EFFECTS OF INTERCROPPING MAIZE *(Zea mays*) WITH BUTTERNUTS (*Cucurbita moschata*) AT VARYING BUTTERNUT POPULATION LEVELS ON MAIZE GROWTH, YIELD AND WEED SUPRESSION

BY

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A research project submitted in partial fulfilment of the requirements for the degree of Bachelor of Science Honours in Crop Production and Horticulture

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MIDLANDS STATE UNIVERSITY

MAY 2016

Declaration of originality of research

I declare and certify that I have supervised this dissertation and it is now ready for evaluation

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ABSTRACT

Intercropping is a cultural technique which gives crops a competitive advantage on weeds therefore contributes to weed management. There is need to choose the plant population which results in weed suppression whilst not negatively affecting the component crops yield. The experiment was set in a Randomised Complete Block Design with 5 treatments which are sole maize crop, maize-butternut intercrops at butternut densities of (30%, 40% and 50% of maize population which is 11110, 13889 and 18518plants/ha respectively) and sole butternut crop. Data on maize plant height, maize grain yield, weed density and biomass were measured and Land Equivalent Ratio (LER) calculated using yields of maize and butternut. It was found that there was no significant difference on maize plant height and weed density. However, there was significant (P<0.05) differences on maize grain yield, (P<0.05) on weed biomass and (P<0.05) on LER. Intercropping maize-butternut at different population levels results in different effect on maize grain yield, weed biomass and LER. Maize grain yield first increases with increase in butternut population density from 11110 plants/ha to 13889 plants/ha and then decreases as population continues to increase from 13889 plants/ha to 18518 plants/ha. Weed biomass decreases as butternut population density increases from 11110 plants/ha to 18518 plants/ha. LER values decreases as butternut population density increases from 11110 plants/ha to 18518 plants/ha. Intercropping maize and butternuts at 13889 plants/ha produce higher maize grain yield than the other intercrops and was similar to sole maize yield, have low weed biomass and also have higher LER. I recommend farmers to intercrop maize-butternut at 13889 plants/ha which produces high yield, have higher impact on weed suppression and have higher land productivity. Further research should be carried out on different crop geometry which can reduce effect of competition between crops.

Dedication

This dissertation is dedicated to husband Memory Mapedze and children Naomi and Tivakudze Mapedze.

ACKNOWLEDGEMENTS

Firstly, I thank God for His guidance through the whole course which was full of hardships and challenges but I successfully completed by His grace. My Supervisor Mr Chagonda in Agronomy Department, l appreciated your contribution, patience and attention you directed in preparation of the whole project up-to its completion. I thank also my lectures in Horticulture Department for the effort they made to this research especially Miss Mudyiwa and Mr Pahla. I also thank my husband Mr Mapedze, my parents Mr and Mrs Muperi, my brothers and children for their moral support and sometimes they also financially supported me during the course. I also thank my family for tolerating my absence from them during my visits to MSU and the encouragement they gave me especially when I was under pressure at work and school work at the same time. I thank also my colleagues in the Horticulture Department especially Manhundu Tatenda for helping me in Statistical Analysis.

TABLE OF CONTENTS

Contents **Page**

Chapter Three

Chapter Four

Chapter Five

List of tables

List of figures

List of appendices

CHAPTER 1

1.0 INTRODUCTION

Intercropping is the growing of at least two crops in the same field and growing season (Takim, 2012). It is the very common cropping system practiced in Africa, Asia and Latin America were about more than 80% of the farmers practice it (Edge 1990). Farmers practice different cropping systems in-order to increase productivity and sustainability. Evan *et al.* (2001) attributed that the main purpose of intercropping is to maximise crop yield on a given piece of land by maximising resources use that would otherwise not be used by single crop efficiently.

Madumbu and Karavira (2012) noted that, the rationale of growing two or more crops together with diverse growth habits or durations is for efficient exploitation of resources from different soil depth and more efficient light interception compared to single crop. Maximum utilisation of growth resources results in yield advantage and increased stability as compared to the sole cropping (Poodineh *et al.,* 2014). Intercropping leads to increased diversification of crops in a piece of land thereby leading to land intensification. Crops when grown together interact corporately to the farmer benefit depending on crop combinations (Hoyt and Coolman 1993).

Increasing the number of crops grown on the piece of land thus diversification, leads to solution to some problems of agriculture (Altieri 1999). In Zimbabwe the most common combinations in intercropping include maize with cucurbits and legumes. Intercropping in sub arid regions obtains some benefits from the added crops whilst producing staple crop simultaneously (Carlson 2008). Intercropping with maize may be a return to traditional techniques, but using the current knowledge and improved technologies will help smallholder farmers to ensure sustainable yields.

Maize and butternut are important food crops to smallholder farmers. Maize which is the first most important cereal crop in Zimbabwe as it is used for both human food and livestock feeds. Also maize is increasingly becoming a demanding industrial raw material for processing of wide range of products and by-products. Intercropping maize and butternut could help farmers since they will be producing staple crop and butternuts fruits which are considered as one of the most delicious vegetable which are a rich source of Vitamin A, Phosphorus and Calcium (Department of Agriculture, Forestry and Fisheries 2011).

Butternuts grow best under warm conditions and its production is confined in summer. It is very frost sensitive that temperatures below 10^0C significantly stops its growth and development or can cause severe damages on the crop. Butternut plants have a vine type growth habit and have extensive root system. Harvested fruits are hardy, have long shelf life and can be left in the field for 1 to 2 months. The fruits have a sweet, nutty taste that is similar to that of pumpkins and they can be eaten after boiling or baking. Butternuts are largely grown for their fruits but its young tender shoots make good vegetable salads (Department of Agriculture, Forestry and Fisheries 2011). Also mature butternuts seeds can be boiled with salt and dried or roasted and eaten as snacks.

