THE EFFECT OF IMAZAPYR – RESISTANT MAIZE (*Zea mays* L.) PLANT DENSITY UNDER BEAN INTERCROP ON WITCHWEED (*Striga hermonthica* (Del.) Benth), MAIZE AND BEAN YIELD

BY

ILLA ABSALOM OBUYA

A Thesis submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Horticulture

DEPARTMENT OF BOTANY AND HORTICULTURE

MASENO UNIVERSITY

ABSTRACT

Maize *(Zea mays* L.*)* is one of the most important crops in East Africa serving both as a staple food and cash crop to millions of people. As a vegetable, it is produced either as green maize cobs, sweet corn or baby corn. Maize yields under farmers' conditions especially in the Lake Victoria Basin average 1.3 t ha^{-1} which is less than 25% of the potential yield. This is attributed to several factors; the greatest being Striga *(Striga hermonthica)* which is a parasitic weed attacking several crops in the grass family. A medium term technological breakthrough in form of a herbicide (imazapyr) resistant maize variety could help reduce seed bank in the soil. The main objective was to evaluate the seasonal performance of imazapyr-resistant (IR) maize at different plant densities under bean intercrop on Striga weed and crop growth. The study was conducted for two seasons on a Striga-free field at Maseno University and on a Striga infested farmer's field in Maseno Division of Kisumu West District. The experiment was laid out as a Split plot design in three replicates with maize variety as the main plot factor at three levels (treated IR maize, untreated IR maize and WH505/H516 as commercial check varieties) and maize density as the sub-plot factor at three levels (44,444 plants ha^{-1}, 66,666 plants ha^{-1} and 88,888 plants ha^{-1}). Data was collected on Striga seed count, days to first Striga emergence, crop stand, Striga incidence, Striga biomass, days to 50% flowering of the crop, crop biomass, and finally on maize and bean yield components. Data was subjected to Analysis of Variance (ANOVA) at 5% using SAS computer software to test for significant differences between treatments and means separated using the Least Significant Difference (LSD). The effect of IR maize plant density on Striga seed bank was not established due to the plot sizes which could not withstand Striga seed invasion from external sources. Treated IR maize delayed Striga attachment on maize thus suppressing Striga parasitism and any late Striga attachments had little or no parasitic effect. Increasing the plant density of treated IR maize up to 88,888 plants ha^{-1} led to an increase in maize yield up to 3.48 t ha^{-1} and this high density can still be intercropped with two rows of beans between the maize rows translating into increased returns per unit area. Treated IR maize should be planted in Striga infested fields at 75cm x 15cm with two rows of bean intercrop 15cm away from the maize rows spaced at 45cm x 15cm.

1.0 INTRODUCTION

1.1 Background of the study

Maize (*Zea mays* L.) is one of the most important cereal crops in East Africa where it serves both as a staple food and cash crop for millions of people. In its vegetable forms as sweet corn and baby corn, it earns the much needed foreign exchange through export. Maize yields under farmers' conditions in the Lake Victoria Basin average 1.3 t ha^{-1} (Hassan, 1998), or less than 25% of the potential yield of 5 t ha^{-1} (Tittonell *et al.,* 2005) under rainfed conditions. The reduced maize yields are majorly attributed to the parasitic weed, witch weed (*Striga hermonthica* (Del.) Benth) amongst other factors like pests and declining soil fertility (Odendo *et al.,* 2001).

Striga (*Striga hermonthica* (Del.) Benth) is a parasitic weed that attacks several cereal grains, particularly maize and sorghum and other native and exotic grasses throughout Africa, and elsewhere in the tropics and warm temperate regions (Odhiambo and Woomer, 2005). In Kenya, Striga infestation is most severe in Nyanza and Western Provinces (Appendix 10), where it occurs in approximately 200,000 ha and results in crop losses estimated at $ 80 million per year. This is a crop loss of 30 – 50% although losses of up to 100% are reported (Hassan *et al.,* 1995).

Germinated Striga seeds infect host roots, feeding on the plant below the ground for several weeks, and then a fast growing shoot emerges that produces prolific flowers and thousands of tiny seeds (Odhiambo and Woomer, 2005). The Striga seed production is so prolific to the tune of between 50,000 and 200,000 seeds per fully mature plant and the seeds can remain dormant in the soil for 20 years (AATF, 2006).

There have been continued attempts to combat Striga by careful weeding and burning but the parasite's infestation continues to grow in size and severity owing to the enormous seed bank in the soil (AATF, 2006). A recent technological breakthrough using the herbicide resistant maize variety has been developed (Kanampiu *et al.*, 2002). Herbicide resistance by maize permits the application of relatively small amounts of imazapyr which is a systemic herbicide to maize seeds that in turn provides several weeks' chemical protection from parasitic Striga (Kanampiu *et al.*, 2002). The imazapyr that is not absorbed by the maize seedling diffuses into the surrounding soil and kills ungerminated Striga seeds. The coated maize still exudes germination stimulants into the rhizosphere thereby inducing germination of Striga seeds which are then killed (Kanampiu *et al.*, 2001). The low dose herbicide seed dressing on IR-maize controls Striga without impacting sensitive intercrops when they are planted 10cm or more from the maize hills (CIMMYT, 2008). It therefore allows small scale farmers to continue intercropping at most with the slight modification while using maize seed treated to control Striga. The roots of several legumes are also known to induce suicidal germination of Striga seeds thus being incorporated into Striga suppression strategies involving cereal legume rotation or intercropping. Legume rotation with soybean/groundnut or soybean/cowpea has been found to significantly reduce Striga seed bank compared to monocropping (Woomer *et al.*, 2005).

In western Kenya where Striga problem is endemic, the farmers produce crops under diverse biophysical and socioeconomic conditions. Maize intercropped with beans are the main crops produced for household food consumption with occasional surpluses sold for cash (Nekesa *et al.,* 1999). This cropping system has been applied as a tool in Striga management. Intercropping maize with two bean rows between maize rows has low Striga emergence which is reflected in high though non-significant maize grain yield. This has been found to be beneficial to the farmers since it increases total yield indicated by a land equivalent ratio greater than one especially during the long rains (Odhiambo and Ariga, 2001). The study therefore aimed at evaluating the effect of imazapyr-resistant maize plant density under bean intercrop on Striga weed and crop growth in a bimodal rainfall regime. This was to provide the optimum imazapyr-resistant maize plant density that would increase the rate of decline of Striga seed bank in the soil at optimum maize yield.

1.2 Problem Statement

Maize (*Zea mays* L.) is an important cereal crop in Kenya serving as a staple food and cash crop to a majority of the farming clientele. It is also grown as a vegetable by being produced as green maize, sweet corn and baby corn thus providing the much needed foreign exchange. Maize production along the Lake Victoria Basin of Kenya especially in Nyanza and Western Provinces has been greatly affected leading to reduced yields. This yield reduction has greatly contributed to food insecurity since maize is the main staple food within the Lake Victoria basin; this has been made worse by the climatic change which has engulfed the whole world. The reduction in yield has been greatly attributed to the parasitic weed *Striga hermonthica* (Del.) Benth. Striga infestation occurs in approximately 200,000 ha of land resulting in crop losses estimated at $ 80 million per year (De Groote *et al.,* 2002). Attempts to control Striga have led to several interventions, the most current being the introduction of imazapyr resistant maize whose seed is coated with small quantities of imazapyr which kills the Striga at the point of attachment to the maize root. The imazapyr that is not absorbed by the maize seedling also diffuses into the surrounding soil and kills ungerminated Striga seeds. This being a recent technological advancement towards

Striga control, there is no study reported on the effect of this imazapyr – resistant maize density on Striga seed bank and Striga emergence. Rate of decline could be affected by the maize plant population through changes in root surface area. This therefore called for exhaustive studies to determine the most suitable plant density that would increase the rate of decline of Striga seed bank in the soil while maintaining good maize yields.

1.3 Objectives

1.3.1 Broad Objective:

To evaluate the effect of imazapyr – resistant maize at different plant densities under bean intercrop on Striga weed and maize and bean productivity in two seasons.

1.3.2 Specific Objectives:

To evaluate:

(a) The effect of imazapyr – resistant maize plant density under maize and bean intercrop on Striga seed bank in the soil within two seasons.

(b) The effect of imazapyr – resistant maize plant density under maize and bean intercrop on Striga emergence within two seasons.

(c) The effect of imazapyr – resistant maize plant density under maize and bean intercrop on the growth and yield of maize and beans within two seasons.

1.4 Research Hypothesis

Increasing the plant density of imazapyr – resistant maize under bean intercrop can increase the rate of decline of Striga seed bank in the soil while maintaining good maize and bean yields.

2.0 LITERATURE REVIEW

2.1 Maize

Maize (*Zea mays* L) originated from Southern Mexico from where it spread to the rest of the world and among the cereals, it ranks third both in terms of area and production in the world (Mahendra *et al.,* 1996). It belongs to the family Poaceae and can be classified into several groups based on the endosperm characteristics. Some of these groups include Flour corn (*Zea mays* var. *amylacea*), Sweet corn (*Zea mays* var. *saccharata*) and Popcorn (*Zea mays* var. *everta*) (Wikipedia, 2008b).

Maize is an annual plant growing to a height of 1.5 – 3.0 m and has a fibrous root system (Mahendra *et al.,* 1996). Its initial vegetative growth comprising the initiation of nodes, internodes, leaves and tillers takes about 20-25 days after sowing after which floral initiation sets in. The peak vegetative growth starts shortly after floral initiation characterized by rapid stem elongation and increase in the leaf area (Mahendra *et al.,* 1996). This is also the peak period of nutrient uptake.

2.1.1 Maize production in Kenya

Maize is the most important food crop in Kenya with a national production of 2.4 million tons in a total area of 1.6 million hactares (Gebrekidan *et al.,* 1992). Shortage of maize in Kenya always results in famine among the poor urban and rural people. It is grown in a wide geographical distribution covering almost every part of Kenya from 0 – 2400 m above sea level (Acland, 1971). The cool conditions at high altitudes lengthen the life cycle and above 2400m severely limit yields. It is therefore an important staple food both in terms of land area and value. Over 90% of the maize is produced in small holdings of less than 5 hactares (Heyer *et al.,* 1976).

2.1.2 Utilization of Maize

Maize is generally used as a staple food, as feed for livestock and as raw material for many industrial products (Mahendra *et al.,* 1996). As a staple food, maize is ground and pounded and the meal may be boiled, baked or fried to give porridge, ugali or corn bread. The whole grain may also be boiled or roasted. Corn oil can be processed from the endosperm. Maize can also be fermented and distilled to produce ethyl, butyl or propyl alcohols, acetaldehyde, acetone, glycerol and acetic, citric and lactic acid (Mahendra *et al.,* 1996).

In as much as maize is grown as a cereal crop, it is also used as a vegetable. Green maize can be boiled or roasted and eaten as such. It can also be cooked in combination with other leafy vegetables and mashed potatoes. There are also two special types of maize used as vegetable. These are Sweet corn (*Zea mays* var. *rugosa*) and Baby Corn. Sweet corn is a variety of maize with high sugar content as a result of a naturally occurring recessive mutation in the genes which control conversion of sugar to starch inside the endosperm of corn kernel (Wikipedia 2008a). Unlike field corn varieties which are harvested when the kernels are dry and fully mature, Sweet corn is picked when immature and eaten as a vegetable rather than a grain. It is cultivated to produce kernels for fresh market and canning industry (Mahendra *et al.,* 1996).

Baby corn is a cereal grain taken from specialized maize plants harvested early, while the ears are very small and immature (Wikipedia, 2008a). They are hand picked as soon as corn silks emerge from the ear tips or a few days after, and this must be carefully timed to avoid ending up with normal corn ears. Baby corn ears are generally about 4.5 cm to 10 cm in length and 7 mm to 17 mm in diameter and are typically eaten whole, cob and all, in contrast to mature maize, whose cob is typically too hard for human consumption (Wikipedia, 2008a). It is consumed both raw and cooked. Sweet corn is highly nutritious providing carbohydrates, proteins and vitamins as shown in table 1.

Table 1: Nutritional value of sweet corn (seeds only) per 100g

Energy	90 Kcal (360kJ)
Carbohydrates	19%
Sugar	3.2%
Dietary fibre	2.7%
Fat	1.2%
Protein	3.2%
Vitamin A equiv. 10μg	1%
Folate (Vit. B9) 46μg	12%
Vitamin C 7mg	12%
Iron 0.5mg	4%
Magnesium 37mg	10%
Potassium 270mg	6%

Source: USDA 2008.

2.1.3 Constraints to Maize Production

Maize production in Kenya has never attained its full potential due to a number of factors. Studies have shown that maize production in western Kenya stands at a low 0.2 – 0.4 t ha^{-1} while research indicates that up to 5 t ha^{-1} can be achieved (Tittonell *et al.,* 2005) under rainfed conditions. The major maize production constraints in Western Kenya are weeds including *Striga hermonthica* parasitism, labour to control them during peak labour requirement in the season and low soil fertility (Odhiambo and Ariga, 2001). *Striga hermonthica* in the Lake Victoria basin has been identified by farmers as the most important constraint to maize production (Hassan *et al.,* 1995).

Odendo *et al.*, 2001 also indicates that the reduced maize yields in western Kenya are majorly attributed to the parasitic weed, witchweed (*Striga hermonthica* (Del.) Benth) amongst other factors like pests and declining soil fertility.

