MAKERERE UNIVERSITY

EFFECT OF WEED CONTROL STRATEGIES ON WEED MANAGEMENT AND MAIZE PERFORMANCE IN WAKISO DISTRICT, UGANDA

BY

ACHAN BRENDA

B.SC. AGRICULTURE

REG NO: 17/U/9

SUPERVISOR

DR. BISIKWA JENIPHER

A SPECIAL PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL PRODUCTION IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN AGRICULTURE OF MAKERERE UNIVERSITY

APRIL 2022

DECLARATION

I, Achan Brenda, do hereby declare that this special project titled "Effect of weed control strategies on weed management and maize performance in Wakiso District, Uganda" is my original work, of my own research and findings and to the best of my knowledge, has never been published or submitted to any University or Institution for any academic award

Signature .... Date: 6th/April/2022.

Mrs. ACHAN BRENDA

College of Agricultural and Environmental sciences (CAES)

School of Agricultural sciences

Bachelor of Science in Agriculture (Crop option)

i

APPROVAL

This special project report has been written and read by Achan Brenda under the supervision of Dr. Bisikwa Jenipher. I therefore approve and forward to the department of Agricultural production for consideration as a requirement for my final examination.

Signature.. Date: 6/4/2022...

Dr. Bisikwa Jenipher

Senior Lecturer, Department of Agricultural Production, School of Agricultural sciences (SAS)

College of Agricultural and Environmental Sciences (CAES)

DEDICATION

First and foremost, I dedicate this work to God who has enabled me to successfully get past every stage of my academic period. I continue to dedicate this work to my parents, Mr. Olwoch Peter and Mrs.Apio Christine Olwoch, for their tireless financial efforts in supporting me while undertaking my research.

ACKNOWLEDGEMENT

Doing this study was a hectic journey unprecedented in my academic path but when I got done, I felt relieved. I was chanceful to have a caring supervisor who was ready to guide me throughout this study and writing this report. I would like to thank God for keeping healthy, giving me wisdom and the courage that drove me to accomplish this report successfully in time. I would like to thank my parents, Mr. Olwoch Peter and Mrs. Apio Christine Olwoch for their financial support. Dr. Bisikwa Jenipher was simply the exceptional researcher and supervisor I have ever dealt with. She was so crucial in guiding me through the research and assembling this report together, her tireless effort and time given during the period of the research and may God reward her abundantly. I would also like to thank Makerere University for providing me with land on which I setup my experiment.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Weeds are among the major production constraints of maize globally. Farmers in Uganda predominantly depend on conventional tillage and they are not aware of alternative means of controlling weeds. Therefore the main objective of this study was to evaluate the effect of weed control strategies on weed management and maize performance. Conventional tillage, pre-emergence herbicide application weed control strategies (and a control of no weeding) were tested for their efficacy in controlling weeds in maize. Seeds of Longe 5 maize variety were planted on 20/04/2021 in a randomized complete block design (RCBD) with three replications at Makerere University Agricultural Research Institute Kabanyolo (MUARIK). The analysis of variance (ANOVA) for the data of this study showed that weed control strategies had no significant effect on number of rows per cob, cob length and number of leaves per plant. Nonetheless, weed control strategies significantly increased plant height, number of ears per plant, number of grains per row, 1000 grain weight and maize grain yield. Whereas, weed vigour and weed density per square metre were reduced significantly. Conventional tillage produced the tallest plants, highest number of ears per plant, highest number of grains per row, highest 1000 grain weight, highest grain yield and lowest weed vigour and density per square metre. However, values for plant height, number of grains per row, grain yield and weed density were statistically similar to those obtained in herbicide treatment. The results of conventional tillage were opposite to those of the weedy check. Conventional tillage was the most effective weed control strategy among the three weed control strategies of this study. I therefore recommend that the farmers use conventional tillage as the most effective strategy for controlling weeds in maize since it produced the highest values for maize growth and yield parameters.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Origin and distribution

Maize (Zea mays L.), belongs to Family *Poaceae* and Genus *Zea* (Kabir *et al*., 2019). Tenaillon and Charcosset (2011) asserted that maize originated from Central America particularly in Mexico from where it spread north ward to Canada and south wards of Argentina. The crop was introduced in Africa through the coastal regions by the Portuguese (Miracle, 1965). It is believed to have spread to West Africa by European traders in the 16th century (Rasool and Khan, 2016). In Uganda, the crop was introduced in 1861 and by 1900 it was already an established crop (Balirwa, 1992; Miracle, 1965).

1.2 Importance of maize

Among the most important cereal crops, maize occupies the third position after wheat and rice (Kabir *et al*., 2019). It is the foremost highly distributed cereal within the World used for human and animal feeds also industrial purposes (Abdulraheem *et al*., 2013). Maize is an important food and feed crop of the world (Perera and Weerasinghe, 2014). Maize takes an important position in world economy as an industrial, feed and a food grain crop.

Several million people within the developing world consume maize as a crucial staple food and derive their protein and calories requirements from it (Mukhtar, 2018).

Maize is actually a crucial component of the farming systems and therefore the diet of the many people within the tropics and may be processed into different products for various end uses both at the normal level and industrial scale, though an outsized production of products utilized in developing countries is obtained via traditional processing while industrial processing meets the majority of the demand in developed countries (Abdulraheem *et al*., 2013). However, the maize production is less than the current demand (Mukhtar, 2018).

1.3 Production of maize

The overall production of maize in the world, Africa and East Africa stood at 1.15e+09, 81,891311, 30,755,075 metric tonnes (MT) respectively. USA, China and Brazil were the top leading countries with each producing 3.47e+08, 2.61e+08 and 1.01e+08 in that order respectively. In Africa, South Africa topped, followed by Nigeria and then Egypt with production of 11,275,500, 11,000,000, and 7,450,000 MT respectively. In East Africa, Tanzania was the leading producer followed by Kenya and then Uganda with production of 5,652,005, 3,897,000 and 2,575,000 MT respectively (FAO, 2019).

1.4 Production constraints

The wide gap in maize yields is due to a wide range of production constraints, which include both biotic and abiotic factors. Among biotic factors, weeds are the main ones (Kebede, 2017). Weed infestation is the major cause of low yield in the production of maize within the country (Fasil *et al*., 2006). Excessive growth of weeds in maize fields have been known to cause yield losses ranging from 25 to 80% or sometimes to a complete crop failure if weeds are left uncontrolled (Karlen *et al*., 2002). Through competition and allelopathy, weeds compete with crop plants for space, light, moisture, nutrients and many other growth factors, resulting in direct loss to quantity and quality of the produce (Gupta, 2004). Effective and economically feasible weed management technologies should be used to enhance maize productivity and production (Kebede, 2017).

Weed control practices in maize can result in 77 to 97% higher grain yield than weedy check (Khan *et al*., 1998). Therefore proper control of weeds in maize can increase yield up to 96% (Tesfaye *et al*., 2014). Different methods have been used to manage weeds however mechanical and chemical methods are more frequently (Kebede, 2017). Cultural methods are useful though expensive, laborious and time consuming (Kebede, 2017). The use of pre-emergence herbicides has been advocated as the best option in weed control because of their ability to control weeds at initial growth stages of crop and also provide an environment that is free of weeds for better establishment of crops. (Sunitha *et al*., 2010; Sharma *et al*., 1985). However, Continuous use of same herbicide for years may create resistance or hardening in weeds plants against that herbicide which reduce herbicide efficacy and the use of alternate herbicides avoids the development of herbicide resistance by weeds (Owen *et al*., 2007). For this reason, there is a need to evaluate the effects of the various weed control methods on weed management and maize performance.