Apart from efficient utilization of resources and yield increment, other benefits of intercropping are soil conservation, reduced pests and diseases and suppression of germination and growth of weeds (Takim 2012). Crops in the intercrop should differ in their use of resources leading to better overall use of the natural resources available. There is also reduced use of pesticides and herbicides in the intercropping system as the component crop act as a barrier since they differ in species hence affected by different pests. Carlson (2008) also observed that intercropping result in increased soil cover help in protecting soil against erosion and also it suppress weeds. Butternut being a vine crop, it has ability of acting as cover crop suppressing weed germination and its growth. According to Dimitrios *et al.*

(2010) intercropping maize and butternuts significantly result in reduced weed numbers when compared with mono-cropping maize by reducing light availability for weeds to germinate. Also resources are efficiently used by the crops so that there is reduced amount of resources channelled to weeds germination and growth. Beets (1990), observed that once butternuts plants are fully established there is maximum leaf cover that prevent most of weeds seeds to germinate thereby reducing weed populations. Not only high plant population in intercropped plots results in reduced weed density but also better ground cover on plant surfaces also inhibit weed seed germination and growth of germinated weeds (Takim 2012). Baumann *et al.* (2000) suggested that intercrops improve weed suppression relative to monoculture where open canopy allows sunlight to penetrate leading to weeds proliferation. Butternut also being a prostrate crop, it reduces weed germination and growth and can also reduce the number of times the maize crop needs to be weeded to achieve maximum yield (Akobundu 1993, Mashingaidze *et al.,* 2000).

Land Equivalent Ratio (LER) measures how effective intercropping is using the resources of environment as compared to sole cropping (Takim 2012, Dhima *et al.,* 2007). Land Equivalent Ratio (LER) is the total land area required under sole cropping producing same yield as obtained from the intercropping mixtures. When LER is greater than 1, intercropping favours growth and yield of the crops, a larger area of land is needed to produce the same yield of sole crop of each component than with intercropping (Dhima *et al.,* 2007). When LER is less than 1, intercropping negatively affects growth and yield of plants in mixtures and when it is equal to 1, there is no advantage to intercropping as compared with the sole cropping.

According to Seran and Brinth (2010), the world population is continuing rising and it has to fulfil the food requirements for all the people living in it. With increase in Zimbabwe population, arable land for food production in rural areas is becoming a limited source to ensure food security. Also on the other side smallholder farmers experience pressure on weeds as they mainly depend on manual weed control method (Mashingaidze 2004). Manual weeding had been described by Chivinge (1990) as a slow method, demands more labour, and inefficient method of weed control. High weed pressure experienced by smallholder farmers, inadequate and high labour costs and use of traditional hoe weeding method limit the size of land to be cultivated leading to reduced yields (Akobundu 1996).

The research was sort to investigate the effects of intercropping maize and butternuts at different butternut population levels on maize growth, yield and weed suppression.

1.1 Main Objective

To determine the effect of intercropping maize (*Zea mays)* and butternuts *(Cucurbita moschata*) at varying butternut population levels on maize growth, yield and weed suppression.

1.2 Specific Objectives

1 To determine the effect of different butternut population levels in an intercrop with maize on maize plant height.

2 To examine the effect of different butternut population levels in an intercrop with maize on maize grain yield.

3 To evaluate the effect of different butternut population levels in an intercrop with maize on weed density and biomass.

4 To assess the effect of intercropping maize and butternut using Land Equivalent Ratio (LER) technique.

1.3 Hypotheses

H_0: There is significant difference between different butternut population levels in an intercrop with maize on maize plant height.

H_0: There is significant difference between different butternut population levels in an intercrop with maize on maize grain yield.

H_0: There is significant difference between different butternut population levels in an intercrop with maize on weed density and biomass.

H_0: There is significant difference between different butternut population levels in an intercrop with maize on the LER.

CHAPTER 2

2.0 LITERATURE REVIIEW

2.1.0 Botany and Importance of Butternuts (*Cucurbita moschata*)

2.1.1 Botany of butternuts

Butternuts (*Cucurbita moschata*) are tender tendril-bearing and vine like plant. Butternut plants have extensive root system and rooting commonly occurs at the stem nodes, which may improve plant vigour. Leaves are rounded and appear heart shaped. Feeder leaf occurs at the node where fruit develops, called feeder leaf because photosynthates from the leaf are channelled to the adjacent fruit (Department of Agriculture, Forestry and Fisheries 2011). Butternuts plants are monoecious, they produce separate male and female flowers on the same plant. Male flowers forms first on long stalks and female form on shorter stalks closer to the stem. Flowers are erect and are lemon yellow to deep orange in colour. Fruit shape differs in shape can be flattened or elongated and shape develops after flower pollination. The shape of Ovary shape before pollination determines the final shape of the fruit (Department of Agriculture, Forestry and Fisheries 2011).

2.1.2 Importance of butternuts (*Cucurbita moschata*)

Butternuts young shoots that are tender, flowers and fruits are used as vegetables. It is tastes good when cooked alone or in combination with other vegetables, fish and meat. Butternuts fruits are a rich source of Vitamin A in a quantity because of the yellow colour it contains and it is also good fibre source, Vitamin E, Vitamin C, manganese, magnesium and potassium (Department of Agriculture, Forestry and Fisheries 2011). Fruits can be boiled or roasted and has a sweet nutty taste similar to that of pumpkins. In addition, seeds of mature fruits can be boiled in salted water dried or roasted and used as snack food. Butternuts can also often used in soup or can be baked on a grill.