2.2 Striga Weed

Striga is a genus in the Scrophulariaceae family. It is commonly known as witchweed. The genus includes about 25 species, a few of which are economically important, for instance *Striga hermonthica, Striga asiatica, Striga gesnerioides*, *Striga densiflora, Striga euphrasioides, Striga aspera* and *Striga forbesii* in order of importance (Ramaiah *et al.,* 1983). Striga is a parasitic weed that attacks several grain crops, particularly maize and sorghum, but also sugarcane, finger millet, napier and other native grasses (Woomer, 2008). The parasitic weed is dependent on its host for the supply of water, nutrients and organic solutes. The removal of these resources by the parasite can adversely affect the growth of infected plants such that biomass accumulation and resource allocation is altered compared with that of their uninfected counterparts (Gurney *et al.,* 2000).

Striga hermonthica (Del.) Benth and *Striga asiatica* (L) Kuntze are the species which cause economically significant damage to cereals (Kiruki *et al.,* 2006). In Kenya, Striga infestation is most severe in Nyanza and Western provinces (Appendix 11), where it occurs in approximately 200,000 ha and results in crop losses estimated at $ 80 million per year (Woomer *et al.,* 2005). Roots emerging from germinating Striga seeds attach to crop roots, and the parasite becomes a major sink for crop photosynthates, debilitating crop growth and yield, up to total loss (Kanampiu *et al.,* 2001). Each host plant can have several attachments of the parasitic weed. Striga damage to the crop is first seen before anthesis on heavily infested plants as a sudden chlorosis of the maize whorl due to a phytotoxic effect which occurs long before the emergence of the Striga flower stalks (Kanampiu *et al.,* 2001).

2.2.1 Biology of Striga species

Striga seeds are produced in enormous numbers. Each seed capsule produces some 400 – 500 seeds and each plant produces several thousands (Ramaiah *et al.,* 1983). Each Striga plant is capable of producing from 50,000 to 500,000 seeds which may remain viable for 14 years in the soil (Berner *et al.,* 1995) although Ramaiah *et al.,* (1983) puts the viability period at 15-20 years. The seeds are extremely small each weighing about 7µg (Berner *et al.,* 1995). The high fecundity together with a high annual viability rate means that a large seed bank can rapidly build up and survive in the soil for many years. The seeds are generally dispersed by wind, water, cattle and man (Ramaiah *et al.,* 1983), although Abayo *et.al.,* (1998) indicates that contaminated seed is probably the major form of Striga dispersal in Africa and harvesting equipment may enhance seed movement.

2.2.1.1 Germination and Attachment

Striga seeds remain dormant until they are stimulated to germinate by biochemical signals from suitable plant roots (Woomer, 2008). They possess the remarkable capacity to remain viable in the soil for 15 – 20 years in the absence of a suitable plant host (Ramaiah *et al.,* 1983). Several germination stimulants have been identified in the root exudates of both hosts and non-host plants and most of them are collectively described as strigolactones (Matusova *et al.,* 2005). Strigol, a strigolactone is produced by both host and non-host plants as it has been identified in the root exudates of cotton (*Gossypium hirsutum* L.), Sorghum (*Sorghum bicolor* (L) Moench), Maize (*Zea mays* L.) and Proso millet (*Pennisetum glaucum* L.) (Sato *et* *al.,* 2005). The Striga seeds require preconditioning (or warm stratification) for a certain period of time at a suitable temperature before the seeds become responsive to germination stimulants (Matusova *et al.,* 2005).The preconditioning period may last some 10-15 days under optimum moisture and temperature conditions (Ramaiah *et al.,* 1983). The seeds have to be very close to the host root to be stimulated. At favourable temperature of 30–35^{0}C, seed germination occurs within 24 hours (Ramaiah *et al.,* 1983). After germination, endosperm nutrients can sustain the seedlings for 3-7 days in the absence of a host. If the seedling does not attach to a host and successfully establish a parasitic link within this period, the seedling dies (Berner *et al.,* 1995). On contact with the root, the tip of the radicle transforms itself into a haustorium due to a chemical secretion from the host root known as the haustorial initiation factor (Ramaiah *et al.,* 1983). There is then the establishment of xylem- to-xylem connections between the parasite and the host (Berner *et al.,* 1995).

2.2.1.2 Striga Parasitism

Once the Striga is established, it becomes a metabolic sink for the carbohydrates produced in the host (Ramaiah *et al.,* 1983). It drains photosynthates, minerals and water as well as damaging its host through phytotoxins before it emerges from the soil. After successful attachment, the developing Striga plants grow underground for 4-7 weeks prior to emergence (Berner *et al.,* 1995). Young Striga seedlings are completely parasitic on the host while they are subterranean and at this stage cause maximum damage to the host (Ramaiah *et al.,* 1983). Following emergence, Striga plants form chlorophyll and begin to photosynthesize, but they are still unable to survive in the absence of host attachment (Berner *et al.,* 1995). The effect of Striga on its host is severe with alterations in host performance usually occurring soon after parasite attachment and prior to the parasite emerging above the ground. The symptoms of Striga parasitism on the host are often dramatic resembling drought stress, nutrient deficiency, vascular disease and severe plant stunting (Berner *et al.*, 1995).

2.2.2 Striga Control

Striga infestation is a consequence of monocropping with cereals which host the parasite and declining soil fertility which weakens the host plant to Striga attack (CIMMYT, 2008). Due to such cropping practices, Striga infested areas have developed very high levels of long-lived Striga seeds in the soil with only some breaking dormancy each season when stimulated by crop exudates. In order to be effective, technologies must control Striga before crop yields are affected and deplete the Striga seed bank in the soil to control further yield losses. The most effective ones are those that act before or during Striga attachment. A number of Striga reduction and control strategies have been employed in the past with their specific limitations. They range from chemical, biological, cultural to integrated approaches (Ramaiah *et al.,* 1983).

2.2.2.1 Cultural control

There are several cultural measures that have been employed to combat Striga. Some of these include:

2.2.2.1.1 Hand weeding

Hand weeding is only practical in preventing build up of the parasite seeds in lightly infested soil (Berner *et al.,* 1995). It aims at preventing the production of Striga seeds and should continue beyond crop harvest. The crop stubble should also be uprooted or burned to prevent the continued growth and seeding of the parasite (Ramaiah *et al.,* 1983). The limitation of this approach is that it is done when substantial damage to the current crop has already occurred and there still remains a substantial reservoir of seeds in the soil for infection the next season (Berner *et al.,* 1995).

2.2.2.1.2 Crop Rotation

This involves rotating cereal hosts with non-host crops that stimulate Striga seed germination to reduce densities of Striga seeds in the soil while maintaining agriculturally productive land. Some of these trap crops include cotton, sunflower, groundnut and soybean (Ramaiah *et al.,* 1983 and AATF, 2006). Some legume root exudates also have suppressive effects on Striga (AATF, 2006).

2.2.2.1.3 Intercropping

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time to maximize beneficial interactions while minimizing competition. It is a type of multiple cropping system which has been practiced traditionally by small scale farmers in the tropics (Tsubo *et al.,* 2003). The practice uses companion planting principles and may benefit crop yield, control some kind of crop pest or may have other agronomic benefits. In intercropping, there is often one main crop and one or more added crops, with the main crop being the one of primary importance because of economic or food production reasons (Wikipedia, 2008c). The two or more crops used in an intercrop may be from different species and different plant families, or they may simply be different varieties or cultivars of the same crop species.

Successful intercropping involves the consideration of spatial arrangements, density, maturity dates and plant architecture of the crops (Oseko, 2007). The various spatial arrangements used give the intercropping types and these include mixed, row and strip intercropping. Mixed intercropping implies the basic form in which the component crops are mixed in the available space with no distinct row arrangements. Row intercropping involves the component crops arranged in alternate rows and this is the pattern usually encountered in intensive agriculture. Strip cropping is a variation of row cropping where multiple rows (or a strip) of one crop are alternated with multiple rows of another crop and the strips are wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically (Oseko, 2007 and Wikipedia, 2008c).

The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop (Wikipedia, 2008c). It should therefore be well planned not to have crops competing with each other for physical space, nutrients, water or sunlight. Plant architecture is commonly used strategically to allow one member of the mix to capture sunlight that would not otherwise be available to the others e.g. maize plants growing above an under storey of beans. Due to the rapid increase in population and less chances of bringing new lands under cultivation, intercropping seems to be one way of increasing productivity and intensifying land use. Most of the farmers have small holdings and are unable to manage their diversified needs from the limited area. This situation therefore warrants the development of an appropriate technique of growing field crops in association with each other without too much intercrop interference and competition (Ullah *et al.*, 2007).

Intercropping may use the benefits of allelopathy. Allelopathy is an interaction between plants where compounds like tannins, alkaloids and phenolics produced in one plant is released into the environment and inhibits or stimulates the growth of another plant. The compounds can be released in several ways. They can be washed off leaves, leached from dry leaves, emitted from roots or released during decomposition of the plant. Allelopathic interactions can be utilized in farming as a cost effective alternative to using synthetic chemical inputs and thus a means of contributing to sustainable agriculture (Kantor, 1999).

Cereal and legume intercropping is recognized as a common cropping system throughout tropical developing countries (Tsubo *et al.,* 2003). Typically, C_4 cereal crops such as maize (*Zea mays* L.), pearl millet (*Penisetum glaucum* (L.) RBr.) and sorghum (*Sorghum bicolor* (L.) Moench) are the dominant plant species, whereas C_3 legume crops such as beans (*Phaseolus vulgaris* L.), Cowpea (*Vigna unguiculata* (L.) Walp), groundnut (*Arachis hypogaea* L.) Pigeon pea (*Cajanus cajan* (L.) Millsp.) and soybean (*Glycine max* (L.) Merr) are the associated or secondary species (Tsubo *et al.,* 2005). Canopy structures and rooting systems of cereal crops are generally different from those of legume crops. In most cereal - legume intercropping, cereal crops form higher canopy structures than legume crops, and the roots of cereal crops grow to a greater depth than those of legume crops (Tsubo *et al.,* 2005). This suggests that the component crops probably have differing spatial and temporal use of environmental resources. This cropping system may thus help improve productivity of low external input farming, which depends largely on natural resources such as rainfall and soil fertility. Cereal-legume intercropping systems have higher productivity than sole cropping systems and Tsubo *et al.,* 2003 indicates that there are yield and growth advantages of maize-bean intercropping. In terms of resource utilization Tsubo *et al.,* 2005 indicates that there may be less competition for water between maize and beans in intercropping situations due to more limited development of the lateral root systems of both maize and beans under rainfed conditions. The radiation use efficiency and water use efficiency of maize-bean intercropping are equivalent to or higher than maize sole cropping (Tsubo *et al.,* 2003) thus planting maize associated with beans is more advantageous than sole cropping.

In western Kenya where Striga problem is endemic, the farmers produce crops under diverse biophysical and socioeconomic conditions. Maize intercropped with beans are the main crops produced for household food consumption with occasional surpluses sold for cash (Nekesa *et al.,* 1999). More than 90% of the farmers are smallholders and practice some form of intercropping, mainly maize-bean intercropping; and with good management maize yields may not be adversely affected by intercropping with beans (Mwania *et al*., 1989). The beans therefore constitute a bonus harvest. Intercropping has been applied as a tool in Striga management. This involves intercropping a cereal with legumes that suppress Striga through suicidal germination while also producing higher value pulse intercrops such as green gram, lablab, groundnut and soybean (AATF, 2006). The evaluation of intercropping maize as a means to reduce Striga emergence and survival established that peanut, bambara nut, bean and soybean were variable in terms of Striga suppression in maize depending on the specific agro-ecological conditions (Oswald *et al*., 2002). The decline of Striga numbers in the intercropping systems was attributed to shading, higher humidity and lower temperatures under the intercrop canopies. Intercropping maize with beans with two bean rows between maize rows has low Striga emergence which is reflected in high though non-significant maize grain yield and it is beneficial to the farmers since it increases total yield indicated by a land equivalent ratio greater than one especially during the long rains (Odhiambo and Ariga, 2001). Khan *et al*., 2007 also indicated that intercropping maize with *Crotolaria ochroleuca* could be combined with other cultural methods for a sustainable control of *Striga hermonthica*.

Odhiambo and Woomer, 2005 indicated that both imazapyr resistant open pollinated variety maize and soybean/cowpea intercropped are more effective in reducing Striga seed bank in the soil compared to other maize varieties or Striga management options. Khan *et al.,* 2002 also observed that intercropping of maize with the fodder legumes *Desmodium uncinatum* and *Desmodium intortum* significantly reduce *Striga hermothica* infestation, when compared to the maize monocrop and significantly increase maize yields. The major limitation here is that desmodium may prove difficult to establish (Woomer, 2008).

2.2.2.1.4 Striga tolerant varieties

Several Striga tolerant varieties are available as either open pollinated or hybrid varieties which evade Striga by producing more roots below the parasite's seed bank distributed within the soil plow layer and by expressing less phytotoxity in response to Striga parasitism (AATF, 2006). Some of the Striga tolerant maize varieties include WS909, WH502, and KSTP 94 (Woomer, 2008).

2.2.2.2 Biological control

The practical biocontrol techniques are yet to be developed but biological control through inundation with locally occurring pests and pathogens may be feasible (Berner *et al.,* 1995). *Smicronyx umbrinus*, a gall-forming weevil that lays eggs in the flower buds has been examined as a biocontrol agent (Ramaiah *et al.,* 1983). Its drawback is that its natural enemies and pathogens limit its efficiency unless inundation is regularly repeated (Berner *et al.,* 1995). *Fusarium* species has also been tested for post emergence Striga control but the limitation has been the cost of application and lack of immediate yield loss abatement (Berner *et al.,* 1995).

