IDENTIFICATION AND CHARACTERIZATION OF NEW SOURCES OF RESISTANCE TO *STRIGA HERMONTHICA* AMONG DIVERSE MAIZE GERMPLASM

Karaya Githu Haron, B.Sc. Agric. Hons, M.Sc. Genetics & Plant Breeding

A Thesis Submitted in Fulfillment of The Requirements For The Award of a Degree of Doctor of Philosophy in Genetics and Plant Breeding, Department of Plant Science and Crop Protection, Faculty of Agriculture, University of Nairobi.

2012

DECLARATION

I declare that this thesis is my own original work. It is being submitted for the degree of Doctor of Philosophy in Genetics and Plant Breeding of the University of Nairobi. It has not been submitted before for any award of degree in this or any other university.

Signed………………………………………………Date 22/08/2012……

Haron Githu Karaya, (Candidate)

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

Signed………………………………………………Date 22/8/12……

Dr. Kiarie Njoroge, PhD.

University of Nairobi, Kenya.

Signed………………………………………………Date 23/8/2012……

Dr. E. Safary Ariga, PhD.

University of Nairobi, Kenya.

Signed………………………………………………Date 22/08/12……

Dr. Stephen Mugo, PhD.

International Maize and Wheat improvement Center (CIMMYT), Kenya.

Signed………………………………………………Date 23/2012……

Prof. John Nderitu, PhD.

University of Nairobi, Kenya.

DEDICATION

This work is dedicated to my parents the late Wilson Karaya Kariuki and Rahab Njeri Karaya who contributed to my being who I am and for their unreserved love for me, the reason for being what I am.

ACKNOWLEDGEMENT

First I thank the Almighty God for the gift of life, health and energy He granted me and my family throughout the study period.

I acknowledge the efforts of my supervisors, Dr. Kiarie Njoroge, Dr. Stephen Mugo, Dr. Emmanuel Ariga, Professor John Nderitu and Dr. Sarah Hearne for their guidance in the research and write up.

I thank CIMMYT specifically Dr. Marianne Banziger, Deputy Director General for Research and Partnership for being instrumental in the whole project and the financial support of this study. She put relentless efforts in ensuring that the study was fully funded with the objective of helping the resource poor farmers who are adversely affected by *Striga* infestation in the Lake Victoria region.

I also thank my other CIMMYT colleagues for the support they gave me during this research. Special thanks go to Dr. F.Kanampiu and Dr.S. Mugo for their understanding even when there was a lot of demand in my normal duties as a CIMMYT employee. You made the environment of my study conducive.

My appreciation goes to field technicians in Kiboko, Kibos and Kakamega for their assistance in planting trials and in setting of other experiments. I particularly appreciated the assistance of Joel Mbithi, Carolyn Adhiambo, Patricia Onyango and George Oriyo.

I am particularly indebted to my family, my wife Anne Githu and my children, Boniface, Wilson and Purity for all their love, encouragement and support during my studies. Many other people who contributed to the success of this study in one-way or the other, to all I say may our Almighty God bless you abundantly.

PREFACE

This work was conducted at the Department of Plant Science and Crop Protection, University of Nairobi. The project involved laboratory, pots and field experiments. Extensive field testing of the germplasm was done in western Kenya for two rainy seasons and the laboratory work was done at Kibos KARI/ CIMMYT facilities.

This thesis is based on the following chapters, which were published, accepted or submitted for publication as indicated:

1. **Karaya, H.**, Njoroge, K., Mugo, S., Ariga, E. S., Kanampiu, F., and Nderitu, J. H. , 2012. Determination of levels of *Striga* germination Stimulants for maize gene bank accessions and elite inbred lines. *International Journal of Plant Production 2012, 6 (2): 209-224).*

2. **Karaya H.**, Kiarie N., Mugo S., Ariga E. S.· Kanampiu F., and Nderitu H., 2012. Identification of new maize inbred lines with Resistance to *Striga hermonthica* (Del.) Benth. *J. Crop Prot. 2012, 1 (2):131-142*

3. **Karaya, H.**, S. Mugo, K. Njoroge, E. Ariga, H. Nderitu and F.Kanampiu. 2010. Screening Maize (Zea mays) Genotypes for *Striga* hermonthica Resistance From Among the Gene Bank Accessions. Paper presented at the 12th KA*RI Biennial Scientific Conference November 8-12 2010, KARI Headquarters Nairobi Kenya, 2010: 388-392*
4. **Karaya H.**, Kiarie N., Mugo S., Nderitu H., Kanampiu F., and Ariga S., 2011. Combining ability of maize inbred lines resistant to *Striga hermonthica* evaluated under artificial *Striga* infestation in Kenya. Abstract presented during 11th World congress on parasitic weeds. 7-12 June Martina Franca, Italy. P107
5. **Haron Karaya**, Kiarie Njoroge, Stephen Mugo, Emmanuel S. Ariga· Fred Kanampiu, and Huria Nderitu. 2012. Combining ability of maize (Zea *mays*) inbred lines resistant to *Striga hermonthica (Del.) Benth evaluated under artificial Striga infestation(African Jounal of Agricultural Research)*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ACRONYMS

AFLP -Amplified fragment length polymorphism

ASI -Anthesis silking interval

BC -Back cross

CIMMYT -International Maize and Wheat Improvement Center

F1 -First filial generation

GLM -General linear model

GLS - Gray leaf spot

GY - Grain yield

Ha -Hectare

IR -Imidazolinone resistant

Masl- metres above sea level

M^2 - per square metre

MSV - Maize streak virus

Mu -Mutator

***Mu*DR** -Mutator transposon-Donald Robertson

SAS -Statistical analysis system

SC - Single cross hybrid

SDR -*Striga* damage rating

WAP - Weeks after planting

IITA - International Institute for Tropical Agriculture

GCA - General combining ability

SCA - Specific combining ability

OPV - Open pollinated variety

KARI - Kenya Agricultural Research Institute

SSA - sub-Saharan Africa

HPR - Host Plant resistance

BLUP - Best Linear unbiased Prediction

Abstract

This study was designed to identify and characterize new sources of variations in *Striga* resistance. Four hundred and twenty (420) maize genotypes which included 370 landraces, 10 improved populations, 36 inbred lines and 4 commercial checks were used both in laboratory and field studies. In the laboratory experiments, preconditioned *Striga* seeds were dabbed on glass fibre discs and arranged radially away from the source of germination stimulants in petridishes. *Striga* germination counts were made after 24-48 hours under the light microscope. Field evaluation was conducted under both artificially infested and *Striga* free plots. Twenty inbred lines of putative diverse resistance sources were crossed in a Line x Tester fashion where 14 inbred lines were designated as females and 6 (IITA) inbred lines as males to generate 84 F_1 hybrids. Highly significant differences (P=0.001) among the germplasm in terms of production of *Striga* germination stimulants were exhibited in the laboratory. Landraces CRIC 51, CUBA-T-31, BRAZ 1758, BRAZ 1279 and VERA 217 had the lowest *Striga* germination ranging from 3.7- 5.9% and inbred lines were generally found to significantly (P=0.001) induce higher *Striga* germination as opposed to the land races. The best performing land races were CHIS 53, JAMA 8, SNLP 104, PAZM 14140 and CUBA-I-66 and these outperformed the commercial checks with a yield of between 50 and 80% under *Striga* infestation. The inbred lines JI-30-19 and OSU231//56/44-6-4-17-3 consistently performed well under both *Striga* free and *Striga* infested environments.The best performing F1 hybrids yielded an average of 6.8 t/ha which was 127% above the commercial checks. A preponderance of additive gene effects and relatively little dominance gene effects in the inheritance of *Striga* resistance traits was exhibited. Inbred lines TESTR 151 and OSU231//56/44-6-4-17 were the best general combiners. These studies identified 5 landraces, 2 inbred lines and 15 single crosses as new sources of resistance to *S. hermothica* which should be of great potential for use in breeding programs in eastern Africa.

CHAPTER ONE

General Introduction

Maize is an important cereal crop in Africa. It constitutes the staple diet of a large population in sub-Saharan Africa as evidenced by high average annual consumption levels of 79kg per capita in the continent and 125 kg per capita in Kenya (Pingali, 2001). Maize is used for three main purposes: as a staple human food, in the developing countries, as livestock feed in the developed countries, and finally as raw material for many industrial products (Onwueme and Sinha, 1991). The demand for maize in the developing countries is expected to increase to about 504 million tons by 2020 which will surpass the demand for both wheat and rice (IFPRI 2000). There is therefore need to develop new high yielding hybrids and open pollinated varieties (OPVs) of maize with high resistance levels to production constraints such as *Striga spp*. For example Kenya's population increased from 27 million in 2005 (CBS, 2005) to about 40 million people by 2009 (CBS, 2009). This calls for increased production per unit area to ensure self-efficiency in food production. Kenya's per capita arable land declined from 0.23 ha in 1981 to 0.15 ha in 1996 (World Bank, 1998), it is still declining. Growing of high yielding and resistant maize varieties to production constraints would offer a solution for food security.

In 1989 the global area under maize production was 129.6 million hectares with a yield of 470.3 million tonnes (Onwueme and Sinha, 1991). This has increased to about 160 million hectares (FAO, 2009). About 100 million hectares are grown in the developing world. The average maize productivity is 2.4 t ha^{-1} in developing countries compared to 5.12 t ha^{-1} in the developed world (Faostat, 2009). In Kenya, 1.9 million hectares were estimated to be under maize cultivation in 2009, with an average grain production of 2.5 million tonnes per year (FAO, 2009). Maize was introduced in Kenya to offset food shortages during the early years of the 20th century resulting from disease epidemics, drought and locust invasions that decimated sorghum and millet, the traditional crops, but quickly replaced these crops to the present prominence (Miracle, 1966). The production and utilization potential of maize in the recent times is attracting the attention of research scientists. Major national and international research organizations have been involved in providing solutions to various production and marketing problems. These maize production constraints include; low grain yield, susceptibility to pests and diseases, adaptation to the specific growing ecologies, and yield loss that result from the devastating effects of drought, low soil fertility and *Striga* parasitic weed (Kim, 1994).

Maize being the main staple food crop in Kenya is predominantly grown in the high to medium potential agricultural areas, which are also highly populated. Land sub-division as a result of population increase has also played a major role in reducing the agricultural arable lands hampering productivity. Nyanza and Western provinces, the major maize growing areas have population densities of between 350 - 406 persons/km^2, respectively (CBS, 2009). Farmers in these areas grow hybrid maize varieties with a potential yield of up to 8 t ha^{-1}, but realize less than 1 t ha^{-1} because of low soil fertility, *Striga* weeds, pests and diseases.

Striga hermonthica is a root parasitic weed that inhibits host growth by competing for nutrients and impairing photosynthesis. It is one of the most important biological constraints to maize production in sub- Saharan Africa. Twenty three (23) species are found in Africa of which, *Striga hermonthica* (Del.) Benth infests about 40% of the arable land causing 30 - 100% loss in maize yield in East Africa (Khan *et al*., 2001; Gressel *et al*., 2004). In Africa, nearly 100 m ha of the African savannah are infested annually with *Striga,* where about 2.3 m ha of land is in eastern and western Africa of which 210,000 ha are in Kenya (Kanampiu and Friesen, 2003). In the Kenya's Lake Victoria region, about 80,000 ha of maize crop are severely infested with

Striga, causing an estimated annual loss of US $10 million to maize farmers (Abayo *et al*., 1998). The yield loss associated with this infestation ranges from 20 to 80% and sometimes complete yield loss has been reported under heavy *Striga* infestation (Berner *et al*., 1995). Yield loss due to *Striga* infestation is more serious in highly populated areas where soil fertility is low due to continuous cropping and erratic rains. Thus development of new drought tolerant maize cultivars adapted to these areas with higher *Striga* resistance levels should be explored to curb this problem.

Witch weed (*Striga* spp) are pernicious root attaching parasitic weeds found in the sub- Saharan Africa. A single *Striga* plant can produce up to 200,000 small dust-like seeds that survive in the soil for up to 20 years (Gressel, *et al*., 2009). In western Kenya, there are about 61-158 million *S. hermonthica* seeds per hectare in the soils (Khan *et al*., 2006; Vanlauwe *et al.,* 2008). Production of large number of seeds coupled with ability to remain viable in the soil for a long period and continuous growing cereals leads to a buildup of a big seed bank in the soil. Growing crops continuously, that is often associated with decline in soil fertility further makes the *Striga* problem more complex (Oswald, 2005). Identification and testing of maize cultivars with tolerance to abiotic stresses such as drought and low nitrogen would help in managing *Striga* menace in resource poor farmers' fields. *Striga hermonthica* attack cereal crops such as sorghum, millets, rice and maize (De Groote *et al*., 2008; Oswald, 2005).

Striga seeds are triggered to germinate by the presence of a potential host or non host through the production of germination stimulant (Oswald, 2005). The parasite attaches to the crop roots and becomes a major sink for crop photosynthate (Gurney *et al*., 1995) and it also exerts phytotoxic effects on the crop growth thus resulting in yield reduction. Identification of maize varieties with low germination stimulant production would reduce the intensity of infection resulting to increased maize yields. The host specificity is achieved by chemical cues from the host plant. On germination, *Striga* attaches to the host plant roots through the haustoria and continues to feed for several weeks while living underground. By the time *Striga* emerges from the soil, it has already caused damage on the host plant. Management of *Striga* should therefore aim at restraining development, seed productions and depletion of the *Striga* seed bank in the soil by growing resistant maize hybrids and OPVs which would not support *Striga* plants to maturity. Several technologies have been developed to control the development of *Striga.* These strategies in isolation are however, not effective. Pre-emergence herbicide, such as Dicamba has been used to control *Striga* (Kanampiu *et al.,* 2005), but the small spectrum of selectivity limits its use in intercrops while the possible post-emergence herbicide 2,4D is applied when substantial damage is already done. The use of IR (Imidazoline-Resistant) maize where herbicide imazapyr inhibits acetolactate synthase is coated on herbicide resistant mutant maize has been promoted for some time (Kanampiu *et al*., 2003). This technology is inexpensive, environmentally safe and fits well within the existing cropping systems. The technology reduces the *Striga* seed bank as it kills any seed that comes into contact with the chemical while trying to attach to the maize roots. However, due to the smaller quantities of the chemical used (30g/ha), some *Striga* seeds germinates later in the season making the technology not feasible for the farmers on its own. Mechanical weeding and hand pulling have traditionally been used, but these are tedious and take a long time before their effects are evident. Ransom and Odhiambo (1994) found that hand weeding of *Striga* before seed set resulted in an increase in maize yield only after four seasons of implementation. However, weeding is effected when a lot of damage has already been done. Application of higher rates of nitrogen fertilizer (> 120 kg/ha) has also been suggested as a means of *Striga* control (Mumera and Bellow, 1993), but it is not affordable to the resource poor farmers. In Kenya, maize cultivars such as, KSTP94, Nyamula, and WH502 have been identified to have some good levels of tolerance to *Striga hermonthica* infestations (Woomer, 2004). However under a heavy *Striga* infestation intensity the tolerance breaks down and the varieties succumb to infection. Identification of new sources of resistance to *Striga* should therefore, be explored in order to develop new maize hybrids which would be able to withstand higher *Striga* infestation levels.

There have been efforts to to research on ways to control *Striga* weed for over 50 years in the sub Saharan Africa region. However, *Striga* distribution and intensity continues to increase drastically due to various factors. These include high growth of human populations resulting in increased population pressure and intensified land use to increase food production, intensification of traditional cropping systems, reduction of fallow periods and the increasing need for major staple food crop cultivation (Kiruki, 2006). In maize, the development of host plant resistance (HPR) has been limited, though it is the most economically feasible and environmentally friendly means of *Striga* control.

In a series of studies at the International Institute of Tropical Agriculture (IITA), Kim, (1994) found some maize varieties that were tolerant to *Striga*. He concluded that the genetic control for tolerance and resistance of maize genotypes tested to *S. hermonthica* was polygenic and the inheritance was quantitative. Twenty inbred lines and seven synthetics which were found to be tolerant and resistant to *S. hermonthica* were developed by 1994 from diverse germplasm through artificial infestation with seeds obtained from various host crops, (Kim, 1994). Some of these germplasm were used in the current work to test their efficacy under Kenyan conditions and to measure their combining abilities that can be used to develop new maize hybrids adapted to eastern Africa.

Host plant resistance such as mutation have been used widely in efforts to breed biotic stress tolerance and disease resistant lines with some success (Cassels and Doyle, 2003). Some work on maize transposon induced mutator lines with *Striga* resistance was conducted by Kanampiu

(Personal communication) and several lines were identified to have *S. hermonthica* resistance in Alupe and Kibos in Western Kenya. These are transposon induced mutator lines. Transposons are genetic elements capable of moving within and between continuous segments of genetic material and are likely to be ubiquitous contributors to genome structures. Mutator transposons are elements that are known to turn on and off processes in plants e.g. in the production of *Striga* germination stimulants. Some of these mutator lines were used in the combining ability studies.The best combining lines were used in the development of maize hybrids resistant to *Striga hermonthica*i in the current studies.

The combining ability of inbred lines is a factor that determines the usefulness of the lines in hybrid combinations. The value of the line can best be expressed through the performance of crossing combinations (Hallauer and Miranda, 1981). The terms general (GCA) and specific (SCA) combining ability were introduced by Sprague and Tatum (1942). In the original sense, the GCA can be determined by using a broad base heterogeneous population as tester, while the differences in the SCA can be revealed using a tester with a narrow genetic base (inbred line or single cross). Understanding the combining ability of *Striga* resistant inbred lines can be important in the development of new maize hybrids resistant to *S.hermonthica*.

None of the existing *Striga* control methods have given complete control for the small scale farmers due to high fecundity and the mismatch between technologies and the farmers' socio-economic conditions (Kiruki, 2006). This study therefore, focused on pyramiding of the already existing *Striga* control approaches such as host plant resistance, herbicide resistance and use of maize mutants to develop superior germplasm for *Striga* resistance.

1.1 Problem statement and justification

The *Striga* prone areas of Western Kenya represents part of the largest fraction of medium to high potential agricultural land in the country. The area receives adequate (1800-2000mm) rainfall for food production, but many people still go hungry because of low food production. Farmers grow high yielding improved maize varieties with potential yield of 8 t ha^{-1} but realize less than 1 t ha^{-1}. *Striga hermonthica* has emerged as one of the major constraints to cereal production in these *Striga* prone areas (Kiruki, 2006). The problem is compounded by erratic rains as a result of climate change and expansion in farming to less potential areas because of the high human population density. Continuous cropping of susceptible cereals season after season results in addition of large quantities of *Striga* seeds into the soil. In badly infested fields, *Striga* causes up to 100% crop yield loss and is responsible for abandonment of large parcels of land. In addition to enhancing the *Striga* seed bank, continuous cereal cultivation also contributes to the depletion of soil fertility.

Several *Striga* control methods in maize have been developed and suggested over the years but none of these methods have been widely adopted by the farmers, due to issues such as labor and financial constraints, and the fact that their benefits are not quickly evident in the short term but only in the long term. Single *Striga* control strategies used in isolation may be inadequate, although host plant resistance is the easiest for farmers to adopt and use as it is incorporated in the seeds as opposed to all other techniques. Growing of maize cultivars with higher *Striga* resistant levels in form of low production of germination stimulants would offer solutions in reduction of *Striga* seed bank in the soil and this would result in an increase of maize yields. Evaluation and characterization of new sources of resistance to *Striga* will give farmers and breeders more options towards effective *Striga* control and management strategies. Incorporation of host plant resistance from transposon induced mutants, drought tolerant background with the available *Striga* control methods such as use of imidazolinone resistant maize inbred lines (IR-maize) and other agronomic practices offer the small scale resource poor farmers more affordable and feasible *Striga* control and management alternatives. If new cultivars have to be F_1 hybrids or synthetics, then information on combining ability of the *Striga* resistant inbred lines is essential in making decisions on the usefulness of the inbred lines.

1.2 Objectives

1.2.1Broad objective:

To identify and characterize new sources of *Striga* resistance in tropical maize.

1.2.2 Specific objectives

1. To identify gene bank maize accessions and elite inbred lines with low *Striga* germination stimulants
2. To identify new sources of *Striga* resistance in drought tolerant germplasm gene bank accessions, improved open pollinated varieties and maize inbred lines.
3. To determine and study combining ability of *Striga* resistant maize inbred lines

1.3 Hypotheses

1. There exist useful maize accessions with low levels of *Striga* germination stimulants.

2. New sources of *Striga* resistance can be found among drought tolerant gene bank accessions, improved open pollinated varieties and maize inbred lines.

4. There exist maize inbred lines with good GCA and SCA from among available *Striga* resistant maize inbred lines.

CHAPTER TWO

GENERAL LITERATURE REVIEW

2.1 *Striga* Species

The genus *Striga* in the *Scrophulariacea* family is composed of about 50 species, which are all parasites of tropical cereals and legumes of which, *Striga hermonthica* (Del.) Benth, *S. asiatica* (L.) Kuntze and *S. gesnerioides* cause the most economically significant damage to cereals in Africa (Butler, 1995). *Striga hermonthica* infect and cause serious damage to major crops like maize, sorghum, millet, sugarcane and upland rice. It is one of the most important weeds limiting maize production in *Striga* prone areas in western Kenya (Oswald and Ransom, 2001). *Striga hermonthica* is most severe in areas where soil fertility is low and population density is high (Oswald, 2005). In Nigeria, the farmers' common field management practices were found to lead to a *S. hermonthica* seed bank increase by 46% (Franke, *et al*., 2005). *Striga hermonthica* reduce yields by competing for water, nutrients and photosynthates with the host plants (El-Halmouch *et al*., 2005). The parasite does not only act as an additional sink but also has a strong 'phytotoxic' or 'pathological' effect on the host (Press and Gurney, 2000; Ast, 2006).

In Africa, crop yield losses associated with *Striga* related infection is about 40% and represents an annual loss of cereals worth US$7 to 13 billion (Khan *et al*., 2001). In East Africa, *S. hermonthica* is the most important species causing an estimated 20-100% total loss for maize, sorghum and millet (Emechebe and Ahonsi, 2003). In Kenya, *Striga* is most pronounced in Nyanza and some parts of Western provinces and the coastal strips, where it occurs in about 210,000 hectares resulting in crop losses accounting for about US$ 53 million per year (Hassan *et al*., 1995). In addition, to yield reduction, *Striga* also cause farmers to abandon arable fields resulting in food insecurity and malnutrition (Gressel *et al*., 2004).

2.2 *Striga* in Sub-Saharan Africa

Striga is native to the grasslands of the African tropics, reaching their greatest diversity in the region where they have co-evolved with cereals (Gressel *et al*., 2004). *Striga hermonthica* is distributed throughout the semi arid tropics of Africa, east to west, throughout the semi arid areas of Ethiopia to the moist savannah of west Africa, and extends to south western Arabia down to Namibia in the south (Riches and Parker, 1995) (Figure 2.1). *Striga hermonthica* attacks maize and sorghum, but also other crops including sugarcane, finger millet, napier grass and other native grasses (Woomer, 2004) while *Striga gesnerioides* parasitizes dicotyledonous plants such as cowpea resulting to yield loss ranging from 41 to 83% (Berner *et al*., 1995)

Striga infestation has worsened with farmers shifting preference to cereal crops including sorghum and millets which produce relatively low but sustainable yields compared to the high yielding maize crop. Maize did not evolve under *Striga* pressure and, may therefore possesses little or no resistance to *Striga spp* (Berner *et al*., 1995) resulting in high yield loss (20 to 80%) and sometimes complete crop loss.

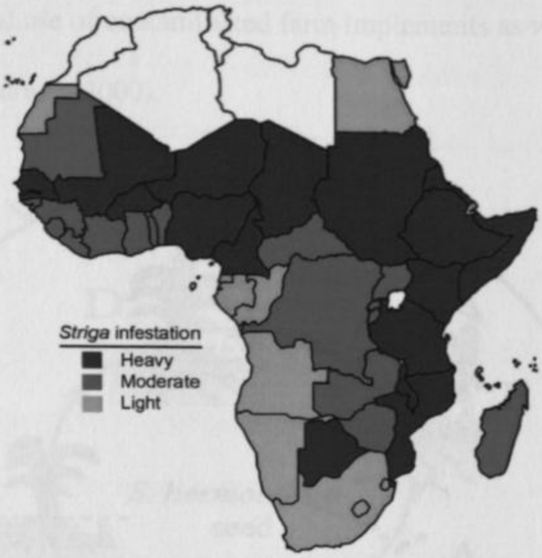

Figure 2.1.Striga infestation in Africa. (Adapted from a report by Gressel et al.,2004).

The infestation worsens every season because of continued addition of seeds which can stay viable for a long time into the soil.

2.3 *Striga* lifecycle

Striga emergence typically starts some 2-3 weeks after forming the attachment (Parker and Riches, 1993) (Figure 2.2). After emergence, *Striga* shoots become chlorophyllous and are capable of carrying out photosynthesis making it a hemi-parasite. At this stage it is capable of photosynthesis, but remains partially dependent on the host for water, minerals and some assimilates. However, the rate of photosynthesis observed in *Striga* is low, (0.5 and 8.0 μmol m^{-2} s^{-1}) and estimated proportion of host derived carbon by *Striga* is 28- 89% (Cechin *et al.*, 1993). On attachment *Striga* plants flower in about 6 weeks, mature in 2 weeks and shed seeds within 4 weeks of flowering (Parker and Riches, 1993). The released seeds are hardly visible to naked eye (about 0.3 mm long) and weigh only about 8 μg each. They are however produced in huge numbers (50,000 - 200,000 seeds per plant) (Kanampiu *et al.*, (2005). *Striga* seeds are dispersed by animals, wind, water and use of contaminated farm implements as well as contamination of sowing seeds (Press and Gurney, 2000).

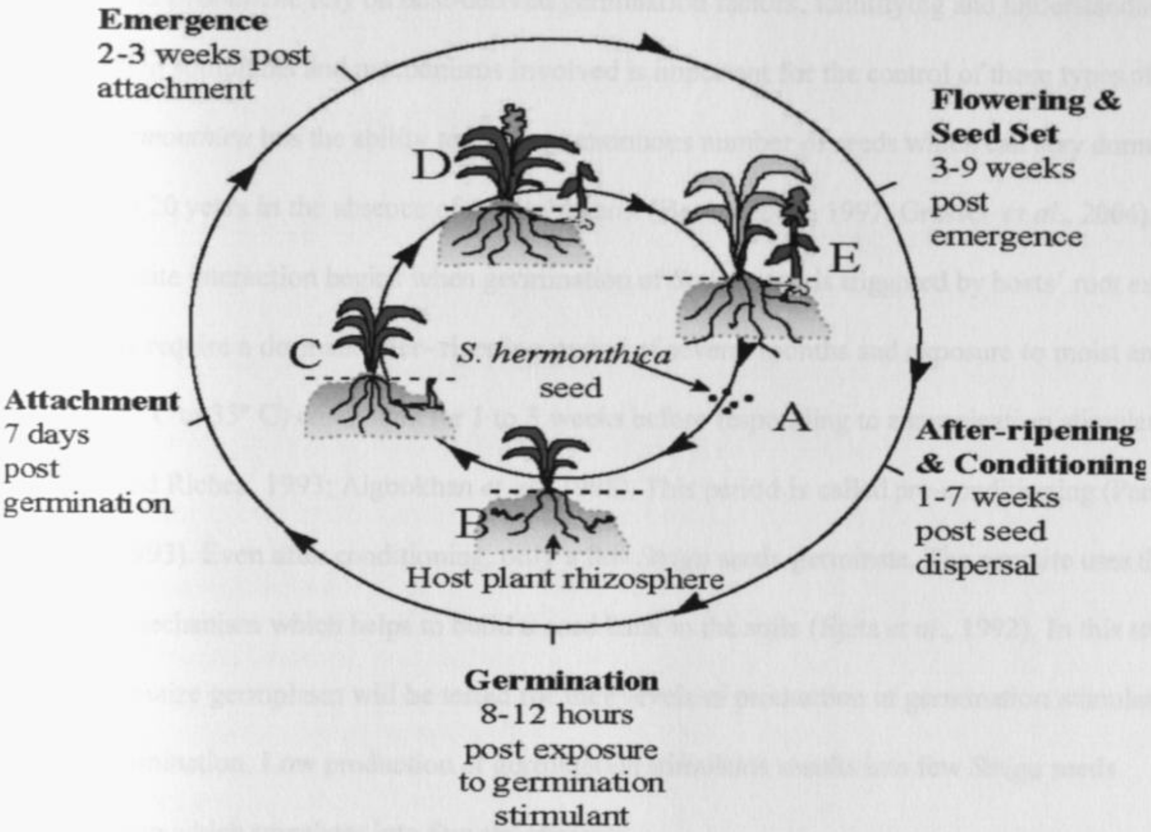

Figure 2.2. The life cycle of *Striga hermonthica* (Adopted from Gressel et al 2004)

Striga seeds have great ability to survive the dry season and build up into a large seed bank within a very short time (Weber *et al.*, 1995; Rodenburg, 2005). Intervention through interfering with the lifecycle is one of the ideal approaches in managing *Striga*. Growing of resistant maize cultivars is likely to interfere with the normal lifecycle as the emerged *Striga* plants do not grow normally (Fakorede, personal communication.).

2.3.1 Germination and stimulation

Seeds of most parasitic plants will readily germinate if appropriate environmental conditions (warmth, water, oxygen and temperature) are met. Some parasites such as those of the genera *Striga*, *Alectra* and *Orobanche* rely on host-derived germination factors. Identifying and understanding the germination stimulants and mechanisms involved is important for the control of these types of weeds. *Striga hermonthica* has the ability to produce enormous number of seeds which can stay dormant for more than 20 years in the absence of a suitable host (Berner *et al*., 1997; Gressel *et al*., 2004). The host- parasite interaction begins when germination of *Striga* seed is triggered by hosts' root exudates. The seeds require a dormant after- ripening period of several months and exposure to moist and warm (22° C to 35° C) conditions for 1 to 3 weeks before responding to a germination stimulant (Parker and Riches, 1993; Aigbokhan *et al*., 1998). This period is called pre-conditioning (Parker and Riches, 1993). Even after conditioning, only a few *Striga* seeds germinate. The parasite uses this as survival mechanism which helps to build a seed bank in the soils (Ejeta *et al*., 1992). In this study different maize germplasm will be tested for their levels of production of germination stimulants to *Striga* germination. Low production of germination stimulants results into few *Striga* seeds germinating which translates into few attachments.

After conditioning, *Striga* seeds respond to the germination stimulants exuded by roots of hosts and even some non-host within three hours to 24 hours (Ejeta and Butler, 1993). In the absence of a suitable germination stimulant, a pre-conditioned seed reverts back to "wet dormancy" in the soil. The adaptation is of evolutionary significance since the tiny seeds with limited food reserves cannot support the seedling for many days after germination unless the host root is invaded (Bouwmeester *et al.,* 2003). The stimulant dependent germination has a significant ecological impact as it ensures that *Striga* seed does not germinate unless a stimulus-exuding host is present and growing.

2.3.2 The impact of *Striga hermonthica* on the host

The effect of *Striga* on its host occurs in different ways. Competition for carbon assimilates, water, mineral nutrients and amino acids results to reduction in growth of the host plant (Taylor and Seel, 1998; Ast, 2006). As a result of *Striga* infestation, growth inhibitors (abscisic acid and fernasol) in the host increase, and growth promoters (cytokinins and gibberellins) decrease due to host stress response, generally impairing the host growth and reproduction (Frost, 1997). *Striga* continues to benefit from its host after emergence despite its green leaves (Seel *et al*., 1992; Rodenburg, 2005). The parasite does not only act as an additional sink but also has a strong 'phytotoxic' or 'pathological' effect on the host (Press and Gurney, 2000; Ast, 2006). Some of these effects are due to the disturbed hormonal imbalance in *Striga*-infected host plants which is usually characterized by increased levels of abscic acid (ABA) and decreased levels of cytokinins and gibberellins (Frost *et al*., 1997; Taylor *et al*., 1996; Ast, 2006). Through altering the host hormonal balance, *Striga* affects host biomass allocation, resulting in the root systems of infected plants being greatly stimulated, while the shoot is stunted and reduced (Parker and Riches, 1993).

Plate 2.1. **Effect of *Striga* infection on host biomass allocation**

The parasite also affects host photosynthesis leading to more biomass allocation to the roots at the expense of the stem (Graves *et al*., 1989; Rodenburg, 2005) (Plate 2.1). Transpiration rates of above ground *Striga* exceed that of its host, show little to no response to darkness and only reduces when the host is subjected to water stress (Rodenburg, 2005). This is basically to ensure a constant flux of water from the host to the parasite (Pageau *et al*., 2003), *Striga* reduces the water use efficiency and strongly affects the water economy of its host through its high transpiration rates and by reducing the stomatal conductance of the host plant (Gebremedhin *et al*., 2000; Gurney *et al*., 1995; Rodenburg, 2005; Ast, 2006). *Striga* symptoms of parasitism are often dramatic but non-descript, resembling drought stress, nutrient deficiency and vascular disease. Severe plant stunting often results in highly susceptible maize varieties and eventually total yield loss (Berner *et al*., 1995).

2.4 Combining ability

General combining ability (GCA) of a line is the mean performance, when expressed as a deviation from the mean of all crosses in a trial. It is the average value of all F1's having this line as one parent, the value being expressed as a deviation from the overall mean of crosses. Any particular cross, then has an 'expected' value which is the sum of the GCA abilities of its two parentals. The cross may, however, deviate from this expected value to greater or lesser extent.

Specific combining ability (SCA) is the deviation of the two parental lines of a cross in a combination (Falconer, 1996). In statistical terms, the general combining abilities are main effects and specific combining ability is an interaction. According to Falconer (1991) the true mean X of a cross between lines P and Q can thus be expressed as:

$$x - \bar{x} = GCAP + GCAQ + SCA_{pQ}$$

Where $\bar{x}$ = mean of all crosses.

X= True mean

$GCAP$= General combining ability for line P

$GCAQ$= General combining ability for line Q

$SCAPQ$= Specific combining ability of the cross between line P and Q.

GCA and SCA are always relative values and depend greatly on the performance of the inbred lines involved in the combinations. The value of GCA tends to express additive gene effects, while SCA is more indicative of dominant and epistatic effects (Spitko *et al*., 2010). In our current study the combining ability studies will help us in the identification of the best combiners for *Striga* resistance traits which can further be used in the development good single cross or three way cross hybrids.

2.4.1 Estimation of combining ability

The method that is convenient for use with plants is known as the polycross method. A number of plants for all the lines to be tested are grown together and allowed to pollinate naturally, self pollination being prevented by the natural mechanism for cross pollination, or by the arrangement of the plants in the plot. The seeds from the plant of one line are therefore a mixture of random crosses with other lines, (i.e. 'polycross') and their performance when grown tests the GCA of that line. The GCA measured is those of lines used as female parents.

The GCA of a line can be estimated by crossing it with individuals from the best population instead of with other inbred lines. This method is known as top crossing (Falconer, 1996).

The Line X Tester (LxT) is an extension of top cross analysis where more than one tester is used in the mating design (Kempthorne, 1957; Sharma, 1998). The LxT mating design provides both full-sib (FS) and half-sib (HS) families simultaneously as opposed to top cross and poly cross which provides only half-sibs. This mating design can be used in determination of SCA of the crosses as well as GCA of lines and testers. Rawlings and Thompson (1962) used line x tester analysis to estimate GCA and SCA of inbred parents. Since the development of new cultivars through hybridization is a continuous process, information on combining ability of inbred lines remains important.

In maize the diallel method of crossing and North Carolina design II can be used. In this study NCD II was used where some maize inbred lines were designated as females (Lines) and males (testers) and factorially mated to generate single crosses.

2.5 *Striga* control approaches

Striga is primarily a problem in small-scale subsistence farming systems with few options for external inputs such as pesticides and fertilizers and control options must therefore be low-cost and practical (Rodenburg, 2005). *Striga* build-up is linked to years of neglect, the intensification of agriculture and the movement of cereal production to pasture areas where *Striga* is endemic. Under these conditions, there are major constraints to effective control of *S. hermonthica*. The parasite causes most of its overall damage to the host crop during its subterranean stage (Parker and Riches, 1993; Ast, 2006). A multitude of control options against *Striga* have been studied ranging from cultural practices through transplanting, delayed sowing or the use of trap crops, chemical control , soil fumigation, biological control and host plant resistance (Rodenburg, 2005; Ast, 2006). These control approaches can be clustered into either direct or indirect methods. Direct *Striga* control methods attack the parasite directly and have an immediate effect on *Striga* densities in the field. These include the use of herbicide coated maize and host plant resistance. Indirect methods are those that aim at the cropping system and soil fertility management, and control the parasite by making its growth conditions less favorable (Oswald, 2005).

2.5.1. Hand weeding

This involves rouging of *Striga* plants through hand pulling, slashing or weeding using a hoe. It is probably the oldest and most widely used method of *Striga* control in subsistence communities. It is not well adopted probably because of the limited immediate returns and the tediousness of the task (Esilaba *et al*., 1997). In a long term study in Western Kenya, Ransom and Odhiambo (1994) found that hand weeding before *Striga* seed set increased yield only after four seasons of implementation. However reduction in *Striga* infestation level does not always immediately result in an improved host performance, because few *Striga* attachments can seriously harm the host plant. In addition uprooting at flowering and fruiting, still leads to broadcasting of viable seeds. The practice of uprooting *Striga* plants with already mature seed and placing them on the roads and footpaths as is mostly done in western Kenya, instead of burning them, further help in increasing and spreading seed bank in the ecosystem. Managing the *Striga* problem through host plant resistance might offer the farmers a better and feasible option for the control of *Striga*.

2.5.2 Chemical control-Use of herbicides

Ethylene and dicamba can effectively control *Striga*. Ethylene gas induces *Striga* to germinate, fields may be covered and fumigated with the compound etherel (Woomer, 2004). Dicamba is applied at the time of attachment, kills *Striga* before it emerges and, therefore, provides yield protection (Odhiambo and Ransom, 1993). Though ethylene is inexpensive to manufacture, it has not been developed for use in *Striga* control in Africa due to logistical and cost difficulties in chemical employment (Ransom *et al*., 1997). Dicamba is not cost effective in Africa in that it does not provide the persistent, continual control of *Striga* (Abayo *et al*., 1998). The development by CIMMYT and Weismann Institute of Imidazolinone resistant adapted African maize germplasm and seed coating technologies with herbicides potentially offers an affordable method of *Striga* control in Africa (Kanampiu *et al*., 1999). This technology combines low doses (30 g ha^{-1}) of a systemic acetolactate synthase-inhibiting herbicide such as imazapyr or pyrithiobac as a seed coating with imidazolinone-resistant (IR) maize seed. The treatment leaves a field virtually clear of emerging *Striga* stalks up to harvest. Since the maize seed is treated, there is no added cost for spraying equipment and no possibility of off-target application (Kanampiu and Friesen, 2003). The use of herbicide coated maize offers a cost effective mechanism in that it combines two major criteria: (1) Controlling *Striga* itself for better crop yields during the same season; and (2) depleting the *Striga* seed bank in the soil to reduce immediate and future maize losses. However the technology has not been well adopted due to logistical issues in its application and hence reduced availability of seed of the herbicide resistant maize.

2.5.3 Host Plant resistance

2.5.3.1 Conventional breeding

Host plant resistance is the plant's ability to prevent attachment of the parasite or to kill the attached parasite resulting in reduced emergence while tolerance is the ability of the plant to withstand the effects of the parasite already attached producing satisfactory yield (Badu-Apraku *et al*., 2007). The tolerance mechanism is based largely on ''avoidance root architectures'' (Hearne, 2001). The varieties with deep rooting nodal and seminal roots and a greater proportion of lateral branching below the plough pan tend to be more tolerant. The tolerance is simply based on the timing of the parasite attachment and the delay lessens the impact on the host.

The selection and development of resistance is a major practical and reliable approach to the management of *Striga* especially in the context of peasant/ subsistence agriculture as it avoids reproduction of the parasite. Resistance to *Striga* has been shown in sorghum cultivars like SRN-39 (Hess and Ejeta, 1992). In maize, a number of *Striga* tolerant varieties have been identified and commercialized in Kenya over the past several years. Affected farmers may purchase either open pollinated (OPVs) or hybrid cultivars. Examples of these varieties are KSTP94 and WH502, commercialized by Kenya Agricultural Research institute (KARI) and Western Seed Company, respectively (Woomer, 2004). The major problem associated with the use of resistant cultivars is the lack of universal resistance, because of the existence of different biotypes of *S. hermonthica* since it is cross-pollinated (Koyama, 2000). It is, therefore, recommended to direct maize breeding efforts towards developing varieties that combine resistance with high levels of tolerance (Rodenburg, 2005; Shew and Shew, 1994). The development of sorghum resistant to *Striga* has been demonstrated as being the most practical and economically feasible approach in fighting *Striga* especially for low input small scale farmers. Investigation on the inheritance in maize inbred lines of tolerance and *Striga* emergence counts concluded that the genetic control for tolerance and resistance of maize genotypes tested to *S. hermonthica* is polygenic and the inheritance is quantitative (Kim, 1994).

The general and specific combining abilities (GCA and SCA) of new maize lines for grain yield and *Striga* emergence counts under artificial *Striga* infestation were studied (Kanampiu *et al*., 2007). Significant GCA effects for grain yield under *Striga* infestation were found, which indicated a uniform transmission of *Striga* resistance or tolerance by parents to their off springs and confirmed the existence of genetic variability for resistance to *Striga* in the inbred lines studied.