1.5 Problem statement

In Uganda, there is an increase in demand for maize however, its productivity is still low and this is partly attributed to use of poor agronomic practices. For example, low use of herbicides (Okoboi *et al*., 2012). The weeds in maize fields are commonly managed conventionally using hand tools such as hand hoes. However, conventional tillage is constrained by a number of factors for example limited labour, intensive soil disturbance which results into soil degradation and difficulty in controlling certain weed species (Micheni *et al.*, 2014). Farmers are less informed about herbicide use i.e. the appropriate herbicide to be used and benefits of using herbicides for weed management in maize production. Therefore, most farmers have stuck to only one weed control strategy and this is less efficient in weed management and as a result, maize productivity is low. Therefore, this study focused on evaluating the effect of weed control strategies on weed management and maize performance.

1.6 Study objectives

1.6.1 General Objective

- To improve maize productivity in Uganda through efficient weed control strategies.

1.6.2 Specific objectives

- To determine the effect of the various weed control strategies on weed management.
- To determine the effect of the weed control strategies on maize crop growth and grain yield.

1.6.3 Hypothesis

- There is no significant difference within weed control strategies applied for weed management in maize
- There is no significant difference in maize growth and yield, as a result of the various weed control strategies

1.7 Justification

Uganda has a large potential market for maize but the maize production in the country is still low and unable to meet the market demand. This can partly be addressed by use of appropriate agronomic practices which will enable an increase in maize productivity. This research evaluated the various weed control strategies to determine the most appropriate in weed management and maize yield increment. Hence this information would direct the country on how best to control weeds as one of the important agronomic practices.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 How weeds affect agricultural production and society

Weeds are undoubtedly among the crop yield reducing factors known worldwide (Adeux *et al*., 2019). Weeds compete with crop plants for essential growth factors like light, moisture, nutrients and space (Wilcut *et al*., 2017; Amare *et al*., 2016; Atera *et al*., 2011). For example, Atera *et al*. (2011) identified that parasitic weeds such as *Orobanche* and *Striga* due to lack of their own root system compensates by penetrating the roots of host plants and thus depriving the essential nutrients for plant growth (Atera *et al*., 2011). Watson *et al*. (1998) reported stagnation in growth of host plants in crop fields with *Striga* infestation (as cited in Atera *et al*., 2011). Secondly, weeds also increase harvesting costs (Sims *et al*., 2019). Weeds reduce quality of crop product by either their effects or physical presence, for example *Bidens pilosa* seeds on cotton lint (Wilcut *et al*., 2017). Weeds also intensify the disease and insect pest problem by serving as alternative hosts (Araj *et al*., 2019).

Weeds are important biological factor in crop production that cause yield reduction and it contributes around 45 to 100 % of crop yield loss if not controlled (Reddy, 2018). Reddy (2018) reported weed competition in the weedy check throughout the crop duration resulted in 100% yield loss in rice. Ejeta (2007) found out that *Striga* alone infests more than 40% of the cereal-producing areas of Sub-Saharan Africa which results in an estimated annual crop loss of US$7 billion, hence affecting livelihoods of approximately 300 million people (as cited in Atera *et al*., 2011). The most affected are subsistence farmers losing about 20 – 80 % of their yield (Altera *et al*., 2011).

2.2 Weed control strategies currently in use

Sims *et al*. (2008) reported that there are four categories of weed control strategies and these are cultural methods, mechanical methods, chemical methods, and biological weed control.

Cultural control can be described as any adjustment or modification to the general management of the crop or cropping systems that contributes to the regulation of weed populations and reduces the negative impact of weeds on crop production (Blackshaw *et al*., 2007). It particularly involves the tactical and strategic level of decision making (Blackshaw *et al*., 2007). Examples of cultural weed control practices frequently used include but not limited to the following; use of trap crops that deplete the soil seed bank, crop rotation to reduced weed pressure, mulching to provide soil cover when the crop is not present or during the planting season, timely seeding of crops to ensure the efficient use of soil moisture and of the growing season, adjusting the crop density can also contribute to reducing weed population, fertilization to give an advantage to the intended crop and so forth (Sims *et al*., 2018).

Mechanical methods of weed control involve use of ploughs and other soil-engaging implements to control weeds without the need for very specific knowledge because soil inversion controls most weeds mechanically (Sims *et al*., 2018). These range from a combination of surface scraping with hand hoes and ploughs, slashing with machetes and hand-pulling or rogueing (Sims *et al*., 2018).

Biological weed control involves the intentional use of living organisms (biotic agents) to reduce the vigour, reproductive capacity, density, or impact of weeds (Kremer, 2004). Examples of biological weed control practices include but not limited to the following; use of ducks in the duck-rice system, use of animals to graze weeds, the use of mobile cages with chickens on fields after harvest is also practised and bio herbicides (Sims *et al*., 2018).

Chemical control involves the judicious application of herbicides to suppress weed growth (Bajwa, 2014). The herbicides may be selective, killing only weeds of a targeted species in a population of non-selective, killing weeds of all species (Sims *et al*., 2018). Selective herbicides are used when the crop is already growth while non-selective herbicides are used when there is no crop growing in the field (Duke, 2005). Sims *et al*. (2018) reported that it is always safer to apply herbicides at the labelled rate than lower rates as in the later case, weeds may not be completely eradicated, hence developing resistance. However, changing herbicides from year to year or using different herbicides within the season (pre- and post-emergence) can prevent the build-up of resistant weed species (Sims *et al*., 2018).

Some farmers use a combination of two or more of the above strategies in what is called integrated weed management (IWM), which refers to a holistic approach to weed management that integrates different methods of weed control to provide the crop with an advantage over weeds. It is practiced globally at varying levels of adoption from farm to farm (Harker and O'Donovan, 2013). IWM has the potential to restrict weed populations to manageable levels, reduce the environmental impact of individual weed management practices, increase cropping system sustainability, and reduce selection pressure for weed resistance to herbicides (Swanton and Weise, 1991). In IWM, the farmer can start up his or her garden by using a trap crop to induce suicidal germination of weeds so as to reduce the soil seed bank (Cléments *et al* 1994). This can be followed by timely planting of seeds of competitive cultivars at higher crop seeding rates (Harker and O'Donovan, 2013; Swanton *et al*., 2008). The few weeds that grow can then be removed mechanically by timely hand hoeing, uprooting or through any other practice (Harker and O'Donovan, 2013). After the crop has been harvested, the next season can have a crop of another species grown, a practice known as crop rotation (Harker and O'Donovan, 2013).

2.34 Effect of weed control strategies on weed parameters

2.3.1 Weed population density

All weed management practices reduce weed density as compared to weedy check plots (Kebede, 2017). However, the levels of reduction vary with experimental treatments based on their nature (Kebede, 2017). Conventionally tilled plots are associated with the lower weed densities compared to chemical control whereas the maximum density is recorded in weedy check (Mohammed, 2014). The minimum weed density observed in hand weeding and pre-emergence herbicides treated plots is attributed to the sufficient and successful weed control achieved by these practices (Kebede, 2017). The maximum weed density achieved in weedy check plots could result from lack of any weed management practices which rendered the chance for better weed emergence, growth and development which means there will be less competition and more time to explore the nutrients from the soil and crop plants by the weeds (Kebede, 2017). The pre-emergence herbicides have an excellent residual effect which inhibits weed germination (Kebede, 2017; Abdullah *et al*., 2008).

