INTEGRATING *STRIGA* MANAGEMENT STRATEGIES FOR IMPROVED MAIZE PRODUCTION IN WESTERN KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university. No part of this thesis may be produced without prior permission of the author and/or University of Eldoret.

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DEDICATION

To my family and friends for their support and encouragement throughout my studies. To my supervisors who guided me through the course of my research and on writing this thesis. To members of the Ruforum CARP team and Ruforum for their support. To farmers and farmer associations BUFFSO, AFDEP and MFAGRO for the effective collaboration we have had with them during the course of this work.

ABSTRACT

Maize is an important crop in Kenya but is adversely affected by *Striga hermonthica* weed that reduces yields considerably, especially in Western Kenya. Single stand-alone management strategies for the weed have been used, but each has had its own demerits. The objective of this study was to integrate and determine the best maize variety and seed coat agents that would manage *Striga* and improve yields of maize, while at the same time obtain yields from soya beans in the same production system. A 4*4 factorial experiment was carried out in Teso, Bungoma, Vihiga and Kibos during the long and short rains seasons of 2012. Two *Striga* tolerant varieties, GAF4 and KSTP 94, a susceptible variety H505 and IR maize were each primed and coated with; a fungus ,*Fusarium oxysporum* (Foxy FK3), Phosphorus based fertilizer (Gro-plus), Gro-plus+Foxy FK3 and a control where seeds were not coated. Planting of maize and soya beans was done in MBILI system. Data was collected on striga numbers and biomass, maize grain weight and weight of shelled soya beans. The data was subjected to ANOVA and means separated using contrast in GENSTAT version 12.2. Gro-plus, Gro plus + Foxy FK3 and Foxy FK3 coatings on all maize varieties led to increased maize grain yield and biomasss and had lower *Striga* biomass and numbers compared to the control. The best performance was observed in Gro-plus maize seed coating but there was no much difference between *Foxy* FK3 and *Foxy* FK3+Gro plus coatings. KSTP94 yielded highest in maize grains when coated with Gro plus, compared to all the other combinations.IR maize technology did not manage to inhibit striga growth. H505 with no seed coating yielded the least. Soya beans grown as intercrop in all the maize variety-coating combinations did not show any significant difference in terms of grain yields. All varieties coated with Gro-plus and Foxy FK3 had more than 50% MRR. This reiterates the importance of using the synergized technology to manage *striga* and improve maize yields. The recommended best package was H505 coated with Gro-plus. Further research however needs to be done to determine the best possible way of combining Foxy FK3 and Gro plus to integrate their individual abilities in managing *striga* and ultimately improving yields of maize.

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LIST OF ABBREVIATIONS

AFDEP	Angurai Farmers Development Project Group
AATF	African Agricultural Technology Foundation
BUFFSO	Bungoma Small Scale Farmers Forum
FURP	Fertilizer Use Recommendation Project
IR	*Imazapyr* Resistant
KARI	Kenya Agriculture Research Institute
KESREF	Kenya Sugar Research Foundation
KSTP	Kakamega Striga Tolerant Population
MFAGRO	Mwangaza Farmers Group
MRR	Marginal Rate of Return
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
TSP	Triple Super Phosphate
TVC	Total Variable Cost

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Maize is an important crop with world production of white maize estimated at around 65-70 million tons. This represents 12-13 percent of the annual world output of all maize. In all the white maize produced, over 90 percent production occurs in the developing countries, where it accounts for around one quarter of total maize output and just under two-fifths of the total maize area (Dowsell *et al*., 1996)

In Africa and the developing world in general, it is one of the most crucial and strategic cereals. Maize is produced in different parts of the continent under diverse climatic and ecological conditions and has become a major staple and cash crop for smallholder farmers due to its increasing importance (FARA, 2009).

In sub-Saharan Africa, it is a staple food for 50% of the population. In Kenya, Maize is a staple food for over 90% of the population (Wambugu *et al*., 2012). It is an important source of carbohydrates, protein, Iron, Vitamin B and minerals. The composition of maize seed is approximately 76-88% carbohydrates, 6-15% protein, 4-5.75 fat and 1.3 % minerals. The production takes place in both small and large scale farms, however the bulk of it is from small scale farmers (MOA, 2011). Yield potential ranges from 4.7tons per acre in the highlands to 1.1 tons per acre in dryland areas of Kenya, with different varieties bred for the different regions (www.infonet-biovision.org). About 1.6 million hectares are under maize annually, 80% of which is owned by smallholder farmers (Wambugu *et al*., 2012).

The high and medium potential zones in Kenya account for more than 70% of the country's maize production and have the highest potential productivity of almost 5 t/ha, although in some parts of Western Kenya, yields as low as 500 kg/ha have been realized (Otingah *et al*., 2007). The low production level has been due to production constrains which include low soil fertility, moisture stress, *Striga hermonthica* infestation on maize, drought and erratic rainfall. *Striga* in particular is the major threat to livelihoods of smallholders and its economic importance has increased over the past three decades (Mwangi *et al.,* 2001, Manyong *et al*., 2007). The significant yield reduction caused by *Striga* has resulted in little or no food at all for millions of subsistence farmers and has consequently aggravated hunger and poverty. *Striga* acts by wounding the outer root tissues of maize and absorbing its supply of moisture, photosynthates, and minerals, which eventually leads to severe grain losses (Khan *et al*., 2007). The weed has the ability to change the host plant architecture and reduce the water-use efficiency in the host (Mignouna *et al*., 2013), while causing characteristic yellowish blotches in the foliage of host plant. In later stages, whole leaves may wilt, become chlorotic and die.

Globally, *Striga* has a greater impact on human welfare than any other parasitic angiosperms. The weed has threatened an estimated approximately 44 million hectares of arable land and affecting the livelihoods of more than 100 million farmers (Mignouna *et al*., 2013). Food production losses due to *Striga* in African countries range from 20% to 90%, amounting to over 10 million tons of food lost annually. *Striga* is responsible for lowering crop productivity in many regions of Africa below subsistence level and has remained uncontrolled despite many years of research, therefore affecting livelihood of millions of people in the continent (Kudra *et al*., 2010). In sub-Saharan and northern Africa, *Striga* is a major contributor of hunger, malnutrition and food insecurity through its effect in reducing crop yields by half. It has adversely affected the livelihoods of about 300 million people (Manyong *et al*., 2007). Over twenty million hectares of cereal grains in sub-Saharan Africa are infested with *Striga*. Estimates on the extent of crop damage in a country or region in the African content vary depending on the prevalent cultural practices, crop cultivar and degree of infestation (Mignouna *et al*., 2013, Parker and Riches 1993). In Kenya, *Striga* infestation is at 225,000ha. of maize, which accounts for 15% of total maize production area.

In Western Kenya, 73% of farms surveyed were found to be affected by *Striga* with an average 161 million seeds per ha resulting in three parasitic stems per maize plant (Woomer and Savala, 2009). This indicates the urgent need for development and packaging of better *Striga* management tehnologies that will assist the small holder farmers in managing the weed and therefore improve their cereal production.

The parasitic weed has the ability to produce a tremendous high number of seeds, which can remain viable in the soil for years (Ejeta and Gressel, 2007). This ability coupled with *Striga*'s intimate physiological interaction with their host plants, are the main difficulties that limit the development of successful control measures that can be accepted and used by subsistence farmers. Several control strategies have been employed in *Striga* management, but the efforts still seem to have limited success. Most of research work done so far on *Striga* management has focused on single control strategies. These control options for *Striga* are currently not very effective and novel management strategies for *Striga* suppression are urgently needed (Watson *et al.*, 2007) in order to find a lasting solution to the problem.

1.2 Statement of the problem

Striga is a major biotic constraint to food production in Africa and is one of the major contributors to hunger, malnutrition, and food insecurity across sub-Saharan Africa. The weed has contributed to halving of cereal yields in the infested areas (Watson *et al*., 2007). The actual *Striga* infested area is estimated at 44 million hectares worldwide (Mignouna *et al*., 2013). These parasites cause losses of up to 100% on farmers' fields, which often have to be abandoned due to their unproductivity. Single control strategies for management of *Striga* have not proven to effectively manage the weed. *Striga* produces thousands of seeds from one single plant when left to flower and form seeds (Ejeta and Gressel, 2007). *Striga*, just like *Orobanche*, sequentially evolves resistance strains to each gene thrown in its path due to its variability. This variability among the *Striga* would therefore jeopardize the sustainability of any stand alone technology (Ejeta and Gressel, 2007).

Stand alone technologies that have been developed in management of *Striga* include: hand pulling which by the time the *Striga* is pulled out, it has already done extensive damage; use of *Striga* tolerant maize varieties which grow alongside *Striga* but yields of maize is not affected although the method does not reduce *Striga* soil seed bank; use of IR maize (*Imazapyr* resistant maize) with resistance by *Striga* likely to evolve in long season maize as semi dorminant *Striga* could easily evolve late in season when part of the herbicide has decipated (Ejeta and Gressel, 2007). Intercropping with legumes that induce suicidal germination of *Striga* has also been practiced, but *Striga* numbers reduced is very low compared to the bank. Some strains of *Fusarium oxysporum* (*Foxy* FK2) have been used to manage *Striga* in west Africa, but have not been introduced in Kenya. Its adaptability in a different environment is also still not known and so the transfer of the technology could still be a challenge. A local Kenyan isolate of *Fusarium oxysporum* (*Foxy* FK3) can be used in management, but its effectiveness has not been adequately tested. Seed coating using soluble Phosphorus and potassium based fertilizer can also reduce *Striga* infestation but does not reduce *Striga* seed soil bank. All these challenges posed by stand alone technologies, coupled by the fact that *Striga* emerges above the soil surface when it has already done extensive damage to a crop indicate that there is need to synergise these *Striga* management technologies so as to enable sustainable management of the weed within a growing season and a reduction in *Striga* soil seed bank. This study aims to integrate some of these technologies to develop an integrated strategy that is efficient in *Striga* management and package it in an effort to improve maize production in Western Kenya.

1.3 Justification

Since stand alone technologies cannot effectively manage *Striga*, there is need to merge some of these technologies capitalizing on each of their individual strengths in an effort to manage the weed. MBILI technology has been more effective when used alongside leguminous crops that are not food for humans, such as Desmodium (Khan *et al*., 2007), but most small holder farmers prefer producing food crops which they see as more profitable. The use of Soya beans in MBILI system is therefore critical because the legumes have the capacity to induce suicidal germination (IITA, 2002) apart from improving food security status.

Striga tolerant maize varieties (KSTP94 and GAF4) grow in *Striga* infested areas and their yields are not affected by the *Striga*. These varieties do not contribute to reduction of *Striga* seed soil bank as they do not have a mechanism for killing the weed. Coating seeds with the *Fusarium oxysporum* (*Foxy* FK3) leads to attacking *Striga* seeds and killing of *Striga* before it attaches to the roots of maize which would help reduce *Striga* seed soil bank (Kroschel *et al*., 1996). Therefore, both these technologies reduce *Striga* seed bank in the soil, prevent production of new seeds and increase grain yield of the crop in the same cropping season. *Fusarium oxysporum (Foxy)* has been found to be cost effective, requires no changes in cropping systems used by farmers and in the case of resistant host plants, no additional labor is required. Therefore, it is assumed to fit into various farming systems. IR maize and *Striga* susceptible varieties like H505 can also be coated with the fungus to enhance their effectiveness in reducing the weed.

The use of soluble P fertilizer (Gro-plus) seed coating would work well even in acidic soils as it acts in a similar way as spot fertilizer application which reduces Phosphorus fixation. Additionally, its effectiveness in inhibiting *Striga* seed germination through suppression of strigolactones production would be enhanced, thereby managing *Striga* within the maize growing season. The integration of *Striga* control strategies where tolerant, susceptible and IR maize coated with soluble P and K based seed coating fertilizer (Gro-plus), *Fusarium oxysporum* (*Foxy* FK3) and a combination of *Fusarium oxysporum* (*Foxy* FK3) +soluble P fertilizer (Gro-plus) grown in MBILI system with soya beans as intercrops can cumulatively reduce *Striga* infestation .

1.4 General objective

To integrate strategies for effective *Striga* management techniques in grain and legume systems of Western Kenya.

1.4.1 Specific objectives

1. To determine the initial Striga load in the soil, soil fertility status, and effect of maize varieties (IR, KSPT 94, GAF 4, H505) planted in MBILI system with maize coated with *Fusarium oxysporum* (*Foxy* FK3), Phosphorus and potassium based fertilizer (Gro-plus) and a combination of *Foxy* FK3 and Gro-plus on *Striga* biomass and *Striga* numbers.
2. To determine the effect of these treatment combinations on maize growth, yields and biomass, and on soya beans yield in Long rains (Season I) and short rains (Season II) in Kibos, Teso, Vhiga and Bungoma.
3. To assess the economic benefits of the combination of *Striga* management technologies.

1.5 Hypothesis

Ho: There is no difference in *Striga* load and soil fertility status in the study sites whereas the use of maize varieties IR maize, KSPT94, GAF 4, H505 planted in MBILI system with the maize coated with *Fusarium oxysporum* (*Foxy* FK3), Phosphorus and potassium based fertilizer (Gro- plus) and a combination of *Foxy* FK3 and Gro-plus has no effect on *Striga* numbers and biomass.

Ho: The treatment combinations have no effect on maize growth, yield and biomass in the two seasons and in the four sites.

Ho: The treatment combinations have no economic benefit.

CHAPTER TWO

LITERATURE REVIEW

2.0. Introduction.

Striga hermonthica is an obligate parasite and therefore modulates its development to correspond with its host life cycle (Ejeta and Gressel, 2007). Germination of the weed proceeds in response to chemicals exuded by the host plants. For parasitic attachment, both germination and haustorial initiation need to occur very near to the host roots. *Striga* seeds pass through a period of dormancy and cannot germinate in the season in which they are produced. This is because of the after ripening requirement, which prevents newly matured *Striga* seed from germinating too late in the season, when host plants capable of supporting a parasitic plant to maturity are scarce (Ejeta and Gressel, 2007). *Striga* produces between 50,000 and 200,000 seeds per fully mature plants which remain dormant in the soil for up to 20 years (AATF, 2006). *Striga* seeds can retain their viability for up to 14 years in *Striga asiatica* but intervals of 2 years seed viability have been realized in *Striga hermonthica* (Ejeta and Gressel, 2007). These seeds are small and therefore have limited energy reserves. This condition will make a germinated *Striga* to survive in a free living state for only a few days because it must solely rely upon its small seed reserves. The weed will therefore need to attach to the host for survival. *Striga's* problem has been in existence from as early as 1936 in fields of farmers within Lake Victoria Basin, Western Kenya (Ndwiga *et al*., 2013). 95% of the continents *Striga*-infested fields are in fifteen countries of Eastern, Southern and Western Africa (Ndwiga *et al*., 2013). Farmers and various organizations using both traditional and conventional single stop gap *Striga* management efforts have tried to eradicate *Striga*, but the weed still pose a challenge.

2.1 Methods of control

2.1.1 Hand pulling

Hand pulling is done through the normal weeding process, that involves uprooting the *Striga* by hand. Hand pulling of *Striga* has been shown to reduce its infeststion, but only if done before seed set, (Parker and Riches, 1993). The method is however time consuming and labour intensive (Khan *et al*., 2003). It is also only effective in reducing the weed infestation during preceding seasons since most of the damage by *Striga* occurs before the weed emerges from the ground. *Striga* also continues to mature in the field after maize has been harvested (Woomer and Savala, 2008), which is a time when hand weeding is not done. This therefore leads to further flowering and shedding of seeds which increases the *Striga* seed soil bank.

2.1.2 Crop rotation

It is a low cost technology and addresses the problem of low soil fertility and *Striga* infestation. Crop rotation with non-host crops has been shown to disrupt production of *Striga*, that leads to a reduction of the weeds. Legume-maize rotation has been found to reduce *Striga* infestation by 35% after one year and by 76% after two years of legumes in the rotation (Kureh *et al*., 2006). Soybean was more effective in reducing *Striga* infestation and also gave higher maize grain yield than cowpea in Guinea savanna of Nigeria (Kureh *et al.*, 2006). With dwindling farm sizes, crop rotation is becoming less feasible because of the increasing demand for land to produce the cereals and where rotations are made, it hardly surpasses the three years required for rotation to be effective in controlling *Striga* (Parker and Riches, 1993)**.** This method offers advantages to small holder farmers in terms of crop diversity and risk avoidance, but this has led to low maize reserves and widespread incidences of pests and diseases. This is because small holder farmers depend on cereals as their main source of food and rotation would not allow them to grow the cereal during certain times when the legumes have been planted. This would lead to a reduction in cereal grain reserves from the previous season. The potential for adoption of the technique depends on whether the break crop is a high value crop that fits into the cropping system. It also depends on whether the seeds for the break crop are widely available. If neighbors do not adopt the system, its effectiveness becomes limited. For pests and diseases, mono cropping during one season would lead to the advance of a particular pest or disease, and if there is an epidemic, the probability of total crop failure is high. A common practice with most small holder farmers in Kenya, however, is intercropping maize with legumes so that the farmers can have yields from both. Crop rotation is therefore not a feasible venture when used alone.

2.1.3 Intercropping

It is the agricultural practice of cultivating two or more crops in the same space at the same time with an aim of matching efficiently crop demands to the available growth resources and labor (Lithourgids *et al*., 2011). The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops (Lithourgids *et al*., 2011).

Oshwald *et al*., (2002) assessed *Striga* control potential of different legumes: cowpeas, soybeans, yellow grams, bambara and groundnuts, in western Kenya. This was done in different planting arrangements with maize. The results led to a conclusion that although *Striga* numbers were reduced by the intercrops, if *Striga* was not uprooted before seed dispersal in a cropping season, the season to season reduction in *Striga* populations was not significant. Some varieties of cowpea, soybean, and groundnut have however been shown to manage *Striga* to some extent through a combination of mechanisms. The strategies used range from induction of suicidal germination of *Striga* seeds, nitrogen fixation, and smothering effect. In Ethiopia, Reda *et al*., (2005) found no significant difference between 10 different legumes intercrop with sorghum in the control of *Striga*. The *Striga* control was not different when the legume intercrops were compared to each other.

According to Khan *et al*.,(2007), on intercropping different legumes with maize and sorghum, the intercrops with beans, crotalaria and green leaf *Desmodium spp* showed some promise as a suitable component of an integrated *Striga* management approach for the small holder farmers, but this would need to be combined with other cultural methods such as hand weeding of the emerged *Striga* to avoid replenishment of *Striga* seed soil bank . In conventional intercrops, competition for light by crops significantly contributes to lower yields (Mukhwama *et al*., 2002). A modification of this conventional intercropping was developed by Tungani *et al*., (2002) to come up with a new technology, Managing Better Interactions for Legume Intercrops (MBILI). It involves staggering every other maize row by 25cm and growing legumes in the resultant wide inter-row holding constant population of maize 44,444 per ha. and legumes at 88,888 per ha. This method disrupts pest cycle and improves opportunities for symbiotic nitrogen fixation (Woomer *et al*., 2004). The system allows legumes to receive adequate light and yet maintain the recommended plant populations, but loses plant intimacy associated with intercropping systems.

MBILI technology allows a farmer to grow a wide range of food legumes as under storey intercrops with maize. This permits more productive intercropping with groundnuts, greengrams, soybean and other legumes that are not normally intercropped with maize because of excessive shading. It permits cultivation of legumes that suppress *Striga hermonthica* such as lablab and Desmodium (Woomer and Omare, 2005), and eventually increasing yields. The technique gives both roots and crowns enough space and plants therefore grow without much competition for resources. This leads to higher yields of legumes (Thuita *et al*., 2007). Intercropping maize with beans with two rows of maize and two rows of beans has led to increased maize yield significantly by 51.2 % and 61.4% over farmers practice and intercropping with one row of beans only (Odhiambo and Ariga, 2001). Legumes intercropped with sorghum has proved to reduce *Striga* infestation in Nigeria, although sorghum yields were not significantly improved (Gworgwor, 2002). The use of soy beans as maize intercrop in MBILI technology can thus lead to an increase in yields of both cereals and legumes while reducing *Striga* infestation.

2.1.4 Push and Pull technology

It is an intercropping strategy where fodder legumes (*Desmodium uncinatum and D. intortum*) are intercropped with *Zea Mays* while *Pennisetum purpureum* is planted around the same field. The 'push-pull' tactic involves trapping stem borers on highly susceptible trap plants (pull) whilst driving them away from the maize crop using repellent inter-crops (push). The *Striga* control tactic is based on the use of inter-crops that act through a combination of mechanisms, including abortive germination of seeds that fail to germinate and attach on the host (Khan *et al*., 2003). This is due to the allelopathic mechanism of *Desmodium spp*, that also inhibits *Striga* haustoria development. The protection mechanism employed by *D. uncinatum* in *Striga* suppression has been established to involve a combination of mechanisms, ranging from increased availability of nitrogen, soil shading, to an allelopathic root exudation that is generated independently of the presence of *Striga* (Khan *et al*., 2002), but cereal crops are significantly reduced. The practice may therefore not be acceptable to farmers (Esilaba, 2006). Farmers are also used to the idea of growing food crops and would prefer growing legumes as intercrops as opposed to use of *Desmodium* spp. *Desmodium* seeds are also expensive and out of reach to most farmers. Only a few small holder farmers keep livestock, thus *Desmodium* would not be an economical crop to them, and would rather grow other food crops on the piece of land. *Desmodium* may prove difficult to establish and the small, slow growing seedlings cannot be easily weeded with the farmers traditional jembes thus small hand weeding tools are required (Ejeta and Gressel, 2007).

2.1.5 Striga tolerant varieties

Striga tolerant maize varieties have been developed in Kenya where evaluations done in Homabay, Kibos and Busia indicated that varieties such as GAF4 developed by KARI-Kibos and KSTP 94 developed by KARI-Kakamega managed to yield 5.12 and 4.06 tons per hectare compared to H513 that yielded 0.75 tones/ha in NPT trials 2009 (Ngesa *et al*., 2010). The *Striga* tolerant varieties do not kill *Striga*, therefore there is need for incorporation of the varieties into other *Striga* management techniques that will ensure *Striga* emerging from the soil is killed so as to reduce the *Striga* seed soil bank.

