ASSESSING THE EFFECTIVENESS AND BENEFITS OF CONVENTIONAL AND MINIMUM TILLAGE ON WEED MANAGEMENT IN MAIZE (*Zea mays* L.)

BY

BONIFACE A. NYAGA ITA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE IN CROP PROTECTION

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2012

DECLARATION

This thesis is my original work and has not been presented to any other University for award of a degree

Boniface A. Nyaga Ita

Sign------------------------------------ Date 6. 8. 2012

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

Professor Ratemo W. Michieka

Sign ---------------------------------- Date 8th Aug. 2012

Dr. Emmanuel S. Ariga

Sign---------------------------------- Date 7/8/2012

Dr. William M. Muiru

Sign ---------------------------------- Date 8/8/12

DEDICATION

I dedicate this work to my wife Aliphina and my children Peris, Edwin, Oliver and Risper for their love, sacrifice, unwavering support and encouragement during the course of my studies.

ACKNOWLEDGEMENTS

I would like sincerely to thank Prof. R.W.Michieka, Dr. E.S.Ariga and Dr.W. M. Muiru for their dedication in supervising me throughout the research period. Their continuous guidance and constructive ideas have enabled me to successfully complete my field study.

I would like equally to thank Hottensiah W. Mwangi (Mrs), Dr. Z.M. Kinyua for their financial support through their projects without which I could not have been able to execute my field work.

My thanks also go to my wife and children, father Titus Ita, mother Charity Nginya, brothers and sisters, friends and workmates for their prayers and moral support in one way or another during my study.

Overall I would like to thank the Almighty Lord who has provided all the resources and conducive atmosphere in the course of my studies. May His name be honoured and glorified for ever.

TABLE OF CONTENTS

Page

LIST OF TABLES...Page

LIST OF FIGURES..Page

ACRONYMS

A	Aggressivity
AYL	Actual Yield Loss
CAN	Calcium Ammonium Nitrate
CBS	Central Bureau of Statistics
CIMMYT	International Centre for the Improvement of Maize and Wheat
CR	Competitive Ratio
EPZA	Export Processing Zones Authority
FAO	Food and Agriculture Organisation (of the United Nations)
FIPSAFRICA Ltd	Farm Input Promotions Africa Limited
IA	Intercropping Advantage
ICRISAT	International Crops Research Institute for the Semi Arid Tropics
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
IRRI	International Rice Research Institute
KARI	Kenya Agricultural Research Institute
KMDP	Kenya Maize Development Programme
KNBS	Kenya National Bureau of Statistics
K	Relative Crowding Coefficient
LER	Land Equivalent Ratio
LH1	Lower Highland 1
LMBL	Late Maturing Big Leaf
LRS	Leaf Reduced Stature
MAI	Monetary Advantage Index
MOA	Ministry of Agriculture
NOMAFSI	Northern Mountainous Agricultural and Forestry Science Institute
NPK	Nitrogen Phosphorous Potassium
NRIL	Natural Resources Institute Ltd
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs

SMP	Soil management project
SOWAP	Soil and Water Protection
UH0	Upper Highland 0
UH1	Upper Highland 1
UM1	Upper Midland 1
UM2	Upper Midland 2
UM3	Upper Midland 3
USDA	United States Development Agency
VNPPI	Vietnamese Plant Protection Institute
WAP	Weeks After Planting
ZTAT	Zero Tillage Association for the Tropics (Brazil)

APPENDICES

ABSTRACT

In Kenya maize is the staple food crop with 80% of the population using it as the main human food and its shortage always causes food crisis threatening economic and political stability. Weeds are a major constraint to maize production due to the associated losses and increased costs of their management. Weeds alone can cause an estimated 80% yield loss in maize depending on species and abundance. The aim of the study was to identify a suitable tillage practice for better management of weeds in maize to increase production. The trial was conducted in Kigumo District near Gatumbi market during the long and short rain seasons in 2010. The treatments comprised of two maize varieties DUMA SC41 and DK8031, four tillage practices glyphosate, conventional, intercropping and weedy. The experiment was laid out in a randomized complete block design (RCBD) and replicated three times. Data on weeds and maize were collected from each plot and analyzed using Gen Stat software package and ANOVA was used to assess the effects of different treatments. Treatments means were separated using Student New Man Keuls and Statistical difference determined at $p < 0.05$. Results for weed count and dry weight biomass showed that glyphosate was more effective in suppressing the weeds than hand weeding. There were no significant differences between glyphosate and hand weeding in maize grain yield in short and long rain seasons. Cost benefit analysis for the two tillage practices showed that glyphosate produced higher returns than hand weeding. Weed count and biomass dry weight results for monocrop and intercrop showed that intercropping was more effective in weed suppression than monocrop. Intercropping increased maize yield for the two maize varieties overall by 47.9% more than monocrop and reduced labour costs. Glyphosate and intercropping had no significant differences for the parameters assessed in both seasons. Glyphosate and intercropping each reduced weed population by 63.6% and 64.4% respectively compared with the weedy/control. Performance of glyphosate and intercropping were not significantly different but since glyphosate may not be affordable by majority of small scale farmers, they should be encouraged to grow maize intercropped with *Dolicos lablab* to manage the weeds, improve maize yield, reduce cost of herbicide or weeding and achieve better utilization of land and labour.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Maize *(Zea mays)* worldwide is ranked second among most popular cereals after wheat while rice is third but maize is the highest in terms of grain production. It is also the second most important food crop in Africa after cassava (FAO, 1992). Today maize is grown in all suitable agricultural regions of the world such that maize crop is harvested somewhere around the earth each month of the year (FAO, 1992).

Tillage has been an integral part of crop production for centuries, tillage practices play an important role in determining the status of weed communities in most Agricultural areas by exerting selection pressure on weed communities thereby creating niches that favour or discourage species (Buhler, 2005). The main purpose of tillage is to eliminate weed competition besides aerating the soil and allowing water percolation thereby creating favourable environment for crop growth. Information on weed population shifts due to tillage practices assists in identifying the vulnerable stages of the weed life cycle that can be utilized in weed management systems as well as species that are favoured by changes in tillage practices. This makes knowledge of weed-crop growth characteristics and the dynamics of weed emergence very vital (Akobundu, 1998).

In Kenya like in many developing countries weed management by conventional tillage practice is the norm for majority of the small scale farmers involved in maize production. The practice is labour intensive characterized by low farm inputs, use of simple tools such as hoes and pangas, and mostly rely on family and to a lesser extent on hired labour or draught animals like oxen and donkeys when affordable (Chui, *et al,* 1996). The practice is inefficient leading to low maize yields due to factors like availability of the draught animals, lack or low level of inputs as most of farmers tend to rely on livestock manure or crop residue since fertilizer is out reach for most of them. Lack of capital to hire labour is a major constraint as family source is inadequate to meet the labour demand especially during the peak periods since most family members are engaged in other activities like studies in schools and higher institutions oflearning, Nyoro, (2002).

Majority of these farmers grow their maize intercropped with leguminous crops like beans, *Dolicos*, green grams, cow peas and pigeon peas or other cereal crops like millet, sorghum, and finger millet to capitalize on the available land, labour and minimize chances of crop failure due to drought or pests (Tegemeo, 2009).

On the other hand minimum tillage/zero tillage practices are capital intensive and are beyond the reach of the small scale farmers due to high resource requirements, (high level of inputs) and are mostly used in developed countries. They involve use of herbicides, mulch, crop rotation, cover crops, rippers or their combinations where possible with the aim of minimizing soil disturbance as much as possible in the process of weed management. In this category the farms are big and machinery are used in all operations like land preparation, fertilizer application, planting and pesticides application for pests control. This system is used by large scale maize producers (commercial maize farmers) who are few in the country compared with small scale farmers (KNBS, 2001).

1.2 Problem statement

The quantity of maize produced in the country today barely meets the needs for the increasing population. Despite the great efforts made to increase maize production, the demand has occasionally outstripped the supply, forcing the government to import substantial quantities to bridge the gap. Earlier information according to Pingali, (2001) ranked Kenya third after Mexico and Malawi with maize per capita consumption of 125 kg putting annual requirement at 3.2 million tons against production of 2.8 million tons leaving a short fall of 0.4 million tons each year. According to KMDP, (2009) maize contributes about 40% of daily calories with an average Kenyan consuming 98 kg of maize each year and the poorest quarter of the population spending 28% of its income on the crop. In Kenya's crop production patterns maize accounts for about 20% of gross farm out-put for small-scale farming sector (Jayne *et al.*, 2001).

An estimated consumption of 37 million bags against production of 23 million bags per annum due to both biotic and abiotic factors is an issue of great concern for the nation (Tegemeo, 2009). Biotic factors include insect pests, arthropods, diseases and weeds, while the abiotic ones are lack of resources (farm inputs) and climate change causing droughts and floods, resulting to poor maize yields and consequently increasing cases of malnutrition in the country.

Among the biotic factors, weeds are the major constraint in maize production as they compete with maize for various resources like water, nutrients, light and space, some act as alternate hosts to insect pests and disease causing microorganisms (IRRI and CIMMYT 2009). Other weed species have allelopathic effects on maize further reducing its productivity. In Kenya maize yield losses of up to 81% have been recorded (Esilaba, 2006), maize yields loss depending on the weed species and density are in the range of 15-90% (Maina, 1997) and 10-100% according to Smalling *et al*, (1991) and on average weeds account for 80% of the crop yield loss depending on the weed species and density (Spitters *et al*, 1989). The most problematic weeds in Kenya include *Striga hermonthica* (Del.) Benth- (purple witch weed), *S. asiantica* (L.) O. Ktze (red witch weed), Sedges (*Cyperaceae*) *Cyperus rotundus* L.(nut grass/water grass), *C. esculentus* (yellow nut sedge), *Digitaria abyssinica* (blue couch grass/couch grass), *Portulaca oleracea* (Purslane weed) and *Oxalis latifolia* (Oxalis sp).

Conventional tillage method most commonly used by peasant farmers to control weeds in maize production is hand weeding which is tedious, drudgery and inefficient Chui *et al.*, (1996). Considering that the critical period of weed competition for maize is 2-6 weeks after crop emergence and maize also requires to be weeded three times minimum to keep weeds at threshold for maximum yield, continued use of this method has led to low productivity due to soil degradation with adverse weather conditions (climate change) worsening maize output (Hobbs, 2007). Labour has become scarce and expensive due to various problems such as chronic illness associated with HIV/AIDS in the society, migration of able bodied segment of the population in search of white collar jobs, thus limiting maize production.

1.3 Justification

Maize grain and its products is the preferred food by the Kenyan society today and its shortage will always cause food crisis in the country despite presence of other food crops, threatening economic and political stability as development funds are diverted and scarce foreign currency drained by its importation. It is used as the gauge for household food security such that a low – income household is considered food insecure if it lacks maize stock in store regardless of other food it has.

Economically suitable areas for maize production in the country especially in the Mt. Kenya region is severely limited by various factors. Depending on Agro ecological zones maize competes with various enterprises. In the Highland zones (UHO, UH1) and above it will not do well due to frost, in the Lower highland (LH1) zones, maize competes with tea and dairy for land use and in the Upper midland (UM1) zones, it competes with tea and coffee, while in the lower (UM2) and (UM3) zones maize production is severely curtailed due to competition with coffee for land. In all these competitions, cash crops and dairy are given preference since they have better returns in terms of income to farmers than maize. In the semi-arid, arid and marginal zones maize will not do well as rainfall is deficient, the last two zones with provision of irrigation facilities have the highest potential for maize production and food security in the country.

Population increase has further reduced the arable land not only for maize production but also other crops adversely affecting the country in terms of available suitable land for farming as the population growth estimated at 3.5 % keeps land demand on the increase (KNBS, 2009) negatively impacting on 17 % of the country which is suitable for rainfed crop production according to Wokabi, (1994).

Climate change has drastically reduced maize production even in areas where the crop does well causing shortages and serious food insecurity in the country (Mati,2000). The impact of these factors has necessitated intensification of maize production in the available areas to increase productivity per unit of land. Employment of weed management practices to avoid yield losses due to weed competition increases cost of production, therefore choice of an efficient and affordable weed management technology should be made. The young energetic generation resent farming sometimes due to use of labour intensive weed management practices abandoning it to the old people. With the adoption of a better weed management practice like zero tillage which is not tiresome farming can become attractive to the youth and improve the crop productivity.

There is scanty information available on difference in maize yield between glyphosate in maize monocrop and intercrop treatments. This study was important to establish a suitable tillage practice in the slopes of Kenya for maize production to prevent erosion due to the steep and hilly nature of the terrain, it was also meant to assist decision makers especially agricultural extension officers to give proven information on tillage practice.

1.4 Objectives

1.4.1 General objective

To increase maize production for food security, nutrition, and ameliorate poverty by identifying a suitable tillage system for weed management.

1.4.2 Specific objectives

1. To compare effectiveness of glyphosate 36% EC a.i (Round up) (zero) and hand weeding (conventional) tillage practices on weed management in maize.
2. To determine cost benefit of weed management for the glyphosate (zero) and hand weeding (conventional) tillage practices in maize production.
3. To assess effects of intercropping and monocropping on weed population and maize yield.
4. To compare effectiveness of glyphosate (zero) and intercropping tillage practices on weed management in maize.

1.5 Hypotheses (H1)

1. There are differences in weed suppression and maize yields between hand weeding (conventional) and zero tillage practices of weed management in maize production.
2. Different tillage practices of weed management in maize production vary in their cost/benefits.
3. Intercropping and monocrop tillage practices of weed management in maize production differ in their weed suppression and maize yields.
4. There are variations in weed suppression maize yields between zero and intercrop tillage practices in maize production .

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin, economic importance and nutritional value of maize

Maize (*Zea mays* L.) belongs to the gramineae (poaceae) family, is an annual plant with extensive shallow fibrous root system which makes it vulnerable to drought, severe winds and nutrient deficiency. Maize unlike other major cereal crops has male and female flowers in different parts of the plant which encourages cross pollination leading to high rate of hybrid corn production (Dowswell, *et al.,* 1996).

'Maize' is an Indian word for corn meaning "literally that which sustains life," it is a grass domesticated by indigenous people in Mesoamerica in pre-historic times. Maize originated from Central America particularly in Mexico, the oldest maize about 7,000 years was found by archaeologists in Teotihuacan, a valley near Puebla in Mexico (FAO,1992). It was cultivated by Aztec and Mayan in numerous varieties in central and southern Mexico although possibly there could be other secondary centres of origin in the Americas FAO, (1992). Maize is thought to have been derived from teosinte, an ancient wild grass from Mexico and Guatemala Sprague *et al.,(* 1988).

From Mexico maize spread northwards to Canada, southwards to Argentina reaching all parts of the continent between 1250 AD and 1700 AD. Between 15th and early 16th century after discovery of the American continent by Christopher Columbus it was introduced to Europe through Spain. From Spain it spread through the warmer climates of the Mediterranean region to northern Europe, and due to its popularity and ability to grow in diverse climates it spread to the rest of the world, reaching Africa in the 16th, century through Portuguese explorers. World maize production stood at 817,110,509 metric tons by 2009, among the world maize producers US leads in production and exportation of maize and maize products in the world about (42.5%) (Table 1), Wikipedia, (2010).

Table 1: Top ten world maize producers 2009

Country	Area (000 ha)	Production (metric tones)	Percentage of the world production	Yield(metric tones/ha)
United States	32,209,277	333,010,910	42.5	10.34
China	30,478,998	163,118,097	20.8	5.35
Brazil	13,791,219	51,232,447	6.5	3.71
Mexico	7,200,000	20,202,600	2.5	2.81
Indonesia	4,160,659	17,629,740	2.2	4.2
India	8,400,000	17,300,000	2.2	2.06
France	-	15,299,900	1.95	-
Argentina	2,337,175	13,121,380	1.67	5.61
South Africa	-	12,050,000	1.5	-
Ukraine	-	10,486,300	1.3	-
World Production	159,531,007	817,110,509[A]		5.12

A = Aggregate (may include official, semi official or estimates)
Source: Wikipedia 2010

The top ten countries produced 83.12% with most of the world maize produced in America by US, Brazil, Mexico and Argentina. Maize production world wide has increased over time, land planted with maize in1961 was 105 million ha compared to 127 million ha in 1987 and although part of the increase was attributed to additional land area planted FAO, (1992), most of the increase was due to genetic improvement and more efficient technological field practices, fertilizer applications and introduction of new highly reproductive varieties. In 2007 more than 150 million ha of maize world wide were planted giving yield of 4,970.9 kg/ha (Wikipedia, 2010).

Worldwide maize is a very important cereal crop, first as a human food where the whole grain either mature or immature may be used, or may be processed by dry milling to give a wide range of products such as maize grits of different particle size, maize meal, maize flour and flaking grits. In developing countries where it is grown under subsistence agriculture maize remains the basic human food supplying 15-20% of the total daily calories in the diets of more than 20 of these developing countries (Dowswell *et al.*, 1996). In these developing countries, maize is the basic human food for majority of the poor people and 68% of the land is utilized to produce only 46% of the crop hence the need to improve the crop productivity (Pingali *et al.,* 2000). Likewise in the sub Saharan African developing countries, two thirds of the world proportional area is set for maize cultivation (Mulaa *et al*, 2011). As human food maize provides carbohydrates, proteins, vitamin B, B_{12} and minerals (Table 2). Maize is deficient in two essential amino acids lysine and tryptophan making it a poor source of protein. People whose diets are maize based (in America and Africa) are susceptible to pellagra a nutritional disease caused by niacin deficiency (Faqs.org.., 2007). Maize oil contains high level of poly unsaturated fatty acids and natural antioxidants (Okoruwa, 1996).

Second, maize grain is used as animal feed in the developed countries while the green plant is used to make silage for livestock. More than 60 percent of the production in the developed countries is used in compounded feeds for poultry, pigs and ruminant animals. In developing countries dried leaves and stalks after harvest are used by small scale farmers as forage for their ruminant animalsFAO, (1992).

Third, in Industry maize is used as a basic raw material for production of corn starch and oil, protein, fructose corn syrup (soft drink), food sweeteners and alcoholic beverages, dextrose for making vitamin C and penicillin, ethanol for fuel and gluten for animal feed, biodegradable chemicals and plastics, paper and textiles (FAO, 1992).

Table 2: Percentage composition of maize kernel

Chemical component	Maize grain part		
	Pericarp	Endosperm	Germ
Protein	3.7	8.0	18.4
Ether extract	1.0	0.8	33.2
Crude fibre	86.7	2.7	8.8
Ash	0.8	0.3	10.5
Starch	7.3	87.6	8.3
Sugar	0.34	0.62	10.8

Source : Watson,1987, In: FAO Corperate document repository (*Maize in human nutrition)*

Different forms of maize grown for food classified as various subspecies based on the starch content are Flour corn – *Zea mays var. amylacea*, Pop corn – *Zea mays var. everta*, Dent corn – *Zea mays var. indentata*, Flint corn –*Zea mays* – *Zea mays var. indurate*, Sweet corn – *Zea mays var. saccharata* and *Zea mays var. rusoga*, Waxy corn – *Zea mays var. ceratina*, Amylomaize – *Zea mays*, Pod corn – *Zea mays var. tunicata larranaga* ex A.St. Hil., and Striped maize – *Zea mays var. japonica*. In spite of its great diversity in form, all main types of maize known today were apparently already being produced by the native populations when the American continent was discovered (Wikipedia, 2010).

2.2 Production requirements

Maize (*Zea mays var. amylacea*- flour corn), considered to be the most important sub species of the *Zea mays* species is found in all parts of the world where it is grown over a wide range of latitudes.

In Canada and former Union of Soviet Socialist Republic, it grows from latitude 58^0 to latitude 40^0 in the Southern Hemisphere and is also grown in regions below sea level in the Caspian Plain and at altitudes of more than 4,000 m above sea level in the Peruvian Andes (FAO,1992). Maize is facultative long night plant which flowers in certain number of growing degree days (10^0C) in the environment where it is adapted. The effects imposed by the long nights on the number of days for the maize to flower is determined by genetic characteristic of the maize through the phytochrome system (FAO, 1992).

According to ICRISAT, (2009), maize prefers medium conditions of temperature, rainfall and altitude up to 2200 m above sea level since it does not tolerate frost. It is a warm weather crop requiring considerable warmth from germination to flowering around 22^0C and night temperature above 15^0C. High noon temperatures above 35^0C for several days will destroy pollen severely reducing the yields. Day temperatures less than 19^0C and night temperatures below 21^0C during the first 3 months will adversely affect the crop. The maize crop requires 500–750 mm of well distributed rainfall for proper growth.

Currently various varieties have been bred to suit different agro ecological zones like late maturing varieties (6-10 months) for high rainfall areas medium varieties (5-7 months) for moderate rainfall areas and early maturing ones (4-5 months) for marginal rainfall areas where they can give satisfactory yields. Maize prefers fertile alluvial or loam soils which are free draining since it is intolerant of water logging (MOA, 1981).

2.2.1 Maize production and consumption trends in Kenya

Development of maize to a major crop in Kenya took place during the first world war through the colonial government encouragement by provision of late maturing white maize variety seed facilitating the transition from millet to maize based economy. After the war emergence of export markets encouraged maize production and by 1930, maize had become the dominant food crop in most of Kenya and Tanzania (Gerhart, 1975). Today maize is the staple food for most of Kenyan communities where 80% of the population use it as the main human food in different forms and serves both as a food and a cash crop (Michael, 1989). Maize is grown in all major Agricultural areas of the country with an estimated area under its cultivation of 1.6 million hectares. Local seeds, composites and hybrids are used for production depending on rainfall regime (KNBS, 2001).