2.1.2 Weed flora composition

Weed flora composition refers to the number of different species of weeds growing in a given area at a particular point in time (Sad *et al*., 1987). Under the natural environmental, this composition is relatively stable (Swanton *et al*., 1993). However, when weed control strategies are deployed, the number of weed species per unit area significantly reduces and this varies with the kind of the strategy (El-Desoki *et al*., 2012). Application of hand hoeing and herbicides has a more adverse effect on broadleaved weeds than grasses (El-Desoki *et al*., 2012; Abouziena *et al*., 2008). This is because of the selective nature of the herbicides (El-Desoki *et al*., 2012). So there is high species number of grasses in fields where herbicides are applied than that for broad leaved weeds (El-Desoki *et al*., 2012).

2.1.3 Weed vigour

Different weed control strategies have varying levels of impacting negatively on the vigour of weeds growing in an area (Andrew *et al*., 2015). There is a remarkable decline in vigour as one move from the weedy check, to plots where hand weeding is done and plots treated with herbicides (Alsaadawi *et al*., 2013). This is because in the weedy check plots there is lack of any weed management practices which render the chance for better weed emergence, growth and development which in turn leads less competition and more time to explore the nutrients from the soil and crop plants by the weeds (Kebede, 2017). With hand hoeing, weeds are constantly removed by physical means hence reducing their numbers and burying weed seeds deeper into the soil profile hence depriving them of the favourable conditions for germination (Rana, 2016). While with pre-emergence, there is a harmful residual effect of the chemical on the growth of the weeds (Kebede, 2017).

2.2 Effect of pre-emergence herbicide on phytotoxicity of maize plants

Phytotoxicity is defined as the capacity of a given compound (for example a plant protection product) to a long-lasting or temporary damage to plants (Nansen *et al*., 2021). The symptoms of Phytotoxicity of herbicides varies partly with the type of the herbicide and these include the following (Boutin *et al*, 2012).

2.2.1 Modifications in the development cycle

Under this heading any inhibition or delay in growth or emergency and all phenological modifications, particularly delays in ripening, fruiting, flowering or nonappearance of certain organs like leaves, flowers, fruits, etc can be considered (Harrison and Loux, 2017).

2.2.2 Thinning

Loss of whole plants, by failure to emerge or to grow after transplanting, or by disappearance of plants after emergence (Harrison and Loux, 2017).

2.2.3 Modifications in colour (plant tissue not destroyed)

The whole plant or some plant parts may be discoloured that is to say chlorosis, whitening, change in intensity of colour (lighter or darker), browning, reddening. The discolouration may be localized (internal or external spots) (Harrison and Loux, 2017).

2.2.4 Necrosis

Necrosis is the local death of tissues or organs, generally appearing first as a discolouration (Majno and Joris, 1995). Necrotic spots on leaves can eventually disappear hence leaving perforations (Rana, 2015).

2.2.5 Deformations

This term covers any morphological modification of the plant or part of it (including roots) making it deviate from the normal range of morphology observed. This includes curling, rolling, stunting or elongation, change in size or volume (the latter sometimes being rated in terms of vigour) (Kurre *et al*., 2018). Effects such as wilting may also be considered under this heading (Harrison and Loux, 2017). Because of the above, there is final reduction in quantity and quality maize yield (Kurre *et al*., 2018).

2.3 Effect of weed control strategies on maize growth traits

2.3.1 Number of leaves per plant

Weed control methods affect the number of leaves per plant than it appears in the weedy check (El-naggar, 2016). The number of leaves per plant is higher in plots where weed control measures are deployed as compared to weedy check (El-naggar, 2016). The significant increase in the number of below and above main ear green leaves per plant as well as the number of total green leaves per plant might be due to weed control treatments as compared with those recorded by the check (El-naggar, 2016). Furthermore, the number of dry leaves per plant appears to increase in the weedy check (El-naggar, 2016). So these facts confirm the view that, weeding treatments affects maize plants which provides better plant growth conditions due to depressed competition of weeds to maize plants where plant nutrients are more available to these plants and hence they keep their leaves green and delay their senescence as expressed in their larger number below and above the main ear (El-naggar, 2016). However, Ahmed *et al*. (2008) reported that weed control measures have no effect on the number of leaves per plant.

2.3.2 Plant height

Highest plant height is measured from the plots applied with hand hoeing followed by herbicides while the lowest plant height is obtained from weedy check plots (Kebede, 2017). This might be availability of sufficient resources for the maize crop plants in the first two cases than in the third case (Kebede, 2017). This might be due to the fact that the lack of weed control strategy in the weed check plots allows vigorous germination and growth of weeds that brings about a severe competition of resource between the crop plant and weeds (Kebede, 2017).

2.4 Effect of weed control strategies on yield components of maize

All weed management treatments convincingly affect yield components of maize over weedy check treatment (Zea and Kordy, 2020; Kebede, 2017). The increase in yield related parameters could result from the successful weed control and efficiency provided by applied treatments against major weeds. Khokhar *et al*. (2007) reported that weed management suppressed the weeds and increased the grain yield and yield components of maize. However, the extent of weed control varies among the control strategies deployed (Zea and Kordy, 2020). Forcella (2021); Perry *et al*. (2004) reported that hoeing is superior to herbicidal application in maize and the effectiveness of hand hoeing treatments might be attributed to the fact that hand hoeing is more efficient in growth stunting and eradication of weeds than the herbicide. The better performance of maize yield related parameters observed in pre-emergence herbicides might have resulted from the fact that the herbicidal application inhibit or suppress the weeds emergency by providing sufficient soil residual action and shift weed crop competition in favour of the crops (Kebede, 2017).

2.4.1 Number of cobs per plant

Mohammed (2014) reported that ear number per plant is significantly affected by weed control methods. The highest number of ears per plant is observed in hand weeded and hoed plots El-naggar (2016), while the least is seen in the weedy check (Khan *et al*., 2013). Additionally, Maqbool *et al*. (2006) found out crop kept weed free after sowing produce higher number of cobs per plant than the weedy check. Decrease in number of cobs per plant with an increase in weed competition duration is due to competition of weeds with maize for different environmental factors for a longer time (Maqbool *et al*., 2006).

2.4.2 Cob length (cm)

Cob length is also very important yield determining factor of maize crop (L *et al*., 2005). Longer the cob length, the more would be number of grains per cob and consequently higher yield in the form of grains (L *et al*., 2005). According to Le *et al*. (2005), all weed control treatments affect cob length than weedy check. In this regard, hand hoeing gives the maximum value for cob length followed by herbicide treatment, while the lowest is seen in the weedy check (L *et al*., 2005). This is mainly attributed to mainly to the timely and efficient control of weeds and thus, less weed competition period in these treatments which allows the maize plant to produce more photosynthetic material by using available nutrients (L *et al*., 2005).

2.4.3 Number of grain rows per cob

Number of grain rows per cob directly affects cob weight and ultimately grain yield of maize (Patel *et al*., 2006; L *et al*., 2005). There is an increase in number of grain rows per cob as one move from the weedy check plot to plots treated with herbicides and then at the very top hand hoeing (L *et al*., 2005). This shows that good weed control practices are effective to getting more number of grain rows per cob (L *et al*., 2005).