2.1.6 *Imazapyr* resistant (IR) maize

It is a maize variety developed by CIMMYT, KARI and BASF through a technology based upon inherited resistance to a systemic herbicide (*imazapyr*) (Woomer and Omare, 2005). The seed is coated with the herbicide and when *Striga* attempts to parasitise the resulting plant, the weed is destroyed. The herbicide acts at the time of *Striga* attachment to the maize root and prevents attachment of the weed on the maize plant besides killing non-germinated seeds in soil surrounding the maize seedling. The maize therefore becomes clear of *Striga* throughout the season. IR maize must however be planted in different holes with legumes while intercropping since the herbicide may affect the legume seed (Woomer and Omare, 2005). Substantial yields of 4.01 t/ha have been realized upon using IR maize (Ngesa *et al*., 2010) in NPT trials of 2009. Although the technology suppresses and reduces *Striga* seed bank, it is toxic to all other crops that do not have *imazapyr* resistance. Very high rainfall can wash the herbicide beyond the root zone, allowing establishment of late germinating *Striga.* There is also likelihood of the risk of the evolution of resistance by *Striga* to the herbicide, especially in long season maize as semi-dormant resistant *Striga* could easily evolve late in the season when part of the herbicide has dissipated. This therefore means that the sustainability of this technology will only be maintained when it is integrated with other technologies (Ejeta and Gressel, 2007).

2.1.7 Strigolactones and Phosphorus in *Striga* supression

The host roots exudates of many *Striga* infested cereals contains strigolactones, which are signalling molecules that promote *Striga* seed germination (Mutusova *et al*., 2005). Strigolactone is a chemical in the class of germination stimulants for parasitic plants, *Striga* and *Orobanche sp*, that includes strigol, sorgolactone, alectrol and orobanchol. They are produced by plants in very low concentrations and induce germination of seeds of the parasites. Plants exude strigolactones to attract symbiotic arbuscular mycorrhizal fungi in the rhizosphere. Abuscular mycorrhizal (AM) fungi are soil beneficial micro organisms that help plants to absorb nutrients, particularly Nitrogen and phosphorus from the soil. When there is limited Phosphorus in the soil, strigolactones are produced by the host plant to enable absorption of the nutrient through AM fungi (Yoneyama *et al*., 2012). These strigolactones will induce more hyphal branching of AM fungi which will lead to more P absorption from the soil. Jamil *et al*., (2011) studied strigolactone exudation, as well as *Striga hermonthica* germination and attachment under different levels of nitrogen (N) and phosphorus (P) in two cultivars of rice (IAC 165 and TN 1). He found out that exudation of strigolactones by rice was the highest under mineral-deficient conditions, and that increasing N and P dose reduced the amount of strigolactones in the exudates. Deficiency of P led to the highest strigolactone exudation, when compared with N or NP deficiency. The results showed that application of P based fertilizer led to *Striga* management, which could be due to the reduction of strigolactones produced and therefore less *Striga* stimulated to germinate. Maintaining suitable N and P nutrient status of soil through fertiliser use might be a promising strategy to reduce damage in cereals by this notorious weed.

Yoneyama *et al*., (2012) concluded that P deficiency promoted strigolactone exudation in tomatoes and alfalfa. Tomato plants grown under sufficient phosphate conditions produced less strigolactones and, as a consequence, less active root exudates (Juan *et al*., 2008). Plants grown under limited P condition secret more hyphal branching factors for arbuscular micorhizal fungi into the rhizosphere through and thus exudation of strigolactones is stimulated (Juan and Bouwmeester, 2008). Phosphorus can therefore be used to manage *Striga*, but it needs to be available to the plant first. The technique might not work in situations where phosphorus is fixed, especially in acidic soil. Phosphorus is immobile in the soil. Seed coating using phosphorus based fertilizer can therefore be an appropriate option in enhancing phosphorus availability within the root zone. Research done on rice in phosphorus seed coating at 0.5kg RP per kg of seed has shown that using rock phosphate did not affect final seedling emergence though it delayed emergence by 2-3 days but quadrupled shoot and root growth (Ross *et al*., 2000). Having the P on the seed surface rather than in the nearby soil where the phosphate fertilizer is applied might well cause the germinating seed to reduce its strigolactone production. This could be applied even in acidic soils as the coating would act as a spot application that would minimize the effect of P fixation, and thus the p available will be utilized by the plant.

2.1.8 Biological control

Biological control refers to the deliberate use of living organisms to suppress, reduce, or eradicate a pest population (Boyetchko, 1999). The means of control comprise of herbivorous insects, microorganisms (especially fungi), and smother plants (Sauerborn and Kroschel, 1996). These biological control agents can be used to manage several pests, including *Striga* weed. Studies have been carried out by

Kroschel *et al*. (1995), and Traoré *et al.* (1996) to investigate the potential of the weevils *S. umbrinus* and *S. guineanus* and the butterfly *Junonia orithya* as biocontrol agents for *Striga* in Burkina Faso and Northern Ghana. The results revealed that as a result of *Smicronyx* infestation, the *Striga* seed production was reduced by 17.4 % on the average (Kroschel *et al*., 1999). However, when *S. umbrinus* is used as the only control agent, it would have to destroy 95% of the *Striga* seeds each year for the cropping years in order to reduce the density of emerged *Striga* plants by 50% (Smith *et al*., 1993), which might not be feasible.

Andrianjaka *et al*., (2007) carried out an experiment on *Striga* management in sorghum using cubiterm termites. This was done by amending the soil with cubitermes mound powder as chemical amendment and natural microbial inoculum, to promote plant growth and reduce damage by *S. hermonthica* on sorghum. Number of emerged *Striga* plants in amended pots was significantly decreased. Cubitermes mound suspensions did not affect *Striga* seed germination under axenic conditions, which therefore suggested that the amendment with Cubitermes powder reduces *Striga* infestation indirectly, i.e. via its effect on the indigenous soil microflora. The effects of the termites on other soil micro organisms have however not been tested, and it is still not clear if the mound powder would affect maize or not, if used as a management option.

Naj Raja (1966) reported the occurrence of *Alternaria* sp., *Cercospora* sp., *Neottiospora* sp. and *Phoma* sp. on *Striga asiatica* and *S. densiflora* in India, which was pathogenic to the weed. *Fusarium sp*. has been found to be effective against striga. Two isolates from Sudan, *F. nygamai* and *F. semitectum* var. *majus* showed potential to be used as bio agents for the control of *Striga.* They led to reduction in emergence of *Striga* plants up to 97 and 82%, respectively, when mixed with soil pre-planting at a rate of 20 g kg^{-1} soil. Sorghum performance in the treated fields was significantly improved (Abbasher and Sauerborn, 1995).

Fusarium oxysporum Schlecht. (*Foxy* 2 & PSM197) has proved to be highly virulent against their target weed *Striga,* (Schaub *et al.,* 2006). They are host specific and can be mass-produced. This therefore offers a good prospect for *Striga* control when the bio-control agents are incorporated into a long-term integrated *Striga* management program. Both granular mycoherbicides (*Foxy* 2 & PSM197) have been effective in controlling *Striga* on both susceptible and resistant maize and sorghum cultivars tested. They have cumulatively reduced the number of emerged *Striga* plants per plot by 75.3 %, *Striga* dry weight by 74.4 %, *Striga* flowers by 83.6 %, and crop plant infested by 64.8 % compared to the controls as seen in field trials in Nigeria (Schaub *et al*., 2006). *F. oxysporum fsp Strigae* attacks all *Striga* underground developmental stages including seeds (Kroschel *et al*., 1996). This leads to a reduction in *Striga* seed bank in the soil and prevents production of new seeds. Eventually, this effect leads to an increase in grain yield of the crop in the same cropping season. In addition to their high potential in *Striga* control, they were found to be cost effective (Elzein 2003, Gupta and Lagoke 2000), require no changes in crop rotation and in case of the resistant host plants, no additional labor required. The technology is therefore assumed to fit into various farming systems. *F. oxysporum f. sp. Strigae* is host limited. Several crop species (sorghum, pearl millet, maize, rice, cotton, groundnut, cowpea and okra) were immune to isolate M12-4A7 of the pathogen. These and other crops have also proved to be immune to isolates from Ghana, Sudan, and Nigeria.

Isolate M12-4A of *S.hermonthica* does not produce mycotoxins under all conditions tested, and hence it does not constitute a known health hazard to humans or livestock (Watson *et al*., 2007). However, its effectiveness has not been widely tested especially in farmers' fields in Kenya to ascertain its effectiveness in reducing *Striga* infestation and therefore improve yields.

Several technologies had been employed to manage *Striga* in farmers fields especially in Western Kenya. Promising results had been obtained, but *Striga* was still a challenge. There was need to merge some of these technologies which would have a cumulative effect in *Striga* management. Some technologies had proven to manage *Striga* to an extent like 'push and pull' using *Desmodium spp*, but overall yield was reduced since most farmers did not embrace the idea of using *Desmodium* and would rather substitute with legumes. The study was to determine how integration of MBILI soya intercrop technology with use of IR maize, susceptible variety H505, *Striga* tolerance varieties GAF 4 and KSTP 94 and coatings of maize varieties using *Fusarium spp* and P and K based fertilizer would influence yields of both maize and legumes. It would also determine how *Striga* could be effectively managed and to what extent. That would provide farmers with an efficient and sustainable method of crop and yield improvement.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study sites

3.1.1 Bungoma site

The Bungoma site was located in Siritanyi in Bungoma county at an altitude of between 1100-2000m above sea level. It has bimodal rain pattern with long rains from March to August and short rains from October to January. It falls under two agro ecological zones the transitional upper midland zone (UM4) and the Lower Midland zones (LM1-LM3). Temperature ranges from about 20 to 22°C in the southern part of Bungoma to about 15 to 18°C on the Northern part of the county. Annual rainfall ranges from 1000-1800mm . The soils are well drained, deep to very deep and vary from dark red nitisols (alfisols) and ferralsols (oxisols) to dark brown acrisols (ultisols) (Republic of Kenya 1997, Franke *et al*., 2011).

3.1.2 Teso site

Teso site was located in Akapar in Busia county at altitude range from 1,300m to 1500m above sea level. Annual rainfall is between 1,270 mm and 2000 mm with bimodal distribution. Temperatures ranges between 26^{o}C and 30^{o}C. Temperature ranges between 14^{o}C and 22^{o}C . Soils are well drained acrisols and feralsols mainly and are of a more sandy texture than the Bungoma soils (Republic of Kenya, 1997).

3.1.3 Vihiga site

The Vihiga site was located in Itando in Vihiga county. It lies in the upper midland one (UM1) agro-ecological zone, has altitude range from 1300 to 1800 meters above sea level and average temperatures of 20.3^{0}C. The site has well drained soils that comprised dystric acrisols and humic nitisols (Jaetzold and Schmidt ,1983., Franke *et al*., 2011). The area receives bimodal rainfall that ranges from 1,800 to 2,000 mm per year.

3.1.4 KESREF – Kibos site

The site was located in Kenya Sugar Research Foundation trial field in Kibos, Kisumu county. It lies at an altitude of 1131m above sea level and between latitude 0^{o} 05’ S and longitude 34^{o} 48’ E on the world map. Average annual precipitation is 1184mm. There are two main cropping seasons: long rains (LRs) (March to June) and short rains (SRs) (September to November). Daily temperature in this region ranges from 21^{o}C to 34^{o}C. (Republic of Kenya, World Weather Information Service, 2009). Predominant soil types in this region are planosol and alluvial soils (FAO, 1996).

3.2. Study Approach

Farmer participatory research approach was used where experiments were carried out in selected farmers fields who had *Striga* in their farms within three Farmer Associations in Western Kenya: AFDEP in Teso, BUSSFFO in Bungoma and MFAGRO in Vihiga. The farmers were involved in site selection, layout of the experiments, planting, site management and data collection. Apart from the farmer groups, another trial site was set up in KESREF-KIBOS as an on-site experiment in a field that had been inoculated with *Striga* in the previous years. Composite soil sampling was done for each of the experimental areas according to Okalebo *et al*., (2002) in order to determine the fertility status of the experimental sites. Initial *Striga* infestation was assessed in the soil before starting the experiments. The map of the study sites is as shown in Fig 1.

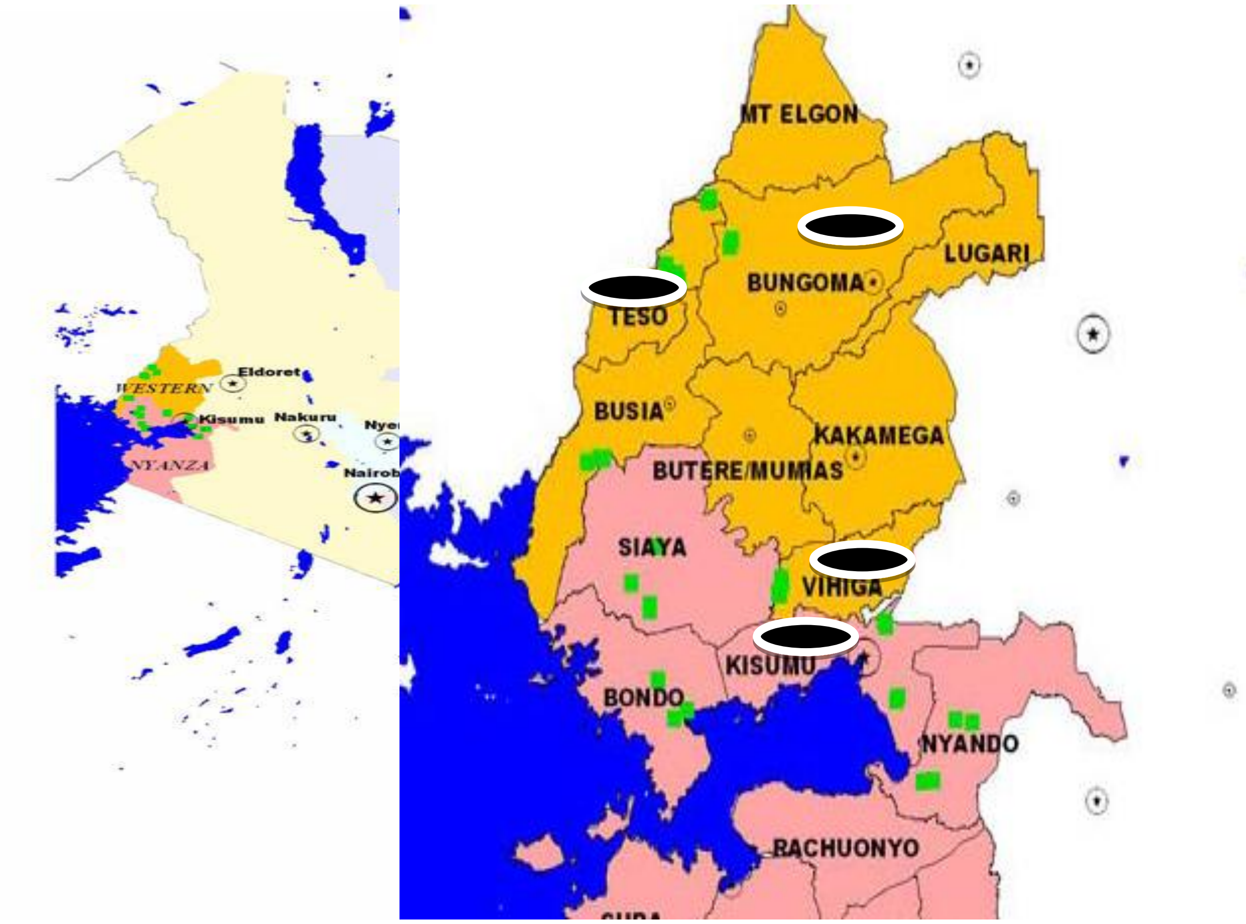

Fig 1. Map showing location of the four study areas.

(Source: Manyong et al., 2007)

3.3 Experimental treatments Design and Field layout

Treatments used consisted of maize varieties and seed coatings.

Maize varieties used:

1. IR maize-Maize variety developed by CIMMYT, KARI and BASF. It is resistant to *imazapyr*, a herbicide that it is coated with. The herbicide kills *Striga* and any other plant it comes into contact with. It therefore reduces striga populations.

2. KSTP94- *Striga* tolerant maize variety developed by KARI- Kakamega. *Striga* can grow in fields planted with the variety but yields of maize are not significantly reduced because of its tolerance to the weed.
3. GAF4- *Striga* tolerant maize variety developed by KARI- Kibos. *Striga* can grow in fields planted with the variety but yields of maize are not adversely affected because of its tolerance to the weed.
4. H505- Striga susceptible maize variety developed by Western Seed company, Kenya.

Maize seed coatings

1. *Fusarium oxysporum* (*Foxy* FK3) – A local *Fusarium oxysporum f.sp strigae* isolated and formulated by Real IPM company, Kenya. It is host specific, and pathogenic to *Striga hermonthica* only. It contains 1×10^{11}cfus/gram (1×10^{11} colony forming units of *Fusarium oxysporum*, *Foxy* FK3 per 1 g of the formulated seed coating agent, which also contains gum arabic glue and a carrier,kaoline clay in the mixture). It is packaged in 50g packs to be used to coat maize.
2. Gro-plus – A phosphorus based seed coating fertilizer formulated and distributed by Real IPM company, Kenya. It is packaged in 50 g packs, used to coat 2 kg maize seed. The 50 g pack contains 26g P_2O_5, 17g K_2O, glue and carrier material.
3. *Fusarium oxysporum Foxy* FK3+Gro plus (*Foxy* FK3+Gro-plus) - Mixture of 50g Gro plus and 50g *Fusarium oxysporum Foxy* FK3.
4. Control - No seed coating for each of the maize varieties.

Each of the four maize varieties was coated with each of the four seed coating treatments. Maize was primed for 12 hours, then coated on farm and dried for 45 minutes before planting. The experimental design used was a 4×4 factorial, where the factors used were varieties and seed coatings, each having four levels. The experiment was laid out in randomized complete block design. There were 16 treatment combinations in each block. This was replicated three times in each site. Plot sizes used measured 2.1m × 3.5m.

3.4. Land preparation and planting.

For long rains (LRs), the experimental plots in all sites were prepared during the month of March, 2012 and planted in April, 2012. For short rains (SRs), the plots were prepared in early August, 2012 and planted by late August 2012. The maize and soya beans were planted in MBILI intercrop system. Maize rows were spaced as 50 cm pairs that are 100cm apart (the gap). Two rows of soybeans were planted within the gap 33 cm row spacing, giving maize plant population of 44,000 plants/ha and legume population of about 88.000 plants/ha. One maize plant was left in each hole after thinning.

Phosphorus fertilizer was applied per planting hole in the form of TSP at a rate of 26kgP/ha uniformly for all treatments. Nitrogen fertilizer was applied in two splits, 30kgN/ha during planting to act as starter Nitrogen and 45kgN/ha when the maize and soy bean crop was knee high according to FURP, (1994). This was also done uniformly in all the treatments.

Weeding was done manually giving same treatments to all experimental units. The first weeding was done four weeks after planting using a hoe, and subsequent weedings were done by hand pulling leaving only *Striga* in the maize and soya bean plots. Bulldock was applied to control insect pests in the early stages of growth.

Harvesting of the maize and soy bean was done manually at harvest maturity.

3.5. Data collection and analysis

Data was collected on striga count, Soil, Maize and Soya beans as outlined below:

Striga

A composite soil sample was obtained from each of the blocks by randomly sampling soil from each plot and thoroughly mixing to obtain a composite sample. Two 1 kg samples were obtained from the composite sample, one for *Striga* and the other for soil analysis. The 1kg soil sample for *Striga* was mixed thoroughly and taken to KARI-CIMMYT centre in Kibos for *Striga* seed count determination. Average *Striga* counts was determined for each of the sites through potassium carbonate separation method as outlined in Berner et al., (1997).

Striga numbers – This was done through counting the total number of *Striga* in each of the plots. The counting was done in weeks 6,8,10,12 and 14 after planting maize.

Striga biomass-This was assessed at the time of harvesting maize. All the striga in each of the plots was uprooted, put in bags and air dried for 14 days, weighed and recorded

Soil

The 1 kg sample for soil analysis was taken to the laboratory and analysis done to determine available P using Olsen method, % organic carbon and % N through digestion and pH using pH meter as outlined in Okalebo *et al*., (2002).

Maize growth

Plant height was measured at intervals in weeks 6, 10 and at harvest. This was done by measuring the height from the soil surface to the arch of the uppermost leaf that was at least 50% emerged.

Total number of cobs harvested per plot counted.

Weight of the cobs per plot at harvest.

Dry weight of the cobs per plot which were dried at 13% moisture content.

Grain weight of the shelled cobs.

Maize biomass-Maize stalks were cut near the soil surface and their total fresh weight taken. A subsample was thereafter taken from the total stalks in each plot, weighed and recorded. The sub-sample was thereafter dried and weighed. The weights for both were used to calculate the maize biomass.

Soya beans.

Weight of the pods at harvest.

Dry weight of the pods.

Weight of shelled grain.

The data collected was subjected to general analysis of variance (ANOVA) to determine whether there were significant differences in the effect of the treatments. This analysis was conducted using GENSTAT statistical software, version 12.2.

Different maize varieties coated with the different seed coatings were considered as TREATMENT. Significant differences were tested at 5% level of significance and mean reactions separated by CONTRAST COMPARISON. The mean separation approach was chosen mainly to avoid the demerits of other multiple comparison procedures (MCPs), and to answer specific questions such as how the different maize varieties, seed coatings and variety-coating interactions differed from each other in the parameters observed.

The model for data analysis is represented here

$$X_{ijklmn} = \mu + S_i + Se_j + \beta_{k(ij)} + V_l + C_m + SSe_{(ij)} + SV_{(il)} + SC_{(im)} + SeV_{(jl)} + SeC_{(jm)} + VC_{(lm)} + SSeV_{(ijl)} + SVC_{(ilm)} + SeVC_{(jlm)} + SseVC_{(ijlm)} + \varepsilon_{ijklm(n)}$$

Where: X_{ijklmn} = Total observation

μ = mean

S_i = Site

Se_j = Season

$\beta_{k(ij)}$ = Block effect

V_l = Variety

C_m = Coatingf

$SSe_{(ij)}$ = Site season interaction

$SV_{(il)}$ = Site variety interaction

$SC_{(im)}$ = Site coating interaction

$SeV_{(jl)}$ = Season variety interaction

$SeC_{(jm)}$ = Season coating interaction

$VC_{(lm)}$ = Variety coating interaction

$SSeV_{(ijl)}$ = Site, season, variety interaction

SVC(ilm) = Site variety coating interaction

SeVC(jlm) = Season, variety, coating interaction

SSeVC(ijlm)= Season, site, variety, coating interaction

εijklm(n) = Error term

3.6 Economic analysis of Agronomic data

Economic analysis was done according to CIMMYT (1988). This was done on the pooled results of the experiment carried out in Kibos, Teso, Bungoma and Vihiga for one recommendation domain. The average yield across all the sites for each of the treatments was determined and pooled results obtained. The average yields were adjusted downwards by 10 % because of the differences between experimental data and yields farmers might get when applying the same treatment (CIMMYT, 1988). This is because of management differences between researchers and farmers. Researchers are precise regarding spacing, fertilizer application and timing of planning. The small plot sizes could also overestimate the yield, therefore the need to scale down the yields. The analysis was done through development of a partial budget for the experiment, then doing a marginal analysis and later on calculating marginal rate of return.