In 1964-1975 Kenya showed flourishing maize production potential by attaining yield of 2 metric tones per hectare due to introduction of maize hybrids and accompanying technologies often referred to as "Kenya's green revolution" (Kibaara, 2005). During the period of bumper harvest the country sold the surplus maize to Tanzania, Uganda, Rwanda, Zaire, Sudan and Ethiopia among other countries. Conversely the trend changed to a conspicuous yield decline up to 1977 from 1.85 metric tones per hectare in the period 1985-1989 to 1.57 metric tonnes per hectare. Currently, maize production in Kenya is 2 tonnes per hectare, nevertheless the country's 6 tonnes per hectare potential is achievable by use of, improved maize varieties, good agronomic practices like better methods of weeds, insect pests and diseases management among others, when farm inputs and weather conditions are not limiting (EPZA, 2005). The last two decades have witnessed the country changing from a maize exporter to an importer to bridge the gap between the production quantity and the consumption requirement as a result of sector reforms since 1992. According to Kirimi *et al.*,(2004), the gap between maize production and consumption in Kenya keeps on widening and is bridged by imports from Uganda, South Africa, USA and Zambia (Table 3).

Table 3: Kenya maize production statistics per province 2009

Province	Item		
	Crop area (Ha)	Bags (90kg)	Yields (Bags/Ha)
Rift Valley	644,895	13,225,039	20.5
Nyanza	262,453	3,711,215	14.1
Eastern	462,401	3,903,141	8.4
Western	225,302	4,163,878	18.5
Coast	129,379	1,079,383	8.3
Central	157,063	1,047,879	6.7
North Eastern	2,525	5,520	2.2
Nairobi	1,053	6,420	6.1
Total Production	1,885,071	27,142,475	14.4
Consumption/yr		36,000,000	
Deficit		-8,857,525	

Source: Economic review of Agriculture, 2010

According to Economic review of Agriculture (2010) maize consumption was estimated at 36,000,000 (90kg bags) and production at 27,142,475 (90kg bag) leaving a deficit of 8,857,525 (90kg bags) in 2009.

In a favourable year with adequate rainfall and optimal weather conditions a total of 34 million tones of maize grain is produced in Kenya but in a drought year yields have been noted to fall as low as 18 million tonnes. Maize is produced under rain-fed conditions by two categories of farmers, the small scale and the large scale farmers. Small scale farmers are about 3.5 million producing 75% of the crop, they are spread all over all the maize growing zones in the country (Figure 1), they grow most of the maize mainly for domestic use and will only sell the excess or when need arises. Large scale farmers (commercial maize producers) are about 1,000 concentrated in the Rift valley districts of

Trans Nzoia, Uasin Gishu and Nakuru accounting for 25% of the crop production in the country (KNBS, 2001).

The overall mean maize productivity measured in 90-kg bags per acre gives a consistent and encouraging growth from 6.6 bags in 1997, 7.2 bags in 2000, 8.2 bags in 2004, to 9.3 bags in 2007, similar trend was reported by the Ministry of Agriculture. Nationally the increase in maize yield was attributed to good weather, use of improved seeds, application of higher fertilizer and adoption of modern farming technologies according to KNBS, (2008).

The high potential maize zone, Central highlands, Western transitional and the Western highlands had higher productivity compared with the Coastal lowlands, Eastern lowlands, Western lowlands and the Marginal rain shadow. Inspite of this, the lower maize productivity regions of Coastal lowlands, Eastern lowlands and Western lowlands over the decade had substantial increase in maize productivity per acre: from 2.0 bags in 1997 to 4.2 bags in 2007 for Coastal lowlands; from 2.3 bags in 1997 to 4.7 bags in 2007 for Eastern lowlands; and from 3.0 bags in 1997 to 5.6 bags in 2000 for Western lowlands (Kibaara *et al*, 2008).

The Marginal rain shadow also increased maize productivity from 2.1 bags/acre in 1997 to 4.6 bags/acre in 2007. The high potential maize zone, often known as the Kenyan grain basket, recorded maize productivity increase from 11.5 bags/acre in 1997 to 13.3 bags/acre in 2007 according to Kibaara *et al*, (2008).

Maize yield in the two categories of cropping systems shows that maize productivity has been on an increasing trend for both the pure stand and intercrop. Productivity for the sole crop has been high compared to that of the intercrop. The mean maize yield per acre for the sole crop rose from 9.8 bags in 1997 to 11.2 bags in 2007, while that of the intercrop rose from 6.1 bags in 1997 to 9.1 bags in 2007 (Kibaara *et al*, 2008). It was also noted that productivity for the intercrop maize was very close to the overall maize productivity. Maize yield data for the long and short rains seasons, show that productivity is generally higher in the long rains season than in the short rains season (Kibaara *et al*, 2008).

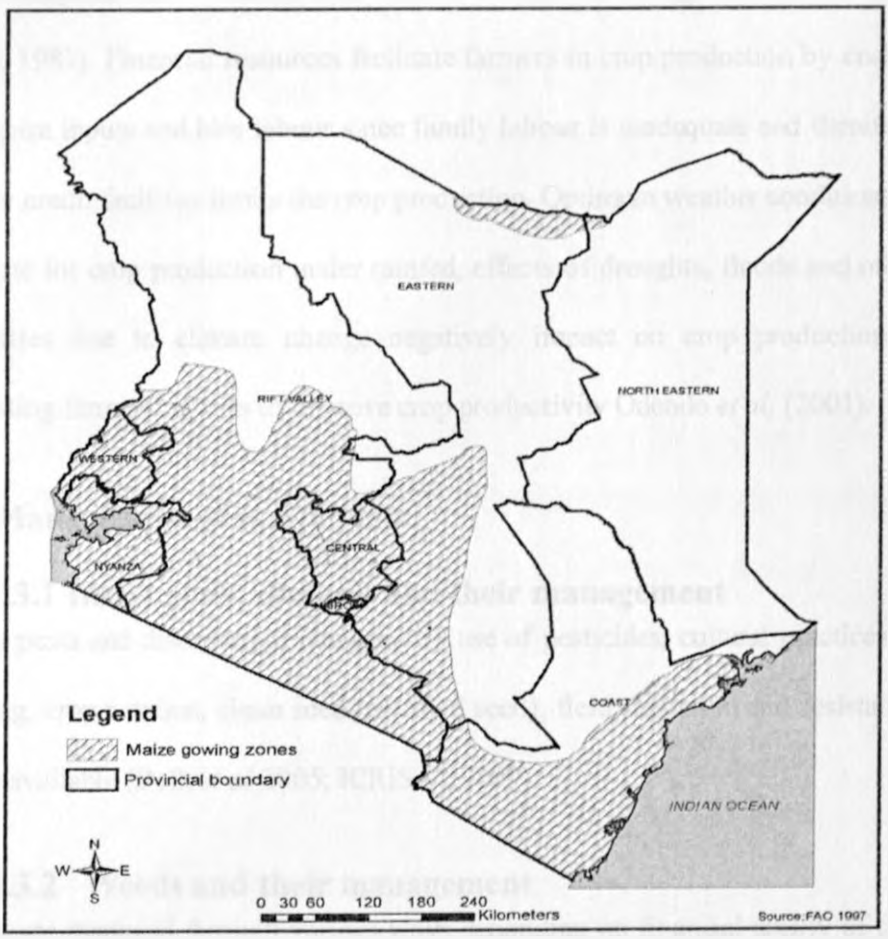


Figure 1: Maize growing zones of Kenya

Source: FAO, 1997

2.2.2 Maize production constraints

Maize production is affected by various factors which include both biotic and abiotic, some of them can cause disastrous effects on crop if not checked. This necessitates intervention by the authorities for high and sustainable production by the farmers for the country to be self sufficient with food. Biotic factors include pests of maize such as insect pests, arthropods, birds, rodents, wild animals, diseases and weeds while abiotic ones include aspects like resources and weather conditions among others (Bell, *et al*, 2005; MOA, 1981). Financial resources facilitate farmers in crop production by enabling them to acquire inputs and hire labour since family labour is inadequate and therefore lack of cash or credit facilities limits the crop production. Optimum weather conditions are a pre-requisite for crop production under rainfed, effects of droughts, floods and other natural calamities due to climate change negatively impact on crop production seriously frustrating farmers' efforts to improve crop productivity Odendo *et al*, (2001).

2.3 Management of maize pests

2.3.1 Insect pests, diseases and their management

Insect pests and diseases are managed by use of pesticides, cultural practices like early planting, crop rotation, clean seed (certified seed), field sanitation and resistant varieties where available (Bell, *et al* 2005; ICRISAT 2009).

2.3.2 Weeds and their management

Weeds are managed through various ways depending on financial ability of the farmer, they range from the simplest ones like slashing, hand weeding, cultural practices, use of resistant varieties, to mechanical and use of herbicides (IRRI and CIMMYT, 2007).

2.3.2.1 Cultural management practices

These involve prevention of spread of noxious weeds like *Striga*, intercropping with plants such as desmodium to prevent germination of *Striga* seeds, use of trap crop in *Striga* then ploughing once the *striga* has germinated, intercropping with leguminous crops to suppress weeds, crop rotation, early planting, use of weed seed free planting materials, mulching, maintenance of hygienic field conditions (FAO,2011; Oswald *et al*, 2002; Abdin, *et al*, 2000; MOA, 1981).

2.3.2.2 Resistant varieties

This involves use of resistant varieties for parasitic weeds like *Striga* (Haussmann *et al*, 2002), use of resistant varieties is the cheapest way for farmers to manage parasitic weeds in maize but their availability is a problem since it takes along period for breeders to come up with them (Zeyaur, *et al*, 2000).

2.3.2.3 Chemical methods

These are very fast in activity and are readily available in the market but prices may be sometimes inhibitive for the small scale farmers. The herbicide may be applied either as pre - emergence to the soil before both crop and weeds have emerged. It may also be applied as post emergence in which case it is selective or may be directed to the weeds during spraying (Kurt *et al*, 2003).

2.3.2.4 Mechanical methods

These involve use of draught animal pulled ploughs, tractors in land preparation and also to weed for the crop when young, the crop has to be in rows for any of these to be used in weeding (IRRI and CIMMYT, 2007).

2.4 Effects of different tillage methods on weed and maize yield

According to work done in west Africa by Kombiok *et al;* (2007), pre-planting application of glyphosate (zero-tillage) results revealed that glyphosate suppressed weed infestation significantly ($p < 0.05$) at three weeks after planting (3 WAP) by an average of 97.3%.

It was also found that at harvest due to lack of weed control in crops the weed populations and weed dry matter on zero-tillage were similar to those of the hand hoe treatment. Grass weed populations were not affected by the tillage systems. Hand hoe and zero-tillage practices had no effect on broad-leaved weed their populations were similar and significantly higher ($p < 0.05$) than those of the tractor and bullock treatments. The hand hoe and the zero-tillage gave a balanced populations between the broad-leaved and the grass weeds but use of the tractor and bullock tillage produced statistically higher ($p < 0.05$) grass count than broad-leaved weeds. Zero-tillage reduced maize plant height and grain yield significantly ($p < 0.05$) by 4% and 30%, respectively, compared with other tillage practices. According to Kombiok *et al,* (2007) bullock tillage system was considered the most appropriate choice for peasant farmers in northern Ghana, taking into account the cost of herbicides, tractor services, and the labour demand in hand hoeing.

According to NOMAFSI, (2010) paraquat 20% EC a.i (Gramoxone) use reduced soil erosion, produced higher maize yields than conventional tillage and an increase of 50% more compared with glyphosate which produced low yields due to the slow acting effect. Planting for glyphosate treatment was delayed for 15 days unlike for paraquat which was done after 2 days. Intensive use of glyphosate in Vietnam has led to emergence of more dominant weed species becoming resistant to it. Use of paraquat as an alternative non selective herbicide with a different mode of action in weed management practices has eliminated problems of weed shifts and resistance (NOMAFSI, 2010).

Paraquat is a non selective broad spectrum herbicide but crop leaves contact with little amount of the herbicide may cause negligible or no damage because its mode of action is contact and not translocated like glyphosate hence convenient for inter-row use to remove weeds growing between the crop rows.

Conservation tillage brings changes in physical, chemical and biological properties of a soil making it more suitable for plant growth (Bescanca *et al.*,2006). The changes in Soil physical properties influenced by conservation tillage include bulk density, infiltration and water retention (Osunbitan *et al.*, 2004). Improvement of rainwater infiltration into the soil increases water availability to plants, reduces surface run off and enhances ground water recharge (Lipiec *et al.*, 2005).

Paraquat is the only other option for zero tillage but its mammalian toxicity could be a problem. Other herbicides such as Afalo (linuron) are used as pre and post emergence and will involve ploughing the field before application. Current approach in herbicides use is to reduce mechanical weed control and adopt reduced and no tillage crop production systems by application of integrated weed management to avoid environmental pollution, reduce cost of maize production and at the same time relief the farmers from the burden of hand weeding.

Research by IITA revealed that extensive tillage was responsible for erosion making soil more dense as finer particles are removed leaving sandy or gravelly material. The process reduces soil capacity to form stable aggregate after removal of the organic matter (binding material) thereby reducing soil productivity (Stewart, 1993).

2.5 Cost benefit of conventional, zero and minimum tillage

Zero tillage using herbicides is helpful in reducing the burden of weeding, labour requirement in maize production and increasing maize production, reducing costs of production and saving time for the farmers to attend to other enterprises.

Zero tillage demonstration plots of Sasakawa in farmers' fields in 1999 and 2000, using herbicides to control weeds showed that yields were higher under zero tillage than under conventional tillage according to Aune *et al.*, (2000). Also cash expenditures were 550 birr/ha (31.9USD/ha) higher under zero tillage because of herbicide costs. If farmers paid for weeding labour costs and ox rental, cash expenditures would have been 235birr/ha (13.6 USD/ha) higher under conventional tillage.

According to Projects in Kenya by International Development Research Centre (IDRC), (2009), reduced or minimum tillage gave comparable maize yields with conventional tillage and in all cases conventional tillage gave slightly higher yields than furrow or spot planting. Besides conserving the soil and stabilizing yields, conservation agriculture reduces weed population thus making it the appropriate choice for crop production.

In Kenya maize yields produced by conventional tillage is comparable to those achieved by minimum tillage. Conservation tillage (zero tillage) gives equal or higher yields than those of conventional tillage due to provision of early sowing time and reduction in weed infestation according to Kenya Maize Development Program (KMDP) (2010).

Maize yields in central Kenya highlands have remained low, average yield is seldom more than 1 t/ha despite development of new maize varieties with a yield potential of 5-10 t/ha. This has been attributed to low level of adoption of new varieties combined with poor soil according to a case study by Natural Resources Institute Ltd (NRIL) and KARI Embu station, (2005). Use of hybrid 513 under conservation tillage increased maize yields by 40% more than conventional tillage while glyphosate and lasso atrazine in no till system reduced cost of production by 50% compared to conventional tillage.

Use of conventional tillage has reduced maize crop yields and profitability, increased the costs of production due to use of more fertilizer and fuel to plough the land. It is responsible for soil degradation while conservation (zero) tillage offers the best chance for halting degradation by reducing soil losses, restoring and improving soil productivity according to Cereal knowledge bank, by IRRI and CIMMYT (2007). According to Hobbs, (2007), conventional tillage exposes soil organic matter to the air where it is oxidized resulting to its decline, it interferes with roots and microbial activity pores. The soil aggregates of the bare surface after tillage are susceptible to breakdown by the rain drops with consequences of clogged soil pores, reduced water infiltration, accelerated runoff and ultimately soil erosion by water. Also the bare surface is vulnerable to wind erosion and the crusting of the surface as it dries forms barrier to plant emergence.

Reduced soil cultivation lowers energy requirements for labour in the farm and overall costs in farming since a small area is tilled (Monzon *et al*, 2006). Minimum tillage reduces costs of fuel, time, labour and machinery and due to savings on these costs gives higher net returns. Use of this tillage practice helps in conservation of soil and moisture, reduction of environmental degradation both locally and globally (IDRC, 2009). Studies on minimum tillage or reduced tillage and no-tillage practices showed that, there is reduced demand upon family labour, higher yields in semi-arid areas due to minimized soil moisture evaporation and reduced erosion through minimized soil disturbance (IDRC, 2009).

Weeding accounts for 60% of time the peasant farmer spends in farming and saving this time means the farmer can engage in other profitable income generating activities according to Cereal Knowledge bank by IRRI and CIMMYT, (2007). Syngenta sponsored study on minimum tillage in Vietnam found that farmers on average saved 80 days per ha of time spent on hand weeding, reduced cultivation costs by 2.6 million Vietnamese Dong per hectare (US $ 117/ha). Minimum tillage also reduced the time taken to grow the crop by more than 10 days thereby enabling the farmers to plant another crop on the same land each year, boosting production and livelihoods, Syngenta, (2010).

According to Soil and Water Protection, (2010) Conservation tillage lowers costs of crop establishment by reducing the number of operations required, with No tillage in particular reducing costs by 70%. In Hungary, conservation tillage reduced crop establishment costs by almost 40% while in Belgium and UK costs saved on average were 20% compared to mouldboard plough costs. It also established that, generally yields from conservation tillage fields were lower but frequently within 10% of that achieved by the conventional tillage crop.

Results of tillage practices by Najafinezhad *et al*, (2007) found that, reduced and conventional tillage performed better and similarly with grain yield of 15.29 and 14.87t/ha (an increase of 22.81 and 19.43%) respectively, compared to minimum tillage. The high grain yield was attributed to decrease in compaction, better root proliferation and more uniform distribution of nutrients in soil profile. The results conform to those of Uri, (2000), who found that grain yield of maize decreased with minimum tillage.

According to FAO and (ZTAT) of Brazil, (2000) zero tillage was found to be attractive to farmers since it is simple to manage, cheap, provides adequate planting time, produce higher yields, crops have high drought tolerance and has reduced investment on farm machinery.

2.6 Effects of intercrop and monocrop on weed and maize yield

Intercropping of maize with *Dolicos* or other leguminous crops can increase maize yield, help the farmers to get two crops from the same field same season, reduce weeding burden and save time for farmers to do other business. In intercropping the competition between the two species (maize and legume) tend to affect economics of the planting pattern unlike when the same species are in solitary cropping according to Yilmaz, *et al*, (2007).The effect of competition between the intercropped plant species is determined by different competitive indices which include land equivalent ratio (LER), relative crowding coefficient (*K*), aggressivity (A), competitive ratio (CR), actual yield loss (AYL), monetary advantage index (MAI) and intercropping advantage (IA) according to Yilmaz, *et al*, (2007).

Maize legume intercropping verses pure stand through competition indices in the Mediterranean region revealed that, intercropping maize with common bean or cow pea in different planting patterns and mix-proportions has effect on cropping for using resources of the environment compared to mono cropping according to Dhima *et al*, (2007). When the LER is greater than 1, the intercropping favours the growth and yield of the intercropped species. Unlike when the LER is less than 1, the inter cropping adversely affects the growth and yield of the intercropped plants according to Caballero *et al* , (1995); Dhima *et al*, (2007).

Some green manure cover crops grow very vigourous effectively reducing weed abundance if used in a rotation as intercrops or sole crops, reasonable weed control can be achieved by intercropping with velvet beans (*Mucuna pruriens*), lablab (*Lablab purpureus*) and Sunn hemp (*Crotalaria juncea*) according to Theirfelder and Wall, (CIMMYT) (2007).

Intercropping maize and *Dolicos* (in KARI Kisii and KARI Kitale, Soil management project) according to work done by Mureithi *et al; (* 2005) increased yields and income per unit area, reduced soil erosion, increased effective utilization of nutrients, water, land and light, reduced pests and diseases, reduced risk in food production and weeds, improved soil fertility and labour utilization. According to Maina, (1997) intercropping maize with beans had a higher weed suppression than maize monocrop.

Maize and legume intercropping in organic farming found that maize legume intercropping increased canopy cover (leaf area index) than sole crops cutting off light from weeds thereby considerably reducing weed density and dry matter compared to maize pure stand according to Bilalis e*t al,*(2010).

According to Swinton *et al,*(1994) intercropping maize with edible legumes and incorporating their residues increased crop yields and income per unit area; improved efficiency in nutrients, water, land and light utilization, soil fertility and labour utilization; reduced soil erosion, pests, weeds, diseases and risks in food production.

Intercropping of maize and edible legumes and incorporating their residues into the soil increases the yields as a result of improvement in soil fertility. According to Santalla *et al,* (2001); Karadag and Buyukburc, (2004); Carr *et al,* (2004); Agegnehu *et al*, (2006); Banik *et al,* (2006); and Dhima *et al,* (2007); competition between the intercropped species is thought to be the major factor influencing yield as compared with solitary cropping of cereals.

The competition between the two intercropped species depends on the species selection, seeding ratios, and competition capability of the species which may affect the growth of the intercropped species in rain-fed areas according to Santalla *et al.* (2001); Karadag and Buyukburc, (2004); Carr *et al*, (2004); Agegnehu *et al*, (2006); Banik *et al*, (2006); Dhima *et al*, (2007).

Studies to assess the effects of using cover crops to minimize adverse effects of no weeding in maize found that intercropping coordinated with right timing of hoe weeding smoother weeds satisfactory for small holder farmers (Zuofa and Tariah, 1992). In the tropics cereals intercropping with legumes has been found to be popular with farmers (Hauggaard *et al*., 2001); and rain-fed areas of the world (Banik *et al*., 2000); (Ghosh, 2004); (Agegnehu *et al*., 2006; Dhima *et al*., 2007); gives resistance to lodging and increases yield (Anil *et al*, 1998); increases yields (Chen *et al*., 2004); effect on weed control (Poggio, 2005; Banik *et al*, 2006); controls the parasitic infections of the legume root (Fenandez *et al*, 2007).

2.7 Response of different maize varieties under minimum tillage and weed pressure

Studies on six maize hybrids in 1989 and 1990, found they had significant differences among them in leaf angle, leaf width, leaf number, plant height, leaf area index, plant dry matter, grain and stover yields. In 1989 a significant interaction was found between hybrid and weed control for grain yields, implying that some hybrids were more competitive during the period of high weed pressure as reported by Ford *et al*., (1994).