Besides the nutritive value of butternuts, they may have other benefits when intercropped with staple cereal crops. Being a prostrate, vine crop, it have ability to act as live mulch, suppressing weed germination and growth and also improving soil moisture conservation under the cereal crop canopy.

2.2.0 Botany and Importance of maize (*Zea mays*)

2.2.1 Botany of maize

Maize plant is an annual grass monocot which forms a seasonal adventitious root system bearing a single erect stem made up of nodes and internodes. However some cultivars may develop elongated lateral branches or tillers that save as feeder to the root system. Maize height varies with varieties and its height ranges from about 0.5 to 5meters standing at flowering, but normally average height is 2.4m (Mejia 2003).Maize plant produce one to four ears. Maize plant has distichous leaves which are produced in alternate position forming ranks of single leaves (Mejia 2003). Each leaf consists of a sheath surrounding the stalk and an expanded blade connected to the sheath by the blade joint or collar. The leaves are held at right angles by the leaf blades and to the sun by stiff mid-ribs. Mejia (2003) reported that the outer surface of the leaf blade has little hairy structures for trapping solar energy and the internal surface is shiny and hairless with has a number of stomata for gaseous exchange and is hairiness and shiny.

The male inflorescence which is the tassel forms at the top of the stem and is arranged in a loose panicles. The flowers are organised into paired spikelet into each spikelet there are two functional florets and each one has three anthers which contains pollen. Each male tassel may produce around 25 000 000 pollen grains this means that there are available for each kernel to be fertilized an average of 25 000 pollen grains on an average of 1 000 kernels per ear (Mejia 2003). On the leaf axis of the maize plant develops shanks and they end in a female inflorescence, an ear. The shank consists of nodes and short internodes and the length of internodes vary between maize races. The ears arise from axillary bud apices. The ear is covered with a number leaves called husks. These husks appearance differ when compared to those on the stalks as they surround and protect the developing ear (Department of Health and Ageing Office of the Gene Technology Regulator 2008). The thick axis of the ear, the cob bears an even number of rows between 4 and 30 of ovaries each containing a single ovule. The number of ovules that will develop into kernels ranges from 300-1000 and is dependent on the cultivar or variety as well as factors occurring later in development. The silks of the maize ear are the stylar canals of the mature ovaries (Department of Health and Ageing Office of the Gene Technology Regulator 2008).

2.2.4 Importance of maize (*Zea mays*)

Maize (*Zea mays*) is the most important cereal crop grown in Zimbabwe. It is the staple cereal for about 99% of Zimbabwe inhabitants. Farnham *et al.* (2003) indicated that maize comes first in production for both smallholder and large scale commercial producers, and also covers the largest area among all crops grown in Zimbabwe. Maize according to Farnham *et al.* (2003) is one of the crop species which is highly productive with the average yield of more than 4t/ha. Maize has more uses than any other cereal, as human food, as food grain, as fodder crop and for many industrial purposes because of its broad global distribution, prices reasonably low compared to other cereals, grain type are various and its wide range of biological and industrial properties (Downswell *et al.*, 1996). Maize is cultivated mainly for grain which is the most crucial however every maize plant part, the leaves, stalk, tassels, husks and the cob all are important for different purposes (Fussell *et al.*, 1992). Isaac (2011) indicated that maize is very important as human food, constitutes about 70.4% carbohydrate and is used in different ways as a staple food. Maize can directly consumed as food at various developmental stages from baby corn to mature grain. Fresh maize can be consumed boiled or roasted. Also crushed or pounded maize grain can prepare various foods. In the USA maize has various uses as human food, it is processed to number different consumable items like corn flakes, maize flours, breakfast cereals are partially derived from maize (Downswell *et al.*, 1996).

Farnham *et al.* (2003) observed that in the tropics about 40% of the maize produced is for animal feeding and in developed countries more than 60% of maize harvested is used as livestock feeds. The relatively low price of maize compared to other cereals and its availability have contributed to its wide use in livestock feeds. Maize compared to other grains used in livestock feeds gives highest conversion ratio to milk, meat and eggs (Isaac 2011). Also maize is low in fibre contents and high in starch thus becoming an excellent energy source for livestock production. Maize is also used as fodder for livestock at different growth stages mainly from the early reproductive stage onwards and maize is a high energy forage crop (Isaac 2011). Dried stalks and leaves of maize can be used as animal fodder which is called stover after harvesting of the grain.

Maize demands in industry is exponentially rising with industrial developments, it is becoming a vital industrial raw material for production of starch, gluten, oil, flour, alcohol and for further processing to produce a wider range of products and by-products (Makinde and Bello 2009). White (1994) indicated that maize is the main starch source worldwide and is used as food ingredient, either in its natural form or when modified chemically. In industry maize is also an important raw material for production of ethanol and fuel. In brewing and fermentation based industries, manufacture of adhesives and pharmaceutical industries maize plays an important role as a raw material.

2.3. Intercropping and benefits derived from intercropping

2.3.0 Intercropping

According to Beets (1990), intercropping is the practice of cultivating two or more crops simultaneously in alternating rows in the same field. It is a practice often associated with sustainable agriculture and organic farming, intercrop is one form of poly-culture using companion planting principles. The simultaneous growing of more than one crop has proved better resource utilization than in sole cropping (Willey 1990). The crops grown in an intercrop may come from different crop species and different plant families or they may be of the same crop species but have different variety or cultivars (Poodineh *et al.,* 2014). Evan *et al.* (2001) indicated that the main intension of intercropping is to raise production on a given piece of land by maximising utilization of resources that would otherwise not be used by a single crop efficiently. Intercropping with maize is a way to grow a staple crop while obtaining several benefits from the added crop.