3.6.1 Partial budget

This was developed by calculating the expected gross benefits for maize and soya beans in Ksh/Ha and establishing the variable costs for each of the treatments through inputs and labour, and using the data to determine the net benefits of each treatment. The calculations were done as part of planning process before the experiment was carried out to get an idea of the cost of the various treatments that were being considered for the experimental program. A partial budget was therefore developed for all the treatments in the experiment.

3.6.2 Dominance analysis

This was done to examine the cost and benefits of each treatment so as to eliminate some of the treatments from further consideration in the analysis. Treatments were listed in order of their increasing total costs that vary (Total variable cost). The treatments whose net benefits did not increase were termed 'dominated' treatments and were eliminated from further consideration.

3.6.3 Marginal analysis

In order to know how the net benefits from the treatments increased as the amount invested in the treatments increased, Marginal analysis was done. The marginal rate of return (MRR) was calculated. MRR is the change in net benefits divided by the change in cost when changing from one treatment to the next. The marginal rate of return indicateed what on average, farmers can expect to gain in return for their investment when they decide to change from one treatment combination to the other.

To estimate the minimum rate of return acceptable to farmers, a range of 50% to 100% of MRR per crop cycle was considered acceptable.

CHAPTER FOUR

RESULTS

4.1. Initial *Striga* determination and soil analysis

Composite soil samples taken from each site before the start of the experiment indicated that both soil fertility status and *Striga* numbers in the seed soil bank varied in the four sites (Table 1). Kibos and Teso sites had the highest number of *Striga* counts with similar quantities in the two sites. Bungoma had a lower number while Vihiga had the least. Similarly, Kibos site had highest % nitrogen, % organic carbon and available P. It also had a moderate pH of 5.4. This was followed closely by Vihiga, Teso and Bungoma respectively with decreasing status of %N, % organic carbon and available phosphorus (Table 1).

Table 1. Initial average *Striga* counts and soil analysis results for the four sites.

Site	Average *Striga* seed counts per 250g soil	Soil pH (1:2.5) H2O	% Organic Carbon	Available P mg kg^{-1}Soil	% N
Bungoma	8	5	1.94	1.098	0.156
Teso	14	5.51	2.09	3.831	0.188
Kibos	14	5.4	2.65	5.619	0.24
Vihiga	1	5.07	2.42	5.185	0.21

4.2 Effect of Seed coatings on *Striga* numbers and biomass.

The results on emerged *Striga* counted at 14 weeks after planting showed varied levels of significant differences in the maize varieties with the different seed coatings (Fig 2, Appendix 1,2).

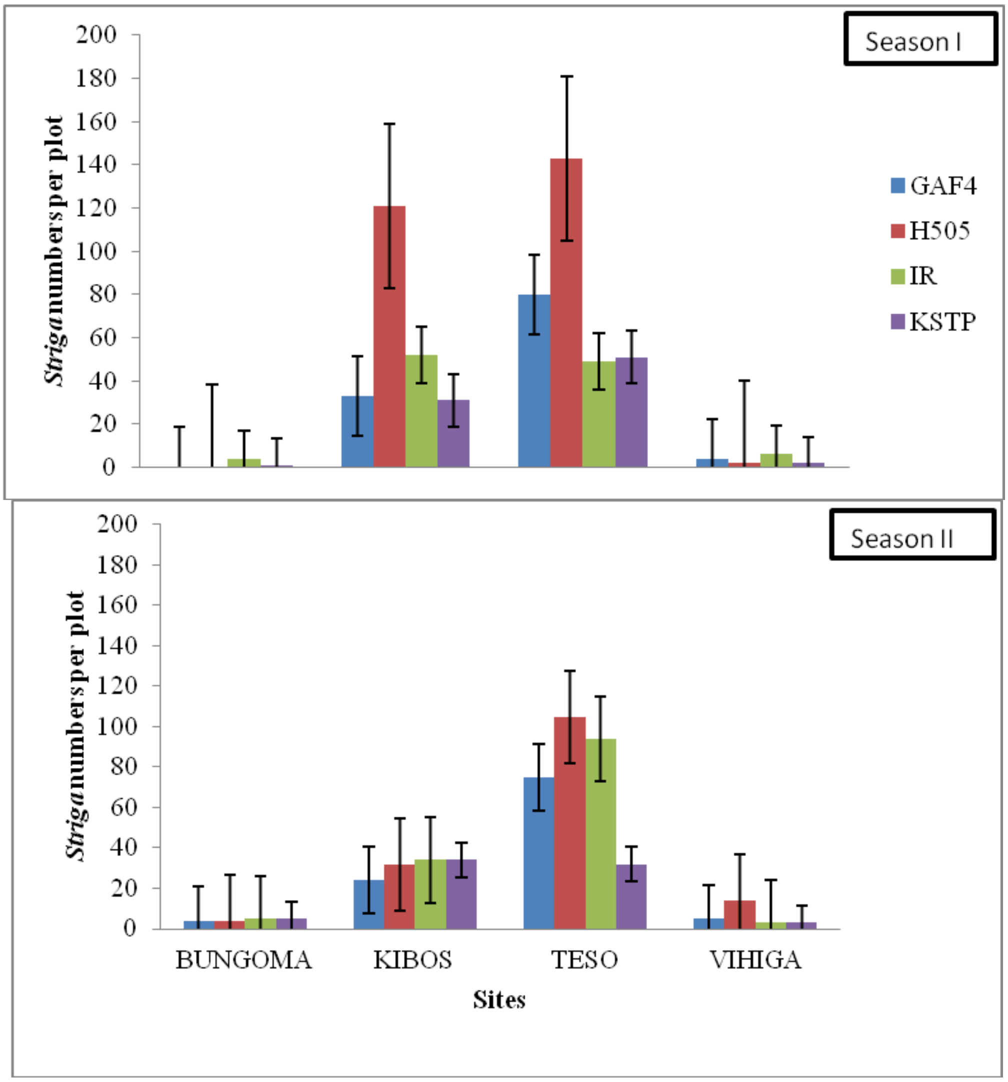

Fig.2 *Striga* numbers in the sites with the maize varieties at 14 weeks after planting for Seasons I (Long rains 2012) and Season II (Short rains 2012).Error bars represent standard error (SE) of means.

Season I had significantly higher *Striga* numbers than season II with means of 36 and 29 respectively. Bungoma and Vihiga had very low counts of *Striga* (Appendix 1). Teso had the highest count in both seasons. Vihiga had a higher number of Striga than Bungoma (Fig 2).

H505 had the highest *Striga* numbers in seasons I for Teso and Kibos compared to other varieties. In season II, there was no significant difference in all maize varieties in all sites, except Teso that had significantly low striga numbers in KSTP94. *Striga* numbers in GAF4, IR maize and KSTP94 were not significantly different in both seasons, except for KSTP that had lower *Striga* numbers in Teso in Season II (Fig 2). For all the maize varieties used, there was a general reduction in *Striga* numbers from season I to season II.

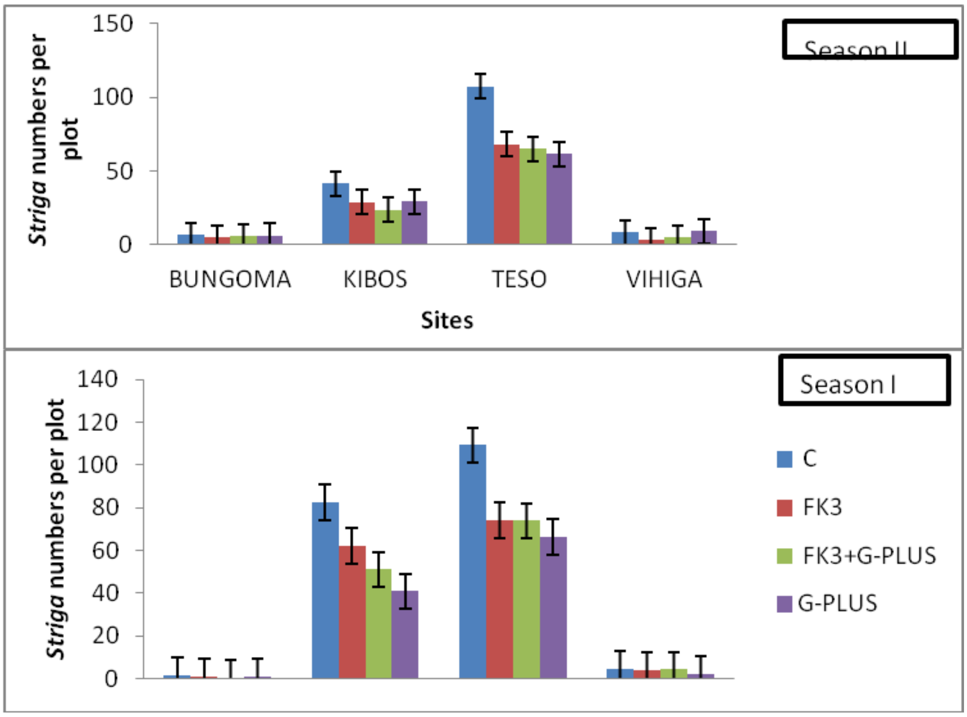

Fig 3. *Striga* numbers in the sites with maize varieties coated with the agents at 14 weeks after planting maize for Season I (Long rains 2012) and Season II (Short rains 2012). Error bars represent standard error (SE) of means.

Season I had significantly higher *Striga* counts than season II in Kibos and Teso. While counts in Teso were similar, in season I, Kibos had significantly higher *Striga* count compared to season II. The other two sites, Vihiga and Bungoma had very low counts in both seasons (Fig 3). The coatings had significantly lower *Striga* counts. Gro-plus had the lowest *Striga* counts in both seasons (Fig 3).

When *Striga* emergence in the sites was compared weekly, *Striga* was more prominent in week 6 in Kibos and Teso, while in Vihiga and Bungoma, emergence was more from weeks 8 and 10 after planting maize (Fig 4). H505 had the highest *Striga* emergence in Kibos for season I, and Teso in both seasons I and II. KSTP94 had the lowest striga emergence. In season II however, Kibos site showed inconsistency in *Striga* response to maize varieties. Maize varietal differences in *Striga* emergence was also not consistent in Bungoma and Vihiga.

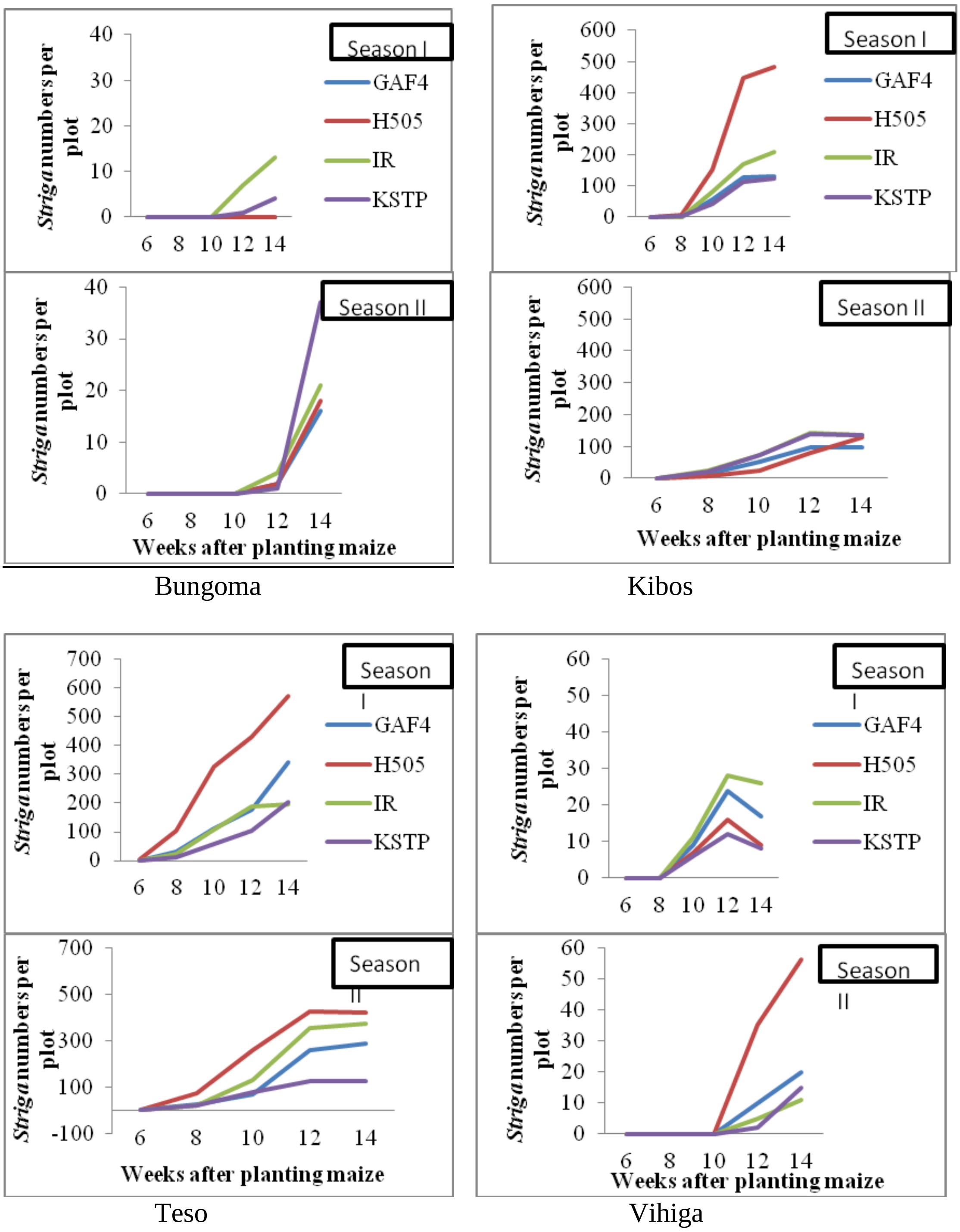

Fig 4. *Striga* emergence during the 14 weeks of maize growth in short rains (Season I) and Long rains (Season II)(For maize varieties).

Gro-plus had the lowest *Striga* emergence in the two sites, except in season II in Kibos which had Gro-plus+Foxy FK3 with the lowest emergence. *Striga* emergence was highest in the control treatment in Teso and Kibos in the two seasons compared to the other coatings. In Vihiga and Bungoma however, there was no trend in the effect of seed coatings on Striga emergence as all coatings were exhibiting very different responses (Fig 5).

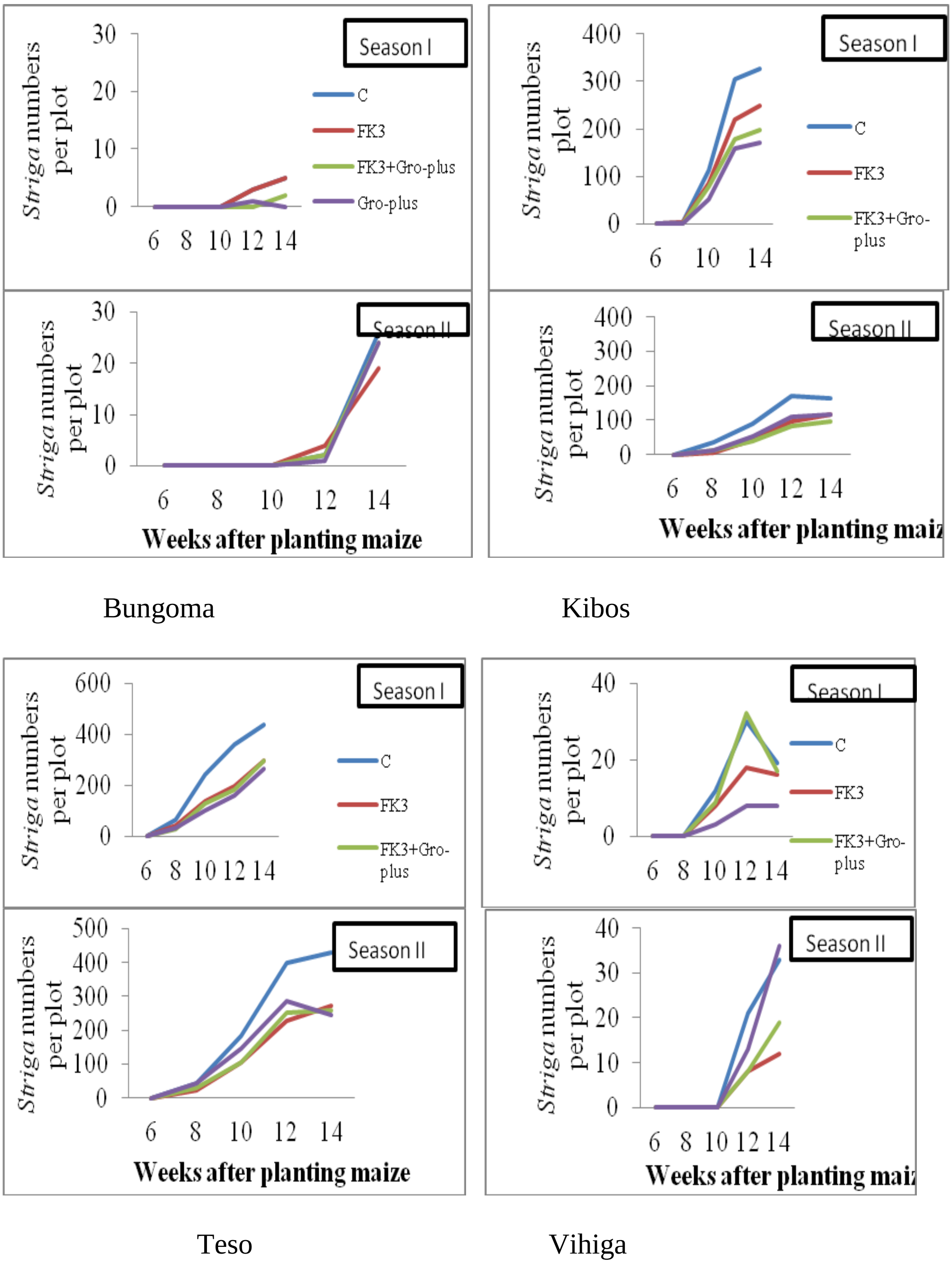

Fig 5. ***Striga*** **emergence during the 14 weeks of maize growth in the two seasons, short rains (Season I) and Long rains (Season II) (For seed coatings).**

There was a significant difference of *Striga* biomass ($P<0.05$) from season I to season II in both Teso and Kibos sites. Teso had significantly higher *Striga* biomass compared to Kibos in season I but in season II the biomass in the two sites was not significantly different (Fig 6,7, Appendix 2). This was in both maize varieties and seed coatings. The varieties and coatings performed differently between and within the sites. There was however a general trend between the sites where all the varieties and seed coatings either decreased or increased when the sites were compared to each other. There was no significant difference ($P>0.05$) in *Striga* biomass in seed coatings on the different maize varieties (Appendix 2). In Vihiga and Bungoma, only traces of *Striga* biomass observed (Appendix 2)

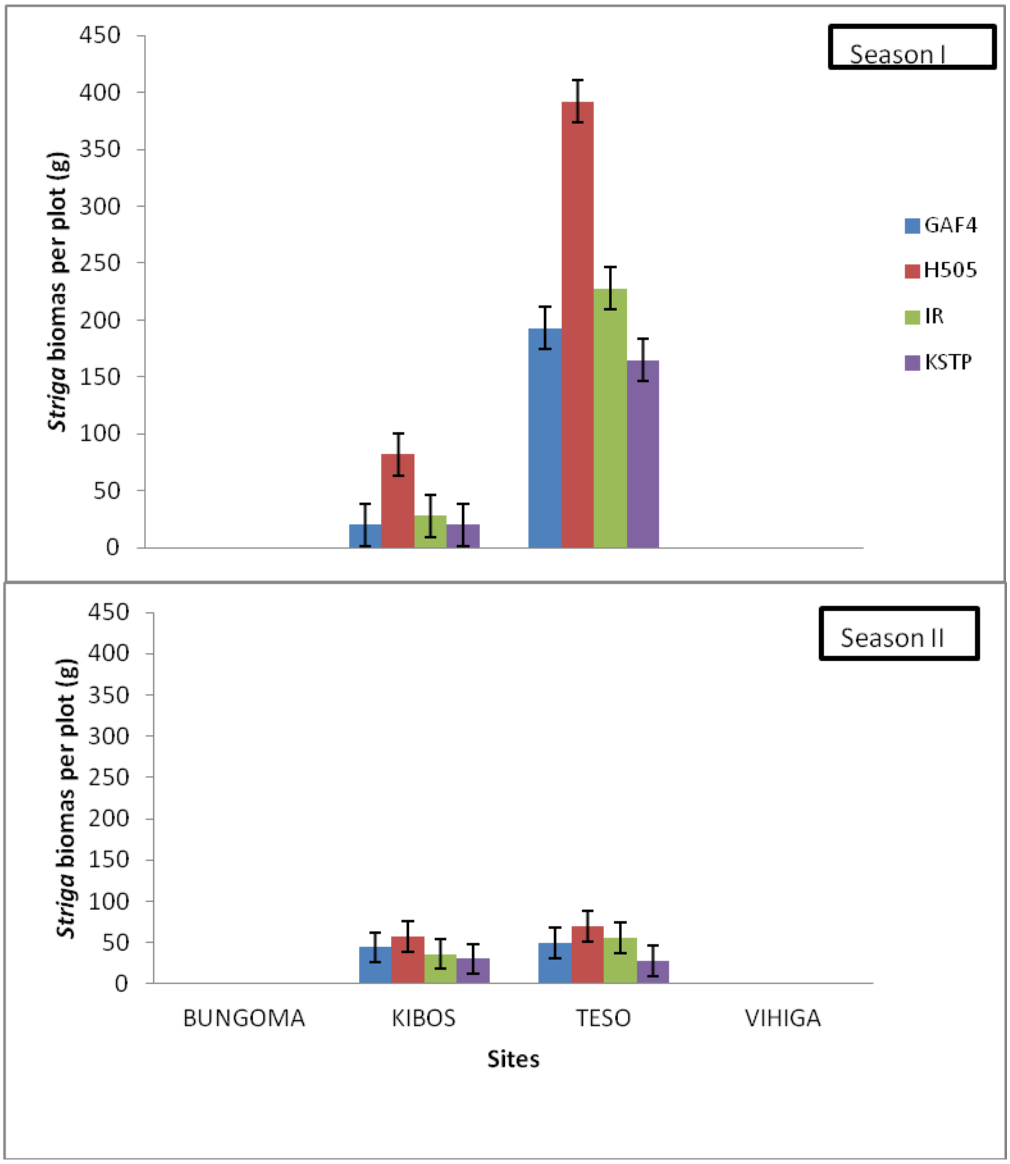

Fig.6. ***Striga*** **biomass in the sites with the maize varieties at 14 weeks after planting in the two seasons, Short rains (season I) and Long rains (Season II). Error bars represent standard error (SE) of means.**