According to Begna *et al*., (2001), weed pressure test with three hybrids found that, plant height of the leafy reduced-stature (LRS) variety was reduced by weed pressure than that of the tall hybrids. The late maturing big leaf (LMBL) grain yield was found to be much higher than that of LRS, the early maturing LRS hybrid yield appeared least affected by weed pressure implying it has higher tolerance or competitive ability to weeds.

2.8 Effects of weed competition and allelopathy on maize

Maize and weeds interaction sets an environment of direct competition for limited plant growth resources and an indirect one involving production of allelopathic chemicals and due to weeds genetic diversity, ability to adapt and take advantage of conditions created by crop production systems. Some of the allelophathic weeds enumerated (Duke,1985) include Velvet leaf (*Abutilon theophrasti*), Quack grass (*Agropyron repens*), Pig weed (*Amaranthus sp*), Rag weed *(Ambrosia sp)*,Wild oat (*Avena fatua),* Mustard (*Brassica sp*), common lambsquarters (*Chenopodium album*), Star,Bermuda grass (*Cynodon dactylon*), Yellow nutsedge (*Cyperus esculentus*), Purple nutsedge (*Cyperus rotundus),* Crab grasss *(Digitaria sanguinalis),* Barn yard grass (*Echinochloa crus-galli),* Sunflower *(Helianthus annus),* Alang-alang,spear grass (*Imperata cylindrica*), Blue grass (*Poa sp*), Purslane (*Portulaca oleracea*), Rottboelia (*Rottboelia exaltata*), Giant fox tail (*Setaria fabari*), Johson grass (*Sorghum halepense*).

Weeds have capacity for heavy nutrient absorption and accumulation as well as gathering substantial quantities of dry matter thereby reducing the achievable yield of the crop. The effect of the competition depends on crop growth stage, weed species, weed abundance, nutrition and water status (CIMMYT, 2010). Maize is susceptible to competition from weeds during the critical period of weed competition (2-6 weeks after emergence, or 3-8 leaf stage). With good weed control during the critical period, yield loss due to weeds can be reduced to less than 5% since later germinating weeds have little effects on yields and low weed seed production. When control measures are delayed to later part of the critical period significant yield losses are incurred (Omafra, 2009). After 6th week from emergence maize reduces the sun light rays reaching the weeds, later germinating weeds can only have impact on maize if the crop is under moisture and nutrients stress or if weeds are very aggressive to overtake the crop. Weed competition during period of abundant moisture has less effect on crop yield losses Omafra, (2009), (Table 4).

Table 4: Corn yield losses due to weeds under adequate and inadequate soil moisture conditions

Precipitation (mm) May to August	Yield losses due to weeds (%)
458	18
218	96

Source: Weed Science Research Program, Department of Plant Agriculture-University of Guelph (1986-2008)

Investigation in south western Kenya found that *Striga sp* (parasitic weed) effects on maize yield loss varied from 10% to total crop failure (Smaling, *et al*, 1991). Other studies on wild proso millet showed that at density of 10 plants /m^2 Corn (*Zea mays* L.) yield reduction ranged from 13% to 22% (Wilson and Westra, 1991), (Table 5). Studies have also revealed that even with the same weed density yield loss varied among locations and years according to Cowan, (1998) and Jasieniuk *et al*, (1999).

According to results by Knezevic *et al*, (2003) weed control in corn was influenced by the level of N fertilizer and that the critical period for weed control varied among years and locations. These results indicated that an increase in the supply of N increased the tolerance of corn to weed presence in the early part of the season, the yield losses in corn ranged from 1.5 to 3% depending on the N levels. Early season addition of N increased corn growth rates and leaf area expansion, showing that its application significantly improved corn competitiveness against weeds.

Table 5: Corn yield losses due to different weed species of known population densities (with assumptions that weeds emerged with the crop)

Weed species	**% Yield Loss**	
ANNUAL BROAD LEAVES	**(1plant/m^2)**	**(5plants/m^2)**
Giant ragweed	13	36
Lamb's quarters (*Chenopodium album*)	12	35
Amaranthus spp	11	34
Cocklebur *(Xanthium sp)*	6	22
Ragweed (*Ambrosia sp*)	5	21
Wild mustard	5	18
Velvet leaf (*Abutilon theophrasti*)	4	15
Lady's thumb	2	13
Wild buck wheat	2	10
Eastern black nightshade	2	7
ANNUAL GRASSES		
Giant foxtail (*Setaria fabari*)	2	10
Proso millet	2	10
Barnyard grass (*Echinochloa crus-galli*)	2	7
Green foxtail	2	7
Yellow foxtail (*Setaria sp*)	1	5
Old witch grass	1	5
Crab grass (*Digitaria sp*)	1	3

Source: Adapted from w.w.w. weedpro 75.com (In: OMAFRA, 2009)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Geographical and climatic characteristics of the study area

The experimental site was in Kigumo district near Gatumbi Market about 115km North west of Nairobi. The district covers an area of about 293km^2 with a population of 123,766 people and average family size of 4.4 (KNBS, 2009) and potential agricultural land of 164km^2. It stretches over six agro ecological zones according to classification by Jaetzold and Schmidt, (1983) in a descending order from the slopes of Aberdare ranges namely UHO, UH1, LH1, UM1, UM2 and UM3. Most (95%) of the district lies in the UM1 and LH1 zones and this is where most of agricultural activities are concentrated (MOA,2010). The district altitude ranges from 1200- 2950 m above sea level with a bimodal rainfall classified as long and short rains from March to June and October to December respectively. Average annual rainfall ranges from 1200 - 2400mm and average annual rainfall of 1500 mm and mean annual temperature ranging between 14-24^0 C, soils are mainly loam (MOA,2010). The average farm size is 0.81 ha with various agricultural activities taking place such as livestock keeping, cash and food crops farming (MOA, 2010). The food crops include maize, beans, yams and vegetables, fruits like avocados, citrus, passion, mangoes and bananas they serve as both food and cash crops with coffee and tea serving purely as cash crops.

The experimental site is traversed by longitude 36^0 59'E and latitude 0^0 41.5'S in the upper midland agro ecological zone (UM1) (the coffee – tea zone) formerly upper midland zone (main coffee zone) UM2, which is characterized by steep slopes except in a few valley bottoms. Construction of Ndakaini dam completely changed the ecological zone of the area that saw farmers who initially used to plant 500 maize hybrids series (511,512 and 513) start planting tea, and 600 maize hybrids series (612,622,624,625 and

626) which take 6-9 months to mature but due to climate change farmers can no longer rely on these hybrids as the rains can cease before crop maturity. As a result farmers need advice on alternative maize varieties (early maturing) for the area and a suitable tillage practice due to steep terrain of the land that will help to conserve soil and water for higher maize production.

3.2 Treatments (maize varieties and weed management practices)

Two maize varieties and four weed management practices were combined to make a total of eight treatments used in the experiment as shown below (Table 6).

Table 6: Experimental treatments

Treatment	Maize variety	Weed management practice
1	DK8031	Conventional (hand weeding)- monocrop: Hand digging, weeding at 3WAP, 7WAP and 11WAP
2	DUMA SC41	Conventional (hand weeding)- monocrop: Hand digging, weeding at 3WAP, 7WAP and 11WAP
3	DK8031	Intercropping with *Dolicos:* Hand digging, weeding at 3WAP, 7WAP and 11WAP
4	DUMA SC41	Intercropping with *Dolicos*: Hand digging, weeding at 3WAP, 7WAP and 11WAP
5	DK8031	Zero tillage: Glyphosate applied 4 times; Preplant, 3WAP, 7WAP and 11WAP
6	DUMA SC41	Zero tillage: Glyphosate applied 4 times; Preplant, 3WAP, 7WAP and 11WAP
7	DK8031	Weedy (control) : Hand dug, no weeding
8	DUMA SC41	Weedy (control): Hand dug, no weeding

3.3 Experimental design and layout

The experiment was a 2 x 4 factorial, the treatments comprised of two maize varieties DK8031 and DUMA SC41 and four weed management practices namely hand weeding (conventional tillage - monocrop), glyphosate (zero tillage), intercropping with *Dolicos lablab* and weedy /control making a total of eight treatments.

The experiment was laid out in a randomized complete block design (RCBD) replicated three times for two seasons (Table 7). Plots measuring 5 x 3 m were used and in all treatments maize spaced at 75 x 30 cm between the rows and plants respectively, with 1.5 m and 1.0 m paths between blocks and plots respectively. In intercrop plots a row of *Dolicos lablab* was planted at the mid of every two rows of maize and the seeds spaced at 30 cm from plant to plant. During planting maize and *Dolicos* holes 5cm and 3cm deep respectively were dug along their respective rows and fertilizer NPK (23:23:0), 20g per planting hole (200kg/ha) was applied in both maize and *Dolicos lablab* where applicable and thoroughly mixed with the soil. Two seeds of maize and *Dolicos* were placed in their respective holes and rows then covered with soil. After crops' germination insect pests and diseases were monitored and controlled accordingly, top dressing of maize was done with CAN 26 % (200kg/ha) at knee height or after second weeding.

Table: 7 Experimental layout

Rep I	6	3	5	8	4	2	1	7
Rep II	5	2	4	1	7	3	8	6
Rep III	1	7	8	3	2	6	4	5

Rep = replicate; Numbers 1,2,3,4,5,6,7 ,8 = treatments

3.4 Description of how treatments were applied

3.4.1 Glyphosate (Zero tillage)

Plots were sprayed with glyphosate (36% EC a.i) to kill weeds five days before planting at the rate of 1.0 kg a.i/ha (2.2kg/ha), that is 20mls/litre (4 litres/ ha) using a knapsack sprayer of 15 litres with a Teejet flat fan nozzle at a pressure of 2 bars (28 PSI) maintained by pumping. Two litres of water was measured using a 500mls measuring cylinder and put into the sprayer. Glyphosate 40mls was measured using a 100mls measuring cylinder added into the sprayer and thoroughly mixed with water. Safety of the applicator during spraying was ensured by wearing a complete protective kit. After crop germination a repeat of glyphosate application was done using a hood to protect crops from herbicide injury at 3WAP, 7WAP and 11WAP. At the end of spraying each plot the amount of chemical used was arrived at by measuring the quantity in the sprayer and subtracting it from the initial amount put before commencement of spraying. At the start and the end of spraying each plot time was recorded, then time taken was arrived at by subtracting starting time from the finishing time. The average amount of chemical sprayed and time taken per plot were calculated from the total amount of chemical sprayed and time taken respectively for the total number of plots sprayed.

3.4.2 Hand weeding three times (Conventional tillage) - monocrop

Plots were dug and leveled using hoes of similar sizes, shape and weight by both male and female adults randomly allocated to the plots. First weeding was done 3WAP second one 4weeks after the first one or 7WAP and third weeding 11WAP. At the start and end of digging and every weeding for each plot time was recorded. Time taken was arrived at by subtracting starting time from the finishing time and the mean time calculated from the total time taken and the total number of plots dug and weeded respectively.

3.4.3 Intercropping with *Dolicos lablab*

Plots preparation and weeding were done as those of hand weeding above. In this treatment one row of *Dolicos* was factored in between every two rows of maize and 3cm deep holes were dug along the rows at 30 cm intervals.

3.4.4 Weedy (Control)

Plots were prepared as those of hand weeding and intercropping above but after crop emergence no weeding was done up to maturity.

3.5 Weed assessment

3.5.1 Weed population

Weed scoring in all treatments was done by identification of individual species and their numbers in a marked area of 3x1.5m in each plot. First weed count was done 3 weeks after planting (3WAP) while other four weed counts were done each a month later at 7 WAP, 11 WAP, 15 WAP and 19 WAP. Although the weed scores were done from 3WAP to 19WAP the weed scores from 3WAP to 11WAP were used to indicate weed species persistence since that is the time of treatments application and also part of the critical period of weed competition in maize.

3.5.2 Weed biomass

Biomass data was taken once after the last weed scoring by cutting at the ground level all weeds species inside the marked area (3 x 1.5m) in each plot. All broad leaf weeds were put together and weighed when fresh, same thing was done for all gramineae and the sedges. The three categories of weeds (broad leaved, gramineae and sedges) were all dried in an oven at 60 ^{0}C for 72 hrs and weighed separately.

3.6 Crop assessments

3.6.1 Maize germination and vigour assessment

A marked area of 3 x 1.5m in each plot was used for both weeds and crop data collection. The number of emerged maize and *Dolicos* seedlings in this area was counted and assessed twice at 3rd, and 5th, weeks after planting (WAP) for percentage germination,vigour and their averages determined. The crop vigour was assessed by visual examination and recorded on a scale of 0-9, where 0-3 denotes low growth vigour, 4-6 moderate growth vigour, and 7-9 high growth vigour.

3.6.2 Maize plant height, number of cobs per plant, cob weight and grain yield

At physiological maturity of the crop during harvesting time the height of each maize plant in the marked area was measured in meters using a tape measure. Maize cobs from each plant in the marked area were harvested, counted and weighed. All the cobs for each plot were dried and kept separately. Later the cobs were shelled and a moisture meter used to ascertain grain moisture content (14%) at the time of taking weight. Maize grain weights of the same treatments from the three blocks were added together, their mean determined and the same used to translate grain weight to yield in terms of 90 kg bags and tones /ha.

3.6.3 *Dolicos lablab* assessment

The number of *Dolicos* branches for each plant in the marked area 3x1.5m of the plot was 19 weeks after planting, yield of *Dolicos* was attained by counting and harvesting all the mature and dry pods from each plant in the marked area of the plot. The number of seeds in each pod was counted and the totals for each plot weighed and the mean for all plots was used to translate yield to kg/ha.

3.7 Cost benefit determination

The process of calculating cost benefit for glyphosate involved conversion of hours to mandays (8 working hours is equivalent to one manday) spent in pre-spraying and spraying plots at 3WAP, 7WAP and 11WAP to an hectare then costs. Cost of the herbicide spent in the four spraying occasions plus cost of labour for harvesting constitute the cost of maize production based on an hectare. Then the maize out-put based on 90kg bag per hectare is multiplied by price per bag to get total income minus total cost of production giving the net return.

Cost benefit calculation for hand weeding involved conversion of hours to mandays (8 working hours is equivalent to one manday) spent in the digging plots and weeding them at 3WAP, 7WAP and 11WAP to an hectare then costs, plus cost of labour for harvesting which all constitute the cost of maize production based on an hectare. Then the maize out put based on 90kg bag per hectare is multiplied by price per bag to get total income minus total cost of production giving the net return. Marginal rate of returns for each maize variety under glyphosate and conventional tillage practices respectively during the long and short rain seasons was calculated as follows, total cost of maize under glyphosate (Tc_1) less total cost of maize under hand weeding (Tc_0) = {Marginal cost (Tc_1-Tc_0) = x}. Total revenue from maize under glyphosate (Tr_1) less total revenue from maize under hand weeding (Tr_0) = {Marginal net benefit (Tr_1-Tr_0) = y};

{(Tc_1-Tc_0) - (Tr_1-Tr_0) = y-x = z}.

Marginal rate of return = (MRR) = z/x; (see calculated MRR for DK8031under glyphosat and hand weeding on page 50).

3.8 Statistical data analysis

Data was analysed using GenStat computer soft ware package Pyne *et al*, (2009), analysis of variance (ANOVA) was conducted to determine the effects of different treatments on weed population and maize yield by comparing their respective means. Difference between the treatments means were separated using Student New man Keuls and the level of significance (statistical difference) between the means determined at ($P < 0.05$).

CHAPTER FOUR: RESULTS

4.1 COMPARATIVE EFFICIENCY OF GLYPHOSATE AND HAND WEEDING ON WEED CONTROL IN MAIZE (*Zea mays* L.)

4.1.1 District rainfall in 2010

During the trials (2010) the long rains averaged 971.6mm and fairy distributed over 81 days while the short rains were low and poorly distributed with 398.8mm over a period of 28 days, thus crops experienced moisture stress (Appendix 1).

4.1.2 Effectiveness of glyphosate and hand weeding on weed management

4.1.2.1 Weed population

In both long and short rains seasons a total of forty one weed species were identified while another eight species could not be identified by either common or scientific names except by local names (Appendices 11and 12). In the long rains season from first to fifth weed count there were no significant differences between glyphosate and hand weeding in the number of weed species in both maize varieties at $p < 0.05$ (Appendix 7) although hand weeding (conventional tillage) had higher number of weed species than glyphosate (zero tillage) in both maize varieties. Both glyphosate and hand weeding significantly differed from the non weeded plots in the number of weed species at $p < 0.05$ (Appendix 7).

During the long rains season DUMA SC41 and DK8031 under both glyphosate and hand weeding at 11WAP the most persistent weeds were *Digitaria velutina, Ageratum conyzoides, Galinsoga parviflora* and *Bidens pilosa* (Tables 8 and 9). It was noted that, the above weeds were controlled better by glyphosate than hand weeding except *Galinsoga parviflora* which was controlled better by hand weeding than glyphosate.

For weed persistence, weed management and species interaction effects was significant, *Lsd* for interaction effects was 36.37 and CV% of 546.2 indicating high variability of weed species persistence by their counts (Table 9).

Table 8: Weed counts/m^2 during the long rain season (March–June) 2010

Maize variety	Weed control	Weed counts/m^2					Average
		3WAP*	7WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	2.2^a	8.2^a	4.2^a	2.0^a	4.2^a	4.2
	Weedy (control)	8.7^b	25.1^b	18.2^{ab}	7.1^b	6.2^{ab}	13.1
	Hand weeding	4.0^a	7.8^a	6.7^a	3.3^a	4.2^a	5.2
DK8031	Glyphosate	2.7^a	8.0^a	2.9^a	1.6^a	3.3^a	3.7
	Weedy (control)	5.8^{ab}	14.4^{ab}	11.1^a	5.1^{ab}	4.2^a	8.1
	Hand weeding	2.7^a	7.1^a	2.9^a	3.1^a	4.0^a	4.0
Lsd (0.05) weed management		*3.5*	*11.6*	*12.6*	*2.4*	*2.5*	
Lsd interaction (variety .wmngt)*		*15.8*	*52.0*	*56.8*	*10.8*	*11.1*	
CV%		*48.3*	*59.5*	*114.7*	*39.3*	*33.5*	

WAP* = weeks after planting;
In the table means bearing the same letter are not significantly different per variety along the columns.
wmngt*= weed management

Table 9: Weed persistence at 3WAP , 7WAP and 11WAP under different weed management practices during the long rains season 2010

Weed species	Weed management practices		
	Glyphosate	Weedy/control	Hand weeding
Galinsoga parviflora	$24^{efghijk}$	56^{cde}	42^{cdefgh}
Digitaria velutina	$37^{cdefghij}$	134^{b}	63^{cd}
Oxygonum sinuatum	3^{ijk}	6^{hijk}	1^{jk}
Bidens pilosa	$21^{efghijk}$	47^{cdefg}	$39^{cdefghi}$
Richardia brasiliensis	$39^{cdefghi}$	343^{a}	53^{cdef}
Elusine indica	8^{hijk}	$32^{cdefghijk}$	7^{hijk}
Commelina benghalensis	3^{ijk}	6^{hijk}	2^{jk}
Cyperus rotundus	0^{k}	5^{ijk}	1^{jk}
Oxalis latifolia	2^{jk}	3^{ijk}	3^{ijk}
Cleome monophylla	0^{k}	3^{ijk}	0^{k}
Ageratum conyzoides	$23^{efghijk}$	$20^{efghijk}$	$36^{cdefghijk}$
Paspalum dilatatum	5^{ijk}	$30^{defghijk}$	3^{ijk}
Cynodon dactylon	10^{hijk}	1^{jk}	8^{hijk}
Dactyloctenium aegyptium	0^{k}	1^{k}	0^{k}
Cyperus esculentus	18^{fghijk}	$30^{defghijk}$	17^{ghijk}
Stellaria media	0^{k}	1^{k}	0^{k}
Cyperus blysmoides	3^{ijk}	8^{hijk}	8^{hijk}
Digitaria abyssinica	11^{ghijk}	2^{jk}	6^{hijk}
Emilia decifolia	10^{hijk}	10^{ghijk}	3^{ijk}
Chenopodium murale	1^{k}	1^{k}	0^{k}
Malva verticillata	0^{k}	1^{k}	0^{k}
Cyperus grandibulbosus	0^{k}	1^{k}	0^{k}
Galium spurium	1^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{jk}	1^{k}
Fallopia convolvulus	17^{ghijk}	12^{ghijk}	12^{ghijk}
Cyathula polycephala	0^{k}	1^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05 (f pr mngt*& spp*)	0.001	0.001	0.001
CV% 546.2			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 5.90; *Lsd* species 18.18; *Lsd* interaction 36.37.
mngt*= management; spp*= species

During the short rains season first and second weed counts done 3WAP and 7WAP respectively there were no significant differences between glyphosate and hand weeding practices in number of weed species as well as interaction effect at ($F_{[3,14]} = 6.63$, $p < 0.01$) (Table 10). In third weed count done 11 WAP there was significant difference in number of weed species ($F_{[3,14]} = 20.14$, $p < 0.01$) between glyphosate (zero tillage) and hand weeding (conventional tillage) practices with the former having lower number of weed species than the latter at $p < 0.05$ (Table 10).

In fourth weed count done 15 WAP there was significant difference ($F_{[3,14]} = 6.15$, $p < 0.01$) in the number of weed count between the two tillage practices with glyphosate (zero tillage) having lower number of weed species than hand weeding (conventional tillage) (Table 10). Fifth weed count done at 19WAP showed there was significant difference ($F_{[3,14]} = 3.85$, $p < 0.05$) in the number of weed species between the two tillage practices with glyphosate (zero tillage) having lower weed scores than hand weeding (conventional tillage) (Table 10).