This type of resistance can partially solve the problem when *Striga* infestation level is low and the soil is not shallow. However, on shallow soils and under heavy *Striga* infestation the tolerance can break down. Incorporation of resistance and tolerance in new maize cultivars offers a better solution in handling the *Striga* menace in the resource poor farmers' fields.

2.5.3.2 Mutation Breeding

Mutation breeding is important in that it can be introduced into the best commercial varieties to satisfy the demands on yield, quality, disease resistance, winter hardness or other critical properties creating new variations such as *Striga* resistance in maize (Konstantinov and Snezana, 2007). Mutation techniques have been used widely in efforts to breed for abiotic stress tolerance and disease resistant lines with successes (Cassels and Doyle, 2003). There are two types of mutations: Spontaneous mutations and induced mutations. Spontaneous mutations occur in natural populations while induced mutations occur through induction by treatment with certain physical or chemical agents (Singh 1995).

2.5.3.2.1 Spontaneous mutations

These are mutations which occur in natural populations without any artificial treatment. They occur at a low rate, generally one in ten lacs i.e. 10^{-6}. Spontaneous mutations have been reported in field crops eg.the opaque-2 gene in maize which governs the lysine content (Borojevic, 1990). A dwarf mutant which was registered in a sorghum cultivar standard milo served as basic stock in breeding short mechanically combinable types of grain sorghum in many countries (Poelman, 1983; Powell *et al*., 1996).

2.5.3.2.2 Induced mutations

These are mutations which are artificially induced by treatment with certain physical or chemical agents, or mutagens. These mutations occur at relatively higher frequency (Sing, 1995). Induced mutations occur more or less randomly in the genome and their target cannot be directed. The frequency of induced mutations doubles spontaneous mutations (10^{-3}) (Borojevic, 1990). Only one of the two or more alleles of a locus is affected. Inheritance is almost ever recessive and, therefore, homozygosity is normally required for proper expression (Alexander, 2008). The results are often more useful in self pollinating plant species. Cases of mutant heterosis have been reported by many researchers (Micke, 1976; Römer and Micke, 1974; Maluszynski *et al*., 1989). Specific mutations concerning male sterility (Daskalov and Michailov, 1988) and grain quality which proved to be useful in cross-pollinating species have been reported (Röbbelen, 1990). Mutations can be produced through irradiation, which involves exposing an organism to radiation. It can be classified as ionizing or non-ionizing, depending on its effect on atomic matter (Sing, 1995). The ionizing radiations have enough energy to ionize atoms or molecules. Radioactive material is a physical material that emits ionizing radiation (Bly, 1998).

The effects of physical and chemical mutagens are well characterized and are very similar to the spontaneous mutation arising in vitro (somaclonal variation). Somaclonal variation has contributed to the development of abiotic and biotic stress resistant varieties in major crops (Brar and Jain, 1998).

2.5.3.2.3 Transposon induced mutation

Transposons are genetic elements capable of moving within and between continuous segments of genetic material and are likely ubiquitous contributors to genome structures. These elements are responsible for turning on and off plant processes. Closely related elements are classified into transposon families (Jonathan *et al*., 1994). Within a family, elements can be divided into two functional classes, autonomous and non autonomous. Autonomous elements are capable of directing their own transposition of non autonomous elements by producing the factors (transposases) that are required along with host factors for transposition. Mutator is a powerful system for generating new mutants in maize (Hershberger *et al*., 1991). The mutator family of transposable elements of *Zea mays* is considered to be one of the most efficient gene tagging systems in eukaryotes. *Mutator (Mu)* transposable elements were first recognized by Robertson in a line of maize that exhibited a 50 to 100 fold increase in its spontaneous mutation frequency compared to standard maize stock (Robertson, 1978). During 1998-99, 8,000 mutator tagged maize lines were screened and about 80 showed some level of resistance. This was eventually reduced to 20 and finally to 1 which was the most promising (Hearne S. Personal communication). Some of the derivatives from this line were used in the current study as source of *Striga* resistance in the formation of F_1 single cross hybrids.

CHAPTER THREE

Determination of levels of *Striga* germination Stimulants for maize gene bank accessions and elite inbred lines

Abstract

Parasitism by *Striga hermonthica* (Del) Benth is a severe constraint in maize production in Sub-Saharan Africa. Varying levels of tolerance to *Striga* attack have been identified and exploited in breeding programs of several crops. However, the level and stability of the tolerance is generally unacceptable in field-practice. Only limited exploration has been undertaken among the farmers' landraces to find presence of viable sources of resistance to *Striga.* The objective of this study was to examine and document the presence of the *Striga* germination stimulants from a collection of some 420 maize landraces, populations and elite inbred lines variously sourced from CIMMYT, IITA and KARI. The ability to effect germination as a measure of the amount of germination stimulant produced was used to assess the genotypes, using standard procedures. Data were recorded on *Striga* germination by counting *Striga* seeds with protruding radicle. Highly significant (P=0.001) differences were observed among the germplasm screened. Several gene bank accessions were found to stimulate low levels of *Striga* germination compared to the commercial checks. Gene bank accessions CRIC 51, CUBA T-31, BRAZ 1758, BRAZ 1279 and VERA 217 exhibited the lowest *Striga* germination which ranged from 3.71 to 5.99%, an indication of high level of resistance to *Striga*. The inbred lines were found to have a higher *Striga* germination percent compared to the landraces, a likelihood of a higher concentration of strigol, the stimulant causing chemical. CIMMYT lines CML 202 IR, CML 445 IR and CML

204 IR induced the least amount of *Striga* seeds to germinate, the germination percent ranged from 14.34 to 22.59%. Higher levels of germination of *Striga* seeds were found in the IITA lines which are known to be resistant eg TESTR 153 had 56.55%, depicting a probable avoidance root architecture mode of resistance as opposed to low production of strigol. It was concluded that the landraces with low *Striga* germination percent can be used by breeders in the extraction of new *Striga* resistant inbred lines. The resistant inbred lines were recommended for direct use in the formation of maize synthetics and hybrids resistant to *S. hermonthica*.

Key words: *Striga hermonthica,* maize landraces, tolerance to *Striga,* resistance to *Striga, Striga* germination stimulant

3.1 Introduction

The life cycle of *S. hermonthica* is complex and comprises a series of discrete steps which are intimately tied to that of its host from the seed to the mature or seed producing plants. Understanding *Striga* biology is the starting point to develop technologies towards its control. After dispersal, the seeds are in a state of primary dormancy for up to six months (Kuiper *et al*., 1996). After ripening is a second prerequisite for germination, the preconditioning of the seeds which requires a period of imbibitions of water for several weeks under humid and warm (25-35°C) conditions (Kebreab and Murdoch, 1999; Ast, 2006). Prolonged preconditioning induces secondary dormancy which usually occurs when the *Striga* seeds have reached maximum sensitivity (Matusova *et al*., 2004). Germination of *S. hermonthica* is induced by stimulants exuded by roots of host and some non host plants (Spitko *et al*., 2010). These host-derived germination stimulants are termed as xenognosins (Lynn *et al*., 1981; Yoder, 2001), and they have been identified as sesquiterpene strigolactones (Matusova *et al*., 2005 ; Ayongwa *et al*., 2006).

A brief exposure of pre-conditioned *Striga* seed to a xenognosin is sufficient to initiate germination within 8-12 hours after initial exposure (Ejeta *et al*., 1992). The spatial relationship between host roots and *Striga* seed germination is a function of the distance from the host root (Fate, 1990.). The germination stimulant concentration determines its ability to elicit germination. *Striga hermonthica* being an obligate parasite must form connections with vascular system of a host plant, via the haustorium, in order to obtain water, nutrients, and carbohydrates (Ast, 2006). Seed germination and haustorial initiation cannot be elicited in the absence of specific chemical cues. The chemical elicitors of haustorial initiation are different to those moieties that stimulate germination (Maiti *et al*., 1984, Riopel and Timko, 1995). Chemicals shown to trigger haustorial formation include 2, 6-dimethoxy-p-benzoquinone, and phenolics including, quinones and cytokinins (Estabrook, 1998).

The germinating seed produces a root like structure, the radicle. In order to attain a successful host attachment, germination must take place within 3-4 mm of the host root since *Striga* radicles have limited growth potential (Ramaiah *et al*., 1991). The radicle growth is directed towards the host root under the influence of a gradient of chemical concentration of root exudates (chemotropism) (Patterson and Williams, 1976). It is the emergence of the radicle that is used to indicate germination of the seed, which is followed by a series of physical and biochemical reactions leading to the great losses in productivity of the host plants.

This complex host-parasite interaction during early growth of the parasite is mediated by the intensity of the levels of the germination stimulants that signals initiation of the process. Thus these levels are of special interest in breeding for resistance or tolerance to *Striga.* For example, reduction in amounts or absence of germination stimulants produced by cereal host plants provides means to reduce numbers of seeds germinating at a particular point in time and space. Low or no stimulant production by cereal roots has been shown to be a mechanism of host plant resistance / tolerance to *S. hermonthica* infections (Weerasuriya *et al*., 1993; Heller and Wegmann, 2000; Ayongwa *et al*., 2006). The objective of this study was, therefore, to screen wide range of maize genotypes (420) of different classes and sources to identify the low- or non-germination stimulant producing ones.

3.2 Materials and methods

3.2.1 *Striga* and maize genotypes

Clean *S. hermonthica* seeds were harvested from maize fields in western Kenya and prepared as germination batches following the procedure by Berner *et al*. (1995). The 420 maize genotypes were obtained from various sources, including CIMMYT Gene Bank in Mexico, KARI and IITA (Table 3.1).

Table 3.1. List of germplasm examined to determine the presence of the germination stimulant

Germplasm	Number	Source	Putative trait	Reference
Land races	370	CIMMYT-Mexico Gene bank accessions	Drought tolerant	M. Banziger (Personal communication)
Populations	10	IITA-Nigeria	*Striga* resistant	A. Menkir (Personal communication)
Inbred lines	24	KARI-Muguga	*Striga* resistant	J. Ininda (Personal communication)
Inbred lines	10	IITA-Nigeria	*Striga* resistant	A. Menkir (Personal communication)
Mutator lines	2	CIMMYT	*Striga* resistant	S. Hearne (Personal communication)
Herbicide resistant lines	2	CIMMYT	*Striga* resistant	Kanampiu *et al*, 2005
Susceptible checks	2	Seed companies	Commonly used by farmers	Kanampiu *et al*, 2005

3.2.2 Methods

3.2.2.1 *Striga* cleaning and conditioning

The *Striga* seeds were first surface sterilized with 1% sodium hypochlorite in a beaker and rinsed with sterile water for five minutes. Two 9 cm regular filter papers were moistened and placed in a sterile petri dish. A paper punch was used to extract disks of glass fiber filter paper (5 mm diameter) in order to minimize microbial growth and a pair of forceps was used to dab up small amounts of (about 10-25) *Striga* seeds with the glass fiber disks. The disks were then placed on a moist filter paper lining the petri dish. The petridishes were then covered using aluminium foil to create an artificial darkness and then incubated in an oven at 30 °C for 14 days for pre-conditioning. The maize plants were sown the same day the *Striga* seeds were placed in an incubator to synchronize for the maximum strigol production which occurs during the early stage of root development. The maize plants were grown in small pots 20 cm diameter, containing sterile sand.

Five plants were grown in a single pot. After 14 days of growth the seedlings were uprooted and the roots washed and macerated.

3.2.2.2 Testing the maize for stimulant production

After collecting the root exudates from the macerated maize roots and having conditioned the *Striga* seeds, small aluminum foil rings with a diameter of 1-2 cm and height of 1.5 cm was made and used as wells. Petri dishes were lined with moistened two pieces of regular filter paper; the rings were then placed at the center of the petri dishes. One gram of the mercerated root pieces was weighed and placed into the aluminum well. The glass fiber disks with the conditioned *Striga* seeds were placed next to the aluminum foil well. Four radii of glass fiber disks radiated out from the central well as shown in figure 3.1. The glass fibre disks were used as distances from the source of *Striga* germination stimulant with the closest to the source being distance 1 (D1) up to 4 (D4). Three mililitres of sterile deionized water was added to the roots in the center well. Synthetic germination stimulant GR24 was used as a positive control while sterile water was used as a negative control. The petridishes containing root exudates and conditioned *Striga* seeds were covered with aluminium foil and returned into the incubator for 48 hours. The number of germinated *Striga* seeds on each glass fiber disk was counted after 48 hours under the light microscope, and a tally counter was used to ensure accuracy.

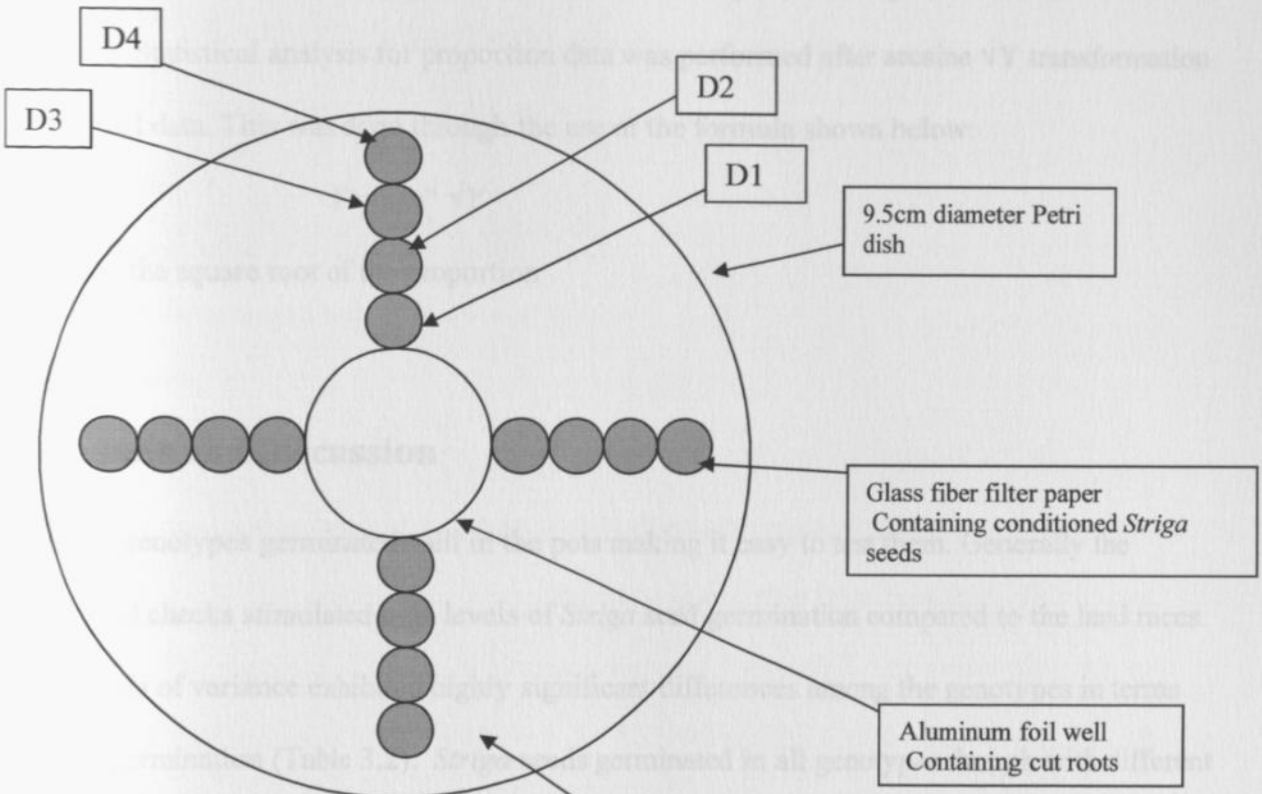

Figure 3.1. Testing for *Striga* germination in the laboratory

3.3 Data collection and analysis

The assessment of *Striga* germination was done under a dissecting microscope by counting the number that had started to germinate or germinated, 2 days after receiving the stimuli. A seed was scored as germinated if the root tip (radicle) was seen having protruded through the seed coat (Plate 3.2). The number of germinating seeds was expressed as a percentage of the total number that received the germination stimulant per disk, per radial position and per petri dish. The data was subjected to analysis of variance (ANOVA) procedures for a randomized block design. The correlation coefficient of the germination percent was also calculated. Statistical analysis system (SAS 9.1) was used and the means were separated using Duncan's linear mean separation. Statistical analysis for proportion data was performed after arcsine √Y transformation of the actual data. This was done through the use of the formula shown below:

$$Y' = sin^{-1} \sqrt{Y}$$

Where Y= the square root of the proportion

3.4 Results and Discussion

All maize genotypes germinated well in the pots making it easy to test them. Generally the commercial checks stimulated high levels of *Striga* seed germination compared to the land races. The analysis of variance exhibited highly significant differences among the genotypes in terms of *Striga* germination (Table 3.2). *Striga* seeds germinated in all genotypes though with different intensities and this showed the presence of germination stimulants (Ma et al., 1996). The genotypes were grouped and tested according to their classes; the inbred lines were grouped together while the landraces and the open pollinated and hybrid checks were grouped together.

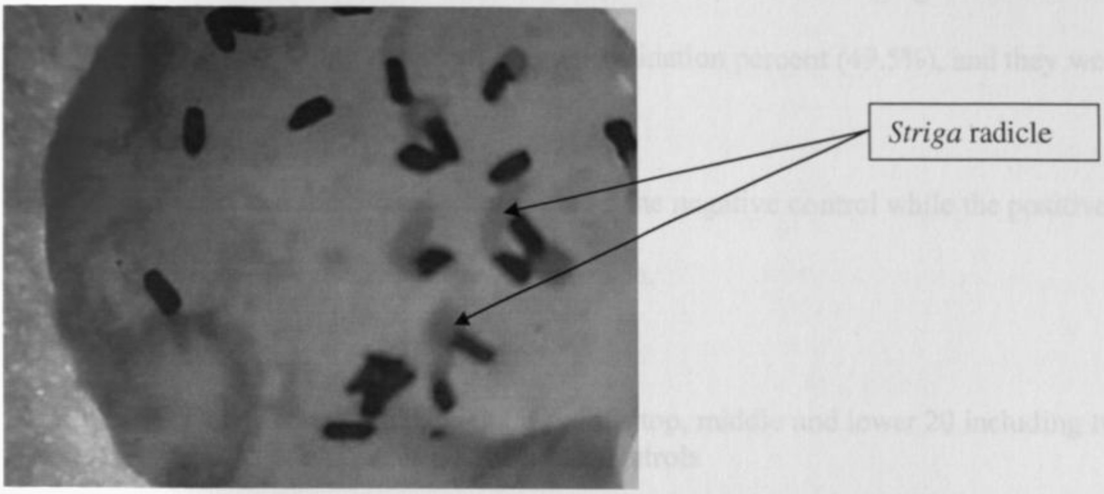

Plate 3.1. Striga radicle observed under a dissecting micro scope

3.4 .1 Land races

Significant differences (P=0.001) were observed among the land races in terms of *Striga* germination percent with a range of 3.71% to 53.4%. The least *Striga* germination was recorded from the land race CRIC 51 (3.71%) while the highest was recorded from the GR24 (58.7%) the synthetic Strigol as expected. The top 20 landraces had less than 10% *Striga* germination while the commercial checks had 37.95% and 49.51% for KSTP94 and PHB3253 respectively. The top five land races with the lowest *Striga* germination percent included; Land races CRIC51, CUBA T31, BRAZ1758, BRAZ 1279 and VERA 217 with 3.7%, 4.4%, 5.2% and 6.0% respectively. These landraces can be regarded as resistant to *Striga*. The Land races with prefix BRAZ constituted about 30% of the genotypes tested and of the 129 land races with the prefix (BRAZ) tested, 49 were among the landraces with low *Striga* germination percent in top 100 genotypes. These particular land races constituted 60% of the top 20 genotypes with the lowest *Striga* germination percent. Low *Striga* germination percent depicts low production of *Striga* germination stimulant which is one of the best characterized mechanism for *Striga* resistance (Vasudeva, 1987). There was no significant difference between the two commercial checks even though KSTP94 is a tolerant variety as opposed to PHB3253 (Table 2) which is susceptible. Variety KSTP 94 a tolerant commercial variety stimulated 38% *Striga* germination while PHB3253 exhibited a slightly higher *Striga* germination percent (49.5%), and they were ranked 330 and 367 out of 375 genotypes.

As expected there was no *Striga* germination in the negative control while the positive control GR24 exhibited a high, 58.7% *Striga* germination.

Table 3.2. *Striga* germination percent (%) of the top, middle and lower 20 including two commercial checks and positive and negative controls

	Rank	Entry	Genotypes	*Striga* germination percent (%)
Top 20	1	106	CRIC 51	3.71
	2	321	CUBA T-31	4.35
	3	167	BRAZ 1758	4.55
	4	151	BRAZ 1279	5.22
	5	105	VERA 217	5.99
	6	170	BRAZ 1832	6.82
	7	337	ARZM 14105	7.68
	8	165	BRAZ 1738	7.73
	9	107	CRIC 52	7.94
	10	189	BRAZ 2151	7.94
	11	314	CHIS 743	8.00
	12	143	BRAZ 917	8.35
	13	153	BRAZ 1384	8.43
	14	146	BRAZ 1114	8.56
	15	79	PARA GP3	8.91
	16	150	BRAZ 1188	9.09
	17	128	PARA 151	9.18
	18	173	BRAZ 1863	9.28
	20	166	BRAZ 1757	9.57
Middle 20	21	265	BRAZ 1059	22.02
	22	90	CAUC 381	22.03
	23	99	VERA 177	22.13
	24	262	PERU 636	22.19
	25	353	PAZM 14107	22.21
	26	327	PAZM 10043	22.42

	Rank	Entry	Genotypes	*Striga* germination percent (%)
	27	120	HAIT 19	22.54
	28	217	BRAZ 1403	22.66
	29	121	HAIT 21	22.71
	30	354	PAZM 14119	22.71
	31	23	HAIT GP6	22.76
	32	211	BRAZ 2093	22.79
	33	247	BRAZ 2258	22.79
	34	230	URUG 116	22.90
	35	114	CUBA 73	22.93
	36	169	BRAZ 1831	23.42
	37	116	CUBA 85	23.49
	38	214	BRVI 100	23.50
	39	52	CUBA 156	23.78
	40	220	BRAZ 1477	23.79
Bottom 20	41	39	SNLP 104	42.18
	42	228	URUG 696	42.18
	43	277	BOLI 461	42.32
	44	368	BRAZ 1731	42.56
	45	340	PAZM 4039	42.63
	46	276	PUEB 101	42.65
	47	93	VALL 385	43.37
	48	275	PUEB 82	44.23
	49	288	NAYA 130	45.20
	50	361	PAZM 14096	46.07
	51	255	ECUA 433	46.37
	52	283	GUAN 36	46.71
	53	317	CUBA 316	46.75
	54	36	GUAT 79	46.96
	55	359	PAZM 2019	48.19
	56	420	PHB3253	49.51
	57	360	PAZM 2036	49.67
	58	296	ARZM 16021	51.62
	59	278	CHIS 39	51.68
	60	363	OAXA 553	53.40
Checks	61	423	Positive control GR24	58.78
	62	424	Distilled water	0.00
	MEAN			25.20
	CV			26.83
	LSD			9.15
	SIG			***

3.4.2 Inbred lines

The inbred lines in the study stimulated a higher *Striga* germination percent with a mean of 38.8% (Table 3.3) compared to that of the land races 25.2%.

The CIMMYT inbred lines were among the top 5 inbred lines with low *Striga* germination percent ranging from 14.3% to 29.7% (Table 3). CML 444IR stimulated the highest *Striga* germination in this group where 49.3% was recorded. Among these lines some were imidazolinone resistant (IR) which is a *Striga* control technology where IR maize seed is treated with herbicide, low doses of imazapyr (30g/ha) is used to coat the maize thereby giving effective control of *Striga* in the early stages of parasitic attachment to maize seedlings (Kanampiu and Friesen, 2003). These lines were not coated with the herbicide and from the results; it shows that other than being herbicide resistant they also stimulate low *Striga* seed germination.

The KARI Muguga inbred lines were the second group with low *Striga* germination percent with a range of 29.7% to 35.8%. The inbred line EARLY-N-POP-7-13-5-1 in this group stimulated the highest *Striga* seeds to germinate 50.1%. Five inbred lines were among the top ten with the lowest *Striga* seed germination.

The IITA inbred lines exhibited higher germination percent compared to other inbred lines though they are known to be *Striga* resistant (Abebe, M., personal communication 2008). The stimulation ranged from 38.5% to the 56.6%. The resistance mechanism of these lines is likely to be through avoidance by having less branched root architecture which resists attachments of the nearby germinated *Striga* or a kind of incompatibility that does not support normal growth of the attached parasites as was observed with the inbred line ZD05 which was developed from *Zea diploperennis* (Amusan *et al*., 2008).

Table 3.3. Different Levels of *Striga* germination percent exhibited by the inbred lines

Rank	Entry	Genotypes	*Striga* germination percent (%)
1	411	CML202IR	14.34
2	417	CML444	22.37
3	415	CML445-IR	22.59
4	416	CML395	23.7
5	394	CML206//56/44-6-3-7-1	29.72
6	388	JI-30-18	33.03
7	399	F1-14-79-4-1-3	34.32
8	382	JI-30-7	34.56
9	386	JI-30-16	35.18
10	400	OSU231//56/44-6-4-17-3	35.79
11	412	CML204IR	35.92
12	383	JI-30-7	36.91
13	372	TESTR 133	38.46
14	380	TESTR 156	39.02
15	391	JI-30-21	40.46
16	387	JI-30-17	40.82
17	397	F1-14-14-24-4-5-4	40.92
18	398	DT//56/4-6-1-15-2	41.27
19	381	JI-30--4	42.03
20	375	TESTR 149	42.9
26	414	CML444-IR	49.26
27	384	JI-30-8	49.87
28	376	TESTR 150	50.03
29	373	TESTR 136	50.04
30	393	EARLY-N-POP-7-13-5-1	50.14
31	379	TESTR 153	56.55
32	423	Positive control GR24	58.71
33	424	Negative control- Distilled water	0.00
	MEAN		**38.75**
	CV		**18.44**
	LSD		**9.78**
	SIG.		*******

Germination was particularly high around the source of stimulant, which suggests the higher the concentration of the stimulant the higher the *Striga* germination. Highly significant positive correlation was observed between *Striga* germination and the distance from the source of the stimulant (Table 3.4). The observed spatial relationship between host roots and *Striga* seed germination as a function of the distance from the host root where germination stimulant is still active, i.e., concentrated enough to elicit germination has been reported by other workers (Fate, 1990).

Table 3.4. Correlation between *Striga* seed germination and the distance from the source of *Striga* germination Stimulant

	Germination percent			
Distance	**D1**	**D2**	**D3**	**D4**
D1				
D2	0.71***			
D3	0.69***	0.75***		
D4	0.62***	0.71***	0.78***	

D= Glass fibre disc

The germination stimulant is mainly exuded in a region 3 to 6 mm from the root apex (Hess *et al*., 1991; Riopel and Baird, 1987). In the present study, the disks which were next to the aluminum foil (the source of stimulant) recorded the highest germination percent compared to the rest. A similar observation was also made by Fasil *et al* (1993) when he reported significance difference in germination distance.

3.5 Conclusions and Recommendations

The land races used in the present study had low levels of *Striga* germination stimulant production compared to commercial checks, and hence could serve as useful sources to select for resistance to *Striga* in maize. The best land races in this score were CRIC 51, CUBA T-31, BRAZ 1758, BRAZ1279 and VERA 217. The land races with the prefix BRAZ were found to be among the best in terms of low *Striga* germination production. These constituted over 60% in the top 20 land races with the lowest *Striga* germination group. The inbred lines induced a higher germination of *Striga* seeds as opposed to the landraces, likelihood that the inbred lines produced higher concentrations of germination stimulant.

Five CIMMYT inbred lines exhibited the lowest germination percent below 23%. These were particularly low, especially the IR inbred lines CML 202 IR, CML 445 IR and CML 204 IR. This suggested that the IR lines may possess good levels of resistance to *Striga* in addition to being herbicide resistant.

The KARI- Muguga sourced inbred lines exhibited moderate levels of *Striga* germination percent which is an indication of good resistance levels to *Striga*. Higher levels of germination percent were also observed from the IITA inbred lines known to be resistant to *Striga.* These inbred lines probably possess resistance through avoidance by growing deep root architecture rather than through low production of *Striga* germination stimulant. This mechanism could be of importance to breeders if used in combination with the ability to produce low stimulants. These types of materials would lead to suicidal *Striga* germination that in the long turn will result in reduced *Striga* seed bank in the soil. Inbred lines with low levels of *Striga* germination percent can be used by maize breeders for further evaluation and also for the development of new maize varieties resistant to *Striga*. The mechanism of resistance found in the IITA inbred lines needs to be studied further as it could be more beneficial in long run.

CHAPTER FOUR

Identification of new sources of resistance to *Striga hermonthica* from CIMMYT maize gene bank accessions under artificial *Striga* infestation

Abstract

Striga hermonthica (Del.) Benth infestation on farmers' fields is one of the major factors responsible for low maize yields (1.5tha^{-1}) in sub-Saharan Africa. It is estimated that 10-40 billion *Striga* seeds are added to the soil each year through continued cropping of susceptible cereals such as maize and sorghum. Identification of new sources of resistance to *Striga* would provide options towards *Striga* control and management. A total of 370 landraces and 11 IITA open pollinated varieties including three commercial checks were tested under both artificial *Striga* infestation and *Striga* free environments in Kibos and Alupe. The most resistant landraces were CHIS53, JAMA 8, SNLP104, PAZM14140 and CUBA I-66, with grain yields ranging 3.0 to 4.5 t/ha. The mean yield in the *Striga* free environment was 4.3 t/ha, but only 2.9 t/ha in the *Striga* infested environment, depicting a yield loss of 33%. These superior genotypes identified from among the gene bank accessions could be used as sources of resistance to *Striga* in the development of maize varieties for *Striga* infested areas.

Key words: *Striga hermonthica,* Landraces, gene bank accessions, *Striga* artificial infestation

4.1. Introduction

Maize is an important cereal crop in Africa. It constitutes the staple diet of many people in sub-Saharan Africa as evidenced by the high annual consumption levels of 79 kg per capita in the continent and 125 kg per capita in Kenya (Groote et al., 2002). However, the parasitic weed *Striga* threatens cereal grain production in many parts of sub-Saharan Africa as it infests 40% of the cereal- producing areas (Idris *et al.,* 2008). The weed is the greatest biotic stress for maize production particularly to resource poor farmers in the western and Lake Region areas of Kenya where about 80,000 ha and increasing area cropped with maize are severely infested causing an estimated $10 million in annual losses to maize producing small scale resource poor farmers (Hassan et al., 1995). The yield losses associated with infestation depend on the crop cultivar, weather and the degree of infestation. The losses range from 20 to 80% and sometimes complete yield loss has been recorded under heavy *Striga* infestation (Berner et al., 1995).

The lifecycle of *Striga* is mainly dependent on that of its host. It produces thousands of minute, dust like seeds that can remain viable in the soil for over a decade (Bebawi et al., 1984; Andrianjaka et al., 2007). *Striga* seed germination is induced by exudates of many hosts and non-host plants including maize. The non host cereal and legume inducers are classified as trap crops (Bouwmeester et al., 2003). Approximately 75% of the overall *Striga* damage to the host is inflicted during its subterranean stage of development (Parker and Riches, 1993). Phytotoxic effects of *Striga* on its host have been demonstrated by (Rank et al., 2004) and damage can reach maximum level before the parasite emerges above ground. This makes it very crucial to manage the weed while below the ground for successful *Striga* management.

The control of *Striga* is difficult to achieve because of its high fecundity and asynchronous seeds germination (Andrianjaka et al., 2007). Its management, therefore, will need an integrated approach that would include host plant resistance, biological, cultural practices, and chemical herbicides. The use of *Striga* resistant or tolerant varieties of maize can be an effective way of reducing *Striga* damage as components of integrated *Striga* management in this crop (Parker and Riches, 1993; Carsky et al., 1996; Franke et al., 2005).

Some variability for *Striga* tolerance exists in maize. However, the level and stability of the tolerance has been less effective in the field. The tolerance mechanism is based largely on ''avoidance root architectures'' where deep rooted crops goes beyond the top 20 cm of the soil where most *Striga* seed are found (Hearne, 2001). Complete resistance or immunity against *Striga* has not yet been found in maize. It is, therefore, recommended to direct maize breeding efforts towards developing varieties that combine resistance with high levels of tolerance (Rodenburg, 2005). Host plant tolerance mechanism against *Striga spp* does not prevent the parasite from developing and producing seeds. The soil *Striga* infestation level is maintained and in some instances increased, thereby resulting in future infections (Ejeta, 2007). Hence tolerance should never be considered a stand-alone defense mechanism because toleraqnce breaks down depending on the *Striga* infestation intensity..

Development and introduction of resistant maize cultivars for western and the Lake Victoria region of Kenya would provide a solution for the resource poor farmers. Breeding *Striga* resistant maize varieties offers an economical and viable option as it is compatible with the low cost input requirements of the subsistence farmers to control *Striga* (Meseka and Nour, 2001). Rao *et al*., (1982) found out that genetic resistance lessens the subterranean damage by *Striga*.

The goal of this study was to identify new sources of resistance to *Striga* from maize gene bank accessions.

4. 2 Materials and Methods

A total of 384 genotypes that included 370 gene bank accessions from CIMMYT Mexico, 11 open pollinated varieties from IITA and three local checks were evaluated on-station at Kibos, Nyanza and Alupe, western province, Kenya under both artificial *Striga* infestation and *Striga* free environments during the 2009 long and short rainy seasons. Kibos with heavy clay soils is located at 0°4'S, 34°48'E at an elevation of 1240 masl. Alupe with loamy soils is located at 0° 29'N, 34° 02' E at an elevation of 1289 masl.

Striga seeds were added to each plot to ensure that each maize plant was exposed to a minimum of 2,000 viable *Striga* seeds (Berner *et al.,* 1995). This was done by first preparing the inoculums following standard procedures (Kim, 1994). These seeds were added in a sand/seed mixture and placed in an enlarged planting hole at a depth of 7–10 cm (directly below the maize seed). The genotypes were planted in single row plots of 5-m length and spaced at 75 cm between rows and 25 cm between hills. Two seeds were sown per hill but later thinned to one plant per hill, giving a plant density of about 53,333 plants per hectare. The trials were planted in an 32 x 12 α- lattice experimental design with 2 replications. Normal agronomic crop husbandry was carried out. Weeding was done 3-weeks after planting and thereafter hand spot pulling was done only to remove weed other than *Striga*. Di-ammonium phosphate (18-46-0) fertilizer was applied at planting at the 50 kg N and 128 kg P_2O_5 per hectare, while top dressing was done 6 weeks later using calcium ammonium nitrate (CAN) at 50 kg N per hectare.

Data were recorded from each plot on agronomic traits, including; days to 50% anthesis, root lodging count and shoot lodging count; and disease scores for gray leaf spot and *Exserohilum* *turcicum* on a 1-5 score (1=no disease symptom, 5=extensive damage) (Kim, 1994); Grain yield estimated from plot grain weights was adjusted to 15% moisture content.

Striga damage rating was recorded using a 1-9 scale (Where 1-3= no damage, 4- 6= extensive leaf blotching, wilting, some stunting and 7-9= complete scotching) (Plate 4.1).

a) *Striga* damage rating score 1-3 (Strga emerged but no physical damage to the crop)

b) *Striga* damage rating score 4-6 (Heavy *Striga* infestation and clear damage to the crop)

c) *Striga* damage rating Scores 7-9 (Overwhelming *Striga* presence and crop devastated)

Plate 4.1. *Striga* damage rating scale 1-9

Striga counts data were recorded by counting the number of *Striga* plants emerged per plot starting at 8 weeks after planting up to 12 weeks after planting. *Striga* count per square metre was computed and the data were later transformed using,

$LOG_{10}(X + 1)$

Where : X= counts per square meter.

These data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the statistical systems (SAS) package (SAS, 2003), at individual and across locations. Means were separated using Duncan's Multiple Range Test at $p<0.05$. $LSD_{(0.05)}$ values based on analysis of variance were also computed to allow pair-wise multiple comparisons among means.

4. 3 Results and Discussion

The yield differences under *Striga* free environment were statistically significant between the genotypes yields which ranged from 3.6 to 6.3 t/ha from a combined analysis (Table 4.2). The mean yield of the land races under *Striga* infestation was 2.9 t/ha while the yield under *Striga* free environment was 4.3t/ha. This depicted a yield loss of about 33%. Berner et al (1995) reported grain yield losses in the range of 20-80% in farmers' fields.

There were highly significant differences ($P<0.001$) among genotypes for grain yield, 50% days to anthesis, *Striga* damage rating(SDR) and *Striga* counts per square meter (M^2) (Table 4.1). This indicated variability in severity of infestation (Plate 4.1) as was reported by Hearne, (2001) and Ransom et al., (1997).

Among the three commercial checks PHB3253 exhibited a high SDR (7.3) even though the number of *Striga* plants in the plot was low thus showing severe damage during the *Striga* sub-terranean stage of development in PH3253. Sub-terranean damage alters the host hormonal balance affecting host biomass allocation thereby compromising the host photosynthesis leading to more biomass allocation to the roots at the expense of the stem and reproductive parts (Graves et al., 1989). Some land races such as CHIS 53 and BRAZ 2225 exhibited a lower SDR scores compared to the PHB3253 even though they had a higher *Striga* emergence. These landraces can therefore be considered as having high levels of tolerance to *Striga* infestation.

Plate 2.2. Flowered *Striga* plants on susceptible and tolerant land races at Alupe

This was a clear confirmation of the big damage caused during the *Striga* sub-terranean stage of development as was reported by (Parker and Riches, 1993). Low SDR scores were exhibited from most of the land races, ranging from 3.6 to 5.5. This complied that the land races were tolerant to the *Striga* infestation, which is an effective way of reducing *Striga* damage. Drought tolerant cultivars have deeper roots and less in mass as opposed to susceptible cultivars (Banziger *et al.*, 2000). Hearne (2009) reported avoidance root architecture as a mode of resistance to *Striga* infestation.Franke *et al*., (2005) made a similar observation. The days to 50% anthesis ranged from 58.5 to 94.2 and the mean was 70.8 and several maize landraces yielded higher compared to the three commercial checks. Based on the varietal differential reaction to *Striga* infestation the landrace CHIS53, JAMA 8, SNLP 104, PAZM14140 and CUBA I-66 performed better than the rest. The mean for the *Striga* counts increased from 8^{th} week after planting up to the 12^{th} week after planting. The grain yield for these varieties ranged from 3.0 to 4.5 Tha^{-1}while the checks grain yield ranged from 2.0 to 2.5 Tha^{-1} (Table 4.1). (The individual site and their combined means have been presented in the Appendix tables 17,18 and 19).These varieties can be regarded as resistant or tolerant as they exhibited higher grain yield and lower *Striga* infestation levels as was observed by (Dogget, 1988). Four populations from IITA, TEL COMP. 1 STR SYN-W-1, OBATAMPA/Z.DIPLO SYN-W-1.ZDIPLO SYN-W-1, OBATAMPA/TZL COMP.1 SYN W-1/TEL COMP.1 SYN W-1and STR-SYN-W1 were among the top 20 best performers in terms of grain yield, low levels of *Striga* count and low SDR score. This confirmed their resistance to *Striga* infestation as was reported by Abebe (Personal communication 2008).

The yields under *Striga* free environment were statistically significant among the genotypes and they ranged from 3.6 to 6.3 t/ha (Table 4.2).

The mean yield of the materials in the *Striga* free environment was 4.3 t/ha while in the *Striga* infested plot the mean yield was 2.9 t/ha depicting a yield loss of about 32.6% which is in agreement with what Berner *et al* (1995) reported. The highest grain yield was observed from one of the checks (PHB3253) under *Striga* free environment but consequently had the

Table 4.1. Combined analysis of the top 20 maize landraces and 3 commercial checks evaluated under artificial *Striga* infestation in Alupe and Kibos research stations.