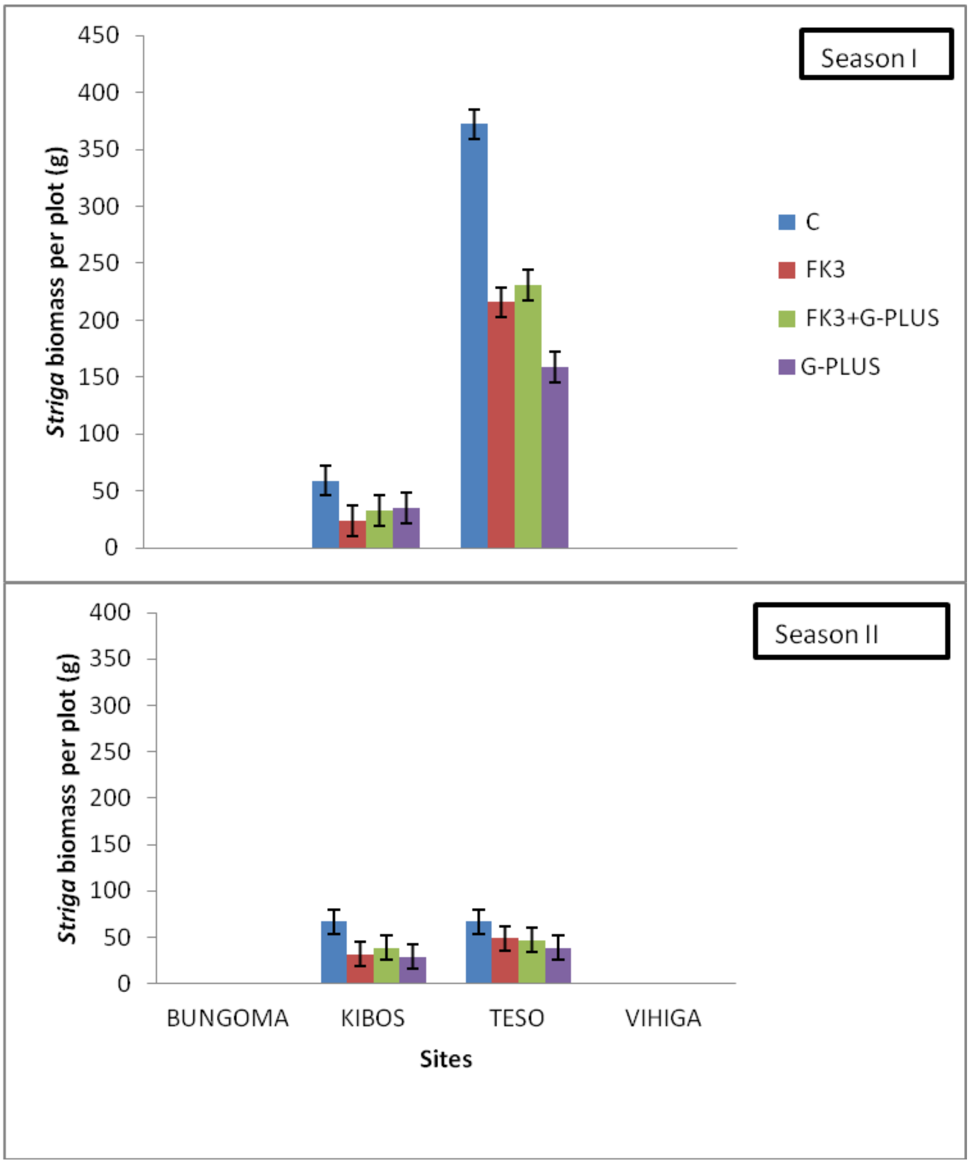

Fig 7. *Striga* biomass in the sites with maize varieties coated with the agents for Season I (Long rains 2012) and Season II (Short rains 2012). Error bars represent standard error (SE) of means.

H505 had the highest *Striga* biomass in season I in both Kibos and Teso, with KSTP94 having the lowest (Fig. 6). In season II, there was no significant difference in *Striga* biomass in all the maize varieties . The control had the highest *Striga* biomass in Teso and Kibos in both seasons I and II (Fig 7). *Foxy* FK3, Foxy FK3 + Gro-plus and Gro-plus were not significantly different in *Striga* biomass, except for season I in Teso where Gro-plus had significantly lower biomass compared to Foxy FK3 and *Foxy* FK3+Gro plus.

4.3 Effect of Seed coatings on maize plant heights at weeks 6, and 10 after planting maize and at harvest.

The average plant heights were higher for Season I compared to season II. There was no significant difference in plant heights between the seed coatings used and the maize varieties (Appendices 3,4,5). Sites showed varying degrees of plant heights in the two seasons. Kibos and Vihiga had the highest plant heights in season I. In season II however, Kibos and Teso had the highest plant heights.

4.4 Effect of Seed coatings of the different maize varieties on Maize grain yield and biomass.

4.4.1 Effect of Seed coatings of the different maize varieties on maize grain yield.

There was a significant ($P<0.05$) decrease in maize grain yield in season II compared to season I with yields dropping from 3.7 tons/ha to 1.6 tons/ha (Appendix 6)

KSTP94 had the highest maize grain yield in all the sites in season I and II except in Bungoma in Season II where yields were highest in GAF4. IR maize and H505 had the lowest maize grain yield in all the sites both in Seasons I and II, except in Kibos in season I where IR had high yields. (Fig 8.)

The control plot had significantly low yields across the two seasons when compared to *Foxy* FK3, *Foxy* FK3+Gro-plus and Gro-plus (Fig 9, Appendix 6). Gro-plus coated maize had the highest yields (Fig 9).

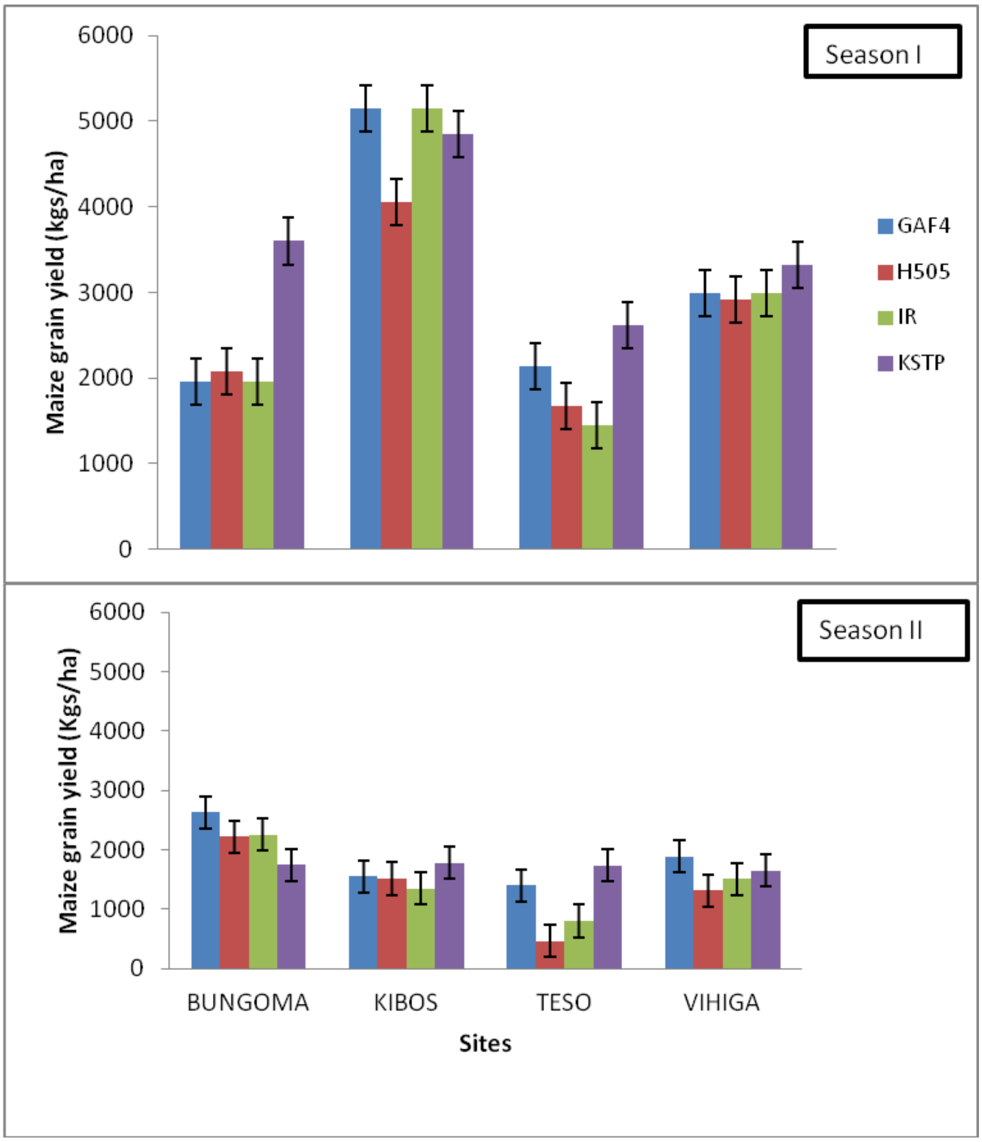

Fig.8. Maize grain yield (Kg/ha) in the sites with the maize varieties for the two seasons, Short rains (Season I) and Long rains (Season II). Error bars represent standard error (SE) of means.

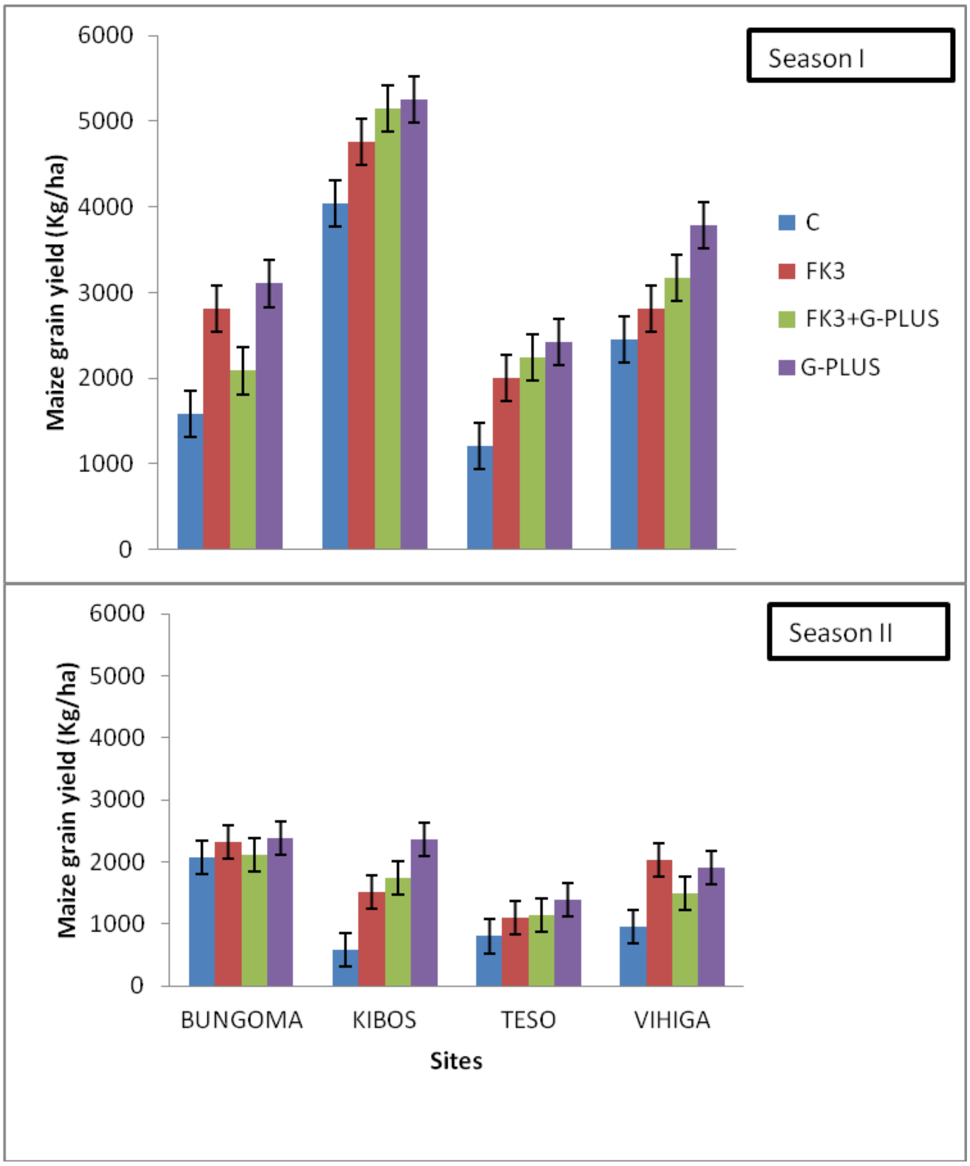

Fig.9. Maize grain yield (Kg/ha) in the sites with the maize seed coatings on the varieties for the two seasons, Short rains (Season I) and Long rains (Season II). Error bars represent standard error (SE) of means.

4.4.2 Effect of Seed coatings of the different maize varieties on maize biomass.

Maize biomass was significantly (P<0.05) higher for season II than season I (Fig 10, Appendix 7). Kibos site had the highest biomass in both seasons, followed by Bungoma, Vihiga then Teso respectively. . There was no significant (P>0.05) difference in maize biomass between the seed coatings used on the different maize varieties.

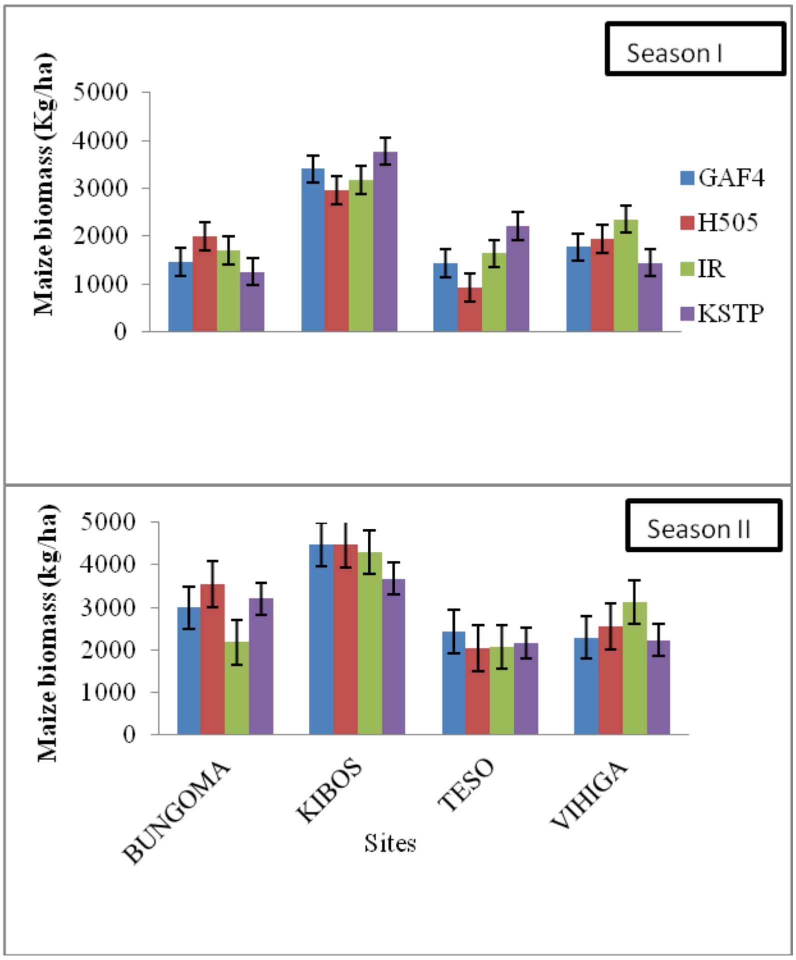

Fig.10. Maize biomass (Kg/ha) of the varieties in the sites for the two seasons, Short rains (Season I) and Long rains (Season II). sError bars represent standard error (SE) of means.

KSTP94 had the highest maize biomass while H505 had the lowest in season I in Kibos and Teso. In season II however, there was no significant difference between the maize varieties in terms of biomass in the two sites (Fig 10). Maize biomass trend in Bungoma and Vihiga showed no consistency , where biomass was highest in H505 and lowest in IR maize while Vihiga had IR maize with the highest biomass and KSPT94 and GAF4 having the lowest.

In both seasons, maize biomass was highest in Kibos. Gro-plus coating had the highest biomass in Kibos and Teso in both seasons (Fig 11). The control had the lowest maize biomass in both seasons in all the sites except for season I in Vihiga where there was no significant difference in all the seed coatings. In Bungoma and Vihiga however, there was no significant difference between the seed coatings, except in Vihiga where the control seed coat had the lowest biomass compared to the other seed coatings. The difference was observed only when the coatings were compared to each other. This therefore meant that the coating effect was not dependant on the maize varieties.

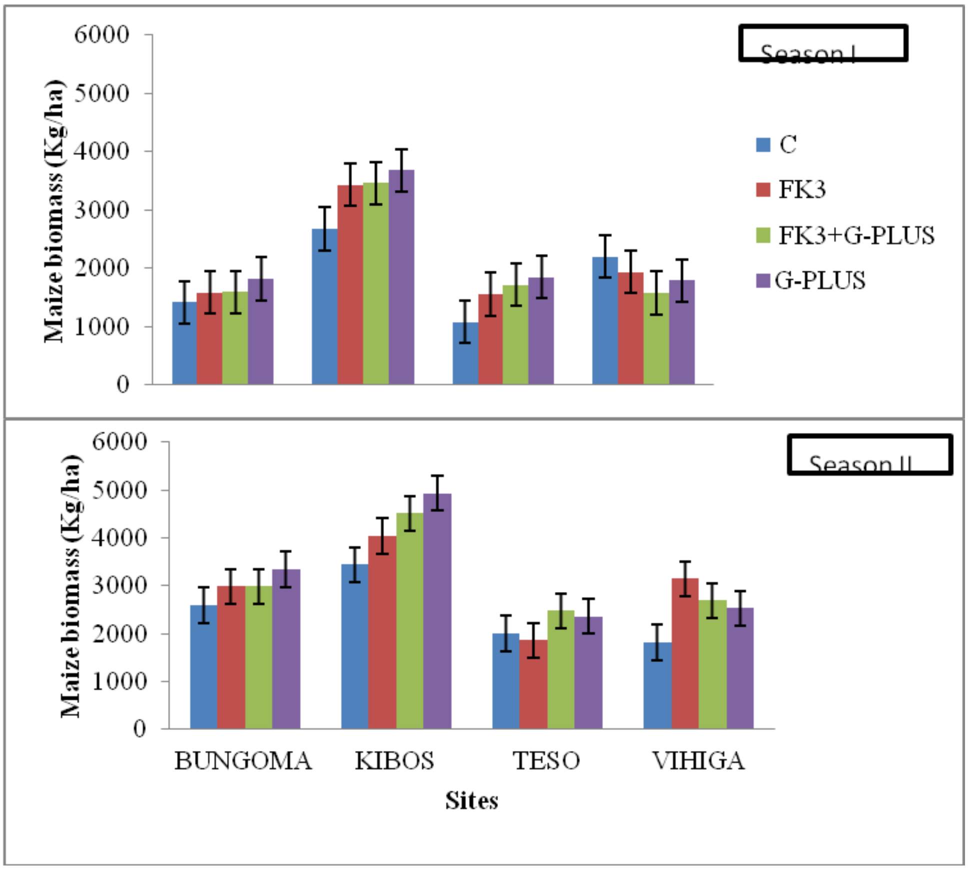

Fig.11. Maize biomass (Kg/ha) of the varieties with the seed coatings in the sites for the two seasons, Short rains (Season I) and Long rains (Season II). Error bars represent standard error (SE) of means.

4.5.0 Effect of treatment combinations on Soya beans yield (Kga/ha).

Soya grain yield was generally higher in Season I than in season II. The soya intercrops on the different maize varieties with coatings did not show significant difference in grain yield of soya. The different sites however showed significant difference in soya beans grain yield. In both seasons I and II, yields were highest in Kibos and Vihiga, compared to Teso and Bungoma (Appendix 8).

4.6.0 Economic analysis

The partial budget developed showed that the net benefits from each of the treatment combinations varied considerably (Table 2) with the highest being H505 coated with Gro-plus and the lowest being H505 without seed coating agent.

Table 2. Partial budget showing costs that vary and net benefits for each of the treatment combinations.