In the short rains season the weed species found to be persistent in DUMA SC41 and DK8031 under glyphosate and hand weeding at 11WAP were *Ageratum conyzoides, Galinsoga parviflora, Richardia brasiliensis, Digitaria velutina, Bidens pilosa, Elusine indica and Fallopia convolvulus.* Hand weeding controlled *Ageratum conyzoides, Galinsoga parviflora and Fallopia convolvulus* better than glyphosate, *Richardia brasiliensis* was contolled better by glyphosate than hand weeding while *Digitaria velutina, Bidens pilosa and Elusine indica* were equally controlled by both hand weeding and glyphosate (Table 11). For weed persistence, weed management and species interaction effects was significant, *Lsd* for interaction effects was 15.64 and CV% 385.0 indicating the degree of weed species persistence variation by their counts (Table 11).

Table 10: Weed counts/m² during the short rains season 2010

Maize variety	Weed control	Weed counts/m²					Average
		3WAP*	7WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	6.5[a]	3.4[a]	3.3[a]	0.7[a]	2.4[a]	2.9
	Weedy	8.8[a]	8.0[b]	8.2[c]	9.9[c]	8.9[c]	8.8
	Hand weeding	6.5[a]	3.4[a]	3.6[b]	4.9[b]	5.5[b]	4.8
DK8031	Glyphosate	5.2[a]	2.5[a]	0.6[a]	1.4[a]	1.6[a]	2.2
	Weedy	8.5[a]	6.2[a]	6.5[c]	6.9[bc]	6.0[b]	6.8
	Hand weeding	5.3[a]	2.2[a]	3.2[b]	4.4[b]	4.3[ab]	3.9
Lsd (0.05)weed management		*NS*	*4.1*	*2.5*	*3.0*	*2.7*	
Lsd variety.weed management		*29.54*	*18.18*	*0.42*	*0.48*	*12.23*	
CV%		*59.6*	*61.9*	*25.5*	*23.2*	*39.4*	

WAP* = Weeks After Planting

In the table means bearing the same letter are not significantly different per variety along the columns

Table 11: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the short rains season 2010

Weed species	Weed management practices		
	Glyphosate	Weedy/control	Hand weeding
Galinsoga parviflora	19^{ghi}	52^{bcd}	33^{efg}
Digitaria velutina	12^{ijk}	41^{cdef}	14^{hijk}
Oxygonum sinuatum	5^{ijk}	17^{hij}	6^{ijk}
Bidens pilosa	12^{ijk}	60^{b}	8^{ijk}
Richardia brasiliensis	13^{ijk}	60^{b}	79^{a}
Elusine indica	15^{hijk}	5^{ijk}	2^{jk}
Commelina benghalensis	6^{ijk}	6^{ijk}	1^{k}
Cyperus rotundus	0^{k}	1^{k}	4^{ijk}
Oxalis latifolia	5^{ijk}	2^{jk}	5^{ijk}
Oxalis corniculata	4^{ijk}	8^{ijk}	0^{k}
Cleome monophylla	0^{k}	2^{jk}	1^{k}
Ageratum conyzoides	37^{def}	36^{ef}	0^{k}
Paspalum dilatatum	8^{ijk}	53^{bc}	11^{ijk}
Cynodon dactylon	1^{k}	14^{hijk}	0^{k}
Dactyloctenium aegyptium	0^{k}	10^{k}	0^{k}
Cyperus esculentus	6^{ijk}	34^{efg}	3^{jk}
Setaria pumila	6^{ijk}	3^{jk}	0^{k}
Stellaria media	0^{k}	1^{k}	0^{k}
Cyperus blysmoides	8^{ijk}	4^{ijk}	3^{jk}
Digitaria abyssinica	0^{k}	4^{ijk}	1^{k}
Emilia decifolia	5^{ijk}	3^{jk}	0^{k}
Solanum nigrum	0^{k}	1^{k}	1^{k}
Chenopodium murale	0^{k}	1^{k}	1^{k}
Spergula arvensis	0^{k}	1^{k}	1^{k}
Malva verticillata	1^{k}	1^{k}	0^{k}
Tagetes minuta	1^{k}	1^{k}	0^{k}
Cyperus grandibulbosus	8^{ijk}	1^{k}	1^{k}
Dichondra repens	0^{k}	1^{k}	0^{k}
Galium spurium	1^{k}	1^{k}	0^{k}
Achyranthes aspera	0^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{k}	0^{k}
Conyza stricta	0^{k}	1^{k}	0^{k}
Fallopia convolvulus	29^{fgh}	6^{ijk}	0^{k}
Cyathula polycephala	1^{k}	2^{jk}	0^{k}
Sonchus oleraceus	1^{k}	1^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05(f pr mngt*; spp*)	0.001	0.001	0.001
CV% 385			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 2.537; *Lsd* species 7.820; *Lsd* interaction 13.545
mngt*= management; spp*= species

4.1.2.2 Weed biomass

In both seasons the results showed that weed biomass for glyphosate and hand weeding treatments were not significantly different at $p < 0.05$. During the long rains season the biomass dry weights were higher than those of the short rains season, also the biomass from the two maize varieties differed with regard to weed management, plots planted with DUMA SC41 in both tillage practices had higher weed biomass than DK8031 (Table 12).

Table 12: Influence of glyphosate, weedy and hand weeding on dry weed biomass (g) during the long and short rain seasons 2010

Maize variety	Weed control	Long rains			Short rains			Average Weed biomass
		Weed category			Weed category			
		Broad Leaf	Grasses	Sedges	Broad Leaf	Grasses	Sedges	
DUMA SC41	Glyphosate	687^{a}	174^{a}	0.7^{a}	41^{a}	109^{a}	0.1^{a}	168.6
	Weedy	1371^{b}	2504^{c}	4.5a	1262^{b}	3090^{c}	9.8^{a}	1373.6
	Hand weeding	600^{a}	760^{a}	2.5^{a}	74^{a}	36^{a}	1.8a	245.7
DK8031	Glyphosate	493^{a}	62^{a}	0.4^{a}	34^{a}	4^{a}	0.6^{a}	99
	Weedy	980^{b}	277^{a}	6.3^{a}	1268^{b}	1890^{b}	13.5^{ab}	739.1
	Hand weeding	271^{a}	144^{a}	4.2^{a}	22^{a}	28^{a}	5.3^{a}	79.1
Lsd (0.05)weed management		*446.6*	*715.2*	*729.1*	*0.67*	*185.9*	*23.7*	
Lsd (variety. Management)		*631.6*	*1011.5*	*1031.1*	*0.954*	*0.765*	*0.869*	
CV%		*57.9*	*103.2*	*139.5*	*38.7*	*23.7*	*24.24*	

In the table means bearing the same letter are not significantly different per variety along the columns

4.1.3 Assessment of weed effect on maize yield component

4.1.3.1 Maize germination and vigour assessment results

In both seasons there were no significant differences in percentage germination of maize across weed management practices and maize varieties. In general percentage germination on average was low to moderate ranging from 59.1% under zero tillage and 67.8% under conventional tillage (Table 13). Crop vigour was moderate ranging from 6.3 for zero tillage and 6.9 for conventional tillage.

Table 13: Maize percentage germination under different tillage practices

Maize variety	Weed control	Germination percentage		Average
		Long rains	Short rains	
DUMA SC41	Glyphosate (zero tillage)	53.9[a]	55.0[a]	54.5
	Weedy (control)	56.3[a]	53.7[a]	55.0
	Hand weeding (conventional tillage)	61.7[a]	54.3[a]	58.0
DK8031	Glyphosate (zero tillage)	66.0[a]	62.7[a]	64.4
	Weedy (control)	62.6[a]	65.0[a]	63.8
	Hand weeding (conventional tillage)	67.4[a]	66.0[a]	66.7
Lsd (0.05)weed management		*NS*	*NS*	
Lsd variety . weed management		*18.94*	*3.88*	
CV %		*33.6*	*11.6*	

In the table means bearing the same letter are not significantly different per variety along the columns

4.1.3.2 Maize plant height

Although the two maize varieties had significant differences in height DK8031 being taller than DUMA SC41, tillage practices had significant effect on plant height. During the long rains season glyphosate (zero tillage) had higher mean plant height in each variety than hand weeding (conventional tillage) and both tillage practices each significantly differed from the weedy in both maize varieties at $p < 0.05$. During the short rains season none of the two varieties exhibited any significant difference between the two tillage practices and between each of them and the weedy respectively in plant height at $p < 0.05$ (Table 14).

4.1.3.3 Number of maize cobs per plant and cob weight

The study showed that there was no significant difference between glyphosate and hand weeding tillage practices in the number of maize cobs per plant in both maize varieties for both long and short rains seasons at $p < 0.05$. Each of the two tillage practices was not significantly different from the weedy in the number of cobs per plant in both maize varieties and seasons (Table 14). The results also revealed DK8031 had higher number of cobs per plant than DUMA SC41 but not significantly different at $p < 0.05$ (Table 14). The two tillage practices were not also significantly different on average cob weight although glyphosate had higher cob weight than hand weeding for the two maize varieties in both seasons. None of the two tillage practices was each significantly different from the weedy on average cob weight in both varieties and seasons at $p < 0.05$ (Table 14).

Table 14: Maize plant height, number of cobs per plant and cob weight under different weed management practices

Maize variety	Weed control	Long rains season			Short rains season		
		Maize height (m)	No. of cobs per plant	Cob weight (g)	Maize height (m)	No. of cobs per plant	Cob weight (g)
DUMA SC41	Glyphosate	1.42[ab]	0.6[a]	24.9[a]	0.68[a]	0.4[a]	21.1[a]
	Weedy	0.91[a]	0.4[a]	20.1[a]	0.67[a]	0.3[a]	18.9[a]
	Hand weeding	1.30[a]	0.5[a]	24.5[a]	0.73[a]	0.4[a]	20.6[a]
DK8031	Glyphosate	1.89[bc]	0.7[a]	60.3[a]	1.04[a]	0.7[a]	48.2[a]
	Weedy	1.06[a]	0.5[a]	50.6[a]	0.71[a]	0.4[a]	28.2[a]
	Hand weeding	1.69[abc]	0.6[a]	52.4[a]	0.95[a]	0.6[a]	40.4[a]
Lsd (0.05)weed management		*0.342*	*NS*	*NS*	*NS*	*NS*	*NS*
Lsd variety. weed management		*0.484*	*0.236*	*0.325*	*0.339*	*0.287*	*0.212*
CV%		*18.8*	*23.5*	*40.3*	*22.5*	*42.1*	*56*

In the table means bearing the same letter are not significantly different per variety along the columns; **NB** Varietal: height *Lsd* 1st season = 0.242; 2nd season =0.169; Varietal no. of cobs *Lsd* season = 0.118; cob weight *Lsd* 1st season=*15.25;* 2nd season *=31.36*

4.1.3.4 Maize grain yield (t/ha)

During the long rains season in both DK8031 and DUMA SC41 varieties there was no significant difference between the glyphosate and hand weeding tillage practices in grain yield and interaction at $p < 0.05$ although glyphosate had higher grain yield than hand weeding in both varieties. In the short rains season there was no significant difference between the two tillage practices in both varieties although glyphosate had higher grain yield than hand weeding in both of them (Table 15). There was significant difference in mean grain yield between the two maize varieties at $p < 0.05$, in other words DUMA SC41 had lower yields than DK8031 in both tillage practices and seasons (Table 15).

Table 15: Maize grain yield (tons /ha) under glyphosate, hand weeding and weedy

Maize variety	Weed control	Yield tons/ha		
		Long rains season	**Short rains season**	**Average**
DUMA SC41	Glyphosate	1.01[ab]	0.87[a]	0.94
	Weedy	0.40[a]	0.08[a]	0.24
	Hand weeding	0.73[ab]	0.85[a]	0.79
DK8031	Glyphosate	2.19[b]	1.37[a]	1.78
	Weedy	1.14[ab]	0.36[a]	0.75
	Hand weeding	1.65[ab]	1.36[a]	1.51
Lsd (0.05)weed management		*1.78*	*NS*	
Lsd variety .weed management		*0.664*	*0.653*	
CV%		*62.4*	*77.4*	

In the table means bearing the same letter are not significantly different per variety along the columns

4.2 COST BENEFIT ANALYSIS OF HAND WEEDING AND GLYPHOSATE IN WEED MANAGEMENT

4.2.1 Cost of maize production under glyphosate and hand weeding

4.2.1.1 Glyphosate (Zero tillage)

4.2.1.1.1 Quantity of glyphosate and time spent in spraying the plots

The average time taken in pre - spraying and spraying during the long rains season was 2.90 mandays/ha translating to an average cost of Kshs 522/ha while during the short rains season time taken was 2.98 mandays/ha with an average cost of Kshs 536.40/ha (Appendix 7). The average amount of glyphosate used in pre - spraying and from first to third spraying during the long rains season was 1.1 litres/ha amounting to an average cost of Kshs 1,430/ha while the average amount for the short rains season was 1.4litres /ha with an average cost of kshs 1,820Kshs/ha (Appendix 8).

4.2.1.2 Hand weeding (conventional tillage)

4.2.1.2.1 Time taken in digging and weeding the plots

The number of mandays taken to dig an hectare in both long and short rains seasons was similar, digging took less mandays and at a lower cost than weeding during the long rains season. During the long rains season the number of mandays increased with subsequent weeding from 39.6 to 48.2 at 3WAP and 11WAP respectively. Third weeding at 11WAP took least mandays during the short rains season, this coincided with low weed density during the same period (Appendix 9).

4.2.2 Maize profit/ loss under hand weeding and glyphosate

4.2.2.1 Long rain season maize yield, its monetary value under hand weeding and glyphosate

During the long rains season DK8031 under glyphosate had a profit of Kshs 8,963 implying a gain of Kshs 4. 36 for every shilling invested while under hand weeding a loss of Kshs 17,941.10 was incurred leading to a loss of Kshs 3.01 for every shilling invested (Tables 16). At the same period DUMA SC41 under glyphosate had a loss of Kshs 15,037 translating to a loss of Kshs 2.60 for every shilling invested while under hand weeding a loss of Kshs 44,941.10 was incurred meaning a loss of Kshs 1.20 for every shilling invested was made (Table 17). These were confirmed by marginal rate of returns (MRR) in Tables 16 and 17, they were calculated as shown below for DK8031variety.

Total cost of maize production under glyphosate (Tc_1) = Kshs 39,037

Total cost of maize production under hand weeding (Tc_0) =Kshs 53,941

Total revenue from maize under glyphosate (Tr_1) = Kshs 48,000

Total revenue from maize under hand weeding (Tr_0) = Kshs 36,000

Marginal cost {(Tc_1- Tc_0 = x) = 39037- 53,941} = - 14,904

Marginal net benefit {(Tr_1-Tr_0 = y)= 36,000- 48,000} = - 12,000

MRR {(y-x = z) =-12,000-14,904} = -26,904; z/x = (-26904/14904) = -1.8

Table 16: Cost benefit comparison for DK8031 between glyphosate and hand weeding during long rain season 2010

Details (Cost per ha)	Glyphosate	Hand weeding
Land preparation	-	4,750.20
Seeds	7,222	7,222
Herbicide costs	6,604	-
Application costs	1,651	-
Fertilizers	5,700	5,700
Fertilizer application and planting	5,400	5,400
Top dressing	720	720
Hand weeding	-	20,187
Stalk borer dust	1,200	1,200
Application cost	540	540
Costs for harvesting	10,000	10,000
Total costs	39,037	53,941.10
Total income (yield)	48,000	36,000
Net return	8,963	- 17,941.10
Cost/benefit ratio	1:4.36	-1:3.01
MRR	-18	-18

Table 17: Cost benefit comparison for DUMA SC41 between glyphosate and hand weeding during the long rain season 2010

Details (Cost per ha)	Glyphosate	Hand weeding
Land preparation	-	4,750.20
Seeds	7,222	7,222
Herbicide costs	6,604	-
Application costs	1,651	-
Fertilizers	5,700	5,700
Fertilizer application and planting	5,400	5,400
Top dressing	720	720
Hand weeding	-	20,187
Stem borer dust	1,200	1,200
Application cost	540	540
Costs for harvest	10,000	10,000
Total costs	39,037	53,941.10
Total income (yield)	24,000	9,000
Net return	-15,037	- 44,941.10
Cost/benefit ratio	- 1: 2.60	-1: 1.20
MRR	- 2.0	-2.0

4.2.2.2 Short rain season maize yield, its monetary value under glyphosate and hand weeding

During the short rains season DK8031 under glyphosate and hand weeding practices had losses of Kshs 8,963 and 23,941.10 respectively implying losses of Kshs 4.52 and 2.25 for every shilling invested respectively (Table 18). DUMA SC41 the same period under glyphosate and hand weeding incurred losses of Kshs 21,037 and 48,941.10 respectively translating to losses of Kshs 1.86 and 10.00 respectively for every shilling invested (Table 19). These were confirmed by marginal rate of returns (MRR) in Tables 18 and 19, which were calculated as shown in the previous page for DK8031 variety

Results from both long and short rain seasons showed use of glyphosate (zero tillage) was economical than hand weeding (conventional tillage) and DK 8031 variety gave higher returns than DUMA SC41 variety in the area.

Table 18: Cost benefit comparison for DK8031 between glyphosate and hand weeding during short rain season 2010

Details (Cost per ha)	Glyphosate	Hand weeding
Land preparation	-	4,750.20
Seeds	7,222	7,222
Herbicide costs	6,604	-
Application costs	1,651	-
Fertilizers	5,700	5,700
Fertilizer application and planting	5,400	5,400
Top dressing	720	720
Hand weeding	-	20,187
Stem borer dust	1,200	1,200
Application cost	540	540
Costs for harvesting	10,000	10,000
Total costs	39,037	53,941.10
Total income (yield)	30,400	30,000
Net return	- 8,637	- 23,941.10
Cost/benefit ratio	-1:4.52	-1:2.25
MRR	-1.0	-1.0

Table 19: Cost benefit comparison for DUMA SC41 between glyphosate and hand weeding during the short rain season 2010

Details (Cost per ha)	Glyphosate	Hand weeding
Land preparation	-	4,750.20
Seeds	7,222	7,222
Herbicide costs	6,604	-
Application costs	1,651	-
Fertilizers	5,700	5,700
Fertilizer application and planting	5,400	5,400
Top dressing	720	720
Hand weeding	-	20,187
Stem borer dust	1,200	1,200
Application cost	540	540
Costs for harvest	10,000	10,000
Total costs	39,037	53,941.10
Total income (yield)	18,000	5,000
Net return	-21,037	- 48,941.10
Cost/benefit ratio	- 1: 1.86	-1: 10
MRR	-1.8	-1.8

4.3 ASSESSMENT OF THE EFFECTS OF INTERCROPPING AND MONOCROP ON WEED POPULATION AND MAIZE YIELD

4.3.1 Effectiveness of intercropping and monocrop on weed management

4.3.1.1 Weed population

During the long rains from first to fifth weed count there were no significant differences between intercropping and monocrop tillage practices in the number of weed species at $p < 0.05$, although monocrop had a higher number of weed species than intercrop (Table 20). The persistent weeds were *Galinsoga parviflora, Digitaria velutina, Bidens pilosa, Richardia brasiliensis* and *Ageratum conyzoides* (Tables 21). Except *Galinsoga parviflora* which was controlled better by monocrop the rest were all controlled better by intercropping.

Weed persistence trend at 3WAP, 7WAP and 11WAP under intercrop and monocrop during the long rains season showed that WAP and species interaction effects was significant, *Lsd* 31.50 and CV% 546.2 indicating high variability of weed species persistence by their count (Table 21).