2.3.1 Benefits of intercropping

2.3.1.1 Weed suppression

Intercropping helps in controlling weeds. Evidence of better weed control is pronounced where intercropping results in a more competitive effect against weeds either in time or space than what is done by mono-cropping (Seran and Brintha 2010)0. The nature and level of crop weed competition varies considerably between mono and intercrop combinations. The crop species, population density, crop distribution, duration, growth rhythm of the component crop, the moisture and fertility status of the soil and tillage influence weed flora in cropping systems (Seran and Brintha 2010). Crop weed competition is determined by growth habits of crop in the intercrop. Beets (1990), observed that increased leaf canopy cover in the intercrop system provide a shading effect which helps to reduce weed populations once crops have established fully. Mixed cropping reduces effect of weed incidences in cropping system (Zuofa *et al.,* 1992).

Makindea *et al.* (2009) found that leafy greens when intercropped with maize lead to weeds control in the tropics and also result in increased productivity. Interception or solar radiation in intercrops is increased and accounts for maximising productivity of intercrop system and their greater competence to suppress weed competition than what mono-crops of either the component crops done (Mashingaidze *et al.,* 2000, Akobundu 1993). Crop mixtures changes both quality and quantity of light and thus reducing the photosynthetic capacity of weeds. Shading results in a reduced incident light which lowers weeds photosynthetic capacity, also reduce the activity of ribulose-biphosphate carboxylase and chlorophyll content of weeds thereby limiting growth of weeds (Madumbu and Karavina 2012).

Maize-pumpkin and maize-bean intercropping reduces weed biomass by 50-66% when established at a density of 12300 plants/ha for pumpkins and 222 000 plants/ha for beans (Mashingaidze 2004). Sole maize crops were weeded twice or thrice to achieve the same weed biomass as intercrops weeded once showing that intercropping could reduce the weeding requirements of maize. The results of some studies have shown that in intercropping compared to mono-cropping result in more effectively use of resources and thereby reducing the amount of available resources channelled towards weeds for them to grow (Yadollahi *et al.,* 2014). Ghanbari *et al.* (2006) observed that in intercropping of maize and squash, weed control was more effective than in maize mono-crop. Weed suppression by crop interference has been referred to as one determinant of yield advantage of intercrop, being a possible alternative to reduce the dependence on use of herbicides in weed management (Agegnehu *et al.,* 2006, Banik *et al.,* 2006). Recent studies have addressed intercropping as an option for Integrated Weed Management (IWM), mainly in those farming systems which have low external inputs. Henrik *et al*, (2003) reported that weed density and biomass is noticeably reduced compared to sole cropping.

2.1.3.2 Yield advantage

Lemlem (2013) reported that the most common intercropping advantage is the production of higher yield on cultivated area by making use of resources available more efficiently. Mashingaidze (2004) observed that there was effective utilization of intercropped land and also yields from that land was improved. The main reason for higher yield in intercropping is that the component crops varies in natural resources use and overall utilization of natural resources is better than when they are individually grown. The common index used to measure land productivity is the Land Equivalent Ratio (LER).

2.1.3.3 Resource utilization

The intension of intercropping is to produce greater yield on a given piece of land. Willey (1990) reported that the main reasons for improved yields in intercropping is that the component crops have competence of using natural resources more effectively and efficiently than when grown separately. The more efficient utilization of the available growth resources leads to yield advantage and increased stability compared to sole cropping. The efficient use of basic resources in the cropping system depends partly on the inherent efficiency of the individual crops that make up the system and partly on complimentary effects between crops. Lemlem (2013) reported that in diverse range of intercropping, it has been shown that it produces greater and more stable yields while the system is associated with minimum use of inputs like pesticides thereby emphasising the production of health, safe and high quality food in the context of environmentally sound production.

Seran and Brintha (2010) reported that different crops grown together have different root and leaf structures which are able to capture more light and make maximum use of water and nutrients available than when the roots and leaves of only one species is present. When only one species is grown, all the roots tend to compete with each other in the same zone since they are all similar in their orientation and below surface depth. Furthermore, plants of the same species have leaves which are directly opposite and rate of growth is the same whereas the leaves of different plant species do not directly compete for sunlight in space and time (Seran and Brintha 2010).

2.1.3.4 Improved moisture conservation

Intercrops have been known to conserve soil moisture mainly because of production of early high leaf area index and thicker canopy cover (Ongindo and Walker 2005). Various root systems helps in reducing soil water loss and also increases infiltration rate of water and transpiration that results in production of cooler microclimate than the surroundings (Innis 1997). Morris and Garrity (1993) indicated that rate of capturing water in intercrops is higher by about 7% compared to monocrop.

2.1.3.5 Soil erosion control

Intercropping helps in soil conservation. Soil erosion is controlled by preventing rain drops from hitting the bare soil where they tend to block surface pores, prevent water from filtrating in the soil and increase surface erosion (Seran and Brintha 2010). In maize-butternut intercropping, butternut acts as cover crop and reduces impact of rain drops and thereby reduces erosion. Reddy and Reddi (2007) reported that taller crops act as wind barrier for short crops. Multiple cropping increases vegetative growth which helps in soil protection during critical erosion periods.

2.1.3.6 Pest and disease control

Maize is susceptible to many diseases and insects. Intercropping appears to be very promising cultural practice for the control of pests and diseases. Seran and Brintha (2010), observed that one component crop of an intercrop system may act as a barrier or buffer against the spread of pests and pathogens. This is because component crops are of different species and different families hence they are not affected by same pests and diseases. Power (1990) reported that maize leaf hopper was reduced under intercrop. Trenbath (1993) noted that pests and diseases were high in mono-cropping compared to intercropping.