Treatments	K C	K FK3	K FK3+Gro	K Gro	IR C	IR FK3	IR FK3+G	IR Gro	G C	G FK3	G FK3+G	G Gro	H C	H FK3	H FK3+Gr	H Gro
Average yield of maize (kgs/ha)	1868	3105	2552	3130	1581	2116	2378	2650	2003	2402	2603	2852	1388	2043	2026	2665
Average adjusted yield of maize (kgs/ha)	1681	2795	2297	2817	1423	1904	2385	2140	1803	2162	2343	2567	1249	1839	1823	2399
Yield*Price for maize (ksh25/kg)	**42033**	**69863**	**57420**	**70425**	**35573**	**47610**	**59625**	**53505**	**45068**	**54045**	**58568**	**64170**	**31230**	**45968**	**45585**	**59963**
Average yield of Soya beans (kgs/ha)	596	597	558	534	563	574	615	554	564	577	581	565	578	593	573	588
Average adjusted yield of soya beans (kgs/ha)	536	537	503	481	507	516	554	499	508	520	523	508	520	533	516	530
Yields*price of soya beans (Ksh 55/kg)	**29498**	**29558**	**27645**	**26437**	**27865**	**28403**	**30443**	**27425**	**27940**	**28574**	**28755**	**27966**	**28620**	**29338**	**28387**	**29128**
Gross field Benefits for maize and soya (Ksh/ha)	**71531**	**99421**	**85065**	**96862**	**63437**	**76013**	**90068**	**80930**	**73008**	**82619**	**87322**	**92136**	**59850**	**75306**	**73972**	**89091**
Costs that vary																
Cost of maize seed	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
Cost of seed coat	0	1500	3000	1500	0	1500	3000	1500	0	1500	3000	1500	0	1500	3000	1500
Cost of soya beans seed (55/kg)	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Cost of labour to apply coat	0	200	200	200	0	200	200	200	0	200	200	200	0	200	200	200
Cost of fertilizer 126kg TSP	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340	11340
Cost of fertilizer 288kg CAN	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280	17280
Fertilizer and seed transport	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Planting	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Weeding	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Total Cost that varies (TCV)	**41925**	**43625**	**45125**	**43625**	**41925**	**43625**	**45125**	**43625**	**41925**	**43625**	**45125**	**43625**	**41925**	**43625**	**45125**	**43625**
Net benefit (Ksh/ha)(GFB-TCV)	29606	55796	39940	53237	21512	32388	44943	37305	31083	38994	42197	48511	17925	31681	28847	45466

KEY: K-KSTP94, IR-IR maize, G-GAF4, H-H505; For seed coatings C-Control, FK3- Foxy FK3, Gro-Gro-plus, FK3+Gro-Foxy FK3+Gro-plus

When the treatments were listed in order of their increasing gross benefit, the 'dominated' treatments eliminated from further consideration were H505 coated with Gro-plus+*Foxy* FK3 and IR maize coated with Gro-plus+*Foxy* FK3 (Appendix 9). The remaining treatment combinations were subjected to marginal analysis (Table 3).

Table 3. Marginal analysis showing how the net benefits from the treatments increased as the amount invested in the treatments increased.

Treatments	Gross benefit	Marginal cost	Net benefits	Marginal net benefits	Marginal rate of return
H505-C	59850		17925		
IR-C	63437	3587	21512	3587	100
KSTP-C	71531	8094	29606	8094	100
GAF4-C	73008	1477	31083	1477	100
H505-FK3	75306	2298	31681	598	26
IR-FK3	76013	708	32388	707	100
IR-Gro	80930	4917	37305	4917	100
GAF4-FK3	82619	1690	38994	1689	100
KSTP-FK3+Gro	85065	2446	39940	946	39
GAF4-FK3+Gro	87322	2257	42197	2257	100
H505-Gro	89091	1769	45466	3269	185
GAF4-Gro	92136	3045	48511	3045	100
KSTP-Gro	96862	4726	53237	4726	100
KSTP-FK3	99421	2558	55796	2559	100

The highest MRR was obtained in H505 coated with Gro-plus. The lowest MRR was obtained in H505 coated with Foxy FK3 (29%) and KSTP94 coated with FK3+Gro-plus (39%). All gro-plus coated seeds irrespective of the maize variety used had MRR of 100% (Table 3).

CHAPTER FIVE

DISCUSSION

5.1 Initial *Striga* soil bank

There was no relationship between *Striga* seed count and the fertility status of the soil. Kibos site was more fertile with high levels of Nitrogen, organic carbon and available phosphorus, compared to Teso which had low levels of the same nutrients, but the *Striga* numbers in the two sites was the same. Soil fertility status in Bungoma was the lowest, but *Striga* seeds were much less compared to Teso and Kibos. *Striga* seed bank is determined by the level of *Striga* plants that flower and produce seeds, coupled with lack of suicidal germination (Ejeta and Gressel, 2007). This is common in low fertility soils. If mitigation measures are not undertaken to prevent or reduce seed production, the weed will continue producing seeds and increase the seed soil bank irrespective of whether the soil is fertile or not. *Striga* seeds are also disseminated through various mechanisms which include: runoff water from *Striga* infested fields which carries them in creeks and rivers and thereafter deposits them on farm plots; seeds eaten by animals and pass through the digestive tracts undamaged, and are later spread through animal droppings; seeds sticking on shoes and clothes, muddy soil and farm tools; and contaminants of planting seeds (Woomer and Savala, 2008). These activities would lead to an increase in *Striga* seed soil bank in areas where the seeds have been deposited irrespective of the soil fertility status in the areas. This would therefore explain the inconsistent relationship between soil fertility and *Striga* seeds in the soil bank. Kibos is a Striga research site that has been constantly inoculated with Striga seeds over the years, and therefore despite the area being fertile, the incidences of *Striga* seeds in the soil seed bank was high.

5.2 *Striga* numbers and biomass

The high *Striga* numbers in Kibos and Teso sites can be attributed to the high initial *Striga* seed soil bank in the two sites (Table 1). This high *Striga* seed bank enabled more *Striga* to emerge as compared to emergence from low *Striga* seed soil bank. Teso however had significantly higher number of *Striga* in season II compared to Kibos . This could be due to the lower soil fertility status in Teso compared to Kibos. *Striga* thrives well in less fertile soils. Bungoma and Vihiga which had very low initial average *Striga* seed in the soil bank also had low *Striga* numbers.

The high *Striga* numbers in H505 was due to its susceptibility to the weed. H505 does not have a defence mechanism against the weed, hence *Striga* easily attaches itself on the maize plants. The low number of *Striga* in KSTP94 and GAF4 could be due to their ability to show some levels of resistance to the weed, which reduced the extent of severity of the *Striga* level. This is supported by a baseline study carried out by Ndwiga *et al*., (2013) looking at the extent of *Striga* infestation on maize grown in Western and Nyanza provinces. For the farmers who grew open pollinated varieties of which KSTP94, GAF4 and IR maize are part of, a low percentage of farmers (28.6% from western and 0% from Nyanza) said that *Striga* infestation was severe in their farms. For hybrid maize, a higher proportion (43.7% from Western and 47.8% from Nyanza) had severe *Striga* infestation in their farms. IR maize has *imazapyr* herbicide that kills the *Striga* when it comes into contact with it, hence the low *Striga* numbers. In season II, maize varieties in Kibos did not show a significant difference in terms of *Striga* numbers. This could be due to the low *Striga* numbers in the site, compared to Teso. There was however more *Striga* numbers in season II in IR maize plots compared to season I. The high *Striga* numbers in IR maize in season II could be due to the development of resistance from *imazapyr* by subsequent *Striga* that emerged in the second generation *Striga* that was not killed by the herbicide (Ejeta and Gressel, 2007).

In terms of seed coatings, Gro-plus, *Foxy* FK3 and their combinations played a role in reducing *Striga* numbers compared to the control. *Foxy* FK3 acts by killing *Striga* seeds while still in the soil and also infects the *Striga* before it emerges from the soil thereby reducing the number of emerged *Striga*.

This was supported by Venne *et al*., (2008) who carried out research on use of *Fusarium oxysporum Foxy 2* on resistant maize varieties. They concluded that synergistic effects between the *Striga*-resistant maize line and *Fusarium oxysporum* f. sp *Strigae* led to over 90% reduction in *Striga* emergence.

Yonli *et al*., (2012) experimenting on the use of *Fusarium oxysporum* inoculum 34-FO in management of *Striga* in sorghum also showed that there was more than 79% reduction in *Striga* emergence when the bio-control was used. Results from the present study showed that there was a 69% reduction in *Striga* numbers when Foxy FK3 treated seeds were compared to the control with Striga numbers 31and 45 respectively (Appendix 1).

The low *Striga* numbers in Gro-plus was due to the work of phosphorus, which is contained in the seed coatings agent. Phosphorus has the ability to reduce strigolactones release and therefore reducing the stimulation of *Striga* germination (Yoneyama *et al*., 2012). Gro plus also contains potassium (K) that has been shown to reduce *Striga* emergence (Ekeleme *et al*., 2013). This finding however is contrary to studies carried out by Ekelema *et al*., (2013) on sorghum who concluded that phosphorus leads to promotion of *Striga* population through the ability of phosphorus to increase root volume in cereals which increases the contact with *Striga* seeds hence increasing germination of the weed. The combination of *Foxy* FK3 and Gro-plus in *Striga* suppression could be due to the combined effect of two *Striga* management technologies. This is supported by the evidence that the control plots had high incidences of *Striga*.

Striga emergence was more prominent in Kibos and Teso early in week 6 (Fig 4,5). This could be due to the high number of *Striga* seeds in th soil bank (Table 1), compared to Vihiga and Bungoma where *Striga* emergence was later from weeks 8 and 10 after planting maize. The inconsistency in *Striga* emergence when the maize varieties were compared in Bungoma and Vihiga in both seasons could be due to the low Striga numbers in the two sites as seen in the low Striga seed soil band (Table 1) and the low Striga emergence when the numbers were counted at week 14 (Fig 2,3). For Kibos however, the inconsistency in Striga emergence in season II could be due to the fact that only a small number of Striga emerged, as was seen in the final Striga counts at week 14. (Fig 2, 3).

The reduction in *Striga* biomass in season I compared to season II in both Teso and Kibos sites could be due to the reduction in *Striga* numbers in season I. The higher *Striga* biomass in Teso could be due to the low soil fertility status of the site compared to Kibos. *Striga* thrives well in soils with poor fertility. All the four sites had soils that had nitrogen and carbon contents that were within the moderate range, 0.12%-0.25% N and 1.5%-3.0% C (Okalebo *et al*., 2002). The values for the different sites however differed within that range, with Kibos having the higher N and C compared to Teso (Table 1). With regard to extractable phosphorus, crop response to phosphate fertilizer has been observed in soils where P test levels are below 10 mg P kg^{-1} soil. All the sites had P levels that were below 10 mg P kg^{-1} soil, but the trend was still similar with the highest levels among the sites observed in Kibos and the lowest in Bungoma (Table 1). The table gives an indication of the high available P, Nitrogen and organic carbon in Kibos compared to Teso, especially when Striga numbers were high.

H505 is a *Striga* susceptible maize variety and is easily attacked by Striga when in high quantities, as was seen in Teso and Kibos in season I. Seed coatings on KSTP94 had the lowest *Striga* biomass which was also due to the low *Striga* numbers in the variety.

The low biomass in Foxy FK3 could be due to the low number of *Striga* in the treatment. Foxy FK3 acts by infeccting the *Striga* with *Fusarium oxysporum* fungus that causes a disease that leads to the reduction in biomass of the *Striga* plants. Venne *et al*., (2008) used pesta formulation of PSM197, a *Fusarium oxysporum* isolate, on maize seeds and reported a reduction of 89 and 69% in *Striga* biomass within the maize crops in Benin and Burkina Faso respectively. He also showed that *Foxy* 2 reduced *Striga* biomass by 56 and 76% when compared to the control. The reduction in *Striga* biomass in Gro-plus seed coating treatment could be due to the reduction in *Striga* numbers caused about by the reduction in strigolactones production. The seed coating with *Foxy* FK3+Gro-plus did not outperform individual seed coating agents *Foxy* FK3 and Gro-plus. There seemed to be no synergy when the two were used.

5.3 Effect of Seed coatings on the performance of maize varieties.

Maize performed better in terms of growth and yields in the long rains (Season I) compared to the short rains (Season II), and therefore the higher plant heights in season I. The difference in plant heights in the sites could be due to the varying soil fertility status in the four sites. The high plant heights in season I in Kibos and Vihiga was because of the high soil fertility status in terms of available P, %N and % C (Table 1) that led to improved growth and development of the plants. In season II, Teso surpassed Vihiga in plant heights. The higher plant heights in Teso compared to Vihiga could be partly due to the lower *Striga* numbers in the second season in Teso that did not adversely affect the nutrient absorption status of the crops. Vihiga had been affected by Maize Lethal Necrotic disease in season II (25%), which led to reduction in growth of the maize plant, therefore it could also be a reason for the lower plant height in the season.

The high maize grain yield in KSTP94 could be due to the very low *Striga* numbers and biomass observed in the variety. For season II in Bungoma, there were more *Striga* numbers in KSTP94 compared to GAF4 which could have contributed to the reduction in yields in KSTP94. IR maize and H505 had the highest *Striga* numbers and biomass which affected the maize plants hence the low yields in the two varieties. When the control was compared to the other coatings, it was found to have low maize yields. The lower maize yield was due to the high *Striga* numbers and biomass that affects the grain yield of maize. *Striga* attaches itself to the roots of host plants and siphons the nutrients and water intended for plant growth. The highest maize grain yield in Gro-plus treated maize was because of the many roles Gro-plus plays in improving the grain yield of crops. It reduces *Striga* emergence and attachment ability on the maize plants through strigolactones suppression through the phosphorus contained in it. Gro-plus is a fertilizer seed coating. It has the advantage over mixing fertilizer with seeds in the same hole when planting due to the high concentration of seed nutrients that may be easily raised after firmly coating seed. The release of phosphorus from fertilizer coated seed is much closer to plant root rather than when fertilizer is mixed with seed before planting. This therefore helps improve crop yields. Besides, high concentration of seed nutrients are important for plant establishment in the soil which is low in nutrient availability, as a massive root system is needed to supply sufficient nutrients to meet the needs of plants (Fukuda *et al*., 2012). The Gro-plus treatments therefore had higher maize grain yields compared to the other treatments.

The increase in maize biomass in season II was due to a decrease in *Striga* numbers compared to season I. This led to less nutrients being absorbed by the *Striga* hence an increase in maize biomass. This is because maize is an exhaustive crop and has higher potential than other cereals. It absorbs large quantity of nutrients from the soil during different growth stages, and among the essential nutrients are phosphorus and nitrogen, which are important nutrients for higher yield in larger quantities. These nutrients control the reproductive growth of the plant. They are needed for utilization of sugar and starch, nucleus formation, cell division, photosynthesis, starch, fat and albumen formation apart from providing energy for metabolism of carbohydrates (Masood *et al*., 2011). If the nutrients have been utilized by *Striga*, then the size of the maize is reduced.

Kibos site still had the highest maize biomass compared to the other sites, which was because of the high soil fertility status of the site. Vihiga had the second highest maize biomass in season I, but in season II, the biomass was lower than that for Bungoma. This was attributed to the incidence of Maize lethal necrotic disease virus that affected the site during this period. The high maize biomass in KSTP94 in Teso and Kibos was due to lower striga plants attacking the variety, and its tolerance nature that reduced the ability of the Striga attacking the plant and utilizing its nutrients. H505 had low biomass because of its susceptibility to parasitisation by *Striga*. In season II, there was generally lower striga numbers, therefore less striga attack on the maize. The varietal effect of the tolerance or susceptibility of the maize to striga was therefore not clearly visible. Gro-plus coated maize had the highest biomass due to the adequate plant establishment brought about by the presence of phosphorus contained in the coating agent. The low Striga plants in the Gro-plus treated maize also contributes to a reduction in parasitisation and nutrient absorption by the striga, when compared to the maize plants which were not coated.

5.5 Effect of treatment combinations on Soya beans yield (Kga/ha).

The yield of Soya beans was dependent on soil fertility status of the sites and not on the maize varieties nor seed treatment combinations. The high yields obtained in Kibos and Vihiga in both seasons I and II was due to the high soil fertility status in the two sites (Table 1). The high soya beans yields in season I compared to season II was due to the long rains effect in season I that is associated with high yields because of the adequate water volumes necessary for improved growth of the crops and ultimately yields. Within the seasons, there was no significant difference ($P>0.05$) in soya beans yields in all treatment combinations, which could be because there was no additional treatments done on the soya beans seeds that were planted which could have altered the yields. Maize plant heights was not significantly different (P>0.05) in all the treatment combinations (Appendices 3,4,5). This therefore ensured relative uniformity in shading effect on soya beans in all treatment combinations, since it reduced the differing spatial and temporal use of radiation (Solanki *et al*., 2011), which could explain the soya beans yields not differing significantly in all treatment combinations. Woomer and Tungani, (2003) carried out an experiment in western Kenya to characterize the penetration of solar radiation into the canopy of different maize-bean intercropping systems. Their findings suggested that light availability to the legume understory is independently managed through the staggered row arrangement of MBILI and the direction of its rows and that these two factors interact with the direction of the sun throughout the day, as opposed to the conventional intercrop system. Furthermore, the effects of MBILI technology are obtained regardless of the row orientation.

5.6.0 Economic analysis

Adopting the integrated technologies would lead to highest returns especially seed coating on H505 which had a marginal rate of return (MRR) of 185%. H505 maize without seed coating (Control) and that with Foxy FK3 coating is not a viable option because of the low MRR of 26%. Combination of Foxy FK3+Gro plus in KSTP94 also had low MRR (39%) and was therefore not viable for farmers to adopt. All Gro-plus seed coatings irrespective of the maize variety had 100%MRR, which meant that farmers would benefit from the adoption of the integrated technology using the seed coating. This study is in tandem with studies carried out by De Groote *et al*.,(2010) on economic analysis on options in integrated pest and soil fertility management.

They asessed the use of “push-pull,” rotations with promiscuous soybean varieties and green manure crops, and imidazolinone resistant- (IR-) maize both with and without fertilizer through on-farm research in six seasons in Siaya and Vihiga. They concluded that Push-pull is more profitable but requires a relatively high initial investment cost. Green manure, rotation and fertilizer use increased yields, but the investments were generally not justified by their increased revenue. IR maize was more profitable than the local varieties, although yields were still low. Maize soya bean rotation was found to be an ecomonic viable option, in the same study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

1. *Striga* thrives well in areas with poor soil fertility, but if *Striga* seeds are available in soil seed bank in fertile soils, *Striga* emergence will still be observed. The yields in fertile soils with high *Striga* numbers was however be higher than in less fertile soils. The weed emerges later in the season in areas where the soil seed bank is low in *Striga*. There is also more *Striga* emergence during the long rains (Season I) compared to the short rains (Season II).
2. H505 maize was more susceptible to *Striga* compared to KSTP94, GAF4 and IR maize. *Striga* numbers and biomass was high in H505, which led to low maize grain yields in the variety. IR maize did not outperform GAF4 and KSTP94 as it had more *Striga* numbers and biomass. KSTP94 had the lowest *Striga* numbers and biomass, and was the highest yielding in terms of maize grain yield. When *Striga* numbers are low however, maize varieties H505, KSTP94, IR and GAF4 do not show any significant difference in *Striga* numbers and *Striga* biomass.
3. The seed coatings used: *Foxy* FK3, Gro-plus and *Foxy* FK3+Gro-plus showed consistency in performance in the two seasons and in all the maize varieties, rendering the applicability of the seed coating technology in any maize variety worthwhile, but it was limited to areas where *Striga* numbers were relatively high, as there was no consistency in areas with low *Striga* numbers. Gro-plus seed coating had the highest yield across all the maize varieties compared to the other seed coatings. *Striga* numbers and biomass was also low in the Gro-plus coated seeds. *Foxy* FK3+gro plus however was not very effective in

managing *Striga* and increasing maize grain yield, when compared to *Foxy* FK3 and Gro-plus used separately. The combination was also not viable considering the low marginal rate of return obtained in the containing treatment combinations.

4. Yields of soya were only affected by the seasonal and site variation, and not by the maize variety seed coating combinations. The site variation in terms of soil fertility played a key role in soya beans grain yield. High yields were obtained in sites with high soil fertility status, as determined by the initial soil analysis of the sites. Long rain season (Season I) had higher soya beans grain yield compared to short rains season (Season II).
5. KSTP94 maize variety coated with Gro-plus in the MBILI maize soya intercrop had the highest maize grain yield. It also had the lowest *Striga* numbers and biomass.
6. On average, all maize varieties coated with Gro-plus and *Foxy* FK3 had high economic benefits to farmers. The highest economic benefit with MRR of 185% was however obtained when H505 was coated with Gro- plus. This was observed when a comparison was made with maize seeds that were not coated.

6.2 Recommendation

1. Single control strategies cannot effectively manage *Striga*. There is need to integrate several technologies to manage the weed. A combination of the use of tolerant or resistant maize varieties coated with either *Foxy* FK3 or Gro plus, and the maize grown in MBILI maize legume intercrop system is one viable option.

2. Farmers can coat any maize variety with Gro-plus or *Foxy* FK3 and be able to manage *Striga* and improve their yields. Hybrid maize can be coated with Gro-plus to realize high economic benefits to farmers in *Striga* prone areas.
3. Soil fertility plays an important role in *Striga* emergence. Farmers should therefore endeavour to improve their soil fertility status to reduce *Striga* infestation and improve their cereal yields.
4. Reducing the *Striga* seed soil bank is important as it will reduce the number of emerging Striga seedlings. This can be done through merging of *Striga* management technologies such as the seed coating technology. This coupled with hand weeding before the *Striga* flowers will held reduce the *Striga* seed population in the soil.
5. Further research needs to be done on the most appropriate rates of combining Gro-plus and *Foxy* FK3 as seed coating agents to manage *Striga* and improve maize grain yields.

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APPENDICES

Appendix I. *Striga* numbers at 14 weeks after planting.

Season	SITES	VARIETY	COATING				Mean (a)	Mean (b)	Mean (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	0	0	0	0	0	1	36
		H505	0	0	0	0	0		
		IR	3	5	2	5	4		
		KSTP94	4	0	0	0	1		
	KIBOS	GAF4	36	36	22	38	33	59	
		H505	187	114	109	73	121		
		IR	74	62	52	20	52		
		KSTP94	32	36	21	33	31		
	TESO	GAF4	105	92	55	69	80	81	
		H505	207	93	140	133	143		
		IR	49	75	40	33	49		
		KSTP94	76	36	61	31	51		
	VIHIGA	GAF4	5	6	5	1	4	4	
		H505	2	4	0	3	2		
		IR	12	5	5	4	6		
		KSTP94	0	1	7	0	2		
II	BUNGOMA	GAF4	2	4	3	7	4		29
		H505	4	1	7	6	4		
		IR	10	3	2	6	5		
		KSTP94	10	11	11	5	9	6	
	KIBOS	GAF4	21	24	20	32	24		
		H505	31	47	34	17	32		
		IR	52	31	21	30	34		
		KSTP94	62	14	20	38	34	31	
	TESO	GAF4	108	72	59	47	72	75	
		H505	132	103	90	94	105		
		IR	139	62	91	82	94		
		KSTP94	49	35	20	24	32		
	VIHIGA	GAF4	3	5	2	11	5	6	
		H505	18	5	13	20	14		
		IR	6	1	3	1	3		
		KSTP94	6	2	2	5	3		
MEAN			45	31	29	27	33	32.875	32.5

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	0.023	<.001	<.001	<.001	<.001	<.001	<.001	0.748	0.004
S.E	2.07	2.93	2.93	2.93	4.14	4.14	5.85	4.14	5.85
S.E.D	2.93	4.14	4.14	4.14	5.85	5.85	8.28	5.85	8.28

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probability	0.804	<.001	0.977	0.338	0.964	0.711
S.E	5.85	8.28	8.28	8.28	11.7	16.55
S.E.D	8.28	11.7	11.7	11.7	16.55	23.41
% C.V	87.1					

KEY: *Mean (a)- Average Striga numbers for each of the maize varieties.*

Mean (b)- Average Striga numbers for each of the sites in the 2 seasons.