2.4.4 Number of grains per cob

The total number of grains per cob is an important yield component parameter of maize (L *et al.*, 2005). It affects the number of grains per cob and cob weight (Farhad *et al.*, 2009). All weed control practices affect the total number grains per cob (L *et al.*, 2005). The maximum number of grains per cob is seen in plots where manual hoeing is done, reducing in plots where herbicides are applied while the least number is observed in the weedy check (L *et al.*, 2005). The highest number of grains per cob in hand hoeing could be as a result of less number of weeds and consequently more photosynthates are available for plant growth and development (L *et al.*, 2005). Dalley *et al*. (2016) stated that season-long weed competition reduced yields more. Reduced grain yield due to weeds may be attributed to several factors, among them include competition between maize and weeds for water and nutrients and allelopathic effects of weeds (Dalley *et al.*, 2016).

2.4.5 1000 seed weight

Apart from combined effect of all the other individual yield determining factors, the ultimate final grains yield of a cereal crop depends upon the 1000-grain weight and seed development nourished under applied inputs and various weed control treatments (Abouziena *et al.*, 2007). Different weeds control methods deployed cause significant variation in thousand grain weight. Heaviest grains are produced by herbicide treated plots and hand weeded plots (Nadeem *et al.*, 2013). Weedy check plots result in lightest grains of maize (Nadeem *et al.*, 2013). This might be due to the increased competition for moisture, light and nutrients and allelopathic effects of weeds (Abouziena *et al.*, 2007). Furthermore, the loss in 1000 grain weight is proportional to duration of weeds competition (Abouziena *et al.*, 2007). Also, competition for water is often considered the most important source of weed–crop competition and that weeds growing with a crop have been shown to reduce moisture (Abouziena *et al.*, 2007). The reductions in soil moisture have been related to increases in weed density or may be length of time weeds remain present with the crop (Abouziena *et al.*, 2007).

2.4.6 Grain yield per hectare

Maize grain yield is the outcome of various yield components that are significantly affected by different weed control methods (Nadeem *et al.*, 2013). Previous studies have shown that hand weeding and herbicide application results in higher grain yield than in weedy check plots (Nadeem *et al*., 2013). This is because in the former, nutrient depletion by weeds is restricted by hand hoeing and herbicides as weed control treatments effectively controlling weed infestation and weed competition thereafter (Nadeem *et al*., 2013). While in the later, there might be higher weed infestation. Elliot (1990) stated that hand weeding reduce weed density thus resulting into higher maize yields. In the same line, Khokhar *et al*. (2007) reported that weed management suppress the weeds and increase the grain yield and yield components of maize.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

This study was carried out at Makerere University Agriculture Research Institute Kabanyolo (MUARIK) located in Wakiso district, Central Uganda (Ocan *et al*., 2008). The research station is located 17 km north of Kampala at 0^{o}28'N and 32^{o}37'E at an elevation of 1150 meters above sea level (Ocan *et al*., 2008). The station has soils classified as latosols or Ferralsols (Ocan *et al*., 2008). The station has two rainy seasons (March to May and September to November) with mean rainfall of 1300 mm annually, 12 hours' day length throughout the year and average daily temperatures in the field ranges between 16^{O}C to 29^{O}C (Ocan *et al*., 2008).

3.2 Experimental materials

Longe 5H hybrid maize (L5H), Glyphosate herbicide, Di-ammonium phosphate (DAP)

3.3 Experimental Design

The study was conducted on a Randomized complete block design (RCBD) with 3 treatments and 4 replicates and each replicate had three plots. The treatments include; herbicide treatment, conventional tillage (hand hoeing) and un-weeded treatment. The three treatments were randomized within and between blocks

3.3.1 Layout of the design

Each of the weed control strategy was laid out in a randomized complete block design (RCBD) with four replications. The experiment was laid on a total land area of 338 square metres (m^2). Plots were marked in a weedy field and each plot measured 4m by 3 m. Plots within a block were separated by a 1.0 m buffer zone path to guard treatments from spilling over between plots. Likewise, replicates were separated by a 2.0 m buffer zone for the same purpose.

3.3.2 Planting

This was done in April 2021 as follows; all the plots were planted with Longe 5H hybrid maize at a recommended spacing of 75cm by 50cm. On the plots marked for herbicide treatment, glyphosate herbicide was applied a day after seeding. Glyphosate herbicide sprays were applied on the actively growing weeds one week after the onset of the rains, the one week delay was to allow weeds to start growing actively after going through periods of dormancy observed during dry spells as witnessed prior to the start of the rains. On plots marked for conventional tillage, the plots were prepared to achieve fine tilth for maize production. Planting holes of about 15 cm deep were dug using a hand hole while following the recommended spacing described above (75cm by 50cm). A full bottle lid (10g) of DAP fertilizer was put into every hole, following the recommended application rate of DAP. This was covered with 5 cm layer of soil and then thereafter, three (3) maize seeds were placed in the hole and covered with 5 cm layer of soil. This was done in all plots. Thinning was done four days after the crop emergence and one seedling was left per hill (Micheni *et al*., 2014).

3.4 Data collection

3.4.1 Data collection on weed parameters

Weed density per square metre.

A 1.0 m^2 quadrant was randomly thrown in each plot. Then the weed plants within the boundaries of the quadrant were physically counted and recorded. This was done three times with a lag of 30 days. Then an average was calculated for the three times.

Weed vigour

This was based on the condition of weed seedlings, survival rate of the weed seedlings, growth rate of the weeds, and health of the weed plants. A score of 1 to 4 was assigned to each individual plot as follows; 1, 2, 3 and 4 representing 'very low', 'low', 'medium' and 'high' weed vigour, respectively at the time of treatments application, crop flowering stage and crop physiological maturity stage. The average of the three stages was then calculated.

3.4.2 Maize growth traits

Number of leaves per plant

Ten plants from the two middle rows were randomly selected and tagged. After complete flowering of all plants, the number of leaves per plant was physically counted for all the tagged plants and then average calculated per plot.

Plant height

After complete flowering, the heights of ten tagged plants were measured using a tape measure from the collar of the plants to last node on the tassel. Then the average of the ten individual plant heights was calculated.

3.4.4 Data collection on yield components

Number of ears per plant

At physiological maturity, the number of ears was physically counted on each of the tagged plants and then the average for each plot was calculated.

Cob length measured in centimetres (cm)

At harvest maturity, ears from the tagged plants were detached and opened to get out the cobs. Using a tape measure, cob length was measured as the length from the point of attachment of the maize cob to the stalk and the tip of the cob.

Number of rows per cob

Number of rows on each cob from the tagged plants was physically counted and then the average calculated for each plot.

Number of grains per row

Kernels per row were got from the cobs obtained from the tagged plants. One row from each cob was randomly selected and the grains shelled off and physically counted. Number of grains per row was obtained from the average which is calculated by dividing the total number of grains per row by the number of cobs sampled.

1000-seed weight

1000-kernels from the harvest of each plot were randomly drawn and weighed using an automatic balance and recorded in grams (g).