2.4. Main aspects to be considered in intercropping

2.4.0 Time of planting

If advantage of intercropping is to be realized, time of planting of component crops is an important factor. Isaac (2011) reported that crops may be planted at the same time to safeguard against drought in areas prone to erratic rainfall and reduce competition between component crops. Singh *et al,* (2002) noted that planting may be staggered to increase temporal differences which result in higher yield advantages. Date of planting depends upon several factors as weather, soil moisture, time, labour constraints faced by farmer, variety and crop production system (Isaac 2011). Most studies have shown that the effect of competitions between crops is greatly reduced when their maximum demands on the environment occur at different times.

2.4.1 Crop geometry

Crop geometry is the pattern of distribution of plants over the ground or the shape of the area available to the individual plant (Isaac 2011). The arrangement and density of crops have to be manipulated to enhance complementarities and to reduce competition between component crops. Different arrangements of component crops in time and space are practiced in intercropping to reduce competition. Some attempts have been made to plant crops in strips to reduce difficulties in crop management like fertilizer application and weeding and also reducing shading effect.

2.4.2 Plant population

Plant population is the number of plants per unit area. Low plant population leads to reduced yield. Most annual crops respond to population changes and this offers choice of planting density that result in better yields. Choice of plant population is vital so as to have less competition on component crops whilst maintaining a high proportion of the potential yield (Isaac 2011). The required plant population of a particular crop in a mixture is governed by the crop species associated and temporal differences between two crops.

2.4.3 Maturity of component crops

When two or more crops are grown together the peak periods of growth should not coincide. Crops which mature at different times should be intercropped. Crops of varying maturity duration should therefore be chosen so that a rapidly maturing crop completes its life cycle before the major growth period of the component crop commences (Seran and Brintha 2010). The component crops peak growth periods should not coincide to reduce competition on the resources. By this time there is high demand of nutrients to crops so these periods should differ to reduce competition on nutrients. Complementarity in an intercrop can occur when the growth patterns of the component crops differ in time or when they make use of resource in space. Isaac (2011) observed that nutrient competition in intercropping can be reduced by selecting the species with different rooting patterns, different nutrient requirement and different time of peak demand for nutrient and plant spacing.

2.5 Evaluating intercropping efficiency using Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) is the most common index used to verify the effectiveness of intercropping for using the resources of the environment compared to sole cropping (Dhima *et al.*, 2007). Willey and Osiru (1992) defined LER as the total land area required under sole cropping to give the yield obtained in the intercrop mixture. Many studies on intercropping has shown that intercrop may give higher and more stable yield than when the components is grown as sole crop because of mutual cooperation due to complementarity effects of the system (Mohammadu *et al.*, 2009). It is expressed as:

$LER = IYM/SYM + IYB/SYB = LER_M + LER_B$

Where: IYM is the intercropped yield of maize,

SYM: is sole yield of maize,

IYB: is intercropped yield of butternuts and

SYB: is sole yield of butternuts.

With this concept, when LER = 1 there is no advantage over sole cropping, when LER > 1, it indicates advantage of intercropping, it implies that the component crops has produced higher than when grown in monoculture, when LER < 1 there is disadvantage in intercropping meaning competition between crops lead to yield reduction of both or one of component crops.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Study site

The study was conducted in ward 29 of Zaka district. The area is 26km West of Zaka district centre. The geographical coordinates of the area are 20^0 $21^1 0^{11}$ South and 31^0 27^1 0^{11}East. Altitude of the area is 1066m above sea level. Zaka district is in Agro-Ecological Region IV which receives rainfall range of 450-650mm per annum. The rainfall season is characterized by mid-season dry spells and droughts. The area experiences high mean temperatures of above 25^0C in summer but during winter temperatures can range from 12-24^0C. The soils on the site are fersiallitic soils which are mixed clays.

3.2 Experimental Design and Treatments

The experiment was carried out in Random Complete Block Design (RCBD) with a blocking factor of slope and four replications. The gross plots were 4m x 5m with 1m walking path between the adjacent plots and 2m path between blocks or replications. The experiment consisted of five treatments which were sole maize crop, sole butternut crop and three maize-butternut intercrops with different butternut population densities. The population levels of butternuts was 11 110 plants/ha, 13 889 plants/ha and 18518 plants/ha which is 30%, 40% and 50% of the maize population respectively.

Table3.1. Treatments table

Treatment number	Treatment
1	Sole maize crop.
2	Maize-butternut intercrop at butternut density of 11110 plants/ha (30%).
3	Maize-butternut intercrop at butternut density of 13889 plants/ha (40%).
4	Maize-butternut intercrop at butternut density of 18518 plants/ha (50%).
5	Sole butternut crop.

3.3. Trial management

The land was ploughed using a mouldboard plough and harrowed with a harrow to obtain a fine tilth. Maize variety SC 513 was planted with butternut variety Waltham. Windmill Compound D N_7: P_{14}: K_7 was applied at 250kg/ha as basal dressing during maize planting. The same compound D was also applied in butternut planting at a rate of 400kg/ha and supplemented by cattle manure at a rate of 1kg/hill. Ammonium Nitrate 34.5%N will be applied as top dressing to maize 5 weeks after planting at rate of 150kg/ha. Also butternuts will be applied top dressing AN 34.5%N at 4 week after planting after the first fruits have form at the rate of the 150kg/ha. Maize was planted at 0.9m x 0.3m to give a population density of 37037 plants/ha. Two seeds of both maize and butternut were planted at each planting station and plants were thinned to leave one plant per station at one week after emergence. In intercropped treatments, butternuts were planted in every second maize row. Butternuts was established at three different spacing which are 0.3m x 1.8m, 0.4m x 1.8m and

0.5m x 1.8m to give population density of 18 518, 13 889 and 11110 plants/ha respectively which is equivalent to 50%, 40% and 30% of the maize population respectively. Weeding was done manually using hoe once at 4 weeks after planting. Fungicide mancozeb was applied to butternuts as a preventative measure of powdery mildew.