Rank	ENTRY	Genotype	Yield (t/ha)	50% Days to Anthesis (days)	*Striga* damage rating (Score 1-9)	*Striga* count 8 WAP /M^2	*Striga* count 10 WAP/ M^2	*Striga* count 12 WAP/ M^2
1	41	CHIS 53	4.5	94.2	4.2	16.93	23.45	47.40
2	405	TEL COMP.1.STR SYN-W-1	4.3	68.3	3.5	5.55	13.08	21.68
3	124	JAMA 8	3.5	73.8	5.0	8.40	18.40	28.48
4	407	OBANTAMPA /Z. DIPLO SYN- W-1/ Z.DIPLO SYN-W-1	3.3	67.5	4.5	5.53	21.20	33.08
5	39	SNLP 104	3.3	70.5	4.0	3.35	11.38	21.15
6	357	PAZM 14140	3.2	74.0	4.0	6.35	24.20	48.40
7	322	CUBA I-66	3.0	70.3	4.5	16.00	29.40	38.40
8	294	VENE 692	2.9	71.5	4.5	9.58	20.73	37.28
9	305	GUAD 302	2.8	66.0	4.5	6.93	19.28	32.60
10	326	PAZM 8030	2.7	70.0	4.8	16.68	40.60	46.68
11	171	BRAZ 1838	2.7	73.6	3.3	4.93	15.75	25.23
12	403	STR-SYN-W1	2.7	68.8	5.5	6.80	21.40	29.50
13	193	BRAZ 2225	2.7	73.9	3.6	4.79	23.48	52.59
14	307	BRAZ BA145	2.7	70.5	4.0	7.85	16.63	28.60
15	406	OBANTAMPA/ TZL COMP.1 SYN W-1/TEL COMP.1 SYN W-1	2.6	66.8	3.5	7.53	17.05	23.63
16	272	VENE 897	2.6	77.0	5.0	10.33	31.48	41.43
17	202	BRAZ 2314	2.6	69.0	4.0	7.35	22.68	30.00
18	311	CUBA T-12	2.6	67.0	4.5	6.93	21.43	33.55
19	329	PAZM 10067	2.5	73.0	3.8	6.83	27.75	42.73
20	35	GUAT 134	2.5	58.5	4.3	7.60	15.95	32.60
		Mean	***3.0***	***71.2***	***4.2***	***8.3***	***21.8***	***34.7***
21	383	PHB3253 (Commercial check)	2.5	66.8	7.3	11.08	24.13	44.95
22	381	KSTP94 (Commercial check)	2.0	64.8	4.0	9.25	22.28	37.10
23	382	WH502 (Commercial check)	2.3	72.5	5.5	0.28	0.68	1.40
	MEAN		**2.9**	**70.8**	**4.4**	**8.1**	**21.0**	**33.9**
	CV		**36.96**	**6.56**	**39.9**	**38.73**	**33.24**	**31.57**
	LSD		**5.21**	**1.25**	**1.82**	**12.5**	**23.11**	**33.36**
	SIG.		***	***	**	***	***	***

*= 0.05, **= 0.01 and ***= 0.001

Table 4.2. Combined analysis for grain yield and other agronomic traits of the top 20 maize landraces and 3 commercial checks evaluated under *Striga* free environments at Alupe and Kibos research stations.

Rank	ENTRY	PEDIGREE	Yield (t/ha)	50% Days to Anthesis (days)	Turcicum (score 1-5)	No. of plants harvested (no)	No. Ears harvested (no)	Ears per plant (ratio)
1	342	PAZM 6053	5.1	65.5	2.7	17.2	15.1	0.9
2	352	PAZM 10135	4.6	69.5	2.5	18.0	13.8	0.8
3	353	PAZM 14107	4.3	69.2	2.2	17.5	15.8	0.9
4	341	PAZM 5056	4.3	77.2	2.4	16.7	14.3	0.9
5	346	PAZM 7128	4.3	67.2	1.7	16.7	15.8	0.9
6	263	PERU 674	4.2	61.2	2.4	15.0	13.1	0.9
7	54	CUBA 94	4.1	68.0	2.5	17.0	14.1	0.9
8	354	PAZM 14119	4.1	71.0	2.7	18.0	16.1	0.9
9	22	HAIT GP3	4.1	66.0	2.7	15.5	15.6	1.0
10	349	PAZM 10090	4.0	71.5	2.4	15.7	13.6	0.9
11	361	PAZM 14096	4.0	74.0	2.4	14.2	12.6	0.9
12	324	PAZM 10036	3.9	71.7	2.7	17.0	12.8	0.8
13	328	PAZM 14094	3.9	72.7	2.1	18.7	14.8	0.8
14	251	BRAZ 2315	3.8	70.7	2.4	15.5	14.1	1.0
15	308	BRAZ SE025	3.8	71.2	2.4	17.0	12.6	0.8
16	360	PAZM 2036	3.8	70.2	2.2	16.5	17.1	1.1
17	203	BRAZ 2394	3.7	66.0	2.9	15.7	16.3	1.1
18	47	JALI 63	3.7	58.0	3.1	16.7	15.8	1.0
19	403	STR-SYN-W1	3.7	63.7	3.1	17.5	15.1	0.9
20	409	TZL COMP.1/Z.DIPLO SYN	3.6	65.7	3.1	18.7	14.8	0.8
21	383	PHB3253 (Commercial check)	6.3	65.7	2.5	16.2	14.1	0.9
22	381	KSTP94 (Commercial check)	5.2	62.5	2.5	13.0	9.8	0.9
23	382	WH502 (Commercial check)	5.9	70.4	2.4	3.4	0.9	0.8
	MEAN		**4.3**	**68.2**	**2.5**	**16.0**	**13.8**	**0.9**
	CV		**24.44**	**6.24**	**13.64**	**35.25**	**34.89**	**35.74**
	LSD		**1.4**	**5.44**	**0.49**	**3.63**	**4.73**	**0.33**
	SIG.		***	***	***	***	***	***

*= 0.05, **= 0.01 and ***= 0.001

highest yield loss as a result of *Striga* infestation. The land races reached 50% days to anthesis between 61.7-77.2 days, while the checks reached 50% days to anthesis within 62.5 to 70.4 days. Though the landraces had not been screened against *Exserohilum turcicum*, they exhibited scores within the acceptable range of 2.5 (Table 4.2).

4. 4 Conclusions

It is evident that new sources for *Striga* resistance can be exploited from landraces as exhibited by the performance of the genotypes under artificial *Striga* infestation. These landraces are recommended to be used in the maize breeding program to develop inbred lines with resistance to *Striga* infestation.

The IITA populations TEL COMP. 1 STR SYN-W-1, OBATAMPA/Z.DIPLO SYN-W-1.ZDIPLO SYN-W-1, OBATAMPA/TZL COMP.1 SYN W-1/TEL COMP.1 SYN W-1and STR-SYN-W1 were confirmed to be tolerant to *S. hermonthica*. They should similarly be useful in breeding programs to develop *Striga* resistant cultivars.

Growing of tolerant maize varieties can increase the yield in the *Striga* infested areas by between 32.6% and 50% thereby improving on food self sufficiency as observed in the current study.

CHAPTER FIVE

Identification of new maize inbred lines with Resistance to *Striga hermonthica* (Del.) Benth

Abstract

Among the most serious biotic constraint to maize (*Zea mays*) production in the farms of the resource poor in sub-Saharan Africa (SSA) is the root hemi-parasitic weed *Striga hermonthica* (Del) Benth. It decimates maize, pearl millet, sorghum and upland rice in Africa. Host plant resistance is the most feasible and potentially durable option for reducing yield loss from *S. hermonthica*. The objectives of this study were to identify new maize inbred lines with good levels of resistance to *S. hermonthica.* The experiments on 36 maize inbred lines were conducted in pots and field for two seasons. This was done in order to determine the variation in *Striga* emergence and the correlation between the parasite attachments to the roots. Significant differences ($P<0.001$) were detected among the inbred lines for grain yield under *Striga* free environment. *Striga* damage rating was significant ($P<0.05$) among the inbred lines. A highly significant and negative correlation coefficient was observed between grain yield and *Striga* damage rating ($r=-0.67$***). Positive correlation coefficients were observed between grain yield and ear aspect ($r=0.46$***) and plant aspect ($r=0.75$***) respectively. For the pot experiment highly significant differences ($P<0.01$) were observed among the inbred lines for the *Striga* resistance traits. *Striga* attachments were found to be correlated to the number of emerged *Striga* plants. A significant correlation was found between *Striga* attachments and *Striga* counts in pot at 10th WAP ($r=0.25$**) and 14th WAP ($r = 0.31$*). Inbred lines JI-30-19 and OSU231//56/44-6-

4-17-3 were identified as the most resistant lines as they consistently performed well under both *Striga* free and *Striga* infested environments. These inbred lines could be used for maize breeding for *Striga* resistant maize varieties.

Key words: Maize, *Striga hermonthica*, host plant resistance, inbred lines

5.1 Introduction

Maize (*Zea mays*) is one of the major staple food crops in sub-Saharan Africa. The demand for the cereal is expected to increase to about 504 million tons by 2020 thus surpassing the demand for both wheat and rice (IFPRI, 2000). Among the most serious biotic constraints to maize production in resource poor farmers land holdings is the root hemi-parasitic weed *Striga hermonthica.* The parasite decimates maize, pearl millet, sorghum and upland rice in Africa wherever it exists. *Striga* is an obligate parasite and it causes deleterious effects on its host as well as robbing the host of water and nutrients (Yallou *et al*., 2009a). This root- attaching parasite affects over 100 million people globally (Kanampiu *et al*., 2007), (Berner *et al*., 1995). Maize yield losses in from *S. hermonthica* infestation in Africa ranges from 20-80% (Berner *et al*., 1995), but the losses can sometimes reach 100% in susceptible maize cultivars under severe field infestations (Ransom *et al*., 1990; Haussmann *et al*., 2000). Development of host plant resistance and tolerance are the most feasible and effective *Striga* control strategy, and is a potentially practical option for reducing yield loss from *S. hermonthica* for farmers who lack the financial means to use high input management practices and other options to control *Striga* in maize fields (Doggett, 1984;Ramaiah *et al*., 1991).

The International Institute for Tropical Agriculture (IITA) have developed artificial field infestation techniques that impart uniform infestation with the parasite and accurately identifies cultivars resistant to *S.hermonthica* from diverse germplasm (Kim, 1991). The institute has also developed many maize lines, hybrids and populations with improved field tolerance and resistance to *Striga* (Kim, 1994; Menkir *et al*., 2001). Tolerant materials support a number of emerged *Striga* plants which may ultimately flower and set seeds resulting in an increase in *Striga* seed bank in the soil. This therefore calls for further screening towards high *Striga* resistance levels as *Striga* resistant varieties reduce parasite seed reproduction and contribute to depletion of the soil seed bank (Haussmann, 2004). To obtain resistant germplasm, a good source of resistance was obtained from elite tropical germplasm as well as populations from local maize collections in Africa and an accession of *Zea diploperennis* in their genetic background as donor parents (Yallou *et al*., 2009). Subsequently resistant inbred lines with high resistance levels were developed through intensive screening of the germplasm in the field.

An ideal maize inbred line with the desired levels of resistance under field conditions should allow few emergence of parasitic plants and show very low parasitism and little loss in grain yield (Kim, 1991; Kim, 1994). Such an inbred line probably would have low levels of *Striga* emergence stimulants, resulting in low emergence. It is of paramount importance to understand the relationship between the number of emerged *Striga* plants in the field and the attachment of the germinated *Striga* seeds to host roots. The aim of this study was therefore to identify maize germplasm with good levels of *Striga* resistance in pots and field from diverse maize inbred lines under artificial *Striga* infestation. The study sought first to confirm the efficacy of the IITA sourced resistance under Eastern Africa conditions and secondly to explore the possible presence of field resistance in germplasm obtained from Kenyan sources.

5.2 Materials and Methods

5.2.1 Field experiment

A total of 36 maize inbred lines from various sources which included KARI, CIMMYT and IITA (Table 5.1) were evaluated on-station at Kibos (0°4'S, 34°48''E) and Alupe (0° 29'N,34° 02'E) under both artificial *Striga* infestation and *Striga* free environments during 2009 long rainy season and short rainy season. Artificial infestation was conducted in a specially developed field facility to screen large numbers of breeding lines. Plants were artificially infested with *S. hermonthica* seeds. *Striga* seeds were added to each plot to ensure that each maize plant was exposed to a minimum of 2,000 viable *Striga* seeds.

Table 5.1. The list of maize inbred lines tested under both *Striga* free and *Striga* infested environments.

Entry	Genotype	Source	Entry	Genotype	Source
1	OSU231//56/44-6-4-17-3	KARI	19	JI-30-17	KARI (MUGUGA)
2	TESTR 152	IITA	20	TESTR 139	IITA
3	JI-30-19	KARI (MUGUGA)	21	CML444-IR	CIMMYT
4	JI-30-1-19	KARI (MUGUGA)	22	DT//56/4-6-1-15-2	KARI (MUGUGA)
5	F1-14-14-24-4-5-4	KARI (MUGUGA)	23	CML395	CIMMYT
6	CML444	CIMMYT	24	JI-30-21	KARI (MUGUGA)
7	F1-14-79-4-1-3	KARI (MUGUGA)	25	JI-30-7	KARI (MUGUGA)
8	TESTR 153	IITA	26	JI-30-8	**KARI (MUGUGA)**
9	JI-30--4	KARI (MUGUGA)	27	TESTR 149	IITA
10	JI-30-18	KARI (MUGUGA)	28	TESTR 132	IITA
11	JI-30--3	KARI (MUGUGA)	29	CML202IR	CIMMYT
12	TESTR 156	IITA	30	MGA19-4-1	KARI (MUGUGA)
13	CML204IR	CIMMYT	31	TESTR 136	IITA
14	EARLY-N-POP-7-13-5-1	KARI (MUGUGA)	32	TESTR 151	IITA
15	JI-30-22	KARI (MUGUGA)	33	E11-133/7/44-6-3-17-3-2	KARI (MUGUGA)
16	TESTR 150	IITA	34	TESTR 133	IITA
17	JI-30-16	KARI (MUGUGA)	35	CML206//56/44-6-3-7-1	KARI (MUGUGA)
18	JI-30-7	KARI (MUGUGA)	36	CML395-IR	CIMMYT

These seeds were added in a sand/seed mixture and placed in an enlarged planting hole at a depth of 7–10 cm (directly below the maize seed).

The genotypes were planted in a 5 m single row plots, spaced at 75 cm between rows and 25 cm between hills, two seeds per hill which was later strategically thinned to one plant per hill, to give a population of approximately 53,333 plants per hectare. The crops were planted in an alpha lattice (0,1) design with 2 replicates. Normal crop husbandry practices were followed; weeding was done three weeks after planting and thereafter hand pulling was done only to remove other types of weed other than *Striga*. Di-ammonium phosphate (18-46-0) was applied during planting at 50 and 128 kg N and P_2O5/ha, and top dressing was done using calcium ammonium nitrate (CAN) at 50 kg N/ha.

Data were recorded from each plot on agronomic traits which included: grain yield, days to 50% anthesis, and days to 50% silking, anthesis silking interval, plant height and ear height. Reaction to major diseases was also assessed, including gray leaf spot and *Exserohilum turcicum*. *Striga* damage rating was recorded using a scoring scale 1-9 (Where 1-3= no damage, 4- 6= extensive leaf blotching, wilting, some stunting and 7-9= complete scotching) (Plate 4.1). *Striga* counts data were assessed by counting the number of *Striga* plants emerged per plot starting at 8 and after every two weeks up to 12 weeks after planting.

5.2.2 Pot experiment

The 36 maize inbred lines were planted in pots 20 cm diameter and 30 cm in height. The pots were filled with sand soils up to 25 cm from the pot bottom. The *Striga* inoculum was applied in each pot using a table spoon to ensure about 2000 viable *Striga* seeds per pot. An enlarged hole was made in the sand in each pot and the maize seeds were placed directly on top of the inoculum. Four maize seeds were sown in each pot and later thinned to two to ensure a uniform stand. The data recorded included *Striga* counts 10, 12 and 14 weeks after planting (WAP), flowering *Striga* plants at 12, 14 and 15 WAP and *Striga* plants setting seeds at 12, 14 and 15 WAP. *Striga* attachments were recorded after washing the maize roots and later counting individual attachments.

5.2.3 Statistical analysis

Striga count per meter squared was calculated and the data was later transformed using,

$LOG10(X + 1)$

Where: X= counts per meter squared.

Adjustment of grain yield to 15% moisture content was done after harvest. The data were then subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the statistical systems (SAS) package (SAS, 2003) at individual and across locations. Means were separated using Duncan's Multiple Range Test at $p<0.05$. LSD (0.05) values based on analysis of variance were also calculated to allow pair-wise multiple comparisons among means.

5.3 Results

5.3.1 Field experiments

5.3.1.1 *Striga* free environment

There were highly significant differences ($P<0.001$) in grain yield among the inbred lines (Table 5.2). The mean grain yield was 1.4 t/ha and the range was 0.1 to 4.3 t/ha. Inbred line OSU231//56/44-6-4-17-3 gave the highest grain yield while CML395IR gave the lowest grain yield. Among the top 10 inbred lines in terms of grain yield seven were from KARI one from CIMMYT and two from IITA.

There were also highly significant (P<0.01) differences observed in days to 50% anthesis, days to 50% silking, plant height, ear height, root lodging, *E. turcicum* and plant aspect. The stem lodge and ear aspect were significant at P<0.05. The most susceptible inbred lines for *E. turcicum* were those from IITA by between 3 and 4 in a scale of 1-5. These materials have not been screened against *turcicum* blight disease. The inbred lines included: TESTR 133, TESTR 136, TESTR 151, TESTR 153, TESTR150 and TESTR 132. However inbred lines TESTR 149, TESTR 139 TESTR 152 and TESTR 156 gave a score of less than 3. Most of the resistant inbred lines with low *turcicum* scores were the KARI- Muguga lines.

5.3.1.2 *Striga* infested environment

There were significant genetic differences (P<0.05) in reaction to *Striga* infection among the maize inbred lines. A mean of 5.1 for *Striga* damage rating (SDR) and a range of 2.5 to 6.5 were observed. The genotypes with desirable SDR scores were identified as JI-30-18, CML 202IR, JI-30-19, JI-30-20, JI-30-22, TETR 150, JI-30-21 and JI-30-16. These inbred lines had a score of 2.5 - 4 which is considered resistant according to the scale described by Kim (1994). Inbred line OSU231//56/44-6-4-17-3, though had a score of 6 was among the top 5 best in terms of grain yield. This line could be considered tolerant as the *Striga* effect on grain yield performance was minimal. It is noted that six out of these eight lines had a JI- prefix which probably underscores a common pedigree of a resistant origin.

Table 5.2. Performance of the maize inbred lines under *Striga* free environment

Rank	Entry	Grain yield (t/ha)	Days to 50% anthesis (days)	Plant height (cm)	Ear height (cm)	Root lodge (%)	Stem lodge (%)	*E. turcicum* (score 1-5)	Plant aspect (score 1-5)	Ear aspect (score 1-5)
1	30	4.3	64.3	200	103	2.5	1.0	2.4	3.5	3.0
2	8	4.1	70.0	145	80	1.5	0.3	2.5	3.8	4.0
3	19	4.0	65.8	184	101	5.3	0.5	2.4	4.0	3.5
4	20	3.9	63.8	199	103	5.5	1.8	2.5	3.5	3.3
5	27	2.4	68.0	190	103	1.5	1.5	2.1	3.3	3.0
6	36	2.3	74.3	135	78	2.3	0.8	2.5	2.8	3.3
7	29	2.2	67.3	195	114	8.3	0.0	2.6	3.5	2.5
8	9	1.9	68.5	169	94	0.8	1.0	3.0	3.3	3.3
9	11	1.6	69.3	111	74	2.5	0.0	2.3	2.5	3.5
10	18	1.5	78.3	146	88	7.0	0.3	2.0	2.8	4.5
11	15	1.5	75.8	136	75	6.5	0.5	2.4	3.0	4.0
12	10	1.4	71.5	146	73	1.5	0.3	2.4	2.5	4.5
13	32	1.4	77.8	134	84	3.3	2.0	2.4	3.5	4.5
14	23	1.4	74.8	133	84	7.0	0.8	2.5	2.8	4.3
15	22	1.3	75.8	138	88	5.5	1.3	2.1	3.8	4.3
16	6	1.2	65.1	136	75	2.3	0.0	3.0	2.0	3.5
17	16	1.1	78.5	115	91	7.3	0.8	2.4	2.3	4.0
18	13	1.1	74.8	123	70	3.5	0.5	2.8	2.3	4.3
19	4	1.1	68.8	114	64	4.0	2.5	2.8	1.8	4.0
20	17	1.1	77.8	134	80	2.8	1.5	2.6	2.5	4.3
21	34	1.1	75.3	136	85	2.0	3.5	2.8	2.8	4.5
22	28	1.0	76.3	104	63	5.5	1.5	2.6	1.8	4.3
23	35	1.0	76.3	154	80	2.3	0.0	2.4	3.3	3.8
24	21	1.0	75.5	140	88	6.3	0.5	2.4	3.0	4.3
25	12	0.9	71.5	123	68	1.8	0.3	2.8	2.0	4.5
26	14	0.8	81.0	121	70	2.8	0.5	2.8	2.5	4.8
27	5	0.7	70.5	153	93	2.8	2.3	2.9	2.8	4.0
28	1	0.6	74.5	149	74	7.5	0.3	3.0	2.3	4.0
29	26	0.5	71.5	128	73	0.8	0.5	3.0	2.0	3.8
30	31	0.5	78.5	106	63	0.0	0.8	2.3	1.8	4.5
31	3	0.4	69.0	126	74	11.3	1.5	3.4	2.0	4.0
32	7	0.4	80.0	165	88	4.0	0.0	3.1	2.5	3.8
33	25	0.2	73.5	159	93	8.5	0.5	2.0	2.0	3.3
34	2	0.1	73.3	93	60	4.3	0.8	4.0	2.3	3.0
35	24	0.1	75.0	150	90	5.3	0.0	2.1	2.5	5.0
36	33	0.1	88.8	87	63	2.8	1.5	2.3	2.0	4.8
	Mean	1.4	73.3	140.9	81.6	4.1	0.9	2.6	2.7	3.9
	CV(%)	30.5	7.7	25.5	22.6	29.9	28.8	16.3	20.9	26.3
	LSD(0.05)	1.94	8.10	50.19	25.61	4.60	1.89	0.58	1.12	11.93
	Sig.	***	***	***	***	***	*	***	***	*

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

There were significant differences among the inbred lines (P<0.05) in grain yield, days to 50% anthesis (AD) and days to 50% silking (Table 5.3). The mean grain yield was 2.1 t/ha and the range was 0.2 to 2.9 t/ha. Inbred lines JI-30-19, OSU231//56/44-6-4-17-3, F1-14-14-24-4-5-4, JI-30-18 and TESTR 156 were the top 5 best performers. They gave desirable grain yield of between 1.9 and 2.9 t/ha under artificial *Striga* infestation. Inbred line JI-30-20 yielded the least (0.2 t/ha). The mean for AD was 68.4 days and the range was 65 to 86.8 days, while the mean for SD was 72.8 and the range was 69.5 to 71.2 days.

There were significant differences in reaction to *E.turcicum* among the inbred lines similar to what was observed under *Striga* free conditions in the present study (Table 5.3). Thus *Striga* infestation does not appear to interfere with expression of resistance or susceptibility to *E. turcicum*.

There were highly significant differences in *Striga* counts (P<0.001) at 12 WAP. Genetic variations among the inbred lines were observed in *Striga* counts 8 , 10 and 12 WAP. The mean *Striga* count at the 12th WAP was 7.9 *Striga* plants per meter squared and the range was 2.85 to 46.48 *Striga* plants per meter squared (Table 5.3). Inbred lines TESTR 139, TESTR 151, TESTR 152, TESTR 132, TESTR 150, TESTR 136, TESTR 156, TESTR 149, JI-30-21 and JI-30-19 gave the least number of *Striga* plants per square meter.

Further assessment on the resistance of the maize inbred lines was done by examining the relationship between the grain yield and the *Striga* resistance traits.

Table 5.3. Performance of the maize inbred lines under artificial *Striga* infestation

Rank	Entry	Grain yield (t/ha)	50% days to anthesis (days)	*E. turcicum* (score 1-5)	Ear aspect (score 1-5)	*Striga* damage rating (score 1-9)	*Striga* count 8 WAP /M^2	*Striga* count 10 WAP /M^2	*Striga* count 12 WAP /M^2
1	19	2.9	75.8	2.3	1.8	3.5	0.48	0.70	0.78
2	30	2.4	65.0	3.0	3.3	6.0	0.95	1.38	1.65
3	27	2.2	68.5	3.5	4.3	5.3	0.88	1.38	1.53
4	10	1.9	73.8	3.5	3.8	5.3	0.55	0.70	0.93
5	18	1.9	77.5	1.8	3.8	2.5	0.48	0.75	1.03
6	23	1.7	80.5	1.8	3.8	4.3	0.35	1.03	1.28
7	29	1.7	75.5	3.5	4.8	4.5	1.03	1.23	1.35
8	11	1.6	68.0	3.3	4.3	4.3	0.78	1.15	1.43
9	15	1.6	78.0	2.5	4.3	4.8	0.58	0.98	1.10
10	24	1.6	76.5	1.8	4.3	4.8	0.45	1.03	1.33
11	9	1.5	73.5	3.8	3.8	4.8	0.65	1.05	1.33
12	33	1.2	74.6	3.0	4.3	4.3	0.48	0.88	1.18
13	31	1.2	75.0	2.8	4.3	3.3	0.40	0.95	1.15
14	14	1.1	77.5	2.0	3.8	4.5	0.33	0.80	0.98
15	16	1.1	78.3	2.0	3.8	4.0	0.63	1.08	1.40
16	12	1.1	77.3	3.3	4.8	5.0	0.50	0.98	1.18
17	7	1.1	72.0	3.8	3.8	4.5	0.20	0.50	0.68
18	21	1.1	79.3	1.5	3.8	4.0	0.80	0.83	1.08
19	6	1.0	68.5	3.5	4.5	4.0	0.18	0.58	0.78
20	4	1.0	70.5	2.5	3.8	5.5	0.10	0.25	0.53
21	13	1.0	78.6	2.5	4.3	6.5	1.03	1.28	1.38
22	22	0.9	76.8	2.3	3.8	4.0	0.68	1.10	1.38
23	32	0.9	74.8	3.3	4.3	5.5	0.98	1.35	1.58
24	5	0.9	69.5	3.3	3.8	4.5	0.30	0.75	0.90
25	17	0.9	86.8	2.5	4.5	4.8	0.60	0.73	0.93
26	3	0.9	71.5	3.0	3.8	5.5	0.23	0.60	0.93
27	36	0.9	73.3	2.8	3.0	4.8	0.55	0.75	1.13
28	28	0.8	79.3	2.5	4.0	5.5	0.73	0.98	1.23
29	35	0.8	77.3	2.8	5.0	4.8	0.65	0.80	1.18
30	26	0.8	71.0	3.5	4.3	4.3	0.48	0.98	1.10
31	25	0.8	74.0	2.5	4.3	5.0	0.83	1.15	1.50
32	2	0.7	68.5	3.8	4.3	6.0	0.53	0.88	1.10
33	8	0.7	85.2	2.5	4.0	5.8	0.30	0.45	0.68
34	34	0.5	75.5	3.0	4.0	5.5	0.50	1.05	1.28
35	1	0.4	75.5	4.0	3.8	5.0	0.55	0.68	0.75
36	20	0.2	83.3	3.8	4.5	4.0	0.68	0.83	1.00
	Mean	2.1	73.8	2.8	3.6	4.5	0.7	1.0	1.2
	CV (%)	27.4	8.7	24.7	17.4	30.4	33.5	34.8	32.9
	LSD (0.05)	1.36	9.25	1.44	1.41	2.02	0.50	0.57	0.52
	Sig.	*	***	**	*	*	**	**	***

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

This was investigated through the use of simple linear correlation coefficients from combined analysis data for the two sites (Table 5.4). A highly significant ($P<0.001$) and negative correlation was observed between grain yield and SDR (r = -0.67***), but no significant correlation was observed between grain yield and *Striga* counts. The *Striga* resistance traits were highly correlated among them selves. *Striga* counts 8 WAP was highly correlated to *Striga* count 10 WAP (r=0.81***) and 12 WAP (r=0.77***). *Striga* count at 10 WAP was positively and highly correlated to *Striga* count 12 WAP (r=0.95***). The grain yield was also found to be positively correlated to ear aspect (r=0.46***) and plant aspect (r=0.75***). It was clear that for the more resistant genotypes, *Striga* counts peaked at week 12 and declined towards the 14^{th} week. Therefore to assess resistance at week 12 should probably be recommended. The decline of *Striga* plants from 12^{th} week after planting could be attributed to plants dying after the host has succumbed to infestation at the maximum level.

Table 5.4. Correlation between yield and the *Striga* resistance traits under *Striga* infested condition

Traits	YLD	AD	SD	ASI	PH	EH	EPP	GLS	RUST	TURC	EA	PA	SDR	STR8	STR10
YLD	1.00														
AD	-0.23														
SD	-0.38*	0.76***													
ASI	-0.13	-0.12	0.37*												
PH	0.35	-0.40**	-0.38**	-0.15											
EH	0.58***	-0.40**	-0.47***	-0.32*	0.43**										
EPP	0.39**	0.33**	-0.03	-0.41**	-0.10	0.20	1.00								
GLS	0.34**	-0.09	-0.08	-0.14	0.06	0.39**	0.14	1.00							
RUST	0.14	-0.16	-0.15	-0.25	0.03	0.29	0.26	0.33**	1.00						
TURC	-0.26	-0.47	-0.20	0.17	0.22	0.01	-0.57***	0.17	0.12						
EA	0.46***	0.11	0.21	0.18	-0.08	-0.30	-0.44	-0.32*	-0.25	0.28	1.00				
PA	0.75***	-0.36**	-0.57***	-0.10	0.33*	0.59***	0.31	0.22	0.11	-0.07	-0.20				
SDR	-0.67***	-0.16	-0.06	0.25	-0.05	-0.49***	-0.24	-0.24	-0.16	0.28	0.16	-0.28	1.00		
STR8	0.17	0.04	0.19	0.37*	0.11	0.12	-0.17	-0.11	-0.15	0.04	0.18	0.01	0.22	1.00	
STR10	0.27	-0.13	-0.04	0.27	0.24	0.23	-0.17	-0.11	-0.14	-0.01	0.21	0.13	0.15	0.81***	1.00
STR12	0.21	-0.15	-0.01	0.35*	0.15	0.18	-0.17	-0.21	-0.24	-0.08	0.22	0.12	0.15	0.77***	0.95***

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

Yld= Yield, AD= days to 50% anthesis, SD= days to 50% silking, ASI= anthesis silking interval, PH= Plant height, EH= ear height, GLS= Gray leaf spot, *turc*= *E.turcicum*, SDR= *Striga* damage rating, STR8= *Striga* counts 8WAP, STR10= *Striga* counts 10WAP and STR12= *Striga* counts 12 WAP

5.3.2 Pot experiment

Highly significant differences were observed among the inbred lines in *Striga* counts at 10 WAP (Table 5.5). But this was not the case at 12 WAP. However at the 14 WAP the number of *Striga* plants which emerged hadhighly significant (P<0.01) differences. The number of emerged *Striga* plants varied among the different genotypes (Plate 5.1). For the susceptible genotypes *Striga* emerged as from the 6WAP which was very early as opposed to the resistant genotypes.

Plate 5.1. Emerged *Striga* plants on maize inbred lines planted in pots

Flowering *Striga* plants per pot was not significant at 12 and 14 WAP, but it was highly significant at 15 WAP. The *Striga* plants setting seeds per pot was not significant at 12 WAP, though it exhibited significant differences (P<0.05) at 14 and 15 WAP. The number of *Striga* attachment observed was not significant. The mean number of attachments per pot was 20.71 and the range was 0 to 74.5 *Striga* attachments per pot (Table 5.5). These observations were similar to those found in the field.

the range was 0 to 74.5 *Striga* attachments per pot (Table 5.5). These observations were similar to those found in the field.

After computing a simple linear correlation between the *Striga* resistance traits, *Striga* attachments were found to be significantly correlated to *Striga* counts at 10 WAP (r=0.25** and 14 WAP (r= 0.31*) (Table 5.6). The *Striga* setting seeds were also significantly correlated to the number of attachments per pot.

Table 5.5. *Striga* resistance traits recorded in pot experiment under artificial *Striga* infestation

Rank	Entry	*Striga* count 10 WAP /M^2	*Striga* count 12 WAP /M^2	*Striga* count 14 WAP /M^2	Flowering *Striga* plants 14 WAP /M^2	Flowering *Striga* plants 15 WAP /M^2	*Striga* plants setting seeds 14 WAP /M^2	*Striga* plants setting seeds 15 WAP /M^2	*Striga* Attachments (no)
1	31	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.50
2	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
4	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
5	7	1.05	1.05	1.30	0.15	0.15	0.15	0.15	28.00
6	5	2.50	3.05	2.60	0.00	0.00	0.00	0.00	29.50
7	6	2.80	2.95	2.70	0.35	0.35	0.00	0.15	7.50
8	36	2.55	2.85	2.75	0.40	0.50	0.30	0.40	32.50
9	26	3.15	3.05	2.75	0.30	0.30	0.00	0.25	73.50
10	4	2.50	2.80	2.85	0.00	0.00	0.15	0.30	25.00
11	1	4.70	5.21	2.90	0.19	0.00	0.00	0.15	5.50
12	15	2.50	2.70	2.90	0.15	0.15	0.00	0.00	19.50
13	20	2.75	3.05	2.90	0.00	0.15	0.30	0.40	22.50
14	35	1.75	1.75	2.95	0.50	0.55	0.40	0.45	4.00
15	19	3.35	3.30	2.95	0.15	0.15	0.30	0.30	9.50
16	16	2.75	3.05	2.95	0.00	0.15	0.00	0.15	38.50
17	22	3.20	3.20	3.05	0.50	0.65	0.40	0.40	20.50
18	23	2.80	2.95	3.05	0.30	0.30	0.15	0.30	26.00
19	2	3.10	3.20	3.15	0.30	0.55	0.00	0.00	3.00
20	13	3.10	3.15	3.15	0.15	0.50	0.00	0.30	3.00
32	29	3.20	3.30	3.35	0.55	0.65	0.15	0.50	74.50
33	12	2.65	3.10	3.40	0.00	0.00	0.15	0.30	44.00
34	17	3.25	3.45	3.45	0.40	0.45	0.15	0.55	23.00
35	11	3.45	3.50	3.55	0.45	0.65	0.15	0.50	14.50
36	14	3.70	3.70	3.60	0.65	0.90	0.00	0.15	14.50
Mean		2.65	16.84	2.72	5.39	0.33	0.11	0.24	20.71
CV (%)		29.84	21.2	14.54	31.20	33.85	31.10	31.00	32.48
LSD(0.05)		1.61	1.41	0.83	0.18	0.49	0.28	0.45	59.87
Significance		***	**	***	***	**	*	*	NS

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

Table 5. Correlation between *Striga* resistance traits

Traits	1	2	3	4	5	6	7	8	9
1.*Striga* count 10 WAP									
2.*Striga* count 12 WAP	0.33*								
3.*Striga* count 14 WAP	0.92***	0.04							
4.Flowering *Striga* plants 12WAP	0.34*	0.99***	0.06						
5.Flowering *Striga* plants 14WAP	0.32*	0.10***	0.03	0.99***					
6.Flowering *Striga* plants 15WAP	0.50***	-0.21	0.57***	-0.17	-0.21				
7.*Striga* setting seeds 12 WAP	0.33*	0.99***	0.03	0.99***	0.99***	-0.23			
8.*Striga* setting seeds 14 WAP	0.15	-0.14	0.25	-0.10	-0.14	0.36**	-0.10		
9.*Striga* setting seeds 15 WAP	0.41**	-0.07	0.47***	-0.06	-0.07	0.53***	-0.07	0.73***	
10.*Striga* attachments	0.25**	-0.13	0.31*	-0.15	-0.13	0.20	-0.14	0.12	0.31*

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

5.4 Discussion

A broad range of genetic variation in *Striga* resistance traits was exhibited in this study particularly in the number of *Striga* plants emerged and the number of *Striga* plants attached. Similar results were reported by Amusan et al., (2008). Under *Striga* infested conditions, the days to 50% flowering for the most susceptible inbred lines was delayed by about 5 days and some maize inbred lines did not reach days to 50% silking. Cases of delayed flowering while testing several maize cultivars under different nitrogen levels were also reported by Kim et al., (1997) . Our results also agree with these results in which some inbred lines never silked leading to reduction in yield due to lack of fertilization. The delay in flowering is a common observation in maize subjected to stresses other than *Striga*, for example drought stress (Banziger et al.,2000).

The ear aspect of the tolerant and resistant inbred lines was significantly superior compared to that of the susceptible inbred lines. The usefulness of the ear aspect in the assessment of host plant response to *Striga* infection was also reported by other workers (Kim et al., 1997) . The inbred line JI-30-19 plant response to *Striga* infection was also reported by other workers (Kim et al., 1997) . The inbred line JI-30-19 exhibited the best ear aspect and also gave the highest grain yield. The number of ears harvested from the maize inbred lines tested in this study proved to be a major component of grain yield under *Striga* infestation as was previously reported by Kim, (1991). Most of the inbred lines with field resistance to *Striga* had significantly fewer attached parasites as opposed to the susceptible inbred lines. These results were consistent with previous observations reported in maize (Kim, 1999; Amusan et al., 2008). *Striga* emergence in some moderately susceptible inbred lines was found to be similar to *Striga* emergence in some resistant and tolerant lines, as was observed in inbred lines tested in the field (Table 4). Previous results from several studies showed that *Striga* emergence counts from tolerant maize cultivars and from moderately susceptible cultivars were not significantly different. This discredits the use of *Striga* emergence counts as the only criterion to distinguish genetic control of *Striga* tolerance in maize (Kim, 1994; Kim and Adetimirin, 1997). This is probably because resistance may often be confounded by tolerance existing in the same germplasm.

A significant and negative correlation has been shown between grain yield and *Striga* damage rating (SDR) (Kim and Adetimirin, 1997; Amusan et al., 2008). Similar observations were made in the present study where a significant ($P<0.001$) and negative correlation was recorded between grain yield and SDR ($r = -0.67$***). However there was no significant correlation between grain yield and *Striga* counts as would have been expected.

In the present study, the observed significant and positive correlation between the attached and emerged *Striga* plants with the *Striga* damage rating and reduction in grain yield of the maize plants indicated that the possibility exists of selecting maize inbred lines with low SDR scores and *Striga* emergence, and with higher grain yields under *Striga* infection.

As was found in this study, the number of *Striga* attachments has similarly been shown in the past to correlate with the number of emerged parasites in the pots (Kim, 1999;Amusan et al., 2008). Several previous studies have revealed a strong correlation between attached *Striga* plants in pots and the number of emerged parasites both in pots and field. In the present study inbred lines TESTR 139, TESTR 151, TESTR 152, TESTR 132, TESTR 150, TESTR 136, TESTR 156, TESTR 149, JI-30-21 and JI-30-19 had significantly fewer emerged *Striga* plants compared to the susceptible lines. These results suggest the possibility of selection for field resistance to *Striga* by using both attached *Striga* and emerging *Striga* either in the pot or in the field.

5.5 Conclusion

Striga-resistant maize inbred lines were identified from among the diverse range of inbred lines tested. The maize inbred lines with fewer emerged *Striga* plants and low SDR scores were considered as the resistant lines, which confirm many previous studies in maize research. The IITA inbred lines were confirmed as having resistance since most of them supported very few emerged *Striga* plants. However the use of *Striga* counts as a criterion in selection for *Striga* resistance was found not to be the most appropriate. On many occasions a small number of emerged *Striga* plants caused heavy *Striga* damage in some of the inbred lines tested. A significant and negative correlation between grain yield and *Striga* damage rating was observed. The number of emerged *Striga* plants was found to be highly correlated to the number of *Striga* attachments on the maize roots. Through the use of the observed significant and positive correlation of the attached and emerged *Striga* plants with the *Striga* damage rating and reduction in grain yield of the maize plants, it is therefore possible to select maize inbred lines with low SDR scores and *Striga* emergence, and with higher yields under *Striga* infection.

CHAPTER SIX

Field evaluation, combining ability studies and prediction of single cross and double cross maize hybrids from germplasm with resistance to *Striga hermonthica*

Abstract

Maize is an important food source in Africa. Its yield and production has been on the decline, making Africa and specifically Kenya a net importer of the grain. The parasitic weed *Striga* affects maize on an estimated 20 m ha, making it a major cause of maize yield reduction from a near world average of 4.2 t/ha few decades a go to the present 1.3 t/ha. The objectives of this study were to; 1) examine the combining ability of 20 maize inbred lines and, 2) identify F_1 single cross hybrids which can be used to develop other hybrids resistant to *Striga hermonthica* (Del) Benth. The 20 inbred lines used consisted of eight *Striga* resistant lines from IITA, nine *Striga* resistant lines from KARI and three CMLs from CIMMYT. Fourteen female inbred lines were crossed using North Carolina Design II with all six males coming from the IITA group resulting to $84F_1$s. The resulting 84 F_1s along with six commercial checks were evaluated in four separate trials for two rainy seasons during 2010. The trials were conducted on station under both artificial *Striga* infestation and under *Striga* free environments using standard procedures at the Kibos and Alupe sites, both in the Kenya's Lake Victoria Basin. Data were recorded on *Striga* counts from 6[th] weeks after planting (WAP) and repeated every 2 weeks up to the 12 WAP. *Striga* damage rating (SDR) was recorded on a 1-9 scale (1= no damage; 9= totally damaged). Days to male and female flowering, plant height, ear height, grain moisture content and grain yield were also recorded. General combining ability (GCA) and Specific combining ability (SCA) effects were computed using SAS, where the females were considered as the tested lines and the males as the testers. The new F_1 hybrids outperformed the commercial checks in grain yield and reaction to *Striga* infection and damage. The best *Striga* resistant F_1 hybrid yielded 6.8t/ha while the tolerant commercial check gave 3.0t/ha. GCA mean squares due to lines and testers were highly significant (P<0.001) for all traits studied. The ratio of GCA/SCA mean squares exhibited a predominance of additive gene effects in the inheritance of *Striga* resistance traits as opposed to dominance gene effects. Estimates of GCA effects indicated that six inbred lines were good combiners for grain yield. A number of single crosses out yielded the six hybrid checks under artificial *Striga* infestation. Prediction of the performance of single and double cross hybrids was performed. Superior double cross hybrids which gave grain yield of > 6 t/ha were identified. This small number of superior hybrids should further be tested under *Striga* infestation without having to test an enormous number of double cross hybrids. The high GCA inbred lines, the superior single crosses and the predicted double cross hybrids could provide a basis for future development of three-way and double cross hybrids suitable for growing in *Striga* prone areas of the Lake Victoria Basin in eastern Africa.