2.2.2.3 Chemical control

The use of both pre-emergent and post-emergent herbicides like Goal$^{®}$ and 2,4-Dichlorophenoxyacetic acid respectively is a valuable control measure of Striga but unfortunately it is beyond the investment abilities of most small scale farmers (AATF, 2006). Odhiambo and Ransom, (1993) indicated that dicamba applied at the time of attachment kills Striga before it emerges thus providing some yield protection. However the limitation is that dicamba does not provide the persistent, continual control necessary to make it cost effective. Post emergent applications are also done at a time when Striga damage to the crop has occurred. Most African farmers also practice cereal – legume intercropping which is incompatible with field spraying. Ethylene gas can also be effective in triggering suicidal germination of Striga seeds in the soil (Ramaiah *et al.,* 1983) but this approach also has a cost implication.

2.2.2.3.1 Herbicide Coated Maize Seed (IR Maize)

This approach combines low dose imazapyr seed coating applied to imazapyr – resistant (IR) maize seed. The approach has been developed on the understanding that parasitic witchweeds inflict most of their damage while still underground and attached to crop roots (Ramaiah *et al.,* 1983). Abayo *et al.,* (1998) indicated that herbicides with known acetolactate synthase (ALS) inhibiting activity can be effectively applied as a seed dressing to provide early season Striga control. ALS catalyzes the production of three branched-chain aliphatic amino acids, valine, leucine and isoleucine required for protein synthesis and cell growth (Tu, 2004). Imazapyr is a systemic herbicide which controls plant growth by preventing the synthesis of branched-chain amino acids. It is absorbed quickly through plant tissue and can be taken up by roots, translocated in the xylem and phloem to the tissues where it inhibits the enzyme acetolactate synthase (Tu, 2004).

Herbicide resistance by maize permits the application of relatively small amounts of imazapyr to maize seeds that in turn provides several weeks' chemical protection from parasitic Striga (Kanampiu *et al.,* 2002). The small quantities of imazapyr coating act at the time of Striga attachment to the maize root and so prevent the exertion of the phytotoxic effect of the Striga on the maize plant which usually occurs even before emergence of the Striga from the soil (CIMMYT, 2008). The ALS-inhibiting herbicides have an important role to improve yields as well as reduce the amount of seed return to the soil (Kabambe *et al.,* 2007).

When IR maize seed is coated with the herbicide, Striga attempting to parasitize the resulting maize plants are destroyed. It has been established that only 30g of imazapyr coated onto seed is sufficient to protect one hactare of maize from Striga for six to eight weeks (AATF, 2006). The imazapyr that is not absorbed by the maize seedling diffuses into the surrounding soil and kills ungerminated Striga seeds. The coated maize still exudes germination stimulants into the rhizosphere thereby inducing germination of Striga seeds which are then killed (Kanampiu *et. al.,* 2001). The low dose herbicide seed dressing on IR-maize controls Striga without impacting sensitive intercrops when they are planted 10cm or more from the maize hills (CIMMYT, 2008). It therefore allows small scale farmers to continue intercropping at most with the slight modification while using maize seed treated to control Striga. The high suppression of witchweed emergence observed with imazapyr is of great significance to integrated management by small scale farmers since most of the other control options do not offer complete Striga control or have certain limitations. This approach therefore serves two main purposes namely controlling Striga itself so that adequate crop yields can be achieved and depleting Striga seed bank in the soil to allow for the cultivation of Striga susceptible crops (Kabambe *et al.,* 2007).

2.2.2.4 Integrated Control

While single control options may lead to increase in crop yield and decrease of Striga seeds in the soil, none of these is completely effective in eliminating Striga infestation. No single Striga control practice is applicable to all situations rather each has its comparative advantages and disadvantages (AATF, 2006). Because of the longevity of Striga seeds in the soil and the variability within and between Striga species, there is a tremendous potential for the parasites to adapt to individual controls (Berner *et al.,* 1995). Sustainable Striga control therefore requires the implementation of integrated systems of control. Combinations of two or more control measures can make a significant impact (Ramaiah *et al.,* 1983). An effective integrated control aims at preventing influx of Striga seeds in the soil, preventing Striga reproduction and reducing crop losses (Berner *et al.,* 1995). The combination of several Striga control methods like hand weeding and soil fertility management ought to be developed as an integrated control approach; and these two methods can further be combined for example, with intercropping, crop rotation or resistant host crops (Oswald, 2005). The major objective of these methods would be to reduce Striga densities to facilitate weeding operations and decrease the inoculum in the soil to diminish the number of emerging Striga plants in subsequent seasons.

2.3 Maize and Plant Density

Plant density refers to the number of plants growing per unit area. It has been recognized as a major factor determining the degree of competition between plants (Hashemi and Herbert, 2008). Plant density is one of the most important cultural practices determining grain yield as well as the important agronomic attributes of maize. It affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Sangoi, 2001). The recommended maize density therefore depends on the variety and environmental conditions.

For every production system, there is a population that maximizes the utilization of available resources, allowing the expression of maximum attainable grain yield at any given environment. There is no single recommendation for all conditions since optimum density varies depending on nearly all environmental factors as well as on controlled factors such as soil fertility, varietal selection, planting pattern amongst others; but maize population for maximum economic grain yield varies between 30,000 to over 90,000 plants per hectare (Sangoi, 2001). Ibeawuchi *et al.,* 2008 indicates that growing maize sole using plant spacing of 75cm x 25cm remains the best recommendation for optimum maize grain yield in the field under rainfed conditions. Water availability is an important factor affecting optimum plant density for maize grain yield under rainfed production systems. High plant density can therefore be used during the long rains when moisture is adequate. Precipitation, soil water and plant population interact, particularly during the rapid growth period of the crop from 30 cm height to silking and the final effect on yield is determined by the level of soil water available to plants at the beginning of rapid growth period, the distribution of precipitation during this period and by the amount of water transpired by the canopy (Sangoi, 2001). This therefore means that the use of high plant population under limited water supply may increase plant water stress and dramatically reduce grain yield. The use of higher plant population enables maize to intercept virtually all the available solar radiation earlier in the season transforming this energy into storage carbohydrates and other foods in more grains per area (Sangoi, 2001).

Plant density generally affects grain yield. Grain yield per unit area is the product of grain yield per plant and number of plants per unit area. At low densities, grain yield is limited by the number of plants while at higher densities it declines due to increase in the number of aborted kernels and barren stalks (Hashemi and Herbert, 2008). High plant density beyond the optimum leads to a decline in the harvest index and increased stem lodging which represents intense interplant competition for photosynthetic photon flux density, soil nutrients and soil water. This results in limited supplies of carbon and nitrogen and consequent increases in bareness and decreases in kernel number per plant and kernel size (Sangoi, 2001). There is an increase in maize grain yield with increased plant density. Muoneke *et al.,* 2007 observed that maize grain yield per unit area increased as maize planting density increased probably due to more maize cobs as maize plant population increased.

Plant density can also be manipulated in an effort to enhance weed control. In an experiment to establish the effect of crop density on weed interference in maize, Tollenaar *et al.,* 1994 observed that the competitiveness of maize with weeds can be enhanced by increasing plant density.

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research was carried out for two consecutive seasons in 2008 at Maseno University research field where Striga incidences have never been recorded and in a farmer's Striga infested field within Maseno Division; the two sites both lying within Kisumu West District of Nyanza Province, Kenya. This is within the Upper – Midland 1 agro ecological zone (G.O.K., 2006). The farmer's field was located at 00° 01.979'S and 34° 36.459'E at an altitude of 1449 m while that of the university research field was 00 00'08 S and 034 35'47 E at an altitude of 1529 m.

The area receives a bimodal mean annual rainfall of 1510 – 1678 mm with the first rains season falling between March and July and the second season falling between September and early December. The mean annual temperature ranges between 21 – 24°C with the hottest season occurring between January and April (Jaetzold *et al.*, 1982). The soils are generally classified as dystric nitisols. They vary in colour, consistency and texture. They are well drained, deep reddish brown, slightly friable clay acidic humic top soils. The moisture and temperature regimes are udic and mesic respectively (FAO/UNESCO, 1990). The gradient is generally sloppy with cases of surface runoff during periods of excess rainfall.

3.2 Experimental Method

The Striga infested field experiment for the 2008 long rains season was conducted from 24th March to 30th July 2008 while the short rains one was from 17th September 2008 to 8th January 2009. The Striga free field experiment was also conducted between 25th March to 5th August 2008 and 28th September 2008 to 15th January 2009 for the long rains and short rains seasons respectively. The experimental plots were cultivated to a fine tilth by deep ploughing and harrowing. Twenty seven (27) plots each measuring 5 m x 3 m were marked out in three blocks of nine (9) plots each with 1m paths between the blocks and 0.5 m between the plots (Appendices 5 and 6). Soil samples were then collected from each plot after tillage using a soil auger at 15 cm depth. At least nine cores per sample were taken following a "W" pattern (Fig. 1) from each experimental unit then mixed and a composite sample of 500 g obtained for Striga seed count. The experimental material (IR maize seeds) was obtained from CIMMYT while the commercial checks were obtained from input shops. 150 g of pre-plant fertilizer, Diammonium phosphate (DAP) was uniformly applied along the furrows in every experimental unit and incorporated into the soil to provide 46 kg P_2O_5 ha^{-1} and 18 kg N ha^{-1}. The maize seeds were then sown in every experimental unit as per the treatments to give five rows of maize each 5 m long per unit after which two rows of GLP2 beans were sown in the inter-row spacings of the maize at a spacing of 0.15 m. The maize and beans were planted on the same day. Weeding was then done using a hand hoe twice before Striga emergence then this was followed by hand pulling of other weeds as need arose to facilitate observation of emerged Striga. After the first weeding at about knee-height, 300 g of Calcium Ammonium Nitrate (CAN) was applied as a top-dress in every experimental unit to top up to provide 60 kg N ha^{-1}. The same management was done for both the Striga infested and Striga free fields for both the long rains and short rains seasons. The Striga infested field was under natural infestation.

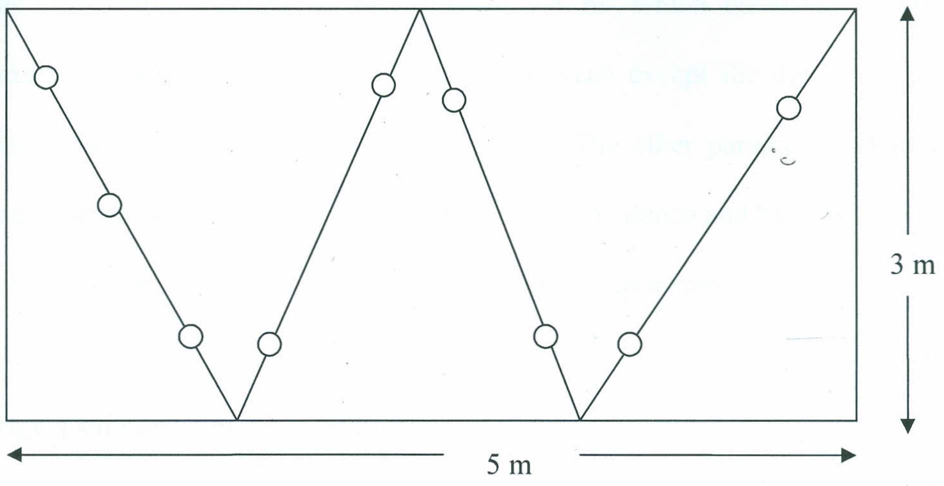

Figure 1: W – Pattern of soil sampling from a subplot

3.3 Experimental Design

The experiment was laid out as a Split Plot Design with Maize variety as the main plot factor and Plant density as the sub-plot factor with three replications (Appendices 5 and 6). Both the main plot factor and the sub-plot factor were at three levels each.

Factors:

Main plot Factor: Maize Variety

V_1 Treated Imazapyr – resistant maize

V_2 Untreated Imazapyr – resistant maize

V_3 WH505/H516 as the commercial check varieties.

N/B: WH 505 was not available in the market in short rains thus H516 was used instead as a Striga susceptible control. Both varieties are susceptible to Striga.

Sub-plot Factor: Maize Density

D_1 44,444 plants ha^{-1} (75 cm x 30 cm) as the recommended spacing for the area

D_2 66,666 plants ha^{-1} (75 cm x 20 cm)

D_3 88,888 plants ha^{-1} (75 cm x 15 cm)

3.4 Data Collection

Data was collected from the net plot area of 7.5 m^2 which consisted of three middle maize rows with four rows of beans in between except for the Striga seed count which was from the entire experimental unit. The other parameters included crop stand count, days to first Striga emergence, Striga incidence and biomass, days to crop flowering, crop biomass and crop yield and yield components.

3.4.1 Striga seed bank determination

This was done as described by Ndung'u *et al.,* 1993 whereby the samples were air dried and ground to pass through a 250 µm sieve. Striga seed numbers were determined using elutriation system of density separation, recovery and counting. A sub sample of 250g of soil was placed within an elutriator overflowing into three sieves of different mesh sizes (850, 250 and 90 µm). Tap water was then passed through the base of the elutriator to lift the lighter soil fractions within samples through a spout into the meshes. Striga seeds were captured within the 90µm mesh while coarse materials were captured within the larger mesh sieves while dispersed finer minerals were washed through the sieves. The 90 µm sample was then recovered by washing with a squeeze bottle into a 500ml glass burette column containing a potassium carbonate solution with a specific density of 1.8g cc^{-1}. Tap water was then applied to the column and Striga seeds were retained between the K_2CO_3-water interfaces. The K_2CO_3 was then drained away using a burette and the seeds drained onto a very fine (<90 µm) white nylon cloth then counted using a stereo binocular microscope. The Striga seeds were then expressed as the number per kg of soil and finally converted to per hectare basis using a soil bulk density of 1.7 g cc^{-1} at 15 cm depth.