Grain yield per hectare

The total yield from each plot (kg) was weighed using a weighing scale and then extrapolated to total yield per hectare (kg) by using the following formulae

$$\frac{\text{Total land area in a hectare x grain yield from a given plot}}{\text{total land area ofthat plot}}$$

3.5 Data analysis

The data obtained was entered in GenStat analytical software version 14th Edition (VSN International, 2012) to assess the significance difference among the three weed control strategies. The least significant difference (LSD) test at 5 % was used for mean comparison from the analysis of variance (ANOVA) results obtained.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Maize growth and yield traits

4.1.1.1 Plant height

There was a significant (P = 0.004) difference for the parameter of plant height for the three weed control strategies (Appendix 1). The tallest plants were in plots where conventional tillage (186.9 cm) (Table 1). This was followed by plants from plots treated with herbicides, while plots where no weeding was done gave the shortest plant heights (Table 1). However, though the value for plant height produced by conventional tillage was higher than the plant height for herbicide treatment, the two were statistically similar but statistically different from height of plants in plots where no weeding was done (Table 1).

Table 1: Means of maize plant height

Treatment	Means of plant height (cm)
No weeding	99.3^{a}
Herbicide	165.4^{b}
Conventional tillage	186.9^{b}
Mean	150.5
F. Pr	0.004
% CV	15.5
$LSD_{(0.05)}$	40.44

4.1.1.2 Number of ears per plant

There was a significant (P = 0.001) difference among weed control strategies for the parameter of number of ears per plant (Appendix 2). Conventional tillage (1.750) produced the highest number of ears per plant, followed by herbicide treatment (1.250) while plots where no weeding (0.500) was done gave the lowest number of ears per plant (Table 2). All weed control strategies produced statistically different number of ears per plant (Table 2).

Table 2: Means of number of ears per plant

Treatment	Means of number of ears per plant
No weeding	0.500[a]
Herbicide	1.250[b]
Conventional tillage	1.750[c]
Mean	1.2
F. Pr	0.001
% CV	21.9
$LSD_{(0.05)}$	0.44

4.1.1.3 Number of grains per row

There was a significant (P = 0.002) difference for the parameter of number of grains per row for the weed control strategies (Appendix 3). Plots treated with herbicides (36.85) produced cobs with the highest number of grains per row (Table 3). While plots where no weeding was done produced cobs with the lowest number of grains per row (Table 3). However, number of grains per for herbicide and conventional tillage were statistically similar but different from those produced in plots where no weeding was done (Table 3).

Table 3: Means of number of grains per row

Treatment	Means of number of grains per row
No weeding	13.70[a]
Herbicide	36.85[b]
Conventional tillage	35.55[b]
Mean	28.7
F. Pr	0.002
% CV	20.7
$LSD_{(0.05)}$	10.29

4.1.1.4 1000 grain weight (g)

There was a significant (P = 0.002) difference among treatments for the parameter of 1000 grain weight (Appendix 4). Conventional tillage (292.5 g) gave the highest 1000 grain weight while plots where there was no weeding (110.0 g) gave the lowest 1000 grain weight (Table 4). The grain weight for herbicide treatment (220.0 g) was the in the middle of the above two treatments (Table 4). All treatments produced statistically different 1000 grain weight (Table 4).

Table 4 : Means of 1000 grain weight

Treatment	Means of 1000 grain weight (g)
No weeding	110.0[a]
Herbicide	220.0[b]
Conventional tillage	292.5[c]
Mean	208
F. Pr	0.002
% CV	19.6
$LSD_{(0.05)}$	70.3

4.1.1.5 Yield (kilograms)

There was a significant (P = 0.003) difference for the parameter of grain yield for the three weed control strategies (Appendix 5). Conventional tillage (2226 kg) produced the highest yield while no weeding (526 kg) produced the lowest yield (Table 5). Both conventional tillage and herbicide treatment produced statistically similar yield statistically different the yield obtained from plots where no weeding was done (Table 5).

Table 5 : Means of maize grain yield

Treatment	Means of grain yield (kg)
No weeding	526[a]
Herbicide	2112[b]
Conventional tillage	2226[b]
Mean	1621
F. Pr	0.003
% CV	28.4
$LSD_{(0.05)}$	796.7

4.1.2 Weed growth attributes

4.1.2.1 Weed vigour score (1 to 5)

There was a significant (P<0.001) difference for the parameter of weed vigour for the three weed control strategies (Appendix 6). Plots where no weeding (3.583) was done had the highest vigorous weed growth most whereas the least vigorous weeds were obtained from plots where conventional tillage (1.333) was done (Table 6). Weed vigour score varied statistically among all the weed control strategies (Table 6).

Table 6 : Means of weed vigour score one day after treatment application

Treatment	Means of weed vigour (1 to 5)
No weeding	3.583^{c}
Herbicide	2.000^{b}
Conventional tillage	1.333^{a}
Mean	2.3
F. Pr	<0.001
% CV	12.5
$LSD_{(0.05)}$	0.50

4.1.2.2 Weed density

There was a significant (P<0.001) difference for the parameter of weed density per square metre for the three weed control strategies (Appendix 7). Plots where no weeding (70.00) was done had the highest weed density whereas plots where conventional tillage (14.17) was done had the lowest weed density (Table 7). Both conventional tillage and herbicide treatments had statistically similar values for weed density and these were statistically different from the weed density value of the plots where no weeding was done (Table 7).

Table 7 : Means of weed density for the three weed control strategies

Treatment	Means of weed vigour (1 to 5)
No weeding	70.00^{b}
Herbicide	14.83^{a}
Conventional tillage	14.17^{a}
Mean	33.00
F. Pr	<0.001
% CV	17.3
$LSD_{(0.05)}$	9.859

4.2 Discussion

4.2.1 Maize growth and yield attributes

4.2.1.1 Maize plant height

Weed control treatments had significantly affected plant height, where the conventional tillage and herbicide application recorded at par higher averages of plant height than un-weeded one. The minimum plant height in weedy check might have been due to more weed density (Table 7) which deprived the maize plants of more moisture and nutrients. The higher plant heights due to weed control were probably a result of elimination of weeds that reduced competition hence increased the availability sunlight, moisture and plant nutrients (in particular nitrogen) to the plants and as a result, the plants grew vigorously to explore higher heights. El-Sobky *et al*. (2016) reported that the increase of plant height and stem diameter due to weed control clearly indicated that weeds in the un-weeded plots competed with maize plants for plant nutrients. Tahiete et al. (2011) reported that the maximum plant height in manual hoeing, which was statistically similar to heights in Foramulsuron + Isoxadifenethyl + Isosulfuron-methyle sodium, while a decrease in herbicide dose resulted in significant reduction in plant height of maize. According to Pannacci and Onofri. (2016), plant height was lowest in the untreated check as well as in the post-emergence treatments, a result they identified to confirm the sensitiveness of maize to weed competition during the seedling stage (critical period) that caused stunting of maize plants.

4.2.1.2 Number of ears per plant

Decrease in number of ears per plant might be a result of an increase in competition between weeds and maize plants for different environmental factors (nutrients, moisture and sunlight) for a longer time. Nawab *et al*. (1999) also reported reduction in number of ears per plant in heavily weedy maize crop. Similarly, Amare *et al*. (2014) found out that number of ears per plant was significantly affected by weed control methods where the highest number of ears per plant was observed in hand weeding and hoeing. Maqbool *et al*. (2006) reported that the number of cobs per plant was significantly affected by different row spacing as well as by the duration of weed competition, where perusal of their data revealed that crop kept weed free after sown in 75 cm spaced rows produced the highest average number of cobs per plant followed by weed free crop sown in 65 and 55 cm spaced rows. So the plant spacing used in this study probably had some influence on the number of ears per plant.

