COMPARATIVE EFFECTIVENESS OF DIFFERENT WEED MANAGEMENT PRACTICES IN ONION (*Allium cepa* L.) PRODUCTION

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Onion is one of the most important vegetable in Tanzania. However, yields are generally low weeds are among the major pests which reduce onion yields. A field experiment was conducted to assess the effectiveness of weed management practices in onion (*Allium cepa* L.) at Sokoine University of Agriculture, Horticulture unit during the dry season of October 2013 to February 2014. The experiment was laid down in a RCBD design with three replications. Three onions varieties (Red Bombay, Red Creole and Mang,ola Red) were used. Six weed management treatments using Galgan® 240 EC herbicide, Rice husks mulch, weeding once, weeding twice, weeding thrice and unweeded as control were evaluated. There were highly significant ($P \leq 0.001$) differences among varieties with respect to weed fresh weight, weed density, bulb height and weed dry weight. Onion plant height differed significantly ($P \leq 0.01$). Moreover, onion bulb yield differed significantly ($P \leq 0.01$) among varieties. It was also found that the treatments had very highly significant ($P \leq 0.001$) effect on weed fresh and dry weights, bulb diameter, bulb weight, bulb height, number of bulbs per plot and onion bulb yield. Different weed control measures also had significant differences on onion plant height ($P \leq 0.01$) and weed density ($P \leq 0.001$).Among the weed management practices, mulch was most effective, followed by Galgan® herbicide, weeding thrice, weeding twice, weeding once and last no weeding. Highest yield of onion bulbs was obtained when plots were mulched and no Onion bulb yield was recorded in control plots. Though the weeding twice and thrice treatments resulted in highest onion bulb yield, weeding is a laborious and time consuming method of weed control as compared to the use of mulch and Galgan® 240 g/l. It is therefore recommended that, the use of mulch and herbicide in onion production be promoted.

DECLARATION

I, **GRACE MATIKU DAVID,** do hereby declare to the Senate of Sokoine University of Agriculture (SUA) that the work presented here is my original work and has not been submitted for a higher degree in any other University.

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The above declaration is confirmed by,

Prof. K.P. Sibuga **Date**

(Supervisor)

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DEDICATION

To the Glory of God in the mighty name of Jesus Christ, that covered me with peace and endurance during all times of my study. Also my beloved mother Regina Amon Mbuya, late father David Marwa Matiku who tirelessly built the foundation of my education. May God, the Almighty bless them ad infinitum, Amen.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BC	Before Christ
CV (%)	Percent coefficient of variation
DAP	Diammonium phosphate
DAS	Days after sowing
FAO	Food and Agricultural Organization
IPM	Intergrated Pest Management
IWM	Intergrated Weed Management
MAFS	Ministry of Agriculture and Food Security
LSD	Least Significant Difference
RA	Index of Relative abundance
RCBD	Randomized Complete Block Design

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Onion (*Allium cepa* L.) belongs to the bulb crops, a group that includes onions (dry and green) belonging to the family Alliaceae. It is a condiment crop consumed fresh and dry as a spice and one of the most important vegetable crops in the world with a total production of about 61 million tons (FAO, 2006). Onion is also one of the most important vegetable crops in Tanzania (ECI Africa, 2004; Kisetua nd Joseph, 2013), which is used nearly every day. Onions can be eaten raw in salad mixed with other vegetables but in most cases, they are cooked mixed with vegetables, meat and other dishes. Onion is one of the major sources of income for many subsistence farmers in Tanzania but the national average yield of 2.9 t ha^{-1}(FAO, 2000) is low compared to the world average of 25 to 30 t ha^{-1} (Brewster, 1994)

Onions can be grown from the tropics to sub-arctic regions. This adaptation is primarily due to differing response to day length. Unlike most other species, day length influences bulbing in onions as opposed to flowering (Shanmugasundaram, 2001). Onion bulbs are placed into three groups based on their response to hours of day length. The short-day bulb varieties with day lengths of 11-12 hours e.g. Red Creole and Yellow Creole, while intermediate bulb varieties with day lengths of 12-13 hours e.g. Fiesta and Sweet Spanish (Sys *et al*., 1993) are found in the mid-temperate regions.

Weeds are one of the main plant protection problems in onion fields. They compete with onions for light, nutrients, water, space and also are host plants of several harmful insects and pathogens (Dunan *et al*., 1996; Ozer *et al.,* 1997; Kizilkaya *et al*., 2001; Ghosheh, 2004; Qasem, 2006; Smith *et al*., 2008). The initial slow growth, shallow roots and lack of adequate foliage makes onions weak against weeds (Wicks *et al*., 1973). Weeds compete with onions for light, nutrients, water, and space. In addition to reducing harvestable bulbs through competition, weeds interfere with the harvesting process by decreasing hand-harvesting and machine harvest efficiency. Weeds can also harbour destructive insects and disease pathogens that can severely damage the present or following crop (Rao, 1989). In addition, the cylindrical upright leaves of onions do not shade the soil to block weed growth. Weed control is therefore essential to reduce the weed population to a level where its usefulness is greater than the damage it could reasonably be expected to cause.

Weed management methods best suited for an individual grower will depend on several factors such as present weed species, crop variety, stage of growth of the crop, labour costs and availability (Bell and Boutwell, 2001). However, overall, managing weeds is critical for successful onions production (Dunan *et al*., 1996)

1.2 Problem Statement

Low Onion yield is attributed to many factors including pests, soil PH and rainfall. Among the pests which affect onion Yield are weeds. In onion production weeds have also been implicated in the spread of bacterial and fungal pathogens, as well as in hosting nematodes and thrips (*Thrips tabaci*) (Singh *et al.,* 1986). Because of slow growth, small stature, shallow roots, and lack of dense foliage cover, onion seedlings cannot withstand competition from weeds (Appleby, 1996). Weeds are a constant component of agro-ecosystems in onions (Mennan and Isik, 2003), hence, weed competition and weed control are the major limiting factors to onion production (Phillips, 1992). Weeds can cause reduction in onion yield due to low initial growth rate, long vegetative period and low competitive ability (Dunan *et al*., 1996). Furthermore, weeds can cause direct yield losses by competing with onions for space, nutrients, water and light resulting in yield losses of 50% or more of the potential yields if left uncontrolled. Weeds in onion do not only reduce total yields, but also reduce quality in that the bulbs produced are likely to be small and thick-necked (Dunan *et al*., 1996).

Therefore, onion being un-competitive against weeds, each 0.19 kg of weed dry matter produced reduce the marketable onion bulb yield by 1kg (Hussein, 2001). Other adverse effects of weeds reduce quality, interference with farm operations, reduce water use efficiency to human and livestock (Rao, 1989). Some previous studies have also indicated that the critical weed competition can go up to 40 days after transplanting (Rajendra *et al.*, 1986). According to Rahman *et al.* (2012) and Mahmood *et al.* (2002) early season competition is most critical and a major emphasis on weed control should be made during this period.

1.3 Justification

Onions are very susceptible to competition from weeds because of their slow growth. For this reason, onions require absolute early weed control. The conventional method of weed control, hand-weeding, is costly, time consuming and difficult due to close planting. While chemical herbicides are making major contribution in weed management in the developed nations, their use is scarce in developing countries including Tanzania. Lack of effective and economically viable weed management options for onion production has been reported as a critical constraint affecting farmers' motivation to continue to grow the crop (Waiganjo, 2004).

Therefore, it is important to evaluate different methods from which a grower can choose depending on their socio-economic and production conditions to reach the global average yield of 25- 30 t /ha. Waiganjo *et al.* (2009) conducted the experiment which was 'Effects of weeds on growth of bulb onion and some cost-effective control options'. Their treatments included black polythene mulch, grass mulch, hand-weeding fortnightly, hand-weeding monthly, pre-emergent herbicide (Linuron) application, herbicide and hand-weeding after eight weeks and the control (un-weeded). Weed control options are often limited in vegetable crops such as onions. The best methods for an individual grower depend on several factors such as weed species present, onion row spacing, availability and cost of labour and herbicides. However, it is important to evaluate different methods from which a grower can choose depending on their socio-economic and production conditions. Weed growth, population density, and distribution vary from place to place depending on the soil characteristics, climatic factors, and farmers' management practices. The information on weed density, distribution, and species composition may help to predict yield losses in onions and subsequently help in decision making as to whether it is economical to control a specific weed problem (Kropff and Spitters, 1991).