3.4. Data collection and analysis

Maize plant height was measured 12 WAP using a tape measure, height was measured from 5plants in each plot and the average height in cm was recorded. Maize grain yield was measured after physiological maturity at 12.5% moisture level (24 WAE), the cobs were allowed to dry, shelled and weighed using a digital scale. Butternut fruit yield was also found after harvesting of fruits 24 WAE. The fruits from each plot were weighed using a digital scale. Weed density and biomass were assessed at 12 WAP by randomly throwing a 1m x 1m quadrant into each plot and weeds numbers were counted by species. Data on weed density were first square root transformed before analysis. For weed biomass, weeds were cut at ground level oven dried at 70^{0}C for 72 hours and weighed using a sensitive balance.

Analysis of Variance (ANOVA) was done using Genstat 14^{th} edition and where there was significant differences, the means were separated using Least Significant Difference (LSD) technique at 5% level of significance.

CHAPTER 4

4.0 RESULTS

4.1. The effect of different butternut population levels in an intercrop with maize on maize plant height.

The results show that there is no significant (P > 0.05) difference in maize plant height between sole maize and maize-butternut intercrops. The height of maize crop was not affected by component crop population densities.

4.2. The effect of different butternut population levels in an intercrop with maize on maize grain yield.

Maize grain yield was statistically (P<0.05) influenced by different butternut population density. Significantly higher maize yield (1.716 t/ha) was obtained in sole maize and in maize-butternut intercrop at 13 889 plants/ha (1.708 t/ha) and there was no significant difference between the two (Fig 1). The lowest maize grain yield (1,566 t/ha) was found in an intercrop of butternut population of 18518 plants/ha.

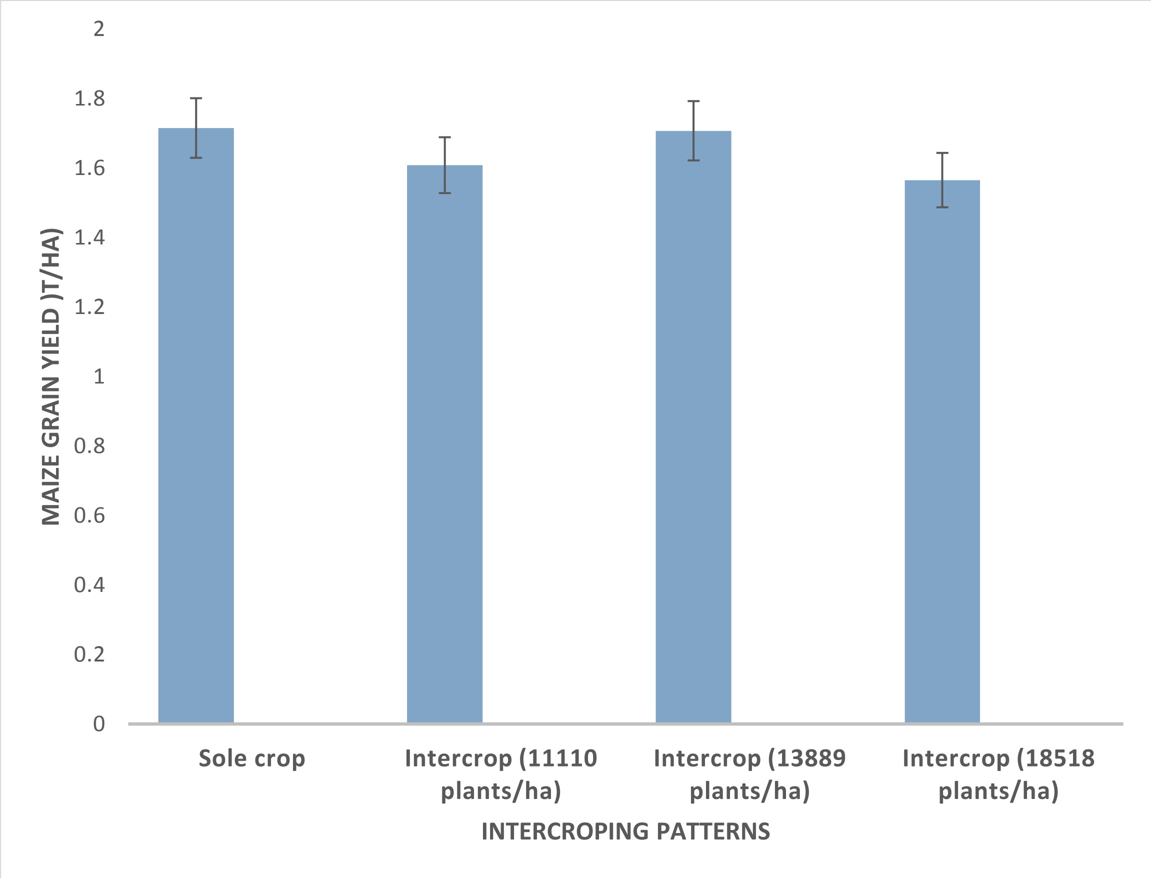

Fig4.1. The effect of different butternut population densities in maize-butternut intercrop on maize grain yield.

4.3. The effect of different butternut population levels in an intercrop with maize on weed density and biomass

The results on weed density/number shows no significant (P>0.05) difference between sole crops and maize butternut intercrops. Cropping systems however indicated a significant (P<0.05) difference on weed biomass (Fig 2). The highest weed biomass (99g) was recorded in sole maize crop, followed by sole butternut (81g) but there was a significant difference between the two. Huge effect on weed suppression (41g) was obtained in maize-butternut intercrop 18518 plants/ha where weed biomass was reduced by 41% and 51% as compared to sole maize and sole butternut respectively. Generally from the results obtained, weed biomass decreases in intercrops as butternut density increases and sole maize indicated the least treatment to suppress weed growth and development.