Table 20: Weed counts/m^2 for intercrop, weedy and hand weeding (monocrop) during the long rain season 2010

Maize variety	Weed control	Weed counts/m^2 3WAP*	7WAP	11WAP	15WAP	19WAP	Average
DUMA SC 41	Intercrop	3.8^a	10.7^a	2.9^a	3.3a	4.4^a	5.0
	Weedy	8.7^b	25.1^b	18.2^b	7.1^b	6.2^{ab}	13.1
	Monocrop	4.0^a	7.8^a	6.7^{ab}	3.3^a	4.2^a	5.2
DK8031	Intercrop	3.3^a	7.6^a	1.3^a	2.0^a	2.9^a	3.4
	Weedy	5.8^{ab}	14.4^{ab}	11.1^{ab}	5.1^{ab}	4.2^a	8.1
	Monocrop	2.7^a	7.1^a	2.9^a	3.1^a	4.0^a	4.0
Lsd (0.05) management		*3.5*	*11.6*	*12.6*	*2.4*	*2.5*	
Lsd var. management		*15.8*	*52.0*	*56.8*	*10.8*	*11.1*	
CV%		*48.3*	*59.5*	*114.7*	*39.3*	*33.5*	

WAP* = Weeks After Planting;

In the table means bearing the same letter are not significantly different per variety along the columns

Table 21: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the long rains season 2010

Weed species	Weed management practices		
	Intercropping	Weedy/control	Monocrop
Galinsoga parviflora	$24^{efghijk}$	56^{cde}	67^{c}
Digitaria velutina	$30^{defghijk}$	134^{b}	63^{cd}
Oxygonum sinuatum	1^{jk}	6^{hijk}	1^{jk}
Bidens pilosa	16^{ghijk}	47^{cdefg}	$39^{cdefghi}$
Richardia brasiliensis	$28^{defghijk}$	343^{a}	53^{cdef}
Elusine indica	7^{hijk}	$32^{cdefghijk}$	17^{fghijk}
Commelina benghalensis	3^{ijk}	6^{hijk}	2^{jk}
Cyperus rotundus	3^{ijk}	5^{ijk}	1^{jk}
Oxalis latifolia	8^{hijk}	3^{ijk}	3^{ijk}
Cleome monophylla	0^{k}	3^{ijk}	0^{k}
Ageratum conyzoides	12^{ghijk}	$20^{efghijk}$	$23^{efghijk}$
Paspalum dilatatum	7^{hijk}	$30^{defghijk}$	3^{ijk}
Cynodon dactylon	6^{hijk}	1^{jk}	8^{hijk}
Dactyloctenium aegyptium	2^{jk}	1^{k}	0^{k}
Cyperus esculentus	5^{ijk}	$30^{defghijk}$	17^{ghijk}
Stellaria media	2^{jk}	1^{k}	0^{k}
Cyperus blysmoides	2^{jk}	8^{hijk}	8^{hijk}
Digitaria abyssinica	1^{jk}	2^{jk}	6^{hijk}
Emilia decifolia	1^{jk}	10^{ghijk}	3^{ijk}
Chenopodium murale	0^{k}	1^{k}	0^{k}
Malva verticillata	0^{k}	1^{k}	0^{k}
Cyperus grandibulbosus	0^{k}	1^{k}	0^{k}
Cyperus rigidifolius	0^{k}	1^{k}	0^{k}
Galium spurium	0^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{jk}	1^{k}
Amaranthus retroflexus	0^{k}	1^{k}	0^{k}
Fallopia convolvulus	7^{hijk}	12^{ghijk}	12^{ghijk}
Cyathula polycephala	0^{k}	1^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05 (f pr mngt* & spp*)	0.001	0.001	0.001
Cv% 546. 2			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 0.001; *Lsd* species 18.18; *Lsd* interaction 36.37
mngt* = management; spp*= species

In the short rains season first and second weed counts there were no significant differences between monocrop and intercrop tillage practices in the number of weed species at $p < 0.05$, although monocrop had a higher number of weed species than intercrop in both counts (Table 22). Third to fifth weed counts of the same period all showed significant differences between the two tillage practices in the number of weed species at $p < 0.05$, both DUMA SC41 and DK8031 under monocrop had higher weed score means than under intercrop (Table 22). Persistent weed species during the short rains season were *Galinsoga parviflora, Digitaria velutina* and *Richardia brasiliensis* and were controlled better by intercropping except *Galinsoga parviflora* which was controlled better by hand weeding/monocrop (Table 23). Weed management and species interaction effect was found to be significant, *Lsd* for interaction was 15.64 while CV% was 385.0 indicating high variability in weed species persistence by their count (Table 27)

Table 22: Weed counts/m² for intercrop, weedy and monocrop during the short rain season 2010

Maize variety	Weed control	Weed counts/m²					Average
		3WAP*	7WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Intercrop	5.3^{a}	1.6^{a}	0.8^{a}	2.7^{a}	2.4^{a}	2.6
	Weedy	8.8^{a}	8.0^{c}	8.2^{c}	9.9^{c}	8.9^{c}	8.8
	Monocrop	6.5^{a}	3.4^{ab}	3.6^{b}	5.8^{b}	5.5^{b}	5.0
DK8031	Intercrop	4.3^{a}	2.7^{ab}	0.8^{a}	1.2^{a}	1.4^{a}	2.1
	Weedy	8.5^{a}	6.2^{bc}	6.5^{c}	6.9^{b}	6.0^{b}	6.8
	Monocrop	5.3^{a}	2.2^{ab}	3.4^{b}	4.4^{b}	4.3^{b}	3.9
Lsd (0.05) management		*NS*	*4.1*	*2.5*	*3.0*	*2.7*	
Lsd var.management		*29.54*	*18.18*	*0.42*	*0.48*	*12.23*	
CV%		*59.6*	*61.9*	*62.3*	*35.0*	*39.4*	

WAP * = Weeks After Planting; In the table means bearing the same letter are not significantly different per variety along the columns

Table 23: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the short rains season 2010

Weed species	Weed management practices		
	Intercropping	Weedy/control	Monocrop
Galinsoga parviflora	19^{ghi}	52^{bcd}	13^{hijk}
Digitaria velutina	12^{ijk}	41^{cdef}	29^{fgh}
Oxygonum sinuatum	10^{ijk}	17^{hij}	6^{ijk}
Bidens pilosa	10^{ijk}	60^{b}	8^{ijk}
Richardia brasiliensis	45^{bcde}	60^{b}	79^{a}
Elusine indica	6^{ijk}	5^{ijk}	2^{jk}
Commelina benghalensis	1^{k}	6^{ijk}	1^{k}
Cyperus rotundus	7^{ijk}	1^{k}	4^{ijk}
Oxalis latifolia	0^{k}	2^{jk}	5^{ijk}
Oxalis corniculata	0^{k}	8^{ijk}	0^{k}
Cleome monophylla	1^{k}	2^{jk}	1^{k}
Ageratum conyzoides	2^{jk}	36^{ef}	0^{k}
Paspalum dilatatum	9^{ijk}	53^{bc}	11^{ijk}
Cynodon dactylon	1^{k}	14^{hijk}	0^{k}
Dactyloctenium aegyptium	0^{k}	10^{k}	0^{k}
Cyperus esculentus	7^{ijk}	34^{efg}	3^{jk}
Setaria pumila	0^{k}	3^{jk}	0^{k}
Stellaria media	0^{k}	1^{k}	0^{k}
Cyperus blysmoides	3^{jk}	4^{ijk}	3^{jk}
Digitaria abyssinica	3^{jk}	4^{ijk}	1^{k}
Emilia decifolia	0^{k}	3^{jk}	0^{k}
Solanum nigrum	0^{k}	1^{k}	1^{k}
Chenopodium murale	0^{k}	1^{k}	1^{k}
Spergula arvensis	0^{k}	1^{k}	1^{k}
Malva verticillata	0^{k}	1^{k}	0^{k}
Tagetes minuta	0^{k}	1^{k}	0^{k}
Cyperus grandibulbosus	2^{jk}	1^{k}	1^{k}
Dichondra repens	0^{k}	1^{k}	0^{k}
Galium spurium	0^{k}	1^{k}	0^{k}
Achyranthes aspera	0^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{k}	0^{k}
Conyza stricta	0^{k}	1^{k}	0^{k}
Fallopia convolvulus	3^{jk}	6^{ijk}	0^{k}
Cyathula polycephala	0^{k}	2^{jk}	0^{k}
Sonchus oleraceus	0^{k}	1^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05 (f pr mngt*;spp*)	0.001	0.001	0.001
Cv% 385			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 2.537; *Lsd* species 7.820; *Lsd* interaction 13.545.
mngt*= management; spp*= species

4.3.1.2 Weed Biomass

Results for both maize varieties and seasons showed there were no significant differences in dry weight weed biomass between monocrop and intercrop although monocrop had higher weight than intercrop in both varieties and seasons (Table 24). The weed biomass from the two maize varieties differed with regard to weed management, DUMA SC41 had higher weed biomass than DK8031 in both monocrop and intercrop (Table 24). In both seasons and maize varieties weedy (control) had significantly different weed biomass for broad leaf and grasses from those of both monocrop and intercrop at $p < 0.05$ (Table 24).

Table 24: Influence of intercrop and monocrop on dry weed biomass (g) during the long and short rain seasons respectively 2010

Maize variety	Weed control	Long rains Weed category			Short rains Weed category			Average Weed biomass
		Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	
DUMA SC 41	Intercropping	432^{a}	431^{a}	0.8^{a}	24^{a}	12^{a}	3^{a}	150.5
	Weedy	1371^{b}	2504^{b}	4.5^{a}	1262^{b}	3090^{b}	9.8^{ab}	1373.6
	Monocrop	600^{a}	760^{a}	2.5^{a}	74^{a}	36^{a}	1.8^{a}	245.7
DK 8031	Intercropping	152^{a}	126^{a}	1.4^{a}	8^{a}	7^{a}	0.3^{a}	49.1
	Weedy	980^{b}	277^{a}	6.3^{a}	1268^{b}	1890^{b}	13.5^{b}	739.1
	Monocrop	271^{a}	144^{a}	4.2^{a}	22^{a}	28^{a}	5.3^{ab}	79.1
Lsd (0.05)management		*446.6*	*715.2*	*729.1*	*0.67*	*185.9*	*23.7*	
Lsd var.management		*631.6*	*1011.5*	*1031.1*	*0.954*	*0.765*	*0.869*	
CV%		*57.90*	*103.2*	*139.5*	*38.7*	*23.7*	*24.24*	

In the table numbers bearing the same letter are not significantly different per variety along the columns

4.3.2 Weeding time

The time taken to weed monocrop and intercrop in both seasons is presented in Appendix 10.

4.3.3 The effect of weed competition on maize yield

4.3.3.1 Maize and *Dolicos* percentage germination and vigour assessment

In both seasons there were no significant differences in maize percentage germination and vigour between the intercrop and the monocrop at $p < 0.05$ (Table 25). Also there were no significant differences in *Dolicos* percentage germination and vigour between those intercropped with DK8031 and the ones intercropped with DUMA SC41 at $p < 0.05$.

Table 25: Maize percentage germination under intercropping, monocrop and weedy tillage practices

Maize variety	Weed control	Germination percentage		Average
		Long rains	Short rains	
DUMA SC41	Intercropping	65.3[a]	56.3[a]	60.8
	Weedy	56.3[a]	53.7[a]	55.0
	Monocrop	61.7[a]	54.3[a]	58.0
DK8031	Intercropping	70.1[a]	67.3[a]	68.7
	Weedy	62.6[a]	65.0[a]	63.8
	Monocrop	67.4[a]	66.0[a]	66.7
Lsd (0.05)weed coontrol		*NS*	*NS*	
Lsd var. weed control		*18.94*	*3.88*	
CV %		*33.6*	*11.6*	

In the table means bearing the same letter are not significantly different per variety along the columns

4.3.3.2 Maize plant height

The results for both long and short rains seasons showed there were no significant differences between intercrop and monocrop tillage practices in average plant height at $p<0.05$ (Table 26) although intercrop had higher plant height than monocrop in both maize varieties and seasons. In DK8031 both intercrop and monocrop respectively, were significantly different from weedy (control) in average plant height in both seasons, in DUMA SC41 none of the two tillage practices respectively was significantly different from weedy (control) in average plant height in both maize seasons.

4.3.3.3 Number of cobs per plant and cob weight

There were no significant differences between intercrop and monocrop in the mean number of cobs per plant and mean maize cob weight in both DUMA SC41 and DK8031 respectively during the long and short rains seasons at $p < 0.05$ (Table 26). Significant differences were only found between the two maize varieties in the number of cobs per plant during the short rains season and mean cob weight in both long and short rains seasons, DK8031 had higher mean number of cobs per plant during the short rains season and mean cob weight than DUMA SC41 in both long and short rains seasons at $p < 0.05$ (Table 26).

Table 26: Maize plant height, number of cobs per plant and cob weight for DUMA SC41 and DK8031 during the long and short rains seasons 2010

Maize variety	Weed control	Long rains season			Short rains season		
		Maize height in (m)	No. of cobs per plant	Cob Weight (g)	Maize height in (m)	No. of cobs per plant	Cob weight (g)
DUMA SC41	Intercropping	1.43^{b}	0.6^{a}	27.9^{a}	0.89^{a}	0.5^{a}	20.6^{a}
	Weedy	0.91^{a}	0.4^{a}	20.1^{a}	0.67^{a}	0.3^{a}	18.9^{a}
	Monocrop	1.30^{ab}	0.5^{a}	24.5^{a}	0.73^{a}	0.4^{a}	20.6^{a}
DK8031	Intercropping	2.06^{b}	0.7^{a}	73.2^{a}	1.22^{b}	0.7^{b}	53.4^{a}
	Weedy	1.06^{a}	0.5^{a}	50.6^{a}	0.71^{a}	0.4^{a}	28.2^{a}
	Monocrop	1.69^{b}	0.6^{a}	52.4^{a}	0.95^{ab}	0.6^{ab}	40.4^{a}
Lsd (0.05)management		*0.342*	*NS*	*NS*	*NS*	*NS*	*NS*
Lsd var.management		*0.484*	*0.236*	*0.664*	*0.339*	*0.287*	*0.267*
CV%		*18.8*	*23.5*	*58.4*	*22.5*	*42.1*	*36.0*

In the table means bearing the same letter are not significantly different per variety along the columns.

NB: Varietal: height *Lsd* 1st season = 0.242; 2nd season =0.169; Varietal no. of cobs *Lsd* season = 0.118; cob weight *Lsd* 1st season=*15.25;* 2nd season =*31.36*

4.3.3.4 Maize grain yield (t/ha)

The results for maize grain yield showed there were no significant differences between intercrop and monocrop in grain yield for both DUMA SC41 and DK 8031 during the long and short rains seasons but the maize yields varied between the two maize varieties and seasons. There was significant difference in yield between DUMA SC41 and DK

8031 in both seasons at $p < 0.05$ (Table 27). The study showed intercrop although not significantly different from monocrop in maize grain yield had higher yields in both maize varieties and seasons. Overall, intercropping increased the maize yield for both maize varieties over the two seasons by 57.5% more than the monocrop.

Table 27: Maize grain yields (t /ha) for DUMA SC41 and DK8031 during the long and short rains seasons 2010

Maize variety	Weed control	Yield (tons/ha)		
		Long rains season	Short rains season	Average
DUMA SC41	Intercropping	1.11^{a}	0.95^{a}	1.03
	Weedy	0.40^{a}	0.08^{a}	0.24
	Monocrop	0.73^{a}	0.85^{a}	0.79
DK8031	Intercropping	3.32^{b}	2.37^{b}	2.85
	Weedy	1.14^{a}	0.36^{a}	0.75
	Monocrop	1.65^{ab}	1.36^{ab}	1.51
Lsd (0.05)weed control		*1.78*	*NS*	
Lsd var.weed control		*0.664*	*0.653*	
cv%		*62.4*	*77.4*	

In the table means bearing the same letter are not significantly different per variety along the columns;

4.3.4 *Dolicos lablab* yield

In both long and short rain seasons there were no significant differences in number of *Dolicos* branches and pods per plant, the number of seeds per pod and grain yield for

0.05. In both seasons *Dolicos* grain yields were on average low 5kg/ha during the long rains season and 71.1kg/ha during the short rains season.

4.4 COMPARISON OF THE EFFECTIVENESS OF GLYPHOSATE AND INTERCROPPING ON WEED MANAGEMENT IN MAIZE CROP

4.4.1 Effectiveness of Glyphosate and intercropping on weed management

4.4.1.1 Weed population

In the five weed counts of both the long and short rains seasons there were no significant differences between glyphosate and intercropping tillage practices in mean number of weed species at $p < 0.05$ (Tables 28 and 29). Each of the two tillage practices was significantly different from weedy (control) in mean number of weed species at $p < 0.05$ in both maize varieties in four of the five weed counts in both the long and short rains seasons respectively. None of them was significantly different from the weedy in mean number of weed species at $p < 0.05$ in the fifth weed count during the long rains season and also in the first weed count during the short rains season (Tables 28 and 29).

Table 28: Weed counts /m²during the long rain season (Mar-Jun) 2010

Maize variety	Weed control	Weed counts/m²					Average
		3WAP*	7 WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	2.2ᵃ	8.2ᵃ	4.2ᵃ	2.0ᵃ	4.2ᵃ	4.2
	Weedy	8.7ᵇ	25.1ᵇ	18.2ᵇ	7.1ᵇ	6.2ᵃ	13.1
	Intercrop	3.8ᵃ	10.7ᵃ	2.9ᵃ	3.3ᵃ	4.4ᵃ	5.0
DK8031	Glyphosate	2.7ᵃ	8.0ᵃ	2.9ᵃ	1.6ᵃ	3.3ᵃ	3.7
	Weedy	5.8ᵃᵇ	14.4ᵃᵇ	11.1ᵃᵇ	5.1ᵇ	4.2ᵃ	8.1
	Intercrop	3.3ᵃ	7.6ᵃ	1.3ᵃ	2.0ᵃ	2.9ᵃ	3.4
Lsd(0.05) management		*3.5*	*15.6*	*12.6*	*2.4*	*NS*	
Lsd var.management		*15.8*	*52.0*	*56.8*	*10.8*	*11.1*	
CV%		*48.3*	*59.5*	*114.7*	*39.3*	*33.5*	

WAP*=Weeks After Planting;
In the table means bearing the same letter are not significantly different per variety along the columns

Table 29: Weed counts/m^2 during the short rain season (Oct-Dec.) 2010

Maize variety	Weed control	Weed counts/m^2					Average
		3WAP*	7WAP	11WAP	15WAP	19WAP	
DUMA SC 41	Glyphosate	6.5^a	3.4^a	3.3^a	0.7^a	2.4^a	2.9
	Weedy	8.8^a	8.0^b	8.2^b	9.9^b	8.9^b	8.8
	Intercropping	5.3^a	1.6^a	0.8^a	2.7^a	2.4^a	2.6
DK8031	Glyphosate	5.2^a	2.5^a	0.6^a	1.4^a	1.6^a	2.2
	Weedy	8.5^a	6.2^{ab}	6.5^b	6.9^b	6.0^{ab}	6.8
	Intercropping	4.3^a	2.7^a	0.8^a	1.2^a	1.4^a	2.1
Lsd(0.05)management		*NS*	*4.1*	*2.5*	*4.8*	*2.7*	
Lsd var.management		*29.54*	*18.18*	*0.42*	*0.48*	*12.23*	
CV %		*59.6*	*61.9*	*62.3*	*35.0*	*39.4*	

WAP* = Weeks After Planting; In the table means bearing the same letter are not significantly different per variety along the columns

The persistence of weed species for the two tillage practices during the long and short rains season comprised of *Galinsoga parviflora, Digitaria velutina, Bidens pilosa, Richardia brasiliensis, Elusine indica,* and *Ageratum conyzoides* (Tables 30 and 31). Among these weed species *Digitaria velutina* and *Richardia brasiliensis* were better controlled by intercropping than glyphosate while the rest of the species were equally controlled by both tillage practices. During the long rains season weed management and species interaction effects was significant, *Lsd* for interaction effects was 36.37 and CV% 546.2 indicating a high weed diversity in weed species persistence by their count (Table 30) and during the short rains season weed management and species interaction effects was significant, *Lsd* for interaction effects was 15.64 and CV% was 385.0 showing high diversity in weed species persistence by their count (Table 31).

Table 30: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the long rains season 2010

Weed species	Weed management practices		
	Intercropping	Weedy/control	Glyphosate
Galinsoga parviflora	42^{cdefgh}	67^{c}	56^{c}
Digitaria velutina	$30^{defghijk}$	134^{b}	$37^{cdefghij}$
Oxygonum sinuatum	1^{jk}	6^{hijk}	3^{ijk}
Bidens pilosa	16^{ghijk}	47^{cdefg}	$21^{efghijk}$
Richardia brasiliensis	$28^{defghijk}$	343^{a}	$39^{cdefghi}$
Elusine indica	17^{fghijk}	$32^{cdefghijk}$	8^{hijk}
Commelina benghalensis	3^{ijk}	6^{hijk}	3^{ijk}
Cyperus rotundus	3^{ijk}	5^{ijk}	0^{k}
Oxalis latifolia	8^{hijk}	3^{ijk}	2^{jk}
Cleome monophylla	0^{k}	3^{ijk}	0^{k}
Ageratum conyzoides	12^{ghijk}	$20^{efghijk}$	$36^{cdefghijk}$
Paspalum dilatatum	7^{hijk}	$30^{defghijk}$	5^{ijk}
Cynodon dactylon	6^{hijk}	1^{jk}	10^{hijk}
Dactyloctenium aegyptium	2^{jk}	1^{k}	0^{k}
Cyperus esculentus	5^{ijk}	$30^{defghijk}$	18^{fghijk}
Stellaria media	2^{jk}	1^{k}	0^{k}
Cyperus blysmoides	2^{jk}	8^{hijk}	3^{ijk}
Digitaria abyssinica	1^{jk}	2^{jk}	11^{ghijk}
Emilia decifolia	1^{jk}	10^{ghijk}	10^{hijk}
Chenopodium murale	0^{k}	1^{k}	1^{k}
Malva verticillata	0^{k}	1^{k}	0^{k}
Cyperus grandibulbosus	0^{k}	1^{k}	0^{k}
Galium spurium	0^{k}	1^{k}	1^{k}
Achyranthes aspera	0^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{jk}	0^{k}
Conyza stricta	0^{k}	1^{k}	0^{k}
Fallopia convolvulus	7^{hijk}	12^{ghijk}	17^{ghijk}
Cyathula polycephala	0^{k}	1^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05(f pr mngt*; spp*)	0.001	0.001	0.001
CV% 546.2			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 5.90; *Lsd* species 18.18; *Lsd* interaction 36.37.