1.4 Objectives

1.4.1 Overall objective

To establish effectiveness of different weed management options for use by onion producers.

1.4.2 Specific Objectives

(i) To determine relative importance of weed species growing together with onion.

(ii) To evaluate chemical and cultural weed control methods in onion.

(iii) To conduct cost benefit analysis of weed control methods in onion production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An Overview

Onion (*Allium cepa* L.) is a popular vegetable grown for its pungent bulbs and flavourful leaves. Onion is widely grown throughout the world and Tanzania is among the countries which grow onions as cash crop and for domestic use by big farmers and smallholder farmers. Tanzania is the 6thlargest onion producing country in Africa after Egypt, Nigeria, South Africa, Kenya and Niger (Kisetu and Joseph, 2013; Abdel-Maksouda and Abdel-Rahman, 2011). Onion cultivation in Tanzania is mainly by smallholder farmers who sell produce to local markets and yield levels are as low as 19 to 33 t ha^{-1} (Mtaita, 1994; Weinberger and Msuya, 2004). Kisetu and Joseph (2013) and Mowo *et al.* (2006) reported that in arid and semi-arid areas the most important constraint of onion production is deficient soil moisture and low soil fertility but Gambo *et al.* (2008) reported combined factors related to crop agronomy and plant genetics.

2.2 The Onion Plant

Onion is usually grown as an annual vegetable crop. The root system is adventitious arising from the short stem. The stem is very short and flattened. It is produced at the base of the plant, which increases in diameter as growth continues. Alternate leaves are produced in successions from the broadening stem apex. The leaf elongates to form a tubular leaf sheath. The thickening of the leaf bases forms bulbs and the bulb formation is photoperiod controlled. When the bulb attains a maximum growth an inflorescence is produced, which elongates from the stem to form an inflorescence stalk (Kalb, 2001).

2.3 Onion Varieties

A survey conducted by Sibuga *et al.* (2010) in Kilosa district indicated that the majority of farmers planted Red Bombay (79.0%), followed by Texas Grano (14.0%) and Red Creole (7.0%). Although many varieties of onion are grown in Tanzania, two varieties are of particular importance in terms of volume of production. These varieties are Red Bombay and Red Creole. Various strains of Red Bombay are maintained in different areas and a good example is the popular Mang'ola Red, which is maintained at Tengeru and Mang'ola stations in Arusha region. Other varieties such as Texas Grano and Early Red are produced in some areas of Tanzania (MAFSC, 2002).

2.4 Ecological Requirement of Onion

Onions can be grown under a wide range of climatic conditions but they perform better in a mild climate without excessive rainfall or great extremes of heat and cold. Cool conditions with an adequate moisture supply are most suitable for growth, followed by warm drier conditions for bulb maturation, harvesting and curing (Okigbo, 1973). They can be grown on a variety of soils, but fertile loam soils give the optimum results.

Onions can be grown successfully on any fertile, well drained, non-crusting soil. The optimum pH range of onion regardless of soil type is 6.0 to 6.8 (Doorenbous and Kassam, 1979), although alkaline soils are also suitable. Optimum temperatures for onion plant development are between 16°C and 22°C because high temperatures favour bulb formation and curing (Sys *et al*., 1993).

2.5 Factors Limiting onion Production

Onion production can be affected by other factors like diseases, insects, drought and so many things.

2.5.1 Diseases

Onion diseases can cause severe losses by reducing yield and quality of marketable onions. These onion diseases can occur in seedbeds, production fields and storage (Langston *et al*., 2007). Purple blotch, caused by *Alternaria porri,* is probably one of the most common diseases of onion and is distributed worldwide (Schwartz, 2004).
Onion downy mildew, caused by the fungus *Peronospora destructor,* is very common through-out most areas of the world (Schwartz, 2004).

Bacterial soft rot, caused by *Erwinia carotovora* pv. *carotovora,* is a common problem in many vegetables, usually during storage. It usually develops in onions after heavy rains or after irrigation with contaminated water. This disease is primarily a problem on mature onion bulbs during warm (68-85 degrees F), humid conditions. (Westcott, 2001).

2.5.2 Insects of onion

Since onions are a winter crop in southeast Georgia, insect problems are not as severe as they would be for spring, summer, or fall crops. Preventive measures and careful scouting can minimize or eliminate any potential problems (Langston *et al*., 2007).

2.5.2.1 Thrips (*Thrips tabaci)*

Thrips are the primary insect pest of onions. Thrips have rasping mouthparts that cause physical damage to the onion leaf. Damaged leaves are more susceptible to subsequent disease infection and are less efficient at photosynthesis. While these insects can appear in the fall, they are much more common in rain season as temperatures rise. Populations of thrips and the severity of this insect problem on onions can vary considerably from year to year (Westcott, 2001).

2.5.2.2 Cutworms

Cutworms are the larval stage of many species of moth in the *Noctuidae* family. These caterpillars generally feed at night and hide during daylight hours. Damage generally is detected as plants cut off near the soil line. Their nocturnal habits and cryptic coloration make cutworms difficult to find, which is required for proper diagnosis of the problem. These pests are more easily detected by examining plants very late or very early in the day (Sparks *et al*., 2010).

2.6 Rationale for Weed Control in Onion Fields

To control weeds successfully, weed management should match the specific problems in a field. Therefore, some basic knowledge on weed and crop ecology and biology is needed to correctly predict the impact of weed infestation on crop yield. Within this context, weed-crop growth characteristics and the dynamics of weed emergence are the important aspects (Akobundu, 1998; Forcella, 1998). Many farmers in the developing world are unaware of several aspects of weed interference and the best time for weed removal although there are a few exceptions (Akobundu, 1998; Labrada, 1996 and 1998). Ellis-Jones *et al*. (1993) found widespread recognition in Zimbabwe of the importance of early weeding for both weed suppression and improvement of rainfall infiltration.

Weed germination patterns generally result in cohorts of seedlings emerging over an extended period of time and are heavily influenced by weather conditions, soil type and cropping system (Vleeshouwers, 1997). The initial emergence time differs from year to year and varies according to the species ecological requirements (mainly temperature and soil moisture content (Forcella *et al*., 1997). It is also well established, and has been experimentally quantified for several crops and types of weed infestation by Zimdahl (1988) and Berti *et al*. (1996) that the relative time of crop-weed emergence and the time of weed removal strongly influenced crop production.

On small-scale farms in developing countries, more than 50% of labour time is devoted to weeding, and is mainly done by the women and children in the farmer's family (Ellis-Jones *et al*., 1993; Akobundu, 1996). In traditional farming systems, the knowledge of the so-called 'critical period' of competition would enable farmers to make the most efficient use of limited labour resources. In conditions of medium-high weed pressure, the critical period is approximately centred on the first one-third of the crop growing cycle. However, the critical period varies with the relative competitiveness of the crop.

2.6.1 Losses in onion due to weeds

As in many crops, weeds cause yield reduction in onions owing to slow emergence, low initial growth rate, long vegetative period and low competitive ability of the crop. For this reason, onions require absolute early weed control. Weeds are underestimated pests causing much of the yield reduction in onions and are mainly found in the tropics than in any other parts of the world (Akobundu, 1984).

Weeds can cause direct yield losses associated with reduction in quality, interference with farm operations, reduce land use efficiency, reduced water use efficiency in water bodies and poison to human and livestock and increase the cost of production (Rao, 1989). Weed control consumes time which could be used for other activities. Also some other weed control measures are very expensive compared to the smallholder farmers' income and literacy levels. Weeds are alternate host of pests and diseases of crops as well as a health risk (Rao, 1989).

Effective weed control is often more difficult to obtain in onion than in many other crops because onions grows more slowly and are less competitive with weeds. Weeds compete with onions for light, nutrients, water, and space. In addition to reducing harvest-able bulbs through competition, weeds interfere with the harvesting process by decreasing hand-harvesting and machine harvest efficiency (Ashton *et al*., 1991). Weeds can also harbour destructive insects and diseases that can severely damage the present or following crop.