Mean (c)-Average Striga numbers for season I (Long rains 2012) and season II (Short rains 2012).

Appendix II. *Striga* biomass (Dry matter weight) at 14 weeks after planting.

Season	Site	Varieties	COATING				MEAN (a)	MEAN (b)	Mean (C)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	Trace	Trace	Trace	Trace	Trace	Trace	71
		H505	Trace	Trace	Trace	Trace	Trace		
		IR	Trace	Trace	Trace	Trace	Trace		
		KSTP94	Trace	Trace	Trace	Trace	Trace		
	KIBOS	GAF4	28	20	20	12	20	38	
		H505	133	24	72	98	82		
		IR	48	26	24	13	28		
		KSTP94	26	24	14	17	20		
	TESO	GAF4	288	185	166	133	193	246	
		H505	523	334	390	322	392		
		IR	427	263	158	62	228		
		KSTP94	250	82	208	119	165		
	VIHIGA	GAF4	Trace	Trace	Trace	Trace	Trace	Trace	
		H505	Trace	Trace	Trace	Trace	Trace		
		IR	Trace	Trace	Trace	Trace	Trace		
		KSTP94	Trace	Trace	Trace	Trace	Trace		
II	BUNGOMA	GAF4	Trace	Trace	Trace	Trace	Trace	Trace	23
		H505	Trace	Trace	Trace	Trace	Trace		
		IR	Trace	Trace	Trace	Trace	Trace		
		KSTP94	Trace	Trace	Trace	Trace	Trace		
	KIBOS	GAF4	82	30	45	19	44	42	
		H505	100	27	51	50	57		
		IR	35	46	40	22	36		
		KSTP94	51	24	21	23	30		
	TESO	GAF4	69	51	35	41	49	51	
		H505	83	75	61	59	70		
		IR	79	43	65	36	56		
		KSTP94	37	26	26	21	28		
	VIHIGA	GAF4	Trace	Trace	Trace	Trace	Trace	Trace	
		H505	Trace	Trace	Trace	Trace	Trace		
		IR	Trace	Trace	Trace	Trace	Trace		
		KSTP94	Trace	Trace	Trace	Trace	Trace		
MEAN			71	40	44	33	47	47	47

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.063	< 0.001	0.11	< 0.001
S.E	4.6	6.5	6.5	6.5	9.3	9.3	13.1	9.3	13.1
S.E.D	6.5	9.3	9.3	9.3	13.1	13.1	18.5	13.1	18.5

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probability	0.976	< 0.001	0.014	0.936	0.998	0.992
S.E	13.1	18.5	18.5	18.5	26.2	37
S.E.D	18.5	26.2	26.2	26.2	37	52.4
% C.V	137.2					

KEY: *Mean (a)- Average Striga numbers for each of the maize varieties.*

Mean (b)- Average Striga numbers for each of the sites in the 2 seasons.

Mean (c)-Average Striga numbers for season I (Long rains 2012) and season II (Short rains 2012).

Appendix III. Plant heights at 6 weeks after planting maize.

Season	Site	Varieties	COATING Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus	Mean (a)	Mean (b)	Mean (c)
I	BUNGOMA	GAF4	37	41	38	44	40	42	65
		H505	31	41	46	48	42		
		IR	50	49	47	46	48		
		KSTP94	30	35	36	43	36		
	KIBOS	GAF4	112	102	90	103	102	102	
		H505	83	105	102	113	101		
		IR	86	94	83	94	89		
		KSTP94	115	119	122	104	115		
	TESO	GAF4	48	56	49	62	54	50	
		H505	54	50	56	47	52		
		IR	37	36	34	50	39		
		KSTP94	55	51	53	54	53		
	VIHIGA	GAF4	72	67	69	68	69	65	
		H505	66	67	65	68	67		
		IR	57	58	58	65	60		
		KSTP94	61	68	68	64	65		
II	BUNGOMA	GAF4	76	67	76	87	77	76	83
		H505	62	82	88	69	75		
		IR	84	97	93	91	91		
		KSTP94	62	60	55	65	60		
	KIBOS	GAF4	91	113	99	99	101	95	
		H505	81	94	96	87	90		
		IR	94	89	100	85	92		
		KSTP94	102	96	85	103	97		
	TESO	GAF4	55	60	68	71	63	64	
		H505	66	60	68	67	65		
		IR	58	55	56	63	58		
		KSTP94	70	64	70	70	69		
	VIHIGA	GAF4	74	81	106	97	89	97	
		H505	94	88	94	98	93		
		IR	110	129	107	112	115		
		KSTP94	95	99	81	85	90		
MEAN			71	74	74	76	74	74	

	Season (Se	Site (Si)	Variety (V	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
'. probabili	<. 0.001	<.0.001	0.945	0.342	<0.001	0.006	<.001	0.938	0.985
S.E	1.36	1.923	1.923	1.923	2.72	2.72	3.847	2.72	3.847
S.E.D	1.923	2.72	2.72	2.72	3.847	3.847	5.44	3.847	5.44

	V x C	Se x Si x '	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probabi	0.931	0.519	1	0.698	0.996	0.996
S.E	3.847	5.44	5.44	5.44	7.694	10.88
S.E.D	5.44	7.694	7.694	7.694	10.88	15.387
% C.V	25.6					

KEY: *Mean (a)- Average maize plant height for each of the four maize varieties.*

Mean (b)- Average maize plant height for each of the sites in the 2 seasons.

Mean (c)-Average maize plant height for season I (Long rains 2012) and season II (Short rains 2012).

Appendix IV . Plant height at 10 weeks after planting maize.

Season	Site	Varieties	COATING				mean (a)	Mean (b)	mean (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	129	149	139	158	144	149	173
		H505	145	152	146	154	149		
		IR	140	151	152	150	148		
		KSTP94	124	140	178	179	155		
	KIBOS	GAF4	193	207	189	220	202	196	
		H505	186	205	186	207	196		
		IR	186	191	175	166	180		
		KSTP94	214	199	204	202	205		
	TESO	GAF4	150	156	161	178	161	158	
		H505	131	136	128	158	138		
		IR	155	147	169	169	160		
		KSTP94	169	176	172	179	174		
	VIHIGA	GAF4	170	176	182	193	180	188	
		H505	184	195	191	200	192		
		IR	169	186	189	184	182		
		KSTP94	182	195	199	206	196		
II	BUNGOMA	GAF4	124	124	116	141	126	112	146.5
		H505	105	98	96	122	105		
		IR	108	116	118	108	112		
		KSTP94	92	102	113	113	105		
	KIBOS	GAF4	207	215	191	213	207	196	
		H505	199	199	193	197	197		
		IR	184	164	165	196	177		
		KSTP94	202	200	203	202	202		
	TESO	GAF4	134	125	160	140	140	150	
		H505	151	138	156	148	148		
		IR	133	136	146	148	141		
		KSTP94	177	161	163	178	170		
	VIHIGA	GAF4	108	117	136	134	124	128	
		H505	125	119	129	120	123		
		IR	142	147	142	142	143		
		KSTP94	132	130	106	113	120		
MEAN			155	158	159	166	159	159	159

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	< 0.001	< 0.001	0.055	0.059	< 0.001	0.607	0.02	0.533	0.787
S.E	2.1	3	3	3	4.2	4.2	5.9	4.2	5.9
S.E.D	3	4.2	4.2	4.2	5.9	5.9	8.4	5.9	8.4

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probability	0.984	0.189	0.994	0.973	0.998	1
S.E	5.9	8.4	8.4	8.4	11.9	16.8
S.E.D	8.4	11.9	11.9	11.9	16.8	23.8
% C.V	18.3					

KEY: *Mean (a)- Average maize plant height for each of the four maize varieties.*

Mean (b)- Average maize plant height for each of the sites in the 2 seasons.

Mean (c)-Average maize plant height for season I (Long rains 2012) and season II (Short rains 2012).

Appendix V. Plant height at harvest.

Season	Site	Varieties	COATING				Mean (a)	Mean (b)	Mean (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	126	110	108	114	114	118	169
		H505	104	151	116	113	121		
		IR	124	133	112	117	121		
		KSTP94	115	112	134	94	114		
	KIBOS	GAF4	267	271	258	261	264	246	
		H505	253	231	254	231	242		
		IR	234	225	252	242	238		
		KSTP94	244	245	236	235	240		
	TESO	GAF4	179	150	159	165	163	149	
		H505	122	137	135	138	133		
		IR	134	122	160	132	137		
		KSTP94	151	166	170	158	161		
	VIHIGA	GAF4	151	151	157	151	152	164	
		H505	167	177	139	157	160		
		IR	156	151	175	192	169		
		KSTP94	160	193	167	180	175		
II	BUNGOMA	GAF4	130	128	120	144	131	117	153
		H505	105	97	103	127	108		
		IR	114	118	128	113	118		
		KSTP94	97	106	121	120	111		
	KIBOS	GAF4	213	220	206	219	215	204	
		H505	208	209	201	208	207		
		IR	192	172	169	205	185		
		KSTP94	205	202	215	212	208		
	TESO	GAF4	140	135	172	146	148	157	
		H505	159	145	158	152	154		
		IR	142	142	148	155	147		
		KSTP94	180	179	177	187	180		
	VIHIGA	GAF4	111	124	143	145	131	134	
		H505	130	123	124	121	124		
		IR	154	154	152	148	152		
		KSTP94	143	134	115	118	128		
MEAN			160	160	162	162	161	161	161

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	<0.001	<0.001	0.102	0.881	<0.001	0.996	0.002	0.644	0.957
S.E	2.16	3.06	3.06	3.06	4.33	4.33	6.12	4.33	6.12
S.E.D	3.06	4.33	4.33	4.33	6.12	6.12	8.66	6.12	8.66

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probability	0.965	0.112	0.9	0.871	0.994	0.984
S.E	6.12	8.66	8.66	8.66	12.25	17.32
S.E.D	8.66	12.25	12.25	12.25	17.32	24.49
% C.V	18.3					

KEY: *Mean (a)- Average maize plant height for each of the four maize varieties.*

Mean (b)- Average maize plant height for each of the sites in the 2 seasons.

Mean (c)-Average maize plant height for season I (Long rains 2012) and season II (Short rains 2012).

Appendix VI. Maize grain yield (Kg/ha) for maize varieties with the different seed coatings for the four sites in seasons I and II.

Season	Site	Varieties	COATING				MEAN (a)	MEAN (b)	MEAN (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	1320	1988	2308	2231	1962	2397	3055
		H505	1763	2096	2349	2098	2077		
		IR	1497	1826	1863	2627	1953		
		KSTP94	1759	5353	1821	5461	3599		
	KIBOS	GAF4	4911	4931	5627	5113	5146	4801	
		H505	3074	4233	3979	4930	4054		
		IR	4528	5053	5383	5630	5149		
		KSTP94	3628	4813	5621	5355	4854		
	TESO	GAF4	1231	2226	2499	2603	2140	1965	
		H505	833	2249	1431	2170	1671		
		IR	745	1233	1998	1811	1447		
		KSTP94	2014	2319	3055	3079	2617		
	VIHIGA	GAF4	2165	2969	3364	3442	2985	3055	
		H505	3051	2653	2865	3106	2919		
		IR	1896	2468	3461	4126	2988		
		KSTP94	2718	3131	2980	4478	3327		
II	BUNGOMA	GAF4	2928	1663	2816	3143	2637	2214	1614
		H505	1631	1958	2011	3282	2220		
		IR	1808	2601	2103	2499	2252		
		KSTP94	1897	3032	1484	584	1749		
	KIBOS	GAF4	1308	1254	1204	2434	1550	1548	
		H505	0	1669	1461	2941	1517		
		IR	577	911	1926	1985	1349		
		KSTP94	419	2224	2349	2116	1777		
	TESO	GAF4	1185	1453	1630	1357	1406	1102	
		H505	279	331	548	705	465		
		IR	665	851	649	1051	804		
		KSTP94	1067	1741	1721	2413	1735		
	VIHIGA	GAF4	972	2731	1376	2495	1893	1592	
		H505	474	1153	1562	2085	1318		
		IR	931	1987	1644	1472	1508		
		KSTP94	1443	2225	1383	1550	1650		
MEAN			1710	2416	2390	2824	2335	2334	2335

	Season (Se	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	<0.001	<0.001	<0.001	<0.001	<0.001	0.063	0.318	0.423	0.489
S.E	67.6	95.7	95.7	95.7	135.3	135.3	191.3	135.3	191.3
S.E.D	95.7	135.3	135.3	135.3	191.3	191.3	270.6	191.3	270.6

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	x Si x V x C
F. probability	0.456	0.002	0.26	0.081	0.24	0.37
S.E	191.3	270.6	270.6	270.6	382.6	541.1
S.E.D	270.6	382.6	382.6	382.6	541.1	765.3
% C.V	40.1					

KEY: *Mean (a)- Average maize yield (Kg/ha) for each of the four maize varieties.*

Mean (b)- Average maize yield (Kg/ha) for each of the sites in the 2 seasons.

Mean (c)-Average maize yield for season I (Long rains 2012) and season II (Short rains 2012).

Appendix VII. Maize biomass (Kg/ha) for maize varieties with the different seed coatings for the four sites in seasons I and II.

Season	Site	Varieties	COATING				MEAN (a)	MEAN (b)	MEAN (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	1169.8	1084.7	1783.8	1795	1458	1605	2088
		H505	1888.1	2183.3	1604.9	2304.5	1995		
		IR	1347.8	1806.1	1737.9	1932	1705		
		KSTP94	1264.1	1271.6	1257.3	1256.5	1262		
	KIBOS	GAF4	2346.2	3947.1	3534.9	3790.2	3404	3314	
		H505	2573.7	2539.1	2773.2	3957.8	2960		
		IR	2828.4	3306.1	3285.1	3271.3	3172		
		KSTP94	2968.3	3949.5	4258	3714.6	3722		
	TESO	GAF4	1042.9	1186.9	1590	1928.7	1437	1554	
		H505	779.8	1082.8	777.4	1078.6	930		
		IR	1056.6	1275.4	2120.7	2098.8	1638		
		KSTP94	1458	2701.9	2385.8	2298.7	2211		
	VIHIGA	GAF4	2038.7	1446.7	1046	2579.3	1778	1880	
		H505	1745.4	2407.5	1958	1661.5	1943		
		IR	3130.9	2180.5	2094.4	2028.2	2358		
		KSTP94	1899.9	1742.3	1238.6	894	1443		
II	BUNGOMA	GAF4	2194.6	3754.6	2441.6	3586.2	2994	2979	2984
		H505	3243.9	3321.5	3403	4200.2	3542		
		IR	1243.9	2816.1	2016.8	2637.2	2178		
		KSTP94	3712.2	2062.2	4088.4	2957.5	3205		
	KIBOS	GAF4	3655.8	3515.3	4839.9	5907.9	4479	4234	
		H505	3883.7	3973	5047.9	5027.6	4483		
		IR	3445.5	4459.5	4896.2	4400.1	4300		
		KSTP94	2780.9	4226.8	3286.2	4406.1	3675		
	TESO	GAF4	2427.3	2102.6	3067.6	2128.3	2431	2176	
		H505	1864.5	1446.5	2395.2	2490.7	2049		
		IR	1918.6	2250.8	2030.9	2050.8	2062		
		KSTP94	1799.2	1664.7	2415.6	2778.7	2164		
	VIHIGA	GAF4	334.1	2938.5	3190.5	2705.1	2292	2548	
		H505	1251.7	3621.6	2460	2858.7	2548		
		IR	4116.8	3158.6	2328.6	2890	3123		
		KSTP94	1574.5	2879.6	2780.7	1693.6	2232		
MEAN			2155	2572	2629	2790	2537	2536	2536

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	< 0.001	< 0.001	0.782	0.003	0.461	0.27	0.315	0.173	0.029
S.E	91.54	129.45	129.45	129.45	183.07	183.07	258.9	183.07	258.9
S.E.D	129.45	183.07	183.07	183.07	258.9	258.9	366.15	258.9	366.15

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	x Si x V x C
F. probability	0.323	0.602	0.513	0.942	0.974	0.996
S.E	258.9	366.15	366.15	366.15	517.81	732.29
S.E.D	366.15	517.81	517.81	517.81	732.29	1035.62
% C.V	49.2					

KEY: *Mean (a)- Average maize biomass (Kg/ha) for each of the four maize varieties.*

Mean (b)- Average maize biomass (Kg/ha) for each of the sites in the 2 seasons.

Mean (c)-Average maize biomass for season I (Long rains 2012) and season II (Short rains 2012).

Appendix VIII. Effect of treatment combinations on Soya beans yield (Kg/ha).

SEASON	SITE	VARIETY	COATINGS				Mean (a)	Mean (b)	Mean (c)
			Control	Foxy FK3	Foxy FK3+Gro-plus	Gro plus			
I	BUNGOMA	GAF4	452	548	646	589	559	505	730
		H505	463	520	424	509	497		
		IR	467	481	456	534	485		
		KSTP94	599	456	467	392	478		
	KIBOS	GAF4	873	889	852	778	848	889	
		H505	1000	963	926	1000	972		
		IR	741	889	1000	778	852		
		KSTP94	1000	815	852	873	885		
	TESO	GAF4	648	620	614	648	632	640	
		H505	695	681	681	629	672		
		IR	692	714	692	581	670		
		KSTP94	570	634	600	548	588		
	VIHIGA	GAF4	829	895	905	857	871	885	
		H505	886	905	886	876	888		
		IR	876	876	876	886	879		
		KSTP94	886	943	876	895	900		
II	BUNGOMA	GAF4	265	311	288	278	285	275	423
		H505	260	298	313	302	293		
		IR	322	231	255	284	273		
		KSTP94	193	309	285	209	249		
	KIBOS	GAF4	618	589	624	643	619	637	
		H505	523	419	592	631	541		
		IR	656	653	864	585	689		
		KSTP94	824	803	628	547	700		
	TESO	GAF4	288	288	272	282	282	310	
		H505	297	392	297	357	336		
		IR	267	370	291	305	308		
		KSTP94	265	320	320	353	314		
	VIHIGA	GAF4	543	478	447	446	478	469	
		H505	501	563	469	404	484		
		IR	484	377	486	480	457		
		KSTP94	431	498	440	457	457		
MEAN			575	585	582	560	576	576	576

	Season (Se)	Site (Si)	Variety (V)	Coating (C)	Se x Si	Se x V	Si x V	Se x C	Si x C
F. probability	<0.001	<0.001	0.881	0.44	<0.001	0.311	0.351	0.994	0.855
S.E	8.2	11.59	11.59	11.59	16.39	16.39	23.18	16.39	23.18
S.E.D	11.59	16.39	16.39	16.39	23.18	23.18	32.79	23.18	32.79

	V x C	Se x Si x V	Se x Si x C	Se x V x C	Si X V X C	Se x Si x V x C
F. probability	0.593	0.012	0.92	0.744	0.166	0.844
S.E	23.18	32.79	32.79	32.79	46.37	65.57
S.E.D	32.79	46.37	46.37	46.37	65.57	92.73
% C.V	19.7					

KEY: *Mean (a)- Average soya beans grain yield (Kg/ha) for each of the four maize varieties.*

Mean (b)- Average soya beans grain yield (Kg/ha) for each of the sites in the 2 seasons.

Mean (c)-Average soya beans hrain yield (Kg/ha) for season I (Long rains 2012) and season II (Short rains 2012).

Appendix IX. Dominance analysis showing treatments listed in order of their increasing total costs that vary, and the dominated treatments.

Treatments	Net benefits	Total Cost that varies (TCV)	
H505-C	17925	**59850**	
IR-C	21512	**63437**	
KSTP-C	29606	**71531**	
GAF4-C	31083	**73008**	
H505-FK3+Gro	28847	**73972**	D
H505-FK3	31681	**75306**	
IR-FK3	32388	**76013**	
IR-Gro	37305	**80930**	
GAF4-FK3	38994	**82619**	
KSTP-FK3+Gro	39940	**85065**	
GAF4-FK3+Gro	42197	**87322**	
H505-Gro	45466	**89091**	
IR-FK3+Gro	44943	**90068**	D
GAF4-Gro	48511	**92136**	
KSTP-Gro	53237	**96862**	
KSTP-FK3	55796	**99421**	

The ‘d’ in treatments with H505-FK3+Gro-plus and IR-FK3+Gro plus are ‘dominated by the preceding treatments in their net benefits, therefore eliminated.