Key words: GCA, SCA, *Striga hermonthica*, maize inbred lines,

6.1 Introduction

Many African countries often produce less maize than what they consume making them net importers of maize although maize is an important food crop in sub-Saharan Africa (SSA) and it providing the bulk of the calories in diet (Vivek, 2009). The average maize yield is 1.3 t/ha much below the world average of 4.2 t/ha (FAO statistics: www.fao.org). This results in net malnourishment of people due to shortage which affects about 300 million people in Africa (Kim *et al*., 1997). Solutions are needed to various production and marketing problems, including low grain yield, susceptibility to pests and diseases, adaptation to the specific growing ecologies, and yield loss that result from the devastating effects of *Striga* parasitic weed (Kim, 1994).

Many *Striga* control approaches have been developed, without much success when used singly (Kiruki, 2006). The major control strategies are: 1) agronomic control which requires intensive work for several seasons, and 2) the herbicide use which has a risk of *Striga* developing resistance to the chemicals. Integration of several *Striga* control methods offers a better and a cost effective *Striga* control for the resource poor farmers in sub-Saharan Africa.

The use of host plant resistance (HPR) has been limited, though it is the most economically feasible and environmentally friendly means of *Striga* control for the farmer. A series of studies at IITA, found some maize varieties that were tolerant to *Striga* (Kim, 1994). These studies concluded that the genetic control for tolerance and resistance of maize genotypes tested to *S. hermonthica* was polygenic and had quantitative inheritance. Twenty inbred lines and seven synthetics which were found to be tolerant and resistant to *S. hermonthica* were developed from diverse germplasm through artificial infestation with seeds obtained from various host crops (Kim, 1994). Some of these lines were used in the present study to determine their usefulness in variety development in this region.

Combining ability of inbred lines is a factor that determines the usefulness of the lines in hybrid combinations. The value of the line can best be expressed through the performance of crossing combinations (Hallauer and Miranda, 1981). Sprague and Tatum (1942) introduced the terms general combining ability (GCA) and specific combining ability (SCA). The general combining ability can be determined by using a broad base heterogeneous population as tester, while differences in the SCA can be revealed using a tester with a narrow genetic base (inbred line or single cross) (Spitko *et al*., 2010). Identification of inbred lines with good GCA and SCA effects rely on the availability of genetic diversity among different groups of genotypes involved in the breeding programme (Legesse *et al*., 2009). GCA expresses the mean performance of a parental line in hybrid combinations, while the SCA is a measure of the value of individual combinations as a function of the mean performance of the parental components. GCA and SCA are always relative values and depend greatly on the performance of the specific inbred lines involved in the crosses (Spitko *et al*., 2010). The value of GCA tends to express additive gene effects, while SCA is more indicative of dominant and epistatic gene effects.

In the SSA maize is grown over a diverse range of environments starting from the lowlands, mid altitude to the highland ecologies (Derek and Carl, 1997). Some of these regions are infested with *S. hermonthica* which cause a yield loss of 40 to 60% in grain yield but can go up to 100%. The grain lost is estimated at seven billion tons annually, affecting about 100 million people (Kanampiu and Friesen, 2003). Enhancement of maize production in the *Striga* prone areas can be achieved by identifying elite *Striga* resistant lines which can be used to develop high yielding resistant varieties.

The best linear unbiased prediction model (BLUP) has been used by breeders in prediction of hybrid performance. This method uses observations of the relatives of a genotype to estimate its breeding value. The breeding value is calculated as the weighted sum of the performance of a particular line and the performance of its relatives, the closer the relative the larger the weight (Makumbi *et al*., 2010).

The objectives of this study were to: 1) evaluate F_1 single cross hybrids, 2) estimate the combining ability effects of the maize inbred lines from IITA, KARI, and CIMMYT for *Striga* resistance traits, grain yield and foliar diseases, 3) identify promising hybrid crosses which may be used directly or be used in the formation of three way cross and double cross hybrids which can be grown by the resource poor farmers.

6.2 Materials and Methods

6.2.1 Genotypes

Twenty (20) maize inbred lines sourced from three different institutions (Table 6.1) including eight *Striga* resistant inbred lines from IITA, nine resistant inbred lines from the .

Table 6.1. The list of maize inbred lines used in the development of 84 single cross maize hybrids

Entry	Pedigree	Source	Male/female	Remarks
1	CML 444	CIMMYT	Female	Adapted
2	TESTR 153	IITA	Female	*Striga* resistant
3	JI-30--4	KARI	Female	*Striga* resistant
4	JI-30--3	KARI	Female	*Striga* resistant
5	JI-30-18	KARI	Female	*Striga* resistant
6	CML204	CIMMYT	Female	Adapted
7	TESTR 132	IITA	Female	*Striga* resistant
8	CML312	CIMMYT	Female	Adapted
9	CML206//56/44-6-3-7-1	KARI	Female	Adapted
10	F1-14-14-24-4-5-4	KARI	Female	*Striga* tolerant
11	F1-14-79-4-1-3	KARI	Female	*Striga* tolerant
12	OSU231//56/44-6-4-17-3	KARI	Female	*Striga* tolerant
13	JI10-76-#	KARI	Female	*Striga* tolerant
14	JI10-28-#	KARI	Female	*Striga* tolerant
15	TESTR 136	IITA	Male	*Striga* resistant
16	TESTR 139	IITA	Male	*Striga* resistant
17	TESTR 149	IITA	Male	*Striga* resistant
18	TESTR 150	IITA	Male	*Striga* resistant
19	TESTR 151	IITA	Male	*Striga* resistant
20	TESTR 156	IITA	Male	*Striga* resistant

Kenya Agricultural Research Institute (KARI) and three well adapted inbred lines from International maize and Wheat improvement center (CIMMYT) were selected and used in a crossing block at Kiboko Kenya. Fourteen (14) inbred lines were used as females while six *Striga* resistant lines were used as males (Table 6.1). Eighty four (84) single cross hybrids were developed through use of North Carolina Design II mating design.

6.2.2 Field evaluation

The 84 single crosses along with six commercial checks (Table 6.2) were evaluated under both artificial *Striga* infestation and *Striga* free environments. The 20 parents and four checks were also evaluated for two seasons during the 2009 and 2010 long rainy seasons each at Kibos ($0^0$40S, $34^0$48'E) and Alupe ($0^0$29^{0}N, $34^0$20'E) in Kenya. The *Striga* inoculum was prepared by mixing 5 kg of fine river sand with 10 grams of *Striga* seeds. Infestation was done by applying the inoculum in an expanded hill of 7-10 cm depth during planting thus transferring about 7,000 viable *Striga* seeds per hill.

The maize seed was placed on top of the inoculum and covered with soil. The experimental design was an alpha (0, 1) lattice design with three replications (Patterson and Williams, 1976). The spacing was 75 cm between rows and 25 cm between hills. The hybrids were over sown with two seeds per hill and later thinned to one to attain a plant density of 53,333 plants per ha. The six checks included KSTP94 and UA Kayongo as the resistant checks and PHB3253, WH505, H513 and DH04 as the susceptible checks.

Trial management practices including fertilizer application and weeding were done differently for each of the *Striga* infested and *Striga* free environment as recommended. For the *Striga* infested trials, the first weeding was done using a hoe but subsequent weeding was done by hand to uproot o other weeds apart from *Striga*.

Table 6.2. The list of F1 hybrids tested for response to *Striga* damage under *Striga* infestation at Kibos and Alupe in 2009-2010

ENTRY	Pedigree	ENTRY	Pedigree
1	CML 444/ TESTR 136	46	JI-30--3/TESTR 150
2	TESTR 153/TESTR 136	47	JI-30-18/TESTR 150
3	JI-30--4/TESTR 136	48	CML204/TESTR 150
4	JI-30--3/ TESTR 136	49	TESTR 132/TESTR 150
5	JI-30-18/ TESTR 136	50	CML312/TESTR 150
6	CML204/TESTR 136	51	CML206//56/44-6-3-7-1/ TESTR 150
7	TESTR 132/TESTR 136	52	F1-14-14-24-4-5-4/ TESTR 150
8	CML312/TESTR 136	53	F1-14-79-4-1-3/ TESTR 150
9	CML206//56/44-6-3-7-1/TESTR 136	54	OSU231//56/44-6-4-17-3/ TESTR 150
10	F1-14-14-24-4-5-4/ TESTR 136	55	JI10-76-#/TESTR 150
11	F1-14-79-4-1-3/ TESTR 136	56	JI10-28-#/TESTR 150
12	OSU231//56/44-6-4-17-3/ TESTR 136	57	CML 444/TESTR 151
13	JI10-76-#/ TESTR 136	58	TESTR 153/TESTR 151
14	JI10-28-#/TESTR 136	59	JI-30--4/TESTR 151
15	CML 444/TESTR 139	60	JI-30--3/ TESTR 151
16	TESTR 153/TESTR 139	61	JI-30-18/TESTR 151
17	JI-30--4/TESTR 139	62	CML204/TESTR 151
18	JI-30--3/ TESTR 139	63	TESTR 132/TESTR 151
19	JI-30-18/TESTR 139	64	CML312/ TESTR 151
20	CML204/TESTR 139	65	CML206//56/44-6-3-7-1/TESTR 151
21	TESTR 132/TESTR 139	66	F1-14-14-24-4-5-4/TESTR 151
22	CML312/ TESTR 139	67	F1-14-79-4-1-3/TESTR 151
23	CML206//56/44-6-3-7-1/TESTR 139	68	OSU231//56/44-6-4-17-3/ TESTR 151
24	F1-14-14-24-4-5-4/TESTR 139	69	JI10-76-#/TESTR 151
25	F1-14-79-4-1-3/ TESTR 139	70	JI10-28-#/TESTR 151
26	OSU231//56/44-6-4-17-3/TESTR 139	71	CML 444/TESTR 156
27	JI10-76-#/TESTR 139	72	TESTR 153/TESTR 156
28	JI10-28-#/TESTR 139	73	JI-30--4/ TESTR 156
29	CML 444/TESTR 149	74	JI-30--3/ TESTR 156
30	TESTR 153/TESTR 149	75	JI-30-18/TESTR 156
31	JI-30--4/ TESTR 149	76	CML204/TESTR 156
32	JI-30--3/TESTR 149	77	TESTR 132/TESTR 156
33	JI-30-18/TESTR 149	78	CML312/TESTR 156
34	CML204/TESTR 149	79	CML206//56/44-6-3-7-1/ TESTR 156
35	TESTR 132/TESTR 149	80	F1-14-14-24-4-5-4/TESTR 156
36	CML312/TESTR 149	81	F1-14-79-4-1-3/ TESTR 156
37	CML206//56/44-6-3-7-1/ TESTR 149	82	OSU231//56/44-6-4-17-3/ TESTR 156
38	F1-14-14-24-4-5-4/ TESTR 149	83	JI10-76-#/TESTR 156
39	F1-14-79-4-1-3/TESTR 149	84	JI10-28-# /TESTR 156
40	OSU231//56/44-6-4-17-3/TESTR 149	85	PHB 3253-COMMERCIAL CHECK
41	JI10-76-#/TESTR 149	86	KSTP94-COMMERCIAL CHECK
42	JI10-28-#/TESTR 149	87	UA KAYONGO -COMMERCIAL CHECK
43	CML 444/TESTR 150	88	WH505-COMMERCIAL CHECK
44	TESTR 153/ TESTR 150	89	H513-COMMERCIAL CHECK
45	JI-30--4/TESTR 150	90	DH04- COMMERCIAL CHECK

Data for all agronomic traits were recorded on per plot basis for each experiment. The data recorded included *Striga* counts, *Striga* damage rating, days to 50% pollen shed, days to 50% silking, diseases gray leaf spot (caused by *Cercospora zea-maydi)* Northern leaf blight (caused by *Exserohilum turcicum*) and Maize streak virus (MSV) (caused by maize streak geminivirus), grain moisture content and grain yield. *Striga* counts were done at 6th, 8th, 10th, and 12th week after planting by counting the number of *Striga* plants emerged in each plot. *Striga* damage rating was recorded at the 10th week using a scale of 1-9 (1= clean with no damage and 9= heavily damaged). Disease data were recorded on maize streak virus (MSV), gray leaf spot (GLS), rust and Nothern leaf blight using a 1-5 scale (1= no disease and 5=severely diseased). Grain yield (t/ha) was computed from unshelled cobs by taking 0.8 shelling percent and adjusting it to 12.5% grain moisture content.

6.2.3 Statistical analysis

Combined analyses of variance were conducted for all the traits measured for each environment separately. Log_{10} function transformation was done on the *Striga* counts. Using the formula;

$$Y = Log_{10}(X+1)$$

where, Y= Transformed data and X = actual *Striga* counts

Line x tester analyses of variance was performed to estimate general combining ability (GCA) and specific combining ability (SCA) according to the model by (Singh and Chaundhary, 1985) statistical model.

$$Y_{hijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + R_h + \varepsilon_{hijk}$$

Where,

Y_{hijk} = the observation of the k-th full-sib progeny in a plot in h-replication of the i-th paternal parent and the j-th maternal parent;

μ = the general mean;

α_i= the effect of the i-th male parent;

β_j= the effect of the j-th female parent;

$(\alpha\beta)_{ij}$= the interaction of paternal and maternal genotypes;

R_h + the effect of h-th replication and

ε_{hijk} = the environment effect and remainder of the genetic effect between full sibs on the same plot.

Statistical analysis system (SAS, 2003) was used with the environment considered as random effect while the genotype was considered as a fixed effect. The mean squares of variance for the lines (females) and the testers (males) and their interaction effects were determined. The GCA effects of all 20 lines and the SCA effects of the 84 single cross hybrids were determined. Test for significance of the GCA and the SCA effects were performed by computing the standard error for lines, testers and crosses and then tested usingthe t-test and taking the degree of freedom of the pooled error mean square.

The predicted performance of hybrids based on GCA can be calculated by adding the GCA of both parents to the overall mean grain yield (GY) of the single cross hybrids.

Prediction of double cross hybrid performance is crucial to plant breeders especially when dealing with many inbred lines; e.g. for a case of 20 maize inbred lines while using diallel mating design would produce $n(n-1)/2= 190$ single crosses and $3n!/[4!)(n-4)!] = 14535$ double crosses without reciprocals (Allard, 1960). It is actually impossible and expensive for the breeder to evaluate the double cross hybrids, thereby, necessitating the prediction of the double crosses from the performance of the single crosses. The most accurate estimate of the yield of the double cross could be made from the mean yield of the four non parental single crosses. The average performance of single crosses *A X C, A X D, B X C* and *B X D* can be used to predict the performance of the double cross *(A X B) (C X D)* (Allard, 1960).

6.3 Results

6.3.1 Inbred lines under *Striga* free environment

Highly significant differences (P<0.001) were observed in grain yield among the inbred lines (Table 6.3). The mean grain yield of the new inbred lines was 2.26 t/ha while the mean of the trial was 2.29 t/ha. The range for grain yield was 0.5- 4.9 t/ha. Entry 11 was the best in grain yield (4.9t/ha) while entry 15 yielded the least (0.5t/ha) (Table 6.1). The best inbred line check gave a yield of 4.13 t/ha while the least gave 1.17 t/ha.

Highly significant differences were observed in days to 50% anthesis, anthesis silking interval, ear aspect and reaction to diseases (Table 6.3). The inbred lines were within the same maturity bracket compared to the checks. There were some earlier maturing inbred lines that flowered in less than 72 days which was the trial mean. The mean score for *E. turcicum* was 2.2 while the trial mean was 2.17 on a scale of 1-5 and a range of 1.3- 4.7. The inbred line checks exhibited low *E. turcicum* scores compared to the new inbred lines indicating resistance to the disease. The inbred lines with high disease score gave low grain yield.

6.3.2 Inbred lines under *Striga* infested environment

There were highly significant (P<0.001) differences observed among the inbred lines under artificial *Striga* infestation in grain yield (Table 6.4). The mean grain yield of the new maize inbred lines excluding the checks was 1.03 t/ha while the trial mean was 0.74 t/ha and the range was 0.27- 2.33 t/ha.

There were highly significant differences (P<0.001) observed on days to 50% anthesis, ears per plant and ear aspect. Reaction to diseases (*E. turcicum*, GLS and rust) was also highly significant (P<0.001) among the inbred lines. The mean days to 50% anthesis were 70.8 days and the trial mean was 71.9 days.

ENTRY	Grain yield (t/ha)	50% days to anthesis (d)	Anthesis silking interval (d)	Ears per plant (no.)	Ear aspect (Score 1-5)	Maize streak virus (Score 1-5)	E. turcicum (Score 1-5)	Gray leaf spot (Score 1-5)	Rust (Score 1-5)
1	0.80	74	-1.5	0.8	3.3	0.0	2.8	1.7	2.2
2	2.17	78	0.3	0.8	2.5	0.0	1.7	2.8	2.5
3	3.27	68	2.0	0.9	1.7	0.3	2.5	2.8	2.3
4	4.00	69	0.7	0.8	1.3	0.7	1.2	2.2	1.8
5	2.97	76	-3.2	1.0	2.7	0.0	1.0	2.3	2.0
6	2.53	80	-5.7	0.9	2.7	2.0	1.5	2.2	1.8
7	2.17	74	3.7	0.9	2.3	0.3	2.2	2.3	1.8
8	4.27	71	4.0	1.0	1.8	1.0	1.3	1.7	2.2
9	3.30	72	0.3	1.0	2.3	0.7	1.5	2.3	2.0
10	0.90	74	3.7	0.6	4.0	1.7	1.3	1.8	3.2
11	4.90	64	-7.7	1.0	1.8	0.0	1.3	2.3	2.3
12	2.97	68	3.3	0.9	2.7	0.3	2.3	2.0	2.0
13	1.33	75	5.7	0.6	3.5	2.7	2.3	1.8	2.7
14	1.30	63	-0.3	0.9	3.7	0.0	3.5	1.7	1.7
15	0.50	72	9.3	0.6	4.5	0.0	4.7	1.5	1.7
16	4.50	72	3.7	0.8	1.7	0.0	1.8	2.2	1.7
17	0.90	72	0.0	0.6	3.7	0.0	2.8	2.2	1.7
18	0.73	70	4.7	0.7	4.0	0.0	2.8	1.8	1.8
19	0.83	71	4.0	0.7	3.8	0.0	2.7	2.0	1.8
20	0.93	74	5.0	0.7	3.5	0.7	2.8	2.5	3.3
Check 1	1.17	77	4.0	0.6	3.8	0.0	2.2	2.0	1.8
Check 2	1.87	70	1.0	0.8	3.7	0.3	2.3	1.7	3.7
Check 3	4.13	73	2.3	0.9	1.7	0.0	1.7	2.0	1.7
Check 4	2.57	73	2.7	0.9	1.8	0.0	1.8	2.2	1.5
Mean	**2.29**	**72**	**1.75**	**0.80**	**2.85**	**0.44**	**2.17**	**2.08**	**2.13**
CV	**27.14**	**2.42**	**24.604**	**20.89**	**13.52**	**27.64**	**16.46**	**16.47**	**16.39**
LSD	**1.02**	**2.96**	**6.9**	**0.27**	**0.63**	**1.08**	**0.59**	**0.56**	**0.57**
SIG.	***	***	***	**	***	***	***	***	***

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

Table 6.4. Reaction of the maize inbred lines to artificial *Striga* infestation across sites ranked by grain yield

Rank	ENTRY	Grain yield (t/ha)	50% days to anthesis (d)	Anthesis silking interval (d)	Ears per plant (no.)	Ear aspect (Score 1-5)	*Striga* damage rating (Score 1-9)	*Striga* counts 6 WAP	*Striga* counts 8 WAP	*Striga* counts 10 WAP	*Striga* counts 12 WAP
1	5	2.33	76.40	0.66	1.03	2.33	1.84	0.17	0.42	0.56	0.64
2	4	2.17	67.96	2.98	0.93	2.17	2.01	0.22	0.58	0.89	0.99
3	12	1.90	67.79	4.83	0.93	3.00	1.51	0.36	0.73	0.92	1.01
4	11	1.90	64.29	4.14	1.00	3.17	2.67	0.41	0.90	1.21	1.33
5	16	1.60	74.46	4.31	0.97	2.83	3.67	0.20	0.31	0.59	0.73
6	6	1.57	76.13	0.64	1.03	3.00	1.34	0.15	0.43	0.80	0.95
7	8	1.27	73.43	4.31	0.83	3.17	3.37	0.11	0.21	0.46	0.70
8	10	1.17	73.29	0.89	0.90	3.00	1.84	0.20	0.59	1.00	1.12
9	2	0.97	75.79	1.08	0.67	3.50	4.17	0.11	0.24	0.63	0.70
10	7	0.73	74.13	4.33	0.97	3.83	4.01	0.19	0.33	0.84	0.88
11	14	0.73	60.96	0.47	0.97	3.83	4.01	0.22	0.43	0.77	0.90
12	20	0.67	70.63	2.65	0.70	3.83	4.01	0.22	0.43	0.60	0.65
13	3	0.57	69.47	3.43	0.70	3.67	3.84	0.27	0.50	0.87	0.96
14	9	0.53	70.29	7.42	0.57	4.00	3.17	0.48	0.92	1.27	1.31
15	13	0.50	71.79	7.62	0.50	3.83	3.51	0.38	0.76	1.02	1.19
16	19	0.47	71.29	2.16	0.60	4.00	3.01	0.11	0.23	0.34	0.41
17	15	0.47	69.96	2.98	0.80	4.17	5.34	0.07	0.16	0.24	0.39
18	1	0.43	69.71	0.71	0.87	4.17	3.17	0.15	0.17	0.38	0.49
19	18	0.37	69.46	5.14	0.67	4.33	4.51	0.10	0.21	0.49	0.60
20	17	0.27	69.46	2.43	0.47	4.00	3.84	0.05	0.16	0.29	0.39
21	23	1.77	70.29	3.08	0.93	2.50	5.01	0.29	0.55	0.85	0.98
22	24	0.70	72.63	6.31	0.70	3.67	5.41	0.11	0.31	0.79	0.92
23	22	0.40	69.96	1.98	0.77	4.33	4.51	0.14	0.43	0.78	0.79
24	21	0.10	74.79	8.40	0.17	4.67	6.67	0.38	0.67	1.07	1.18
	Mean	**0.74**	**71.92**	**4.94**	**0.64**	**3.79**	**5.40**	**0.23**	**0.49**	**0.87**	**0.97**
	CV	**28.47**	**3.7**	**31.46**	**22.8**	**13.86**	**46.85**	**82.94**	**47.83**	**32.69**	**28.67**
	LSD	**0.7822**	**3.11**	**5.4**	**0.2914**	**0.8067**	**1.84**	**0.2**	**0.24**	**0.28**	**0.28**
	SIG.	*****	*****	***	*****	*****	*****	*****	*****	*****	*****

*, **, *** - Significant at 0.05, = 0.01 and = 0.001 respectively

WAP= Weeks after planting

The inbred lines reacted differently to *Striga* infestation with the checks being highly devastated (Plate 6. 1). The *Striga* syndrome rating was highly significant (P<0.001).

Plate 6.1. Effect of *Striga* infestation on susceptible maize inbred lines tested under artificial *Striga* infestation at Kibos

The trial mean for the SDR was 5.40 while the mean of the new inbred lines was 3.24. Maize inbred lines with very good scores were identified as entries 5, 6, 10, and 12, which exhibited resistance as they had scores of lower than 2 and gave significant grain yield. The top best eight (8) entries exhibited SDR scores of between 1.51- 3.37 using a scale of 1-9.

6.3.3 Single cross hybrids under *Striga* free environment

There were highly significant differences observed on grain yield among the F_1 hybrids ($P<0.001$) (Table 6.5). The mean grain yield was 4.6 t/ha and the range was 2.1 – 6.7 t/ha. Among the single crosses in the top 20 best performers 45% consisted of parent TESTR 156 as the male. The best commercial hybrid check gave a yield of 4.8 t/ha, exhibiting the superiority of the new F_1 hybrids, they were ranked ranked 44. The new F_1 hybrids were within the same maturity bracket compared to the commercial checks meaning the varieties fits well in that ecology. The mean for 50% days to anthesis of the F_1's was 65.5 days while that of the commercial checks was 66.5 days.

Highly significant differences ($P<0.001$) were observed in reaction to *E. turcicum,* GLS and rust. The mean for *E. turcicum* was 2.8 and the range was 2.0 - 4.5 in a scale of 1-5. The new F_1 hybrids exhibited a high level of resistance to the major diseases comparable to the commercial checks which were well adapted (Plate 6.2).

It was noted that the single crosses from susceptible parents also succumbed to *E. turcicum* disease (Plate 6.2) as was exhibited by hybrid JI10-28-#/ TESTR 136. The female parent exhibited high *E. turcicum* scores (4.7 using a scale of 1-5). Differences in gray leaf spot and leaf rust among the hybrids were also highly significant ($P<0.001$). The mean for the two diseases were 1.4 using a scale of 1-5. The range for gray leaf spot was 1.2 – 2.0 while the range for rust was 1.1 – 1.9.

Plate 6.2. Reaction of the F_1 hybrids to *E.turcicum*

6.3.4 Single cross hybrids under *Striga* infested environment

There were significant differences observed for grain yield, days to 50% pollen shed, days to 50% silking, *Striga* damage rating, *Striga* counts at 8, 10 and 12 but not at 6 WAP among the genotypes under artificial *Striga* infestation (P<0.01) (Table 6.6). The mean grain yield was 2.50 t/ha and the range was 2.30 to 6.80 t/ha for the new F_1 hybrids while the range for the commercial checks was 2.1 to 3.0 t/ha.

Table 6.5. Mean performance of the top 20 single cross hybrids for yield and other agronomic traits across sites under *Striga* free environment

Rank	ENTRY	Grain yield (t/ha)	50% days to anthesis (d)	Anthesis silking interval (d)	Ear aspect (Score 1-5)	Maize streak virus (Score 1-5)	*E. turcicum* (Score 1-5)	Gray leaf spot (Score 1-5)	Rust (Score 1-5)
1	74	6.7	67.3	0.8	1.9	0.8	2.4	1.5	1.8
2	79	6.6	65.9	1.6	1.8	0.8	2.0	1.3	2.0
3	80	6.4	64.8	1.3	2.1	0.3	2.1	1.5	1.8
4	78	6.3	65.6	0.3	2.0	0.8	2.5	1.5	1.8
5	71	6.3	68.5	-0.6	2.2	0.8	2.6	1.4	1.6
6	75	6.2	67.7	0.8	2.2	0.5	2.3	1.3	2.1
7	82	6.2	69.0	0.8	2.0	1.1	2.3	1.5	2.0
8	76	6.1	68.5	1.1	2.1	0.3	2.5	1.5	1.6
9	32	6.1	65.7	-0.1	2.2	0.3	2.5	1.7	1.2
10	51	6.0	65.5	1.0	2.2	0.3	2.1	1.3	1.2
11	50	5.9	64.9	1.3	2.3	0.6	2.5	1.7	1.3
12	9	5.8	63.8	0.7	2.0	0.6	2.2	1.2	1.8
13	73	5.8	67.1	0.3	2.3	1.0	2.3	1.5	1.7
14	38	5.7	63.9	0.3	2.5	0.5	2.6	1.7	1.2
15	37	5.7	66.3	0.9	2.2	0.3	2.2	1.2	1.2
16	64	5.7	65.9	1.3	2.4	0.4	2.8	1.3	1.5
17	23	5.6	65.3	1.8	2.3	0.3	2.1	1.3	1.2
18	4	5.5	64.0	0.9	2.0	0.4	2.3	1.3	1.7
19	47	5.4	65.5	1.2	2.5	0.6	2.3	1.6	1.2
20	52	5.4	63.6	1.3	2.6	0.3	2.5	1.8	1.1
Mean		***6.0***	***65.9***	***0.8***	***2.2***	***0.5***	***2.4***	***1.4***	***1.5***
46	88	4.8	67.8	1.5	2.7	0.9	2.4	1.3	1.8
48	85	4.8	68.8	2.6	3.0	0.6	2.2	1.2	1.6
54	89	4.5	65.0	3.3	3.0	1.7	2.5	2.0	1.7
60	90	4.4	64.8	1.8	3.1	1.1	2.7	1.6	1.7
69	86	3.7	63.3	3.7	3.2	1.3	2.5	1.6	1.9
85	87	2.7	69.3	2.4	3.5	0.4	2.6	1.3	1.6
Mean		***4.6***	***65.6***	***1.1***	***2.8***	***0.5***	***2.8***	***1.5***	***1.4***
CV		***32.57***	***3.69***	***37.34***	***18.16***	***43.04***	***17.42***	***29.75***	***29***
LSD		***1.21***	***1.94***	***0.89***	***0.41***	***0.66***	***0.39***	***0.34***	***0.33***
Sig.		***	***	***	***	***	***	***	***

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

The mean grain yield of the top 20 F_1 hybrids was 6.18 t/ha while the mean of the commercial checks was 2.6 t/ha. This would depict an increment of over 100% in terms of grain yield if the farmers grew the new single cross hybrids.

Striga damage rating (SDR) scores were highly significant (P<0.001) among the F_1 hybrids. From SDR cores resistant, tolerant and susceptible genotypes were identified. Single crosses JI-30--3/ TESTR 151, JI-30-18/TESTR 151, CML206//56/44-6-3-7-1/ TESTR 149, JI-30-18/TESTR 156 and CML206//56/44-6-3-7-1/TESTR 156 exhibited very low SDR scores in the range of 1.3 - 2.3 on a scale of 1- 9. *Striga* count differences at 6 WAP were not significant as expected as most of the genotypes had very few or no emerged *Striga* plants at that early stage. However *Striga* counts at 8, 10 and 12 WAP were highly significant (P<0.001) (Table 6.6).

Table 6.6. The mean grain yield performance of the top 20 single cross maize hybrids and reaction to artificial *Striga* infestation from a combined analysis in Alupe and Kibos.

Rank	ENTRY	Grain yield (t/ha)	50% days to anthesis	50% days to silking	*Striga* damage rating (Score 1-9)	*Striga* count 6 WAP /M²	*Striga* count 8 WAP /M²	*Striga* count 10 WAP /M²	*Striga* count 12WAP /M²
1	60	6.8	66.0	66.4	1.3	0.03	0.33	0.67	0.93
2	61	6.8	66.0	66.7	1.7	0.03	0.27	0.75	0.96
3	37	6.4	65.4	66.0	1.8	0.04	0.52	1.01	1.18
4	75	6.4	65.8	67.8	2.3	0.13	0.79	1.23	1.38
5	79	6.4	65.7	66.6	1.7	0.08	0.49	1.04	1.25
6	74	6.4	66.3	68.0	1.7	0.08	0.57	1.13	1.31
7	80	6.3	64.3	66.1	1.4	0.06	0.67	1.19	1.34
8	23	6.2	64.5	66.2	2.7	0.04	0.47	1.02	1.17
9	5	6.2	64.5	65.5	1.8	0.01	0.53	0.94	1.09
10	64	6.2	65.4	66.4	1.6	0.08	0.48	0.97	1.26
11	4	6.1	63.8	65.0	1.7	0.02	0.37	0.78	0.98
12	67	6.1	64.8	65.6	1.5	0.04	0.41	0.73	1.02
13	51	6.0	64.4	65.8	3.2	0.04	0.55	1.03	1.20
14	65	6.0	64.9	65.5	1.4	0.11	0.48	0.88	1.08
15	59	6.0	64.5	65.3	1.5	0.03	0.42	0.75	0.91
16	9	5.9	62.6	63.5	2.5	0.06	0.47	0.90	1.06
17	71	5.9	67.3	67.8	2.2	0.08	0.65	1.15	1.33
18	57	5.9	67.2	66.9	1.6	0.06	0.45	0.96	1.07
19	47	5.8	64.9	66.3	2.1	0.07	0.57	1.04	1.18
20	32	5.8	66.5	66.8	1.7	0.02	0.32	0.79	0.93
90	85	2.1	68.5	70.9	4.6	0.04	0.54	1.00	1.23
87	86	2.5	62.3	65.6	3.3	0.08	0.65	1.09	1.26
81	87	3.0	68.9	71.3	2.7	0.01	0.09	0.36	0.65
89	88	2.3	67.0	69.1	4.7	0.13	0.76	1.22	1.35
82	89	3.0	64.7	67.5	5.3	0.07	0.65	1.07	1.20
85	90	2.9	65.3	67.2	5.0	0.10	0.53	1.00	1.15
Mean		**2.48**	**64.63**	**66.56**	**4.10**	**0.07**	**0.53**	**0.97**	**1.12**
CV (%)		**39.26**	**3.95**	**4.28**	**36.07**	**45.42**	**35.24**	**33.01**	**28.1**
LSD (0.05)		**1.29**	**2.13**	**2.4**	**1.25**	**0.11**	**0.29**	**0.26**	**0.26**
Significance		**	***	***	***	**NS**	***	***	***

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively
WAP= Weeks after planting

6.3.5 Agronomic performance under artificial *Striga* infestation

There were highly significant differences (P<0.001) observed in grain yield, days to 50% silking, SDR, *Striga* emergence counts (6, 8, 10 and 12 WAP), MSV, *turcicum*, GLS and leaf rust (Table 6.7). The grain yield of the crosses ranged 2.3- 6.8 t/ha and the trial mean was 5 t/ha while the yield of the six commercial checks ranged 3.8 - 4.1 t/ha with a mean of 4 t/ha. The F_1 hybrids were in the same maturity bracket as that of the commercial checks under artificial *Striga* infestation. The F_1 hybrids exhibited a lower mean score for the SDR (2.4) as opposed to the commercial checks (4.3) (Table 6.7). The F_1 single cross hybrids also performed better in foliar diseases than commercial checks.

The relationship between the yield performance and the *Striga* resistance traits of the hybrids was investigated by a simple linear correlation in a combined analysis for the two sites (Table 6.8). A highly significant (P<0.001) and negative correlation coefficient was observed between grain yield and SDR (r= -0.67***). A positive and significant correlation coefficient was observed between *Striga* counts per m^2 and yield 6 WAP, r= 0.22, and 8 WAP. *Striga* counts 10 WAP and 12 WAP was highly significantly correlated to yield across sites (r=0.44) and (r= 0.30), respectively.

Table 6.7. Performance of the top 40 F1 hybrids under artificial *Striga* infestation across sites

Rank	ENTRY	Grain yield (t/ha)	50% days to anthesis	50% days to silking	*Striga* damage rating (Score 1-9)	*Striga* count 6 WAP /M^2	*Striga* count 8 WAP /M^2	*Striga* count 10 WAP /M^2	*Striga* count 12WAP /M^2	*E. turcicum* (score 1-5)	Gray Leaf spot (Scored 1-5)
1	60	6.8	66.0	66.4	1.3	0.03	0.33	0.67	0.93	2.3	1.3
2	61	6.8	66.0	66.7	1.7	0.03	0.27	0.75	0.96	2.3	1.2
3	37	6.4	65.4	66.0	1.8	0.04	0.52	1.01	1.18	1.8	1.3
4	75	6.4	65.8	67.8	2.3	0.13	0.79	1.23	1.38	1.9	1.6
5	79	6.4	65.7	66.6	1.7	0.08	0.49	1.04	1.25	1.9	1.2
6	74	6.4	66.3	68.0	1.7	0.08	0.57	1.13	1.31	2.1	1.5
7	80	6.3	64.3	66.1	1.4	0.06	0.67	1.19	1.34	2.3	2.0
8	23	6.2	64.5	66.2	2.7	0.04	0.47	1.02	1.17	1.8	1.4
9	5	6.2	64.5	65.5	1.8	0.01	0.53	0.94	1.09	2.1	1.2
10	64	6.2	65.4	66.4	1.6	0.08	0.48	0.97	1.26	2.6	1.4
11	4	6.1	63.8	65.0	1.7	0.02	0.37	0.78	0.98	2.4	1.4
12	67	6.1	64.8	65.6	1.5	0.04	0.41	0.73	1.02	2.3	1.4
13	51	6.0	64.4	65.8	3.2	0.04	0.55	1.03	1.20	2.3	1.3
14	65	6.0	64.9	65.5	1.4	0.11	0.48	0.88	1.08	2.2	1.2
15	59	6.0	64.5	65.3	1.5	0.03	0.42	0.75	0.91	2.4	1.2
16	9	5.9	62.6	63.5	2.5	0.06	0.47	0.90	1.06	2.1	1.2
17	71	5.9	67.3	67.8	2.2	0.08	0.65	1.15	1.33	2.7	1.5
18	57	5.9	67.2	66.9	1.6	0.06	0.45	0.96	1.07	2.8	1.2
19	47	5.8	64.9	66.3	2.1	0.07	0.57	1.04	1.18	2.3	1.7
20	32	5.8	66.5	66.8	1.7	0.02	0.32	0.79	0.93	2.5	1.6
21	81	5.7	67.9	68.7	1.6	0.11	0.51	1.08	1.28	2.3	1.6
22	33	5.7	65.0	65.5	2.0	0.05	0.33	0.94	1.13	2.4	1.7
23	8	5.7	63.8	64.8	1.8	0.03	0.54	0.98	1.26	2.5	1.3
24	76	5.7	68.2	69.5	2.1	0.03	0.49	1.08	1.28	2.4	1.6
25	31	5.7	65.2	65.8	2.2	0.04	0.36	0.93	1.15	2.5	1.6
26	38	5.6	63.2	64.2	1.7	0.12	0.47	1.03	1.18	2.5	1.6
27	78	5.6	64.8	65.8	2.2	0.06	0.70	1.32	1.52	2.5	1.8
28	50	5.6	64.0	65.0	2.2	0.06	0.62	1.23	1.38	2.6	1.7
29	73	5.6	65.6	66.9	2.1	0.08	0.54	1.05	1.17	2.3	1.7
30	68	5.6	67.1	68.1	1.6	0.03	0.36	0.68	0.96	2.4	1.3
31	46	5.5	65.8	67.2	2.2	0.04	0.37	0.87	1.03	2.4	1.6
32	82	5.5	68.6	69.8	2.2	0.03	0.46	1.03	1.33	2.2	1.8
33	10	5.5	62.8	63.3	2.6	0.07	0.57	1.04	1.20	2.3	1.5
34	3	5.4	63.7	64.6	1.7	0.04	0.45	0.80	0.97	2.4	1.3
35	62	5.3	66.6	67.8	1.9	0.06	0.46	0.87	1.05	2.5	1.2
36	40	5.2	66.7	67.7	1.9	0.02	0.47	0.97	1.23	2.3	1.4
37	39	5.2	65.8	65.9	1.8	0.08	0.32	0.74	1.08	2.5	1.4
38	12	5.2	65.9	66.1	2.4	0.12	0.42	0.87	1.06	2.3	1.3
39	54	5.2	66.1	67.8	3.1	0.01	0.47	0.94	1.18	2.1	1.5
40	45	5.1	65.5	66.2	2.4	0.05	0.43	0.78	1.05	2.1	1.8
90	85	2.1	68.5	70.9	4.6	0.04	0.54	1.00	1.23	2.4	1.4
87	86	2.5	62.3	65.6	3.3	0.08	0.65	1.09	1.26	2.8	1.8
81	87	3.0	68.9	71.3	2.7	0.01	0.09	0.36	0.65	2.3	1.4
89	88	2.3	67.0	69.1	4.7	0.13	0.76	1.22	1.35	2.5	1.4
82	89	3.0	64.7	67.5	5.3	0.07	0.65	1.07	1.20	2.7	2.0
85	90	2.9	65.3	67.2	5.0	0.10	0.53	1.00	1.15	2.8	1.9
Mean		**2.48**	**64.63**	**66.56**	**4.10**	**0.07**	**0.53**	**0.97**	**1.12**	**3.14**	**1.57**
CV (%)		**39.26**	**3.95**	**4.28**	**36.07**	**45.42**	**35.24**	**33.01**	**28.1**	**14.59**	**31.1**
LSD (0.05)		**1.29**	**2.13**	**2.4**	**1.25**	**0.11**	**0.29**	**0.26**	**0.26**	**0.31**	**0.42**
Significance		**	***	***	***	**NS**	***	***	***	**	**

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

Table 6.8. Linear correlation between F1 hybrids agronomic traits and the *Striga* resistance traits

	AD	SD	ASI	PH	EH	NP	NE	EPP	YLD	EA	SDR	STR6	STR8	STR10	STR12	MSV	TURC	RUST
1																		
2	0.94***																	
3	0.25**	0.58***																
4	0.33***	0.20*	-0.20*															
5	0.38***	0.24*	-0.23*	0.87***														
6	0.16	0.05	-0.21*	0.50***	0.52***													
7	0.28**	0.14	-0.26**	0.48***	0.55***	0.53***												
8	0.22*	0.11	-0.22*	0.24*	0.36***	0.08	0.77***											
9	0.30***	0.19*	-0.17	0.51***	0.55***	0.54***	0.73***	0.51***										
10	-0.27**	-0.17	0.14	-0.45***	-0.46***	-0.51***	-0.67***	-0.45***	-0.94***									
11	-0.24*	-0.06	0.37***	-0.76***	-0.76***	-0.54***	-0.65***	-0.42***	-0.67***	0.66***								
12	0.03	0.04	0.02	0.14	0.12	0.19	0.17	0.14	0.22*	-0.18	-0.01							
13	0.01	0.07	0.18	-0.03	-0.01	0.26**	0.25**	0.18	0.29**	-0.30***	0.06	0.47***						
14	0.1	0.13	0.12	0.01	0.0002	0.26**	0.30**	0.21*	0.35***	-0.38***	0.01	0.44***	0.87***					
15	0.21*	0.22*	0.1	0.07	0.06	0.32***	0.40***	0.27**	0.44***	-0.46***	-0.06	0.37***	0.81***	0.94***				
16	0.25**	0.32***	0.31***	0.19	0.09	0.09	0.06	-0.001	0.30***	-0.30	-0.01	0.31***	0.36***	0.38***	0.43***			
17	-0.48***	-0.46***	-0.16	-0.28**	-0.35***	-0.34***	-0.61***	-0.44***	-0.82***	0.80***	0.44***	-0.21*	-0.29**	-0.34***	-0.44***	-0.36***		
18	-0.08	-0.01	0.19	0.12	0.04	0.06	-0.21	-0.25	0.03	-0.01	0.20	0.29**	0.23*	0.15	0.13	0.23*	0.01	
19	-0.13	-0.04	0.20*	-0.25	-0.24**	-0.17	-0.05	-0.02	-0.18	0.14	0.32**	-0.01	0.17	0.28**	0.26**	0.18	0.01	-0.03

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

Key:

1-AD= 50% days to anthesis, 2-SD= 50% days to silking, 3-ASI= Anthesis silking interval, 4-PH= Plant height, 5-EH= Ear height, 6-NP= Number of plants harvested, 7-NE= Number of earsharvested, 8-EPP= Ears per plant, 9-Yld= Grain yield in t/ha, 10-EA= Ear aspect, 11-SDR= *Striga* damage rating, 12-STR6= *Striga* count 6 weeks after planting, 13-STR8= *Striga* count 8weeks after planting, 14- STR10-*Striga* count 10weeks after planting, 15-STR12= *Striga* count 10weeks after planting, 16-MSV=Maize streak virus, 17-TURC- *Exserohilum turcicum*, 18-Rust= Maize rust disease

6.4 Combining ability analysis

Significant GCA mean squares (P<0.001) were observed in the traits indicating that there were differences in the agronomic performance of the inbred line parents of the hybrids (Table 6.9). The site x GCA interaction was highly significant (P<0.001) for grain yield, EPP, ear aspect, days to 50% anthesis, days to 50% silking, GLS and *E.turcicum*, indicating that some of the parents performed better at particular sites. This depicts selection based on performance to specific sites should be effective and desirable.