Controlling weeds may suppress or reduce bacterial streak and bulb rot levels as reported by Smith *et al*. (2008). Several weed species commonly infest onion such as

Cynodon dyctalon, but the most common and troublesome are highly influenced by planting time like *Cyperus* ssp. It is important to be aware of the weed species that are expected to flourish in a field planted with onions. Then it is possible to plan and develop a control program. Onions are poor competitors against weeds due to their slow, vertical growth that fails to shade out weeds (Kizilkaya *et al*., 2001). Thus, early weed control is important in onion production.

2.7 Weed Management Practices

Managing weeds is critical for successful onion production. Effective weed control is often more difficult to obtain in onion than in many other crops because onion grows more slowly and is less competitive with weeds.

2.7.1 Cultural methods

The methods include mechanical, mulching, hand weeding and cultivation.

2.7.1.1 Mechanical control

Mechanical control consists of methods that kill or suppress weeds through physical disruption and the methods include pulling, digging, disking, ploughing and mowing (Gavali and Kulkarni, 2007). However, in the process, soil profiles are disturbed and new weed seeds are often exposed (Shrestha *et al*., 2002). Bond and Burton (1996) reported that repeated tillage at 7 to 10 day intervals removed foliage, encouraged re-growth and depleted root's carbohydrate stores weakening plants. However, it was also noted that there are risks associated with tillage which include damage to soil structure, increased compaction or erosion risk, organic matter oxidation and loss as well as the decreased nutrient-holding capacity and water penetration and the high cost of labour and fuel. (Vanapalli *et al.*, 1999; VandenBygaart and Angers, 2006).

2.7.1.2 Mulching

Different mulching materials can be used to prevent weed germination and growth and ultimately reduce time and labour required to remove weeds in the field (Greenly and Rakow, 1995). Mulches fall into two categories namely organic mulches which are derived from plant materials and decompose in the soil, and the inorganic mulches which do not decompose and must be removed from the soil (Litzow and Pellett, 1993).

The effects of mulches on environmental factors and landscape plant growth have been widely studied for a comprehensive review (Chalker-Scott, 2007). Mulches can suppress weeds by shading, lowering soil temperatures, moderating diurnal temperature fluctuation, provide a physical barrier to weed seedling emergence, blocking light required for germination of many small-seeded weed species, increasing seed predation, and release of allelochemical (Abouziena and Radwan, 2014).

Some of the most commonly used organic mulching materials are manures, bark chips, ground corncobs, sawdust, grass clippings, leaves, newspapers (shredded or in layers), rice husks and straws. Black plastic fabric mulches protect onion sets or plants as they mature into bulbs (Kraus, 1998). Organic mulches allow some flexibility in fertilizing and watering, since they can be raked back from the plants (Montague *et al.,* 2007). They should normally be applied in a uniform layer seven to nine centimetres deep around the base of the vegetable plant but straws which contain weed seeds should be avoided. The most commonly used inorganic mulches are the black plastic materials. According to Watson and Kupkowski (1991) clear plastic is not recommended because it does not exclude or reflect the light that is needed by weed seeds need to germinate.

2.7.1.3 Hand weeding

Hand weeding effectively controls most of the weed species. In order to reduce crop damage and to allow for the use of mechanical tools such as hoes, removal of large weeds with extensive root systems may damage crop roots or foliage (Jilani *et al.,* 2003). Although hand weeding is very effective, also it may be very expensive because of time and labour requirements. Hassan and Malik (2002) reported that hand weeding is the best approach for weed control because it provides maximum weeds control in the tested crop field. Hand weeding and herbicide applications proved superior in decreasing weed density (Jilani *et al.,* 2003).

Transplanting onions aids in managing weeds because it avoids 2 months of weed control. According to Rahman *et al.* (2012) proper field preparation cannot be overemphasized as a recommendation to benefit onion growth and minimize weed problems during the crop growth cycle. It is important to be aware of the weed species that are expected to flourish in a field where onion is planted and this helps in planning and developing an appropriate control program.

2.7.1.4 Cultivation

Shallow cultivation around young onions controls most broadleaf weeds. As the plants grow, however, their roots spread and bulbs develop, so the use of a cultivator must be stopped to avoid harming onion roots (Derksen *et al.,* 1993). Removal of weeds by hand is less risky, but it also may disturb the onion plants. It is effective for controlling annual species such as *Bidens pilosa*, but can actually be counterproductive when trying to control perennial weeds such as *Cyperus rotundus, Commelina benghalensis, Cynodon dactylon* and *Physalis angulata*.

2.7.2 Chemical control methods

Herbicide application can provide the most effective and time-efficient method of managing the weeds. According to Ibrahim *et al.* (2011) the application of herbicides reduced labour by 75%. Numerous herbicides are available that provide effective weed control and are selective in that grasses are not injured (Sing *et al*., 1992). Along with the use of herbicides, is the user's responsibility and compliance with all product label requirements for herbicide handling, use, and cleanup. Ahmed *et al.* (1994) reported that, herbicides help to reduce the labour and time needed for effective weed management as compared to cultivation.

The reductions in crop yield losses caused by weeds can directly lead to increased economic returns for the farmer, reduce time and labour requirements for weed control. Herbicides contribute to higher crop yields in many ways other than improved weed control (Zubair *et al.,* 2009). Since onion plant is shallow rooted, deep cultivation must be avoided in order not to damage the roots. Hand pulling and hoeing of weeds are expensive, labour demanding, strenuous and liable to cause damage to the fragile roots and bulbs (Ghaffoor, 2004). The availability of labour force is also unreliable and has become expensive; therefore in commercial onion production chemical weed control is inevitable (Norman, 1992). Herbicides containing oxyfluorfen or bromxynil control broadleaf weeds (Khohlar *et al*., 2006).

2.7.3 Integrated control

Integrated weed management (IWM) includes the application of many types of technology and supportive knowledge in the deliberate selection, integration, and implementation of effective weed control strategies, with consideration of the economic, ecological, and sociological consequences. IWM is a component of integrated pest management (IPM). Most descriptions of IPM mention three elements which are levels that cause economic damage and conservation of environmental quality (Thill *et al*., 1991). An IWM system for a multiple tactics of pest management used in a compatible manner, pest populations maintained below single crop in a single year is relatively simple; however, for long-term IWM to be successful, it must link the farmer's attitude, knowledge, preferences, and abilities with available tools that best fit each situation.

The farmer must then use this knowledge to manage the system to obtain high-quality crop yields while minimizing and, over time reducing, the harmful effects of weeds. A successful IWM system is effective, economic and ecologically sound, stressing integration of control tactics with all other practices that influence the ecosystem, and links weed control to the larger picture of ecosystem management (Thill *et al*., 1991).

2.7.4 Biological control

This refers to the use of biological agents like pests, predators, pathogens and parasites to control weeds. According to Cruttwell (2000), biological control of weeds is the only method that is affordable to many resourcepoor farmers in the developing world. Typically, this means one insect species works to control, not eliminate, one weed species (Khohlar *et al.,* 2006). This type of weed control makes the least sense on cropland and rangeland. Extreme caution must be used with releasing biological control insects and the target weed must be a weed in all forms and in all places.

Weeds are a major problem because when left uncontrolled they can cause over 80% yield loss. The management practices employed to reduce yield losses were herbicides, cultural and integrated weed management which describes a weed control strategy that considers all available weed control techniques and combine to provide economic and sustainable weed management.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location and Characteristics of the Experimental Site

A field experiment was conducted at the Sokoine University of Agriculture (SUA) at the Horticultural Unit located at the foot slopes of the Uluguru Mountain in Morogoro urban, Tanzania. The study was conducted from October 2013 to February 2014. The study site is located at 6^{o} 85' S and 37^{o} 64' E and at an elevation of 568 m above mean sea level. The area experiences a bimodal rainfall distribution and the annual rainfall ranges between 800 and 950 mm but the amount is mostly unreliable (Hatibu *et al.,* 2002). The ten years (10) monthly rainfall for the period October to February 92001 – 2010 and cropping season October 2013 to February 2014 was collected from Tanzania Metrological Agency Morogoro. The area is characterized by kaolinitic clay well drained soils (Kisetu *et al.,* 2013).