3.4.2 Crop stand count

This was taken 14 days after crop emergence by counting the number of plants per net plot area. The crop stand count was separately determined for maize and beans.

3.4.3 Days to first striga emergence

This was determined as the number of days from crop emergence to the date of first Striga emergence in any of the 27 plots. This was determined by observing a small whitish protrusion above the ground.

3.4.4 Striga incidence and biomass

Striga incidence and biomass was determined at 8 and 10 weeks after crop emergence (WAE) by counting the number of emerged Striga plants per sample area.

For Striga biomass, all the emerged Striga plants within the sample area were then carefully uprooted during counting, placed in a paper bag and weighed using an electronic weighing balance to get the fresh weight. They were then dried in an oven at 72^{0}C until a constant weight was obtained then the dry weight was recorded.

3.4.5 Days to 50% Crop flowering

This was taken as the number of days from the date of crop emergence to the date when 50% of the plant population in the net plot had reached anthesis stage. This was done for maize and beans separately.

3.4.6 Crop biomass for maize and beans

Crop biomass was taken at 50% tassel emergence for maize and at physiological maturity for both maize and beans. It was taken as the weight of the above ground vegetative growth. Three plants were harvested destructively at the respective stages, chopped using a panga and placed in brown paper bags then weighed using a weighing balance to obtain the fresh weight. They were then dried in an oven at 72°C up to a constant weight to obtain the dry weight. This was then converted to t ha^{-1} and data transformed as in the Striga biomass transformation.

3.4.7 Yield components for maize and beans

These were determined in different ways depending on the yield component and included:

(i) The number of ears of maize which was counted as the total number of dry maize cobs from the net plot.

(ii) Kernels per ear. Five cobs per plot were randomly picked from the harvested cobs after drying. Each cob was shelled and the number of kernels counted. The average number of kernels per cob was then determined.

(iii) Maize grain yield was determined by shelling the grains from the remaining dried cobs and adding to the earlier counted kernels per plot. The total grain weight was determined using an electronic weighing balance and the moisture content obtained using a moisture meter. This was then converted to t ha^{-1}.

(iv) 100 seed weight was then obtained by randomly selecting 100 seeds from the shelled grains from the net plot and weighed using an electronic weighing balance.

(v) Bean yield. The bean pods were harvested, dried, threshed and winnowed then the dry weight and moisture content determined using an electronic balance and a moisture meter respectively.

3.5 Data Analysis

Due to the large variation in Striga seed numbers but without zero figures, the seed counts were transformed using the formula:

Striga seeds = $\mathbf{Log_{10}(X+1)}$

where **X** is the number of Striga seeds counted per kilogram of soil

Whereas the Striga biomass and incidence data which had large variations with some zeros were transformed using the formula:

Striga incidence/ Striga biomass = $\mathbf{\sqrt{(X+0.5)}}$

where **X** is the number of Striga plants m^{-2} or biomass in t ha^{-1}. (Little and Hills, 1978).

The data collected was subjected to analysis of variance (ANOVA) at 5% level of significance using the General Linear Model of SAS statistical package to test if there were significant differences between the treatments (SAS, 2003).

The means were separated using the Least Significant Difference (LSD) method at 5% probability level. Linear regression was used to compare the relationships between Striga incidence and maize biomass, Striga incidence and maize yield, Striga seed and Striga emergence and finally Striga seed and maize yield.

4.0 RESULTS

4.1 Striga infested field

4.1.1 Striga seed dynamics

The experiment was conducted in a naturally Striga infested field whose analysis indicated no significant interactions or significant differences between the varieties or planting densities on the initial Striga seed counts. The end of the first and second cropping seasons also showed no significant differences in seed counts for maize varieties (Fig. 2) and planting densities.

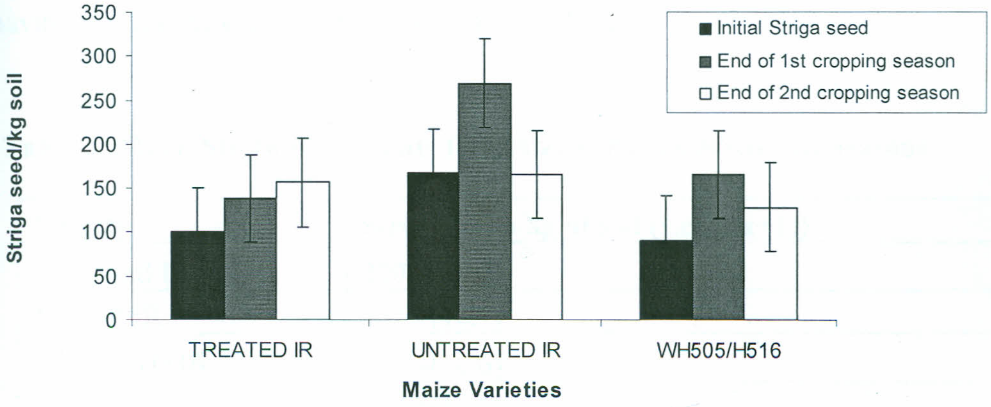

Fig. 2: Change in Striga seed bank for maize varieties over the seasons.

Across season analysis showed significant differences ($p \leq 0.056$) between the seasons with the initial seed count having significantly lower Striga seed count than the end of the second cropping season (Table 2). There was an increase then a decrease in Striga seed by the end of the last season.

Table 2: Mean Striga seed counts at different periods of the seasons

Period	Striga seeds/kg of soil ($Log_{10}(x+1)$)
End of 1st cropping season	190.8(12.7)
End of 2nd cropping season	150.2(11.9)
Before the cropping seasons	119.4(10.4)
Mean	153.5(11.7)
C.V	69.5(35.3)
$LSD_{0.05}$	58.3(2.3)

Data in brackets are transformed.

There were cross season significant differences ($p \leq 0.03$) in Striga seed counts between the maize varieties, with treated IR maize and the commercial check varieties having significantly lower Striga seed counts (Table 3).

Table 3: Mean Striga seed counts for maize varieties across the seasons

Variety	Striga seeds/kg of soil ($Log_{10}(x+1)$)
Untreated IR	200.3(13.7)
Treated IR	131.7(10.7)
WH505/H516	128.4(10.6)
Mean	153.5(11.7)
C.V	69.5(35.3)
$LSD_{0.05}$	58.3(2.3)

Data in brackets are transformed.

4.1.2 2008 Long Rains Season

4.1.2.1 Days to first Striga emergence

There was no significant interaction between maize variety and planting density on the days to first Striga emergence, however there were highly significant differences ($p<0.0001$) between maize varieties on the days to first Striga emergence from the date of crop emergence. Treated IR-maize took significantly longer time for the first Striga to emerge compared to untreated IR-maize and the commercial check. The untreated IR maize and the commercial check were not significantly different from each other (Table 4).

4.1.2.2 Striga incidence at 8 and 10 WAE

There was no significant interaction between maize variety and maize planting density on the Striga counts at 8 and 10 weeks after crop emergence (WAE) but there were highly significant differences between maize varieties and planting densities. WH505 and the untreated IR maize had significantly higher Striga incidence than the treated IR-maize (Table 4).

At 10 weeks after crop emergence (WAE), there were also no significant differences between the planting densities however, the maize varieties showed highly significant differences ($P \leq 0.0006$) with untreated IR maize and WH505 recording significantly higher counts than treated IR maize (Table 4).

In the mean cumulative Striga count from the count at 8 and 10 WAE, there was no significant interaction between maize variety and maize planting density. However, there were highly significant differences ($p \leq 0.0001$) between the maize varieties and significant differences ($p \leq 0.0428$) among the planting densities. Untreated IR maize and WH505 had significantly higher mean cumulative Striga incidence than the treated IR-maize (Table 4).

Table 4: Mean number of DTSE and Striga counts for maize varieties during 2008 LR.

Variety	DTSE	8 WAE	10 WAE	Cumulative count
		Plants m^{-2}	**($\sqrt{x+0.5}$)**	
WH 505	35.8	11.8(3.4)	41.4(6.3)	53.1(7.18)
Untreated IR	35.7	8.9(2.9)	49.9(6.9)	58.4(7.48)
Treated IR	53.7	0(0.7)	9.8(3.02)	9.8(3.03)
Mean	41.7	6.9(2.4)	33.6(5.4)	40.4(5.9)
C.V	2.3	39.5(19.3)	53.4(26.7)	48.3(23.9)
LSD$_{0.05}$	0.9471	2.7(0.5)	17.9(1.4)	19.5(1.4)

DTSE = Days to first Striga emergence from crop emergence. Data in brackets are transformed.

The highest planting density of 88,888 plants ha^{-1} had significantly higher Striga incidence than 44,444 plants ha^{-1} at 8 WAE (Table 5). The higher planting density of 88,888 plants ha^{-1} also had significantly higher mean cumulative Striga incidence than 44,444 plants ha^{-1} (Table 5).

Table 5: Mean Striga counts for maize planting densities across varieties during 2008 LR.

Density ha^{-1}	8 WAE	10 WAE	Cumulative count
	Plants m^{-2}	**($\sqrt{x+0.5}$)**	
88,888	9.6(2.8)	9.56(6.1)	54.4(6.7)
66,666	6.6(2.4)	6.56(5.4)	37.6(5.86)
44,444	4.6(2.0)	4.56(4.8)	29.3(5.1)
Mean	6.9(2.4)	33.6(5.4)	40.4(5.9)
C.V	39.5(19.3)	53.4(26.7)	48.3(23.9)
LSD$_{0.05}$	2.8(0.5)	NS	19.5(1.4)

Data in brackets are transformed.

4.1.2.3 Striga biomass at 8 and 10 WAE

For Striga biomass both at 8 and 10 WAE, there were no significant interactions between maize variety and planting density (Appendices 1c and 1e) but there were highly significant differences between maize varieties ($p<0.0001$) and ($p\leq0.049$) at 8 and 10 WAE respectively. Planting densities only had significant differences ($p\leq0.039$) at 8 WAE. WH505 had the highest Striga biomass followed by untreated IR maize while treated IR-maize had almost no Striga biomass at 8 WAE (Table 6). Treated IR maize also had the lowest Striga biomass at 10 WAE.

In the cumulative Striga biomass, there was no significant interaction between maize variety and planting density whereas there were highly significant differences ($p\leq0.0006$) between the maize varieties (Table 6). WH505 and untreated IR maize had significantly higher cumulative Striga biomass than the treated IR maize.

The highest maize density had significantly higher Striga biomass than the lowest maize density at 8 WAE (Table 7).

Table 6: Mean Striga biomass for maize varieties during 2008 LR.

Variety	**8 WAE (t ha^{-1})**	**10 WAE (t ha^{-1})**	**Cumulative biomass (t ha^{-1})**
WH 505	0.017(0.719)	0.045(0.737)	0.062(0.750)
Untreated IR	0.011(0.715)	0.041(0.736)	0.052(0.743)
Treated IR	0.000(0.707)	0.007(0.712)	0.007(0.712)
Mean	0.0094(0.713)	0.031(0.728)	0.04(0.73)
C.V	45.1(0.42)	73.2(2.1)	63.2(2.3)
LSD$_{0.05}$	0.005(0.003)	0.023(0.015)	0.03(0.02)

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

Table 7: Mean Striga biomass for maize planting densities across varieties during 2008 LR.

Density ha-1	8 WAE (t ha^{-1})	10 WAE (t ha^{-1})
88,888	0.013(0.716)	0.036(0.732)
66,666	0.009(0.713)	0.030(0.728)
44,444	0.007(0.712)	0.027(0.726)
Mean	0.0094(0.713)	0.031(0.728)
C.V	45.1(0.42)	73.2(2.1)
LSD$_{0.05}$	0.005(0.003)	NS

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

4.1.2.4 Days to maize flowering

There was no significant interaction between maize variety and planting density on the number of days from crop emergence to maize flowering. However, there were highly significant differences ($p<0.0001$) between the maize varieties with treated IR maize flowering significantly earlier than the other two varieties (Table 8).

Table 8: Mean number of days to 50% maize flowering from crop emergence during 2008 LR.

Variety	Days
WH 505	65.8
Untreated IR	65.2
Treated IR	63
Mean	64.6
C.V	1.4
LSD$_{0.05}$	0.9

4.1.2.5 Maize biomass at tasseling and at crop maturity

There were no significant interactions between maize variety and planting density on the maize biomass at the two physiological stages. However, there were highly significant differences between the maize varieties on maize biomass both at flowering ($p \leq 0.0001$) and at crop maturity ($p \leq 0.0001$). At flowering, treated IR maize had significantly higher biomass. WH505 and untreated IR maize did not differ significantly. At maturity, the three varieties all differed significantly (Table 9). The biomass accumulated by the treated IR maize at flowering alone was higher than the individual accumulated biomass of the other two varieties at maturity.

Table 9: Mean maize biomass for different varieties during 2008 LR.

	Maize biomass in t ha^{-1}	**($\sqrt{(X+0.5)}$)**
Variety	**Flowering**	**Maturity**
Treated IR	0.45(0.97)	0.61(1.05)
WH 505	0.18(0.82)	0.31(0.89)
Untreated IR	0.12(0.79)	0.15(0.80)
Mean	0.25(0.86)	0.36(0.92)
C.V	35.8(5.9)	41.3(7.98)
$LSD_{0.05}$	0.09(0.05)	0.15(0.07)

Data in brackets are transformed.