The ratio of the GCA: SCA mean squares were higher than unit (> 1.00) in all the traits observed, suggesting that the additive gene action effects are more important than the dominance gene action for the agronomic traits measured.

The GCA mean squares under the *Striga* infested environment were highly significant (P<0.001) for the traits except for SDR (Table 6.10). The GCA mean squares for the *Striga* resistant traits were 1.78, 1.96, 5.31, 13.04 and 14.98 times larger than the SCA mean squares. This also suggested that the additive gene action was more important than dominance gene action for *Striga* resistance for these genotypes. Significant GCA effects were observed on yield, days to 50% anthesis, SDR and *Striga* counts 6, 8, 10 and 12 WAP.

Inbred line TESTR 151, TESTR 156 and OSU231//56/44-6-4-17-3 exhibited significant positive GCA effects for yield (Table 6.11). However inbred line TESTR 156 exhibited significant positive GCA effects for the *Striga* resistance traits. Inbred lines JI10-76-# and JI10-28-# were the best general combiners for the *Striga* resistance traits as they had significant (P=0.001) negative GCA effects for SDR and *Striga* counts (Table 6.11) although they had significant negative GCA effects for yield (Table 6.11). These two inbred lines were however, also found to be very susceptible to *E.turcicum*.

Significant (P<0.01) SCA effects for yield were observed in the F_1 hybrids. These were found out in crosses involving parents 7x2, 13x4, and 14x2. The hybrids 13x4 and 14x2 also had good SCA effects for *Striga* resistance traits (Table 6.12), making them the best F_1 hybrids which could be grown under *Striga* infested fields. Hybrid 7x6 had good SCA effects for *Striga* resistance and diseases but a significant negative SCA effects for yield. This suggests that the single crosses were good in terms of resistance but they would need to be improved for yields.

Table 6. GCA/SCA mean squares of the 20 maize inbred lines under *Striga* free environment

Source	Degrees of freedom	Grain Yield (t/ha)	Ears per plant (no.)	Ear aspect (score 1-5)	50% days to anthesis (days)	Ear height (cm)	Gray leaf spot (score 1-5)	*Exserohilum turcicum* (score 1-5)
REP	2	1.566	0.02768849*	0.4035218	38.727***	9102.257***	0.311**	0.2261905
SITE	3	370.593***	0.321***	19.784***	1411.408***	78776.281***	39.257***	13.268***
LINE (GCA)	13	71.975***	0.111***	17.628***	204.825***	1898.636***	1.253***	20.100***
TESTER (GCA)	5	31.089***	0.018	6.973***	136.556***	5689.251***	3.068***	1.243***
SITE*LINE	39	4.402***	0.032***	0.755***	4.558***	161.9296	0.114***	0.981***
SITE*TESTER	15	10.825***	0.030***	0.656***	4.854***	308.9203**	0.202***	0.898***
LINE*TESTER (SCA)	65	2.258***	0.018***	0.587***	3.069***	151.8365	0.140***	0.335***
SITE*LINE*TESTER	195	1.168***	0.01240456	0.308***	2.133979	172.9445*	0.078**	0.1654139
GCA/SCA		31.88	6.17	30.03	66.74	12.50	8.95	60.00
ERROR	670	0.781	0.011	0.176	2.078	138.3	0.061	0.147
CV		19	11.01	14.9	2.2	10.61	17.01	13.66

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

Table 6.10. GCA/SCA mean squares of the 20 maize inbred lines under *Striga* infestation

Source	Degrees of freedom	Grain Yield (t/ha)	50% days to anthesis (days)	Ear Height (Cm)	Ears per plant (no.)	*Striga* damage rating (Score 1-9)	*Striga* count per M2 (6 WAP)	*Striga* count per M2 (8 WAP)	*Striga* count per M2 (10 WAP)	*Striga* count per M2 (12 WAP)	Gray leaf spot (score 1-5)	*Exserohilum turcicum* (score 1-5)
REP	2	1.493**	149.738	127.797	0.005	0.371	0.005	1.004***	1.772***	1.230***	0.210	0.354
SITE	3	3.568***	806.996***	53380.479***	0.362***	6.567***	1.374***	12.397***	8.004***	8.240***	12.953***	2.186***
LINE GCA	13	5.749***	192.822***	1941.884***	0.089***	0.060	0.015*	0.381***	0.787***	0.999***	1.854***	19.491***
TESTER GCA	5	1.965***	58.461	7264.425***	0.033*	0.248	0.017*	0.538***	1.593***	1.553***	5.891***	1.295***
SITE*LINE(GCA)	32	0.429	81.043	230.885	0.022*	0.148	0.015**	0.071	0.099	0.097	0.199***	0.564***
SITE*TESTER(GCA)	15	0.495	80.595	186.636	0.025*	0.223	0.014*	0.106**	0.168**	0.116	0.554***	0.509*
LINE*TESTER(SCA)	65	0.466*	77.840	190.080	0.017	0.034	0.008	0.072	0.060	0.067	0.206***	0.409**
SITE*LINE*TESTER(SCA)	123	0.368	76.810	187.551	0.014	0.073	0.008	0.055	0.056	0.062	0.112	0.285
GCA/SCA		12.337	2.477	10.216	5.144	1.780	1.955	5.308	13.041	14.979	9.000	47.655
ERROR	245	0.33	77.7	199.62	0.015	0.226	0.009	0.059	0.078	0.078	0.109	0.284
CV		21.09	13.62	12.36	12.2	289.62	95.66	54.53	30.74	25.78	21.54	20.15

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

Table 6.11. The GCA effects of the parental materials under artificial *Striga* infestation

Entry	Grain Yield (t/ha)		50% days to anthesis (d)	*Striga* damage rating (Score 1-9)	*Striga* counts 6 WAP	*Striga* counts 8 WAP	*Striga* counts 10 WAP	*Striga* counts 12 WAP	E. turcicum (Score 1-5)	Gray leaf spot (Score 1-5)
	INF	No-INF								
1	1.7	0.3	1.7	-1.06***	0	-1.06***	0.1**	0.08*	0.01	-0.1*
2	-0.14	-0.66**	-0.14	0.13	0	0.13	0	0	0.38***	0.25***
3	0.04	0.37	0.04	-0.09	0	-0.09	-0.05	-0.04	-0.31***	0.07
4	1.04	0.85***	1.04	0.23	-0.02	0.23	-0.06	-0.06	-0.3***	0
5	0.7	0.66**	0.7	0.2	0	0.2	0.05	0.05	-0.48***	-0.01
6	1.63	0.33	1.63	0.19	-0.01	0.19	0.03	0.07	-0.23**	0.19***
7	1.48	-1.55***	1.48	0.88***	-0.02	0.88***	-0.11**	-0.15***	0.53***	-0.29***
8	0.08	0.91***	0.08	0.01	0.01	0.01	0.23***	0.26***	-0.08	0.07
9	-0.12	1.12***	-0.12	-0.04	0.01	-0.04	0.07*	0.07*	-0.62***	-0.25***
10	-1.12	0.63**	-1.12	0.23	0.03*	0.23	0.1**	0.06	-0.25**	0.14**
11	-2.78**	0.11	-2.78**	0.03	0.02	0.03	-0.04	-0.03	-0.22*	-0.12*
12	2.2*	0.36	2.2*	0.24	0	0.24	-0.03	0.04	-0.37***	-0.05
13	-3.03**	-1.41***	-3.03**	-0.97***	-0.01	-0.97***	-0.14***	-0.17***	0.77***	0.16**
14	-1.65	-2.01***	-1.65	0.03	-0.01	0.03	-0.15***	-0.18***	1.18***	-0.06
15	-0.17	-0.37	-0.99	-0.29*	0	-0.29*	-0.03	-0.05*	0.11*	-0.19***
16	-0.44**	-0.52*	0.36	0.61***	-0.01	0.61***	-0.01	-0.02	-0.1*	0.24***
17	-0.11	0.16	0.36	-0.53***	-0.01	-0.53***	0	0.01	0.1*	0.03
18	-0.05***	0.06	0.14	0.18	0	0.18	0.03	0.02	-0.06	0.08
19	0.41**	-0.02	0.57	-0.23	0	-0.23	-0.14***	-0.13***	0.01	-0.26***
20	0.36**	0.7**	-0.43	0.26*	0.02*	0.26*	0.16***	0.16***	-0.06	0.08

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

Table 6.12.The SCA effects of the best performing F1 hybrids

Crosses	Grain yield (t/ha)	50% days to anthesis (d)	*Striga* counts 6 WAP	*Striga* counts 8 WAP	*Striga* counts 10 WAP	*Striga* counts 12 WAP	E. turcicum (Score 1-5)	Gray leaf spot (Score 1-5)
1X2	-0.09	-0.09	-0.16	0.7**	0	0.01	-0.31*	-0.05
2X5	-0.33	-0.22	0.48	0.42	0.1	0.06	0.05	-0.31***
6X5	-0.13	-0.32	0.17	0.09	0.07	0.03	0.07	-0.26**
6X6	0.34	2.27	-0.14	0.08	-0.02	-0.03	0.02	-0.22**
7X2	0.74**	-1.21	-0.36	0.06	0.06	0.16*	-0.2	-0.15
7X3	0.34	0.29	-0.14	0.02	-0.04	-0.07	-0.31*	0.02
7X4	0.39	-0.74	0.66*	0.05	0.08	0.08	-0.29*	-0.11
7X6	-0.99	2.75	0.08	0.01	-0.2***	-0.19**	0.43**	-0.07
8X1	0.41	0.04	0.17	-0.04	-0.12*	-0.04	-0.13	-0.17*
9X3	0.36	0.47	0.11	-0.11	0.03	0.01	-0.33*	-0.02
11X3	0.06	3.54	-0.46	-0.22	-0.12*	0.02	-0.03	-0.03
13X4	0.83**	0.68	0.09	-0.4	-0.06	-0.06	-0.44**	-0.06
14X2	0.89**	-0.25	-0.09	-0.43	0.01	0.02	-0.19	-0.09
14X5	-0.07	0.13	0.16	-0.62*	-0.09	-0.14*	-0.29*	0.2*

*, **, *** - Significant at 0.05, 0.01 and 0.001 respectively

6.4.1 Prediction of Single and Double cross maize hybrids

Methods that can be used to predict single cross hybrids performance with some accuracy prior to field evaluation are of particular interest to plant breeders. Hybrid grain yield performance predicted from the sum of the two parental GCAs and overall grain yield was strongly correlated with observed hybrid performance under *Striga* infested environment (Figure 6.1) and even much more in *Striga* free environment (Figure 6.2) respectively. The correlation coefficient between observed and predicted grain yield under *Striga* infestation was r= 0.32** while the correlation under *Striga* free environment was r= 0.93***. Similar results were reported for grain yield performance of maize under acid soils (Welcker *et al.*, 2005) and for seed yield in oilseed rape (Diers *et al.*, 1996). Makumbi *et al* (2011) reported similar findings on hybrid performance prediction under low soil nitrogen and drought stress environments. Of the 20 crosses predicted to have the highest grain yield based on the sum of parental GCAs and overall mean yield under both *Striga* infested and *Striga* free environments 4 single cross hybrids appeared consistently. These hybrids include; JI-30—3/TESTR 151, CML 444/TESTR 156, CML 204/TESTR 156 and OSU231//56/44-6-4-17-3/ TESTR156. This confirms the resistance of the single crosses and also the materials can be grown even in areas with no *Striga* within the region.

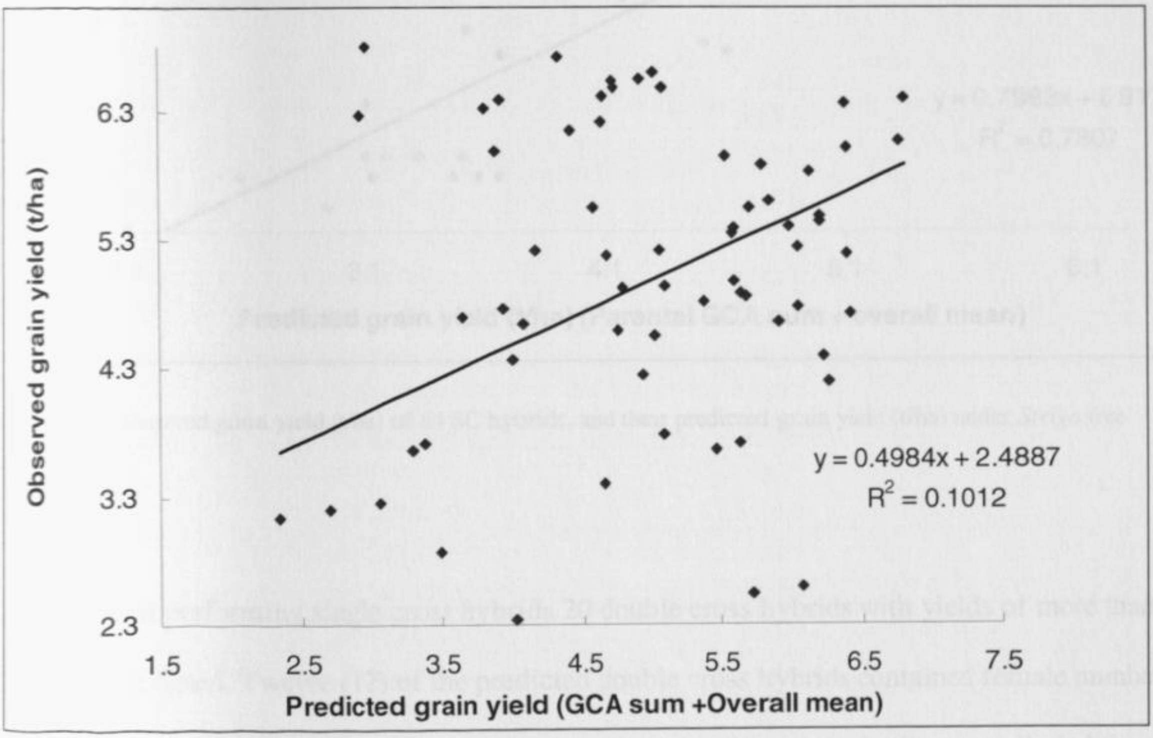

Figure 6.1. Observed grain yield (t/ha) of 84 SC hybrids, and their predicted grain yield (t/ha) under *Striga* infestation

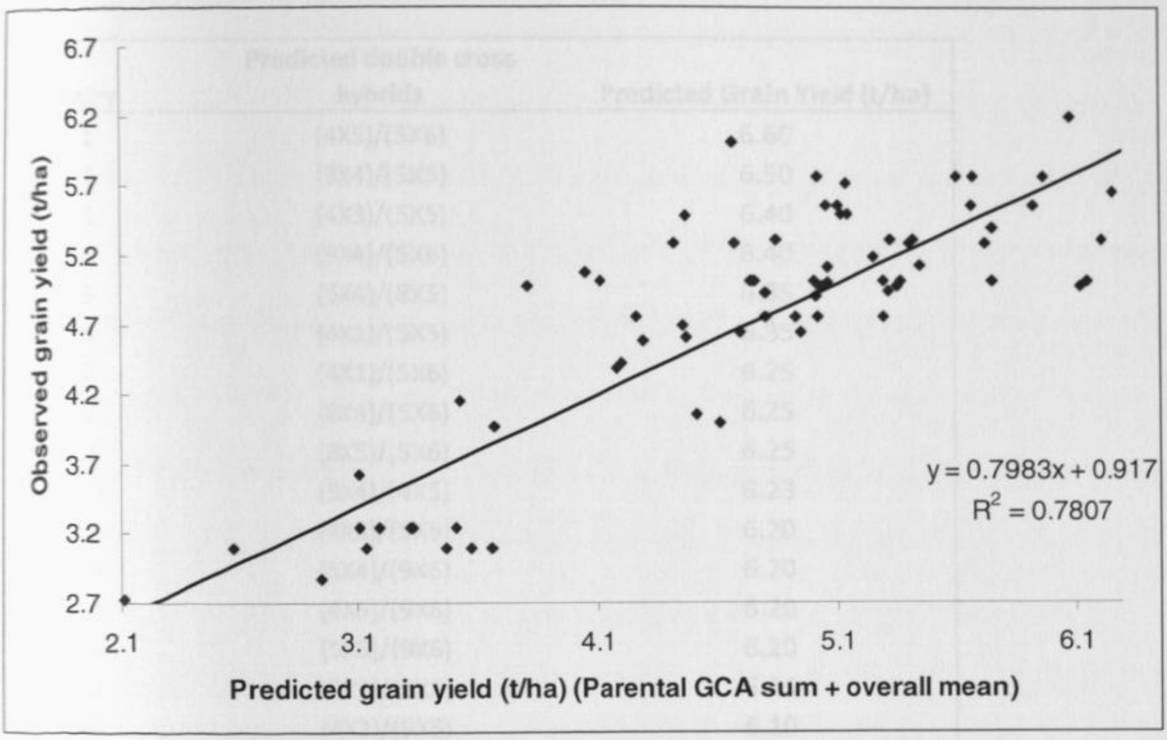

Figure 6.2. Observed grain yield (t/ha) of 84 SC hybrids, and their predicted grain yield (t/ha) under *Striga* free environment

From the best performing single cross hybrids 20 double cross hybrids with yields of more than 6 t/ha were predicted. Twelve (12) of the predicted double cross hybrids contained female number 5 in one of the single cross (Table 6.13). It was evident that this particular line contributed the highest percent of the best double cross hybrids. It should be a useful line in breeding for resistance to *Striga* (on account of high yields).

Table 6.13. Predicted grain yield (t/ha) of top 30 double crosses formed from some of the superior single crosses tested under *Striga* infested environment.

Entry	Predicted double cross hybrids	Predicted Grain Yield (t/ha)
1	(4X5)/(5X6)	6.60
2	(8X4)/(5X5)	6.50
3	(4X3)/(5X5)	6.40
4	(9X4)/(5X6)	6.40
5	(5X4)/(8X5)	6.35
6	(4X1)/(5X5)	6.35
7	(4X1)/(5X6)	6.25
8	(8X4)/(5X6)	6.25
9	(8X5)/(5X6)	6.25
10	(5X4)/(4X5)	6.23
11	(4X3)/(5X6)	6.20
12	(5X4)/(9X6)	6.20
13	(4X5)/(9X6)	6.20
14	(5X5)/(9X6)	6.20
15	(5X1)/(8X5)	6.15
16	(4X3)/(9X6)	6.10
17	(5X3)/(9X6)	6.10
18	(5X5)/(4X6)	6.10
19	(9X4)/(4X5)	6.08
20	(9X4)/(4X6)	6.08
21	(5X1)/(9X6)	6.05
22	(4X1)/(9X6)	6.05
23	(8X4)/(4X5)	6.03
24	(5X4)/(4X6)	6.03
25	(4X1)/(8X5)	6.00
26	(9X3)/(5X5)	6.00
27	(9X3)/(5X6)	6.00
28	(5X3)/(8X5)	5.95
29	(9X1)/(5X5)	5.95
30	(5X3)/(4X5)	5.93

6.5 Discussion

Host plant resistance with reduced *Striga* emergence is considered as the best strategy for long term control of *Striga* in sub-Saharan Africa. Resistant maize inbred lines should be able to support few emerged parasites and sustain less *Striga* damage symptoms and produce high grain yields (Yallou *et al*., 2009). In this case an inbred line which supports few *Striga* plants and finally succumbs to the effect of the parasite is considered not useful in the development of host plant resistance materials (Kim and Adetimirin, 1997). The usefulness of the inbred lines in hybrid combinations is determined through studying their combining ability (Hallauer and Miranda, 1981). Desirable and *Striga* resistant lines should show negative GCA effects for SDR and *Striga* counts and a positive GCA effects for grain yield under *Striga* infested conditions. In our study TESTR 151 and OSU231//56/44-6-4-17-3 lines were considered superior and desirable. Inbred line TESTR 156 exhibited a significant positive GCA effects for grain yield and a positive GCA effects for *Striga* resistance traits making it not suitable for *S. hermonthica* resistance. Inbred lines JI10-76-# and JI10-28-# exhibited very good GCA for *Striga* resistance traits but negative GCA effects for yield. These lines can therefore be utilized only as source of resistance to *Striga* in maize breeding. The importance of additive gene action was observed for grain yield and the *Striga* resistance traits as opposed to non-additive gene action. Similar findings were reported by (Yallou *et al*., 2009) who reported the importance of additive gene effects while studying combining ability of maize inbred lines containing genes from *Zea diploperennis*.

The relative importance of GCA and SCA variance was examined by expressing it as the ratio of additive to total genetic variance. The closer this ratio is to unity, the greater the predictability based on GCA alone (Baker, 1978). In our study the additive gene effects were found to be more important than the dominance effects. The importance of the GCA effects was 12% under *Striga* infested environment and 31% under *Striga* free environment. Makumbi *et al*., (2010) reported GCA effects of 51-79% in well watered environment and 40-64% under water stressed environment.

The correlation coefficient between observed and predicted grain yield under *Striga* infestation and under *Striga* free environment was highly significant. Welcker *et al* (2005) reported similar findings for grain yield performance of maize under acid soils. Other workers such as Diers *et al* (1996) reported similar findings in seed yield when working on oilseed rape.

In the development of maize hybrids resistant to *Striga* the materials should be tested under both *Striga* free and *Striga* infested environments following the procedures developed by Kim (1991). This helps in identifying superior inbred lines in both environments which would be ideal for the farmers as *Striga* infestation in the field is not uniform and the parasite infestation of crop field is erratic. In the *Striga* free environments, TESTR 156 and OSU231//56/44-6-4-17-3 had positive and significant GCA effects for yield making them superior under both environments. Inbred lines JI-30-3, JI-30-18, CML 312, CML 206, and F1-14-14-24-4-5-4 showed positive and highly significant GCA effects for grain yield under *Striga* free environments.

The significant GCA effects as opposed to SCA effects for the SDR and *Striga* counts indicated that the genetic variation for resistance to *S. hermonthica* among the lines was mainly controlled by additive type of gene action. This was in agreement with (Yallou *et al*., 2009) findings who reported significant GCA mean squares for *Striga* counts but contrary on SDR. Further, these results are in contrast to those of Kim, (1994) who found high SCA mean squares than GCA mean squares for *Striga* counts and higher GCA mean squares to SCA mean squares for SDR.

Prediction of single and double cross maize hybrids has been utilized by breeders through use of best linear unbiased prediction model (BLUP) (Balestre *et al* 2011). However it has not been utilized in breeding for *Striga* resistance. Many breeders have been evaluating hybrid materials directly without prior information on their levels of resistance to *Striga* infestation which is cumbersome and unpractical in cases of many inbred lines. Therefore methods that can be used to predict single cross and double cross hybrids performance with some accuracy prior to field evaluation may be crucial to plant breeders. For the single cross hybrids the performance was predicted based on the GCA of the both parents added to the mean grain yield of the single cross. The grain yield of the single cross hybrids predicted from the sum of the two parental GCA's and overall grain yield was strongly correlated with the observed hybrid performance under *Striga* infested and *Striga* free environments. These results were in agreement with Wecker *et al*., (2005) for grain yield performance under acid soils. It was noted that prediction of F_1 hybrids JI-30—3/TESTR 151, CML 444/ TESTR 156 and OSU231//56/44-6-4-17-3/ TESTR 156 exhibited consistent results under the two environments.

6.2.5 Conclusion

The outcome of the present studies confirms the availability and possibility of developing maize hybrids with good levels of resistance to *S. hermonthica*. The importance of additive gene action was demonstrated in breeding for *Striga* resistance as opposed to non-additive gene action. Inbred lines with good GCA for yield and *Striga* resistance traits were identified as TESTR 151, TESTR 156 and OSU231//56/44-6-4-17-3. The inbred lines JI10-76-# and JI10-28-# which are mutants from KARI Muguga might be a very good source of resistance as they gave very good

GCA effects for the *Striga* resistance traits. These inbred lines would be of great use in the breeding for *Striga* resistance in maize. Single crosses involving parents 7x2, 13x4, and 14x2 were identified as the best yielding hybrids in *Striga* infested fields. These could therefore be recommended for growing by farmers in the *Striga* prone areas as single crosses.

Prediction of single cross and double cross hybrids is possible and feasible to plant breeders especially when handling many maize inbred lines. High yielding double cross hybrids were predicted from the single cross hybrids under *Striga* infested environment which could further be tested in the field.

Striga resistant F_1 hybrids with low *Striga* emergence were identified. However susceptible F_1 hybrids which supported few and many *Striga* plants were also present.

CHAPTER SEVEN

General Discussion and Conclusions

Striga hermonthica is one of the most important constraints to maize production in the sub-Saharan Africa. Several *Striga* control approaches in maize have been developed and suggested over the years but none of these have been widely adopted by the farmers due to being financially demanding and for being labour intensive. Therefore having been designed, generally these options have met negligible success. Identification of new sources of resistance to *Striga hermonthica* from among maize cultivars with tolerance to abiotic stresses such as drought tolerance and low nitrogen can help in managing the *Striga* problems in resource poor farmers' fields would be desirable. Studies have shown that cultivars with ability to tolerate drought posse's roots which go deeper although reduced in mass as opposed to susceptible cultivars (Banziger *et al*., 2000). The superior landraces with few emerged *Striga* plants such as JAMA 8, SNLP 104, BRAZ 1838 and BRAZ 145 probably utilized this mechanism of being deep rooted. These particular land races supported few *Striga* plants ranging between 21 to 29 *Striga* plants per square meter indicating presence of good levels of resistance. These landraces could be termed to probably possessing specialized roots as was reported by Hearne (2009).

Striga infestation has been primarily a problem in small scale subsistence farming systems that have few options to access external inputs such as pesticides and fertilizers to manage the parasite. This is because control options must be low cost and practical (Rodenburg, 2005), and therefore breeding for effective genetic resistance offers the best strategy. Drought tolerant land races such as CHIS 53, JAMA 8 and SNLP 104 outperformed the commercial checks in terms of grain yield and resistance to *Striga* under infestation. The results suggested that these landraces should be strongly recommended in the *Striga* prone areas that mostly receive erratic rains. Selection and development of resistance from a wide range of maize germplasm is a major practical and reliable approach to the management of *Striga* in the context of peasant or subsistence agriculture. Resistant maize cultivars are more desirable because they reduce and curb the reproduction of the parasite to manageable levels. A major requirement for a viable method would be its ability to drastically reduce the rich seed bank so common in *Striga* prone environment as found in Kenya's Lake Victoria Basin. Identification and growing of maize cultivars with higher *Striga* resistance levels would offer a solution in reduction of *Striga* seed bank which would finally culminate in maize yield increments. In Nyanza and Western provinces of Kenya, *S. hermothica* has proven to be a serious constraint to maize production especially when compounded by erratic rains. Global climate change and expansion of farming into low potential areas due to rising population densities greatly exacerbates this problem. Continuous cropping of susceptible cereals season after season has resulted in addition of large quantities of *Striga* seeds into the soil. However there has been evidence that growing of resistant varieties especially the drought tolerant ones have the ability to grow below the plough pan where most of the *Striga* seeds are found. It was therefore important to explore new sources of resistance from among the drought tolerant germplasm.

Development of successful host plant resistance (HPR) to *Striga* in maize has been limited, though it is the most economically feasible and environmentally friendly means of *Striga* control. Maize varieties tolerant to *Striga* infestation such as KSTP94 and WH502 have been released in Kenya. However their levels of tolerance are not sufficiently acceptable especially under high

Striga infestation intensities. The tolerance is overwhelmed to resulting in too many emerged *Striga* plants which plays a major role in addition of *Striga* seeds to the seed bank. For example in our study the best performing landraces in the field yielded 55% and 48% more than KST94 and WH502 respectively. This shows that the landraces tested were more superior to what is commercially available in the market. Koyama (2000) reported existence of different *Striga* biotypes due to cross pollination. It is therefore important to identify and develop maize cultivars with higher levels of resistance to *Striga* infestation as they have been shown to interfere with the normal reproduction of *S. hermothica* (Fakorede, B., personal communication) which curtails addition of more *Striga* seeds into the seed bank.

Growing of maize cultivars with low *Striga* germination stimulants can be used as a method for control of *Striga* infestation in the field as *Striga* seeds will only germinate and attach when the germination stimulant is available. Depletion of soil *Striga* seed bank remains one of the most important options for control of *Striga*. Stimulation of *Striga* seed in the absence of a host plant (also referred to as suicidal germination) and trap cropping is one of the ways of depletion of the seeds bank. The practice results in death of the *Striga* seedlings and finally depletion of the seed bank in the soil. In our study some maize land races such as SNLP104 (42.2%) elicited a higher percent of *Striga* seed germination but it was surprisingly among the best performing land races in the field experiment in terms of grain yield and *Striga* resistance traits under *Striga* infestation. This particular land race could probably be having the suicidal germination mechanism and also being deep rooted due to the fact that it was drought tolerant. Growing maize cultivars with low levels of *Striga* germination stimulants production would significantly reduce the number of germinated or attached *Striga* seeds. Land races CRIC 51 and CUBA T-31 elicited very low levels of *Striga* germination percent below 5% compared to the control GR24 (58.8%). These land races are recommended to be grown in *Striga* infested hot spots in the region. This is because the land races would help in reducing the seed bank if grown for many seasons. Studies in sorghum showed that low germination stimulant varieties resulted in improved resistance to S. *hermonthica* (Ejeta, 2003). A wide variation within different maize genotypes on the ability to stimulate S. *hermonthica* seed germination was observed. Some land races such as OAXA 553 and CHIS 39 exhibited a higher stimulating ability for the *Striga* seed germination, 53 and 52% respectively compared to the commercial check PHB3253 which recorded 49% *Striga* seed germination. From the study, twenty (20) landraces elicited less than 10% *Striga* seed germination. The evaluation of the land races, inbred lines and improved populations revealed presence of maize germplasm with superior levels of *Striga* germination stimulants compared to the commercial checks. These materials included land races CRIC51, CUBA-T31, BRAZ1758, BRAZ1279 and VERA 217; they stimulated *Striga* germination ranging between 3.7 to 6%. These land races can be used further in breeding for *Striga* resistance in maize through pure line extraction, development of top crosses or be used directly as improved populations. The identified land races are therefore strongly recommended to serve as genetic source of variation for *Striga* resistance in maize breeding programmes in the region.

Differences in the mode of resistance among the inbred lines were revealed. Among the lines with low levels of *Striga* germination percent were CML202-IR, CML444, CML445-IR, CML395 and CML206//56/44-6-3-7-1. They stimulated *Striga* germination ranging between 14.3 to 29.7%. Out of the five best inbred lines, 2 were imidazolinone resistant (IR) maize inbred lines developed by CIMMYT. These inbred lines were developed through continued screening against imazapyr herbicide. The herbicide resistant inbred lines are coated with low doses of the herbicide (30 gms/ha) which is a systemic herbicide which kills the *Striga* seeds when they come into contact (Kanampiu *et al*., 1999). These inbred lines induced very low levels of *Striga* germination 14.3 and 22.6% for CML202-IR and CML445-IR respectively even though they are known to be susceptible without the herbicide. Coupled with herbicide coating these inbred lines could therefore be utilized as good source of *Striga* resistance in the development of maize hybrids resistant to S. *hermonthica*.

Management of *Striga* menace should aim at restraining development, seed production and depletion of the *Striga* seed bank in the soil by integrating all available *Striga* control strategies. Growing resistant maize cultivars such as CHIS53 and TEL COMP.1STR SYN-W-1 with high levels of resistance would curtail growth and development of the parasite. While the herbicide resistant inbred lines such as CML202-IR and CML445-IR when used in the development of new maize hybrids using resistant maize germplasm would reduce the *Striga* seed bank and also interfere with the reproduction of new seeds by the parasite. It is therefore important to embrace integrated *Striga* management strategies through incorporation of HPR, herbicide resistance, hand weeding and also improving soil fertility.

Inbred lines sourced from IITA reportedly known to be resistant to *Striga* (Abebe personal communication) TESTR 153, TESTR 136 and TESTR 150 elicited a higher level of *Striga* germination ranging between 50 and 57%. This suggested presence of a different mode of resistance other than the absence of *Striga* germination stimulant. The mode of resistance for these inbred lines appears as a form of suicidal germination as was reported by Sun *et al* (2004) while working in sorghum, whereby the host or non-host stimulates the *Striga* seeds to germinate but they do not attach to the host roots. This type of resistance is probably the most desirable in maize breeding as continued planting of these materials would result in reduction of the *Striga* seed bank in long run.

Testing the germplasm in the field revealed genetic variations under both *Striga* infested and *Striga* free conditions. Three features, *Striga* damage rating (SDR), number of emerged *Striga* plants and grain yield under *Striga* infestation are important traits for defining the degree of resistance of genotypes to S.*hermonthica*. A significant genetic variation for the three *Striga* resistance traits was detected among the elite maize inbred lines and land race accessions. The land race JAMA 8 and an improved IITA population TEL COMP.1STR SYN-W-1 were found to be resistant by using the above mentioned traits They consistently recorded low SDR scores, few emerged *Striga* plants and high yield compared to the commercial checks. Inbred lines JI-30-19 and OSU 231//56//44-6-4-17-3 were also found to be resistant as they recorded low SDR scores, few emerged *Striga* plants and high yield. Menkir (2004) reported the importance of the three traits while selecting resistant maize cultivars from among elite germplasm and western Africa land races. Using the three traits, a number of superior land races were identified as CHIS 53, JAMA 8, SNLP 104, PAZM 14140 and CUBA-I-66. The four IITA populations TEL COMP. 1 STR SYN-W-1, OBATAMPA/Z.DIPLO SYN-W-1.ZDIPLO SYN-W-1, OBATAMPA/TZL COMP.1 SYN W-1/TEL COMP.1 SYN W-1 and STR-SYN-W1 were confirmed to be resistant to S. *hermonthica*. These open pollinated varieties can be grown directly by farmers in the *Striga* prone areas in the region after undergoing formal release through the regulatory body.

Exploiting host genetic variability to increase the level of resistance to the parasite can be a major component of an integrated approach to minimize yield losses from S. *hermonthica* in farmers' fields. A good number of promising maize inbred lines with consistently few emerged parasites, low SDR scores and high grain yield under *Striga hermonthica* infestation at Kibos and Alupe were identified. Inbred lines with few emerged *Striga* plants and low SDR scores were identified as TESTR 150, TESTR 151 and JI-30-19. The first two had been sourced from IITA and the results of the laboratory experiment exhibited a higher level of *Striga* germination stimulant suggesting a suicidal germination mode of resistance.

Studying combining ability of maize inbred lines is useful in testing procedures and comparing of inbred lines in hybrid combinations. Combining ability determines the future usefulness of the inbred lines in hybrid combinations (Hallauer and Miranda, 1981). The productivity of a line in crosses is the ability of the parents to combine amongst each other during hybridization in order for the favorable genes to be transmitted to their progenies. Information on combining ability of maize inbred lines with high *Striga* resistance levels would be useful in the development of new maize hybrids resistant to *Striga hermonthica.*

Combining ability studies, revealed that there is a possibility of developing maize hybrids with high levels of resistance to S. *hermonthica* adapted to *Striga* prone areas of Nyanza and Western parts of Kenya. Additive type of gene action was generally demonstrated as opposed to dominance type of gene action. The ratio of GCA: SCA for grain yield was 12.34 while the ratio for *Striga* resistance traits such as SDR and emerged *Striga* plants per square meter 12 WAP were 1.78 and 14.98 respectively. Inbred lines with good general combining ability (GCA) for grain yield and *Striga* resistance traits were identified from among the inbred lines studied. These inbred lines should be used further in breeding programmes as source of genetic variations in the development of *Striga* resistant maize hybrids. Single cross maize hybrids with high levels of *Striga* resistance were identified which are strongly recommended for utilization by farmers in the *Striga* prone areas of Nyanza and Western Kenya.

Prediction of single cross and double cross maize hybrids has been utilized by breeders through use of best linear unbiased prediction model (BLUP) (Balestre *et al* 2011). However it has not been utilized in breeding for *Striga* resistance. Many breeders have been evaluating hybrid materials directly without prior information on their levels of resistance to *Striga* infestation which is cumbersome and unpractical in cases of many inbred lines. Therefore methods that can be used to predict single cross and double cross hybrids performance with some accuracy prior to field evaluation may be crucial to plant breeders. For the single cross hybrids the performance was predicted based on the GCA of the both parents added to the mean grain yield of the single cross. The grain yield of the single cross hybrids predicted from the sum of the two parental GCA's and overall grain yield was strongly correlated with the observed hybrid performance under *Striga* infested and *Striga* free environments. These results were in agreement with Wecker *et al*., (2005) for grain yield performance under acid soils. It was noted that prediction of F_1 hybrids JI-30—3/TESTR 151, CML 444/ TESTR 156 and OSU231//56/44-6-4-17-3/ TESTR 156 exhibited consistent results under the two environments.

Prediction specifically of double cross hybrid performance is essential to plant breeders when dealing with many inbred lines such as twenty (20) with an objective of developing double cross hybrids. For example 20 inbred lines, while using diallel mating design would result in 14,535 double crosses without reciprocals (Allard, 1960). To test such a huge number of double cross hybrids in the field is actually difficulty and expensive for the breeder thereby necessitating the prediction of the double crosses from the performance of the single crosses. In our study prediction of double cross hybrids was made from the mean yield of the four non-parental single crosses and the average performance of the single crosses was used to predict the performance of the double cross hybrids. Twenty double cross hybrids with yield of > 6 t/ha were predicted. Female five (5) proved to be a good combiner as it produced 12 out of 20 best predicted double cross hybrids. It is therefore strongly recommended that these predicted good hybrids should be tested more widely with the aim of releasing them for cultivation.

In conclusion, this research has helped to identify drought tolerant land races with good levels of resistance to S. *hermonthica* through determination of the levels of *Striga* germination stimulants production. The research has further verified the resistance in the field where *Striga* emergence was found to be directly correlated to SDR, grain yield and *Striga* attachments on the maize roots. This information is important to the maize breeders in the sub-Saharan Africa in their breeding programs. New single cross maize hybrids with high yield (>6t/ha) under *Striga* infestation environment were identified in the course of this research. These hybrids should be grown in the *Striga* prone areas, and further testing, formal release through the government regulatory body should follow. Prediction of superior double cross hybrids was achieved from among the single cross hybrids tested.

Constitution and evaluation of these hybrids would probably hasten development of double cross hybrids with high levels of resistance to *Striga hermonthica*. The screened drought tolerant land races, new single cross and double cross hybrids with high levels of resistance to *Striga* aims at contributing to global food security and enhancement in the exploitation of worldwide genetic resources in an attempt to significantly contribute to science.

References

Abayo, G.O., E. Terry, E.E. Robert, F. Kanampiu, J.K. Ransom, and J. Gressel. 1998. Control of parasitic witch weeds (*Striga* spp.) on corn (*Zea mays*) resistant to acetolactate synthase inhibitors. Weed Science, **46**: pp 459-466.

Akobundu, I.O. 1991. Integrated weed management for *Striga* control in cropping systems in Africa, *In* S. K. Kim, ed. Combating *Striga* in Africa. Proceedings, International Workshop Organized by IITA, ICRISAT and IDRC,August 22-24, 1988, IITA, Ibadan, Nigeria. pp 122-125.

Allard, W. R. 1960. Principles of plant breeding, John Wily & Sons, Inc. pp 266-277.

Alexander, M. 2008. Mutations in plant breeding [Online]. Available by http://www.plantmutations.com/mutation_breeding.htm.