3.2 Treatments and Experimental Design

The experiment was laid out in randomized complete block design (RCBD) with three replications, in a split plot arrangement. The main plots were the three onion varieties namely Red Bombay, Red Creole and Mang'ola Red and sub-plots were the six weed management practices (Table 1)

Table 1: Detail of Weed management practices used in the trial

S. No.	Weed management practices	Description
1.	Galgan® 240 EC, a.i(Oxyfluorfen)	A selective herbicide Galgan® 240g/l was applied to kill the emerged weeds after transplanting. The application rate was 3L/ha in 200-500L of water per ha. The spray was done by using a knapsack sprayer with flat fan nozzle to spray the recommended spray volume at a pressure of 100-200 kpa. The herbicide application was done three (3) weeks after transplanting where weeds are emerged, and irrigated one day before to moist the soil and spray in the morning to maintain the weed control efficacy.
2.	Rice husks mulch(10 cm)	During transplanting, three days (3) after transplanting rice husks mulch of 10cm thick were applied
3.	Weeding 3WAT	The plot was hoe-weeded once,
4.	Weeding 3, 6WAT	Hoe-weeding was done three weeks and at six weeks after transplanting
5.	Weed 3, 6, 9WAT	Weeding was done three, six and nine weeks after transplanting.
6.	Unweeded	No weed control measure was applied

3.3 Nursery Preparation

Commercially available seeds of the three onion varieties were drilled in lines and covered with soil on a nursery bed. The nursery beds were irrigated daily in the evening from drilling up to 2 weeks. There after watering was done at an interval of 2 days till they were ready for transplanting.

3.4 Land Preparation, Transplanting, Crop establishment and Management

Land was prepared by a mouldboard ploughing tractor and then harrowed to fine tilth. Forty nine days old onion seedlings with about 2-3 leaves were transplanted to the experimental plots at one seedling per hole. Spacing used was 20 cm between rows and 10 cm between plants in a row, in plots of 3 m × 2.5 m each. Each plot had 20 rows and 25 plants in a row making a total of 500 plants per plot, which makes a total of 6,680,000 plant population/ha. The diammonium phosphate (DAP) at a rate of 80 kg/ha P and Urea at a rate of 226 kg/ha N were applied during transplanting and three weeks after transplanting, respectively. There were short intermittent periods of drought during which the crop received supplementary surface irrigation which was irrigated to water field capacity and the maximum application rate was twice per week. The crop received a total of 32 applications of supplementary irrigation. Weeds were removed by hand with the aid of a hoe. During the growing season Mupacron 500 EC, profenofos was sprayed to control Onion thrips (*Thrips tabaci*) at the rate as per Manufacturers label. No disease attack occurred during the experimental period.

3.5 Data Collection

3.5.1 Weed counts in different treatment

Twenty one days after transplanting, weeds species were counted from 2 quadrants of 0.5 x 0.5 m located at the middle and corner of the onion plots. This was done one day before herbicides application and hand weeding where applicable. The counting of weeds was repeated three times at three weeks, six weeks and nine weeks after transplanting. The weed count data was later used to derive weed density, weed frequency, weed uniformity, mean field density, mean infested field density and index of relative abundance following procedures described by Thomas (1985).

3.5.2 Fresh weight of weeds

The weeds counted and collected in section 3.5.1 were spread on shade to reduce the moisture content for twenty four hours (24). They were then weighed and their weights recorded in grams. This exercise was done at every weed count, i.e 3, 6 and 9 weeks after transplanting.

3.5.3 Dry weight of weeds

After obtaining the fresh weeds, then weeds were placed in an oven drier at the temperature of 70° C for 72 hours. After drying, the weeds were weighed using a sensitive digital weighing balance.

3.5.4 Onion plant height

The heights of ten randomly selected onion plants from each plot were taken from the ground level to the top of the highest leaf using a tape measure. Mean plant height (cm) was calculated at the maturity stage before leaves started falling down.

3.5.5 Yield and yield components

The number of onion plants in 12 rows (minus two guard rows) from each plot were counted and recorded just before harvesting. Ten bulbs were randomly selected from each treatment and used to determine the following data:

3.5.5.1 Diameter (Size)

The diameter of onion bulbs was determined using verniercalliper and the average bulb diameter was calculated

3.5.5.2 Bulb Weight

The weights of the 10 bulbs in 3.4.5.1 was recorded and used to calculate the average bulb weight.

3.5.5.3 Onion yields

Onion bulbs from each plot were harvested and dried under shade for two weeks to constant moisture content. The dryness of onion bulb was determined when the following were seen: The roots break off easily when touched; onion skin dries and becomes uniform in colour, exhibiting a brittle texture and the stem area shrinked and dried. The weight was determined by a weighing balance and yield was expressed in t ha^{-1}.

3.6 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using GenStat software V.3 statistical package (VSN International, U.K). Data on weed count were subjected to square root transformation before analysis. The statistical model for the split plot experimental design used was: Xijk = X + Mi + Bj + dij + Sk + (MS)ik + Eijk; Where

X = general mean common to all observations,

Mi = main plot treatment effect (varieties),

Bj = the block effect, dij = the main plot error (error a),

Sk = the sub plot treatment effect (Weed control methods),

(MS)ik = the main plot and subplot interaction effect of a respective Varieties with given weed treatments , Eijk = subplot error (error b).

Treatment means were separated using Turkey's honestly significant test to determine differences at 5% level of significance

CHAPTER FOUR

4.0 RESULTS

4.1 Weather Condition

During the growing season (2013-2014), where the experiment was conducted the amount of rainfall received was lower than that of the previous ten years averages of (2001 – 2010), except in October the rainfall was above averages, but in December and January the amount of rainfall received was below average for 119.7 mm. Fig. 1.

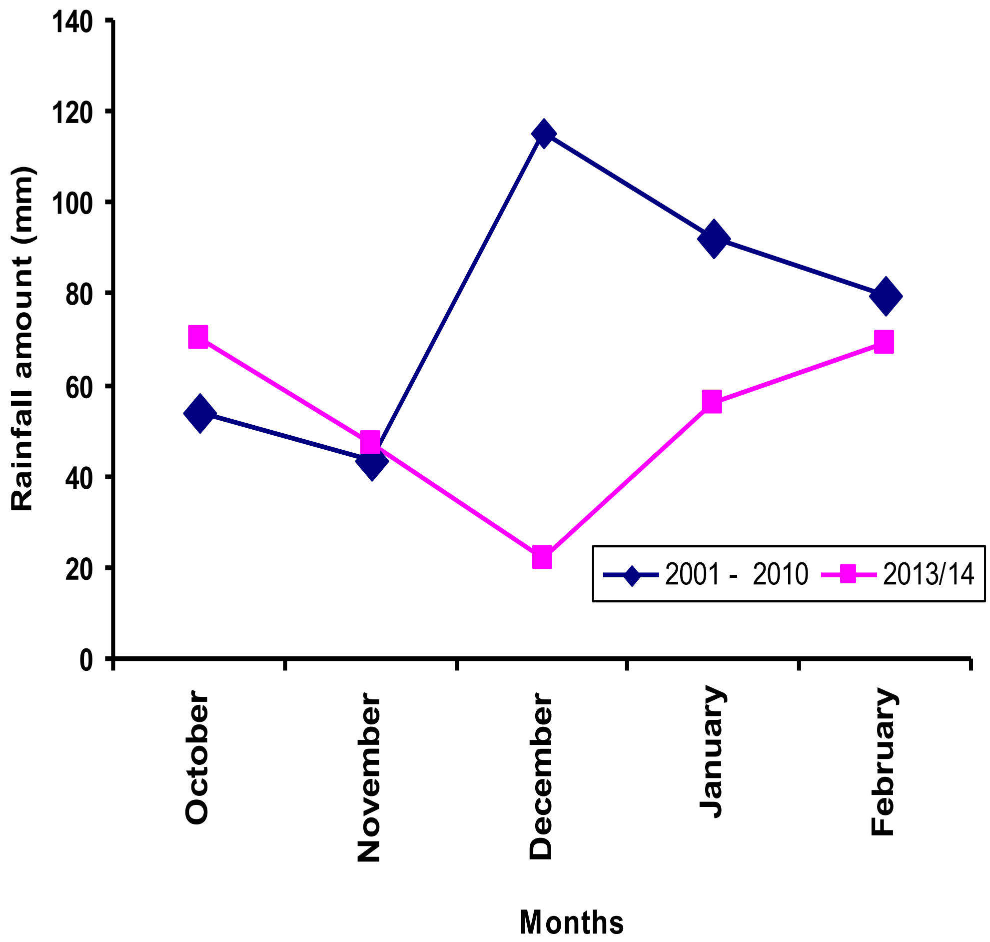

Figure 1: 10-year monthly rainfall for the period Oct. – Feb. (2001 – 2010) and cropping season (Oct. 2013 – Feb. 2014) by TMA Morogoro

4.2 Statistical Significance of Analysed Variables

There were highly significant ($P \leq 0.001$) difference among varieties with respect to weed fresh weight, weed density, bulb height and weed dry weight. Onion plant height differed significantly ($P \leq 0.01$). Moreover, onion bulb yield differed significantly ($P \leq 0.01$) among varieties (Table 2). It was also found that control measures had very highly significant ($P \leq 0.001$) effect on weed fresh and dry weights, bulb diameter, bulb weight, bulb height, number of bulb per plot and onion bulb yield (Table 2). Different control measures also had significant difference on onion plant height ($P \leq 0.01$) and weed density ($P \leq 0.001$).