Table 31: Weed persistence at 3WAP, 7WAP and 11WAP under different weed management practices during the short rains season

Weed species	Weed management practices		
	Intercropping	Weedy/control	Glyphosate
Galinsoga parviflora	13^{hijk}	52^{bcd}	33^{efg}
Digitaria velutina	14^{hijk}	41^{cdef}	29^{fgh}
Oxygonum sinuatum	10^{ijk}	17^{hij}	5^{ijk}
Bidens pilosa	10^{ijk}	60^{b}	12^{ijk}
Richardia brasiliensis	45^{bcde}	60^{b}	13^{ijk}
Elusine indica	6^{ijk}	5^{ijk}	15^{hijk}
Commelina benghalensis	1^{k}	6^{ijk}	6^{ijk}
Cyperus rotundus	7^{ijk}	1^{k}	0^{k}
Oxalis latifolia	0^{k}	2^{jk}	5^{ijk}
Oxalis corniculata	0^{k}	8^{ijk}	4^{ijk}
Cleome monophylla	1^{k}	2^{jk}	0^{k}
Ageratum conyzoides	2^{jk}	36^{ef}	37^{def}
Paspalum dilatatum	9^{ijk}	53^{bc}	8^{ijk}
Cynodon dactylon	1^{k}	14^{hijk}	1^{k}
Dactyloctenium aegyptium	0^{k}	10^{k}	0^{k}
Cyperus esculentus	7^{ijk}	34^{efg}	6^{ijk}
Setaria pumila	0^{k}	3^{jk}	6^{ijk}
Stellaria media	0^{k}	1^{k}	0^{k}
Cyperus blysmoides	3^{jk}	4^{ijk}	8^{ijk}
Digitaria abyssinica	3^{jk}	4^{ijk}	0^{k}
Emilia decifolia	0^{k}	3^{jk}	5^{ijk}
Solanum nigrum	0^{k}	1^{k}	0^{k}
Chenopodium murale	0^{k}	1^{k}	0^{k}
Spergula arvensis	0^{k}	1^{k}	0^{k}
Malva verticillata	0^{k}	1^{k}	1^{k}
Tagetes minuta	0^{k}	1^{k}	1^{k}
Cyperus grandibulbosus	2^{jk}	1^{k}	8^{ijk}
Dichondra repens	0^{k}	1^{k}	0^{k}
Galium spurium	0^{k}	1^{k}	1^{k}
Achyranthes aspera	0^{k}	1^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{k}	0^{k} .
Conyza stricta	0^{k}	1^{k}	0^{k}
Fallopia convolvulus	3^{jk}	6^{ijk}	29^{fgh}
Cyathula polycephala	0^{k}	2^{jk}	1^{k}
Sonchus oleraceus	0^{k}	1^{k}	1^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}
Lsd 0.05(f pr mngt*; spp*)			
CV% 385			

In the table means bearing the same letter are not significantly different per variety along the columns. *Lsd* management 2.537; *Lsd* species 7.820; *Lsd* interaction 13.545.
mngt*= management; spp*= species

4.4.1.2 Weed Biomass

Results for both seasons showed there were no significant differences between intercrop and glyphosate in weed biomass dry weight at $P < 0.05$ but were both significantly different from weedy in biomass dry weight at $P < 0.05$ during the short rains season (Table 32). During the long rains season both intercrop and glyphosate were significantly different from weedy only in broad leaf biomass at $P < 0.05$ (Table 32).The weed biomassfrom the two maize varieties differed with regard to weed management, DUMASC41 had significantly higher weed biomass than DK8031 in both tillage practices (Table 32).

Table 32: Influence of glyphosate, weedy and intercrop on dry weed biomass (g) during the long and short rain seasons 2010

Maize variety	Weed control	Long rains season Weed category			Short rains season Weed category			Average weed biomass
		Broad leaf	Grasses	Sedges	Broad Leaf	Grasses	Sedges	
DUMA SC41	Glyphosate	687[a]	174[a]	0.7[a]	41[a]	109[a]	0.1[a]	168.6
	Weedy	1371[b]	2504[b]	4.5[a]	1262[b]	3090[c]	9.8[ab]	1373.6
	Intercropping	432[a]	431[a]	0.8[a]	24[a]	12[a]	3.0[a]	150.5
DK8031	Glyphosate	493[a]	62[a]	0.4[a]	34[a]	4[a]	0.6[a]	99
	Weedy	980[b]	277[a]	6.3[a]	1268[b]	1890[b]	13.5[b]	739.1
	Intercropping	152[a]	126[a]	1.4[a]	8[a]	7[a]	0.3[a]	49.1
Lsd (0.05) management		*446.6*	*715.2*	*729.1*	*0.67*	*185.9*	*23.7*	
Lsd var.management		*631.6*	*1011.5*	*1031.1*	*0.954*	*0.765*	*0.869*	
CV%		*57.9*	*103.2*	*139.5*	*38.7*	*23.7*	*24.24*	

In the table means bearing the same letter are not significantly different per variety along the columns

4.4.2 Assessment of weed effect on maize yield component

4.4.2.1 Maize percentage germination and vigour

In both seasons there were no significant differences in maize percentage germination and interactions between the two maize varieties and the two tillage practices at $p < 0.05$ (Table 33). In both seasons there were no significant differences in maize vigour between glyphosate and intercropping evaluated on scale of 0- 9 which on average was moderate ranging from 6.2 for intercrop and 6.3 for glyphosate.

Table 33: Maize percentage germination for DUMA SC41 and DK8031 under intercropping, glyphosate and weedy for the long and short rains seasons 2010

Maize variety	Weed control	Germination percentage		Average
		Long rains	Short rains	
DUMA SC41	Intercropping	65.3[a]	56.3[a]	60.8
	Weedy	53.9[a]	53.7[a]	53.8
	Glyphosate	53.9[a]	55.0[a]	54.5
DK8031	Intercropping	70.0[a]	67.3[a]	68.7
	Weedy	62.6[a]	65.0[a]	63.8
	Glyphosate	66.0[a]	62.7[a]	64.4
Lsd(0.05) management		*NS*	*NS*	
Lsd var.management		*18.94*	*3.88*	
CV %		*33.6*	*11.6*	

Glyphosate = zero tillage; Weedy = control: In the table means bearing the same letter are not significantly different per variety along the columns

4.4.2.2 Maize plant height

There was no significant difference in maize height (meters) between glyphosate and intercrop in both seasons for the two maize varieties at $p < 0.05$, height variation was only evident between the two varieties. In both glyphosate and intercrop maize height each significantly differed from the weedy (control) in DK8031 variety in both long and short rains seasons, and in DUMA SC41variety only during the long rains season but not in the short rains season at $p < 0.05$ (Table 34).

4.4.2.3 Number of cobs per plant and cob weight

In both maize varieties and seasons there were no significant differences between glyphosate and intercrop in the number of maize cobs per plant, but in both seasons significant differences in the mean number of cobs per plant were only observed between the two maize varieties at $p < 0.05$ (Table 34). Although no significant differences between each of the two tillage practices and the weedy in the number of maize cobs per plant, each had higher mean number of maize cobs per plant than the weedy in both varieties and seasons at $p < 0.05$ (Table 34). Also in both maize varieties and seasons there were no significant differences between glyphosate and intercrop on average maize cob weight at $p < 0.05$ (Table 34). Both glyphosate and intercrop each had higher average cob weight than the weedy in both varieties and seasons although they were not significantly different at $p < 0.05$ (Table 34).

Table 34: Maize plant height, number of cobs per plant and cob weight for DUMA SC41 and DK8031 during the long and short rain seasons 2010

Maize variety	Weed control	Long rains season			Short rains season		
		Maize height in (m)	No. of cobs per plant	Cob weight (g)	Maize height in (m)	No. of cobs per plant	Cob weight (g)
DUMA SC41	Glyphosate	1.42[b]	0.6[a]	24.9[a]	0.68[a]	0.4[a]	21.1[a]
	Weedy	0.91[a]	0.4[a]	20.1[a]	0.67[a]	0.3[a]	18.9[a]
	Intercropping	1.43[b]	0.6[a]	27.9[a]	0.89[a]	0.5[a]	20.6[a]
DK8031	Glyphosate	1.89[b]	0.7[a]	60.3[a]	1.04[ab]	0.7[a]	48.2[a]
	Weedy	1.06[a]	0.5[a]	50.6[a]	0.71[a]	0.4[a]	28.2[a]
	Intercropping	2.06[b]	0.7[a]	73.2[a]	1.22[b]	0.7[a]	53.4[a]
Lsd(0.05) management		*0.342*	*NS*	*NS*	*NS*	*NS*	*NS*
Ls d var.management		*0.484*	*0.236*	*0.325*	*0.49*	*0.287*	*0.212*
CV%		*18.8*	*23.5*	*40.3*	*22.5*	*42.1*	*56.0*

In the table means bearing the same letter are not significantly different per variety along the columns. **NB:** Varietal height *Lsd= 0.242;* varietal no. of cobs *Lsd* = 0.118; varietal cob weight *Lsd* 1st season= 15.25; 2nd season= 31.36:

4.4.2.4 Maize grain yield (t/ha).

The maize yield results varied with varieties used and the two seasons. In both the long and short rains seasons there were no significant differences in grain yield between glyphosate and intercrop for both DUMA SC41and DK 8031 maize varieties at $P < 0.05$ although intercrop had higher grain yield than glyphosate (Table 35). Overall there was significant difference in grain yield between DUMA SC41 and DK 8031 in both seasons at $P < 0.05$ (Table 35). Significant differences between each of the two tillage practices and the weedy in yield were observed in DK8031 but none in DUMA SC41 in both seasons (Table 35).

Table 35: Maize grain yield (tons /ha) for long and short rain seasons 2010

Maize variety	Weed control	Yield tons/ha		
		Long rains season	Short rains season	Average
DUMA SC41	Glyphosate	1.01^{a}	0.87^{a}	0.94
	Weedy	0.40^{a}	0.08^{a}	0.24
	Intercropping	1.11^{a}	0.95^{a}	1.03
DK8031	Glyphosate	2.19^{ab}	1.37^{ab}	1.78
	weedy	1.14^{a}	0.36^{a}	0.75
	Intercropping	3.32^{b}	2.37^{b}	2.85
Lsd(0.05) management		*1. 78*	*1.39*	
Lsd var.management		*0.664*	*0.653*	
CV%		*62.4*	*77.4*	

Varietal *Lsd* yield 1st season = 0.737; 2nd season = 0.327; In the table means bearing the same letter are not significantly different per variety along the columns

4.4.2.5 *Dolicos lablab* percentage germination, vigour and yield for long and Short rain seasons 2010

In both long and short rain seasons there were no significant differences in percentage germination and vigour between the *Dolicos* intercropped with DUMA SC41 and DK8031respectively at $P < 0.05$. In both seasons there were no significant differences between the number of *Dolicos* branches and pods per plant, the number of seeds per pod and grain yield for *Dolicos* intercropped with DUMA SC41 and DK8031 respectively at $p < 0.05$. For the two seasons the average germination percentages and yields were 54.5% and 56.9% respectively and 5kg/ha and 71kg/ha also respectively.

CHAPTER FIVE: DISCUSSION

5.1 Evaluation of Comparative efficiency of glyphosate and hand weeding on weed management in maize (*zea mays* L.)

The study showed that there were no significant differences in percentage germination and crop vigour between the two maize varieties and the tillage practices in both seasons. The results of the three weed counts done at 11WAP, 15WAP and 19WAP showed there were significant differences in number of weed species between glyphosate and hand weeding at $p < 0.05$, indicating that glyphosate (zero tillage) was more effective in suppressing the weeds than hand weeding (conventional tillage). This has also been found to be the case in a study reported by International Weed Science Society in Guatemala (*htt: //paraquat.com/knowledge-bank*) which noted that use of herbicides (paraquat and glyphosate) were found to be much more effective in weed control than hand weeding.

The dry weed weight biomass for both glyphosate (zero tillage) and hand weeding (Conventional tillage) in both seasons significantly differed from the weedy (control) at $p < 0.05$ but were not significantly different between themselves at $p < 0.05$ although hand weeding had higher weed biomass compared with glyphosate in both seasons with broad leaved weeds being dominant. This conforms to findings by Kombiok, *et al;* (2007) that although glyphosate effectively suppressed weeds than hand hoeing at 3WAP in the absence of weeding, at harvest the weed populations and weed dry matter on zero-tillage were similar to the hand hoe treatment. The tillage practices were found to have significant effect on plant height during the long rain season but none during the short rain season, the three tillage practices all significantly differed at $p < 0.05$. During the long rains and within the same maize variety, glyphosate had taller plants than hand weeding although not significantly different. Generally, maize plants were shorter during the short rains season than long rains season irrespective of variety, perhaps due to less rains. These results conform to those of Najafinezhad *et al*, (2007) who reported that reduced tillage produced maximum maize height of 198.6 cm while hand weeding (conventional tillage) produced maximum maize height of 192.6cm indicating that tillage practices had significant effect on maize plant height.

There were no significant differences between the two tillage practices in the average number of cobs per plant and cob weight for both varieties in the two seasons at $p < 0.05$. The significant differences were only between the two maize varieties in the mean number of cobs per plant and cob weight where the results revealed DK8031 had significantly higher number of cobs per plant and cob weight than DUMA SC41 at $p < 0.05$. The study revealed that there were no significant differences between the two tillage practices in maize grain yield for the two maize varieties in both seasons at $p < 0.05$ although glyphosate had higher grain yield than hand weeding in both seasons.

The only significant difference in grain yield (tones /ha) was between the two maize varieties where DK8031 had higher grain yield than DUMA SC41 irrespective of weed control practices. Better performance of glyphosate probably could be due to the fact that it kills the weeds without any soil disturbance this denies buried weed seeds chance for germination hence low weed population unlike in hand weeding where favourable environmental conditions for weed germination are created by exposing them to the soil surface during weeding and after germination compete with the crop before weeding is done. Higher glyphosate performance could have also been attributed to low soil moisture loss through evaporation unlike when the soil is opened by weeding, leading to loss of moisture, the dead weeds act as mulch to cover the ground thereby preventing moisture loss before they decay and add organic matter to the soil for the crop use next season, lack of soil disturbance also prevents nutrients leaching thereby conserving them for the crop use. This is unlike in hand weeding where the weeds are either removed from the field to non crop areas where they rot without adding any fertility to the soil. This is in agreement with Aune, *at el.,* (2000) who found that use of herbicides in weed management in maize production the yields were higher under zero tillage than under hand weeding (conventional tillage).

Paraquat is another option for zero tillage but its mammalian toxicity could be a problem while other herbicides such as Afalo (linuron) are used as pre-emergence and will involve ploughing the field before application. Use herbicides today is expected to be part and parcel of integrated weed management to avoid environmental pollution, reduce cost of maize production and at the same time relief the farmers from the burden of hand weeding.

5.2 Cost benefit analysis of hand weeding and glyphosate in weed management

DK8031 under glyphosate during the the long rains season had a profit of Kshs 8,963 while under hand weeding had a loss of Kshs 17,941, implying a gain of Kshs 4.36 for every shilling invested under glyphosate and a loss of Kshs 3.0 for every shilling invested under hand weeding. At the same period DUMA SC41 under glyphosate and hand weeding practices made losses of Kshs 15,037 and 44,941respectively, translating to losses of Kshs 2.60 and 1.20 for every shilling invested under glyphosate and hand weeding practices respectively. During short rainy season both maize varieties had losses under both tillage practices, DK8031 variety had losses of Kshs 8,637 and 23,941under glyphosate and hand weeding respectively, translating to losses of Kshs 4.52 and 2.25 for every shilling invested under glyphosate and hand weeding practices respectively. DUMA SC41 variety for the same period incurred losses higher than DK8031 of Kshs 21,037 and 48,941 under glyphosate and hand weeding tillage practices respectively translating to losses of Kshs 1.86 and 10.0 respectively for every shilling invested under glyphosate and hand weeding respectively.

DK8031 variety performed better than DUMA SC41 in both tillage practices, the latter having almost three times the losses incurred by the former in both tillage practices, the loss was contributed by the high cost of weeding amounting to Kshs 20,187 for each variety against low maize yield. The performance was worse under hand weeding especially during the short rains season probably due to limited/unreliable rainfall during that period which needed to be supplemented by irrigation. The high losses made by DUMA SC41 variety under both tillage practices makes it unsuitable for the area since growing it in the area will mean maize dearth and as a result food insecurity and perpetuation of poverty. Glyphosate use in maize production was profitable with DK8031 due to its higher returns than hand weeding with the same variety. Its use has no adverse effects on environment since it is not persistent and is biodegradable. Resistance build up by the weeds against glyphosate can be prevented by applying the correct dose and at the susceptible weed stage and application of integrated weed management to avoid over reliance on it. Use of the two tillage practices and the two maize varieties in the trial revealed that although cost of some tillage practices can be considerably high to reduce the maize crop benefits for the farmers to minimum, maize productivity depending on variety attributes (governed by genetic) will determine the amount of benefits the farmers can reap from the crop production regardless of the tillage practice used. Use of the right maize variety for a given area will benefit the farmers but if the right tillage practice is employed the farmers will get higher benefits. This was clearly demonstrated by DUMA SC41variety which made losses under both tillage practices while DK8031 made profit under glyphosate but incurred losses under hand weeding showing that weed control practice choice is tied to maize variety in order to reap maximum profit.

5.3 Assessment of the effects of intercropping and monocrop on weed population and maize yield

The results of weed count showed monocrop had significantly higher number of weed species compared with intercrop at $P< 0.05$ indicating that intercropping was more effective in suppressing the weeds thereby reducing their population. This is in agreement with work done by Bilalis *et al.*, (2010) who reported that maize legume intercropping led to reduction of weed density and dry matter compared to pure maize stand. Also the results are in agreement with those of Maina, (1997) who reported that weed suppression was higher in maize bean intercrop than in the monocrop. Time taken to weed maize intercropped with *Dolicos* and maize monocrop was the same implying intercropping was beneficial in labour saving (better labour utilization) unlike when the two crops were planted separately. This conforms with findings by Maina, (1997) who found that time taken to weed maize - bean intercrop and maize monocrop was similar. In both long and short rainy seasons the results of weed biomass dry weight for monocrop was not significantly different from that of intercrop at $p < 0.05$, although monocrop figures were higher than those of intercrop in both seasons. Despite lack of significant difference between monocrop and intercrop in maize grain yield at $p < 0.05$, the results showed intercropping was beneficial in increasing maize yield compared with monocrop. Intercropping on average increased yield for the two maize varieties in the two seasons by 47.9% over monocropping maize.

The yield of the two maize varieties varied in the two seasons due to the prevailing weather conditions during the crop growth. During the long rain season 971.6mm of rainfall was received and distributed over 81 rainy days compared with short rains season which had 398.8mm spread over 28 rainy days and hence higher yields for both varieties during the long rains season than during the short rains season. The rainfall is expected to be well distributed during the crop growth period diminishing towards the crop maturity. Unlike the first season which had a longer period of wet days the second season had very few wet days such that the rains came and lasted for a duration of less than a month. DUMA SC41 and DK8031 require 100-110 days and 120 days respectively to mature, the period of rainfall during the short rains season was in deficit by 82 days for DUMA SC41 and 92 days for DK8031, the former is a drought tolerant while the latter is a very strong drought tolerant according to FIPSAFRICA Ltd *Fipsafrica.org/Monsanto cooperation*, hence the differences in performance between the two maize varieties in the same season and each of them in the two seasons respectively.

Intercropping maize with *Dolicos* increased maize grain yield probably due to nitrogen fixation by the *Dolicos*, suppression of weeds that could have utilized the plant growth resources like nutrients and water thereby conserving them for the crop. This is accomplished by *Dolicos* foliage covering the ground. This is in agreement with findings by Mureithi, *et al;* (2005), in work done in Kisii and Kitale where intercropping maize and *Dolicos* increased maize yield and income per unit area for the farmers. The results also agree with those obtained by Chen *et al.,* (2004) who found intercropping maize with legumes to be beneficial in yield increment due to improved soil fertility, less competition for water and nutrients between maize and weeds as the latter are suppressed by leguminous crop. In both seasons the grain yields of the *Dolicos* (intercropping legume) were on average low 5kg/ha during the long rains season and 71.1kg/ha during the short rains season. The poor performance of the crop especially during the long rains season could have been attributed to excess rain, cold weather and lack of sunshine during the crop growth period. The short rains season had less rains unlike the long rains season, it was characterized by dry spell with a lot of sunshine. If the weather was favourable for both crops intercropping could have had an added advantage of getting two crops from the same plot in one season It is also worth to note that the crop of interest during the trial was maize, so if the legume could perform the function of weed suppression efficiently, save the farmers the burden of weeding and increase maize yield then its poor performance in grain yield is compensated for.

5.4 Comparison of the effectiveness of zero tillage and intercropping on weed management in maize crop

The results of weed count showed there was no significant difference between glyphosate and intercropping in the number of weed species at $p < 0.05$, although in most of weed counts glyphosate had higher number of weed species compared with intercrop indicating that intercropping was more effective than glyphosate in suppressing the weeds thereby reducing their population. This is in agreement with work done by

Maina,(1997) who reported that use of herbicides and intercropping significantly controlled the weeds, during the early stage of crop growth the herbicide controlled the weeds while maize-bean and maize-potato intercrop each separately effectively suppressed weeds such that weeds did not have any significant effect on the yields. Also the author found that intercropping using the right bean varieties and spacing replaced two weedings in one of the experimental sites and was cheaper than use of herbicide. The results of weed biomass showed there were no significant differences between glyphosate and intercropping in weed dry weight in both seasons at $p < 0.05$. The ability of maize/legume intercropping to suppress weeds better or the same as glyphosate means intercropping could be beneficial to the small scale farmers who practice it in weed management by not only reducing cost of herbicide but also maximizing on available land by enabling the farmers to get two crops from the same plot and season respectively. Intercropping can also be a useful tool in combating weed problem by eliminating drudgery of weeding especially if it can replace one or two weedings in a crop's growth period by reducing labour requirement and time for weeding. Due to reduced labour requirement by intercropping, the cost of maize production would be low thereby encouraging farmers to increase maize acreage leading to considerable increase in both maize yield and net returns for them. The ability of the *Dolicos lablab* to suppress the weeds emanates from its growth habit, like most of leguminous plants having high leaf area index due to massive forage that precludes light from reaching the ground where weeds are growing.

The maize yield results in both seasons showed there were no significant differences between intercropping and glyphosate in grain yield at $p < 0.05$ although intercrop had slightly higher grain weight than glyphosate in two cases. This conforms to other results obtained by Chui, *et al,* (1996) who reported that herbicide application, intercropping maize with beans both effectively controlled weeds and their maize grain yields were not significantly different. The various factors that can influence this type of results are nitrogen fixation by the legume leading to higher grain yield, the legume cover inhibits weed growth eliminating weed competition for resources with the crop. Soil moisture loss through evaporation is minimized by the legume cover reserving it for the crop. Intercropping is relatively cheap compared with use of glyphosate costing Kshs 1,400 per litre which is not affordable to small scale resource poor farmers who form more than 75% of the farmers in Kenya. Use of intercrop would result into environmental conservation from pollution by the herbicide and reduce weed developing resistance due to repeated use of the same herbicide. Use of herbicide in terms of safe handling also requires technical know how which is low among the small scale farmers.

It is worth to note that weed management and variety interactions in both long and short rain seasons 0.56 and 0.28 respectively were not significant but weed management, species and their interactions in both seasons each was 0.001 and were all significant.