Amusan, I.O., J. R., Patrick, A. Menkir, H. Thomas, and E. Gebisa. 2008. Resistance to *Striga hermonthica* in a maize inbred line derived from *Zea diploperennis*. DOI: 10.1111/j.1469-8137.2007.02355.x.

Andrianjaka, Z., R. Bally, M. Lepage, J. Thioulouse, G. Comte, M. Kisa, and R. Duponnois. 2007. Biological control of *Striga hermonthica* by cubitermes termite mound powder amendment in sorghum culture. Elsevier B.V. doi: 10.1016/ j.apsoil.2007.03.001.

Ast, A.V. 2006. The influence of time and severity of *Striga* infection on the Sorghum bicolor-*Striga hermonthica* association. PhD Thesis, Wagengen, the Netherlands, p55.

Ast, A.V., L. Bastiaans, and S. Katile. 2005. Cultural control measures to diminish sorghum yield loss and parasite success under *Striga hermonthica* infestations. Crop Protect. **24**: pp1023-1034.

Ayongwa, G.C., J.T. Stomph, A.M. Emechebe, and T.W. Kuyper. 2006. Root nitrogen concentration of sorghum above 2% produces least *Striga hermonthica* stimulation DOI .

Ba¨nziger, M., Edmeades, G.O., Beck, D., Bellon, M., 2000.Breeding for drought and nitrogen stress tolerance in maize. From theory to practice. CIMMYT, Mexico, DF.

Bebawi, F.F., R.E. Eplee, C.E. Harris, and R.S. Norris. 1984. Longevity of witchweed (*Striga* asiatica) seed. Weed Sci. **32**: pp 494-497.

Benito, M., and V. Walbot. 1997. Characterization of the maize mutator transposable element MURA Transposase as a DNA-Binding protein, Molecular and Cellular Biology, **8**:pp 5165-5175.

Bennetzen, J.L. 1996. The mutator transposable element system of maize, *In* H.Saedler and A.Gierl (ed),Transposable elements. Spriger- Verlag, New York, **12:** pp 195-229.

Bennetzen, J.L., P.S. Springer, A D Cresse, and M. Hendrickx. 1993. Specificity and regulation of the Mutator transposable element system in maize. Plant sci.**22**: pp 15-20.

Berner, D.K., J.G. Kling, and B.B. Singh. 1995. *Striga* Research and Control. A perspective from Africa. Plant Dis. **79:** pp 652-660.

Bly, J.H. 1998. Electron Beam Processing, Yardley, PA.

Borojevic, S., (ed.) 1990. Principles and Methods of Plant Breeding. Elsevier Science Publishers B.V.

Bouwmeester, H., R. Matusova, S. Zhongkui, and M.H. Beale. 2003. Secondary metabolite signaling in host parasitic plant interactions. Curr. Opin. Plant Biol **6**: pp 358-364.

Brar, D.S., and S.M. Jain. 1998. Somaclonal variation, mechanisms and applications in crop improvement, *In*:Somaclonal variation and induced mutations in crop improvement. Kluwer, Dordrecht, pp 15-38.

Butler, L.G. 1995. Chemical communication between parasitic weed *Striga* and its crop host. A new dimension in allelochemistry Agricultural experiment station purdue University. West Lafayette, pp 156-166.

Carsky, R.J., R. Ndikawa, R. Kenga, L. Sing, M. Fobasso, and M. Kamuanga. 1996. Effects of sorghum variety on *Striga hermonthica* parasitism and reproduction. Plant Var. seeds **9**: pp 111-118.

Central Bureau of Statistics (CBS), 2005. http:// www.cbs.go.ke. Kenya population ensus, Government of Kenya.

Central Bureau of Statistics (CBS), 2009. http:// www.cbs.go.ke. Kenya population ensus, Government of Kenya.

Cassels, A.C., and B.M. Doyle. 2003. Genetic engineering and Mutation Breeding for tolerance to abiotic and Biotic Stresses: Science, Technology and Safety. Bulg.J. Plant Physiol **30**: pp 52-82.

Chopra, V.L., (ed.) 2001. Breeding Field Crops. Mohan Primlan, Oxford &IBH publishing Co Pvt. Ltd, Janpath, New Delhi 110 001, **66**, pp 1- 181.

Daskalov, S., and L. Michailov. 1988. A new method for hybrid seed production based on cytoplasmic male sterility combined with a lethal gene and a female sterile pollenizer in Capsicum annuum L. Theor.Appl. Genet. **16**: p.76.

Derek, B., and K.E. Carl. 1997. Africa's Emerging Maize Revolution Lynne Rienner publishers, Inc. pp 38-60.

Dier, B.W., McVetty PBE., Osborn, T.C., 1996. Relationship between heterosis and genetic distance based on restriction fragment length polymorphism markers in oil seed rape (brassica napus L.) Crop Sci. **36**: pp79 -83.

Dogget, H., (ed.) 1988. Sorghum, Tropical Agriculture series 2nd edition. Longmans, Essex, England, pp 26-40.

Doggett, H. 1984. *Striga*, its biology and control: an overview, *In* E. S. Ayensu, ed. *Striga* Biology and Control: International Council Science Union, Paris, and International Council of Scientific Unions. ICSU Press and the International Research Development Center. ICSU Press Symposium Series no. 2, Paris, France. pp 27-36.

Egley, G.H.R., E. Eplee, and R.S. Norris. 1990. Discovery and development of ethylene as a witch weed seed germination stimulant, *In* R. E. E. P. F. Sand, and R. G. West brooks, ed. Witch weed Research and Control in the United States. Weed Science Society of America, Champaign, IL, pp 56-67.

Ejeta, G. 2007. The *Striga* scourge in Africa: A growing pandemic, *In* G. J. Ejeta G, ed. Integrating New Technologies for *Striga* Control, Towards Ending the Witch-hunt. World Scientific, pp 3-15.

Ejeta, G., L. Butler, and A.G.T. Babiker. 1992. New approaches to the control of *Striga* research at Purdue University, p 27.

Eplee, R.E., R.G. Westbrooks, and R.S. Norris. 1991. Chemical control of *Striga*, *In* L. J. Mussel man, ed. Parasitic Weeds in Agriculture, Vol. 1. CRS Press, Boca Raton, FL, pp 173-183.

Estabrook, E.M., and Yoder, J.I.,1998. Plant-plant communications: rhizosphere signaling between parasitic angiosperm and their hosts. . Plant physiology, **116**: pp 1-7.

FAO. 2003. http://apps.fao.org/page/collections?Subset=agriculture.

FAO stat. 2009. http://apps.fao.org/page/collections?Subset=agriculture.

Fate, G.D., Chang, M., and Lynn, D.G., 1990. Control of germination in *Striga asiatica*: Chemistry of spatial definition. . Plant physiology, **93**: pp 201-207.

Franke, A.C., J. Ellis-Jones, G. Tarawali, S. Schulz, M.A. Hussein, I. Kureh, R. White, D. Chikoye, B. Douthwaite, B.D. Oyewole, and A.S. Olanrewaju. 2005. Evaluating and scaling-up integrated *Striga hermonthica* control technologies among farmers in northern Nigeria. Crop protection **25** :Pp.868-878.

Frost, D.L., A.L., Gurney, M.C.,Press, and J.D. Scholes. 1997. *Striga hermonthica* reduces photosynthesis in Sorghum: the importance of stomatal limitations and a potential role of ABA? Plant, cell and Environment, **20 :** pp 483-492.

Gebremedhin, W., J. Goudriaan, and H. Naber. 2000. Morphological, phenological and water use dynamics of sorghum varieties (Sorghum bicolor) under *Striga hermonthica* infestation. Crop protection, **2**: pp 51-56.

Graves, J.A., M.C. Press, and G. Stewart. 1989. A carbon balance model of the sorghum *Striga hermonthica* host-parasite association. Plant, Cell and Environment.

Gressel, J., A. Hauafi, Head, G.,W. Marasas, Obolana, A.B. J., Ochanda, Soussi, T., and , and G. Tzotzos. 2004. Major heretofore intractable biotic constrants to African food security that may be amendable to novel biotechnological solutions. Crop protection.

Gressel, J. and B.E. Valverde, 2009. “A strategy to provide long term control of weedy rice while mitigating herbicide resistance transgene flow, and its potential use for other crops with related weeds.” *Pest Manag Sci.,* **65** (7): pp 723- 731.

Groote, H.D., C. Bett, O.J. Okuro, M. Odendo, L. Mose, and E. Wekesa. 2002. Direct estimation of maize losses due to stem borers in Kenya, preliminary results from 2000 and 2001 D. K. Friesen and A. F. E.

Groote, H.D., Wangare, L., F. Kanampiu, Odendo, D.A.O. M., H. Karaya, and F. Dennis. 2008. The potential of an herbicide resistant maize technology for *Striga* control in Africa. Agricultural systems, **97**: pp83-94.

Gurney, A.L., M.C. Press, and J.K. Ransom. 1995. The angiosperm *Striga hermonthica* can reduce Photosynthesis of its Sorghum and Maize hosts in field. Journal of Experimental Botany ,**46**:pp 1817-1823.

Hallauer, A.R., and J.B. Miranda, (eds.) 1981. Quantitative genetics in maize breeding. Iowa state Univ. press, Ames USA.

Hassan, R., J.K. Ransom, and J. Ojiem. 1995. The spatial distribution and farmers strategies to control *Striga* in maize: Survey results from Kenya, *In* J. e. a. (ed), ed. Proc. of the Fourth Eastern and Southern Africa Regional Maize conference, , Harare, Zimbabwe ,28 Mar.-1 Apr. 1994 CIMMYT, Harare, Zimbabwe.

Haussmann, B.I.G., D.E. Hess, H.G. Welz, and H.H. Geiger. 2000. Improved methodologies for breeding *Striga* resistance sorghums. Field Crops Res. **66**: pp 195-211.

Haussmann, B.I.G., D.E. Hess, G.O. Omanya, R.T. Folkertsma, B.V.S. Reddy, M. Kayentao, H.G. Welz, H.H. Geiger, and 2004. Genomic regions influencing resistance to the parasitic weed *Striga hermonthica* in two recombinant inbred populations of sorghum. Theor. Appl. Genet. **109**: pp 1005-1016.

Haussmann, B.I.G., D. E. Hess, G. O. Omanya, R. T. Folkertsma, B.V. S. Reddy, M. Kayentao, H. G. Welz, and H. H. Geiger, . 2004. Genomic regions influencing resistance to the parasitic weed *Striga hermonthica* in two recombinant inbred populations of Sorghum. Theor. Appl. Genet **109**:pp1005-1016.

Hearne, S. 2001. Morphological, Physiological and Molecular interactions between maize and the parasitic angiosperm *Striga hermonthica*. PhD Thesis University of Sheffield, U.K.

Hearne, S.J. 2009. Control- the *Striga* Conundurum (www. Interscience Wiley.com) **10**: p 1735.

Heller, R., and K. Wegmann. 2000. Mechanisms of resistance to *Striga hermonthica* (Del.) Benth. In Sorghum bicolor (L.) Moench, *In* D. E. H. B.I.G. Haussmann, M.L. Koyama, L. Grivet, H.F.W. Rattunde H.H. Geiger, ed. Breeding for *Striga* Resistance in Cereals, IITA, Ibadan, Nigeria, pp 19–28.

Hershberger, J.R., A.C. Warren, and V. Walbot. 1991. Mutator activity in maize correlates with the presence and expression of the Mu transposable element Mu9 Proc. Natl. Acad. Sci. USA **88**: pp10198-10202.

Hess, D.E., G. Ejeta, and L.G. Butler. 1991. Research into germination of *Striga* seeds by sorghum root exudates, *In* L. J. M. A. D. W. J.K. Ransom, C. Parker, ed. Proceedings of the fifth International Symposium of parasitic weeds, Nairobi Kenya CIMMYT, pp 217-222.

IFPRI. 2000. 2020 Projections IFPRI, Washington, DC IRRI (1998) IRRISTAT for Windows, version 4.0.International Rice Research Institute, Manilla.

Kanampiu, F., and D. Friesen. 2003. A New Approach to *Striga* Control. The Royal society of Chemistry **22**: pp 51-53.

Kanampiu, F., A. Diallo, and H. Karaya. 2007. Herbicide-seed coating technology: a unique approach for *Striga* control in maize. African Crop Science Conference proceedings **8**: pp 1095-1098.

Kanampiu, F., G. Omanya, N. Muchiri, F. Nang'ayo, P. Werehire, D. Tyrell, and V. Sthamer. 2005. Launch of *STRIGA*WAY (IR-Maize) technology for *Striga* control in Africa In launch of the *STRIGA*WAY (IR-Maize) technology, Kisumu,Kenya.

Kanampiu, F.K., J.K. Ransom, and J. Gressel. 1999. Imazapyr seed dressings for *Striga* control on acetolactate synthase target- site resistant corn. Agronomy Journal.

Kebreab, E., and A.J. Murdoch. 1999. A quantitave model for loss of primary dormancy and induction of secondary dormancy in imbibed seeds of Orobanche spp Journal of Experimental Botany: **50**: pp 211-219.

Kempthorne, O., 1995. *An introduction of genetics statistics*. John Willey and Sons Inc. New York, USA, pp 468 – 473.

Khan, Z.R., Picket, J.A., Wadhams, L., and Muyekho, F., 2001. Habitat management strategies for the control of cereal stem borers and *Striga* in maize in Kenya. *Insect Science and its Application* ***21*** *(4): 375-380.*

Khan, Z.R., Midega, C.A.O., Hassanali, A., Pickett, J. A., Wadhams, L.J. and Wanyonya, A., 2006.Management of witch weed, *Striga hermonthica*, and stermborers in sorghum,*sorghum bicolor*, through intercropping with green leaf desmodium, *Desmodium intortum*. *International J. Pest management* **52** (4): pp 297-302.

Kim, S.K. 1991. Breeding maize for *Striga* tolerance and the development of a field infestation technique, Combating *Striga* in Africa, IITA, Ibadan, pp 96-108.

Kim, S.K., 1994. Genetics of maize tolerance of *Striga hermonthica*. Crop. Sci. **34** (4): pp 900-907.

Kim, S.K., and V.O. Adetimirin. 1997. Responses of tolerant and susceptible maize hybrids to timing and rate of nitrogen under *Striga hermonthica* infestation. Agron. J. **89:** pp 38-44.

Kim, S.K., A. Y. Akintunde, and P. Walker,. 1999. Responses of maize inbreds during development of *Striga hermonthica* infestation. Maydica **441**: pp 333-339.

Kiruki, S., Onek, L.A., Limo, M. 2006. Azide-based mutagenesis suppresses *Striga hermonthica* seed germination and parasitism on maize varieties. African Journal of Biotechnology **5** (10): pp 866-870.

Kling, J.G., J.M. Fajemisin, B. Badu-Apraku, A. Diallo, A. Menkir, and A. Melake-Berhan. 2000. *Striga* resistance breeding in maize, *In* D. E. H. B. I. G. Haussmann, M. L. Koyama, L. Grivet, H. F.W. Rattunde, and H. H. Geiger, ed. Breeding for *Striga* Resistance in Cereals, Proceedings of a Workshop. Margraf Verlag, Weikersheim, Germany, IITA, Ibadan, Nigeria, 16–20 August 1999, p p 103-118.

Konstantinov, K., and M.D. Snezana. 2007. Molecular genetics- Step by step Implementation in maize breeding. Genetika **39**: pp139-154.

Kuiper, E., J.A. CVerkleij, and A.H. Pieterse. 1996. Differences in the primary dormancy pattern of *Striga* species; an ongoing study, *In* J. I. C. Eds M.T. Moreno, ed. Advances in parasitic plant Research.Proceedings of the sixth International symposium on parasitic plants, Cordoba, Spain, pp 441-450.

Legesse, B., K.V. Pixley, and A.M. Botha. 2009. Combining ability and heterotic grouping of highland transition maize inbred lines. Maydica **54** : pp1-9.

Lynn, D.G., J.C. Steffens, and V.S. Kamat. 1981 Isolation and characterization of the first host recognition substance for parasitic angiosperms. Journal of the American Chemical society **103**: pp 1866-1877.

Ma, Y.Q., G.T.B. Abdel, and A.A. Imad. 1996. *Striga* hermonthica (Del.) Benth germination Stimulant(s) from Menispermum dauricum (DC.) Root culture. J. Agric. Food Chem **44**: pp 3366-3359.

Makumbi, D., Betra´n, J.F., Ba¨nziger, M., Ribaut JM., 2010. Combining ability, heterosis and genetic diversity in tropical maize (Zea mays L.) under stress and non-stress conditions. Euphytica, DOI 10.1007/s10681-010-0334-5.

Maiti, R.K., K.V. Ramaiah, S.S. Bisen, and V.L. Chidley. 1984. A comparative study of the haustorial development of *Striga asiatica* (L.) Kuntze on sorghum cultivars. Annals of Botany, **54**: pp 447-457.

Maluszynski, M., A. Fuglewicz, I. Szarejko, and A. Micke. 1989. Barley mutant heterosis, *In* D. Kluwer, ed. Current Options for Cereal Improvement: In: Doubled Haploids, Mutants and Heterosis, p p 129-146.

Matusova, R., T.V. Mourik, and H.J. Baumeester. 2004. Changes in the sensitivity of parasitic weed seeds to germination stimulants. Seed science research **14**: Pp 335-344.

Matusova, R., K. Rani, F.W.A. Verstappen, M.C.R. Franssen, M.H. Beale, and H.J. Bouwmeester. 2005 The strigolactone germination stimulants of the plant-parasitic *Striga* and Orobanche are derived from the carotenoid pathway. Plant Physiology, **139**: pp 920-934.

M'boob, S.S. 1989. A regional programme for *Striga* control in west and central Africa, *In* T. O. R. a. H. R. Broad, ed. proceedings of the FAO/OAU All- Africa governments consultation on *Striga* control *Striga* Improved Management in Africa, Rome: FAO.

Menkir, A. 2006. Assessment of reactions of diverse maize inbred lines to *Striga hermonthica* (Del) Benth. Plant breeding **125**: pp 131-139.

Menkir, A., J.G. Kling, B. Badu-Apraku, C The, and O. Ibikunle. 2001. Recent advances in breeding maize for resistance to *Striga hermonthica* (Del.) Benth, Proceedings of the Seventh Eastern Africa regional Maize Conference. 11th – 15th February, pp 151-155.

Meseka, S.K., and A.M. Nour. 2001. Screening maize (*Zea mays*) genotypes for *Striga hermonthica* resistance in Sudan, Seventh Eastern and Southern Africa Regional Maize conference. 11th- 15th February, 2001, pp 179-182.

Micke, A. 1976. Hybrid vigor in mutant crosses: Prospects and problems of exploitation studied with mutants of sweet clover, Induced Mutations in Cross Breeding, IAEA Vienna, pp 199-218.

Miracle, M. 1966. Maize in tropical Africa. University of Wisconsin press, Madison.

Mumera, L.M., and F.E. Below. 1993. Role of nitrogen in resistance to *Striga* parasitization of maize. Crop Sci. **33**: pp758-763.

Odhiambo, G.D., and J.K. Ransom. 1993. Effect of Dicamba on the Control of *Striga hermonthica* in corn in Western Kenya. African crop Sci.J, **1**: pp 105-110.

Onwueme, I.C., and T.D. Sinha. 1991. Field crops production in Tropical Africa. Technical Centre for Agricultural and Rural Co-operation.

Oswald, A. 2005. *Striga* control technologies and their dissemination. Crop protection: **23** pp 333-342.

Pageau, K., P. Simier, B.L. Bizec, R.J. Robins, and A. Fer. 2003. Characterization of Nitrogen relationships between Sorghum bicolor and the root hemiparasitic angiosperm *Striga hermonthica* (Del.) Benth. Using KISNO3 as isotopic tracer. Journal of Experimental botany: **16** pp 789-799.

Parker, C. 1991. Protection of crops against parasitic weeds. Crop Prot. **10**: pp 6-22.

Parker, C., and C.R. Riches. 1993. Parasitic weeds of the world: Biology and Control. CAB International, Wallingford, UK, P 332.

Patterson, H.D., and E.R. Williams. 1976. A new class of resolvable incomplete block designs. Biometrika **63**: pp.83–89.

Pingali, P.L. 2001. CIMMYT 199-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector CIMMYT, Mexico, D.F.pp 4-20.

Poelman, J.M. 1983. Breeding field crops, 2nd ed, AVI Westport, Conn. (USA), p. 86.

Powell, W., G.C. Machray, and J. Provan. 1996 Polymorphism revealed by simple sequence repeats. Trends Plant Sci. **12** :215–222.

Press, M.C., and A.L. Gurney. 2000. Plant eats Plant: Sap feeding witch weeds and other parasitic angiosperms. Biologist: **35** pp189 -193.

Ramaiah, K.V., V.L. Childley, and L.R. House. 1991. A time course study of early establishment stages of the parasitic angiosperm *Striga asiatica* on susceptible sorghum roots. Annals of applied Biology,**118**: pp 403-410.

Rank, C., L.S. Rasmussen, S.R. Jensen, S. Pierce, M.C. Press, and J.D. Scholes. 2004. Cytotoxic constituents of Alectra and *Striga* species. Weed Res. **44:** pp265-270.

Ransom, J.K., R.E. Eplee, and M.A. Langston. 1990. Genetic variability for resistance to *Striga asiatica* in maize. Cereal Res. Commun **18**: pp 329-333.

Ransom, J.K., G.D. Odhiambo, G. Abayo, and A. Oswald. 1997. An update on *Striga* control research in Africa, 9 16th East African Biennial weed Science conference proceedings, pp 215-21.

Rawlings, J.O., D.L. Thompson, 1962. Performance level as criterion for the choice of maize testers. Crop Sci. **2**: pp217 – 220.

Riches, C.R., and C. Parker. 1995. Parasitic plants as weeds, *In* J. D. G. M.C. Press, ed. Parasitic plants Chapman and hall, London, UK, pp 226-255.

Riopel, J.L., and W.V. Baird. 1987. Morphogenesis of the early development of primary haustoria in *Striga asiatica*, *In* L.J.Musselman, ed. Parasitic in Agriculture, Vol. Volume I. *Striga* CRC press, Inc., Boca Raton, Florida, **1**: pp 107-125.

Riopel, J.L., and M.P. Timko. 1995. Haustoria initiation and differentiation, *In* J. D. G. M.C. Press, ed. Parasitic plants. Chapman and Hall, London, pp 39-79.

Röbbelen, G. 1990. Mutation breeding for quality improvement - A case study for oilseed crops. Mutation Breeding Review No.6 IAEA, Vienna, pp1-44.

Robertson, D.S. 1978. Characterization of a Mutator system in maize. Mutat. Res **51**: pp21-28.

Rodenburg, J. 2005. The role of sorghum genotypes in the interaction with the parasitic weed, *Striga hermonthica*. PhD thesis Wagenigen University, Wagenigen, the Netherlands, pp138.

Römer, F.W., and A. Micke. 1974. Combining ability and heterosis of radiation-induced mutants of Melilotus albus DES, Polyploidy and Induced Mutations in Plant Breeding Proc. FAO/IAEA/EUCARPIA Meeting, Bari (Italy) 1972. IAEA, Vienna, pp 275-276.

SAS. 2003. SAS ® 9.1 for Windows SAS Institute Inc, Cary, NC.

Sauerborn, J. 1991. The economic importance of the phytoparasite Orobanche and *Striga*, *In* L. J. M. J. K. Ransom, A. D. Worsham and C. Parker, ed. Proceedings of the Fifth International Symposium on Parasitic Weeds,, Mexico City: CIMMYT, pp 137 - 143.

Scholes, J.D., and M.C. Press. 2008. *Striga* infestation of cereal crops – an unsolved problem in resource limited agriculture. Current Opinion in Plant Biology **11**: pp180–186.

Seel, E.D., I. Cechin, C.A. Vincent, and M.C. Press. 1992. Carbon partitioning and transport in parasitic angiosperms and their hosts, *In* J. F. F. a. A. J. G. C.J. Pollock, ed. Carbon partitioning within and between organisms. Bios scientific publishers Ltd, Abingdon, Oxford shire, pp 199-223.

Shew, H.D., and B.B. Shew. 1994. Host resistance, *In* D. M. B. C.L. Campbell, ed. Epidemiology and Management of Root Diseases. Springer Verlog, Berlin, pp 244-275.

Sing, R.K., and B.D. Chaundhary. 1985. Biometrical methods in quantitative genetics analysis. 2nd ed. Kalyan publishers, New Delhi.

Spitko, J., L. Sagi, J. Pinter, C. Marton, and B. Barnabas. 2010. General and specific combining ability of invitro doubled haploid maize lines in the field. Acta Agronomica Hungarica **58**: pp167-177.

Sprague G.F., and L. A., Tatum, 1942. General versus specific combining ability in single crosses corn. *J. Amer. Soc. Agron.* **34**: pp 923 -32.

Taylor, A., and W.E. Seel. 1998. Do *Striga hermonthica*- induced changes in soil matric potential cause the reduction in stomatal conductance and growth of infected maize plants? New Phytologist, **138**: pp 67-73.

Taylor, A., J. Martin, and N.E.,Seel. 1996. Physiology of the parasitic association between Maize and witch weed (*Striga hermonthica*): is ABA involved? Journal of Experimental Botany,**47**: pp1057-1065.

Vanlauwe, B., Kanampiu, F., Odhiambo, G.O., De Groote, H., Washams, L.J. and Khan, Z.R., 2008. Integrated management of *Striga hermonthica*, stemborers and declining soil fertility in Western Kenya. *Field Crops Research* **107**: pp102-115.

Vasudeva, M.J.R. 1987. Techniques for screening sorghum for resistance to *Striga*, Parasitic weeds in agriculture, *Striga* CRC Press, Boca Raton, **1**: pp 281-304.

Vivek, B.S., Crossa, J., Alvarado, G., 2009. Heterosis and combining ability among CIMMYT's Mid-altitude early to intermediate maturing maize (*Zea mays* L.) populations. Maydica **54**: pp 97-107.

Weber, G.K., K. Elemo, S.T.O. Lagoke, A. Awad, and S. Oikeh. 1995. Population dynamics and determinants of *Striga hermonthica* on maize and Sorghum in Savanna farming systems Crop protection, **14**: pp 283-290.

Weerasuriya, Y., B.A. Siame, D. Hess, G. Ejeta, and L.G. Butler. 1993. Influence of conditions and genotype on the amount of *Striga* germination stimulants exuded by roots of several host crops Journal of Agricultural and Food Chemistry, **41**: pp1492–1496.

Welker, C.,The, C, Andreau, B., 2005. Heterosis and combining ability for maize adaptation to tropical acid soils: implications for future breeding strategies. *Crop science* **45**: pp 2405 - 2430.

Woomer, P. 2004. New approaches to Controlling *Striga* infestation Farmers journal: pp 2-4

World Bank. 1998. World development indicators. Warshington D. C., USA.

Yallou, C.G., A. Menkir, V.O. Adetimirin, and J.G. Kling. 2009. Combining ability of maize inbred lines containing genes from *Zea diploperennis* fro resistance to *Striga hemonthica* (Del.) Benth. Plant Breeding **128**: pp143-148.

Yoder, J.I. 2001. Host plant recognition by parasitic *Scrophulariaceae*. Current opinion in plant Biologgy, **4**: pp 359-365.

Appendices

Appendix 1. Climatic data for Kisumu during 2008 growing period

Month	Rainfall (mm)	Temperature (°C)	
		Maximum	Minimum
January	27.9	31.3	17.3
February	0.0	31.3	17.7
March	164.6	30.3	17.8
April	152.2	29.0	17.4
May	165.2	29.0	17.3
June	106.7	28.1	16.7
July	127.2	27.9	16.8
August	90.8	28.8	16.7
September	149.7	29.4	17.3
October	206.2	29.2	17.9
November	143.4	29.2	18.3
December	37.7	31.1	17.6
Total	**1371.6**	.	.
Mean	**102.8**	**29.6**	**17.4**

Appendix 2. Climatic data for Kisumu during 2009 growing period

Month	Rainfall (mm)	Temperature (°C)	
		Maximum	Minimum
January	114.2	31.6	17.2
February	45.9	31.6	17.7
March	79.9	32.3	18.3
April	273.7	29.3	18.4
May	124.8	28.9	18.0
June	27.6	30.0	16.4
July	30.7	30.0	16.4
August	79.6	30.9	17.7
September	148.1	30.7	17.7
October	48.3	30.7	17.9
November	123.8	30.1	18.3
December	186.0	30.9	17.9
Total	**1282.6**	.	.
Mean	**111.0**	**30.6**	**17.7**

Appendix 3. Analysis of variance on grain yield for the landraces under artificial *Striga* infestation

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
REP	1	34.77	34.77	42.97	<.0001
ENTRY	383	559.87	1.47	1.81	<.0001
SITE*ENTRY	384	795.86	2.08	2.57	<.0001

Appendix 4. Analysis of variance on *Striga* damage rating for the land races

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.94	0.94	0.55	0.458
ENTRY	383	791.85	2.07	1.21	0.0138
SITE*ENTRY	384	856.00	2.23	1.31	0.0011

Appendix 5. Analysis of variance on *Striga* counts 8 weeks after planting for the land races

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
REP	1	2704.74	2704.74	33.35	<.0001
ENTRY	383	44325.46	116.04	1.43	<.0001
SITE*ENTRY	384	59288.67	154.80	1.91	<.0001

Appendix 6. Analysis of variance on *Striga* counts 10 weeks after planting for the land races

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
REP	1	2080.48	2080.48	7.5	0.0063
ENTRY	383	171560.53	449.11	1.62	<.0001
SITE*ENTRY	384	151060.31	394.41	1.42	<.0001

Appendix 7. Analysis of variance on *Striga* counts 12 weeks after planting for the land races

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
REP	1	11722.55	11722.55	20.29	<.0001
ENTRY	383	355748.35	931.28	1.61	<.0001
SITE*ENTRY	384	259377.50	677.23	1.17	0.0344

Appendix 8.Analysis of variance on grain yield for the landraces under *Striga* free environment

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	1167.029	1167.029	943.64	<.0001
REP	1	0.196045	0.196045	0.16	0.6906
ENTRY	383	1091.255	2.84923	2.3	<.0001

Appendix 9. Analysis of variance on grain yield for the inbred lines under artificial *Striga* infestation

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	12.13	12.13	14.6800	0.0002
REP	1	0.09	0.09	0.1100	0.7397
ENTRY	36	45.68	1.27	1.5400	0.0514

Appendix 10. Analysis of variance on *Striga* damage rating for the inbred lines under artificial *Striga* infestation

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	46.55	46.55	22.41	<.0001
REP	1	0.33	0.33	0.16	0.0505
ENTRY	36	95.47	2.65	1.28	0.0016

Appendix 11. Analysis of variance on *Striga* counts 8 weeks after planting for the inbred lines under artificial *Striga* infestation

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	839.092973	839.092973	7.45	0.0074
REP	1	59.448919	59.448919	0.53	0.4691
ENTRY	36	5708.305	158.564028	1.41	0.0511

Appendix 12. Analysis of variance on *Striga* counts 12 weeks after planting for the inbred lines under artificial *Striga* infestation

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	87.66	87.66	0.450	0.502
REP	1	829.12	829.12	4.300	0.041
ENTRY	36	13309.67	369.71	1.920	0.005

Appendix 13.Analysis of variance on grain yield for the inbred lines under *Striga* free environment

Source	Degrees of freedom	Type III SS	Mean Square	F Value	Pr > F
SITE	1	79.5933059	79.5933059	47.04	<.0001
REP	1	0.0003134	0.0003134	0	0.9892
ENTRY	36	168.7261792	4.6868383	2.77	<.0001

Appendix 14.Analysis of variance on grain yield for the lines and testers under artificial *Striga* infestation

Source	**Degrees of freedom**	**Type III SS**	**Mean of squares**	**F Value**	**Pr> F**
RE P	2	0.82959	0.4147	1.65	0.1975
LI NE	13	21.9425	1.6846	6.69	<.0001
TESTER	5	7.5738	1.5147	6.02	<.0001

Appendix 15.Analysis of variance on grain yield for the single cross hybrids under *Striga* free environment

Source	**Degrees of freedom**	**Type III SS**	**Mean of squares**	**F Value**	**Pr> F**
REP	2	3.131984	1.565992	0.68	0.5053
ENTRY	83	1237.8992	14.914448	6.51	<.0001
SITE	1	85.04605	85.04605	37.09	<.0001

Appendix 16.Analysis of variance on reaction to *E. turcicum* for the single cross hybrids

Source	**Degrees of freedom**	**Type III SS**	**Mean of squares**	**F Value**	**Pr> F**
REP	2	0.7007944	0.35039718	2.74	0.0654
ENTRY	83	33.930395	0.40879994	3.2	<.0001
SITE	1	10.402371	10.402371	81.49	<.0001

Appendix 17. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
1	1.1	58.8	6.5	1.30	1.55	1.60
2	1.0	67.3	4.8	0.80	1.18	1.50
3	2.0	58.3	5.5	0.90	1.10	1.38
4	2.0	75.0	4.5	0.75	1.45	1.68
5	1.1	75.0	5.3	1.10	1.58	1.73
6	1.6	71.5	4.5	1.23	1.58	1.78
7	1.0	80.8	5.0	1.25	1.65	1.75
8	1.5	76.2	4.8	0.60	1.10	1.33
9	1.0	73.4	4.8	0.93	1.40	1.60
10	0.5	87.2	5.5	1.05	1.43	1.40
11	1.5	89.8	4.3	0.58	1.08	1.43
12	0.7	88.3	4.5	0.80	1.20	1.35
13	0.9	73.3	6.0	1.35	1.63	1.73
14	1.0	81.5	5.3	0.93	1.33	1.60
15	1.1	74.8	4.5	0.78	1.35	1.48
16	0.8	71.3	5.8	1.03	1.38	1.53
17	1.6	74.8	3.8	0.78	1.35	1.38
18	1.4	67.3	4.8	1.00	1.43	1.50
19	1.4	66.8	5.8	0.83	1.35	1.45
20	1.8	83.5	5.5	0.88	1.33	1.60
21	1.1	73.3	5.0	1.08	1.58	1.73
22	1.8	70.3	4.3	0.83	1.35	1.55
23	1.6	81.8	3.8	0.75	1.33	1.48
24	0.9	68.5	5.8	0.83	1.35	1.55
25	0.9	77.5	6.0	1.25	1.58	1.68
26	1.3	77.0	5.3	0.88	1.48	1.65
27	1.1	71.0	5.5	0.73	1.48	1.70
28	0.9	82.6	6.0	0.98	1.40	1.53
29	0.8	73.8	6.3	1.13	1.53	1.75
30	0.8	80.9	5.3	1.13	1.58	1.70
31	2.1	57.3	5.3	0.78	1.18	1.28
32	0.7	61.8	6.5	0.73	1.13	1.33
33	0.8	60.3	5.8	0.53	0.83	1.15
34	1.7	53.0	6.0	0.93	1.08	1.40
35	2.5	58.5	4.3	0.80	1.08	1.48
36	0.6	74.3	5.3	0.40	0.88	1.18
37	1.2	76.0	4.8	0.53	0.90	1.35
38	0.3	86.0	6.5	0.80	1.13	1.38
39	3.3	70.5	4.0	0.48	1.05	1.33

Appendix 18 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
40	1.8	78.3	4.8	0.98	1.58	1.70
41	6.0	94.2	5.8	7.68	8.50	1.60
42	0.7	76.0	4.1	0.46	0.97	1.35
43	1.1	60.8	5.5	0.48	0.90	0.98
44	0.0	61.3	6.0	0.28	0.63	0.78
45	1.5	66.3	4.5	0.40	1.00	1.33
46	0.5	71.8	5.5	0.93	1.48	1.50
47	1.7	60.5	5.0	1.15	1.45	1.50
48	0.9	65.3	5.3	1.05	1.48	1.68
49	1.0	64.0	6.3	1.25	1.60	1.63
50	1.3	70.0	5.8	1.10	1.45	1.70
51	0.4	73.3	4.8	0.50	0.83	1.08
52	0.4	76.1	4.5	0.70	1.15	1.45
53	1.3	71.8	5.3	1.18	1.55	1.75
54	2.1	70.5	5.3	1.00	1.20	1.35
55	1.8	76.3	4.0	0.90	1.38	1.55
56	1.3	74.0	5.0	0.85	1.23	1.43
57	1.4	75.3	4.3	0.55	0.90	1.10
58	1.7	70.8	3.8	0.65	0.98	1.28
59	0.4	77.8	5.0	0.58	0.95	1.20
60	2.2	82.3	4.8	0.80	1.15	1.38
61	0.8	75.0	6.3	0.98	1.28	1.43
62	-0.1	71.4	5.7	0.25	0.57	0.70
63	-0.2	80.2	3.2	0.16	0.74	0.55
64	1.0	69.8	5.3	0.95	1.08	1.33
65	-0.1	69.8	4.5	0.78	1.60	1.30
66	0.1	73.3	6.2	0.80	1.20	1.35
67	1.2	71.5	4.8	0.63	1.20	1.40
68	0.6	73.8	6.5	0.80	1.28	1.53
69	0.7	74.0	5.5	1.15	1.33	1.73
70	1.3	69.0	4.3	1.10	1.50	1.63
71	0.7	73.0	5.5	1.28	1.50	1.70
72	1.3	80.5	4.3	0.78	1.35	1.58
73	0.5	87.7	6.3	0.95	1.50	1.63
74	0.7	82.8	7.1	6.68	15.73	1.43
75	1.7	68.7	5.5	1.23	1.47	1.65
76	1.3	72.3	4.5	0.90	1.48	1.55
77	0.4	86.3	5.8	0.83	1.38	1.63
78	1.2	83.0	4.5	0.83	1.33	1.68
79	1.2	69.8	4.3	1.08	1.50	1.58

Appendix 19 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
80	1.7	77.5	5.3	1.08	1.50	1.58
81	1.0	76.8	4.3	1.08	1.50	1.63
82	0.3	70.3	5.0	1.00	1.43	1.63
83	1.2	73.0	5.3	1.05	1.30	1.55
84	0.8	75.4	5.0	1.15	1.50	1.73
85	2.0	67.8	4.5	1.08	1.38	1.60
86	1.0	74.0	4.0	0.33	0.80	0.98
87	-0.2	79.3	6.0	0.98	1.33	1.45
88	0.5	74.0	5.0	0.75	1.05	1.35
89	1.0	77.9	5.3	0.90	1.40	1.63
90	1.1	94.9	4.3	0.30	0.73	0.93
91	1.4	78.5	4.0	0.88	1.40	1.60
92	1.6	72.8	5.3	1.05	1.40	1.45
93	0.7	77.0	5.3	1.05	1.65	1.83
94	1.1	71.3	4.3	0.68	1.25	1.45
95	0.4	99.0	5.8	0.90	1.28	1.35
96	1.1	73.0	5.0	0.75	1.20	1.55
97	2.1	76.5	4.0	0.98	1.38	1.63
98	2.0	88.3	3.5	0.43	0.85	1.15
99	0.7	71.5	5.0	1.20	1.63	1.78
100	0.5	81.3	5.0	0.28	0.58	0.93
101	1.0	86.3	4.3	0.83	1.45	1.75
102	1.0	88.2	5.5	1.13	1.55	1.73
103	1.7	77.0	6.0	0.88	1.40	1.53
104	1.6	83.2	5.0	1.08	1.35	1.65
105	1.1	79.0	5.0	1.13	1.43	1.60
106	1.1	74.3	4.8	0.73	1.30	1.55
107	0.9	72.0	4.8	0.95	1.35	1.55
108	1.7	65.8	5.3	0.73	1.33	1.45
109	1.2	70.3	5.8	1.10	1.53	1.60
110	0.6	70.8	6.0	0.88	1.20	1.53
111	1.1	73.3	5.5	1.13	1.43	1.63
112	0.8	75.0	4.5	0.83	1.38	1.50
113	1.1	71.3	5.0	1.10	1.45	1.70
114	1.5	73.0	3.8	0.80	1.18	1.55
115	0.3	74.2	5.6	0.40	0.88	1.18
116	0.7	75.5	5.3	0.75	1.25	1.35
117	2.1	72.5	5.8	0.78	1.30	1.58
118	1.7	78.8	3.8	0.53	0.70	1.03
119	1.7	72.5	4.5	0.73	1.20	1.48