Table 2: Summary table of ANOVA of all Variables

VARIABLES	VARIETY(V)	CONTROL MEASURES (C)	V×C
Weed density	***	**	Ns
Weed fresh weight	***	***	**
Weed dry weight	***	***	***
Onion plant height	*	*	Ns
Bulb diameter	Ns	***	Ns
Bulb weight	*	***	Ns
Bulb height	***	***	Ns
Number of bulbs	*	***	*
Yield (t/ha)	**	***	***

Ns = non significance
* = significant at ($P \leq 0.05$)
** = highly significant at ($P \leq 0.01$)
*** = very highly significant at ($P \leq 0.001$)

4.3 Weed Occurrence

Weeds found in the experimental area comprised of predominantly broadleaf and grasses, only one species of sedges was found in the field. The most dominant weed species was *Mariscus flabellifrmis* (sedge) with the highest frequency and index of relative abundance of 99 and 8, respectively (Table 3). This was followed by *Celosia trigyna* L. 7. The least dominant weed species were *Physalis angulata, Brachiaria lata, and Eleucine indica*, which indicated that there were significant differences (P<0.05) with other weed species. This implies that the mentioned weed species are less competitive as compared to the other species. *Mariscus flabelliformis* and *Celosia trigyna* L. were the most uniformly distributed weed species in that order with uniformity value of 33 and 31, respectively. The most poorly distributed weed species were *Eleucine indica* 10, *Brachiaria lata* 9 and *Physalis angulata* 8.

Mariscus flabelliformis had the highest mean field density of 0.005 weeds per meter square but not significantly with other species like *Celosia trigyna* L., *Euphorbia heterophylla* L., and *Echnochloa stagnina* in mean infested field density and index of relative abundance. The lowest mean field density was *Physalis angulata* with a mean field density of 0.0011 weeds per meter square. The results showed significantly (P<0.05) differences among weed parameters. It was found that, weed frequency, Uniformity, mean field density and mean infested field density differed significantly (P<0.05) among weed species (Table 3).

Table 3: Frequency, uniformity, average field density, mean infestation of weeds in the Onion field

Weed sp.	**Type**	**Frequency**	**Uniformity**	**Mean field density**	**Mean infested field density**	**Index of relative abundance**
Mariscus flabelliformis	S	99cdefg	33cde	0.005cdef	0.002b	8bcd
Celosia trigyna L.	B	92cdefg	31cde	0.004cde	0.002b	7bcd
Euphorbia heterophylla L.	B	88cdef	29cd	0.004cde	0.002b	7bcd
Echnochloa stagnina	G	87cdef	29cd	0.004cde	0.002b	7bcd
Amaranthus spp.	B	85cdef	28cd	0.004cde	0.002b	6.8bc
Setaria barbata	G	78cde	26cd	0.0036cd	0.002b	6.3bc
Boerhavia diffusa L.	B	77cde	26cd	0.0035cd	0.002b	6.2bc
Trianthema portulacastrum L.	B	77cde	26cd	0.0035cd	0.002b	6.2bc
Panicum laxum	G	76cde	25cd	0.0035cd	0.002b	6.1bc
Comelina benghalensis	B	74cd	25cd	0.0034cd	0.002b	6bc
Cynodon dactylon	G	72c	24c	0.0033cd	0.003b	6bc
Bidens pilosa	B	71c	24c	0.0032cd	0.003b	6bc
Portulaca oleracea	B	65c	22c	0.0030c	0.003b	5b
Oxygonium sinuatum	B	63c	21c	0.0029c	0.004b	5b
Launaea cornuta.	B	51b	17b	0.0023b	0.005c	4b
Eleucine indica	G	30a	10a	0.0014a	0.001a	2a
Brachiaria lata	G	28a	9a	0.0013a	0.001a	2a
Physalis angulata	G	24a	8a	0.0011a	0.001a	2a
Mean		68.66	22.88	0.0031	0.005	5.554
SE		5.19	1.73	0.0002	0.003	0.419
CV (%)		32.08	32.08	31.881	273.5	32.016

Key: B, G and S represent Broadleaf, Grass and Sedges, respectively. Means of the same column followed by the same letter are not significantly different at 5% probability level using Tukey's test.

The data collected showed that there were significant ($P \leq 0.001$) variations among the mean weed densities. Red Bombay and Red Creole plots applied with rice husks mulch had significantly ($P \leq 0.01$) lower weed density compared to other treatments. Weeding frequencies and application of herbicide gave smaller weed values compared to control. It was also found that in plots grown with variety Mang`ola Red, there were no significant differences ($P \geq 0.05$) in weed density when different weed control measures were used compared to control (Table 4).

Different control measures resulted to significant differences ($P \leq 0.001$) in mean fresh weight compared to control (Table 5). There was no significant difference ($P \leq 0.05$) comparing plots applied with herbicide, rice husks, weeding twice and weeding thrice with respect to weed fresh weight. Moreover weeding once resulted to weed fresh weight values comparable to control (unweeded plots) for plots grown with variety Red Bombay. Similar results were found for plots grown with Mang`ola red variety.

Table 4: Effect of chemical and cultural weed control methods on weed densities in three onion varieties

Weed management practices	**Red Bombay**				**Red Creole**				**Mang'ola Red**			
	B	**G**	**S**	**Mean**	**B**	**G**	**S**	**Mean**	**B**	**G**	**S**	**Mean**
Galgan®240 g/l	28.22	36.00	41.89	35.4b	48.11	14.56	73.33	45.3b	18.89	26.11	66.00	37a
Rice husks mulch (10 cm)	14.67	17.33	20.33	17.4a	15.33	6.56	32.89	18.26a	13.22	16.22	37.33	22.26a
Weeding once 3WAT	48.00	36.56	74.44	53b	63.00	11.78	64.78	46.52b	91.44	26.11	40.89	52.81a
Weeding twice 3, 6WAT	42.44	35.56	31.89	36.6b	49.67	17.89	34.33	33.96b	54.11	16.11	59.11	43.11a
Weeding thrice 3, 6, 9WAT	43.11	19.33	99.11	53.9b	34.11	18.33	78.00	43.5b	35.11	14.00	32.44	27.2a
Unweeded	54.56	16.11	60.33	43.7b	76.44	12.89	52.22	47.2b	51.56	33.00	41.67	42.1a
Mean	38.5	36.1	54.7		47.8	13.7	55.9		44.1	21.9	46.24	
SE	0.31	0.3	0.5		0.4	0.3	0.4		0.147	0.59	0.53	
CV (%)	18.4	19.6	24.1		21.4	21.7	20.3		8.7	46	29	

Values in the same column and rows, respectively, followed by the same letter do not differ significantly (P≤0.05) according toTukey's Honestly significant difference test

Key: B, G and S represent Broadleaf, Grass and Sedges, respectively.

