higher yield development.

5.1.3.33 Effect of tillage practices and cropping systems on harvest index of maize

The non-significant results of the corn harvest index obtained in this study are consistent with the results of Patil and Sheelavantar (2009) and Anjum *et al.* (2019). They obtained negligible results of the corn harvest index in conventional agricultural plots and protected agricultural plots.

The results of the harvest index of the current study contradict the results of Amanullah *et al.* (2015) observed that due to the more favorable ecological conditions and the improvement of the feeding of the crops in the CT plots, the corn harvest index has increased significantly. The results obtained also contradict the findings of Bakht *et al.* (2011) and Rasheed *et al.* (2003) Who

reported that the corn harvest index of conservation tillage plots was higher than that of traditional tillage plots.

The results obtained from this study can accept the hypothesis that conservation tillage practices increase soil moisture content, improve soil health, and improve the physiological parameters of corn and beans.

5.2 Conclusions

1. Implementation of CT practices resulted in significantly high soil moisture content in the F/R plots in comparison to ZT and CVT.
2. Practicing CT practices led to a significant increase in the soil organic carbon, soil nitrogen content and soil pH suggesting an improvement in the soil health for plots under CT practices in comparison with those under CVT practices.
3. Conservation Tillage practices improved the crop physiological parameters such as leaf area index, leaf chlorophyll concentration, bean and maize sugars and the starch content. This helps to explain the observed increase in the bean grain yields under the CT plots in comparison to those grown under the CVT plots.

5.3 Recommendations

1. The experiment should be conducted for a longer time to capture the long term effects of CT practices (ZT and F/R) in the study area and in the other geographical regions.
2. More studies need to be conducted on maize and bean physiological parameters such as transpiration rates, photosynthetic rates, and plant's relative water content, stomatal conductance, leaf temperatures, grain sugars, starch and proteins under the CT practices.
3. The government should train and sensitize farmers about benefits of CT practices and the farmers should adopt the F/R tillage practices for enhanced soil moisture content and improved soil health which is conducive for the growth of maize and beans in the region.

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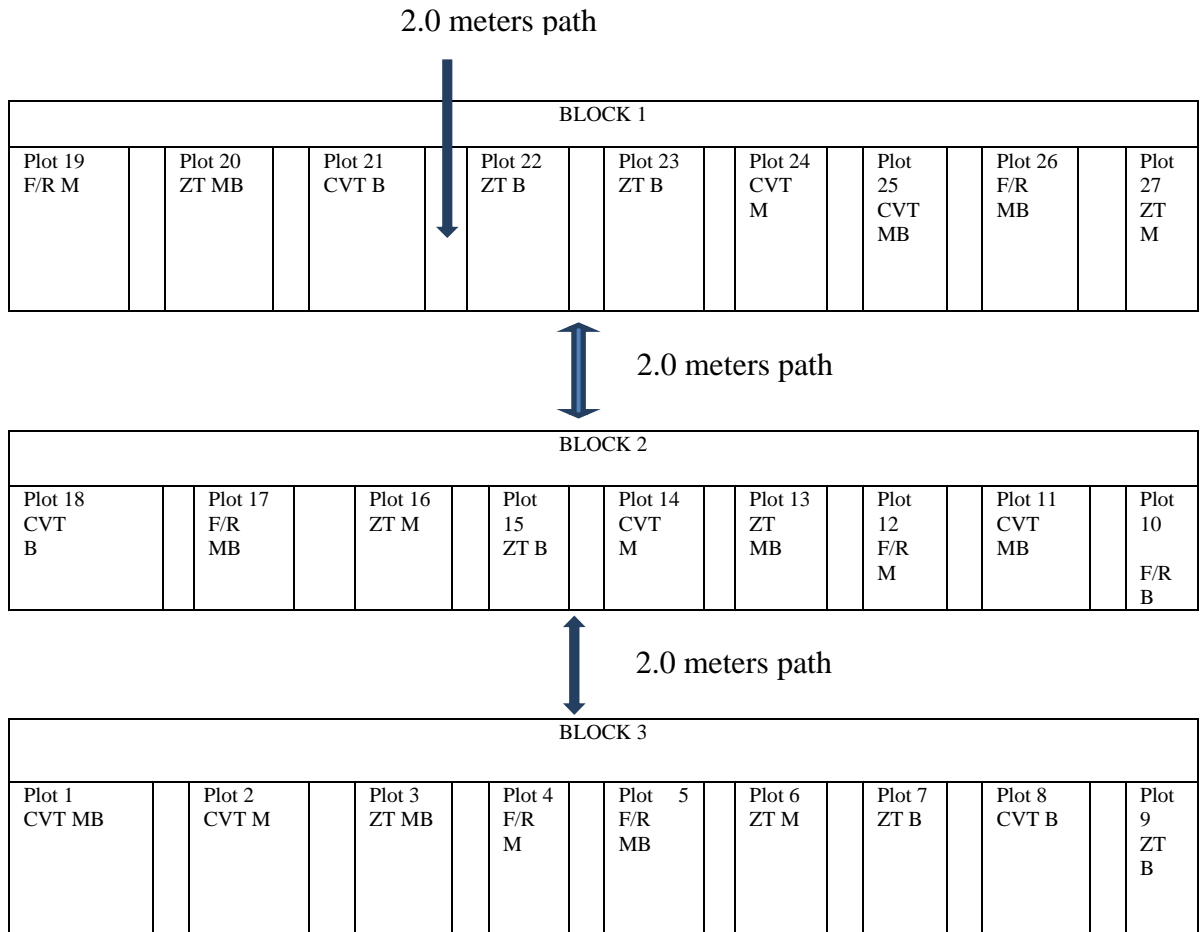
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APPENDICES