4.1.2.6 Relationship between total Striga number and maize biomass at maturity.

A regression analysis between Striga incidence and maize biomass at maturity revealed a weak negative linear relationship between the two variables with a correlation coefficient of 0.24 (Fig. 3).

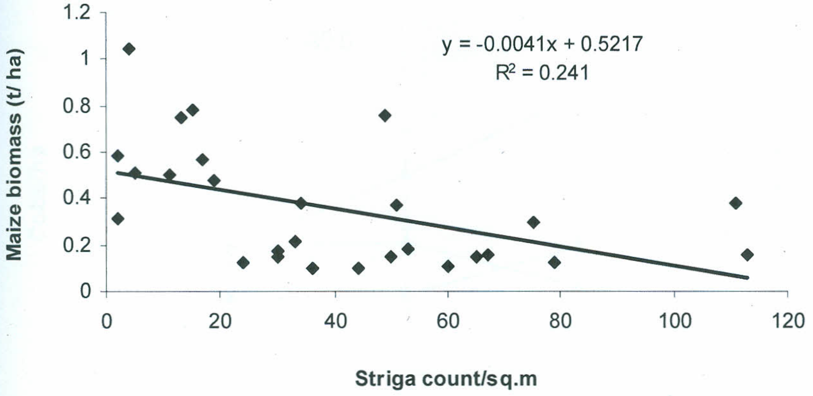

Fig. 3: Relationship between total Striga counts and maize biomass at maturity.

4.1.2.7 Bean biomass and yield

Bean biomass at maturity and bean yield was not significantly affected by maize varieties (Table 10) or maize plant density. The mean yield was 0.36 t ha^{-1}.

Table 10: Bean performance across the maize varieties in 2008 LR.

Variety	Bean biomass (t ha^{-1})	Bean yield (t ha^{-1})
WH505	0.042	0.36
Untreated IR	0.041	0.4
Treated IR	0.038	0.31
Mean	0.041	0.36
C.V	31.5	26.3
LSD$_{0.05}$	NS	NS

4.1.2.8 Maize yield and yield components

4.1.2.8.1 Number of maize cobs

There were significant interactions between maize variety and maize planting density ($p \leq 0.025$) on number of maize cobs ha^{-1}. Increasing plant density led to a steady increase in the number of cobs of treated IR maize and a decrease for WH505 (Fig. 4).

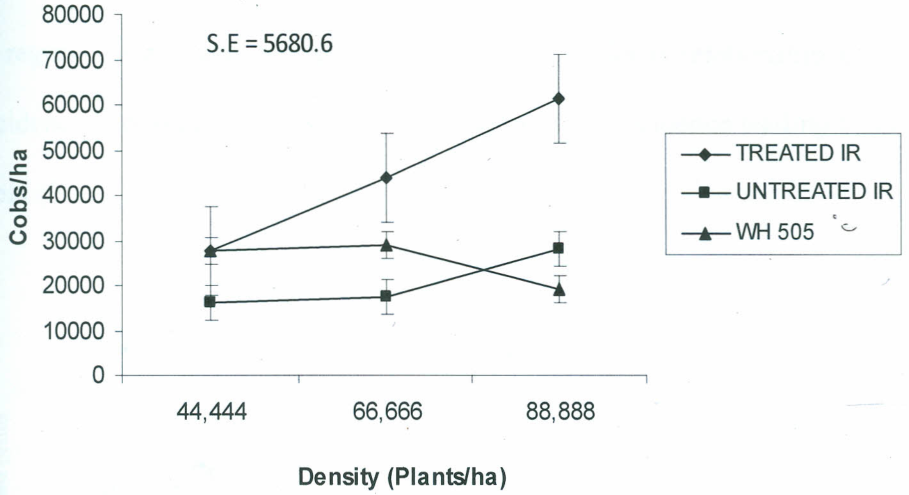

Fig. 4: Mean number of cobs of maize varieties at various plant densities

4.1.2.8.2 Maize yield

There were highly significant interactions ($p \leq 0.015$) between maize variety and plant density in the overall maize yield. Increasing plant density in treated IR maize led to increased yields while the yield of WH505 decreased with increasing plant density (Fig.5). Treated IR maize at the highest plant density had a mean yield of 3.48 t ha^{-1} while WH505 and untreated IR-maize had 0.19 t ha^{-1} and 0.45 t ha^{-1} respectively at the same density.

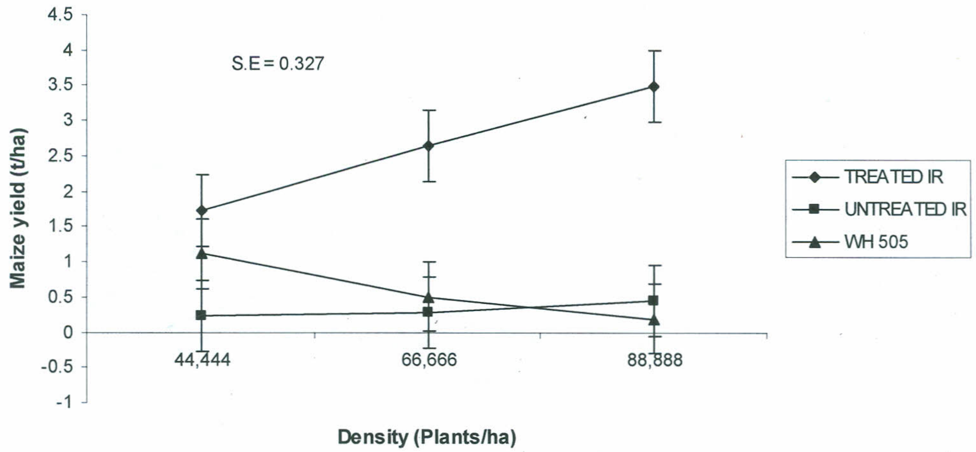

Fig. 5: Mean yield of maize varieties at various plant densities

4.1.2.8.3 Relationship between Striga number and maize yield

A regression analysis revealed a weak negative linear relationship between Striga incidence and maize yield with an increase in Striga incidence leading to a decrease in yield (Fig. 6).

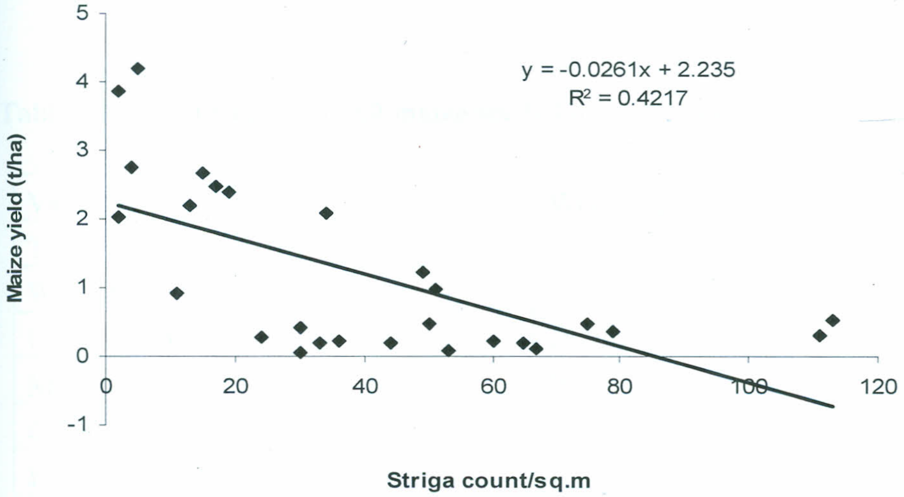

Fig. 6: Relationship between total Striga counts and maize yield.

4.1.2.8.4 Relationship between Striga seed in the soil and maize yield

A regression analysis between striga seed bank in the soil and maize yield showed that there was no relationship between the two variables with a correlation coefficient of 0.16 (Fig. 7).

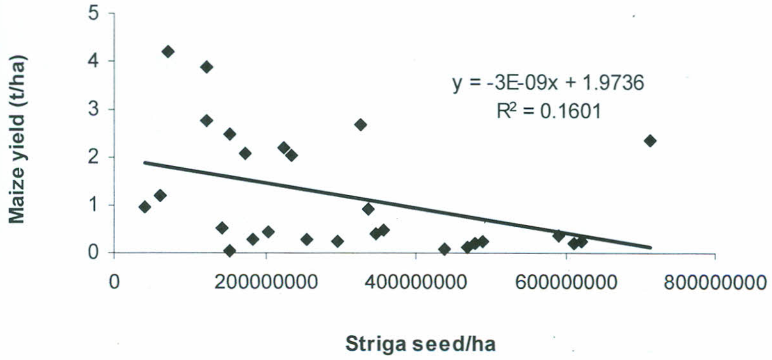

Fig. 7: Relationship between Striga seed and maize yield.

4.1.2.8.5 Maize seed weight.

There was no significant interaction between maize variety and planting density on the 100 maize seed weight. However, there were highly significant differences ($p \leq 0.0001$) between maize varieties, with treated IR maize having significantly higher mean weight than WH505 and untreated IR maize (Table 11).

Table 11: Mean weight of 100 maize seeds for maize varieties during 2008 LR.

Variety	**Weight (g)**
Treated IR	22.9
WH 505	17.9
Untreated IR	16.9
Mean	19.3
C.V	10.2
$LSD_{0.05}$	1.97

There were also significant differences ($p \leq 0.0507$) between maize planting densities with 66,666 plants ha^{-1} having significantly higher mean weight than 88,888 plants ha^{-1}. Increasing maize plant density reduced the 100 seed weight of maize (Table 12).

Table 12: Mean weight of 100 maize seeds for plant densities across varieties during 2008 LR.

Density ha-1	**Weight (g)**
66,666	20.2
44,444	19.7
88,888	17.8
Mean	19.3
C.V	10.2
$LSD_{0.05}$	1.97

4.1.2.8.6 Number of Kernels per cob

There were no significant interactions between maize variety and planting density on the number of kernels per cob. However, there were highly significant differences ($p \leq 0.0001$) between maize varieties, whereby treated IR-maize had significantly higher mean number of kernels than untreated IR-maize and WH505 (Table13).

Table 13: Mean number of kernels per cob for maize varieties during 2008 LR.

Variety	**Kernels cob^{-1}**
Treated IR	502.7
Untreated IR	223.3
WH 505	205.9
Mean	310.6
C.V	32.9
LSD$_{0.05}$	102.5

4.1.3 2008 Short Rains Season

4.1.3.1 Days to first Striga emergence

There was no significant interaction between maize variety and planting density on the days to first Striga emergence, however, there were highly significant differences ($p<0.0001$) between maize varieties in the days to first Striga emergence from the date of crop emergence. Treated IR-maize took significantly longer time for Striga to emerge compared to untreated IR-maize and the commercial check variety. The untreated IR maize and the commercial check were not significantly different from each other (Table 14).

4.1.3.2 Striga incidence at 8 and 10 WAE

There was no significant interaction between maize variety and planting density on Striga incidence at both 8 and 10 WAE. However, there were highly significant differences ($p<0.0001$) between the maize varieties both at 8 and 10 WAE with the treated IR maize having significantly lower Striga counts than untreated IR maize and the commercial check variety (Table 14). There were significant differences ($p\leq0.03$) between the planting densities in Striga incidence at 8 WAE, with 88,888 plants ha^{-1} having significantly higher incidence than the lower densities (Table 15).

Results of the cumulative total Striga counts showed no significant interactions between maize variety and planting density. However, there were significant differences between the maize varieties ($p<0.0001$) and between the maize planting densities ($p\leq0.05$), with treated IR maize and 88,888 plants ha^{-1} having significantly lower and higher total counts, respectively (Tables 14 and 15).

Table 14: Mean number of DTSE and Striga counts for maize varieties during 2008 SR.

Variety	**DTSE**	**8 WAE**	**10 WAE**	**Cumulative count**
		Plants m^{-2}	**($\sqrt{x+0.5}$)**	
H516	36.1	12.2(3.3)	23.4(4.7)	35.6(5.7)
Untreated IR	38.3	11.7(3.4)	23.3(4.9)	35.03(5.9)
Treated IR	58.8	0.2(0.8)	2.7(1.6)	2.9(1.6)
Mean	44.4	60.4(2.52)	16.48(3.7)	24.5(4.4)
C.V	7.0	55.8(28.02)	47.3(28.2)	49.3(29.4)
LSD$_{0.05}$	3.1	4.5(0.7)	7.8(1.04)	12.1(1.3)

DTSE = Days to Striga emergence from crop emergence. Data in brackets are transformed.

Table 15: Mean Striga counts for maize plant densities across varieties during 2008 SR.

Density ha^{-1}	8 WAE	10 WAE	Cumulative Total Count
	Plants m^{-2}	($\sqrt{x+0.5}$)	
88,888	11.5(3.02)	21.7(4.3)	33.2(5.2)
66,666	6.9(2.4)	14.8(3.6)	21.6(4.2)
44,444	5.7(2.2)	12.97(3.3)	18.6(3.8)
Mean	8.01(2.52)	16.48(3.7)	24.5(4.4)
C.V	55.8(28.0)	67.6(28.2)	49.3(29.4)
LSD$_{0.05}$	4.5(0.7)	NS	12.1(1.3)

Data in brackets are transformed.