Table 5: Effect of chemical and cultural weed control methods on weed fresh weight (gm) from three onion varieties at 3, 6, and 9 weeks after transplanting

Weed management practices	Red Bombay				Red Creole				Mang'ola Red			
	B	**S**	**G**	**Mean**	**B**	**S**	**G**	**Mean**	**B**	**S**	**G**	**Mean**
Galgan® 240 g/l	13	19.7	12.3	15.0a	19.7	44.7	13.01	25.81ab	10.16	20.94	11.46	14.19a
Rice husks mulch (10 cm)	38.7	10.3	10.0	19.7a	11.9	7.1	7.51	8.84a	37.33	14.37	1.8	17.83a
Weeding once 3WAT	74.6	38.7	50.7	54.7b	39.0	27.4	32.8	33.07ab	151.03	35.32	57.76	81.37b
Weeding twice 3, 6WAT	34.1	15.8	12.6	20.8a	18.4	11.3	8.08	12.61a	31.79	27.37	6.87	22.01a
Weeding thrice 3, 6, 9WAT	33.5	45.6	9.5	29.5a	13.5	29.5	7.26	16.77a	30.9	29.31	9.19	23.13a
Unweeded	163.9	60.8	66.9	97.2b	69.5	41.0	47.01	52.54b	161.77	32.49	81.4	91.89b
Mean	59.6	31.	27.0		28.7	26.9	19.3		70	26.6	28.1	
SE	66.6	18.7	28.5		10.9	14.5	18.48		36.1	15.48	25.07	
CV (%)	61.4	71.8	129.5		46.5	66.2	117.4		62.7	71.2	109.3	

Values in the same column and row, respectively, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey’s Honestly significance test.

Key: B, G and S represent Broadleaf, Grass and Sedges, respectively.

Control measures resulted to significant ($P \leq 0.001$) difference in weed dry weight (Table 6). Mulched plots gave the lowest weed dry weight similar to those obtained from plots applied with Galgan and weeded plots which differed from control. Mulching resulted to similar dry weight values comparable to weeding thrice.

4.4 Onion Plants

4.4.1 Height of onion plants

Different onion varieties had different plant heights under the applied weed control measures (Table 7). There was no significant difference in plant height when different weed control measures were employed in plots grown with Red Bombay variety. However, mulched plots gave plants with relatively long heights. For Red Creole and Mang`ola Red varieties, mulched plots led to plants with significantly ($P \leq 0.01$) higher height (Table 7). Weeding frequencies resulted to plants with similar heights.

Table 6: Effect of chemical and cultural weed control methods on weed dry weight (gm) of weeds from three onion varieties at 3, 6, and 9 weeks after transplanting

Weed management practices	Red Bombay				Red Creole				Mang'ola Red			
	B	**S**	**G**	**Mean**	**B**	**S**	**G**	**Mean**	**B**	**S**	**G**	**Mean**
Galgan® 240 g/l	7.1	14.8	7	9.63a	10.8	30.6	8.8	16.72a	6.4	16.4	9.2	10.67a
Rice husks mulch (10 cm)	11.9	7	7.5	8.84a	12.8	15.8	3.2	10.6a	11.5	10.1	1.3	7.63a
Weeding once 3WAT	39	27.4	32.8	33.07b	55.9	32.8	11.8	33.53a	61.3	24.2	39.5	41.67b
Weeding twice 3, 6WAT	18.4	11.3	8.1	12.61a	35.2	12.2	8.8	18.73a	15.5	20	4.7	13.42a
Weeding thrice 3, 6, 9WAT	13.5	29.5	7.3	16.77a	16.2	19.5	7.1	14.28a	13.6	20.4	6.1	13.35a
Unweeded	69.5	41	47	52.52b	94.5	31.8	28.2	51.52b	50.1	20.6	52.8	41.15b
Mean	26.6	21.9	18.3		37.6	23.8	11.3		26.4	18.6	18.9	
SE	10.23	12.79	18.23		21.55	8.65	7.98		9.43	10.46	17.57	
CV (%)	47.1	71.6	122.1		70.2	44.6	86.2		43.8	68.8	113.7	

Values in the same column and row, respectively, followed by the same letter(s) do not differ significantly (P≤0.05) according toTukey's Honestly significance test.

Key: B, G and S represent Broadleaf, Grass and Sedges, respectively.

Table 7: Effect of chemical and cultural weed control methods on heights of onion plants (cm) from three onion varieties

Weed management practices	Varieties and height (cm)			
	Red Bombay	**Red Creole**	**Mang'ola Red**	**Mean**
Galgan® 240 g/l	44.5a	31.4a	45.4a	40.4
Rice husks mulch (10 cm)	51.1a	48.7b	50.7b	50.2
Weeding once 3WAT	50.9a	43.4ab	41.5a	45.2
Weeding twice 3, 6WAT	48.4a	41.4ab	39.1a	43.0
Weeding thrice 3, 6, 9WAT	44.4a	40.9ab	40.2a	41.8
Mean	47.86	41.16	43.38	
S.E: main-plot = variety (V)	0.0996			
S.E: sub-plot = weed control (W)	0.1286			
S.E: V*W =	0.2227			
CV%:	6.6			

Values in the same column and rows respectively, followed by the same letter do not differ significantly ($P \leq 0.05$) according to Tukey's Honestly significant difference test.

4.4.2 Yield and yield components

4.4.2.1 Onion bulb diameter

Weed control measures had no significant ($P \geq 0.05$) difference on onion bulb diameter for varieties, Red Creole and Mang`ola Red (Table 8). However, variety Red Bombay showed significant ($P \leq 0.01$) difference with respect to weed control measures. Plots applied with rice husks (mulched) resulted to plants with larger bulb diameter compared to other control measures. Herbicide application and weeding frequencies resulted to plants with similar bulb diameter.

Table 8: Effect of chemical and cultural weed control methods on bulb diameter (cm) from three onion varieties

Weed management practices	Red Bombay	Red Creole	Mang'ola Red	Mean
Galgan® 240 g/l	3.2ab	3.1	3.3	3.2
Rice husks mulch (10 cm)	3.7b	3.3	3.8	3.6
Weeding once 3WAT	2.6a	2.4	3.0	2.7
Weeding twice 3, 6WAT	3.1ab	3.4	3.5	3.3
Weeding thrice 3, 6, 9WAT	3.2ab	3.4	3.2	3.3
Mean	3.2	3.1	3.4	
S.E: main-plot = variety (V)	0.1352			
S.E: sub-plot = weed control (W)	0.1745			
S.E: V*W =	0.3022			
CV%:	11.6			

Values in the same column and rows respectively, followed by the same letter do not differ significantly (P≤0.05) by Tukey's Honestly significant difference test. Ns = non-significant

4.4.2.2 Onion bulb weight

Bulb weights of onion varieties are presented on Table 9. Weed management practices had significant differences (P≤0.001). The largest mean bulb weight (31.0 g) was obtained from mulching treatments while the lowest bulb weight (13.0g) were harvested from plots which were weeded once.

Table 9: Effect of chemical and cultural weed control methods on bulb weight (g) from three onion varieties

Weed management practices	Red Bombay	Red Creole	Mang'ola Red	Mean
Galgan® 240 g/l	21.5ab	17.8	24.8	21.4
Rice husks mulch (10 cm)	33.7b	24.4	35.0	31.0
Weeding once 3WAT	13.5a	11.4	16.6	13.8
Weeding twice 3, 6WAT	21.7ab	20.6	26.6	23.0
Weeding thrice 3, 6, 9WAT	21.0ab	22.8	22.0	21.9
Mean	22.3	19.4	25.0	
S.E Main plot 2.101				
S.E Sub plot 2.712				
S.E M*S 4.697				
CV (%) 25.9%				

Values in the same column and rows respectively, followed by the same letter do not differ significantly (P≤0.05) by Tukey's Honestly significant difference test. Ns = non significant.

4.4.2.3 Onion bulb heights

The results presented for onion bulb height (Table 10) indicated significant differences (P≤0.001) in bulb heights among treatments. Red Bombay and Mang`ola Red bulbs harvested from mulched plots had significantly (P≤0.001) larger bulb heights compared to other weed control methods. However, there were no significant (P≤0.05) differences in onion bulbs heights obtained from bulbs harvested from plots grown with Red Creole variety (Table 10). Nevertheless, bulbs from mulched plots gave relatively larger bulb heights.