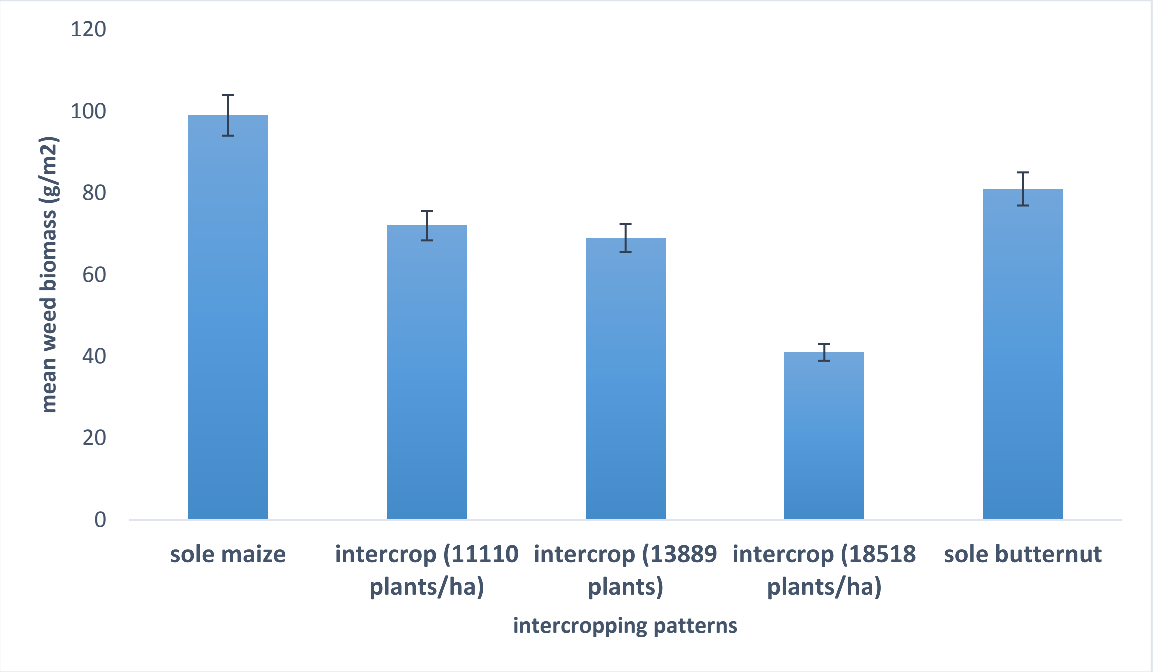

Fig 4.2. The effect of different intercropping systems on weed biomass.

4.4. The effect of different butternut population levels in an intercrop with maize on Land Equivalent Ratio (LER)

There was a significant ($P<0.05$) difference on LER value on different maize-butternut intercrops. The LER values on all intercrops was greater than that of sole maize and sole butternut as indicated with LER values greater than 1 ranging from 1.75 to 1.83 (Table 4.1). The highest LER value (1.830) was observed in maize-butternut intercrop with 11110 plants/ha but was not statistically different to LER value (1.827) of maize-butternut intercrop with 13889 plants/ha. The least LER value (1.750) was obtained on maize-butternut intercrop with 18518 plants/ha.

Table 4.1 The effect of intercropping maize-butternut at different butternut population density on LER

Treatment	LER
Maize-butternut intercrops	
Butternut density of 11110 plants/ha	1.830[a]
Butternut density of 13889 plants/ha	1.827[a]
Butternut density of 18518 plants/ha	1.750[b]
Grand mean	1.8025
CV%	5.1
LSD (0.05)	0.04382
P value	0.007

CHAPTER 5

5.0 DISCUSSION

5.1. The effect of different butternut population levels in an intercrop with maize on maize height.

Maize plant height was not significantly affected by different butternut population levels. The highest maize height (1.97cm) was recorded in maize-butternut intercrop with 18518 plants/ha and decreases as butternut population decreases. Lowest maize height (1.92cm) was found in sole maize crop however there was no significance difference between maize plant heights in all treatments. This could be because butternut crop as prostrate crop, it induces less above ground intra-specific competition for sunlight with maize. Also less competition could be because of crops geometry that is the pattern or arrangement of component crops.

5.2. The effect of different butternut population levels in an intercrop with maize on maize yield.

Maize yield was significantly affected by different butternut population densities. Higher yields was obtained in sole maize and maize-butternut intercrop at 13 889 plants/ha could be because different butternut populations produce different shading on the ground surface resulting in different capacity of moisture conservation. Also, a possible increase in population has a competitive effect on nutrients and water. The reason why intercrop of 11110 plants/ha have significantly low yield could be because it did not produce good cover on the surface thereby not having good moisture conservation effect. An intercrop of 18518 plants/ha had a significantly low yield and this could be because of high density resulting in competition of plants for water and nutrients. Intercrop of 13889 plants/ha indicated to be the optimum population level to produce yield which was not significantly different to sole maize crop. This could be because the population level good enough to produce leafy canopy which was able to conserve moisture than 11110 plants/ha and the plants have little competition for moisture as compared to that with 18518 plants/ha. These results were not in agreement with the findings of Madumbu and Karavira (2012) who reported that maize was not significantly affected by different densities in an intercrop with pumpkins which are of same family and growth habits with butternuts.