4.1.3.3 Striga biomass at 8 and 10 WAE

There were no significant interactions between maize variety and planting density on Striga biomass both at 8 and 10 WAE. However, there were highly significant differences between the varieties both at 8 WAE ($p<0.0001$) and at 10 WAE ($P \leq 0.001$). Treated IR maize had significantly lower Striga biomass in both periods (Table 16). The maize planting densities only showed significant differences ($p \leq 0.03$) in Striga biomass at 8 WAE, with 88,888 plants ha^{-1} having significantly higher Striga biomass than the lower densities (Table 17).

There were also no significant interactions between maize variety and planting density in the cumulative total Striga biomass. However, there were significant differences ($p \leq 0.0007$) between the maize varieties, with treated IR maize having significantly lower Striga biomass than untreated IR maize and the commercial check variety (Table 16).

Table 16: Mean Striga biomass for maize varieties during 2008 SR.

Variety	8 WAE (t ha^{-1})	10 WAE (t ha^{-1})	Cumulative Striga biomass
H516	0.014(0.717)	0.038(0.733)	0.051(0.742)
Untreated IR	0.009(0.713)	0.032(0.730)	0.041(0.735)
Treated IR	0.00006(0.707)	0.0019(0.708)	0.0019(0.708)
Mean	0.0074(0.712)	0.024(0.724)	0.031(0.729)
C.V	67.6(0.49)	76.2(1.71)	72.2(2.1)
LSD$_{0.05}$	0.005(0.004)	0.018(0.012)	0.023(0.015)

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

Table 17: Mean Striga biomass for maize plant densities across varieties during 2008 SR.

Density ha^{-1}	8 WAE (t ha^{-1})	10 WAE (t ha^{-1})	Cumulative Striga Biomass
88,888	0.011(0.715)	0.032(0.729)	0.043(0.74)
66,666	0.0061(0.711)	0.022(0.722)	0.028(0.73)
44,444	0.0047(0.710)	0.018(0.720)	0.023(0.73)
Mean	0.0074(0.712)	0.0024(0.724)	0.031(0.729)
C.V	67.6(0.49)	76.2(1.71)	72.2(2.1)
LSD$_{0.05}$	0.005(0.004)	NS	NS

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

4.1.3.4 Bean biomass and yield

There were no significant interactions or significant differences in both bean biomass and yield. The mean bean yield was 0.65 t ha^{-1} (Table 18).

Table 19: Mean number of days to flowering of maize (DTFM), yield, cobs and kernels per cob for maize varieties during 2008 SR.

Variety	DTFM	Yield (t ha^{-1})	Cobs ha^{-1}	Kernels cob^{-1}
H516	59	1.21	47555	258.7
Treated IR	62	0.99	31852	305.4
Untreated IR	60	0.62	39407	249.6
Mean	60.4	0.94	39604.9	271.2
C.V	1.12	48.9	31.2	17.4
$LSD_{0.05}$	0.7	0.46	12347	47.2

Data in brackets are transformed.

4.2 Striga-free field

4.2.1 2008 Long Rains Season

This was a striga free field which did not have any emerged striga throughout the season.

4.2.1.1 Maize Biomass

There were no significant interactions between maize variety and planting density on maize biomass at flowering, but there were only highly significant differences ($p \leq 0.0018$) between maize varieties where WH505 had significantly higher biomass than treated IR maize and untreated IR maize (Table 20). At physiological maturity, there were no significant differences in maize biomass.

4.2.1.2 Maize yield and yield Components

There were no significant interactions between maize variety and planting density on the overall maize yield. However, there were significant differences ($p \leq 0.0035$) between the maize varieties, where WH505 had significantly higher overall yield than treated and untreated IR maize (Table 20).

In terms of the yield components, there were no significant interactions between maize variety and planting density on the number of cobs, but there were significant differences between maize varieties ($p<0.0001$) and between planting densities ($p\leq0.0028$) (Table 21). WH505 and untreated IR maize had significantly higher number of cobs than treated IR maize. Plant densities of 88,888 plants ha^{-1} and 66,666 plants ha^{-1} also gave significantly higher number of cobs than 44,444 plants ha^{-1} (Table 21). There were neither significant interactions between maize variety and planting density nor significant differences in the number of kernels per cob. There were also no significant interactions between maize variety and planting density and no significant differences between planting densities on the 100 maize seed weight. However, there were significant differences ($p\leq0.0479$) between the maize varieties, with WH505 having significantly higher mean 100 seed weight than treated and untreated IR maize (Table 20).

Table 20: Maize variety performance in the Striga-free field during 2008 LR.

Variety	Maize biomass at flowering (t ha^{-1})	Maize yield (t ha-1)	Cobs ha^{-1}	Maize 100 Seed Weight (g)
WH 505	0.84(1.15)	5.98	60296	31.15
Untreated IR	0.49(0.99)	3.70	56148	26.71
Treated IR	0.40(0.94)	2.09	30963	26.30
Mean	0.58(1.03)	3.93	49135.7	28.05
C.V	38.5(10.05)	51.9	23.2	14.9
LSD$_{0.05}$	0.22(0.1)	2.03	11413	4.19

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

biomass (Table 22). There were however no significant interactions or differences in the maize biomass at maturity.

Due to the excessive drought in the season (Appendix 9), the maize crop could not be harvested thus the maize yield and yield components were not obtained.

Table 22: Mean number of days to flowering of maize (DTFM) and maize biomass at flowering for maize varieties during 2008 SR.

Variety	DTFM	Maize Biomass (t ha^{-1})
Treated IR	68.2	0.15(0.80)
Untreated IR	67	0.24(0.86)
H516	65.1	0.29(0.89)
Mean	66.8	0.23(0.85)
C.V	1.6	29.7(4.6)
LSD$_{0.05}$	1.07	0.07(0.04)

Data in brackets are transformed using the formula $\sqrt{(X+0.5)}$.

4.2.2.2 Bean yield

The bean yield and its 100 seed weight did not differ significantly for all the sources of variation and the mean yield was 0.19 t ha^{-1} with 100 seed weight mean of 29.5 g (Table 23).

Table 23: Bean performance across the maize varieties during 2008 SR.

Variety	Bean yield (t ha^{-1})	Bean 100 seed wt (g)
Untreated IR	0.23	29.4
H516	0.18	28.6
Treated IR	0.16	29.5
Mean	0.19	29.2
C.V	39.4	4.9
LSD$_{0.05}$	NS	NS

5.0 DISCUSSION

5.1 Striga infested field

5.1.1 Striga seed dynamics

The Striga seed counts before the application of the experimental treatments showed no significant difference either in terms of how the varieties were allocated or how the plant densities were assigned. This shows that however heterogeneous the experimental field might have been, the allocation of the treatments were not biased and any differences in response of the treatments would only be attributed to the treatment effects.

The Striga seed reduction was not significant even with the treated IR maize although the Striga emergence was significantly reduced. There was an increase followed by a decline by end of 2008 SR in the Striga seed bank with all the maize varieties. This was in contrast with the findings of Odhiambo and Woomer, (2005) where Striga seed bank was significantly reduced with IR maize in 60 m^2 plots after one season. Kanampiu *et al.,* 2001 also reported that IR maize technology should be coupled with stopping the introduction of new Striga seed from off-farm sources to reduce the seed bank. Since all the emerged Striga plants were counted and uprooted and none was allowed to flower in the field, the Striga seed bank was not expected to rise. The observed rise in Striga seed bank could have been caused by heavy surface runoff which could have carried Striga seeds from the upper parts of the field outside the experimental area. The rise was however small in the treated IR maize indicating that if the probable external source of Striga seed from surface runoff could have been uniform for all the maize varieties, then the Striga seed in the surface runoff to treated IR maize was controlled by the herbicide coating. The plot sizes were relatively small (5 m x 3 m); and given the small size of Striga seeds and mode of dispersal (Berner *et* *al.,* 1995), the movement of Striga seeds could have been significant to infest neighboring plots. The technology may also require several seasons to realize significant Striga seed reduction especially in the midst of heavy Striga infestation. The observed rise in Striga seed could also have been due to sampling errors probably at the end of the first season; since it rose then went back to its initial level.

The decline by the end of 2008 SR could however be justified by the fact that apart from the expected reduction from the herbicide effects of treated IR maize and suicidal germination caused by beans, the emerged Striga plants were also uprooted during the season before flowering and none was allowed to set seeds.

5.1.2 Days to first Striga emergence

The results suggest that there was suppression of Striga emergence from the treated IR maize due to the herbicide coating on the seeds resulting in late emergence for the treated IR maize. Treated IR maize therefore reduced Striga emergence in both seasons and delayed the time to emergence thus delaying the attachment of the parasitic Striga onto the maize. This was in contrast to the WH505, H516 or the untreated IR-maize, which did not have the protection, thus the Striga was able to attach early. This was in agreement with the observations of Abayo *et al*., (1998), which indicated that imazapyr coating delays Striga attachment and emergence. The early Striga attachments lead to more effects on the host crop which translates to crop yield effects as reported by Vanlauwe *et al.,* 2008. This was also supported by the findings of De Groote *et al.,* 2007 and Kanampiu *et al.,* 2001. The delayed emergence is an indication of late attachments thus protection of the crop from Striga parasitism during the critical initial growth period of the crop. The late attachments are attributed to a likely decrease in herbicide activity with time due to dilution by infiltrating rainfall and adsorption of the herbicide to the soil matrix (Pusino *et al.,* 1997) and given that a very low dosage (30 g ha^{-1}) of the herbicide is used compared to the 600 g ha^{-1} used for the commercial product. The unprotected maize had Striga emerging within 35 to 38 days after crop emergence for both seasons while the protected maize had no Striga for 53 to 58 days after crop emergence, thus the parasitic relationship starts quite early in the unprotected maize, exerting a lot of pressure on the crop and subsequently impacting negatively on its growth and performance. Early Striga attachments have more effects on maize yield compared to late attachments as reported by Vanlauwe *et al*., 2008. De Groote *et al.,* 2008 also indicated that a Striga plant that emerged after six weeks had a larger impact on yield reduction than one that emerged two weeks later.

5.1.3 Striga counts and biomass

In 2008 LR season at 8 weeks after crop emergence, the unprotected maize varieties had the highest Striga counts while the treated IR maize had no Striga. A similar trend was repeated in the 2008 SR season although treated IR maize had a mean count of 0.2. This shows that the imazapyr coating on the IR-maize killed or controlled Striga thus made the maize to be free from Striga parasitism especially during the critical growth period. This is in agreement with the findings of Kanampiu *et al.,* 2002 which indicated that herbicide resistance by maize permits the application of relatively small amounts of imazapyr to maize seeds that in turn provides several weeks' chemical protection from parasitic Striga.

The highest plant density also had the highest mean count of 9.6 Striga plants m^{-2} at 8 WAE in the 2008 LR season and 11.5 Striga plants m^{-2} in the SR season, while the lowest planting density had the lowest mean count of 4.6 Striga plants m^{-2} in the LR season and 5.7 Striga plants m^{-2} in the SR season. This could be attributed to the higher root surface area in the high density planting which led to high amounts of Striga germination stimulant exuded from the host roots. This is supported by Babalola and Odhiambo, (2007), who reported a linear trend of increasing Striga counts with increasing maize density. The high germination stimulant and the presence of a suitable host increase the chances of Striga germination and attachment as reported by Berner *et al*., 1995. This therefore explains the higher Striga incidence in high maize plant density.

The trend observed in the Striga incidence at 8 weeks after crop emergence was similar to that of the Striga biomass where WH505 and H516 had the highest Striga biomass and treated IR maize having 0 – 0.00006 t ha^{-1} of biomass. The WH505, H516 and the untreated IR-maize were susceptible to Striga parasitism thus after attachment, the Striga became a metabolic sink for the carbohydrates produced in the host (Ramaiah *et al*., 1983) and consequently led to high Striga biomass accumulation. The highest plant density had the highest Striga biomass and the lowest density also had the lowest Striga biomass. The high crop density with a high host root surface area led to high amount of Striga seed germination thus higher Striga incidence and subsequently higher biomass.

At 10 weeks after crop emergence for the two seasons, the unprotected maize varieties still had the highest Striga count while treated IR maize had the lowest count. The cumulative Striga counts for treated IR maize was 9.8% and 2.9% of the total emerged Striga for the three varieties for 2008 LR and 2008 SR, respectively while for the commercial check varieties, it ranged between 43.8 – 48.4%. The incidence at 10 WAE shows that despite the herbicide coating on treated IR-maize, Striga emergence under IR maize is not totally prevented since the activity of the herbicide coating is likely to be decreasing in time due to dilution of the herbicide around the seed by infiltrating rainfall and adsorption of the herbicide to the soil matrix (Pusino *et al.,* 1997). The low herbicide dosage of 30 g ha^{-1} is however capable of protecting the IR maize during the critical stage of Striga parasitism and Striga is therefore able to emerge from treated IR-maize later in the season with minimal if any parasitic effect. The trend of Striga counts was reflected in the Striga biomass with the unprotected maize varieties having higher Striga biomass.

The Striga counts were however low in the second season compared to the first season (Appendix 8) despite the fact that there was an insignificant rise in Striga seed bank. Increased Striga seed does not necessarily result in increased Striga emergence as no relationship existed between the two (Appendix 7). The high amount of Striga seeds can remain viable in the soil for up to 14 years and only a fraction of these seeds germinate in any season in the presence of a susceptible host (Berner *et al.,* 1995). Striga emergence therefore not only depends on the presence of viable seeds but also on the susceptible host and a successful Striga conditioning process. The low Striga counts in the short rains could have been attributed to drought situation which prevailed in the short rains season (Appendix 9), since optimum water availability during conditioning is necessary to enhance maximum germination of *Striga hermonthica* seeds and increasing water stress strongly suppresses germination of the seeds (Dzomeku and Murdoch, 2007). The low Striga counts in the short rains is not unique as reported by Odhiambo and Woomer, (2005).