Table 10: Effect of chemical and cultural weed control methods on Bulb height (cm) from three onion varieties

Weed management practices	Red Bombay	Red Creole	Mang'ola Red	Mean
Galgan®240g/l	4.0a	3.7	4.2a	4.0
Rice husks mulch (10 cm)	5.2b	4.4	5.2b	4.9
Weeding 3WAT	4.1a	3.4	3.9a	3.8
Weeding 6WAT	4.2a	4.4	4.3a	4.3
Weeding 9WAT	3.9a	3.8	4.1a	3.9
Mean	4.3	3.8	4.4	
S.E Main plot 2.117				
S.E Sub plot 2.733				
S.E V*M 4.733				
CV (%) 13.1%				

Values in the same column and rows respectively, followed by the same letter do not differ significantly (P≤0.05) by Tukey's Honestly significant difference test.

4.4.2.4 Number of onion bulbs/plot

There was a higher number of onion bulbs for Red Bombay and Red Creole plants in mulched plots (Table 11). It was found that herbicide application; mulching, weeding twice and weeding thrice resulted to a similar number of plants/bulbs per plot. Weeding once resulted into fewer plants per plot (Table 11).

Table 11: Effect of chemical and cultural weed control methods on number of bulbs/plot from three onion varieties

Weed management practices	Red Bombay	Red Creole	Mang'ola Red	Mean
Galgan® 240 g/l	198.7b	169.0b	184.0b	183.9b
Rice husks mulch (10 cm)	206.0b	184.7b	178.3b	189.7b
Weeding once 3WAT	110.7a	115.3a	105.3a	110.4a
Weeding twice 3, 6WAT	197.3b	175.3b	162.7b	178.4b
Weeding thrice 3, 6, 9WAT	177.0b	168.0b	203.0b	182.7b
Mean	177.9	162.5	166.7	
S.E Main plot 5.29				
S. E. Sub plot 6. 83				
S. E. M*S 11.83				
CV (%) 8.6				

Values in the same column and rows respectively, followed by the same letter do not differ significantly (P≤0.05) according to Tukey's Honestly significant difference test.

4.4.2.5 Onion bulb yield

Yield of onion bulbs collected from the field based on different weed management practices showed that there were significant (P≤0.01) differences in onion bulb yield among the varieties and treatments (Table 12). Results indicated that mulched plots resulted into higher yields compared to weeding thrice. When plots were weeded once, onion bulb yields were significantly lower compared to other weed management measures (Table 12).

Table 12: Effect of chemical and cultural weed control methods on Onion bulb yield (t ha^{-1}) from three onion varieties

Weed management practices	Red Bombay	Red Creole	Mang'ola Red	Mean
Galgan® 240 g/l	13.1b	11.5a	18.0c	14.2
Rice husks mulch (10 cm)	21.5c	13.2c	14.7b	16.5
Weeding once 3WAT	6.4a	7.6a	7.2a	7.1
Weeding twice 3, 6WAT	15.9bc	14.0c	15.9b	15.3
Weeding thrice 3, 6, 9WAT	14.5bc	15.1c	16.3bc	15.3
Mean	14.3	12.39	14.4	
S.E: main-plot = variety (V)	0.647			
S.E: sub-plot = weed control (W)	0.835			
S.E: V*W =	1.446			
CV(%):	13.0			

Values in the same column and rows respectively, followed by the same letter do not differ significantly ($P \leq 0.05$) according to Tukey's Honestly significant difference test.

4.5 Cost benefit Assessment of Onion Production

The high cost of producing onions was obtained from weeding thrice due to high labour cost in weeding (Table 13). The weeding cost was Tsh 3 620 000/=/ha while the profit obtained was (Tshs 11 680 000/=/ha) as compared to use of (Galgan®) where the cost was 1 830 000/= Tshs/ha and the profit was 12 770 000/= Tshs/ha, and rice husks mulch which used 1 982 000/=/ha Tshs giving profit of 14 517 400/= Tshs/ha. Weeding twice used the large amount of costs of about 2 020 000/= Tshs and the profit also was high of 12 480 000/= Tshs/ha. Unweeded treatment indicated no profit since no yield was obtained.

Table 13: Partial budget analysis (InTshs)

The cost of producing onion in different weed control measures in the season of Oct. 2013 to Feb. 2014

Production costs	**Galgan®**	**Rice husks mulch**	**Weeding once 3WAT**	**Weeding twice 3, 6WAT**	**Weeding thrice 3, 6,9WAT**	**Unweeded**
Variable costs						
Land preparation	120 000	120 000	120 000	120 000	120 000	120 000
Seeds	135 000	135 000	135 000	135 000	135 000	135 000
Transplanting	375 000	375 000	375 000	375 000	375 000	375 000
Weeding	00	00	900 000	1 800 000	2 700 000	00
Pesticides application	200 000	200 000	200 000	200 000	200 000	200 000
Fertilizer application	140 000	140 000	140 000	140 000	140 000	140 000
Herbicides application	610 000	00	00	00	00	00
Mulch/transport/labour	00	762 600	00	00	00	00
Harvesting	250 000	250 000	250 000	250 000	250 000	00
Total variable costs(TVC)	1 830 000	1 982 600	2 020 000	2 820 000	3 620 000	970 000
Yield (t/ha)	14.2	16.5	7.1	15.3	15.3	00
Price of onion	1000	1000	1000	1000	1000	1000
Gross Revenue	14 200 000	16 500 000	7 100 000	15 300 000	15 300 000	00
Marginal Return (MR)=GB-TVC	12 770 000	14 517 400	5 080 000	12 480 000	11 680 000	00
Benefit Cost Ratio(BCR) = GB/TVC	7.7	8.3	3.5	5.4	4.2	00

*Exchange rate 2014 was an average Tshs 1635 to 1 USD.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Weeds and their Management Practices

Onion is one of the most sensitive crops to weed competition. The groups of weeds found in the onion field shows that broadleaves were the dominant group compared to other groups such as sedges and grasses. However, *Mariscus flabelliformis* (sedge) was the only weed species in the sedge group. But also the most two dominant weed species and *Celosia trigyna* L. species with the large frequency, uniformity mean field density and largest index of relative abundance. This may be due to the fact that sedges tend to produce allelochemical phytotoxins levels which hinder root development of other neighbouring plants resulting to poor nutrients and moisture absorption (Rao, 1983). Onion production needs moist soil near field capacity achieved through frequent irrigation which in turn favors sedge growth and proliferation (Wang *et al*., 2008). This implies that *Mariscus flabelliformis* and *Celosia trigyna* L. were the most prevalent weed species and contributed greatly to competition with onions. *Eleucine indica*, *Brachiaria lata* and *Physalis angulata* were the least abundant weed species. The findings are similar to Sibel *et al.* (2010) who reported on weeds in onion fields applied with herbicides.

Mulched plots gave the lowest weed density and weed dry weight. This imply that covering the soil surface with plant mulches supress weeds and encourage crop competitiveness (Duppong *et al*., 2014). Mulching decreased weed density, dry weed biomass and increased crop yields except for Mango`la Red which had no significant different in weed density, the cause of this insignificancy it is hard to explain because all treatments used to all varieties are the same. These findings were similar to Sinkeviciene *et al*. (2009) and Waiganjo *et al.* (2009), who reported that mulching as a weed control method in onion had least mean weed infested field compared to other methods and proved superior in decreasing weed density, followed by the use of Pendimethaline and S-metolachlor herbicides. Using of mulch for weed control effectively suppresses the development of weeds because of its influence on light interception.

On the other hand, the highest total biomass of weeds was recorded in unweeded plots. These findings are similar to those of Vanderlinden (2008) who reported significant reduction in total biomass of weeds because of using mulch as a control measure to weeds.

5.2 Performance of Onion under Different Weed Management Practices

Onion plants from mulched treatment were significantly taller than those from weeding only once. This can be explained by the fact that mulches help to control weed proliferation by excluding light from germinating seedlings where by reducing competition for light, water, and nutrients. Onion plants in herbicide treated plots were significantly shorter than plants from all the other treatment plots, due to chemical injuries and stresses. Mulched plots were not weeded. The lack of cultivations lead to less crop root pruning hence increased height of the crop in mulched plots. However, these findings are not similar to the findings of Waiganjo *et al.* (2009) who reported that the unweeded plots resulted in taller plants compared to all the other treatments.