APPENDIX 1: Trial layout



Where;

CVT B Conventional tillage sole beans

CVT M Conventional tillage sole maize

CVT MB Conventional tillage maize bean intercrop

ZT B Zero tillage sole beans

ZT M Zero tillage sole maize

ZT MB Zero tillage maize bean intercrop

F/R B Furrows and ridges sole beans

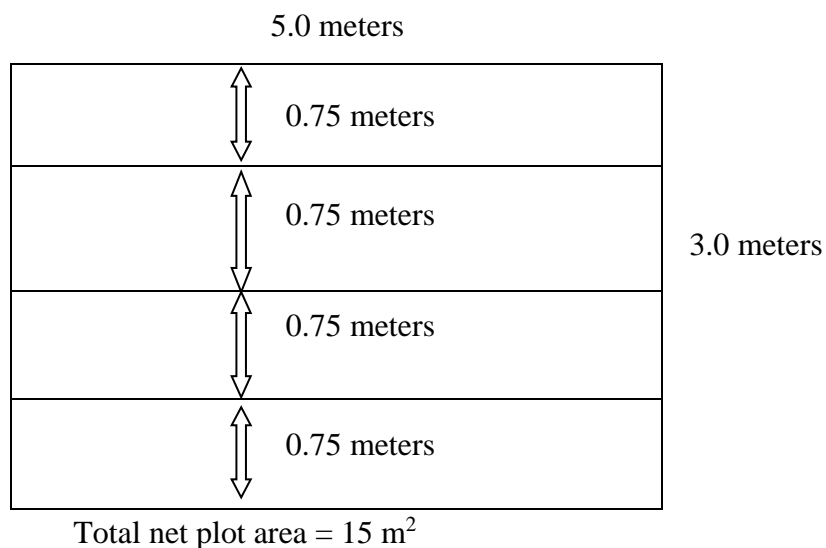
F/R M Furrow and ridges sole maize

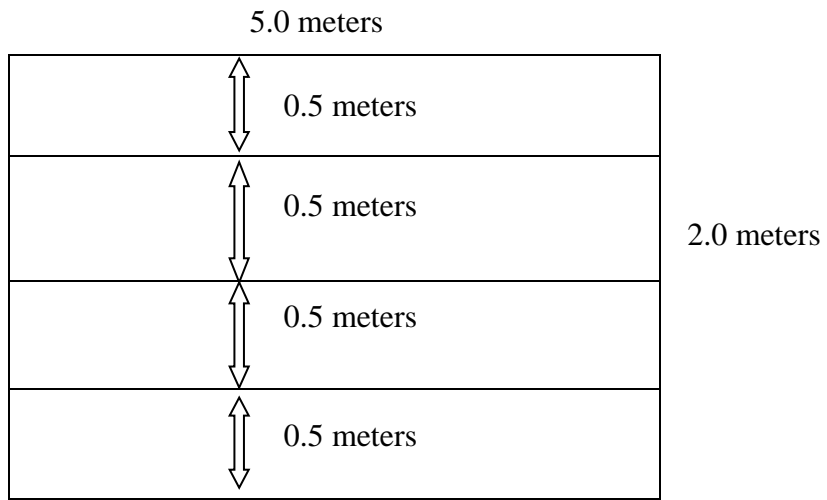
F/R MB Furrow and ridges maize bean intercrop

APPENDIX 2: Maize and Bean net plots

The net plots where data collection took place were determined by laying a 5 meters long rope across the experimental plots five times on five rows of each test crop. This gave the length of the net plots. The width of the net plots was determined by adding the total spacing of the crops between the rows. The area of the net plots was then determined by multiplying the length by the width. The side rows and the plants at the start and at the end of each row were not considered during data collection.