Appendix X. Anova table for reaction of seed coatings on *Striga* numbers at 14 weeks after planting maize

Analysis of variance (Contrasting coating) Variate: Striga_counts					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
BLOCKS stratum	2	1851.6	925.8	1.13	
Season	1	4293.4	4293.4	5.22	0.023
SITES	3	368572.1	122857.4	149.5	<0.001
VARIETY	3	55763.5	18587.8	22.62	<0.001
SEED_COATING	3	19973.7	6657.9	8.1	<0.001
Contrast 1: C Vs F	1	10019.6	10019.6	12.19	<0.001
Contrast 2: C Vs (F+P)	1	13200.3	13200.3	16.06	<0.001
Contrast 3: C Vs P	1	15750.6	15750.6	19.17	<0.001
Contrast 4: F Vs (F+P)	1	218.9	218.9	0.27	0.606
Contrast 5: F Vs P	1	645.3	645.3	0.79	0.376
Contrast 6: (F+P) Vs P	1	112.5	112.5	0.14	0.712
Season.SITES	3	16397.1	5465.7	6.65	<0.001
Season.VARIETY	3	15456.5	5152.2	6.27	<0.001
SITES.VARIETY	9	63087.1	7009.7	8.53	<0.001
Season.SEED_COATING	3	1003.1	334.4	0.41	0.748
Season.Contrast 1	1	2.3	2.3	0	0.958
Season.Contrast 2	1	13	13	0.02	0.9
Season.Contrast 3	1	686.3	686.3	0.84	0.362
Season.Contrast 4	1	26.3	26.3	0.03	0.858
Season.Contrast 5	1	768	768	0.93	0.335
Season.Contrast 6	1	510.3	510.3	0.62	0.431
SITES.SEED_COATING	9	20401.5	2266.8	2.76	0.004
SITES.Contrast 1	3	9990.3	3330.1	4.05	0.008
SITES.Contrast 2	3	12172.4	4057.5	4.94	0.002
SITES.Contrast 3	3	16417	5472.3	6.66	<0.001
SITES.Contrast 4	3	602.9	201	0.24	0.865
SITES.Contrast 5	3	1298.8	432.9	0.53	0.664
SITES.Contrast 6	3	321.6	107.2	0.13	0.942
VARIETY.SEED_COATING	9	4369.6	485.5	0.59	0.804
VARIETY.Contrast 1	3	2882.2	960.7	1.17	0.322
VARIETY.Contrast 2	3	863.1	287.7	0.35	0.789
VARIETY.Contrast 3	3	2742.3	914.1	1.11	0.345
VARIETY.Contrast 4	3	1041.6	347.2	0.42	0.737
VARIETY.Contrast 5	3	408.2	136.1	0.17	0.919
VARIETY.Contrast 6	3	801.8	267.3	0.33	0.807
Season.SITES.VARIETY	9	38625.9	4291.8	5.22	<0.001
Season.SITES.SEED_COATING	9	2156	239.6	0.29	0.977
Season.SITES.Contrast 1	3	289.3	96.4	0.12	0.95
Season.SITES.Contrast 2	3	702.9	234.3	0.29	0.836
Season.SITES.Contrast 3	3	1970.9	657	0.8	0.495
Season.SITES.Contrast 4	3	108.5	36.2	0.04	0.988
Season.SITES.Contrast 5	3	823.6	274.5	0.33	0.801
Season.VARIETY.SEED_COATING	9	8400.2	933.4	1.14	0.338
Season.VARIETY.Contrast 1	3	7222.5	2407.5	2.93	0.034
Season.VARIETY.Contrast 2	3	3103.7	1034.6	1.26	0.289
Season.VARIETY.Contrast 3	3	3041.6	1013.9	1.23	0.298
Season.VARIETY.Contrast 4	3	1532.9	511	0.62	0.601
Season.VARIETY.Contrast 5	3	1482.4	494.1	0.6	0.615
SITES.VARIETY.SEED_COATING	27	12379.5	458.5	0.56	0.964
SITES.VARIETY.Contrast 1	9	3364.1	373.8	0.45	0.904
SITES.VARIETY.Contrast 2	9	2859.8	317.8	0.39	0.941
SITES.VARIETY.Contrast 3	9	6705.1	745	0.91	0.52
SITES.VARIETY.Contrast 4	9	1950.9	216.8	0.26	0.984
SITES.VARIETY.Contrast 5	9	6432	714.7	0.87	0.553
Season.SITES.VARIETY.SEED_COATING	27	18417.8	682.1	0.83	0.711
Season.SITES.VARIETY.Contrast 1	9	14771.8	1641.3	2	0.04
Season.SITES.VARIETY.Contrast 2	9	3793.7	421.5	0.51	0.865
Season.SITES.VARIETY.Contrast 3	9	6370.5	707.8	0.86	0.56
Season.SITES.VARIETY.Contrast 4	9	6204.6	689.4	0.84	0.581
Residual	254	208734.4	821.8		
Total	383	859883			

Appendix XI. Anova table for reactions of different maize varieties on *Striga* numbers at 14 weeks after planting maize.

Analysis of variance (Contrasting varieties) Variate: Striga_counts					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
BLOCKS stratum	2	1851.6	925.8	1.13	
Season	1	4293.4	4293.4	5.22	0.023
SITES	3	368572.1	122857.4	149.5	<0.001
VARIETY	3	55763.5	18587.8	22.62	<0.001
Contrast 1: G Vs H	1	29850.2	29850.2	36.32	<0.001
Contrast 2: G Vs IR	1	450.2	450.2	0.55	0.46
Contrast 3: G Vs KSTP	1	2655.2	2655.2	3.23	0.073
Contrast 4: H Vs IR	1	22968.8	22968.8	27.95	<0.001
Contrast 5: H Vs KSTP	1	50310.8	50310.8	61.22	<0.001
Contrast 6: IR Vs KSTP	1	5292	5292	6.44	0.012
SEED_COATING	3	19973.7	6657.9	8.1	<0.001
Season.SITES	3	16397.1	5465.7	6.65	<0.001
Season.VARIETY	3	15456.5	5152.2	6.27	<0.001
Season.Contrast 1	1	7227.5	7227.5	8.79	0.003
Season.Contrast 2	1	1017.5	1017.5	1.24	0.267
Season.Contrast 3	1	36.7	36.7	0.04	0.833
Season.Contrast 4	1	13668.7	13668.7	16.63	<0.001
Season.Contrast 5	1	8295	8295	10.09	0.002
Season.Contrast 6	1	667.5	667.5	0.81	0.368
SITES.VARIETY	9	63087.1	7009.7	8.53	<0.001
SITES.Contrast 1	3	25546.1	8515.4	10.36	<0.001
SITES.Contrast 2	3	2295.2	765.1	0.93	0.426
SITES.Contrast 3	3	11879	3959.7	4.82	0.003
SITES.Contrast 4	3	23946.4	7982.1	9.71	<0.001
SITES.Contrast 5	3	55559.3	18519.8	22.54	<0.001
SITES.Contrast 6	3	6948.1	2316	2.82	0.04
Season.SEED_COATING	3	1003.1	334.4	0.41	0.748
SITES.SEED_COATING	9	20401.5	2266.8	2.76	0.004
VARIETY.SEED_COATING	9	4369.6	485.5	0.59	0.804
Contrast 1.SEED_COATING	3	3580.4	1193.5	1.45	0.228
Contrast 2.SEED_COATING	3	940.7	313.6	0.38	0.766
Contrast 3.SEED_COATING	3	665.4	221.8	0.27	0.847
Contrast 4.SEED_COATING	3	1201.6	400.5	0.49	0.691
Contrast 5.SEED_COATING	3	1842.2	614.1	0.75	0.525
Contrast 6.SEED_COATING	3	508.9	169.6	0.21	0.892
Season.SITES.VARIETY	9	38625.9	4291.8	5.22	<0.001
Season.SITES.Contrast 1	3	14745.1	4915	5.98	<0.001
Season.SITES.Contrast 2	3	7811.7	2603.9	3.17	0.025
Season.SITES.Contrast 3	3	795.9	265.3	0.32	0.809
Season.SITES.Contrast 4	3	22412.1	7470.7	9.09	<0.001
Season.SITES.Contrast 5	3	18437.6	6145.9	7.48	<0.001
Season.SITES.SEED_COATING	9	2156	239.6	0.29	0.977
Season.VARIETY.SEED_COATING	9	8400.2	933.4	1.14	0.338
Season.Contrast 1.SEED_COATING	3	3164.2	1054.7	1.28	0.281
Season.Contrast 2.SEED_COATING	3	1236.4	412.1	0.5	0.682
Season.Contrast 3.SEED_COATING	3	512.8	170.9	0.21	0.891
Season.Contrast 4.SEED_COATING	3	6989	2329.7	2.83	0.039
Season.Contrast 5.SEED_COATING	3	3755.8	1251.9	1.52	0.209
SITES.VARIETY.SEED_COATING	27	12379.5	458.5	0.56	0.964
SITES.Contrast 1.SEED_COATING	9	8185	909.4	1.11	0.358
SITES.Contrast 2.SEED_COATING	9	3228.4	358.7	0.44	0.915
SITES.Contrast 3.SEED_COATING	9	2128.1	236.5	0.29	0.978
SITES.Contrast 4.SEED_COATING	9	3186.9	354.1	0.43	0.918
SITES.Contrast 5.SEED_COATING	9	6468.6	718.7	0.87	0.549
Season.SITES.VARIETY.SEED_COATING	27	18417.8	682.1	0.83	0.711
Season.SITES.Contrast 1.SEED_COATING	9	5913.2	657	0.8	0.617
Season.SITES.Contrast 2.SEED_COATING	9	2360.2	262.2	0.32	0.968
Season.SITES.Contrast 3.SEED_COATING	9	3115.6	346.2	0.42	0.923
Season.SITES.Contrast 4.SEED_COATING	9	11089.5	1232.2	1.5	0.148
Residual	254	208734.4	821.8		
Total	383	859883			

Appendix XII. Anova table for reactions of different maize seed coatings on *Striga* biomass.

Analysis of variance (CONTRASTING COATINGS) Variate: Biomass (g)					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	2	5869	2935	0.71	
Season	1	215761	215761	52.47	< 0.001
Site	3	1396612	465537	113.2	< 0.001
Varieties	3	78651	26217	6.38	< 0.001
Coating	3	78876	26292	6.39	< 0.001
Contrast 1: C Vs F	1	44919	44919	10.92	0.001
Contrast 2: C Vs (F+P)	1	34862	34862	8.48	0.004
Contrast 3: C Vs P	1	68993	68993	16.78	< 0.001
Contrast 4: F Vs (F+P)	1	636	636	0.15	0.694
Contrast 5: F Vs P	1	2573	2573	0.63	0.43
Contrast 6: (F+P) Vs P	1	5769	5769	1.4	0.237
Season.Site	3	687961	229320	55.76	< 0.001
Season.Varieties	3	30337	10112	2.46	0.063
Site.Varieties	9	184654	20517	4.99	< 0.001
Season.Coating	3	25039	8346	2.03	0.11
Season.Contrast 1	1	14256	14256	3.47	0.064
Season.Contrast 2	1	10860	10860	2.64	0.105
Season.Contrast 3	1	21965	21965	5.34	0.022
Season.Contrast 4	1	231	231	0.06	0.813
Season.Contrast 5	1	830	830	0.2	0.654
Season.Contrast 6	1	1935	1935	0.47	0.493
Site.Coating	9	127332	14148	3.44	< 0.001
Site.Contrast 1	3	60968	20323	4.94	0.002
Site.Contrast 2	3	52165	17388	4.23	0.006
Site.Contrast 3	3	116626	38875	9.45	< 0.001
Site.Contrast 4	3	660	220	0.05	0.984
Site.Contrast 5	3	10957	3652	0.89	0.448
Site.Contrast 6	3	13287	4429	1.08	0.359
Varieties.Coating	9	10874	1208	0.29	0.976
Varieties.Contrast 1	3	1942	647	0.16	0.925
Varieties.Contrast 2	3	5635	1878	0.46	0.713
Varieties.Contrast 3	3	7379	2460	0.6	0.617
Varieties.Contrast 4	3	2921	974	0.24	0.871
Varieties.Contrast 5	3	3563	1188	0.29	0.833
Varieties.Contrast 6	3	307	102	0.02	0.995
Season.Site.Varieties	9	127597	14177	3.45	< 0.001
Season.Site.Coating	9	87948	9772	2.38	0.014
Season.Site.Contrast 1	3	42669	14223	3.46	0.017
Season.Site.Contrast 2	3	33430	11143	2.71	0.046
Season.Site.Contrast 3	3	81785	27262	6.63	< 0.001
Season.Site.Contrast 4	3	567	189	0.05	0.987
Season.Site.Contrast 5	3	6609	2203	0.54	0.658
Season.Varieties.Coating	9	14679	1631	0.4	0.936
Season.Varieties.Contrast 1	3	4153	1384	0.34	0.799
Season.Varieties.Contrast 2	3	10738	3579	0.87	0.457
Season.Varieties.Contrast 3	3	8342	2781	0.68	0.567
Season.Varieties.Contrast 4	3	3841	1280	0.31	0.817
Season.Varieties.Contrast 5	3	1653	551	0.13	0.94
Site.Varieties.Coating	27	42898	1589	0.39	0.998
Site.Varieties.Contrast 1	9	3422	380	0.09	1
Site.Varieties.Contrast 2	9	14720	1636	0.4	0.936
Site.Varieties.Contrast 3	9	24176	2686	0.65	0.751
Site.Varieties.Contrast 4	9	17057	1895	0.46	0.9
Site.Varieties.Contrast 5	9	21990	2443	0.59	0.801
Season.Site.Varieties.Coating	27	50222	1860	0.45	0.992
Season.Site.Varieties.Contrast 1	9	14532	1615	0.39	0.938
Season.Site.Varieties.Contrast 2	9	14508	1612	0.39	0.938
Season.Site.Varieties.Contrast 3	9	14013	1557	0.38	0.945
Season.Site.Varieties.Contrast 4	9	25989	2888	0.7	0.707
Residual	251	1032227	4112		
Total	380	4196821			

Appendix XIII. Anova table for reactions of different maize varieties on *Striga* biomass.

Analysis of Variance (CONTRASTING VARIETIES) Variate: Biomass (g)					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Block stratum	2	5869	2935	0.71	
Season	1	215761	215761	52.47	< 0.001
Site	3	1396612	465537	113.2	< 0.001
Varieties	3	78651	26217	6.38	< 0.001
Contrast 1: G Vs H	1	43326	43326	10.54	0.001
Contrast 2: G Vs IR	1	6702	6702	1.63	0.203
Contrast 3: G Vs KSTP	1	3064	3064	0.75	0.389
Contrast 4: H Vs IR	1	15947	15947	3.88	0.05
Contrast 5: H Vs KSTP	1	69434	69434	16.88	< 0.001
Contrast 6: IR Vs KSTP	1	18829	18829	4.58	0.033
Coating	3	78876	26292	6.39	< 0.001
Season.Site	3	687961	229320	55.76	< 0.001
Season.Varieties	3	30337	10112	2.46	0.063
Season.Contrast 1	1	22494	22494	5.47	0.02
Season.Contrast 2	1	7145	7145	1.74	0.189
Season.Contrast 3	1	41	41	0.01	0.92
Season.Contrast 4	1	4284	4284	1.04	0.308
Season.Contrast 5	1	20609	20609	5.01	0.026
Season.Contrast 6	1	6100	6100	1.48	0.224
Site.Varieties	9	184654	20517	4.99	< 0.001
Site.Contrast 1	3	102718	34239	8.33	< 0.001
Site.Contrast 2	3	6913	2304	0.56	0.642
Site.Contrast 3	3	5017	1672	0.41	0.748
Site.Contrast 4	3	82633	27544	6.7	< 0.001
Site.Contrast 5	3	152318	50773	12.35	< 0.001
Site.Contrast 6	3	19709	6570	1.6	0.19
Season.Coating	3	25039	8346	2.03	0.11
Site.Coating	9	127332	14148	3.44	< 0.001
Varieties.Coating	9	10874	1208	0.29	0.976
Contrast 1.Coating	3	1239	413	0.1	0.96
Contrast 2.Coating	3	3752	1251	0.3	0.822
Contrast 3.Coating	3	2228	743	0.18	0.91
Contrast 4.Coating	3	3105	1035	0.25	0.86
Contrast 5.Coating	3	2074	691	0.17	0.918
Contrast 6.Coating	3	9350	3117	0.76	0.519
Season.Site.Varieties	9	127597	14177	3.45	< 0.001
Season.Site.Contrast 1	3	72994	24331	5.92	< 0.001
Season.Site.Contrast 2	3	9910	3303	0.8	0.493
Season.Site.Contrast 3	3	729	243	0.06	0.981
Season.Site.Contrast 4	3	81183	27061	6.58	< 0.001
Season.Site.Contrast 5	3	83585	27862	6.77	< 0.001
Season.Site.Coating	9	87948	9772	2.38	0.014
Season.Varieties.Coating	9	14679	1631	0.4	0.936
Season.Contrast 1.Coating	3	1031	344	0.08	0.969
Season.Contrast 2.Coating	3	8887	2962	0.72	0.541
Season.Contrast 3.Coating	3	1858	619	0.15	0.929
Season.Contrast 4.Coating	3	5902	1967	0.48	0.698
Season.Contrast 5.Coating	3	928	309	0.08	0.973
Site.Varieties.Coating	27	42898	1589	0.39	0.998
Site.Contrast 1.Coating	9	2449	272	0.07	1
Site.Contrast 2.Coating	9	18127	2014	0.49	0.881
Site.Contrast 3.Coating	9	8917	991	0.24	0.988
Site.Contrast 4.Coating	9	16711	1857	0.45	0.906
Site.Contrast 5.Coating	9	4877	542	0.13	0.999
Season.Site.Varieties.Coating	27	50222	1860	0.45	0.992
Season.Site.Contrast 1.Coating	9	3427	381	0.09	1
Season.Site.Contrast 2.Coating	9	21763	2418	0.59	0.807
Season.Site.Contrast 3.Coating	9	4970	552	0.13	0.999
Season.Site.Contrast 4.Coating	9	29764	3307	0.8	0.613
Residual	251	1032227	4112		
Total	380	4196821			

Appendix XIV. Anova table for reactions of different sites on plant height at 10 weeks after planting maize.

Analysis of variance (CONTRASTING SITES) Variate: Height wk 10					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3311.5	1655.7	1.95	
Season	1	67412.4	67412.4	79.59	< 0.001
Site	3	208934.1	69644.7	82.23	< 0.001
Contrast 1 (BUNGOMA VS KIBOS)	1	203160	203160	239.87	< 0.001
Contrast 2 (BUNGOMA VS TESO)	1	26253.9	26253.9	31	< 0.001
Contrast 3 (BUNGOMA VS VIHIGA)	1	35122.6	35122.6	41.47	< 0.001
Contrast 4 (KIBOS VS TESO)	1	83348.9	83348.9	98.41	< 0.001
Contrast 5 (KIBOS VS TESO)	1	69338.7	69338.7	81.87	< 0.001
Contrast 6 (TESO VS VIHIGA)	1	644.1	644.1	0.76	0.384
Varieties	3	6527.5	2175.8	2.57	0.055
Coating	3	6746	2248.7	2.66	0.049
Season.Site	3	53626.5	17875.5	21.11	< 0.001
Season.Contrast 1	1	16307.3	16307.3	19.25	< 0.001
Season.Contrast 2	1	9602.7	9602.7	11.34	< 0.001
Season.Contrast 3	1	6269.7	6269.7	7.4	0.007
Season.Contrast 4	1	882.5	882.5	1.04	0.308
Season.Contrast 5	1	42799.9	42799.9	50.53	< 0.001
Season.Contrast 6	1	31390.9	31390.9	37.06	< 0.001
Season.Varieties	3	1558.7	519.6	0.61	0.607
Site.Varieties	9	17076.4	1897.4	2.24	0.02
Contrast 1.Varieties	3	4723.1	1574.4	1.86	0.137
Contrast 2.Varieties	3	5662	1887.3	2.23	0.085
Contrast 3.Varieties	3	1659.7	553.2	0.65	0.582
Contrast 4.Varieties	3	6822	2274	2.68	0.047
Contrast 5.Varieties	3	9061.2	3020.4	3.57	0.015
Contrast 6.Varieties	3	6225	2075	2.45	0.064
Season.Coating	3	1862.4	620.8	0.73	0.533
Site.Coating	9	4661.5	517.9	0.61	0.787
Contrast 1.Coating	3	2731.5	910.5	1.08	0.36
Contrast 2.Coating	3	787.9	262.6	0.31	0.818
Contrast 3.Coating	3	609.6	203.2	0.24	0.868
Contrast 4.Coating	3	2692.9	897.6	1.06	0.367
Contrast 5.Coating	3	1515.6	505.2	0.6	0.618
Contrast 6.Coating	3	985.7	328.6	0.39	0.762
Varieties.Coating	9	1985.5	220.6	0.26	0.984
Season.Site.Varieties	9	10663.5	1184.8	1.4	0.189
Season.Contrast 1.Varieties	3	1228.6	409.5	0.48	0.694
Season.Contrast 2.Varieties	3	6292.4	2097.5	2.48	0.062
Season.Contrast 3.Varieties	3	2045	681.7	0.8	0.492
Season.Contrast 4.Varieties	3	2101.4	700.5	0.83	0.48
Season.Contrast 5.Varieties	3	2419.8	806.6	0.95	0.416
Season.Site.Coating	9	1513.3	168.1	0.2	0.994
Season.Contrast 1.Coating	3	387.2	129.1	0.15	0.928
Season.Contrast 2.Coating	3	742	247.3	0.29	0.831
Season.Contrast 3.Coating	3	175.9	58.6	0.07	0.976
Season.Contrast 4.Coating	3	614.7	204.9	0.24	0.867
Season.Contrast 5.Coating	3	701.1	233.7	0.28	0.843
Season.Varieties.Coating	9	2308.8	256.5	0.3	0.973
Site.Varieties.Coating	27	8472.6	313.8	0.37	0.998
Contrast 1.Varieties.Coating	9	2737.1	304.1	0.36	0.953
Contrast 2.Varieties.Coating	9	4583.8	509.3	0.6	0.795
Contrast 3.Varieties.Coating	9	4408.5	489.8	0.58	0.814
Contrast 4.Varieties.Coating	9	2461.3	273.5	0.32	0.967
Contrast 5.Varieties.Coating	9	2297	255.2	0.3	0.974
Season.Site.Varieties.Coating	27	6250.5	231.5	0.27	1
Season.Contrast 1.Varieties.Coating	9	3105.3	345	0.41	0.931
Season.Contrast 2.Varieties.Coating	9	2074.5	230.5	0.27	0.982
Season.Contrast 3.Varieties.Coating	9	1028.4	114.3	0.13	0.999
Season.Contrast 4.Varieties.Coating	9	2362.6	262.5	0.31	0.971
Residual	254	215125.9	847		
Total	383	618037.2			

Appendix XV. Anova table for reactions of different sites on maize plant height at harvest.