4.2.1.3 Number of grains per row

Number of grains per row was an important yield component that contributed positively to final grain yield of maize. Analysis of the results of this study showed that conventional tillage and herbicide treatment produced a higher number of grains per row which perhaps was due to effective elimination of weeds using that enabled maize plants to grow well and made them have competitive advantage against weeds hence producing high number of grains. There was efficient utilization of soil and climatic resources by maize plants in the presence of relatively low weed numbers in different weed control treatments led to increased grain number and weight. Khan *et al*. (2012) identified minimized competition due to better weed control, maize plants took up more water and nutrients that resulted in vigorous growth at early stages and also improved the yield components such as cob length, number of grains per row, 1000-grain weightQuddus *et al*. (2012) reported significant variation among the different weed control treatments with respect of the number of grains per row in spring crop. Genetic and environmental factors have direct or indirect influence on the number of grains per row (Jhala *et al*., 2014).

4.2.1.4 1000 grain weight

Apart from combined effect of all the other individual yield determining factors, the ultimate final grains yield of the maize crop was dependent on the 1000-grain weight and seed development nourished under various weed control treatments. Any variation in the 1000-grain yield affected the grain yield. The low 1000 grain weight in plots where no weeding was done was possibly a result of increased competition for moisture, nutrients and light. The higher 1000-grain weight in plots where weeding was done (conventional tillage and herbicide application) than weedy check was likely to be a result of better growth and development of maize plants and availability of more resources which resulted in more seed assimilates. Similar findings were reported by Kaswar *et al*. (2011), in which the heaviest grains were produced by herbicide treated plots (256.7 g) which was statistically similar to hand weeded plots (245.7 g), while the weedy check plots resulted in the lightest grains of maize (212.3 g). Tahir *et al*. (2009) reported mechanical and chemical weeds control plots resulted in maximum grain weight as compared to untreated plots. Tahir *et al*. (2009) however, reported that the maximum 1000-grains weight (540.4 g) was attained with manual hoeing which was statistically similar to 100-grain weight from herbicide treatment (527.6 g) and the significantly minimum 1000-grains weight (306.3 g) was found in weedy check plots.

4.2.1.5 Maize yield

Maize grain yield was a function of the above various yield components that were significantly affected by different weeds control methods. The increase in maize yield and its components in conventional tillage and herbicide treatment as opposed to the weedy check might be attributed to the higher efficiency of the weed control treatments in weed elimination that enabled crop plants to make good use of environmental resources; thus, increasing the competitiveness of maize plants against weeds. Therefore, the higher yield in conventional tillage and herbicide treatment was mainly because of more number of grains per cob and 1000s-grain weight over weedy check. Similar results were reported by Westwood *et al*. (2018); Saudy (2013);s Liebman *et al*. (2000). In addition, conventional tillage improved soil structure, water penetration, aeration and the availability of some nutrients for crop plants. Saudy (2013) found out that the herbicide is absorbed through roots from the soil and is translocated to shoots; and inhibits photosynthesis resulting in blocking electron transport thereby stopping CO2 fixation and production of ATP and $NADPH_2$. Munsif *et al*. (2011) reported restriction of nutrient depletion by weeds by application of pre-emergency herbicides as a weed control treatment effectively controlling weed infestation and weed competition thereafter. Tahir *et al*. (2009) attributed lowest grain yield in weedy check to maximum weed density which suppressed the growth and development of maize plants by competing for moisture, light and nutrients. Maqbool *et al*. (2006) reported duration of weed competition to affect the grain yield significantly. Iderawumi *et al* (2018) reported that, of the four groups of agricultural production hazards namely. Diseases, Insect pests, Rodents/Predatory animals and Weeds, weeds have been found to cause the greatest losses in crop production.

4.2.2 Weed growth attributes

4.2.2.1 Weed vigour

Weed vigour was highest in the weedy check probably due to no weed control intervention made so the weeds remained intact throughout the experimental period hence their proliferation in number, vigorous and luxuriant growth. Rogosa, (2016); Delborne, (2005) reported high rate of weed growth in the weedy check than plots where weed controls measure were applied. In plots treated with herbicides, the chemical probably could have been toxic to the weed seeds thereby reduced the seed bank and also inhibited their proper germination. Furthermore, because of the relative persistence of the chemical in the soil, some of the weed seeds that germinated were likely to have absorbed the chemical by their roots which possibly inhibited the physiological functions in such weeds. Hilhorst and Karssen (2000) reported altered phenology of weeds in plots that were treated with pre-emergency herbicides. While in plots where conventional tillage was done, weed vigour was the lowest probably due to exposure of weed seeds to harsh environmental conditions such as high temperature and low moisture content. Korres *et al*. (2016) reported that hand hoeing involved churning of the soil hence bringing the buried weed seeds on the soil surface. In addition, there was mechanical uprooting and damaging of weeds and their seedlings hence reduced weed number and growth.Abouziena *et al*. (2008) reported high mortality rate of weeds in plot where hand hoeing was done than in plots treated with herbicides.

4.2.2.2 Weed density

The higher weeds density in weedy check plots may be attributed to the open soil surface and niches that were available to the weeds for free and aggressive growth. The high mortality rate of weeds in manual hoeing could be attributed to the uprooting and mechanical injury of weeds, while the pre-emergency herbicide perhaps had considerable phototoxic effects on weeds and reduced their population to a significant level as compared to weedy check treatments. Kawsar Ali *et al*. (2011) identified weed density to be highest in weedy check plots (82 weeds m^{-2}), while application of herbicide Primextra gold and hand weeding resulted in lower weed densities of 25.7 and 24.3 m^{-2}, respectively. In line with the above, Tahir *et al*. (2009) found out that the total weed density was significantly affected by all the weed control treatments, where the maximum reduction in the weeds density (88.97 %) was recorded in plots where manual hoeing was done and this was followed by treatment where Pendimethalin + Prometryn was applied which reduced the weeds density up to 70.36 %.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. Weed control strategies significantly affected the following parameters; plant height, number of ears per plant, number of grains per row, 1000 grain weight and grain yield for maize. While the weed parameters that were significantly affected included; weed vigour and weed density.

ii. Weed control strategies did not significantly affect the following parameters; cob length, number of rows per cob and number of leaves per plant.

iii. Conventional tillage was the most effective weed control strategy among the three weed control strategies of this study. This because it had the tallest plant heights, highest number of ears per plant, highest number of grains per row, highest 1000 grain weight, highest grain yield, lowest weed vigour and density.

5.2 Recommendations

i. A similar study should be carried out in several agro-ecological zones since the incidence and prevalence of weeds can vary with geographical location as a result of different soil and climatic conditions.

ii. A similar experiment should be carried out for at least two different seasons since the conditions for growth may vary from one season another in the same year.

iii. Integrated weed management should be incorporated into the farming systems in order to; restrict weed population to manageable levels, reduce the environmental impact of individual weed management practices, increase cropping system sustainability and reduce selection pressure for weed resistance to herbicides.

iv. I wrap-up the write up by recommending to farmers the use of conventional tillage as the most effective strategy for controlling weeds in maize since it produced the highest values for maize growth and yield parameters as described in the section for conclusions above.