(i) Maize net plot



(ii) Bean net plot

APPENDIX 4: Publication

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**African Journal of Agricultural
 Research**

Full Length Research Paper

Effects of conservation tillage on maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) chlorophyll, sugars and yields in humic nitisols soils of Embu County, Kenya

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An experiment was conducted to determine the effects of conservation tillage (CT) practices on leaf chlorophyll content, sugars and yields of *Zea mays* L. and *Phaseolus vulgaris* L. for two consecutive cropping seasons at the Kenya Agricultural and Livestock Research Organization farm in Embu County, Kenya. The experimental design was a Randomized Complete Block Design with 9 treatments replicated 3 times. The treatments were, conventional tillage sole maize, zero tillage sole maize, Furrows/Ridges sole maize, conventional tillage sole bean, zero tillage sole bean, furrows and ridges sole bean, conventional tillage maize-bean intercrop, zero tillage maize-bean intercrop, furrows/ridges maize-bean intercrop. *Zea mays* L. and *Phaseolus vulgaris* L. plants grown under the CT plots had significantly more chlorophyll content, more sugar content and more grain weight than those under conventional tillage practices (CVT). The results provided a physiological basis for the observed increase in yields. They led to a conclusion that the CT method is suitable for improving crop productivity through enhancing physiological functions in the leaf.

Key words: Conservation tillage, chlorophyll, grain weigh.

INTRODUCTION

Approximately 65% of agricultural land in Sub-Saharan Africa (SSA) is degraded (Rockstrom et al., 2009). A major cause is intensive soil tilling and removal of crop residues (Rockstrom et al., 2009). Arable agriculture across sub-Saharan Africa is exposed to climate stress and climate change is predicted to further increase risks


of both extreme temperatures and drought (Niang et al., 2014). Negative impacts on crop yields are therefore expected (Schlenker and Lobell, 2010; Lobell et al., 2011).

According to Chivenge et al. (2007), tillage practice plays an important role in the manipulation of nutrient

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APPENDIX 5 Research Authorization



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GRADUATE SCHOOL**

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Our Ref: 156/CE/23734/2013 DATE: 1st March 2016

Director General,
National Commission for Science, Technology
& Innovation
P.O Box 36023-00100
NAIROBI

Dear Sir/Madam,


RE: RESEARCH AUTHORIZATION FOR MUNYAO JOSEPH KYALO- REG. NO. 156/CE/23734/2013.

I write to introduce Mr. Munyao Joseph Kyalo who is a Postgraduate Student of this University. He is registered for M.Sc. degree programme in the Department of Plant Sciences.


Mr. Munyao intends to conduct research for a M.Sc. Proposal entitled, "Effects of Conservation Agriculture Practices on Soil Moisture Retention, Organic Carbon, Maize and Bean Physiological Parameters and Yields".

Any assistance given will be highly appreciated.

Yours faithfully,


23 MAR 2016
MRS. LUCY N. MISAABU
FOR: DEAN, GRADUATE SCHOOL

APPENDIX 6 Research Approval



**KENYATTA UNIVERSITY
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Internal Memo

FROM: Dean, Graduate School **DATE:** 10th March 2016

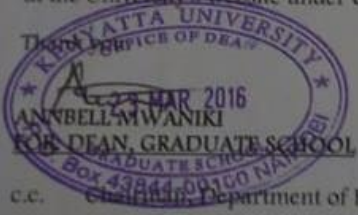
TO: Munyao Joseph Kyalo **REF:** 156/CE/23734/13
 C/o Plant Science Department.

SUBJECT: APPROVAL OF RESEARCH PROPOSAL
 =====

This is to inform you that Graduate School Board, at its meeting of 24th February 2016, approved your Research Proposal for the M.Sc. Degree Entitled, "Effects of Conservation Agriculture Practices on Soil Moisture Retention, Organic Carbon, Maize and Bean Physiological Parameters and Yields".

You may now proceed with data collection, subject to clearance with the Director General, National Commission for Science, Technology and Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking forms per semester. The form has been developed to replace the progress report forms. The supervision Tracking Forms are available at the University's website under Graduate School webpage downloads.



c.c. Chief, Plant Science Department of Plant Sciences

Supervisors:

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AM/m