5.3. The effect of different butternut population levels in an intercrop with maize on weed density and biomass.

Weed density was not significantly (P>0.05) affected by the systems either sole cropping and intercropping. This could be because of weeding which was done which have effect of disposing weeds seeds buried underground. Weeding brings seeds near to the surface and allows them to germinate because they will be exposed to sunlight. Any soil disturbance will stimulates weed seed germination as cultivation improves soil aeration and light penetration. Harper (1990) reported that weeding results. Therefore intercropping or sole cropping had no mechanism of hindering weed seed from germinating. This was similar to what Madumbu and Karavira (2012) and Mashingaidze (2004) observed in their research on maize-pumpkin intercrops and they indicated that live mulch crops may not affect weed density because they take time to fully cover the surface.

Weed biomass was significantly reduced in maize butternut intercrops. Higher weed biomass (99g) was found in sole maize, followed by sole butternut (81g) but there is significant difference between the two. This indicated that butternut have the smothering effect on weeds. When it is intercropped with maize, it prove that it greatly suppress weed growth. Lowest weed biomass (41g) was obtained in maize-butternut intercrop of 18518 plants/ha were weed biomass was decreased by 41% and 51% as compared to sole maize and sole butternut respectively. The degree of suppressing weed growth however differs with the population of butternuts in intercrops were weed biomass decreases with increase in butternut population. This could be because if butternut population is high it quickly cover the ground surface and provide thick foliage which shades the ground thereby reducing the photosynthetic capacity of weeds. Hasanuzzaman (2015) indicated that light quality and quantity are important aspects in weed suppression. He indicated that availability of dense leaf canopy decreases both quality and quantity of light available to weeds and decreases the photosynthetic rate and activity of ribulose-biphosphate carboxylase and chlorophyll content of weeds. Generally from the results, this indicated that weed biomass decreased in intercrops as butternut density increases. Sole crops stood out to be the least treatment to suppress weed as compared to intercrops.

5.4. The effect of different butternut population levels in an intercrop with maize on LER.

LER values (Table 4.1) shows that intercropping was superior as compared to sole cropping because all LER values was greater than one ranging from 1.83 to 1.75. This shows that there was advantage in intercropping maize and butternuts than growing the two separately. Highest LER value (1.83) was obtained in maize-butternut intercrop with 11110 plants/ha, but was not significantly different from LER value (1.827) in intercrop of 13889 plants/ha. This shows that maize yield was not negatively affected by intercropping with butternuts hence there is benefit in growing the two crops together. LER values greater than one could be because of complementarities relationship in maize-butternut intercropping as butternut act as live mulch. Butternuts covers surface of maize crop, prevent weeds to proliferate, reduce moisture loss thus allowing efficient utilization of resources by the crops instead of weeds hence resulting to yield advantage. High productivity could also be caused by reduced pest and diseases occurrence in maize-butternut intercropping as mixing of crops provides barrier to spread of pests and diseases. Intercropping is a promising Integrated Pest

Management (IPM) programme for controlling pests. This is supported by Seran and Brintha (2010) who noted that one component crop of an intercrop system may act as buffer against spread of pests and pathogens as crops of different species and families are not affected by same pests and diseases. Mashingaidze (2000) observed the same in his maize-pumpkin intercrop which is of same family and growth habits with butternuts and his results of LER values ranges from 1.04 and 3.48.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDESATIONS

Intercropping maize-butternut at different population levels results in different effect on maize grain yield, weed biomass and LER. Maize grain yield first increases with increase in butternut population density from 11110 plants/ha to 13889 plants/ha and then decreases as population continues to increase from 13889 plants/ha to 18518 plants/ha. Weed biomass decreases as butternut population density increases from 11110 plants/ha to 18518 plants/ha. LER values decreases as butternut population density increases from 11110 plants/ha to 18518 plants/ha.

RECOMMENDATIONS

I would recommend farmers to intercrop maize-butternut at 13889 plants/ha which produces yield of 1.708t/ha which is not significantly different sole maize yield of 1.716t/ha, also had higher impact on weed suppression which is not significantly different from that in intercrop of 11110 plants/ha with lowest weed biomass and have higher productivity shown by LER value of 1.827 which is also not significantly different from 1.83 in 11110 plants/ha. I would recommend further research on different crop geometry which can reduce effect of competition between crops.

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APPENDICES

APPENDIX1. ANOVA TABLE FOR MAIZE PLANT HEIGHT

Variate: maize height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.002919	0.000973	0.47	
rep.*Units* stratum					
treat	3	0.004169	0.001390	0.67	0.589
Residual	9	0.018556	0.002062		
Total	15	0.025644			

APPENDIX2. ANOVA TABLE FOR MAIZE GRAIN YIELD

Variate: maize yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.00043025	0.00014342	3.32	
rep.*Units* stratum					
treat	3	0.06630825	0.02210275	511.05	<.001
Residual	9	0.00038925	0.00004325		
Total	15	0.06712775			

APPENDIX3. ANOVA TABLE FOR WEED DENSITY

Variate: weed_number

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.1359	0.0453	0.22	
rep.*Units* stratum					
treat	4	0.2315	0.0579	0.28	0.883
Residual	12	2.4499	0.2042		
Total	19	2.8173			

APPENDIX4. ANOVA TABLE FOR WEED BIOMASS

Variate: weed_bio

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	1.600	0.533	0.07	
rep.*Units* stratum					
treat	4	7116.800	1779.200	231.06	<.001
Residual	12	92.400	7.700		
Total	19	7210.800			

APPENDIX5. ANOVA TABLE FOR LAND EQUIVALENT RATIO

Variate: LER

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.0032250	0.0010750	1.68	
Rep.*Units* stratum					
Treat	2	0.0165500	0.0082750	12.90	0.007
Residual	6	0.0038500	0.0006417		
Total	11	0.0236250			