5.1.4 Days to maize flowering

The number of days from crop emergence to maize flowering was only affected by the maize varieties. The treated IR maize took significantly shorter time to flower in the long rains. This could be attributed to its faster and efficient growth; free from Striga parasitism as opposed to the untreated IR maize and the local check variety coupled with adequate moisture. The growth rates of the untreated IR maize and the local check variety were negatively affected by Striga parasitism leading to slower growth rate thus longer vegetative phase. There was therefore poor performance of treated IR maize under inadequate rainfall in the short rains season.

5.1.5 Maize biomass

In the 2008 LR season, maize biomass accumulation was affected by maize variety whereby the treated IR-maize accumulated more dry matter than the untreated IR-maize and the WH505. The amount of dry matter accumulated by the treated IR-maize at flowering (0.45 t ha^{-1}) was higher than the combined dry matter of the other two varieties at maturity (0.44 t ha^{-1}). The low dry matter accumulation in the untreated IR-maize and WH505 was attributed to the effect of Striga parasitism on these two susceptible varieties which had high Striga counts compared to the treated IR-maize. Due to the high number of emerged Striga plants in the two unprotected varieties, there was high level of parasitism leading to diversion of nutrients to the parasite thus less biomass accumulation. The parasitic Striga predisposes the host to photo-inhibition or photo-damage during periods of high irradiances thereby lowering the ability of the host to fix carbon especially due to Striga-induced stomatal closure (Gurney *et al.,* 2000). On the other hand, the treated IR-maize got protection from the herbicide coating to the extent that there was no Striga incidence at 8 weeks after crop emergence. This is supported by the report of Kanampiu *et al.,* 2002, which indicated that the herbicide coating on IR maize provides several weeks' chemical protection from the parasitic Striga. The increased Striga incidence from the unprotected maize varieties led to a heavy parasitic association with the maize thus leading to a decline in maize biomass.

This trend of biomass accumulation was however not observed in the 2008 SR season. Whereas the differences in biomass accumulation in the long rains season were majorly attributed to Striga parasitism, this might not have had significant effects in the second season owing to the low Striga counts observed in the short rains (Appendix 8). The low Striga counts in the short rains did not cause a serious parasitic relationship with the susceptible hosts. This therefore led to reduced negative effects on the susceptible maize hosts. The Striga effect was therefore less adverse in the short rains than the long rains season.

5.1.6 Maize yield and yield components

Maize yield was affected by maize variety in the 2008 LR season with treated IR-maize having the highest mean yield of 2.6 t ha^{-1}. This represented an increase of 2.3 t ha^{-1} (766%) above the untreated IR-maize and 2.0 t ha^{-1} (333%) above the WH505. From the result of the Striga incidence, it could be observed that there was no massive Striga infestation of the treated IR-maize during the critical growth period before flowering as compared to the untreated IR-maize and the WH505. Therefore, the massive Striga infestation in the untreated IR-maize and WH505 led to serious competition thus reduced yields. These results showed that the coating of IR-maize with imazapyr delays and suppresses the development of Striga especially in the early stages of crop growth as had been observed by De Groote *et al*., 2007, thus leading to a dramatic increase in yields. Early Striga attachments have severe effects on grain yield as reported by Gurney *et al.,* 2000; therefore if Striga attachment is delayed then the effect on grain yield is significantly reduced. The Striga also influences the physiology of the host resulting in lower grain and biomass accumulation, alters resource allocation and an impairment of host photosynthesis. This was slightly reflected in the weak negative linear relationship observed between Striga incidence and maize yield. Although the treated IR-maize had a few emerged Striga plants at 10 weeks after crop emergence, they seemed to be late attachments with little effects on the yield. This is in agreement with the report of Kanampiu *et al*., (2001), which indicated that the treated IR maize had only a few late attachments with parasite emergence which had little effect on the crop.

The trend of maize yield in the 2008 LR season was however not observed in the short rains season where the Striga susceptible control H516 gave the highest yield of 1.21 t ha^{-1} although this was statistically similar to the yield of treated IR maize. The improved performance of H516 compared to treated IR maize could be attributed to the low Striga emergence in the short rains coupled with low rainfall. This led to reduced Striga parasitic effects on the susceptible hosts as evidenced even by the non significant differences in maize biomass accumulation. Due to the low genetic potential of IR maize (Vanlauwe *et al*., 2008), and under reduced Striga parasitism, IR maize could not rival H516 in yield.

Increasing plant density led to a yield increase in treated IR-maize and a decrease in WH505. The major factor affecting maize yield here was Striga infestation, thus with the suppression of Striga from the herbicide coating in the treated IR-maize, there was bound to be an increase in yield. The highest mean yield was therefore obtained from treated IR-maize at 88,888 plants ha^{-1} indicating that with treated IR-maize under

Striga infested fields, 88,888 plants ha^{-1} is optimal. Increasing plant density in untreated IR-maize and WH505 led to more parasitic effects from increased Striga incidences resulting from high root surface area thus more Striga germination. This subsequently led to a substantial yield reduction. This could be supported by the report of Babalola and Odhiambo, (2007) which indicated that increasing plant density increases the proportion of plants without ears due to plant competition for nutrients and available resources.

The results of the number of maize cobs for the long rains season showed that treated IR-maize had significantly higher number of cobs than the untreated IR-maize and WH505. Striga parasitism can be so severe to the extent of no cob formation (Gurney *et al.,* 2000), thus with the treated IR-maize being protected from Striga parasitism, most if not all plants had higher chances of producing a cob. This enabled treated IR maize to have more cobs than the unprotected varieties, which experienced higher Striga infestation and even had cases of plants without ears thus effectively reducing their number of cobs. Higher plant population gave the highest number of cobs. This would be expected due to the number of plants per unit area. Increasing planting density for treated IR-maize led to a substantial increase in the number of cobs while for the unprotected varieties, it led to a decrease in the number of cobs. The increased Striga parasitism in the susceptible varieties at higher plant densities therefore led to serious negative effects on cob formation and development. The number of cobs in the short rains was higher in H516 and low in treated IR maize due to reduced Striga effects, moisture stress and differences in genetic potential of the varieties.

The results of the 100 seed weights in 2008 LR showed that treated IR-maize had the highest mean weight of 100 seeds. This could be attributed to lack of competition from Striga since the herbicide coating provided protection to the plants resulting in near complete hindrance to Striga parasitism. This subsequently led to increased assimilate supply to the treated IR-maize and as a consequence proper grain filling. This was in contrast to untreated IR-maize and the WH505 which were susceptible to Striga parasitism therefore the assimilates which could have contributed to proper grain filling were diverted to the parasitic plants. The short rains season did not show significant differences in the 100 seed weight due to reduced Striga incidence which would have otherwise given treated IR maize an advantage over the unprotected varieties. The effect of the reduced precipitation in the SR also led to reduced mean weights.

The results of the long rains season showed that higher planting density resulted into lower 100 seed weight. This could be attributed to intense interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water (Sangoi, 2001), resulting in limited supply of carbon and nitrogen and a consequent decrease in kernel size. Under high plant density, there may be limitations in the capacity for endosperm growth either by the number, size or activity of endosperm cells. This is due to the fact that final kernel mass depends on the number of cells and starch granules formed particularly in the endosperm tissue. The non significant results in the short rains season indicated that the drought affected the maize plant development to the extent that genetic differences could not be expressed especially for kernel development which required adequate moisture during the grain filling stage.

The number of kernels per cob in the long rains season indicated that treated IR-maize had significantly higher mean than the untreated IR-maize and the WH505. This was a reflection of the effect of Striga parasitism, evident in the two susceptible varieties with lower number of kernels per cob. The competition for assimilate supply posed by the Striga led to insufficient supply to the maize crop thus reduced kernel formation. However in the short rains, H516 was statistically similar to treated IR maize in the number of kernels owing to the fact that the H516 was not much affected by Striga due to drought.

5.1.7 Bean Biomass and yield

There were no significant differences in bean biomass or bean yield due to maize variety or maize crop density for the two seasons. This shows that this Striga control technology is compatible with cereal-legume intercropping. Cereal-legume intercropping system is almost synonymous with tropical developing countries (Tsubo *et al.,* 2003). The herbicide coating on the IR-maize does not pose any danger to the intercropped beans since the yield of beans from the treated IR-maize does not differ from the beans from the other maize intercrops. The differences in either the maize varieties or the maize planting density does not affect the bean performance thus intercropping two rows of beans between two maize rows even at higher maize density does not affect beans and is favourable. The IR-maize is therefore suitable for the Striga endemic regions of Kenya where intercropping maize and beans is the most common cropping system (Odhiambo and Ariga, 2001).

5.2 The Striga free field

5.2.1 Days to maize flowering

There were neither significant interactions nor differences in the number of days from crop emergence to maize flowering in the long rains. The long rains season was characterized by adequate rains and given the absence of Striga in this field; there was no comparative advantage between the maize varieties; as opposed to the short rains where IR maize took significantly longer time to flower. The longer vegetative growth could have been attributed to the effect of drought and apparent low genetic potential of the IR maize in the absence of Striga compared to the local check variety.

5.2.2 Maize biomass

The significant differences in maize biomass at flowering in the long rains season could be attributed to the inherent genetic composition of the varieties. As had been reported by Vanlauwe *et al.,* (2008), the yield potential of IR maize is likely not exceeding that of the locally available varieties. Therefore with similar environmental conditions, the genetic differences determine output, thus WH505 would have a higher potential over IR maize with regard to carbohydrate partitioning and dry matter accumulation. The same trend was also observed in the short rains with H516 apparently having a higher genetic potential than the IR maize thus accumulating more biomass.

5.2.3 Maize yield and yield components

The significant differences in maize yield could still be attributed to their genetic potential. The WH505 performed better than the imazapyr-resistant maize in the long rains. The imazapyr coating which makes the difference between treated and untreated IR maize only protects the maize from Striga parasitism (Kanampiu *et al.,* 2001), thus in the absence of Striga, their genetic potential is the same. The maize yield data could however not be obtained in the short rains season due to the extended drought but from the maize biomass accumulation results, H516 could have performed better due to the apparent high genetic potential.

In terms of the number of cobs, the differences were attributed to varietal genetic differences. The highest plant density had the highest number of plants per unit area which translated to the number of cobs if other factors were not limiting. This is in agreement with Muoneke *et al.,* 2007 who observed that maize grain yield per unit area increased as maize planting density increased probably due to more maize cobs from increased maize population. The number of kernels per cob however did not show significant differences. This indicated that 88,888 plants ha^{-1} was still optimum if other factors are not limiting since beyond the optimum density, there would be an increase in the number of aborted kernels and barren stalks (Hashemi and Herbert, 2008). The maize 100 seed weight which is a reflection of carbohydrate partitioning showed significant differences attributed to maize variety only which was still an indication of varietal differences due to difference in genetic potential.

5.2.4 Bean performance

The non significant differences observed in the bean performance indicated that the maize varieties or the maize planting density do not affect the bean performance. Intercropping two rows of beans between two maize rows spaced 75 cm apart even at higher maize density of 88,888 plants ha^{-1} does not affect beans and is favourable.

6.0 CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusions

The effect of IR maize plant density on Striga seed reduction was not observed since the Striga seed numbers were not affected. This was due to the plot sizes which could not adequately withstand invasion of Striga seeds from the other plots or outside the experimental area given that the field was generally infested with Striga.

The results of the research have however clearly indicated that treated IR maize is able to overcome Striga parasitism under Striga infested fields with few if any emerged Striga plants. The Striga incidences are rare especially during the critical vegetative growth period with few if any late Striga attachments with little or no parasitic effects. Higher maize plant density has higher Striga incidences but these can be hand pulled to prevent reseeding. Under Striga free conditions, the use of high potential maize varieties should be upheld.

The treated IR maize yields higher with increased plant density as opposed to the Striga susceptible varieties which will decrease in yield. The treated IR maize performs best at a high plant population of 88,888 plants ha^{-1}. This can be intercropped with two rows of beans with the maize rows spaced at 75 cm. Maize-bean intercropping thus works out even at high plant density translating into increased returns per unit area. The positive attributes of IR maize are made possible by adequate rainfall without which the treated IR maize is not capable of attaining its full potential.

6.2 Limitations

- The plot sizes were small amidst a naturally Striga infested field thus could not withstand Striga seed invasion from adjacent plots/fields. This coupled with surface runoff could have affected the seed dynamics. The plots were also varied in seed counts since the experiment was conducted under natural Striga infestation.

- The rainfall data could only be obtained from Maseno veterinary farm which was the nearest weather station from the experimental sites. This might not have reflected well the rainfall received at the Striga infested field (Lela) which was about 3 km from the weather station.

- The low Striga counts in the short rains hampered the observation of Striga effects even on the susceptible check variety.

- The drought situation in the short rains season affected the Striga free field to the extent that the crop did not reach maturity. The maize yield components were therefore not obtained.

6.3 Recommendations

- There is need to artificially infest the experimental plots with Striga seeds to have uniformity at the start of the experiment. The IR maize technology should be combined with other cultural Striga eradication practices like weeding and prevention of introduction of new Striga seeds to reduce the seed bank.

- Higher maize planting density should be used then any emerging Striga should be uprooted and not allowed to flower in the field to prevent reseeding.