Appendix 20 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
120	1.1	76.3	5.0	1.05	1.63	1.80
121	0.8	81.3	5.3	0.80	1.40	1.73
122	1.0	78.0	5.0	0.98	1.40	1.60
123	2.0	81.2	3.5	0.95	1.53	1.53
124	3.5	73.8	5.0	0.75	1.18	1.45
125	2.4	78.3	3.3	0.65	1.05	1.43
126	0.8	79.0	6.3	1.10	1.50	1.73
127	0.9	78.3	4.5	1.00	1.55	1.78
128	1.6	69.5	4.3	1.13	1.50	1.58
129	1.0	76.5	5.3	0.88	1.35	1.60
130	0.2	89.8	5.0	0.95	1.43	1.63
131	1.0	81.3	5.3	1.05	1.38	1.78
132	0.0	76.8	4.8	0.50	0.90	1.05
133	1.6	78.2	5.3	0.65	0.85	1.00
134	1.7	71.8	4.8	1.00	1.45	1.68
135	1.1	73.0	5.0	0.85	1.33	1.60
136	1.0	77.0	3.5	0.98	1.40	1.55
137	0.8	69.3	4.5	1.20	1.55	1.73
138	0.6	71.5	5.5	0.85	1.18	1.45
139	1.0	78.3	5.0	0.75	1.20	1.58
140	1.2	76.3	5.0	0.85	1.30	1.50
141	1.1	73.3	4.8	1.13	1.53	1.63
142	1.3	71.3	4.8	0.90	1.55	1.70
143	-0.1	75.4	6.3	0.38	0.83	1.13
144	0.2	70.8	5.0	0.15	0.80	1.18
145	2.0	74.8	4.3	0.78	1.13	1.25
146	1.3	74.3	5.0	0.80	1.20	1.38
147	0.8	69.8	5.3	0.98	1.40	1.53
148	1.4	72.5	4.3	0.98	1.20	1.50
149	1.6	72.8	4.8	0.95	1.35	1.58
150	1.0	72.3	4.8	0.88	1.38	1.58
151	1.3	73.5	4.8	0.75	1.05	1.38
152	1.9	73.5	4.8	0.93	1.38	1.55
153	1.9	68.8	5.0	0.80	1.10	1.28
154	0.5	72.8	5.8	1.08	1.48	1.55
155	0.8	71.8	5.0	0.83	1.40	1.50
156	0.6	71.4	5.3	1.00	1.48	1.68
157	1.6	72.8	4.0	0.78	1.38	1.53
158	0.7	64.5	6.5	1.35	1.60	1.75
159	1.0	75.8	5.5	1.23	1.55	1.68

Appendix 21 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
160	1.6	75.0	3.8	1.13	1.60	1.83
161	1.5	74.0	4.3	0.95	1.33	1.43
162	2.4	82.5	4.5	0.75	0.88	1.33
163	0.6	91.3	3.8	0.58	0.88	1.43
164	0.8	88.6	5.0	0.60	1.25	1.45
165	1.2	82.3	5.3	1.08	1.58	1.80
166	0.5	78.1	5.0	0.73	1.18	1.43
167	1.1	87.2	4.8	1.08	1.45	1.70
168	1.5	76.0	3.8	0.83	1.45	1.60
169	0.4	92.6	5.3	1.03	1.53	1.78
170	1.1	78.3	4.3	1.05	1.40	1.60
171	2.7	73.6	3.3	0.63	1.13	1.43
172	0.2	84.6	5.3	0.48	0.95	1.15
173	0.7	83.7	5.5	1.15	1.65	1.75
174	1.5	81.9	5.0	0.98	1.43	1.58
175	0.5	84.2	5.3	0.75	1.23	1.58
176	1.6	79.5	3.8	1.03	1.55	1.80
177	1.6	81.3	4.8	1.08	1.43	1.65
178	1.0	79.5	3.5	1.08	1.60	1.73
179	0.9	87.8	5.5	0.78	1.38	1.53
180	1.3	79.0	5.5	1.15	1.50	1.58
181	2.0	75.8	4.3	0.98	1.33	1.50
182	-0.1	91.4	6.0	0.95	1.33	1.53
183	0.4	89.1	4.8	1.13	1.53	1.78
184	0.5	84.5	6.0	1.03	1.40	1.60
185	0.4	77.1	6.2	7.10	11.80	1.75
186	0.6	89.9	4.9	0.80	1.31	1.42
187	1.8	75.8	4.3	0.88	1.23	1.43
188	0.8	88.5	4.5	0.90	1.38	1.58
189	1.2	72.3	5.0	1.18	1.50	1.73
190	1.0	83.3	5.3	1.15	1.53	1.63
191	0.7	80.0	4.8	0.98	1.48	1.60
192	1.9	85.0	5.0	8.60	1.46	64.92
193	2.7	73.9	3.6	0.63	1.34	1.72
194	1.3	77.8	4.3	1.25	1.53	1.78
195	1.6	84.3	4.3	0.90	1.43	1.65
196	0.9	81.4	2.9	1.14	4.32	1.42
197	0.7	81.8	5.0	1.08	1.65	1.75
198	1.1	72.0	5.5	1.03	1.38	1.45
199	1.8	70.5	4.3	1.03	1.48	1.68
200	1.0	85.2	5.5	1.43	1.88	1.90

Appendix 22 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
201	2.1	67.8	4.5	0.93	1.53	1.68
202	2.6	69.0	4.0	0.60	1.23	1.45
203	1.7	71.8	5.3	0.93	1.35	1.65
204	2.3	70.3	5.0	1.05	1.45	1.65
205	0.3	84.1	3.4	0.40	2.66	1.28
206	1.1	67.3	5.3	0.58	1.08	1.30
207	1.5	75.6	4.8	0.90	1.13	1.43
208	1.6	74.0	4.8	0.68	1.13	1.33
209	1.6	67.0	5.0	1.13	1.45	1.53
210	0.7	80.0	5.8	1.10	1.73	1.68
211	1.0	83.5	4.8	0.93	1.50	1.63
212	0.4	83.6	5.5	1.10	1.58	1.63
213	2.2	80.8	4.5	1.00	1.38	1.65
214	1.1	72.3	5.5	1.33	1.75	1.80
215	1.3	69.5	4.5	1.00	1.40	1.63
216	0.8	71.8	5.8	1.15	1.48	1.68
217	0.9	71.8	5.0	1.08	1.45	1.60
218	2.2	70.3	4.8	0.98	1.43	1.75
219	2.1	67.8	5.3	0.90	1.05	1.25
220	1.1	75.0	3.8	0.60	1.05	1.38
221	1.0	70.3	5.0	1.15	1.50	1.63
222	0.3	81.8	6.0	1.08	1.25	1.48
223	1.4	75.8	3.5	0.85	1.38	1.58
224	1.6	74.0	4.0	1.13	1.65	1.70
225	0.7	77.0	5.8	0.98	1.48	1.65
226	1.6	80.4	5.0	0.80	1.28	1.53
227	1.3	60.3	5.8	0.93	1.30	1.30
228	1.5	71.0	5.3	0.93	1.40	1.53
229	1.2	58.0	6.3	0.80	1.23	1.33
230	0.9	61.0	6.5	1.13	1.45	1.55
231	1.3	58.5	5.8	0.90	1.20	1.35
232	1.1	58.8	5.8	1.23	1.48	1.53
233	1.1	58.8	6.5	1.20	1.48	1.58
234	1.4	92.6	4.3	0.88	1.33	1.50
235	1.4	86.5	4.5	0.80	1.38	1.70
236	1.8	68.5	5.0	0.90	1.28	1.55
237	1.2	71.3	4.3	0.98	1.38	1.60
238	0.9	74.0	6.3	1.13	1.53	1.68
239	1.1	73.0	6.5	1.33	1.63	1.83
240	2.1	67.0	4.5	0.88	1.35	1.53
241	0.7	71.8	5.3	0.90	1.33	1.50

Appendix 23 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
242	1.4	70.0	4.3	0.90	1.30	1.50
243	1.7	75.5	3.5	0.93	1.53	1.65
244	0.7	85.2	5.0	1.03	1.38	1.65
245	0.5	93.9	5.5	0.90	1.40	1.58
246	1.1	70.1	5.5	1.00	1.45	1.65
247	0.2	89.2	5.3	1.23	1.58	1.75
248	1.1	90.0	6.4	7.10	9.00	1.70
249	1.6	68.3	4.9	1.07	1.37	1.55
250	1.8	71.5	4.8	0.70	1.20	1.40
251	1.3	77.3	5.0	1.05	1.45	1.68
252	1.1	66.3	6.0	1.20	1.58	1.68
253	1.9	73.3	5.0	1.35	1.55	1.65
254	0.6	72.3	6.3	0.60	1.03	1.30
255	1.4	65.5	5.0	0.50	0.80	1.00
256	-0.3	95.9	5.5	0.00	0.00	0.33
257	1.2	80.3	5.5	0.48	0.78	1.03
258	1.6	74.5	4.5	0.80	1.30	1.60
259	0.9	59.3	6.3	0.93	1.23	1.33
260	0.9	79.9	5.0	0.73	1.28	1.48
261	0.5	75.8	4.8	0.85	1.33	1.53
262	0.5	73.3	4.8	0.58	0.93	1.10
263	2.1	74.3	4.8	0.63	1.10	1.51
264	1.3	78.5	3.8	0.88	1.45	1.65
265	1.2	75.5	5.0	1.00	1.38	1.55
266	1.4	77.3	5.0	1.00	1.48	1.70
267	0.8	76.5	5.5	1.35	1.45	1.68
268	1.4	74.8	5.3	1.03	1.35	1.53
269	1.0	87.0	4.5	0.80	1.23	1.48
270	1.1	71.8	6.0	1.23	1.60	1.68
271	1.9	67.8	5.5	1.13	1.50	1.63
272	2.6	77.0	5.0	0.95	1.50	1.63
273	1.4	73.3	5.0	1.00	1.53	1.68
274	1.1	56.5	6.3	1.00	1.33	1.40
275	0.7	72.0	5.0	0.95	1.43	1.55
276	1.4	69.8	5.3	0.78	1.10	1.35
277	1.1	71.8	4.8	1.13	1.25	1.68
278	0.8	84.8	4.5	0.88	1.20	1.43
279	0.8	78.8	4.5	0.90	1.20	1.43
280	1.0	69.0	4.8	0.65	1.00	1.25
281	1.5	60.5	5.0	0.85	1.25	1.40
282	1.1	53.3	6.0	0.55	0.78	0.95

Appendix 24 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
283	2.0	61.8	4.0	0.85	1.43	1.55
284	0.7	65.0	6.0	0.85	1.20	1.33
285	1.6	70.3	5.5	1.03	1.58	1.70
286	2.0	68.0	3.8	0.85	1.20	1.40
287	0.8	65.5	6.0	1.28	1.63	1.65
288	1.7	80.0	4.8	0.90	1.18	1.38
289	1.2	58.8	5.0	1.05	1.25	1.33
290	0.9	65.5	5.5	1.13	1.53	1.68
291	1.8	71.5	5.3	1.13	1.43	1.65
292	2.1	74.5	4.3	0.75	1.13	1.35
293	2.1	70.5	5.3	1.20	1.63	1.73
294	2.9	71.5	4.5	0.93	1.30	1.55
295	1.2	73.3	5.5	0.88	1.45	1.70
296	1.2	60.3	6.8	1.13	1.40	1.50
297	1.1	68.8	6.0	0.98	1.33	1.40
298	2.2	67.8	4.5	0.55	0.90	1.15
299	1.3	58.8	5.8	0.98	1.30	1.33
300	0.9	58.5	5.5	0.95	1.38	1.40
301	0.8	73.5	5.8	1.05	1.48	1.58
302	0.2	71.8	6.0	1.25	1.45	1.70
303	1.7	68.8	5.5	1.23	1.55	1.65
304	2.4	72.0	4.5	1.05	1.50	1.68
305	2.8	66.0	4.5	0.80	1.28	1.50
306	0.6	72.3	4.8	0.70	1.15	1.33
307	2.7	70.5	4.0	0.60	1.15	1.43
308	1.6	73.8	5.5	1.08	1.73	1.75
309	1.0	69.0	4.8	1.00	1.33	1.50
310	1.0	61.3	6.5	0.98	1.48	1.65
311	2.6	67.0	4.5	0.75	1.25	1.48
312	1.9	73.3	4.3	0.70	1.30	1.53
313	1.4	73.6	5.0	0.85	1.30	1.53
314	1.4	77.3	4.8	1.18	1.65	1.75
315	0.6	73.5	5.3	0.70	1.18	1.43
316	1.4	72.0	5.5	0.80	1.25	1.58
317	1.3	67.3	5.0	0.88	1.43	1.60
318	0.8	71.3	6.0	1.00	1.30	1.58
319	0.9	75.6	5.5	1.08	1.50	1.70
320	1.5	69.5	4.3	1.15	1.55	1.73
321	1.6	70.0	5.3	1.10	1.43	1.68
322	3.0	70.3	4.5	0.80	1.38	1.50
323	2.0	72.0	4.8	0.75	1.30	1.58

Appendix 25 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
324	1.4	72.3	4.5	1.00	1.45	1.68
325	2.4	73.0	4.0	0.80	1.45	1.60
326	2.7	70.0	4.8	1.20	1.60	1.65
327	1.2	73.0	4.8	1.33	1.65	1.75
328	1.9	72.8	3.8	0.83	1.48	1.63
329	2.5	73.0	3.8	0.73	1.33	1.65
330	2.2	78.2	4.8	1.28	1.53	1.55
331	1.3	56.3	5.0	1.03	1.33	1.45
332	2.1	59.0	5.5	0.55	1.03	1.15
333	1.9	60.0	4.8	0.68	1.05	1.30
334	2.0	58.5	4.5	0.95	1.28	1.38
335	1.2	74.3	5.3	1.15	1.58	1.75
336	1.1	57.3	5.3	0.95	1.20	1.38
337	1.5	60.8	5.3	0.75	1.18	1.35
338	0.7	79.3	5.0	1.05	1.58	1.73
339	2.2	75.3	3.5	0.65	1.35	1.55
340	1.7	73.3	5.3	1.13	1.45	1.60
341	0.5	82.9	5.5	1.35	1.65	1.75
342	1.5	69.5	5.0	1.13	1.63	1.70
343	1.0	81.0	5.0	1.23	1.60	1.80
344	1.6	77.5	5.0	1.20	1.55	1.75
345	1.7	70.3	4.5	0.83	1.33	1.58
346	1.7	71.5	5.0	1.03	1.58	1.75
347	0.6	78.0	20.5	22.88	22.95	1.50
348	2.2	74.6	3.9	1.13	1.34	1.45
349	2.3	74.8	4.3	0.93	1.50	1.65
350	1.3	74.0	4.0	1.05	1.50	1.80
351	2.4	72.8	4.8	0.73	1.48	1.73
352	1.3	72.0	4.3	1.13	1.60	1.73
353	1.5	72.5	5.3	0.88	1.60	1.60
354	1.8	71.8	4.5	1.13	1.50	1.83
355	1.8	69.8	5.0	1.20	1.53	1.78
356	1.3	79.5	3.5	0.75	1.40	1.63
357	3.2	74.0	4.0	0.75	1.18	1.40
358	2.1	73.0	4.0	1.00	1.40	1.65
359	1.4	70.8	5.0	1.13	1.58	1.75
360	1.0	74.0	5.5	1.00	1.50	1.63
361	1.7	72.8	4.5	1.28	1.55	1.73
362	0.9	81.3	4.3	0.83	1.33	1.60
363	1.4	76.3	5.5	0.85	1.33	1.50
364	1.5	57.8	5.3	0.93	1.35	1.55

Appendix 26 Continued. Performance of the land races under artificial *Striga* infestation in Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
365	0.8	69.8	6.0	1.28	1.53	1.58
366	1.1	73.8	6.5	1.00	1.45	1.60
367	0.9	66.5	4.3	0.88	1.28	1.33
368	0.5	80.8	4.8	0.80	1.38	1.68
369	0.9	77.5	5.3	1.10	1.48	1.60
370	1.4	72.8	4.5	0.90	1.33	1.50
401	1.9	69.8	4.5	0.93	1.33	1.53
402	1.5	67.3	5.3	0.83	1.03	1.20
403	2.7	68.8	5.5	0.78	1.13	1.28
404	1.3	68.5	4.5	0.83	1.25	1.43
405	4.3	68.3	3.5	0.75	1.18	1.33
406	2.6	66.8	3.5	0.73	1.08	1.23
407	3.3	67.5	4.5	0.75	1.33	1.48
408	2.3	69.8	4.0	0.90	1.35	1.60
409	2.5	67.3	3.8	1.10	1.38	1.53
410	2.0	68.8	5.5	1.10	1.45	1.58
417	1.5	72.5	5.5	0.08	0.15	0.30
418	2.0	64.8	4.0	0.90	1.28	1.53
419	0.5	72.5	5.5	0.08	0.15	0.30
420	2.5	66.8	4.3	0.88	1.35	1.63
MEAN	**1.3**	**73.9**	**5.0**	**1.0**	**1.5**	**1.7**
CV	**25.8**	**9.56**	**29.9**	**35.6**	**30.9**	**31.7**
SIG.	***	***	**	*	*	***

Key: YLD= grain yield (t/ha), AD= days to 50% anthesis, SDR= Striga damage rating (Score 1-9), STR8TR= Striga count 8 weeks after planting (WAP), Striga count 10 weeks after planting, Striga count 12 weeks after planting

Appendix 27. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
1	1.3	60	64	4	137.5	65.0	1.8	7.0	1.3	1.5	1.7	1.1
2	1.7	70	73	3	175.0	92.5	2.8	4.0	0.0	0.7	1.2	0.9
3	2.2	59	62	3	125.0	40.0	1.3	6.5	0.9	1.1	1.5	0.9
4	3.5	74	79	5	177.5	95.0	3.0	4.0	0.2	1.2	1.5	1.3
5	1.6	76	85	9	162.5	82.5	2.3	5.5	0.8	1.5	1.7	0.9
6	2.6	72	75	4	157.5	85.0	2.5	5.0	1.1	1.6	1.8	1.1
7	1.7	82	88	6	155.0	72.5	2.3	5.0	1.2	1.6	1.8	0.9
8	2.2	79	93	14	155.0	77.5	2.5	4.5	0.2	1.0	1.1	1.0
9	1.7	75	84	9	160.0	85.0	2.0	6.0	0.7	1.4	1.7	1.0
10	0.8	90	97	8	137.5	67.5	2.0	5.5	1.0	1.5	1.7	0.9
11	2.5	85	91	6	175.0	100.0	3.0	4.5	0.5	1.1	1.4	1.1
12	1.3	89	98	10	190.0	117.5	3.0	4.0	0.5	0.9	1.1	1.1
13	1.1	75	84	9	145.0	75.0	2.3	6.5	1.2	1.6	1.7	1.0
14	1.7	85	94	9	167.5	90.0	2.5	6.0	0.8	1.2	1.5	1.1
15	1.4	77	87	10	145.0	75.0	2.3	5.5	0.4	1.2	1.4	1.0
16	1.5	72	80	8	130.0	57.5	2.0	6.5	1.2	1.5	1.6	0.9
17	2.5	76	97	21	167.5	90.0	3.0	3.5	0.6	1.1	1.0	1.1
18	2.6	68	72	4	150.0	72.5	2.3	5.0	0.9	1.4	1.5	0.6
19	1.3	70	74	4	107.5	42.5	1.5	7.5	1.0	1.6	1.7	1.1
20	2.8	79	84	5	185.0	110.0	2.5	5.0	0.7	1.3	1.7	1.0
21	1.2	76	83	7	157.5	70.0	2.3	6.0	1.2	1.7	1.7	0.9
22	3.0	75	77	2	160.0	75.0	2.3	4.0	0.7	1.2	1.6	0.9
23	2.5	82	87	5	182.5	102.5	2.5	4.0	0.5	1.1	1.5	1.3
24	1.8	71	77	6	140.0	70.0	2.5	5.5	0.3	1.0	1.4	1.0
25	1.2	83	87	8	122.5	52.5	1.5	6.5	1.1	1.5	1.6	1.1
26	1.8	79	86	8	142.5	65.0	2.3	4.5	0.5	1.3	1.6	1.1
27	1.2	70	83	13	127.5	57.5	2.0	6.0	0.4	1.4	1.7	1.0
28	1.3	81	91	10	130.0	62.5	2.0	6.5	0.7	1.3	1.5	1.2
29	1.3	73	85	12	155.0	75.0	2.8	5.5	0.7	1.4	1.8	1.0
30	0.9	84	94	11	137.5	57.5	1.8	5.5	1.0	1.6	1.7	1.0
31	2.6	59	62	3	152.5	60.0	2.0	5.0	0.4	0.9	1.1	1.0
32	0.5	63	76	13	117.5	42.5	1.3	8.0	0.6	1.1	1.4	1.2
33	0.5	63	76	13	110.0	47.5	1.0	7.0	0.9	1.2	1.4	1.0
34	2.2	54	57	3	132.5	50.0	2.0	6.0	0.8	1.2	1.3	1.0
35	2.9	65	62	-3	150.0	60.0	2.3	5.0	0.5	0.8	1.3	1.0
36	0.9	74	84	10	147.5	85.0	2.3	5.5	0.2	0.8	1.2	1.0
37	0.9	77	87	.	137.5	75.0	2.0	5.5	0.5	0.7	1.3	1.0
38	-0.3	92	.	10	117.5	45.0	1.3	8.0	0.8	1.2	1.5	0.9
39	4.2	70	73	3	185.0	95.0	3.0	4.0	0.3	1.0	1.4	1.0
40	1.8	80	82	8	160.0	77.5	2.5	5.0	0.7	1.5	1.7	1.0

Appendix 28 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
41	8.5	101	103	1	137.5	62.5	3.5	14.0	51.3	56.1	1.8	1.0
42	1.5	77	87	10	207.4	109.4	3.3	4.3	0.7	1.2	1.3	0.9
43	1.1	63	68	5	132.5	62.5	1.8	5.5	0.5	1.0	1.0	1.1
44	0.6	64	71	7	135.0	45.0	2.0	6.5	0.3	0.7	0.9	1.0
45	2.1	82	72	-10	177.5	85.0	2.8	4.5	0.4	1.2	1.5	1.1
46	0.7	76	80	4	127.5	67.5	2.0	6.5	0.9	1.5	1.5	1.1
47	1.8	61	68	7	127.5	50.0	1.5	6.5	1.2	1.4	1.5	0.6
48	0.6	66	80	14	117.5	42.5	1.5	6.5	1.2	1.6	1.7	1.1
49	1.4	63	76	13	145.0	52.5	2.0	7.0	1.1	1.6	1.7	1.1
50	2.1	72	79	7	132.5	67.5	2.3	6.0	1.0	1.4	1.8	1.0
51	0.9	74	82	9	142.5	60.0	2.3	5.5	0.2	0.5	0.9	1.0
52	1.0	75	81	6	150.0	77.5	2.3	5.0	0.7	1.1	1.5	1.2
53	2.2	75	84	11	115.0	50.0	1.5	6.5	1.1	1.5	1.7	1.1
54	3.1	71	77	6	150.0	70.0	2.3	5.0	0.8	1.0	1.2	1.0
55	2.5	78	84	6	162.5	95.0	2.5	4.5	0.5	1.2	1.4	1.0
56	2.0	76	88	12	140.0	77.5	2.3	5.0	0.7	1.1	1.4	1.1
57	2.4	77	79	2	182.5	95.0	3.0	3.5	0.1	0.3	0.6	1.2
58	2.2	73	79	6	157.5	77.5	2.5	4.5	0.6	0.9	1.3	1.2
59	0.9	79	83	4	135.0	70.0	1.5	5.5	0.4	0.7	1.0	1.0
60	3.9	82	89	7	200.0	125.0	3.3	3.5	0.4	0.8	1.2	1.0
61	0.7	75	72	1	115.0	45.0	1.8	6.0	0.6	0.9	1.3	1.2
62	0.4	74	88	15	135.0	57.5	2.3	6.0	0.0	0.4	0.8	0.9
63	0.1	87	92	12	90.0	42.5	2.8	3.6	15.0	2.1	32.4	1.0
64	1.0	70	72	2	102.4	49.4	1.3	6.3	1.3	1.0	1.2	0.9
65	0.1	72	86	15	102.5	35.0	1.5	7.0	0.5	1.0	1.2	1.1
66	0.7	78	86	8	105.0	42.5	1.5	7.0	0.6	1.2	1.4	0.9
67	1.3	74	80	6	185.0	105.0	2.8	5.0	0.3	1.2	1.5	1.3
68	1.0	76	86	10	165.0	85.0	2.5	7.0	0.2	1.0	1.3	1.3
69	0.7	78	85	7	117.5	50.0	1.5	6.5	1.2	1.3	1.6	1.2
70	2.1	71	76	6	182.5	100.0	2.5	4.5	1.0	1.6	1.7	1.0
71	1.1	76	81	7	135.0	62.5	1.8	7.0	1.2	1.6	1.9	1.1
72	2.5	83	80	-3	180.0	90.0	3.0	3.5	0.5	1.1	1.4	1.0
73	0.9	90	96	6	152.5	82.5	2.3	6.5	0.6	1.3	1.5	1.0
74	0.0	87	97	11	117.5	57.5	5.3	24.5	45.5	111.0	1.7	0.7
75	1.4	70	76	6	137.4	69.4	1.8	5.3	1.8	2.2	2.0	0.9
76	1.8	70	77	8	155.0	72.5	2.3	5.5	0.9	1.7	1.7	1.0
77	0.1	91	91	5	145.0	65.0	2.3	6.0	1.2	1.6	1.8	1.0
78	1.4	86	94	8	167.5	95.0	2.5	5.0	0.6	1.1	1.6	1.1
79	1.7	71	78	7	162.5	72.5	2.5	5.0	1.1	1.6	1.7	1.2

Appendix 29 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
80	2.3	76	84	9	162.5	80.0	2.5	5.5	0.9	1.5	1.6	1.1
81	1.7	83	90	15	137.5	67.5	2.3	5.0	0.9	1.4	1.5	1.0
82	0.5	73	84	11	147.5	75.0	2.3	6.0	0.6	1.2	1.5	1.0
83	2.2	80	72	-8	167.5	85.0	2.5	5.0	0.8	1.2	1.4	1.3
84	1.2	81	93	12	177.5	102.5	2.5	5.5	1.0	1.5	1.7	1.0
85	2.6	70	74	4	195.0	102.5	2.5	3.5	0.8	1.1	1.5	1.0
86	1.5	76	87	12	200.0	107.5	3.3	4.0	0.0	0.4	0.6	1.2
87	0.3	83	93	12	110.0	57.5	1.5	7.0	1.0	1.3	1.5	1.0
88	0.6	75	88	13	142.5	75.0	2.0	5.5	0.7	1.0	1.3	0.9
89	1.6	80	89	9	215.0	130.0	3.0	5.0	0.8	1.6	1.8	1.2
90	1.6	99	99	1	200.0	130.0	3.3	4.5	0.1	0.4	0.6	1.4
91	1.8	86	95	9	195.0	122.5	3.0	3.5	0.6	1.3	1.5	1.0
92	2.2	75	86	11	152.5	82.5	2.3	5.0	0.7	1.3	1.2	0.9
93	0.8	79	87	9	115.0	55.0	1.8	5.5	1.0	1.6	1.8	1.1
94	1.7	73	84	12	150.0	77.5	2.0	5.0	0.5	1.1	1.4	1.1
95	0.4	115	81	6	132.5	65.0	2.3	6.0	0.5	0.9	1.0	0.9
96	1.3	75	84	7	152.5	87.5	2.0	5.5	0.6	0.9	1.5	0.9
97	2.4	78	89	6	175.0	92.5	2.8	4.0	0.8	1.3	1.6	1.1
98	2.5	97	86	14	187.5	100.0	3.3	3.5	0.1	0.5	1.0	1.0
99	0.9	72	95	15	125.0	50.0	1.8	6.0	1.3	1.8	1.9	1.0
100	0.9	80	97	12	165.0	85.0	2.3	5.0	0.5	0.9	1.3	1.0
101	1.4	83	89	1	142.5	67.5	2.3	4.5	0.6	1.3	1.8	1.2
102	1.6	86	88	8	157.5	85.0	2.5	5.5	1.1	1.7	1.8	1.3
103	3.2	80	91	6	137.5	72.5	2.3	6.0	0.7	1.5	1.6	1.1
104	2.3	85	89	5	172.5	87.5	2.5	4.5	0.7	1.1	1.5	1.1
105	1.9	84	88	21	155.0	75.0	2.8	5.5	1.0	1.4	1.7	1.1
106	1.9	67	84	10	157.5	82.5	2.8	5.5	0.7	1.3	1.6	1.2
107	1.6	74	74	8	150.0	72.5	2.3	5.0	1.0	1.4	1.6	1.1
108	1.9	67	79	8	162.5	80.0	2.3	5.5	0.5	1.3	1.5	1.2
109	2.0	71	89	15	167.5	80.0	2.8	6.0	0.9	1.5	1.5	1.1
110	0.4	74	85	9	112.5	40.0	1.5	8.0	0.6	1.1	1.4	1.4
111	1.1	76	83	6	157.5	72.5	2.0	6.0	1.1	1.6	1.6	1.0
112	1.5	77	80	9	157.5	80.0	2.5	5.0	0.9	1.5	1.6	1.2
113	1.7	71	80	4	165.0	85.0	2.5	4.0	0.6	1.1	1.5	1.0
114	3.0	76	93	19	180.0	95.0	3.0	3.0	0.5	0.9	1.5	1.0
115	0.9	74	89	12	137.5	62.5	1.5	6.0	0.3	0.8	1.3	1.0
116	0.6	78	79	6	102.5	42.5	1.3	7.0	1.1	1.4	1.5	1.1
117	2.6	73	90	3	162.5	85.0	2.5	6.0	0.4	0.9	1.4	1.2
118	2.6	87	84	11	170.0	95.0	3.0	3.0	0.0	0.1	0.5	1.2
119	1.6	73	88	13	152.5	80.0	2.0	4.5	0.4	1.0	1.3	1.0

Appendix 30 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
120	1.8	75	86	7	162.5	80.0	2.5	5.5	0.7	1.5	1.8	1.0
121	1.3	83	88	6	142.5	77.5	2.3	5.5	0.4	1.3	1.6	1.1
122	1.8	82	89	8	130.0	57.5	2.3	5.0	0.6	1.1	1.6	1.2
123	3.6	81	86	9	190.0	102.5	3.3	3.5	0.6	1.4	1.6	1.1
124	4.6	77	85	6	155.0	75.0	2.3	6.5	0.5	1.1	1.4	1.1
125	4.3	80	90	9	227.5	142.5	4.3	3.0	0.1	0.5	1.2	1.2
126	1.4	81	86	7	165.0	85.0	2.5	6.0	1.0	1.4	1.7	1.1
127	1.6	79	82	10	165.0	80.0	2.8	5.0	1.0	1.5	1.8	1.1
128	2.2	72	91	9	142.5	67.5	1.8	4.0	1.0	1.4	1.5	0.9
129	1.4	82	97	13	140.0	67.5	2.0	6.0	1.0	1.3	1.7	1.0
130	0.4	99	96	12	137.5	75.0	2.3	5.5	0.6	1.2	1.5	1.0
131	1.6	84	90	9	155.0	82.5	2.3	4.5	0.9	1.0	1.7	0.9
132	0.4	81	87	6	155.0	90.0	2.0	5.5	0.4	0.7	1.1	0.7
133	2.7	82	78	4	187.5	100.0	3.5	5.0	0.2	0.5	0.7	1.0
134	2.5	74	80	7	172.5	85.0	2.3	4.5	1.0	1.4	1.7	0.9
135	1.7	73	96	10	152.5	75.0	2.0	5.5	0.8	1.4	1.8	1.0
136	1.2	86	83	11	145.0	72.5	2.3	4.0	0.6	1.1	1.3	1.1
137	1.1	72	85	10	145.0	62.5	2.0	5.5	1.1	1.5	1.7	0.9
138	0.8	75	95	9	127.5	65.0	1.8	6.5	0.6	0.9	1.3	0.5
139	1.5	87	85	5	152.5	72.5	2.3	5.5	0.5	0.8	1.4	1.1
140	1.2	81	82	6	135.0	60.0	2.0	6.5	0.7	1.2	1.5	1.1
141	1.6	76	83	11	147.5	72.5	2.0	5.0	0.8	1.3	1.4	1.0
142	1.9	73	89	12	170.0	87.5	2.3	4.5	0.7	1.5	1.7	1.0
143	0.5	77	80	6	122.5	40.0	1.8	6.5	0.4	0.9	1.2	1.0
144	0.2	71	83	7	105.0	42.5	1.3	5.0	0.2	0.9	1.3	1.0
145	3.1	77	87	11	192.5	107.5	3.0	4.5	0.4	0.9	1.1	1.8
146	2.0	76	83	12	147.5	70.0	2.5	5.5	0.5	1.1	1.2	1.2
147	1.4	71	79	5	147.5	70.0	2.3	5.5	0.9	1.4	1.5	1.1
148	2.0	74	79	7	137.5	67.5	2.0	5.5	0.8	1.2	1.5	0.9
149	2.5	72	83	10	160.0	80.0	2.5	4.5	0.7	1.3	1.5	1.0
150	1.3	73	82	8	162.5	77.5	2.5	6.0	0.6	1.2	1.6	1.1
151	1.8	74	82	8	677.5	97.5	2.5	4.5	0.3	1.0	1.2	1.1
152	3.0	74	68	-3	185.0	100.0	3.0	3.5	0.6	1.2	1.5	1.1
153	2.4	71	81	7	162.5	80.0	2.8	4.5	0.6	1.0	1.2	1.1
154	0.4	76	83	3	105.0	45.0	1.5	7.0	0.9	1.4	1.5	1.0
155	1.5	80	86	6	137.5	60.0	1.8	6.0	0.6	1.3	1.5	1.0
156	0.7	74	81	7	135.0	112.5	2.0	6.5	0.8	1.3	1.6	1.0
157	2.7	74	73	6	177.5	92.5	2.8	4.5	0.3	1.1	1.4	1.1
158	0.9	67	82	8	112.5	40.0	1.8	7.0	1.3	1.5	1.7	1.0
159	1.9	74	85	8	152.5	92.5	2.5	5.0	0.9	1.3	1.5	1.1

Appendix 31 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
160	2.0	77	87	12	162.5	92.5	2.3	4.0	1.0	1.6	1.8	1.1
161	1.4	76	94	6	147.5	77.5	2.0	4.5	1.1	1.5	1.7	0.9
162	3.7	88	97	9	175.0	97.5	3.0	3.0	0.0	0.1	0.9	1.2
163	0.7	88	98	10	207.5	122.5	3.5	4.0	0.0	0.3	1.0	1.4
164	1.3	89	91	8	152.5	82.5	2.5	5.5	0.6	1.0	1.3	1.0
165	1.9	83	87	4	172.5	85.0	2.5	5.0	0.9	1.5	1.8	1.1
166	0.4	83	94	7	122.5	62.5	1.3	6.0	0.5	0.9	1.2	1.3
167	1.5	90	85	9	152.5	70.0	2.3	5.0	1.0	1.5	1.8	1.1
168	1.9	77	81	1	167.5	92.5	2.8	4.5	0.6	1.4	1.6	1.0
169	0.3	100	82	9	125.0	60.0	1.8	6.5	0.8	1.4	1.8	0.9
170	1.8	80	93	8	150.0	80.0	2.3	4.5	0.9	1.3	1.6	0.9
171	4.1	73	89	4	212.5	125.0	3.5	3.0	0.4	1.0	1.4	1.0
172	0.4	83	92	8	177.5	97.5	2.3	5.5	0.6	1.0	1.3	1.2
173	1.3	89	89	6	130.0	60.0	2.3	6.0	0.9	1.6	1.7	1.0
174	2.2	84	89	7	167.5	100.0	3.0	4.0	0.7	1.3	1.5	1.0
175	0.8	88	88	7	140.0	77.5	2.0	6.5	0.5	1.2	1.7	0.9
176	2.1	82	92	10	170.0	92.5	2.8	4.5	1.0	1.5	1.7	1.2
177	2.1	83	100	4	160.0	87.5	2.5	5.0	0.9	1.3	1.5	0.9
178	1.7	83	81	2	160.0	82.5	2.5	4.0	1.0	1.5	1.7	1.1
179	1.7	96	84	6	167.5	82.5	3.0	5.5	0.3	1.0	1.3	0.9
180	2.0	79	105	12	125.0	57.5	1.8	5.5	1.2	1.6	1.6	1.0
181	2.6	78	97	-1	162.5	85.0	2.3	4.5	0.8	1.3	1.5	1.3
182	0.4	94	89	2	130.0	57.5	2.0	6.5	0.8	1.2	1.5	0.6
183	0.9	98	91	7	150.0	80.0	2.5	5.5	1.0	1.3	1.7	1.1
184	0.8	86	90	4	157.5	85.0	2.3	7.0	0.8	1.3	1.5	0.8
185	0.6	84	86	7	117.5	50.0	1.8	7.0	1.4	1.5	1.7	0.9
186	1.1	92	89	13	160.0	75.0	2.3	5.0	0.5	1.2	1.4	0.7
187	2.1	79	96	11	157.5	85.0	2.3	5.5	0.6	1.0	1.2	1.2
188	0.4	99	92	10	127.5	67.5	3.8	3.5	5.7	29.8	1.3	0.5
189	1.1	76	97	8	122.6	50.6	1.7	6.7	0.9	1.1	1.5	0.9
190	0.9	87	83	6	122.5	50.0	2.0	6.5	1.2	1.4	1.6	1.4
191	1.3	82	86	5	167.5	92.5	2.5	4.5	0.7	1.4	1.5	0.9
192	0.6	93	92	6	152.5	82.5	2.6	2.8	1.1	1.5	36.9	0.6
193	2.5	77	97	11	157.6	70.6	2.2	4.7	0.2	1.0	1.6	0.8
194	1.3	81	82	8	155.0	82.5	2.3	5.0	1.4	1.6	1.9	1.1
195	2.7	86	82	9	187.5	102.5	2.8	4.5	0.5	1.2	1.4	1.0
196	1.4	86	94	7	157.5	70.0	4.0	3.0	3.4	19.5	1.1	0.4
197	0.6	90	72	3	112.6	50.6	1.7	5.7	1.1	1.4	1.9	2.0
198	1.8	74	76	5	187.5	102.5	2.8	5.5	0.7	1.1	1.2	1.1
199	2.8	73	76	3	142.5	65.0	2.5	4.5	0.7	1.3	1.6	1.1

Appendix 32 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
200	1.2	87	79	7	175.0	100.0	2.5	5.0	1.4	1.8	1.9	1.1
201	3.3	69	79	3	177.5	92.5	2.8	4.0	0.6	1.4	1.7	1.1
202	3.4	71	82	6	187.5	97.5	3.0	3.5	0.1	1.0	1.3	1.1
203	2.5	73	82	4	145.0	60.0	2.3	5.5	0.8	1.1	1.5	1.1
204	2.5	72	83	6	157.5	80.0	2.3	5.5	0.9	1.5	1.7	1.1
205	2.7	76	73	5	200.0	120.0	5.0	1.5	0.1	10.9	0.9	0.6
206	1.5	76	88	5	182.6	90.6	2.7	4.7	-0.5	0.1	0.8	1.0
207	2.2	78	87	7	170.0	80.0	2.5	5.5	1.0	1.1	1.4	0.9
208	2.6	77	97	10	155.0	85.0	2.5	5.0	0.1	0.8	1.1	1.0
209	2.2	69	85	5	155.0	75.0	2.3	6.0	1.1	1.5	1.6	1.0
210	1.0	83	83	10	137.5	67.5	1.8	6.0	1.0	1.6	1.7	0.9
211	1.7	85	79	8	167.5	90.0	2.8	4.5	0.9	1.5	1.6	0.9
212	0.4	89	86	11	127.5	60.0	2.0	6.5	1.3	1.7	1.8	0.8
213	3.3	80	70	-15	185.0	105.0	2.8	3.5	0.6	1.1	1.5	1.0
214	1.2	74	75	5	147.5	75.0	2.3	5.5	1.2	1.8	1.9	1.0
215	1.9	71	75	6	147.5	67.5	2.0	5.5	1.0	1.4	1.7	0.9
216	1.2	75	83	8	140.0	65.0	2.0	5.5	0.9	1.4	1.7	1.0
217	1.8	79	78	5	162.5	67.5	2.3	4.5	0.6	1.2	1.4	0.8
218	2.8	70	81	6	177.5	95.0	2.8	4.0	0.8	1.4	2.2	1.0
219	2.7	70	80	5	182.5	95.0	3.0	4.5	0.6	0.8	1.1	1.3
220	1.1	81	98	12	160.0	82.5	2.3	5.0	0.3	0.8	1.1	1.1
221	1.7	73	89	7	140.0	67.5	2.3	4.5	0.9	1.4	1.6	1.0
222	0.4	92	65	4	130.0	65.0	1.5	7.5	0.9	1.2	1.5	0.7
223	2.0	76	81	10	195.0	105.0	2.8	4.0	0.7	1.2	1.5	0.8
224	2.8	75	65	6	182.5	95.0	2.8	3.5	1.0	1.6	1.6	1.0
225	0.6	86	70	6	117.5	50.0	2.0	7.5	0.6	1.2	1.6	1.3
226	2.2	83	65	4	175.0	87.5	2.8	4.5	0.6	1.3	1.6	1.0
227	1.8	61	69	8	130.0	52.5	1.8	6.0	0.5	1.1	1.2	1.3
228	2.3	72	66	7	132.5	77.5	1.8	5.5	0.7	1.2	1.4	2.0
229	1.4	60	93	8	135.0	50.0	1.8	6.5	0.4	1.1	1.3	1.2
230	1.1	64	88	4	122.5	40.0	1.5	7.0	0.9	1.4	1.5	0.7
231	1.9	61	75	5	132.5	55.0	1.5	7.0	0.6	1.1	1.2	1.1
232	1.4	61	82	11	122.5	45.0	1.8	6.0	1.2	1.5	1.6	1.0
233	1.9	59	101	27	142.5	65.0	2.0	7.0	1.0	1.4	1.5	1.1
234	1.8	98	78	6	200.0	100.0	2.8	3.5	0.6	1.2	1.4	1.1
235	1.7	84	75	7	160.0	82.5	2.5	5.0	0.6	1.1	1.5	1.1
236	2.1	70	79	6	155.0	77.5	2.3	4.5	0.8	1.1	1.5	1.1
237	2.0	72	79	7	180.0	92.5	2.5	5.0	0.8	1.3	1.5	1.0
238	1.3	74	81	6	122.5	62.5	2.0	6.5	0.8	1.4	1.7	1.1
239	1.7	75	93	7	135.0	65.0	2.3	6.5	1.2	1.5	1.7	1.0