There was significant effect on number of onion bulbs and yield (t/ha) among the various weed management practices with the lowest harvests from the unweeded control where no onions were harvested. The possible reason for harvesting the lowest number of bulbs from the weeding once treatment could have been due to the presence of a higher number of weeds which competed with the onion bulbs for light, water, space and nutrients. Eliminating weeds reduces the competition for resources such as nutrients and water necessary for crop growth thus enhancing yield gains for the onion crop. This is consistent with findings of Rajendra *et al*. (1986), Porwal and Singh (1993), Verma and Singh (1997), Hussain *et al.* (2008), Hassan and Malik (2001) and Marwat *et al*. (2002).

Mulching increased onion bulb yield due to the fact that it created a more conducive soil micro-environment for the onion plant to grow and develop more fully (Inusah *et al*., 2013). Rice husk mulches also increased the water absorption rate of soils. The reduced soil temperatures under mulches encourage root growth in the upper soil layer where there is more oxygen and fertilizer (Hanada, 1991). These results are corroborated with the findings of Waiganjo *et al.* (2009). Onion bulb yield (t/ha) among varieties with mulching was generally highest for Red Bombay and lowest for the Red Creole variety. This anormally in trend suggests that Red Bombay variety is more susceptible to physical stress than others. With mulching the stress to the crop was minimal hence favored better crop development and establishment.

5.3 The cost of producing onion in different weed control measures

Mulching, herbicide and weeding twice had the highest marginal return of Tshs. 14 517 000/=, 12 770 000/= and 12 480 000/= (Table 14). The cost of labour required for hand weeding was high. These findings are in agreement with those of Waiganjo *et al.* (2009). Adoption of any agricultural practice to a large extent is governed by its economics.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions were drawn from the study:

- The most dominant weed species in onion production were *Mariscus flabelliformis* (sedge) *Celosia trigyna* L.
- Mulch was an effective weed control method mostly in broadleaf and grass weeds in onion production with the highest yield.
- Mulch hard the highest amount of variable cost compared to herbicides but also had the highest profit.

6.2 RECOMMENDATIONS

(i) Mulching as a weed control method in onion has economic benefits and its use in onion production should be promoted.

(ii) The use of rice husks mulch is recommended as cost effective weed control alternative to hand weeding for small holders farmers in areas where rice husks is available. Herbicides is a more practical weed control measure for large scale farmers.

(iii) Further studies are needed to evaluate other types of mulch, individually or in combinations with different control measures for better weed control in onion production.

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APPENDICES

Appendix 1: Different formula by Thomas 1985 used to derive different weed parameters.

i) The density of each weed group (D_{ki}) being it broadleaf, grass and/or sedges was computed using the formula:

$$D_{\mathbf{ki}} = \frac{\Sigma Z_j}{A}$$

Where D_{ki} = density (number of plants or spikes/panicles/m^2) of the species k in field i; Z_j = number of plants/spikes/panicles in each 1 m^2 sample; A = Land area in m^2

ii) **Frequency** = ratio of the number of fields where the species was present, to the total number of fields:

$$F_k = \Sigma Y_{j \text{ x}100 / \text{n}}$$

Where

F_k = frequency of the species k

Yi = presence (1) or absence (0) of the species k in field i

N = number of fields

iii) **Uniformity** = the average percentage of samples (from each field) in which a given species is present

$$U_k = \Sigma\Sigma X_{ij \text{ x } 100 / 3\text{n}}$$

Where

U_k = Coefficient of uniformity of the species k

X_{ij} = presence (1) or absence (0) of the species in the sub-sample j in field i

n = number of fields

iv) **Mean field density**

$MFD_k = \Sigma D_{kj/n}$

Where

n = number of fields

v) **Mean infested field density (MIFD)** = the density value referring to the number of fields where the species were present:

$MIFD_k = \Sigma D_{kj} / n\text{-}a$

Where

a = the number of fields in which the species is absent

vi) **Index of relative abundance (RA)** = Relative importance value

An overall evaluation of the importance of each species with respect to others calculated as:

$RA_k = RF_k + RU_k + RD_{k;}$ where

RA_k = the relative abundance of species k

To determine RA_k, individual values for RF_k, RU_k, and RD_k, were calculated as follows:

RF_k = the frequency of species k x100/sum of all frequencies of all species

RU_k = uniformity of species k x 100/sum of all uniformity values for all species

Appendix 2: Partial budget analysis

Production costs	**Galigan**	**Rice husks mulch**	**Weeding once 3WAT**	**Weeding twice 3, 6WAT**	**Weeding thrice 3, 6,9WAT**	**Unweeded**
Variable costs						
Land preparation	120 000	120 000	120 000	120 000	120 000	120 000
Seeds	135 000	135 000	135 000	135 000	135 000	135 000
Transplanting	375 000	375 000	375 000	375 000	375 000	375 000
Weeding	00	00	900 000	1 800 000	2 700 000	00
Pesticides application	200 000	200 000	200 000	200 000	200 000	200 000
Fertilizer application	140 000	140 000	140 000	140 000	140 000	140 000
Herbicides application	610 000	00	00	00	00	00
Mulch/transport/labour	00	762 600	00	00	00	00
Harvesting	250 000	250 000	250 000	250 000	250 000	00
Yield (t/ha)	14.2	15.3	7.1	16.5	15.3	00
Price of onion	1000	1000	1000	1000	1000	1000
Total variable costs(TVC)	1 830 000	1 982 600	2 020 000	2 820 000	3 620 000	970 000
Gross Benefit (GB)	14 200 000	15 300 000	7 100 000	16 500 000	15 300 000	00
Marginal Return (MR)=GB-TVC	12 770 000	13 317 400	5 080 000	13 680 000	11 680 000	00
Benefit Cost Ratio BCR = GB/TVC	7.7	8.3	3.08	5.5	4.2	00

Appendix 3: Statistical significance of analysed variables

VARIABLES	VARIETY	CONTROL MEASURES	V×C
Weed density	***	**	Ns
Weed fresh weight	***	***	**
Weed dry weight	***	***	***
Onion plant height	*	*	Ns
Bulb diameter	ns	***	Ns
Bulb weight	*	***	Ns
Bulb height	***	***	Ns
Number of bulbs	*	***	*
Yield (t/ha)	**	***	***

Appendix 4: Summary of analysis of variance for varieties (Main plots)

VARIABLES	VARIETY MEAN SQUARE	ERROR MEAN SQUARE	F-VALUE
Weed density	41604	2042	20.37
Weed fresh weight	4221.8	355.9	11.86
Weed dry weight	899.58	74.33	12.10
Onion plant height	173.68	33.60	5.17
Bulb diameter	0.3461	0.1370	2.53
Bulb weight	116.79	33.09	3.53
Bulb height	1.443258	0.07440	19.25
Number of bulbs	959.5	209.8	4.57
Yield (t/ha)	21.084	3.137	6.72

Appendix 5: Summary of analysis of variance for weed control treatments (Sub plots)

VARIABLES	TREATMENT MEAN SQUARE	ERROR MEAN SQUARE	F-VALUE
Weed density	8526	2042	4.17
Weed fresh weight	6484.5	355.9	18.22
Weed dry weight	2262.51	74.33	30.44
Onion plant height	130.91	33.60	3.90
Bulb diameter	1.0715	0.1370	7.82
Bulb weight	336.87	33.09	10.81
Bulb height	1.90913	0.07440	25.66
Number of bulbs	9795.4	209.8	46.68
Yield (t/ha)	128.447	3.137	40.95

Appendix 6: Summary of analysis of variance (Varieties × Weed control)

VARIABLES	VARIETY × WEED CONTROL MEAN SQUARE	ERROR MEAN SQUARE	F-VALUE
Weed density	3561	2042	1.74
Weed fresh weight	1176.4	355.9	3.31
Weed dry weight	312.74	74.33	4.21
Onion plant height	43.74	33.60	1.29
Bulb diameter	0.0881	0.1370	0.64
Bulb weight	18.36	33.09	0.55
Bulb height	0.07443	0.07440	1.04
Number of bulbs	580.0	209.8	2.76
Onion yield (kg)	19819474	3136767	6.32
Yield (t/ha)	19.819	3.137	6.32

F-tabulated (8, 28; ɑ=0.05) = 2.291

Appendix 7: Monthly rainfall during crop period (Oct. 2013 – Feb. 2014)