- Treated IR maize should be planted in Striga infested fields at a spacing of 75cm x 15cm giving a maize plant population of 88,888 plants ha^{-1}. The returns from the field can be improved by intercropping two rows of beans 15 cm away from the maize rows spaced at 45 cm x 15 cm. This gives better maize yields without affecting the bean intercrop. Under Striga free environments, IR maize should be avoided and use of high potential maize varieties should be upheld.

6.4 Suggestions for further research

The effect of treated IR maize on Striga seed bank could be better studied using larger plot sizes that would not be unduly influenced by foreign Striga seeds from adjacent plots or fields.

Further research should be done to improve the yield potential of IR maize to make it comparable to other maize varieties even under Striga free conditions. This could focus on increasing the kernel size and number of cobs per plant.

REFERENCES

AATF, 2006. Empowering African Farmers to eradicate Striga from maize croplands. The African Agricultural Technology Foundation. Nairobi, Kenya.

Abayo, G.O., English, T., Eplee, R.E., Kanampiu, F.K., Ransom, J.K., and Gressel, J., 1998. Control of Parasitic witchweeds (*Striga* Spp.) On corn (*Zea mays*) resistant to acetolactate synthase inhibitors. *Weed Science* **46:** 459 – 466.

Acland, J.D., 1971. East African Crops. Longman Group Limited. London

Babalola, O.O., and Odhiambo, G.D., 2007. *Klebsiella oxytoca* '10*mkr*7' stimulates *Striga* suicidal germination in *Zea mays*. *Journal of Tropical Microbiology and Biotechnology* **2:** 13-19.

Berner, D.K., Kling, J.G., and Singh, B.B., 1995. Striga Research and Control; a perspective from Africa. *Plant Disease* **79(7):** 652 – 659.

CIMMYT, 2008. Striga Weed control with herbicide-coated maize seed from <http://www.Cimmyt.org/Research/maize/results/control.pdf> accessed on 28/02/2008

De Groote, H. Wangare, L. and Kanampiu, F., 2007. Evaluating the use of herbicide-coated imidazolinone-resistant (IR) maize seeds to control *Striga* in farmers' fields in Kenya. *Crop Protection* **26,** 1496-1506.

De Groote, H. Wangare, L. and Kanampiu, F., 2002. Potential impact of herbicide resistant maize for striga control in Kenya. Presented to the Herbicide-coated IR maize Promotional Workshop, Imperial Hotel, Kisumu, Kenya, 4-6 July 2002. CIMMYT, Nairobi.

Dzomeku, I.K., and Murdoch, A.J., 2007. Effects of prolonged conditioning on Dormancy and Germination of *Striga hermonthica*. *Journal of Agronomy* **6(1)**: 29-36.

FAO/UNESCO, 1990. Soil Classification Map. United States Department of Agriculture.

Frost, H., 1995. *Striga hermonthica* surveys in Western Kenya. In: Brighton Crop Protection Conference – Weeds – 1995, Brighton. Pp. 145-150.

G.O.K., 2006. Kisumu District, Ministry of Agriculture Annual Report.

Gebrekidan, B., Wafula B.M., and Njoroge K., 1992. Agro ecological Zoning in relation to maize research priorities in Kenya. In: KARI Proceedings of a workshop, Review of the National Maize Research Program, KARI/ISNAR Management Training Linkage Project. 1990.

Gurney, A.L., Adcock, M., Scholes, J.D., and Press, M.C., 2000. Physiological processes during Striga Infestation in maize and sorghum. In: Haussmann, B.I.G., Hess D.E., Koyama M.L., Grivet L., Rattunde H.F.W and Geiger H.H. (Eds), 2000. Breeding for striga resistance in cereals. Proceedings of a workshop held at IITA, Ibadan Nigeria, from 18-20 August 1999. Margraf Verlag, Weikersheim, Germany. Pp 3-17.

Hashemi, M. and Herbert S., 2008. Response of Corn to plant Density. <http://www.umass.edu/cdl/Researchpubs/a-corndensity-02.htm> accessed on 01/04/2008.

Hassan, R., Ransom, J.K. and Ojiem, J.O., 1995. The spatial distribution and farmers strategies to control striga in corn: survey results from Kenya. In: Jewell, D.C., Waddington, S., Ransom, J.K., Pixley, K., (Eds.), Proceedings of the fourth Eastern and Southern Africa Regional corn conference. CIMMYT, Harare, Zimbabwe, Pp. 250-254.

Hassan, R.M., 1988. Maize technology development and transfer: A GIS application for research planning in Kenya. CAB International/CIMMYT/KARI, Wallingford, U.K.

Heyer J., Maitha J.K., and Senga W.M., 1976. Agricultural Development in Kenya. An economic assessment. Oxford University Press. Nairobi.

Ibeawuchi, I.I., Mathews-Njoku, E., Ofor, M.O., Anyanwu, C.P. and Onyia, V.N., 2008. Plant spacing, Dry Matter Accumulation and Yield of Local and Improved Maize Cultivars (Abstr.). *The Journal of American Science* **4(1)**: 11-19.

Jaetzold, R. and Schimidt, H., 1982. Farm Management Handbook of Kenya Vol. 2. Ministry of Agriculture, Kenya.

Kabambe V.H., Kanampiu F., Nambuzi S.C., and Kauwa A.E., 2007. Evaluation of the use of herbicide (imazapyr) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi. *African Journal of Agricultural Research* **2(12)**: 687-691.

Kanampiu, F.K., Ransom, J.K., and Gressel, J., 2001. Imazapyr seed dressings for Striga control on acetolactate synthase target-site resistant maize. *Crop Protection* **20,** 885-895.

Kanampiu, F.K., Ransom, J.K., Friesen, D., and Gressel J., 2002. Imazapyr and Pyrithiobac movement in soil and from maize seed coats to control striga in legume intercropping. *Crop Protection* **21,** 611-619.

Kantor, S., 1999. Intercropping. Washington State University Co-operative Extension, King Country.

Khan, Z.R., Hassanali, A., Overholt W., Khamis T.M., Hooper A.M., Picket J.A., Wadhams L.J., and Woodcock C.M., 2002. Control of witchweed *Striga hermonthica* by intercropping with *Desmodium* spp., and the mechanism defined as allelopathic. *Journal of Chemical Ecology* **28(9):** 1871 – 1885.

Khan, Z.R, Midega, C.A.O., Hassanali, A., Pickett, J.A. and Wadhams L.J., 2007. Assessment of Different Legumes for the control of *Striga hermonthica* in Maize and Sorghum (Abstr.) *Crop Science* **47:** 730-734.

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

Little, T.M. and Hills, F.J., 1978. Agricultural Experimentation Design and Analysis. John Wiley and Sons, 605 Third Avenue, New York, N.Y. 10016.

Mahendra, P., Deka, J. and Rai, R.K., 1996. Fundamentals of Cereal Crop Production. Tata McGraw-Hill Publishing Company Limited. New Delhi.

Matusova, R., Rani, K., Verstappen, F.W.A., Franssen, M., Beale, M.H. and Bouwmeester, H.J., 2005. The Strigolactone Germination Stimulants of the Plant – Parasitic Striga and Orobanche spp. Are Derived from the Carotenoid Pathway. *Plant Physiology* **139(2):** 920 – 934.

Muoneke, C.O., Ogwuche M.A.O. and Kalu, B.A., 2007. Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agro ecosystem. *African Journal of Agricultural Research* **2(12):** 667-677.

Mwania, N.M., Shiluli, M.C. and Kamidi, M.K., 1989. Towards appropriate agronomic recommendations for small-holder maize production in the highlands of Western Kenya. In: Gebrekidan, B. (Ed). Maize improvement, production and protection in Eastern and Southern Africa. Proceedings of the Third Eastern and Southern Africa Regional Maize workshop, Nairobi and Kitale, Kenya, Sept 18-22, 1989, pp 321-337.

Ndung'u, D., Odhiambo, G.D. and Ransom, J.K., 1993. Methodology for quantifying Striga seed numbers in soils of East Africa. In: African Crop Science Conference Proceedings, Kampala, Uganda, pp. 220-221.

Nekesa, P., Maritim, H.K., Okalebo, J.R and Woomer, P.L., 1999. Economic analysis of maize-bean production using a soil fertility replenishment product (prep-pac) in Western Kenya. *African crop Science Journal* **7(4):** 585-590.

Odendo, M., De Groote, H., and Odongo, O.M., 2001. Assessment of Farmers' Preferences and constraints to maize Production in the moist mid-altitude zone of Western Kenya. In: ACSA (Ed.), African Crop Science Conference Proceedings. African crop science Association, Kampala, Uganda, Pp. 769-775.

Odhiambo, G.D. and Ariga E.S., 2001. Effect of Intercropping maize and beans on Striga incidence and grain yield. Seventh Eastern and Southern Africa Regional Maize Conference 11th – 15th February, 2001. Pp. 183-186.

Odhiambo, G.D. and Ransom, J.K., 1993. Effect of dicamba on the control of *Striga hermonthica* in corn in Western Kenya. *African crop science Journal* **1:** 105-110

Odhiambo, G. and Woomer, P.L., 2005. Striga emergence and seed bank dynamics under different maize management practices in Western Kenya. In: Tenywa, J.S., Adipala E., Nampala, P., Tusiime, G., Okori P. and Kyamuhangire, W. (Eds.). African Crop Science Conference Proceedings, Kampala, Uganda. Vol. 7 pp. 473-477.

Oseko, J.K., 2007. Performance of African Indigenous Vegetables under sole and intercropping Systems: A case of African Kale (*Brassica carinata*). Msc. Thesis. Maseno University, Kenya.

Oswald, A., 2005. Striga Control – technologies and their dissemination. *Crop Protection* **24,** 333-342.

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

Pusino, A., Petretto, S., and Gessa, C., 1997. Adsorption and desorption of imazapyr by soil. *Journal of Agriculture and Food chemistry* **45,** 1012-1016.

Ramaiah, K.V., Parker, C., Vasudeva Rao, M.J., and Musselman, L.J., 1983. Striga identification and control handbook. Information Bulletin No. 15. Patancheru, A.P., India: International crops Research Institute for the Semi – Arid Tropics.

Sangoi, L., 2001. Understanding plant density effects on maize growth and development: an important issue to maximize grain yield. *Cienc. Rural* **31(1)**

SAS, 2003. *SAS/STAT User's guide,Release 9.1. Cary, NC,* Cary, NC.

Sato, D., Awad, A.A., Takeuchi, Y., and Yoneyama K., 2005. Confirmation and Quantification of Strigolactones, Germination Stimulants for Root Parasitic Plants Striga and Orobanche, produced by Cotton. *Biosci. Biotechnol. Biochem* **69(1):** 98-102.

Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Giller, K.E., 2005. Estimating yields of tropical maize genotypes from non-destructive, on-farm plant morphological measurements. *Agriculture, Ecosystems and Environment* **105:** 213-220.

Tollenaar, M., Dibo, A.A., Aguilara,A., Weise, S.F. and Swanton, C.J., 1994. Effect of crop density on Weed Interference in Maize (Abstr.) *Agronomy Journal* **86:** 591-595.

Tsubo, M., Mukhala, E., Ogindo, H.O. and Walker, S. 2003. Productivity of mazie-bean intercropping in a semi arid region of South Africa. *Water S.A.* **28(4):** 381-388.

Tsubo, M., Walker, S., and Ogindo, H.O., 2005. A simulation model for cereal – legume intercropping systems for semi-arid regions. I. Model development. *Field Crops Research* **93:**10-22.

Tu, 2004. Weed Control Methods Handbook, The Nature Conservancy from <http://tncweeds.ucdavis.edu> accessed on 28/02/2008.

Tumwesigye, K.E. and Musiitwa, F., 2001. Characterizing drought patterns for appropriate development and transfer of drought resistant maize cultivars in Uganda. In: Proceedings of the Seventh Eastern and Southern Africa Regional Maize Conference, 11th – 15th February 2001, pp 260 – 262.

Ullah, A., Bhatti, M.A., Gurmani, Z.A. and Imran, M., 2007. Studies on planting patterns of maize (*Zea mays L.*) facilitating legumes intercropping. *Journal of Agricultural Research* **45(2):** 113-118.

USDA 2008. Nutrient database from
(http://www.nal.usda.gov/fnic/foodcomp/search/) accessed on 26/02/2008.

Vanlauwe, B., Kanampiu, F., Odhiambo, G.D., De Groote, H., Wadhams, L.J. and Khan, Z.R., 2008. Integrated management of *Striga hermonthica*, stemborers and declining soil fertility in Western Kenya. *Field Crops Research* **107:**102-115.

Wikipedia, 2008a. Sweet corn from Wikipedia, the free encyclopedia.
http://en.wikipedia.org/wiki/sweetcorn accessed on 01/04/2008.

Wikipedia, 2008b. Maize from Wikipedia, the free encyclopedia.
http://en.wikipedia.org/wiki/maize accessed on 26/02/2008

Wikipedia, 2008c. Intercropping from Wikipedia, the free encyclopedia.
http://en.wikipedia.org/wiki/intercropping accessed on 01/04/2008.

Woomer, P., 2008. New approaches to controlling striga Infestation. AATF Striga management Project from<http://www.aatfafrica.org/UserFiles/File/Strigareprint.pdf> accessed on 21/02/2008.

Woomer, P.L., Tungani, J., Odhiambo, G. and Mwaura, F.M., 2005. Striga management options in Western Kenya. In: Tenywa, J.S., Adipala E., Nampala, P., Tusiime, G., Okori P. and Kyamuhangire, W. (Eds.). African Crop Science Conference Proceedings, Kampala, Uganda. Vol. 7 pp. 479 – 484.