The high cv% weed species persistence in both long and short rain seasons 546.2 and 385 respectively were attributed to high variation in the number of weed species among the different weed management practices in each season.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The study established that glyphosate and hand weeding tillage practices had no effect on percentage germination and maize vigour upto 5WAP.

Glyphosate was more effective in weed suppression than hand weeding as was shown by both the weed counts and biomass dry weight.

Weed management practices had significant difference on maize height in the long rain season but none during the short rain season.

Weed management practices did not have any significant difference on the number of maize cobs per plant and average cob weight in both seasons.

There was no significant difference between glyphosate and hand weeding tillage practices in maize grain yield.

Glyphosate in maize production was profitable than conventional tillage when used with the right maize variety for a given area.

Maize variety DK8031 is more suitable than DUMA SC41 for growing in the areas of the same ecological zone (UM1) and altitude of about 1,800 m above sea level as the experimental site.

The study showed that in maize production higher returns can only be achieved by use of the suitable variety for a given area combined with an appropriate tillage practice.

Intercropping or monocrop did not have any effect on percentage germination and vigour of the crop species involved.

Intercropping maize with *Dolicos lablab* was more effective in weed suppression than monocrop.

Time taken to weed for maize intercropped with *Dolicos* and maize monocrop was the same.

Intercropping maize with *Dolicos lablab* increased maize yield more than monocrop on average by 47.9%.

There was no significant difference in weed suppression between glyphosate and intercropping maize with *Dolicos lablab*. The study has also shown that intercropping maize with *Dolicos lablab* and use of glyphosate produced similar maize grain yields.

6.2 RECOMMENDATIONS

If farmers can afford, glyphosate should be used in maize production since it suppresses weed better than hand weeding to save time, reduce labour requirement and for soil and water conservation instead of hand weeding.

Further trials for glyphosate (zero tillage) performance in two applications at pre-planting, 3WAP and 7WAP equivalent to two hand weeding only instead of three should be done to minimize its use, lower cost of maize production and improve farmers' net returns.

DK8031 variety should be used in areas of similar agro ecological zones (UM1) to that of the trial site while DUMA SC41 should be tried in agro-ecological zone LH1 to cater for the farmers welfare in the region.

Small scale farmers should be encouraged to grow maize intercropped with *Dolicos lablab* or other leguminous crops to assist in weed management, improve maize yield, reduce cost of herbicide or weeding and better utilization of land and labour.

REFERENCES

Abdin, O. A; Zhou, X. M; Cloutier, D; Coulman, D. C; Farris, M. A. and Smith, D.L; (2000). Cover crops and interrow tillage for weed control in short season. European Journal of Agronomy, Vol 12, Issue 2, March 2000 pp 93-102.

Agegnehu, G., Ghizam, A. and Sinebo, W., (2006). Yield performance and land use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. EUr.J.Agron.25: 202-207.

Akobundu, O., (1998). Basic elements for improved weed management in the developing world. In Report of the Expert Consultation on Weed Ecology and Management. pp. 93-101. FAO, Rome.

Anil, L., Park, J., Phipps, R. H. and Miller, F. A.,(1998). Temperate intercropping of cereals for forage; a review of the potential for growth and utilization with particular reference to the UK. Grass For. Sci. 53: 301-317.

Aune, J. B., Teklehaimot, R.D.A. and Bune, B.T., (2000). Zero tillage or reduced tillage: Key to intensification of crop livestock system in Ethiopia. In: Ed. Pender, J; Place, F. and Ehui, S., Strategies for sustainable land management in East African Highlands, IFPRI publication 2006, 2033K Street, N.W. Washington D.C; Chapter 12, pp 309.

Banik, P., Midya, A., Sarkar, B.K. and Ghose, S. S., (2006). Wheat and chick pea inter cropping systems in an additive series experiment: advantages and weed smothering. EUr. J. Agron. 24: 325 – 332.

Banik, P., Sasmal, T., Ghosal, P. K. and Bagchi, D.K., (2000). Evaluation of Mustard (Brassica compestris var.Toria) and legume intercropping under 1;1 and 2:1 row replacement series systems. J. Agron. Crop Sci. 185: 9-14.

Begna, S.H; Hamilton, R. I; Dwyer, L.M; Stewart, D. W; Cloutier, D; Assemat, L; Foroutan, P. K. and Smith, D.L; (2001). Morphology and yield response to weed pressure by corn hybrids differing in canopy architecture. European Journal of Agronomy, Vol 14, Issue 4, pp 293-302.

Bell, R.A.,(2005).Insect pests of maize in Kwazulu-Natal; *Agriculture.kzntl.gov.za/Insect Pests of maize in KwaZulu-Natal;* accessed on 12.02. 2010.

Bescansa, P., Imaz, M. J., Virto, I., Enrique, A. and Hoogmoed, W. B., (2006). Soil water retention as affected by tillage and residue management in semi-arid Spain. Soil and Tillage Research, 87: 19-27.

Bilalis, D., Panayiota, P., Konstantas, A., Patsiali, S., Karkanis, A. and Ethimiadou, A., (2010). Weed-suppressive effects of maize –legume inter cropping in organic farming International Journal of pest management. Vol. 56. Issue 2, pp 173-181.

Buhler, D.D.,(2005). Impacts of tillage on weed management; Extension Bulletin E- 2931 Michigan State University, East Lansing. Davis. MI, USA, accessed on 12.06.2010.

Caballero, R., Goicoechea and Hernaiz, P. J., (1995). Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch. Field Crop Res. 41: 135 - 140.

Carr, P. M., Horsley, R. D. and Poland W. W., (2004). Barley, oat and cereal-pea mixtures as dry land forages in the Northern Great plains. Agron. J. 96: 677- 684.

Cereal knowledge bank, IRRI and CIMMYT; (2007). Are reduced tillage practices suitable for growing maize? *knowledge bank.irr.org/ckb/index.php/agronomy*, accessed on 29.10.2010.

Chen, C., Westcott, M., Neill, K., Wichman, D. and Knox, M., (2004). Row configuration and nitrogen application for barley–pea intercropping in Montana. Agron. J. 96: 1730 -1738.

Chui, J. N; Kusewa, T. M; and Kabumbura, J. M; (1996). Use of cultural practices, physical and chemical methods on weed control in maize and bean cropping systems. In: Sutherland, J.A; (1999). Towards increased demand driven technology (KARI/DFID NARP II Project) end of project conference 23rd to 26th March 1999 Nairobi, Kenya.

CIMMYT; (2010). Weed competition, *Maize doctor.Cimmyt.org/index.com*, accessed on 8.2.2011.

Cowan, P., Weaver, S. E. and Swanton; (1998). Interference between pigweed (*Amaranthus spp*), barnyard grass (*Echinochloa crus-galli*), and Soybean (*Glycine max*).Weed Sci. 46 : 249 – 256.

Dhima, K. V., Lithourgidis, A. A., Vasilakoglou, I.B. and Dordas, C. A., (2007). Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crop Res.100: 249 - 256.

Dowswell, C., (1996). Maize in the third world West view press, USA. In: Gramene, *Zea* introduction; *www.gramene.org/Zea introduction* (Gramene Reference ID 9391), accessed on 20.01.2011.

Duke, S. O., (1985). Weed Physiology, Vol. 1: Reproduction and Ecophysiology CRC Press E. L. Rice, 1984. Allelopathy. Academic press N.Y.

Economic Review of Agriculture, (2010). Maize production 2005-2009: Central planning and monitoring unit, Ministry of Agriculture, Nairobi, Kenya.

Esilaba, O. A.,(2006).Options for *Striga* management in Kenya, KARI Technical Report no.19, 2006. Nairobi, Kenya.

Export processing zones authority (EPZA), (2005). Grain production in Kenya; *www.epzakenya.com*, accessed on 21.06.2011.

FAO, ZTAT, (2000). Rural communities actively implementing conservation agriculture; *www.fao.org/ Implementing conservation agriculture practices*, accessed on 23.2.2010.

FAO, (2011). Intercropping sorghum with cowpeas against striga infestation, *www.fao.org/Intercropping sorghum with cowpeas against striga infestation*, accessed on 2.12.2011.

FAO, (1992). Maize in human nutrition,(FAO, Food and nutrition series, No.25), *www. fao.org/ maize origin.htm*, accessed on 20.01.2011.

FAO, (1992). Maize in Human Nutrition, *www.fao.org/ Maize in Human Nutrition*, accessed 20.01.2011.

Faqs. org., (2007). Nutrition and Well-Being A to Z, *www.faqs.org/ Corn or Maize Based Diets*, accessed on 20.1.2011.

Fenandez-Aparicio, M., Josefina, C. and Sillero, D. R., (2007). Intercropping with legumes reduces infection by *Orobanche crenata* in legumes. Crop Protec. 26: 1166-1172.

Ford, G. T., and Pleasant, J. MT., (1994). Competitive abilities of six corn (*Zea mays* L.) hybrids with four weed control practices. JSTOR: Weed Technology, vol. 8, No.1 pp.124-128.

Gerhart, J; (1975). The Diffusion of Hybrid maize in western Kenya. Report for International Maize and Wheat Improvement Centre (CIMMYT), Mexico City, D.F.CIMMYT. Government of Tanzania.

Ghosh, P. K., (2004). Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Res. 88: 227-237.

Hauggaard, N. H; Ambus, P. and Jensen, E. S; (2001). Evaluating pea and barley cultivars for complementary in intercropping at different levels of soil N availability. Field Crop Res. 72: 185-196.

Haussmann, B. I. G., Hess, D. E., Welz, H. G. and Geiger, H. H., (2000). Improved methodologies for breeding striga-resistant sorghums. Field Crops Research 66: Issue 3 pp 195-211.

Hobbs, P.R., (2007). Conservation Agriculture: What is it and why is it important for future sustainable food production? Department of Crops and Soil Sciences, Cornell University, Ithaca NY, 14853 USA. Journal of Agricultural Science 145, 127-137.

ICRISAT, (2009). Virtual Academy for the Semi Arid –Tropics (VASAT)
International Weed Science Society in Guatemala (*htt://paraquat.com/knowledge-bank/*Crop – production and protection/Maize – cropping), accessed on 20.1.2011.

ICRISAT, (2009). Maize requirements, *vasat.icrisat.org/index/climatic requirements of maize crop*, accessed on 20.1.2011.

IRRI and CIMMYT, (2007). Weed management in maize-based cropping systems, *www.knowledgebank.irri.org/ckb/index/weed management in maize-based cropping systems*, accessed on 3.9.2010.

Jaetzold, R. and Schmidt, H., (1983). *Farm management Hand book of Kenya*. Natural Conditions and Farm Management Information. Central Kenya Volume 11B, Ministry of Agriculture, Nairobi, Kenya 739P.

Jasieniuk, M., Maxwell, B. D., Anderson, R. L., Evans, J. O., Lyon, D. J., Miller, S. D., Morishita, D. W., OggJr, A.G., Seefeldt, S., Stahlman, P. W., Northam, F. E., Westra, P., Kebede, Z. and Wicks, G. A., (1999). Site – to -site and year – to - year variation in *Triticum aestivum-Aegilops cylindrical* interference relationships. Weed Sci. 47: 529-537.

Jayne, T. S; Yamano, T; Nyoro, J. and Awour, T; (2001). Do Farmers Really Benefit from High food prices? Balancing Rural interests in Kenya's maize pricing and marketing policy. Working paper 2b, Tegemeo Institute, Nairobi, Kenya.

Kardag, Y. and Buyukbur, U., (2004). Forage qualities, forage yields and seed yields of some legume – triticale mixtures under rainfed conditions. Acta Agri. scan. Sec. B. Soil and plant Sci. 54: 140 -148.

Kenya maize development program, (2009). Boosting household incomes, rising Productivity, *www.acdivoca.org/Kenya Farmers*, P.O. Box 5523, 00200 Nairobi, Kenya, accessed on 3.09.2010.

Kenya Maize Development program, (2010); Kenya maize hand book, *www.acdivoca.org/Kenya -Usaid maize hand book 2010.* P.O. Box 5523, 00200 Nairobi, Kenya, accessed on 3.09.2011.

Kenya National Bureau of Statistics (KNBS), (2001). Economic Survey by Kenya Ministry of Planning and National Development, Government printer, Nairobi, Kenya.

Kenya National Bureau of Statistics, (2008). Economic Survey by Ministry of Planning and National Development, Government printer, Nairobi, Kenya.

Kenya National Bureau of Statistics, (2009). Kenya census 2009 results, Ministry of Planning and National Development, Government printer, Nairobi, Kenya.

Kibaara, B.W., (2005); Technical efficiency in Kenya's maize production, an application of Stochastic frontier approach (MSc Thesis), Department of Agricultural and Resource Economics, Colorado State University.

Kibaara, B., Ariga, J., Olwande, J., Jayne, T. S., (2008). Trends in Kenyan Agricultural productivity 1997- 2007. Tegemeo Institute of Agricultural policy and development (Egerton University), Nairobi, Kenya.

Kirimi, L; Swinton, S. M; (2004). Estimating maize costs of production, Estimating cost efficiency among maize producers in Kenya and Uganda. Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039, U.S.A.

Knezevic, Z. S; Evans, S. P. and Mainz, M., (2003). Yield penalty due to delayed weed control in corn and soy bean, *Crop mngt doi: 10.1094|CM-2003-0219-01-RS.*

Kombiok, J. M., Alhassan, A. Y., (2007). Tillage effects on subsequent weed types, population and biomass in maize cropped in Northern savanna zone of Ghana. In Journal of sustainable Agri. Vol 30. Issue 1, pp 47-57.

Kurt, G. Steiner; (GTZ), Steve Twomlow (ICRISAT), (2003). Weed management in conservation tillage systems. African conservation tillage net work (ACT) information series No. 8; University of Zimbabwe, P.O. Box MP 167, Harare Zimbabwe. *www.fao.org/act-network.*

Lipiec, J., Kus, J., Slowinska-Jurkiewicz, A. and Nosalewicz, A., (2005). Soil porosity and water infiltrations influenced by tillage methods. Soil Tillage research, 89: 210-220.

Maina, J. Mukami, (1997). Effects of Intercropping on weeds and weed management in maize growing in Kenya, PhD Thesis University of Reading.

Mati, M. B., (2000).The influence of climate change on maize production in the semi-humid, semi-arid areas of Kenya (JKUAT). Journal of Arid Environments vol 46, issue 41, pp 333- 344.

Michael, N.N., (1989). Experiences in weed control problems in maize (*Zea mays L.*) seed production in the Trans-Nzoia District of Kenya. In 12,th Biennial conference of weed Science Society for Eastern Africa, 14-18th August 1989 Nairobi, Kenya.
Ministry of Agriculture, (1981). Major crops, Technical Hand book, Nairobi, Kenya.

Ministry of Agriculture, (2010). Kigumo District Annual Report, Central Province, Kenya.

Monzon, J. P., Sadras, V.O. and Andrade, F. H., (2006). Fallow soil evaporation and water storage as affected by stubble in sub-humid (Argentina) and semi-arid (Australia) environments. Field Crops Research, 98: 83-90.

Mulaa, M. M., Bergvinson, D. J., Mugo, S. N., Wanyama, J. M., Tende, R. M., De Groote, H. and Tefera, T. M., (2011). Evaluation of Stem borer resistance, Management strategies for Bt maize in Kenya based alternative host refugia. African journal of biotechnology vol 10 (23), pp.4732- 4740.

Mureithi, J. G., Nzambi, A. W., Makini, F., Tong'I, E., Kidula, N., Munyi, D., Mwangi, G., Odhok, H., Kotonya, J., and Mutai, E, (2005). Intercropping with legumes and incorporating crop residues; Soil management project, KARI, Kenya.

Najafinezhad, H; Javaheri, M. A; Gheibi, M. and Rostami, M. A., (2007). Influence of tillage practices on the grain yield of Maize and some soil properties in Maize –Wheat cropping system of Iran. Journal of Agriculture and Social Sciences 1813-2235/2007/03-3-87-90.

Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI) of Vietnam, (2010). Fast acting paraquat means more maize, *paraquat.com/fast acting paraquat means more maize*, accessed on 1.11.2010.

NRIL and KARI Embu station, (2005). Improved access to appropriate farm inputs for integrated maize crop management by small scale farmers in Embu and Kirinyaga districts in Kenya, KARI, Kenya.

Nyoro, J., K., (2002). Kenya's competitiveness in domestic maize production. Implications for food security; A paper presented in a seminar at the African Study Centre, University of Leiden, on 7,th November 2002, Room1. A12, Pieter de la Court building, Wassenaarseweg 52, Leiden.

Odendo, M., H., De Groote and Odongo, O. M., (2001). Assessment of farmers' preferences and constraints to maize production in moist mid altitude zone of western Kenya. A paper presented at the 5,th International conference of the *African Crop Science Society,* Lagos, Nigeria, October 21 - 26, 2001.

Okoruwa, A., (1996). "Nutrition and Quality of Maize." International Institute of Tropical Agriculture; *www.iita.org/info*, accessed on 20.01.2011.

Omafra, (2009). Weed Control: Crop yield losses due to weeds, Agronomy guide for field crops publication No.811, Ministry of Agriculture, food and rural affairs, Ontario, Canada, accessed on 21.6.2011.

Osunbitan, J. A., Oyende, D. J., Adekalu, K. O., (2004). Tillage effects on bulky density, hydraulic conductivity and strength of a loamy sand soil in south western Nigeria. Soil and Tillage Research, 82: 57- 64.

Oswald, A., Ransom, J.K., Kroschel, J. and Sauerborn, J., (2002). Intercropping controls *Striga* in maize based farming systems. Crop Protection 21: 367- 374.

Pingali, P. and Pandey, S., (2000). CYMMIT World maize facts and trends; In: Gramene, *Zea* introduction; *www.gramene.org/Zea* (Gramene Reference ID 9392), accessed on 20.01.2011.

Pingali, P. L., (2001). CIMMYT 1999-2000: Meeting world maize needs; Technological opportunities and priorities for the public sector. CIMMYT, Mexico, D. F., Mexico, *www.gramene.org/Zea nutrition* accessed on11.02.2011.

Poggio, S. L; (2005). Strucure of weed communities occurring in monoculture and intercropping of field pea barley. Agr. Ecosyst. Environ. 109: 48-58.

Projects in Kenya by International Development Research Centre (IDRC), (2009). Minimum tillage Studies on reduced tillage or No-tillage systems w.w.w.idrc.ca/esaro/ev-83049-201 870315-1-IDRC ADM INFO.html accessed on 26.8.2010.

Projects in Kenya by International Development Research Centre (IDRC), (2009). Weed management in maize based cropping systems. w.w.w.idrc.ca/esaro/ev-83049-201 870315-1-IDRC ADM INFO. html accessed on 26.8.2010.

Pyne, R.W; Munay, D.A; Harding, S. A; Baird, D. B and Souter, D.M; (2009). Gen Stat for Windows (12th Edition) Introduction VSN International, Henel Hemsteed.

Santalla, M., Rodino, A. p., Casquero, P. A. and de Ron. A. M., (2001). Interactions of bush bean intercropped with field and sweet corn. EUr. J. Agron. 15: 185-196. Sci.46:533-539.

Smalling, E. M. A; Stein, A. and Sloot, P. H. M; (1991). A statistical analysis of the influence of *Striga hermonthica* on maize yields in fertilizer trials in south western Kenya, Plant and soil 138: 1- 8.

Soil and water protection, (2010). Impact of conservation tillage on costs and yields, European journal of Agronomy Vol 33 pp 231- 241, accessed on 2.11.2011.

Spitters, C. J. T., Kropff, M. J.and Groote, dew., (1989).Competition between maize and *Echinochloa crus-galli* analysed hyperbolic regression model. Ann. App. Biol. 115:541-551.

Sprague, G., eds., (1988). Corn and corn improvement: 3,rd Edition. American Society of Agronomy. Inc., In: Gramene, *Zea* introduction; *www.gramene.org/Zea introduction* or Gramene Reference ID 9393, accessed on 20.01.2011.

Stewart, B. A., (1993). Tillage and residue management for sustainable land use. In: Stanley Mwangi Wokabi (1994); Quantified land evaluation for maize yield gap analysis, PhD Thesis, University of Ghent, Belgium.

Swinton, S. M., Buhler, D. D., Forcella, F., Gunsolus, J. L. and King, R. P., (1994). Intercropping maize with edible legumes and incorporating their residues is beneficial Weed Science, Vol. 42, No. 1, pp. 103-109.

Syngenta, (2010). Preserving the land we grow on: Reducing soil erosion from maize fields in Vietnam, *www.Syngenta.com/Preserving the land we grow on*, accessed on 21.6. 2011.

Tegemeo Institute of Agriculture policy and Development (Egerton university), (2009). Maize production outlook and implications for food security; (National maize production and consumption trends 2000-2008), Egerton University, Kenya.

Thierfelder, C., and Wall, P.C., (CIMMYT), (2007). Weed control in small holder conservation Agriculture. Journal of Agricultural Science 2007, Vol. 145 (2), pp 127-137. (accessed on 29.10.2010) as weed control in small holder conservation Agriculture a CIMMYT technical bulletin.

Uri, N. D., (2000). Perception of the use of no-till farming in production agriculture in the United States. An analysis of the survey results. Agric. Ecosyst, Environ, 77: 263-266. Wikipedia, (2010). Maize, *en.wikipedia.org/maize*, accessed on 20.1.2011.

Wilson, R. G. and Westra, P., (1991). Wild proso (*Panicum milliaceum*) influence in corn (*Zea mays* L.), Weed science vol. 39: 217- 220.

Wokabi, S. M., (1994); Quantified land evaluation for maize yield gap analysis, PhD Thesis, University of Ghent, Belgium.