REFERENCES

Abdullah, G. H., Khan, I. A., Khan, S. A., and Ali, H. (2008). Impact of planting methods and herbicides on weed biomass and some agronomic traits of maize. *Pak. J. Weed Sci. Res*, *14*(3-4), 121-130.

Abouziena, H. F., El-Karmany, M. F., Singh, M., and Sharma, S. D. (2007). Effect of nitrogen rates and weed control treatments on maize yield and associated weeds in sandy soils. *Weed technology*, *21*(4), 1049-1053.

Abouziena, H. F., Hafez, O. M., El-Metwally, I. M., Sharma, S. D., and Singh, M. (2008). Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation, and glyphosate. *HortScience*, *43*(3), 795-799.

Adeux, G., Vieren, E., Carlesi, S., Bàrberi, P., Munier-Jolain, N., and Cordeau, S. (2019). Mitigating crop yield losses through weed diversity. *Nature Sustainability*, *2*(11), 1018-1026.

Ahmed, S. A., Shams, H. M., El–Metwally, I. M., Shehata, M. N., and El–Wakeel, M. A. (2008). Efficiency of some weed control treatments on growth, yield and its attributes of maize (Zea mays, L.) Plants and associated weeds. *Journal of Plant Production*, *33*(7), 4777-4789.

Alsaadawi, I. S., Khaliq, A., Lahmod, N. R., and Matloob, A. (2013). Weed management in broad bean (Viciafaba L.) through allelopathic Sorghum bicolor (L.) Moench residues and reduced rate of a pre-plant herbicide. *Allelopathy Journal*, *32*(2).

Amare, T., Raghavaiah, C. V., and Zeki, T. (2016). Productivity, yield attributes and weed control in wheat (Triticum aestivum L.) as influenced by integrated weed management in central high lands of Ethiopia, East Africa. *Advances in Crop Science and Technology*, 1-4.

Andrew, I. K. S., Storkey, J., and Sparkes, D. L. (2015). A review of the potential for competitive cereal cultivars as a tool in integrated weed management. *Weed research*, *55*(3), 239-248.

Araj, S. E., Shields, M. W., and Wratten, S. D. (2019). Weed floral resources and commonly used insectary plants to increase the efficacy of a whitefly parasitoid. *BioControl*, *64*(5), 553-561.

Atera, E. A., Itoh, K., and Onyango, J. C. (2011). Evaluation of ecologies and severity of Striga weed on rice in sub-Saharan Africa.

Bajwa, A. A. (2014). Sustainable weed management in conservation agriculture. *Crop Protection*, *65*, 105-113.

Balirwa, E. K. (1992). Maize research and production in Uganda. *Ministry of Agriculture, Uganda*.

Bàrberi, P. A. O. L. O. (2002). Weed management in organic agriculture: are we addressing the right issues?. *Weed research*, *42*(3), 177-193.

Blackshaw, R. E., Anderson, R. L., and Lemerle, D. E. I. R. D. R. E. (2007). Cultural weed management. *Non-Chemical Weed Management: Principles, Concepts and Technology, Wallingford, UK: CAB International*, 35-48.

Boutin, C., Aya, K. L., Carpenter, D., Thomas, P. J., and Rowland, O. (2012). Phytotoxicity testing for herbicide regulation: shortcomings in relation to biodiversity and ecosystem services in agrarian systems. *Science of the Total Environment*, *415*, 79-92.

Cléments, D. R., Weise, S. F., and Swanton, C. J. (1994). Integrated weed management and weed species diversity. *Phytoprotection*, *75*(1), 1-18.

Dalley, C. D., Bernards, M. L., andKells, J. J. (2006). Effect of weed removal timing and row spacing on soil moisture in corn (Zea mays). *Weed Technology*, *20*(2), 399-409.

Duke, S. O. (2005). Taking stock of herbicide-resistant crops ten years after introduction. *Pest Management Science: formerly Pesticide Science*, *61*(3), 211-218.

El-Desoki, E. R., Abouziena, H. F., El-Wahed, M. S. A. A., and Eldabaa, M. A. T. (2012). Effect of crop spatial arrangement, plant density and weed management on maize (Zea mays, L) productivity and ambient weeds in the sandy soil under drip irrigation system. *Journal of Applied Sciences Research*, (December), 5627-5638.

Elliot, P. C., and Moody, K. (1990). Evaluation of various weed control practices in maize (Zea mays) in Misamis Oriental. *Philippine Journal of Weed Science*, *17*, 39-50.

El-Sobky, E. E. A., and El-Naggar, N. Z. (2016). Effect of weed control treatments and planting density in maize (Zea mays L.). *Egypt. J. Agron*, *38*(1), 55-77.

FAO. (2014). Production _Crops_E_All_Data

Farhad, W., Saleem, M. F., Cheema, M. A., and Hammad, H. M. (2009). Effect of poultry manure levels on the productivity of spring maize (Zea mays L.). *J. Anim. Plant Sci*, *19*(3), 122-125.

Forcella, F. (2000). Rotary hoeing substitutes for two-thirds rate of soil-applied herbicide. *Weed Technology*, *14*(2), 298-303.

Gupta, O. P. (2004). Modern weed management 2nd Ed. *Agrobios Jodhpur*, *India5*, 18-23.

Harker, K. N., and O'Donovan, J. T. (2013). Recent weed control, weed management, and integrated weed management. *Weed Technology*, *27*(1), 1-11.

Harrison, S. K., and Loux, M. M. (2017). Chemical weed management.In *Handbook of weed management systems* (pp. 101-153).Routledge.

Iderawumi, A. M., and Friday, C. E. (2018). Characteristics effects of weed on growth performance and yield of maize (zea mays). *Biomedical Journal*, *1*, 4.

Kabir, S. H., Das, A. K., Rahman, M. S., Singh, S. K., Morshed, M., and Marma, A. S. H. (2019). Effect of genotype on proximate composition and biological yield of maize (Zea mays L.). *AAES*, *4*, 185-189.

Kandil, E. E. E., and Kordy, A. M. (2013). Effect of hand hoeing and herbicides on weeds, growth, yield and yield components of maize (Zea mays L.). *Journal of Applied Sciences Research*, *9*(4), 3075-3082.

Karlen, L. D., Buhler, D. D., Ellusbury, M. M., and Andrews, S. S. (2002). Soil, weeds and insect management strategies for sustainable agriculture. *Journal of biological Sciences*, *2*(1), 58-62.

Kebede, M., and Anbasa, F. (2017). Efficacy of pre-emergence herbicides for the control of major weeds in maize (Zea mays L.) at Bako, Western Oromia, Ethiopia. *American Journal of Agriculture and Forestry*, *5*(5), 173-180.

Khan, S. A., Hussain, N., Khan, I. A., Khan, M., and Iqbal, M. (1998). Study on weeds control in maize. *Sarhad Journal of Agriculture (Pakistan)*.

Khatam, A., Khan, M. Z., Nawab, K., Mian, I. A., and Ahmad, W. (2013). Effect of various herbicides and manual control on yield, yield components and weeds of maize. *Pakistan Journal of Weed Science Research*, *19*(2).

Khokhar, K. M., Mehmood, T., and Shakeel, M. (2007). Evaluation of integrated weed management practices for chilies in Pakistan. *Crop Protection*, *26*(8), 1135-1139.

Kremer, R. J. (2004). Weed control. *Corn: origin, history, technology and production. Wiley, Hoboken*, 717-752.