Appendix 33 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
240	3.1	69	81	8	172.5	35.0	2.8	4.0	0.6	1.3	1.5	1.0
241	1.4	74	96	10	150.0	70.0	2.0	5.5	0.5	1.1	1.4	0.8
242	2.4	72	94	8	160.0	75.0	2.3	4.5	0.6	1.1	1.5	1.0
243	2.7	75	76	6	192.5	107.5	3.3	3.5	0.8	1.5	1.7	0.9
244	0.9	89	78	6	140.0	72.5	2.3	5.5	0.8	1.3	1.7	0.9
245	0.5	102	86	5	127.5	60.0	1.8	5.5	0.6	1.3	1.6	1.2
246	1.2	73	76	8	112.5	47.5	1.5	7.0	0.9	1.4	1.6	1.1
247	0.8	90	81	8	162.5	90.0	2.0	5.0	1.3	1.7	1.9	0.8
248	1.3	95	88	12	160.0	87.5	2.8	5.0	0.4	1.2	1.5	0.9
249	2.1	70	74	6	155.0	85.0	2.5	5.0	0.9	1.2	1.6	1.1
250	2.1	72	107	9	170.0	90.0	2.5	5.0	0.6	1.2	1.4	1.1
251	2.0	81	104	8	142.5	65.0	2.3	5.5	0.7	1.2	1.6	1.2
252	1.5	68	81	6	150.0	70.0	2.5	7.0	1.1	1.7	1.7	1.2
253	2.5	74	71	8	147.5	67.5	2.3	5.5	1.3	1.6	1.6	1.1
254	0.8	76	86	5	122.5	60.0	1.5	7.0	0.7	1.1	1.4	1.1
255	1.8	68	77	7	160.0	80.0	2.3	5.5	0.6	0.9	1.2	1.1
256	0.3	98	85	9	147.5	67.5	2.3	6.0	0.0	0.0	0.6	0.9
257	0.4	99	103	7	87.5	40.0	1.3	8.0	0.0	0.3	0.7	1.2
258	2.6	76	91	12	182.5	105.0	2.5	4.0	0.7	1.3	1.6	1.2
259	1.0	63	80	3	112.5	40.0	1.5	8.5	0.7	1.1	1.1	0.9
260	1.7	81	88	8	172.5	95.0	2.3	5.0	0.4	1.1	1.5	1.2
261	0.8	70	86	9	142.5	70.0	1.8	5.0	0.6	1.2	1.5	0.9
262	0.9	76	88	10	165.0	100.0	2.5	4.5	0.2	0.4	0.6	0.8
263	0.9	96	89	3	97.6	45.6	1.2	5.7	-0.5	0.1	1.1	1.3
264	1.5	80	85	11	167.5	92.5	2.5	4.5	0.9	1.6	1.8	1.0
265	2.3	79	73	3	137.5	60.0	2.0	5.5	0.8	1.2	1.5	1.0
266	1.6	80	87	7	147.5	70.0	2.3	6.0	0.8	1.3	1.7	1.0
267	1.2	77	78	3	140.0	70.0	2.0	5.5	1.2	1.6	1.8	1.0
268	2.0	78	63	5	145.0	75.0	2.3	5.0	0.6	1.0	1.3	1.0
269	1.3	92	85	13	165.0	90.0	2.8	5.5	0.6	0.9	1.3	0.9
270	1.5	74	76	7	125.0	47.5	2.0	6.5	1.1	1.5	1.6	0.8
271	2.2	70	83	9	125.0	52.5	1.8	6.5	0.9	1.4	1.6	1.0
272	3.8	80	91	7	162.5	87.5	2.8	5.0	0.7	1.4	1.6	1.1
273	1.5	76	92	15	140.0	70.0	2.0	6.0	1.0	1.6	1.7	1.0
274	1.2	58	78	8	122.5	45.0	1.5	7.0	0.6	1.2	1.3	1.0
275	1.2	72	68	5	170.0	100.0	2.5	4.5	0.8	1.4	1.6	1.0
276	2.0	70	70	14	177.5	102.5	2.5	5.0	0.8	1.2	1.5	1.1
277	0.9	75	73	11	152.5	77.5	2.0	6.0	1.1	1.1	1.7	1.0
278	1.1	94	76	9	122.5	55.0	1.8	5.5	0.6	0.9	1.3	1.1
279	1.3	77	73	4	152.5	77.5	2.5	5.0	0.7	0.9	1.2	1.1

Appendix 34 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
280	1.4	70	74	6	147.5	85.0	2.0	5.0	0.2	0.8	1.1	1.0
281	2.3	63	96	29	175.0	80.0	2.5	4.5	0.5	1.2	1.3	1.0
282	1.8	56	95	9	112.5	45.0	1.3	7.5	0.4	0.5	0.8	1.0
283	2.0	62	76	15	177.5	95.0	2.5	4.5	0.8	1.3	1.5	0.9
284	1.2	67	82	14	155.0	75.0	2.3	5.5	0.8	1.2	1.4	1.1
285	2.2	69	80	10	185.0	100.0	2.8	5.5	0.6	1.6	1.7	1.0
286	3.2	68	85	10	202.5	110.0	3.0	3.5	0.6	1.0	1.3	1.2
287	0.9	67	76	4	147.5	80.0	2.0	7.0	1.2	1.7	1.8	1.0
288	2.2	87	77	5	165.0	82.5	2.8	4.0	0.4	0.8	1.1	1.3
289	1.6	61	84	8	120.0	40.0	1.8	6.0	0.7	1.0	1.2	1.0
290	1.5	68	72	10	115.0	47.5	1.8	6.5	1.1	1.6	1.7	1.2
291	2.3	72	80	13	165.0	85.0	2.5	5.5	1.0	1.3	1.6	1.3
292	3.5	75	77	14	192.5	100.0	3.0	3.5	0.4	0.8	1.2	1.0
293	3.0	72	61	-15	645.0	72.5	2.3	5.0	0.9	1.5	1.7	1.1
294	4.0	73	64	3	162.5	82.5	2.5	5.0	0.8	1.3	1.6	1.0
295	1.1	76	78	4	140.0	65.0	2.0	6.0	0.7	1.5	1.8	1.1
296	1.1	62	81	9	105.0	32.5	1.5	8.0	1.1	1.4	1.5	1.0
297	1.3	67	76	5	107.5	45.0	1.5	7.0	0.9	1.4	1.5	1.3
298	2.2	63	78	6	142.5	60.0	2.0	6.0	0.3	0.6	1.0	1.2
299	1.8	76	69	3	135.0	60.0	2.5	5.5	0.7	1.2	1.3	1.1
300	1.2	61	85	13	132.5	50.0	1.8	6.0	0.8	1.4	1.4	1.0
301	1.3	74	74	4	117.5	45.0	1.8	6.0	1.0	1.4	1.6	1.0
302	0.8	72	79	6	100.0	40.0	1.5	7.0	1.3	1.5	1.8	1.2
303	1.9	71	86	16	110.0	50.0	1.8	6.5	1.0	1.6	1.7	1.0
304	2.9	72	68	6	172.5	97.5	2.5	4.5	0.9	1.5	1.7	1.0
305	4.2	67	71	4	175.0	90.0	2.8	3.5	0.6	1.2	1.5	1.2
306	0.9	72	79	6	182.5	90.0	2.5	5.0	0.3	0.8	1.1	0.8
307	4.1	70	86	11	190.0	100.0	3.3	4.0	0.1	1.1	1.3	1.0
308	2.5	73	83	8	132.5	75.0	2.0	6.0	0.7	1.7	1.7	1.1
309	1.1	71	79	7	110.0	45.0	1.3	6.0	1.1	1.5	1.5	0.9
310	1.4	63	78	5	105.0	45.0	1.3	6.5	0.6	1.4	1.6	0.6
311	3.6	67	76	7	172.5	85.0	0.8	5.0	0.5	1.1	1.4	1.2
312	2.8	74	86	13	162.5	80.0	2.5	5.0	0.3	1.1	1.4	1.1
313	2.0	75	89	11	160.0	85.0	2.5	5.5	0.8	1.4	1.8	1.2
314	2.2	83	80	9	155.0	80.0	2.5	5.0	0.8	1.6	1.7	0.9
315	1.3	74	76	5	165.0	95.0	2.3	4.5	0.7	1.3	1.6	1.0
316	1.0	73	79	8	120.0	50.0	1.8	7.0	0.5	1.1	1.5	0.7
317	1.6	69	83	9	125.0	60.0	2.0	5.5	0.7	1.3	1.6	1.1
318	1.3	74	84	6	135.0	65.0	2.0	6.0	0.8	1.2	1.5	1.1
319	1.3	78	79	5	157.5	85.0	2.3	6.0	1.0	1.5	1.8	1.0

Appendix 35 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
320	2.4	71	74	3	180.0	87.5	2.5	4.5	1.0	1.4	1.6	1.1
321	2.5	75	83	8	140.0	70.0	2.0	5.0	0.7	1.3	1.6	0.8
322	4.0	71	80	6	187.5	110.0	3.3	3.5	0.1	1.0	1.2	1.1
323	2.8	74	81	7	180.0	90.0	3.0	5.0	0.3	1.0	1.6	1.1
324	2.2	78	78	4	150.0	70.0	2.0	5.0	0.9	1.4	1.6	1.0
325	4.8	74	63	6	210.0	122.5	3.5	4.0	0.2	1.2	1.4	1.1
326	2.9	71	63	3	140.0	70.0	2.3	5.5	1.0	1.5	1.6	1.0
327	1.7	76	78	14	137.5	62.5	2.0	5.5	1.4	1.8	1.9	1.0
328	3.5	75	65	4	177.5	97.5	3.3	4.0	0.5	1.2	1.4	1.1
329	2.6	74	84	8	157.5	90.0	2.5	4.5	0.7	1.3	1.7	1.1
330	2.0	83	64	6	130.0	62.5	2.0	5.5	1.2	1.7	1.7	1.0
331	2.1	58	69	7	152.5	72.5	2.3	4.5	0.8	1.2	1.3	1.0
332	2.2	61	90	11	172.5	90.0	2.5	5.0	0.0	0.7	0.9	1.0
333	2.0	64	81	5	145.0	72.5	2.0	5.0	0.5	0.8	1.3	0.9
334	2.2	61	83	9	147.5	65.0	2.3	5.5	0.8	1.2	1.3	1.1
335	1.5	76	101	12	137.5	65.0	2.0	6.0	1.2	1.6	1.8	0.9
336	1.6	58	77	5	125.0	55.0	1.5	6.5	0.7	1.1	1.4	1.0
337	1.9	62	92	7	135.0	50.0	1.8	6.5	0.7	1.1	1.2	1.2
338	1.2	80	84	6	152.5	80.0	2.3	5.0	0.7	1.4	1.7	1.0
339	3.3	76	80	7	170.0	90.0	3.0	4.5	0.4	1.3	1.5	1.0
340	3.0	74	82	9	145.0	65.0	2.3	5.0	0.8	1.3	1.4	1.1
341	0.7	88	84	9	145.0	67.5	2.0	6.0	1.4	1.8	1.9	0.9
342	2.7	72	92	16	142.5	67.5	2.3	5.5	1.1	1.6	1.7	1.0
343	1.7	85	83	8	172.5	95.0	2.8	5.0	1.2	1.7	1.9	1.0
344	1.7	81	86	10	132.5	60.0	1.8	7.0	1.2	1.6	1.9	1.0
345	2.3	73	79	6	145.0	57.5	2.0	5.5	0.7	1.2	1.4	1.1
346	2.0	73	78	4	145.0	70.0	2.3	5.5	0.7	1.4	1.6	1.0
347	1.1	82	83	9	112.5	42.5	1.5	6.5	1.0	1.2	1.3	1.0
348	2.3	77	81	7	137.5	60.0	2.5	4.5	1.0	1.3	1.7	0.9
349	2.7	76	77	6	155.0	70.0	2.5	4.0	0.5	1.2	1.4	1.2
350	2.4	77	89	10	165.0	85.0	2.5	4.0	0.7	1.3	1.7	0.8
351	3.6	74	82	5	155.0	75.0	2.5	5.5	0.4	1.4	1.7	1.1
352	1.8	74	80	6	155.0	75.0	2.3	4.0	0.9	1.5	1.7	1.1
353	2.3	75	81	9	137.5	65.0	2.0	5.5	0.7	1.6	1.6	0.9
354	2.7	74	88	11	142.5	62.5	2.3	5.5	0.8	1.3	1.7	1.0
355	1.7	71	82	8	127.5	55.0	2.0	6.0	1.1	1.6	1.9	1.1
356	1.6	82	93	4	142.5	72.5	2.3	4.5	0.7	1.3	1.7	0.8
357	4.2	77	86	9	167.5	90.0	3.0	4.5	0.5	0.9	1.2	2.7
358	3.0	74	64	5	167.5	85.0	2.8	5.0	0.6	1.2	1.6	1.0
359	0.9	72	82	11	152.5	77.5	2.5	6.0	0.9	1.4	1.6	0.8

Appendix 36 continued. Performance of the land races under artificial *Striga* infestation at Kibos

ENTRY	YLD	AD	SD	ASI	PH	EH	PA	SDR	STR8TR	STR10TR	STR12TR	EPP
360	1.6	77	76	2	125.0	55.0	1.5	6.0	0.6	1.3	1.5	1.0
361	1.8	74	74	6	152.5	75.0	2.3	5.0	1.1	1.4	1.7	1.1
362	1.7	89	90	12	157.5	80.0	2.3	4.5	0.4	0.9	1.4	1.3
363	2.1	79	72	1	132.5	52.5	2.0	6.0	0.7	1.2	1.4	1.1
364	1.9	60	83	8	150.0	67.5	1.8	5.0	0.5	1.1	1.4	1.0
365	1.1	72	77	4	122.5	47.5	1.5	7.0	0.9	1.3	1.4	0.8
366	1.7	74	76	6	137.5	70.0	2.0	5.5	0.6	1.2	1.5	0.9
367	1.7	68	71	2	152.5	72.5	2.3	4.5	1.0	1.4	1.3	1.0
368	1.0	78	75	5	160.0	85.0	2.8	4.5	0.3	1.0	1.6	1.0
369	1.0	81	71	2	145.0	57.5	1.5	7.0	1.0	1.3	1.5	1.1
370	2.6	75	83	8	140.0	75.0	2.5	4.5	0.7	1.2	1.4	1.0
401	2.4	73	77	4	152.5	72.5	2.5	5.5	0.9	1.4	1.6	1.0
402	1.3	70	76	6	112.5	45.0	1.5	7.0	0.7	0.8	1.1	0.9
403	4.1	69	71	2	137.5	55.0	2.0	6.0	0.5	0.8	1.0	1.0
404	1.2	71	75	5	152.5	65.0	2.3	5.0	0.6	1.0	1.2	1.1
405	5.9	69	71	2	160.0	75.0	2.8	4.0	0.7	1.2	1.4	1.2
406	3.5	69	73	4	162.5	80.0	2.5	4.5	0.5	0.9	1.1	1.0
407	4.3	69	71	2	160.0	72.5	2.8	5.5	1.0	1.5	1.7	1.1
408	2.7	72	74	2	137.5	57.5	2.0	5.5	0.7	1.4	1.6	1.1
409	3.7	70	71	1	162.5	72.5	2.8	4.5	0.8	1.2	1.3	1.1
410	2.6	71	77	6	127.5	55.0	2.0	7.0	1.0	1.5	1.6	1.1
418	3.3	66	69	3	165.0	80.0	2.3	4.5	0.8	1.1	1.4	1.1
419	0.7	78	78	0	127.5	60.0	1.8	6.5	0.2	0.3	0.6	0.9
420	3.8	68	70	2	665.0	77.5	2.8	4.0	0.5	1.3	1.6	1.0
MEAN	**1.9**	**76**	**82**	**7**	**154.5**	**74.6**	**2.3**	**5.5**	**1.1**	**1.8**	**1.7**	**1.1**
CV	**35**	**7.3**	**7.4**	**41.6**	**45.23**	**30.23**	**27.9**	**35.6**	**19.88**	**23.36**	**19.88**	**24.1**
SIG	*******	*******	*******	******	*****	*******	*******	******	**NS**	*****	*******	**NS**

Key: YLD= Grain yield t/ha, AD = days to 50% anthesis, SD= days to 50% silking, ASI= anthesis silking interval, PH= Plant height (cm), EH= ear height (cm), PA= Plant aspect (score 1-5), SDR= *Striga* damage rating (score 1-9), STR8TR= *Striga* count 8 WAP, STR10TR=*Striga* count 10 WAP, STR12TR=*Striga* count 12 WAP and EPP= ears per plant

Appendix 37. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
1	1.1	58.8	6.5	1.3	1.6	1.6
2	1.0	67.3	4.8	0.8	1.2	1.5
3	2.0	58.3	5.5	0.9	1.1	1.4
4	2.0	75.0	4.5	0.8	1.5	1.7
5	0.9	75.0	5.3	1.1	1.6	1.7
6	1.6	71.5	4.5	1.2	1.6	1.8
7	1.0	80.8	5.0	1.3	1.7	1.8
8	1.3	76.0	4.8	0.6	1.1	1.3
9	1.0	73.0	4.8	0.9	1.4	1.6
10	0.5	87.3	5.5	1.1	1.4	1.4
11	1.5	89.8	4.3	0.6	1.1	1.4
12	0.7	88.3	4.5	0.8	1.2	1.4
13	0.9	73.3	6.0	1.4	1.6	1.7
14	1.0	81.5	5.3	0.9	1.3	1.6
15	1.1	74.8	4.5	0.8	1.4	1.5
16	0.8	71.3	5.8	1.0	1.4	1.5
17	1.6	74.8	3.8	0.8	1.4	1.4
18	1.4	67.3	4.8	1.0	1.4	1.5
19	1.4	66.8	5.8	0.8	1.4	1.5
20	1.7	83.5	5.5	0.9	1.3	1.6
21	1.1	73.3	5.0	1.1	1.6	1.7
22	1.8	70.3	4.3	0.8	1.4	1.6
23	1.6	81.8	3.8	0.8	1.3	1.5
24	0.9	68.5	5.8	0.8	1.4	1.6
25	0.9	77.5	6.0	1.3	1.6	1.7
26	1.3	77.0	5.3	0.9	1.5	1.7
27	1.3	71.0	5.5	0.7	1.5	1.7
28	0.8	84.5	6.0	1.0	1.4	1.5
29	0.7	73.8	6.3	1.1	1.5	1.8
30	0.7	80.8	5.3	1.1	1.6	1.7
31	1.8	57.3	5.3	0.8	1.2	1.3
32	0.7	61.8	6.5	0.7	1.1	1.3
33	0.8	60.3	5.8	0.5	0.8	1.2
34	1.5	53.0	6.0	0.9	1.1	1.4
35	2.5	58.5	4.3	0.8	1.1	1.5
36	0.6	74.3	5.3	0.4	0.9	1.2
37	1.1	76.0	4.8	0.5	0.9	1.4
38	0.2	86.0	6.5	0.8	1.1	1.4
39	3.3	70.5	4.0	0.5	1.1	1.3
40	1.5	75.0	4.8	1.0	1.6	1.7
41	0.5	93.5	5.8	1.1	1.5	1.7
42	0.8	75.5	4.0	0.5	1.0	1.3
43	0.9	60.8	5.5	0.5	0.9	1.0
44	0.3	61.3	6.0	0.3	0.6	0.8
45	1.5	66.3	4.5	0.4	1.0	1.3
46	0.5	71.3	5.5	0.9	1.5	1.5
47	1.7	60.5	5.0	1.2	1.5	1.5

Appendix 38 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
48	0.9	65.3	5.3	1.1	1.5	1.7
49	1.0	64.0	6.3	1.3	1.6	1.6
50	1.1	70.0	5.8	1.1	1.5	1.7
51	0.5	73.3	4.8	0.5	0.8	1.1
52	0.5	75.0	4.5	0.7	1.2	1.5
53	1.3	70.5	5.3	1.2	1.6	1.8
54	2.1	70.5	5.3	1.0	1.2	1.4
55	1.8	76.3	4.0	0.9	1.4	1.6
56	1.3	74.0	5.0	0.9	1.2	1.4
57	1.4	75.3	4.3	0.6	0.9	1.1
58	1.7	70.8	3.8	0.7	1.0	1.3
59	0.4	77.8	5.0	0.6	1.0	1.2
60	2.2	82.3	4.8	0.8	1.2	1.4
61	0.7	72.8	6.3	1.0	1.3	1.4
62	0.4	73.5	6.0	0.0	0.4	0.8
63	0.3	74.5	3.3	0.1	0.6	0.5
64	0.9	69.8	5.3	1.0	1.1	1.3
65	0.1	69.8	5.5	0.3	0.8	1.0
66	0.4	72.5	6.0	0.8	1.2	1.4
67	1.0	71.5	4.8	0.6	1.2	1.4
68	0.6	73.8	6.5	0.8	1.3	1.5
69	0.7	74.0	5.5	1.2	1.3	1.7
70	1.3	69.0	4.3	1.1	1.5	1.6
71	0.7	71.5	5.5	1.3	1.5	1.7
72	1.3	80.5	4.3	0.8	1.4	1.6
73	0.5	83.8	6.3	1.0	1.5	1.6
74	0.9	82.0	6.3	0.9	1.4	1.6
75	1.5	68.3	5.3	1.3	1.6	1.7
76	1.3	72.3	4.5	0.9	1.5	1.6
77	0.5	83.3	5.8	0.8	1.4	1.6
78	1.2	83.0	4.5	0.8	1.3	1.7
79	1.2	69.8	4.3	1.1	1.5	1.6
80	1.2	77.5	5.3	1.1	1.5	1.6
81	1.0	72.5	4.3	1.1	1.5	1.6
82	0.3	70.3	5.0	1.0	1.4	1.6
83	1.2	73.0	5.3	1.1	1.3	1.6
84	0.8	76.0	5.0	1.2	1.5	1.7
85	1.9	67.8	4.5	1.1	1.4	1.6
86	1.0	74.0	4.0	0.3	0.8	1.0
87	0.2	78.0	6.0	1.0	1.3	1.5
88	0.5	74.0	5.0	0.8	1.1	1.4
89	1.1	78.3	5.3	0.9	1.4	1.6
90	1.1	94.0	4.3	0.3	0.7	0.9
91	1.4	78.5	4.0	0.9	1.4	1.6
92	1.4	72.8	5.3	1.1	1.4	1.5
93	0.7	76.0	5.3	1.1	1.7	1.8
94	1.2	71.3	4.3	0.7	1.3	1.5

Appendix 39 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
95	0.4	99.0	5.8	0.9	1.3	1.4
96	1.1	73.0	5.0	0.8	1.2	1.6
97	1.9	76.5	4.0	1.0	1.4	1.6
98	2.0	81.8	3.5	0.4	0.9	1.2
99	0.7	71.5	5.0	1.2	1.6	1.8
100	0.7	83.0	5.0	0.3	0.6	0.9
101	1.0	86.8	4.3	0.8	1.5	1.8
102	1.0	88.0	5.5	1.1	1.6	1.7
103	1.9	84.0	6.0	0.9	1.4	1.5
104	1.3	83.5	5.0	1.1	1.4	1.7
105	1.1	79.0	5.0	1.1	1.4	1.6
106	1.0	74.3	4.8	0.7	1.3	1.6
107	0.9	72.0	4.8	1.0	1.4	1.6
108	1.8	65.8	5.3	0.7	1.3	1.5
109	1.0	70.3	5.8	1.1	1.5	1.6
110	0.6	70.8	6.0	0.9	1.2	1.5
111	1.2	73.3	5.5	1.1	1.4	1.6
112	0.9	75.0	4.5	0.8	1.4	1.5
113	1.0	71.3	5.0	1.1	1.5	1.7
114	1.5	73.0	3.8	0.8	1.2	1.6
115	0.5	75.5	5.5	0.4	0.9	1.2
116	0.7	75.5	5.3	0.8	1.3	1.4
117	1.4	72.5	5.8	0.8	1.3	1.6
118	1.6	78.8	3.8	0.5	0.7	1.0
119	1.7	72.5	4.5	0.7	1.2	1.5
120	1.1	76.3	5.0	1.1	1.6	1.8
121	0.8	78.8	5.3	0.8	1.4	1.7
122	1.0	78.0	5.0	1.0	1.4	1.6
123	2.0	82.5	3.5	1.0	1.5	1.5
124	3.5	73.8	5.0	0.8	1.2	1.5
125	2.4	78.3	3.3	0.7	1.1	1.4
126	0.7	78.5	6.3	1.1	1.5	1.7
127	0.9	77.8	4.5	1.0	1.6	1.8
128	1.1	69.5	4.3	1.1	1.5	1.6
129	1.0	76.5	5.3	0.9	1.4	1.6
130	0.2	83.0	5.0	1.0	1.4	1.6
131	1.0	81.3	5.3	1.1	1.4	1.8
132	0.2	76.8	4.8	0.5	0.9	1.1
133	1.6	77.8	5.3	0.7	0.9	1.0
134	1.5	71.8	4.8	1.0	1.5	1.7
135	0.9	73.0	5.0	0.9	1.3	1.6
136	1.0	77.0	3.5	1.0	1.4	1.6
137	1.0	69.3	4.5	1.2	1.6	1.7
138	0.4	71.5	5.5	0.9	1.2	1.5
139	1.0	78.3	5.0	0.8	1.2	1.6
140	1.4	76.3	5.0	0.9	1.3	1.5
141	1.1	73.3	4.8	1.1	1.5	1.6

Appendix 40 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
142	1.3	71.3	4.8	0.9	1.6	1.7
143	0.3	75.0	6.3	0.4	0.8	1.1
144	0.2	72.0	5.0	0.2	0.8	1.2
145	2.0	74.8	4.3	0.8	1.1	1.3
146	1.2	74.3	5.0	0.8	1.2	1.4
147	0.8	69.8	5.3	1.0	1.4	1.5
148	1.4	72.5	4.3	1.0	1.2	1.5
149	1.4	72.8	4.8	1.0	1.4	1.6
150	1.0	72.3	4.8	0.9	1.4	1.6
151	1.3	73.5	4.8	0.8	1.1	1.4
152	1.6	73.5	4.8	0.9	1.4	1.6
153	1.3	68.8	5.0	0.8	1.1	1.3
154	0.5	71.3	5.8	1.1	1.5	1.6
155	0.9	71.8	5.0	0.8	1.4	1.5
156	0.6	71.3	5.3	1.0	1.5	1.7
157	1.5	72.8	4.0	0.8	1.4	1.5
158	0.7	64.5	6.5	1.4	1.6	1.8
159	1.0	74.5	5.5	1.2	1.6	1.7
160	1.6	75.0	3.8	1.1	1.6	1.8
161	1.7	74.0	4.3	1.0	1.3	1.4
162	1.9	82.5	4.5	0.8	0.9	1.3
163	0.6	90.3	3.8	0.6	0.9	1.4
164	0.7	89.8	5.0	0.6	1.3	1.5
165	1.2	82.3	5.3	1.1	1.6	1.8
166	0.7	78.5	5.0	0.7	1.2	1.4
167	1.1	85.5	4.8	1.1	1.5	1.7
168	1.5	76.0	3.8	0.8	1.5	1.6
169	0.7	90.3	5.3	1.0	1.5	1.8
170	1.1	78.3	4.3	1.1	1.4	1.6
171	2.2	75.3	3.3	0.6	1.1	1.4
172	0.3	87.0	5.3	0.5	1.0	1.2
173	0.8	80.0	5.5	1.2	1.7	1.8
174	1.4	82.3	5.0	1.0	1.4	1.6
175	0.6	80.5	5.3	0.8	1.2	1.6
176	1.6	79.5	3.8	1.0	1.6	1.8
177	1.5	79.8	4.8	1.1	1.4	1.7
178	1.0	79.5	3.5	1.1	1.6	1.7
179	0.9	87.8	5.5	0.8	1.4	1.5
180	1.3	79.0	5.5	1.2	1.5	1.6
181	2.0	75.8	4.3	1.0	1.3	1.5
182	0.3	83.8	6.0	1.0	1.3	1.5
183	0.6	90.5	4.8	1.1	1.5	1.8
184	0.5	84.5	6.0	1.0	1.4	1.6
185	0.4	78.0	5.5	1.1	1.4	1.7
186	0.8	87.0	5.5	0.6	1.1	1.3
187	2.1	75.8	4.3	0.9	1.2	1.4
188	0.8	88.5	4.5	0.9	1.4	1.6

Appendix 41 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
189	1.1	72.3	5.0	1.2	1.5	1.7
190	1.0	83.0	5.3	1.2	1.5	1.6
191	0.7	80.0	4.8	1.0	1.5	1.6
192	0.9	82.5	4.8	1.1	1.6	1.7
193	2.2	73.3	3.8	0.8	1.4	1.8
194	1.3	77.8	4.3	1.3	1.5	1.8
195	1.6	84.3	4.3	0.9	1.4	1.7
196	1.2	79.0	4.8	0.7	1.1	1.4
197	0.7	78.5	5.0	1.1	1.7	1.8
198	0.9	72.0	5.5	1.0	1.4	1.5
199	1.8	70.5	4.3	1.0	1.5	1.7
200	1.0	85.5	5.5	1.4	1.9	1.9
201	2.1	67.8	4.5	0.9	1.5	1.7
202	2.6	69.0	4.0	0.6	1.2	1.5
203	1.7	71.8	5.3	0.9	1.4	1.7
204	2.4	70.3	5.0	1.1	1.5	1.7
205	1.4	79.5	4.8	0.4	0.8	1.1
206	1.1	67.3	5.3	0.6	1.1	1.3
207	1.3	75.8	4.8	0.9	1.1	1.4
208	1.6	74.0	4.8	0.7	1.1	1.3
209	1.7	68.3	5.0	1.1	1.5	1.5
210	0.7	80.0	5.8	1.1	1.7	1.7
211	1.0	80.5	4.8	0.9	1.5	1.6
212	0.6	81.0	5.5	1.1	1.6	1.6
213	2.2	80.8	4.5	1.0	1.4	1.7
214	1.1	72.3	5.5	1.3	1.8	1.8
215	1.2	69.5	4.5	1.0	1.4	1.6
216	0.7	71.8	5.8	1.2	1.5	1.7
217	0.9	74.5	5.0	1.1	1.5	1.6
218	1.4	70.3	4.8	1.0	1.4	1.8
219	1.7	67.8	5.3	0.9	1.1	1.3
220	1.1	71.5	3.8	0.6	1.1	1.4
221	1.0	70.0	5.0	1.2	1.5	1.6
222	0.3	81.8	6.0	1.1	1.3	1.5
223	1.4	75.8	3.5	0.9	1.4	1.6
224	1.6	74.0	4.0	1.1	1.7	1.7
225	0.7	77.0	5.8	1.0	1.5	1.7
226	1.1	75.0	5.0	0.8	1.3	1.5
227	1.3	60.3	5.8	0.9	1.3	1.3
228	1.3	70.0	5.3	0.9	1.4	1.5
229	1.2	58.0	6.3	0.8	1.2	1.3
230	0.9	61.0	6.5	1.1	1.5	1.6
231	1.3	58.5	5.8	0.9	1.2	1.4
232	1.1	58.8	5.8	1.2	1.5	1.5
233	1.1	58.8	6.5	1.2	1.5	1.6
234	1.3	84.0	4.3	0.9	1.3	1.5
235	1.4	86.5	4.5	0.8	1.4	1.7

Appendix 42 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
236	1.8	68.5	5.0	0.9	1.3	1.6
237	1.2	70.3	4.3	1.0	1.4	1.6
238	0.9	74.0	6.3	1.1	1.5	1.7
239	1.1	71.0	6.5	1.3	1.6	1.8
240	1.7	67.0	4.5	0.9	1.4	1.5
241	0.8	71.8	5.3	0.9	1.3	1.5
242	1.4	70.0	4.3	0.9	1.3	1.5
243	1.5	75.5	3.5	0.9	1.5	1.7
244	0.8	82.5	5.0	1.0	1.4	1.7
245	0.7	91.3	5.5	0.9	1.4	1.6
246	1.1	70.0	5.5	1.0	1.5	1.7
247	0.4	87.5	5.3	1.2	1.6	1.8
248	1.3	83.5	4.5	0.7	1.4	1.6
249	1.1	68.8	4.8	1.0	1.3	1.6
250	1.8	71.5	4.8	0.7	1.2	1.4
251	1.3	77.3	5.0	1.1	1.5	1.7
252	1.1	66.3	6.0	1.2	1.6	1.7
253	1.9	73.3	5.0	1.4	1.6	1.7
254	0.6	72.3	6.3	0.6	1.0	1.3
255	1.5	65.5	5.0	0.5	0.8	1.0
256	0.2	82.0	5.5	0.0	0.0	0.3
257	1.2	78.3	5.5	0.5	0.8	1.0
258	1.6	74.5	4.5	0.8	1.3	1.6
259	0.9	59.3	6.3	0.9	1.2	1.3
260	0.9	80.8	5.0	0.7	1.3	1.5
261	0.5	78.8	4.8	0.9	1.3	1.5
262	0.5	73.3	4.8	0.6	0.9	1.1
263	1.5	79.5	5.0	0.6	1.0	1.4
264	1.3	77.5	3.8	0.9	1.5	1.7
265	1.2	74.0	5.0	1.0	1.4	1.6
266	1.4	77.3	5.0	1.0	1.5	1.7
267	0.8	76.5	5.5	1.4	1.5	1.7
268	1.0	74.8	5.3	1.0	1.4	1.5
269	1.0	83.8	4.5	0.8	1.2	1.5
270	1.1	71.8	6.0	1.2	1.6	1.7
271	2.0	67.8	5.5	1.1	1.5	1.6
272	2.2	77.0	5.0	1.0	1.5	1.6
273	1.4	73.3	5.0	1.0	1.5	1.7
274	1.1	56.5	6.3	1.0	1.3	1.4
275	0.7	72.0	5.0	1.0	1.4	1.6
276	1.3	69.8	5.3	0.8	1.1	1.4
277	1.1	71.8	4.8	1.1	1.3	1.7
278	1.0	80.3	4.5	0.9	1.2	1.4
279	0.8	78.8	4.5	0.9	1.2	1.4
280	1.0	69.0	4.8	0.7	1.0	1.3
281	1.5	60.5	5.0	0.9	1.3	1.4
282	1.1	53.3	6.0	0.6	0.8	1.0

Appendix 43 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
283	2.0	61.8	4.0	0.9	1.4	1.6
284	0.7	65.0	6.0	0.9	1.2	1.3
285	1.5	70.3	5.5	1.0	1.6	1.7
286	2.0	68.0	3.8	0.9	1.2	1.4
287	0.9	65.5	6.0	1.3	1.6	1.7
288	1.7	80.0	4.8	0.9	1.2	1.4
289	1.2	58.8	5.0	1.1	1.3	1.3
290	0.9	65.5	5.5	1.1	1.5	1.7
291	1.8	70.3	5.3	1.1	1.4	1.7
292	2.1	74.5	4.3	0.8	1.1	1.4
293	1.9	70.5	5.3	1.2	1.6	1.7
294	2.5	71.5	4.5	0.9	1.3	1.6
295	1.2	73.3	5.5	0.9	1.5	1.7
296	1.2	60.3	6.8	1.1	1.4	1.5
297	1.1	68.8	6.0	1.0	1.3	1.4
298	2.2	67.8	4.5	0.6	0.9	1.2
299	1.4	58.8	5.8	1.0	1.3	1.3
300	0.9	58.5	5.5	1.0	1.4	1.4
301	0.8	73.5	5.8	1.1	1.5	1.6
302	0.4	71.8	6.0	1.3	1.5	1.7
303	1.8	68.5	5.5	1.2	1.6	1.7
304	2.4	72.0	4.5	1.1	1.5	1.7
305	2.3	66.0	4.5	0.8	1.3	1.5
306	0.6	72.3	4.8	0.7	1.2	1.3
307	2.7	70.5	4.0	0.6	1.2	1.4
308	1.9	72.8	5.5	1.1	1.7	1.8
309	1.3	69.0	4.8	1.0	1.3	1.5
310	1.0	61.3	6.5	1.0	1.5	1.7
311	2.6	67.0	4.5	0.8	1.3	1.5
312	1.9	73.3	4.3	0.7	1.3	1.5
313	1.0	74.3	5.0	0.9	1.3	1.5
314	1.4	73.0	4.8	1.2	1.7	1.8
315	0.7	72.0	5.3	0.7	1.2	1.4
316	1.4	72.0	5.5	0.8	1.3	1.6
317	1.3	67.3	5.0	0.9	1.4	1.6
318	0.8	71.3	6.0	1.0	1.3	1.6
319	0.9	75.8	5.5	1.1	1.5	1.7
320	1.5	69.5	4.3	1.2	1.6	1.7
321	1.4	67.5	5.3	1.1	1.4	1.7
322	2.6	70.3	4.5	0.8	1.4	1.5
323	1.9	72.0	4.8	0.8	1.3	1.6
324	1.4	72.3	4.5	1.0	1.5	1.7
325	2.4	73.0	4.0	0.8	1.5	1.6
326	2.7	70.0	4.8	1.2	1.6	1.7
327	1.2	73.0	4.8	1.3	1.7	1.8
328	1.9	72.8	3.8	0.8	1.5	1.6
329	2.5	73.0	3.8	0.7	1.3	1.7

Appendix 44 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
330	2.5	72.0	4.8	1.3	1.5	1.6
331	1.3	56.3	5.0	1.0	1.3	1.5
332	2.1	59.0	5.5	0.6	1.0	1.2
333	1.9	60.0	4.8	0.7	1.1	1.3
334	2.0	58.5	4.5	1.0	1.3	1.4
335	1.2	74.3	5.3	1.2	1.6	1.8
336	1.1	57.3	5.3	1.0	1.2	1.4
337	1.5	60.8	5.3	0.8	1.2	1.4
338	0.9	80.3	5.0	1.1	1.6	1.7
339	2.2	75.3	3.5	0.7	1.4	1.6
340	1.7	73.3	5.3	1.1	1.5	1.6
341	0.6	81.5	5.5	1.4	1.7	1.8
342	1.5	69.5	5.0	1.1	1.6	1.7
343	1.0	81.0	5.0	1.2	1.6	1.8
344	1.6	75.5	5.0	1.2	1.6	1.8
345	1.7	70.3	4.5	0.8	1.3	1.6
346	1.7	71.5	5.0	1.0	1.6	1.8
347	0.6	74.3	6.3	1.1	1.5	1.5
348	1.8	74.8	4.0	1.2	1.4	1.6
349	2.3	74.8	4.3	0.9	1.5	1.7
350	1.3	74.0	4.0	1.1	1.5	1.8
351	1.9	72.8	4.8	0.7	1.5	1.7
352	1.3	72.0	4.3	1.1	1.6	1.7
353	1.5	72.5	5.3	0.9	1.6	1.6
354	1.8	71.8	4.5	1.1	1.5	1.8
355	2.1	69.8	5.0	1.2	1.5	1.8
356	1.3	77.8	3.5	0.8	1.4	1.6
357	3.0	74.0	4.0	0.8	1.2	1.4
358	2.1	73.0	4.0	1.0	1.4	1.7
359	1.4	70.8	5.0	1.1	1.6	1.8
360	1.0	74.0	5.5	1.0	1.5	1.6
361	1.7	72.8	4.5	1.3	1.6	1.7
362	0.9	81.3	4.3	0.8	1.3	1.6
363	1.4	74.8	5.5	0.9	1.3	1.5
364	1.5	57.8	5.3	0.9	1.4	1.6
365	0.8	69.8	6.0	1.3	1.5	1.6
366	1.0	73.8	6.5	1.0	1.5	1.6
367	0.9	66.5	4.3	0.9	1.3	1.3
368	0.6	80.8	4.8	0.8	1.4	1.7
369	0.9	72.0	5.3	1.1	1.5	1.6
370	1.4	72.8	4.5	0.9	1.3	1.5
401	1.3	69.8	4.5	0.9	1.3	1.5
402	1.7	67.3	5.3	0.8	1.0	1.2
403	2.2	68.8	5.5	0.8	1.1	1.3
404	1.3	68.5	4.5	0.8	1.3	1.4
405	4.3	68.3	3.5	0.8	1.2	1.3
406	2.6	66.8	3.5	0.7	1.1	1.2

Appendix 45 continued. Combined analysis of the land races performance under artificial *Striga* infestation at Kibos and Alupe

ENTRY	YLD	AD	SDR	STR8TR	STR10TR	STR12TR
407	3.2	67.5	4.5	0.8	1.3	1.5
408	2.3	69.8	4.0	0.9	1.4	1.6
409	2.5	67.3	3.8	1.1	1.4	1.5
410	2.0	68.8	5.5	1.1	1.5	1.6
418	2.0	64.8	8.0	0.9	1.3	1.5
419	0.7	72.5	4.9	0.1	0.2	0.3
420	2.5	66.8	5.3	0.9	1.4	1.6
MEAN	**1.3**	**73.5**	**5.0**	**0.9**	**1.3**	**1.5**
CV	**36.96**	**5.1**	**26.3**	**38.73**	**33.24**	**31.57**
LSD	**5.21**	**1.25**	**1.82**	**0.52**	**0.45**	**0.37**
SIG.	***	***	**	***	***	***

Key: YLD = grain yield (t/ha), AD= dyas to 50% anthesis, SDR= *Striga* damage rating (Score 1-9), STR8TR= *Striga* counts 8 WAP, STR10TR= *Striga* counts 10 WAP, STR12TR= *Striga* counts 12 WAP,