Yilmaz, S., Atak, M., Erayman, M., (2007). Identification of advantages of Maize legume intercropping over solitary cropping through competition indices in the Mediterranean region. Turk J Agric. For 32 (2008) 111- 119

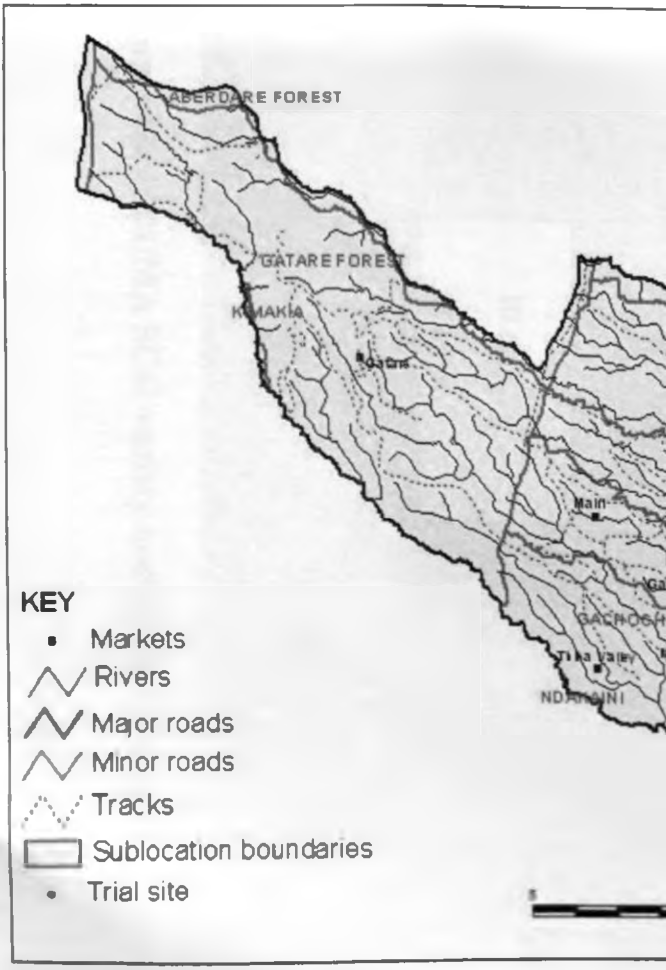
Zeyaur, R. Khan; John, A. Pickett; Johnnie, Van de Berg; Lester, J. Wadhams and Christine M.Woodcock, (2000). Exploiting chemical, ecology and species diversity: Stem borer and *Striga* control for maize and sorghum in Africa. Pest management Science Vol. 56, Issue 11, Oct 2000.

Zuofa, K. and Tariah, N. M., (1992). Effects of weed control methods on maize and inter crop yields and net income of small-holder farmers in Nigeria. The journal of faculty of Agriculture (Imperial College of Tropical Agriculture, University of West Indies, vol. 69, No 2).

APPENDICES

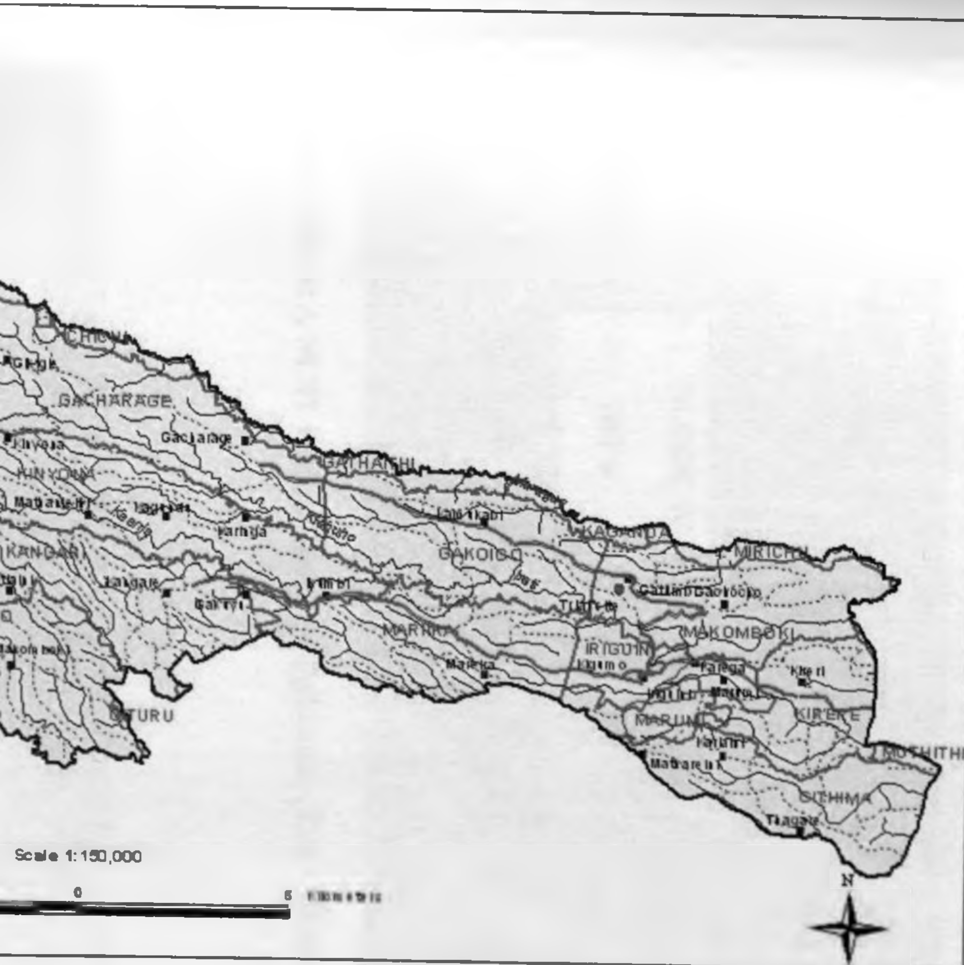
Appendix 1: Kigumo rainfall data for 2009 and 2010

Month	Year 2009		Year 2010	
	Rainfall amount (mm)	No. of wet days	Rainfall amount (mm)	No. of wet days
JAN	12	4	162	11
FEB	33	3	184.4	11
MAR	37.2	8	233.5	18
APR	175	15	280.6	25
MAY	445.5	26	280.6	25
JUN	11	66	176.9	13
JULY	7	5	24.7	8
AUG	22.5	8	112	16
SEP	46	9	24.5	11
OCT	380.5	19	250.6	15
NOV	216	15	148.2	13
DEC	305	21	0	0
Total	1691	199	1712	166

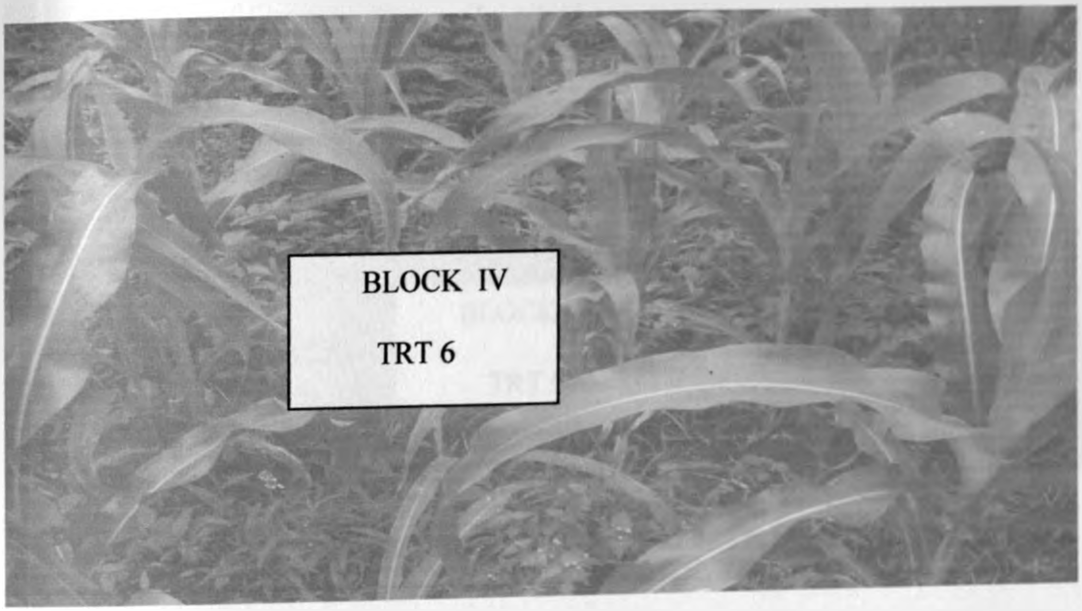


Printed by Kenya Soil Survey, 2011

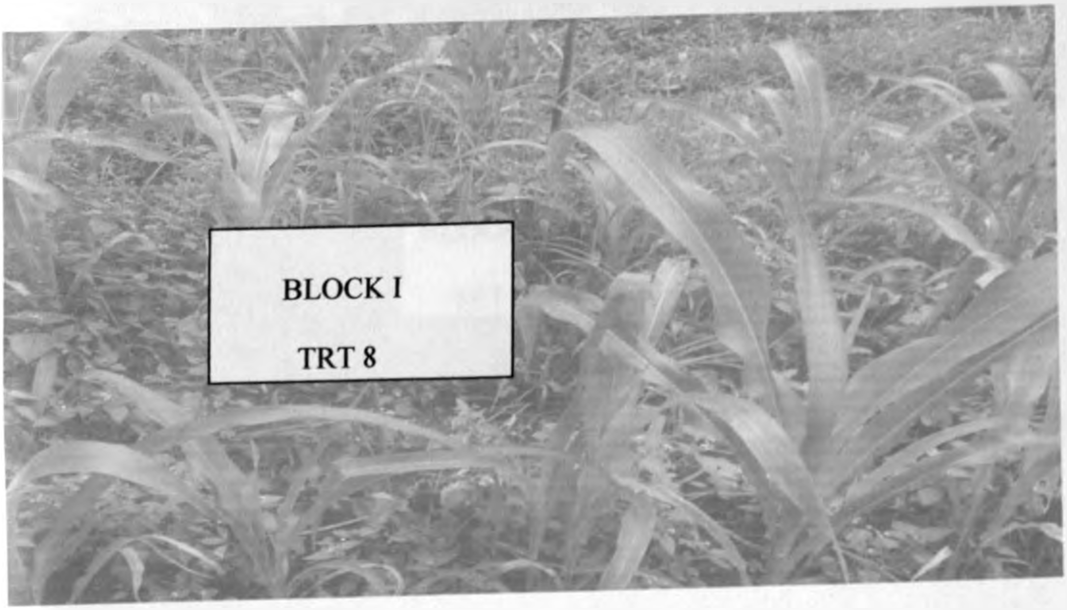
Appendix 2: Map of Kigumo District



This map is not an authority on administrative boundaries



Appendix 3: DUMA SC41 variety under glyphosate (Zero tillage)



Appendix 4: DUMA SC41 variety under weedy (control)

Appendix 5: DK8031 variety under glyphosate (zero tillage)

Appendix 6: K8031 variety under conventional tillage (monocrop)

Appendix 7: Time (mandays) used in spraying glyphosate in zero tillage plots and its value in Kshs

Long rains season				Short rains season			
Activity	Item			Activity	Item		
Spraying	Time minutes (mean)	Mandays Spent	Cost/ha Kshs	Spraying	Time minutes (mean)	Mandays spent	Cost/ha Kshs
*Pre- Spray Spraying	2.1	2.9	522	Pre-Spray Spraying	2.2	3.1	558
1st (3WAP)	2.0	2.8	504	1st (3WAP)	2.0	2.8	504
2nd (7WAP)	2.2	3.1	558	2nd (7WAP)	2.1	2.9	522
3rd(11WAP)	2.0	2.8	504	3rd (11WAP)	2.2	3.1	558
Average	2.1	2.9	522	Average	2.1	2.98	536

*Pre- Spray: Application of glyphosate before planting

Appendix 8: Amount in litres of glyphosate used in spraying zero tillage plots and its value in Kshs

Long rains season				Short rains season			
Activity	Item			Activity	Item		
Spraying	Glyphosate amount (mean) lt	Cost/ litre Kshs	Cost/ ha Kshs	Spraying	Glyphosate amount (mean) lt	Cost/ litre Kshs	Cost/ ha Kshs
*Pre-Spray Spraying	1.1	1,300	1,430	Pre spray Spraying	1.4	1,300	1,820
1st (3WAP)	1.1	1,300	1,430	1st (3WAP)	1.4	1,300	1,820
2nd (7WAP)	1.1	1,300	1,430	2nd (7WAP)	1.4	1,300	1,820
3rd (11WAP)	1.1	1,300	1,430	3rd 11WAP)	1.3	1,300	1,690
Average	1.1		1,430	Average	1.375		1,787

* Pre-spray: Application of glyphosate before planting

Appendix 9: Time taken (mandays) in digging and weeding a plot

Long rains season				Short rains season			
Activity	**Item**			**Activity**	**Item**		
	Mean time (minutes)	**Man days* spent**	**Cost/ha Kshs**		**Mean time (minutes)**	**Man days spent**	**Cost/ha Kshs**
Digging	19.2	26.7	4,806	Digging	18.9	26.3	4,734
1st Weeding (3WAP)	28.5	39.6	7,128	1st Weeding (3WAP)	15.8	21.9	3,942
2nd Weeding (7WAP)	31.4	43.6	7,848	2nd Weeding (7WAP)	30.8	42.8	7,704
3rd Weeding (11WAP)	34.7	48.2	8,676	3rd Weeding (11WAP)	6.3	8.8	1,584
Average	28.5	39.5	7,115	Average	17.9	24.9	4,489

1 Man day*= 8hours; Payment per manday = Kshs 180

Appendix 10: Time (mean) minutes taken in weeding intercrop and monocrop plots during the long and short rains seasons 2010

Maize variety	Weed control	Long rains season				Short rains season			
		First weeding	Second weeding	Third weeding	Average	First weeding	Second weeding	Third weeding	Average
DUMA SC 41	Intercrop	26.7	31.7	33.3	30.6	25.6	33.9	29.7	29.7
	Monocrop	29.3	34.7	40	34.7	27.1	30.4	35.2	30.9
DK8031	Intercrop	29	28.7	31.3	29.7	32.7	34.0	29.2	32.0
	Monocrop	29	30.7	34	31.2	28.6	31.3	26.8	28.9

Appendix 11: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the long rain season

Weed species	Weed management practices			
	Glyphosate	Weedy/control	Intercropping	Hand weeding
Galinsoga parviflora	42^{cdefgh}	56^{cde}	67^{c}	$24^{efghijk}$
Digitaria velutina	$37^{cdefghij}$	134^{b}	$30^{defghijk}$	63^{cd}
Oxygonum sinuatum	3^{ijk}	6^{hijk}	1^{jk}	1^{jk}
Bidens pilosa	$21^{efghijk}$	47^{cdefg}	16^{ghijk}	$39^{cdefghi}$
Richardia brasiliensis	$39^{cdefghi}$	343^{a}	$28^{defghijk}$	53^{cdef}
Elusine indica	8^{hijk}	$32^{cdefghijk}$	17^{fghijk}	7^{hijk}
Commelina benghalensis	3^{ijk}	6^{hijk}	3^{ijk}	2^{jk}
Cyperus rotundus	0^{k}	5^{ijk}	3^{ijk}	1^{jk}
Oxalis latifolia	2^{jk}	3^{ijk}	8^{hijk}	3^{ijk}
Oxalis corniculata	1^{k}	0^{k}	1^{jk}	1^{k}
Cleome monophylla	0^{k}	3^{ijk}	0^{k}	0^{k}
Ageratum conyzoides	$36^{cdefghijk}$	$20^{efghijk}$	12^{ghijk}	$23^{efghijk}$
Paspalum dilatatum	5^{ijk}	$30^{defghijk}$	7^{hijk}	3^{ijk}
Cynodon dactylon	10^{hijk}	1^{jk}	6^{hijk}	8^{hijk}
Dactyloctenium aegyptium	0^{k}	1^{k}	2^{jk}	0^{k}
Cyperus esculentus	18^{fghijk}	$30^{defghijk}$	5^{ijk}	17^{ghijk}
Setaria pumila	1^{jk}	0^{k}	1^{jk}	1^{k}
Stellaria media	0^{k}	1^{k}	2^{jk}	0^{k}
Cyperus blysmoides	3^{ijk}	8^{hijk}	2^{jk}	8^{hijk}
Digitaria abyssinica	11^{ghijk}	2^{jk}	1^{jk}	6^{hijk}
Amaranthus hybridus	4^{ijk}	0^{k}	$31^{cdefghijk}$	0^{k}
Emilia decifolia	10^{hijk}	10^{ghijk}	1^{jk}	3^{ijk}
Solanum nigrum	1^{k}	0^{k}	0^{k}	0^{k}
Cynodon nlemfuensis	0^{k}	0^{k}	1^{k}	1^{k}
Chenopodium murale	1^{k}	1^{k}	0^{k}	0^{k}
Spergula arvensis	0^{k}	0^{k}	0^{k}	1^{k}
Malva verticillata	0^{k}	1^{k}	0^{k}	0^{k}
Tagetes minuta	1^{k}	0^{k}	0^{k}	1^{k}
Cyperus grandibulbosus	0^{k}	1^{k}	0^{k}	0^{k}
Cyperus rigidifolius	1^{k}	0^{k}	0^{k}	0^{k}
Dichondra repens	0^{k}	0^{k}	0^{k}	1^{k}
Galium spurium	1^{k}	1^{k}	0^{k}	0^{k}
Achyranthes aspera	0^{k}	0^{k}	0^{k}	1^{k}
Gutenbergia cordifolia	0^{k}	1^{jk}	0^{k}	1^{k}
Amaranthus retroflexus	1^{k}	0^{k}	0^{k}	0^{k}
Conyza stricta	0^{k}	0^{k}	0^{k}	1^{k}
Fallopia convolvulus	17^{ghijk}	12^{ghijk}	7^{hijk}	12^{ghijk}
Cyathula polycephala	0^{k}	1^{k}	0^{k}	0^{k}
Sonchus oleraceus	1^{k}	0^{k}	0^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}	0^{k}
Euphorbia hirta	0^{k}	0^{k}	1^{k}	1^{k}

Appendix 12: Weed persistence trend at 3WAP, 7WAP and 11WAP under different weed management practices during the short rain season

	Weed management practices			
Weed species	**Glyphosate**	**Weedy/control**	**Intercropping**	**Hand weeding**
Galinsoga parviflora	33^{efg}	52^{bcd}	13^{hijk}	19^{ghi}
Digitaria velutina	14^{hijk}	41^{cdef}	29^{fgh}	12^{ijk}
Oxygonum sinuatum	5^{ijk}	17^{hij}	10^{ijk}	6^{jk}
Bidens pilosa	12^{ijk}	60^{b}	10^{ijk}	8^{ijk}
Richardia brasiliensis	13^{ijk}	60^{b}	45^{bcde}	79^{a}
Elusine indica	15^{hijk}	5^{ijk}	6^{ijk}	2^{jk}
Commelina benghalensis	6^{ijk}	6^{ijk}	1^{k}	1^{k}
Cyperus rotundus	0^{k}	1^{k}	7^{ijk}	4^{ijk}
Oxalis latifolia	5^{ijk}	2^{jk}	0^{k}	5^{ijk}
Oxalis corniculata	4^{ijk}	8^{ijk}	0^{k}	0^{k}
Cleome monophylla	0^{k}	2^{jk}	1^{k}	1^{k}
Ageratum conyzoides	37^{def}	36^{ef}	2^{jk}	0^{k}
Paspalum dilatatum	8^{ijk}	53^{bc}	9^{ijk}	11^{ijk}
Cynodon dactylon	1^{k}	14^{hijk}	1^{k}	0^{k}
Dactyloctenium aegyptium	0^{k}	10^{k}	0^{k}	0^{k}
Cyperus esculentus	6^{ijk}	34^{efg}	7^{ijk}	3^{jk}
Setaria pumila	6^{ijk}	3^{jk}	0^{k}	0^{k}
Stellaria media	0^{k}	1^{k}	0^{k}	0^{k}
Cyperus blysmoides	8^{ijk}	4^{ijk}	3^{jk}	3^{jk}
Digitaria abyssinica	0^{k}	4^{ijk}	3^{jk}	1^{k}
Amaranthus hybridus	1^{k}	0^{k}	0^{k}	0^{k}
Emilia decifolia	5^{ijk}	3^{jk}	0^{k}	0^{k}
Solanum nigrum	0^{k}	1^{k}	0^{k}	1^{k}
Cynodon nlemfuensis	1^{k}	0^{k}	1^{k}	1^{k}
Chenopodium murale	0^{k}	1^{k}	0^{k}	1^{k}
Spergula arvensis	0^{k}	1^{k}	0^{k}	1^{k}
Malva verticillata	1^{k}	1^{k}	0^{k}	0^{k}
Tagetes minuta	1^{k}	1^{k}	0^{k}	0^{k}
Cyperus grandibulbosus	8^{ijk}	1^{k}	2^{jk}	1^{k}
Cyperus rigidifolius	0^{k}	0^{k}	1^{k}	0^{k}
Dichondra repens	0^{k}	1^{k}	0^{k}	0^{k}
Galium spurium	1^{k}	1^{k}	0^{k}	0^{k}
Achyranthes aspera	0^{k}	1^{k}	0^{k}	0^{k}
Gutenbergia cordifolia	0^{k}	1^{k}	0^{k}	0^{k}
Amaranthus retroflexus	2^{jk}	0^{k}	0^{k}	0^{k}
Conyza stricta	0^{k}	1^{k}	0^{k}	0^{k}
Fallopia convolvulus	29^{fgh}	6^{ijk}	3^{jk}	0^{k}
Cyathula polycephala	1^{k}	2^{jk}	0^{k}	0^{k}
Sonchus oleraceus	1^{k}	1^{k}	0^{k}	0^{k}
Solanum incanum	0^{k}	1^{k}	0^{k}	0^{k}
Euphorbia hirta	1^{k}	0^{k}	0^{k}	1^{k}