Kurre, D. K., Bharati, V., Prasad, S. S., Kumar, M., and Singh, A. (2018). Impact of herbicides on weeds, yield and yield attributing characters of kharif maize. *Crop Research*, *53*(1and2), 21-26.

Majno, G., and Joris, I. (1995). Apoptosis, oncosis, and necrosis.An overview of cell death. *The American journal of pathology*, *146*(1), 3.

Maqbool, M. M., Tanveer, A., Ata, Z., and Ahmad, R. (2006). Growth and yield of maize (Zea mays L.) as affected by row spacing and weed competition durations. *Pakistan Journal of Botany*, *38*(4), 1227.

Micheni, A., Mburu, D., Kanampiu, F., Mugai, N., and Kihanda, F. (2014). Glyphosate-based herbicides on weeds management and maize performance under conservation agriculture practices in eastern Kenya. *International Journal of Agricultural Resources, Governance and Ecology 27*, *10*(3), 257-268.

Miracle, M. P. (1965). The introduction and spread of maize in Africa. *The Journal of African History*, *6*(1), 39-55.

Nadeem, M. A., Idrees, M., Ayub, M., Tanveer, A., and Mubeen, K. (2013). Effect of different weed control practices and sowing methods on weeds and yield of cotton. *Pakistan Journal of Botany*, *45*(4), 1321-1328.

Nansen, C., Purington, R., and Murdock, M. (2021). Using Advanced Optical Sensing to Quantify Phytotoxicity in Ornamental Plants. *HortTechnology*, *1*(aop), 1-3.

Ocan, D., Mukasa, H. H., Rubaihayo, P. R., Tinzaara, W., and Blomme, G. (2008). Effects of banana weevil damage on plant growth and yield of East African Musa genotypes. *Journal of Applied Biosciences*, *9*(2), 407-415.

Owen, M. J., Walsh, M. J., Llewellyn, R. S., and Powles, S. B. (2007). Widespread occurrence of multiple herbicide resistance in Western Australian annual ryegrass (Loliumrigidum) populations. *Australian Journal of Agricultural Research*, *58*(7), 711-718.

Patel, V. J., Upadhyay, P. N., Patel, J. B., and Patel, B. D. (2006). Evaluation of herbicide mixtures for weed control in maize (Zea mays L.) under middle Gujarat conditions.

Perera, K. T. G. K., and Weerasinghe, T. K. (2014). A study on the impacts of corn cultivation (Zea mays (L.)Family–Poaceae) on the properties of Soil. *International Journal of Scientific and Research Publications*, *4*(7), 1-6.

Perry, J. N., Firbank, L. G., Champion, G. T., Clark, S. J., Heard, M. S., May, M. J., ... and Pidgeon, J. D. (2004). Ban on triazine herbicides likely to reduce but not negate relative benefits of GMHT maize cropping. *Nature*, *428*(6980), 313-316.

Rana, S. S., and Rana, M. C. (2016). Principles and practices of weed management. *Department of Agronomy, College of Agriculture, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur*, *138*.

Rasool, S., and Khan, M. (2016). Growth and yield of maize (Zea mays L.) as influenced by integrated weed management under temperate conditions of North Western Himalayas. *Journal of Experimental Agriculture International*, 1-9.

Reddy, C. (2018). A study on crop weed competition in field crops. *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 3235-3240.

Sharma, R. K., and Sandhu, K. S. (1985). Residual effect of Atrazine and Simazine applied to Fodder Maize sown on different Dates on the succeeding Wheat1. *Indian Journal of Weed Science*, *17*(1), 29-34.

Sime, G., and Aune, J. B. (2014). Maize response to fertilizer dosing at three sites in the Central Rift Valley of Ethiopia. *Agronomy*, *4*(3), 436-451.

Sims, B., Corsi, S., Gbehounou, G., Kienzle, J., Taguchi, M., and Friedrich, T. (2018). Sustainable weed management for conservation agriculture: Options for smallholder farmers. *Agriculture, 8*(8), 118.

Sunitha, N., Reddy, P. M., and Sadhineni, M. (2010). Effect of cultural manipulation and weed management practices on weed dynamics and performance of sweet corn (Zea mays L.).

Swanton, C. J., and Weise, S. F. (1991). Integrated weed management: the rationale and approach. *Weed technology*, *5*(3), 657-663.

Swanton, C. J., Clements, D. R., and Derksen, D. A. (1993). Weed succession under conservation tillage: a hierarchical framework for research and management. *Weed Technology*, *7*(2), 286-297.

Swanton, C. J., Mahoney, K. J., Chandler, K., and Gulden, R. H. (2008). Integrated weed management: knowledge-based weed management systems. *Weed Science*, *56*(1), 168-172.

Tahir, M., Javed, M. R., Tanveer, A., Nadeem, M. A., Wasaya, A., Bukhari, S. A. H., and Rehman, J. U. (2009). Effect of different herbicides on weeds, growth and yield of spring planted maize (Zea mays L.). *Pak. j. life soc. sci*, *7*(2), 168-174.

Tenaillon, M. I., and Charcosset, A. (2011). A European perspective on maize history. *Comptesrendusbiologies*, *334*(3), 221-228.

Tesfay, A., Amin, M., and Mulugeta, N. (2014). Management of weeds in maize (Zea mays L.) through various pre and post emergency herbicides. *Adv Crop Sci Tech*, *2*(5), 151-155.

Wilcut, J. W., York, A. C., and Jordan, D. L. (2017). Weed management systems for oil seed crops. In *Handbook of weed management systems* (pp. 343-400).

APPENDICES

Appendix 1: ANOVA for maize plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	1090.8	363.6	0.67	
REPLICATE.*Units* stratum					
Treatment	2	16663.4	8331.7	15.26	0.004
Residual	6	3277.0	546.2		
Total	11	21031.1			

Appendix 2: ANOVA for number of ears plant.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	0.40667	0.13556	2.07	
REPLICATE.*Units* stratum					
Treatment	2	3.16667	1.58333	24.15	0.001
Residual	6	0.39333	0.06556		
Total	11	3.96667			

Appendix 3: ANOVA for number of grains per row

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	141.51	47.17	1.33	
REPLICATE.*Units* stratum					
Treatment	2	1353.38	676.69	19.14	0.002
Residual	6	212.11	35.35		
Total	11	1707.00			

Appendix 4: ANOVA for 1000 grain weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	6958.	2319.	1.40	
REPLICATE.*Units* stratum					
Treatment	2	67550.	33775.	20.44	0.002
Residual	6	9917.	1653.		
Total	11	84425.			

Appendix 5: ANOVA for maize yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	1006093.	335364.	1.58	
REPLICATE.*Units* stratum					
Treatment	2	7229788.	3614894.	17.05	0.003
Residual	6	1272124.	212021.		
Total	11	9508005.			

Appendix 6: ANOVA for weed vigour

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	0.25000	0.08333	1.00	
REPLICATE.*Units* stratum					
Treatment	2	10.68519	5.34259	64.11	<.001
Residual	6	0.50000	0.08333		
Total	11	11.43519			

Appendix 7: ANOVA for weed density per square metre

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATE stratum	3	176.07	58.69	1.81	
REPLICATE.*Units* stratum					
Treatment	2	8214.89	4107.44	126.50	<.001
Residual	6	194.81	32.47		
Total	11	8585.78			