Analysis of variance (CONTRASTING SITES) Variate: Height_at_harvest					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	27357.8	13678.9	15.2	
Season	1	25377.1	25377.1	28.2	< 0.001
Site	3	594933.8	198311.3	220.38	< 0.001
Contrast 1 (BUNGOMA VS KIBOS)	1	554879.2	554879.2	616.62	< 0.001
Contrast 2 (BUNGOMA VS TESO)	1	60847.5	60847.5	67.62	< 0.001
Contrast 3 (BUNGOMA VS VIHIGA)	1	47565	47565	52.86	< 0.001
Contrast 4 (KIBOS VS TESO)	1	248232.4	248232.4	275.86	< 0.001
Contrast 5 (KIBOS VS TESO)	1	277526.7	277526.7	308.41	< 0.001
Contrast 6 (TESO VS VIHIGA)	1	816.7	816.7	0.91	0.342
Varieties	3	5641.5	1880.5	2.09	0.102
Coating	3	597.8	199.3	0.22	0.881
Season.Site	3	42051.1	14017	15.58	< 0.001
Season.Contrast 1	1	21077.1	21077.1	23.42	< 0.001
Season.Contrast 2	1	1026.7	1026.7	1.14	0.286
Season.Contrast 3	1	10591	10591	11.77	< 0.001
Season.Contrast 4	1	31407.8	31407.8	34.9	< 0.001
Season.Contrast 5	1	1786.5	1786.5	1.99	0.16
Season.Contrast 6	1	18213	18213	20.24	< 0.001
Season.Varieties	3	51.2	17.1	0.02	0.996
Site.Varieties	9	23973.4	2663.7	2.96	0.002
Contrast 1.Varieties	3	4320.8	1440.3	1.6	0.19
Contrast 2.Varieties	3	9090.4	3030.1	3.37	0.019
Contrast 3.Varieties	3	3667.9	1222.6	1.36	0.256
Contrast 4.Varieties	3	6935.9	2312	2.57	0.055
Contrast 5.Varieties	3	13685.4	4561.8	5.07	0.002
Contrast 6.Varieties	3	10246.5	3415.5	3.8	0.011
Season.Coating	3	1504.8	501.6	0.56	0.644
Site.Coating	9	2837.5	315.3	0.35	0.957
Contrast 1.Coating	3	661.8	220.6	0.25	0.865
Contrast 2.Coating	3	1323	441	0.49	0.689
Contrast 3.Coating	3	171.4	57.1	0.06	0.979
Contrast 4.Coating	3	1101.8	367.3	0.41	0.747
Contrast 5.Coating	3	550.8	183.6	0.2	0.894
Contrast 6.Coating	3	1866.2	622.1	0.69	0.558
Varieties.Coating	9	2661.6	295.7	0.33	0.965
Season.Site.Varieties	9	13064.5	1451.6	1.61	0.112
Season.Contrast 1.Varieties	3	3574.2	1191.4	1.32	0.267
Season.Contrast 2.Varieties	3	7202.6	2400.9	2.67	0.048
Season.Contrast 3.Varieties	3	1775.8	591.9	0.66	0.579
Season.Contrast 4.Varieties	3	1359.6	453.2	0.5	0.68
Season.Contrast 5.Varieties	3	5418.6	1806.2	2.01	0.113
Season.Site.Coating	9	3723.9	413.8	0.46	0.9
Season.Contrast 1.Coating	3	1048.8	349.6	0.39	0.761
Season.Contrast 2.Coating	3	1092.5	364.2	0.4	0.75
Season.Contrast 3.Coating	3	2488.4	829.5	0.92	0.431
Season.Contrast 4.Coating	3	444.9	148.3	0.16	0.92
Season.Contrast 5.Coating	3	1849.1	616.4	0.68	0.562
Season.Varieties.Coating	9	4078.7	453.2	0.5	0.871
Site.Varieties.Coating	27	10678.3	395.5	0.44	0.994
Contrast 1.Varieties.Coating	9	4386.8	487.4	0.54	0.843
Contrast 2.Varieties.Coating	9	2921.6	324.6	0.36	0.953
Contrast 3.Varieties.Coating	9	6683.7	742.6	0.83	0.593
Contrast 4.Varieties.Coating	9	2387	265.2	0.29	0.976
Contrast 5.Varieties.Coating	9	3160.3	351.1	0.39	0.939
Season.Site.Varieties.Coating	27	12015.9	445	0.49	0.984
Season.Contrast 1.Varieties.Coating	9	5253.6	583.7	0.65	0.755
Season.Contrast 2.Varieties.Coating	9	4060.6	451.2	0.5	0.873
Season.Contrast 3.Varieties.Coating	9	4286.9	476.3	0.53	0.853
Season.Contrast 4.Varieties.Coating	9	3136.9	348.5	0.39	0.941
Residual	254	228565.7	899.9		
Total	383	999114.5			

Appendix XVI. Anova table for reactions of different maize seed coatings on maize grain yield.

Analysis of variance (CONTRASTING COATING) Variate: Grain yield (kgs)					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2688073	1344037	1.53	
Season	1	199218215	199218215	226.78	< 0.001
Site	3	129101624	43033875	48.99	< 0.001
Varieties	3	23156349	7718783	8.79	< 0.001
Coating	3	61398792	20466264	23.3	< 0.001
Contrast 1: C Vs F	1	23955289	23955289	27.27	< 0.001
Contrast 2: C Vs (F+P)	1	22178239	22178239	25.25	< 0.001
Contrast 3: C Vs P	1	59589081	59589081	67.83	< 0.001
Contrast 4: F Vs (F+P)	1	34238	34238	0.04	0.844
Contrast 5: F Vs P	1	7980525	7980525	9.08	0.003
Contrast 6: (F+P) Vs P	1	9060212	9060212	10.31	0.002
Season.Site	3	124661172	41553724	47.3	< 0.001
Season.Varieties	3	6505106	2168369	2.47	0.063
Site.Varieties	9	9231075	1025675	1.17	0.318
Season.Coating	3	2471774	823925	0.94	0.423
Season.Contrast 1	1	229000	229000	0.26	0.61
Season.Contrast 2	1	1260393	1260393	1.43	0.233
Season.Contrast 3	1	2042038	2042038	2.32	0.129
Season.Contrast 4	1	414907	414907	0.47	0.493
Season.Contrast 5	1	903374	903374	1.03	0.312
Season.Contrast 6	1	93836	93836	0.11	0.744
Site.Coating	9	7459775	828864	0.94	0.489
Site.Contrast 1	3	497557	165852	0.19	0.904
Site.Contrast 2	3	4585171	1528390	1.74	0.16
Site.Contrast 3	3	2905168	968389	1.1	0.349
Site.Contrast 4	3	4081972	1360657	1.55	0.203
Site.Contrast 5	3	1562226	520742	0.59	0.62
Site.Contrast 6	3	1287456	429152	0.49	0.691
Varieties.Coating	9	7767021	863002	0.98	0.456
Varieties.Contrast 1	3	4886576	1628859	1.85	0.139
Varieties.Contrast 2	3	263779	87926	0.1	0.96
Varieties.Contrast 3	3	1437966	479322	0.55	0.652
Varieties.Contrast 4	3	4946888	1648963	1.88	0.135
Varieties.Contrast 5	3	2524564	841521	0.96	0.414
Varieties.Contrast 6	3	1474269	491423	0.56	0.642
Season.Site.Varieties	9	24689479	2743275	3.12	0.002
Season.Site.Coating	9	9976563	1108507	1.26	0.26
Season.Site.Contrast 1	3	5141535	1713845	1.95	0.123
Season.Site.Contrast 2	3	955172	318391	0.36	0.78
Season.Site.Contrast 3	3	4944848	1648283	1.88	0.135
Season.Site.Contrast 4	3	3007090	1002363	1.14	0.334
Season.Site.Contrast 5	3	3339671	1113224	1.27	0.287
Season.Varieties.Coating	9	13836996	1537444	1.75	0.081
Season.Varieties.Contrast 1	3	640260	213420	0.24	0.866
Season.Varieties.Contrast 2	3	2233635	744545	0.85	0.47
Season.Varieties.Contrast 3	3	8697138	2899046	3.3	0.022
Season.Varieties.Contrast 4	3	1253901	417967	0.48	0.7
Season.Varieties.Contrast 5	3	7746919	2582306	2.94	0.035
Site.Varieties.Coating	27	28417427	1052497	1.2	0.24
Site.Varieties.Contrast 2	9	6854944	761660	0.87	0.556
Site.Varieties.Contrast 4	9	17719302	1968811	2.24	0.021
Season.Site.Varieties.Coating	25	23702110	948084	1.08	0.37
Season.Site.Varieties.Contrast 2	9	1808408	200934	0.23	0.99
Season.Site.Varieties.Contrast 3	9	14743999	1638222	1.86	0.06
Season.Site.Varieties.Contrast 4	9	6120414	680046	0.77	0.64
Residual	185	162513440	878451		
Total	312	674141276			

Appendix XVII. Anova table for reactions of different maize varieties on maize grain yield.

Analysis of Variance (CONTRASTING VARIETIES) Variate: Grain yield (KGS)					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	521033	260516	0.16	
Season	1	135914119	135914119	82.84	< 0.001
Site	3	96533941	32177980	19.61	< 0.001
Varieties	3	12190922	4063641	2.48	0.062
Contrast 1: G Vs H	1	4719701	4719701	2.88	0.091
Contrast 2: G Vs IR	1	4969395	4969395	3.03	0.083
Contrast 3: G Vs KSTP	1	237308	237308	0.14	0.704
Contrast 4: H Vs IR	1	3218	3218	0	0.965
Contrast 5: H Vs KSTP	1	7073630	7073630	4.31	0.039
Contrast 6: IR Vs KSTP	1	7378592	7378592	4.5	0.035
Coating	3	69984444	23328148	14.22	< 0.001
Season.Site	3	80027276	26675759	16.26	< 0.001
Season.Varieties	3	2759649	919883	0.56	0.642
Season.Contrast 1	1	7577	7577	0	0.946
Season.Contrast 2	1	450237	450237	0.27	0.601
Season.Contrast 3	1	2164369	2164369	1.32	0.252
Season.Contrast 4	1	340998	340998	0.21	0.649
Season.Contrast 5	1	1915825	1915825	1.17	0.281
Season.Contrast 6	1	640292	640292	0.39	0.533
Site.Varieties	9	21247594	2360844	1.44	0.173
Site.Contrast 1	3	3954783	1318261	0.8	0.493
Site.Contrast 2	3	5448094	1816031	1.11	0.347
Site.Contrast 3	3	3189539	1063180	0.65	0.585
Site.Contrast 4	3	928057	309352	0.19	0.904
Site.Contrast 5	3	12411468	4137156	2.52	0.059
Site.Contrast 6	3	16563248	5521083	3.36	0.02
Season.Coating	3	5284984	1761661	1.07	0.361
Site.Coating	9	8890151	987795	0.6	0.795
Varieties.Coating	9	14798665	1644296	1	0.439
Contrast 1.Coating	3	1264972	421657	0.26	0.856
Contrast 2.Coating	3	2153356	717785	0.44	0.726
Contrast 3.Coating	3	7599389	2533130	1.54	0.204
Contrast 4.Coating	3	1457286	485762	0.3	0.828
Contrast 5.Coating	3	8480864	2826955	1.72	0.163
Contrast 6.Coating	3	8641463	2880488	1.76	0.157
Season.Site.Varieties	9	20999290	2333254	1.42	0.18
Season.Site.Contrast 1	3	10725247	3575082	2.18	0.092
Season.Site.Contrast 2	3	1664862	554954	0.34	0.798
Season.Site.Contrast 3	3	7904319	2634773	1.61	0.189
Season.Site.Contrast 4	3	7920558	2640186	1.61	0.188
Season.Site.Contrast 5	3	4295538	1431846	0.87	0.456
Season.Site.Coating	9	13640524	1515614	0.92	0.505
Season.Varieties.Coating	9	8763200	973689	0.59	0.802
Season.Contrast 1.Coating	3	2761498	920499	0.56	0.641
Season.Contrast 2.Coating	3	2385809	795270	0.48	0.693
Season.Contrast 3.Coating	3	3733560	1244520	0.76	0.519
Season.Contrast 4.Coating	3	4276009	1425336	0.87	0.458
Season.Contrast 5.Coating	3	4006585	1335528	0.81	0.487
Site.Varieties.Coating	27	49313612	1826430	1.11	0.327
Site.Contrast 1.Coating	9	19130169	2125574	1.3	0.241
Site.Contrast 2.Coating	9	13690415	1521157	0.93	0.502
Site.Contrast 3.Coating	9	18376494	2041833	1.24	0.269
Site.Contrast 4.Coating	9	21652267	2405807	1.47	0.162
Site.Contrast 5.Coating	9	16674024	1852669	1.13	0.343
Season.Site.Varieties.Coating	27	38998408	1444385	0.88	0.64
Season.Site.Contrast 1.Coating	9	16602045	1844672	1.12	0.347
Season.Site.Contrast 2.Coating	9	12697077	1410786	0.86	0.562
Season.Site.Contrast 3.Coating	9	14700627	1633403	1	0.445
Season.Site.Contrast 4.Coating	9	13692096	1521344	0.93	0.502
Residual	212	347844803	1640777		
Total	341	845674085			

Appendix XVIII. Anova table for reactions of different maize seed coatings on maize above ground biomass

Analysis of variance (CONTRASTING COATING) Variate: Stover_wt_kg_ha					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1221437	610718	0.42	
Season	1	77115637	77115637	53.12	< 0.001
Site	3	211783568	70594523	48.62	< 0.001
Varieties	3	342279	114093	0.08	0.972
Coating	3	21071304	7023768	4.84	0.003
Contrast 1: C Vs F	1	8313760	8313760	5.73	0.018
Contrast 2: C Vs (F+P)	1	10758032	10758032	7.41	0.007
Contrast 3: C Vs P	1	19359257	19359257	13.33	< 0.001
Contrast 4: F Vs (F+P)	1	157279	157279	0.11	0.742
Contrast 5: F Vs P	1	2299943	2299943	1.58	0.209
Contrast 6: (F+P) Vs P	1	1254337	1254337	0.86	0.354
Season.Site	3	2846151	948717	0.65	0.582
Season.Varieties	3	4915539	1638513	1.13	0.338
Site.Varieties	9	17096396	1899600	1.31	0.233
Season.Coating	3	2937696	979232	0.67	0.568
Season.Contrast 1	1	815837	815837	0.56	0.454
Season.Contrast 2	1	2521936	2521936	1.74	0.189
Season.Contrast 3	1	1813707	1813707	1.25	0.265
Season.Contrast 4	1	468983	468983	0.32	0.57
Season.Contrast 5	1	196695	196695	0.14	0.713
Season.Contrast 6	1	58236	58236	0.04	0.841
Site.Coating	9	13361522	1484614	1.02	0.423
Site.Contrast 1	3	4365970	1455323	1	0.393
Site.Contrast 2	3	6769738	2256579	1.55	0.201
Site.Contrast 3	3	7283203	2427734	1.67	0.174
Site.Contrast 4	3	3364671	1121557	0.77	0.51
Site.Contrast 5	3	3998535	1332845	0.92	0.433
Site.Contrast 6	3	940927	313642	0.22	0.885
Varieties.Coating	9	7959795	884422	0.61	0.789
Varieties.Contrast 1	3	657530	219177	0.15	0.929
Varieties.Contrast 2	3	2326536	775512	0.53	0.659
Varieties.Contrast 3	3	6243036	2081012	1.43	0.234
Varieties.Contrast 4	3	658009	219336	0.15	0.929
Varieties.Contrast 5	3	3142907	1047636	0.72	0.54
Varieties.Contrast 6	3	2891572	963857	0.66	0.575
Season.Site.Varieties	9	24882908	2764768	1.9	0.052
Season.Site.Coating	9	9188582	1020954	0.7	0.706
Season.Site.Contrast 1	3	5696196	1898732	1.31	0.273
Season.Site.Contrast 2	3	2298094	766031	0.53	0.664
Season.Site.Contrast 3	3	3730484	1243495	0.86	0.464
Season.Site.Contrast 4	3	1795526	598509	0.41	0.744
Season.Site.Contrast 5	3	4114173	1371391	0.94	0.42
Season.Varieties.Coating	9	4089747	454416	0.31	0.97
Season.Varieties.Contrast 1	3	1440538	480179	0.33	0.803
Season.Varieties.Contrast 2	3	1755030	585010	0.4	0.751
Season.Varieties.Contrast 3	3	498433	166144	0.11	0.952
Season.Varieties.Contrast 4	3	2252524	750841	0.52	0.671
Season.Varieties.Contrast 5	3	1796106	598702	0.41	0.744
Site.Varieties.Coating	27	23300219	862971	0.59	0.946
Site.Varieties.Contrast 1	9	10957013	1217446	0.84	0.581
Site.Varieties.Contrast 2	9	7854735	872748	0.6	0.795
Site.Varieties.Contrast 3	9	8136467	904052	0.62	0.777
Site.Varieties.Contrast 4	9	8502233	944693	0.65	0.753
Site.Varieties.Contrast 5	9	3198649	355405	0.24	0.987
Season.Site.Varieties.Coating	27	32673856	1210143	0.83	0.705
Season.Site.Varieties.Contrast 1	9	18293986	2032665	1.4	0.189
Season.Site.Varieties.Contrast 2	9	10817354	1201928	0.83	0.591
Season.Site.Varieties.Contrast 3	9	8929517	992169	0.68	0.724
Season.Site.Varieties.Contrast 4	9	9587155	1065239	0.73	0.678
Residual	231	335372128	1451827		
Total	360	764327258			

Appendix XIX. Anova table for reactions of different maize varieties on maize above ground biomass.

Analysis of variance (CONTRASTING VARIETIES) Variate: Stover wt kg/ha					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	77045	38523	0.02	
Season	1	83374617	83374617	51.83	< 0.001
Site	3	250452386	83484129	51.89	< 0.001
Varieties	3	1737156	579052	0.36	0.782
Contrast 1: G Vs H	1	1383943	1383943	0.86	0.355
Contrast 2: G Vs IR	1	1126751	1126751	0.7	0.404
Contrast 3: G Vs KSTP	1	877360	877360	0.55	0.461
Contrast 4: H Vs IR	1	13208	13208	0.01	0.928
Contrast 5: H Vs KSTP	1	57473	57473	0.04	0.85
Contrast 6: IR Vs KSTP	1	15578	15578	0.01	0.922
Coating	3	23398827	7799609	4.85	0.003
Season.Site	3	4166827	1388942	0.86	0.461
Season.Varieties	3	6354750	2118250	1.32	0.27
Season.Contrast 1	1	2541539	2541539	1.58	0.21
Season.Contrast 2	1	682948	682948	0.42	0.515
Season.Contrast 3	1	36245	36245	0.02	0.881
Season.Contrast 4	1	5859436	5859436	3.64	0.058
Season.Contrast 5	1	3184804	3184804	1.98	0.161
Season.Contrast 6	1	404528	404528	0.25	0.617
Site.Varieties	9	16951134	1883459	1.17	0.315
Site.Contrast 1	3	7900992	2633664	1.64	0.182
Site.Contrast 2	3	2170891	723630	0.45	0.718
Site.Contrast 3	3	1252433	417478	0.26	0.855
Site.Contrast 4	3	7641589	2547196	1.58	0.194
Site.Contrast 5	3	10768293	3589431	2.23	0.085
Site.Contrast 6	3	4168069	1389356	0.86	0.461
Season.Coating	3	8078856	2692952	1.67	0.173
Site.Coating	9	30650066	3405563	2.12	0.029
Varieties.Coating	9	16767860	1863096	1.16	0.323
Contrast 1.Coating	3	584100	194700	0.12	0.948
Contrast 2.Coating	3	9578059	3192686	1.98	0.117
Contrast 3.Coating	3	7259034	2419678	1.5	0.214
Contrast 4.Coating	3	6012070	2004023	1.25	0.294
Contrast 5.Coating	3	4635858	1545286	0.96	0.412
Contrast 6.Coating	3	5466599	1822200	1.13	0.337
Season.Site.Varieties	9	11806538	1311838	0.82	0.602
Season.Site.Contrast 1	3	1416154	472051	0.29	0.83
Season.Site.Contrast 2	3	1597750	532583	0.33	0.803
Season.Site.Contrast 3	3	6842894	2280965	1.42	0.238
Season.Site.Contrast 4	3	3175519	1058506	0.66	0.579
Season.Site.Contrast 5	3	3475455	1158485	0.72	0.541
Season.Site.Coating	9	13251297	1472366	0.92	0.513
Season.Varieties.Coating	9	5548401	616489	0.38	0.942
Season.Contrast 1.Coating	3	150426	50142	0.03	0.993
Season.Contrast 2.Coating	3	2492031	830677	0.52	0.671
Season.Contrast 3.Coating	3	478028	159343	0.1	0.96
Season.Contrast 4.Coating	3	1958414	652805	0.41	0.749
Season.Contrast 5.Coating	3	1081753	360584	0.22	0.88
Site.Varieties.Coating	27	23054328	853864	0.53	0.974
Site.Contrast 1.Coating	9	11600068	1288896	0.8	0.616
Site.Contrast 2.Coating	9	5307517	589724	0.37	0.95
Site.Contrast 3.Coating	9	11037177	1226353	0.76	0.651
Site.Contrast 4.Coating	9	3877512	430835	0.27	0.983
Site.Contrast 5.Coating	9	8892441	988049	0.61	0.784
Season.Site.Varieties.Coating	26	16752348	644321	0.4	0.996
Season.Site.Contrast 1.Coating	9	6684716	742746	0.46	0.899
Season.Site.Contrast 2.Coating	9	6918401	768711	0.48	0.889
Season.Site.Contrast 3.Coating	9	7145522	793947	0.49	0.878
Season.Site.Contrast 4.Coating	9	4942739	549193	0.34	0.96
Residual	228	366795758	1608753		
Total	356	851213280			

Appendix XX. Anova table for reactions of different sites on Soya grain yield (Kg/ha).

Analysis of variance Variate: Soya grain yield_kgs_ha					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	339762	169881	13.17	
Season	1	8968237	8968237	695.3	<.001
Site	3	8724670	2908223	225.47	<.001
Contrast 1 (BG vs KIB)	1	6776752	6776752	525.4	<.001
Contrast 2 (BG vs TESO)	1	369259	369259	28.63	<.001
Contrast 3 (BG vs VIHIGA)	1	4013347	4013347	311.15	<.001
Contrast 4 (KIBOS vs TESO)	1	3982232	3982232	308.74	<.001
Contrast 5 (KIBOS vs VIHIGA)	1	359863	359863	27.9	<.001
Contrast 6 (TESO vs VIHIGA)	1	1947887	1947887	151.02	<.001
Varieties	3	8610	2870	0.22	0.881
Coating	3	34966	11655	0.9	0.44
Season.Site	3	530064	176688	13.7	<.001
Season.Contrast 1	1	8663	8663	0.67	0.413
Season.Contrast 2	1	132780	132780	10.29	0.002
Season.Contrast 3	1	435898	435898	33.79	<.001
Season.Contrast 4	1	73610	73610	5.71	0.018
Season.Contrast 5	1	321657	321657	24.94	<.001
Season.Contrast 6	1	87519	87519	6.79	0.01
Season.Varieties	3	46408	15469	1.2	0.311
Site.Varieties	9	129941	14438	1.12	0.351
Contrast 1.Varieties	3	87613	29204	2.26	0.082
Contrast 2.Varieties	3	49571	16524	1.28	0.282
Contrast 3.Varieties	3	25013	8338	0.65	0.586
Contrast 4.Varieties	3	51128	17043	1.32	0.269
Contrast 5.Varieties	3	25087	8362	0.65	0.585
Contrast 6.Varieties	3	21471	7157	0.55	0.645
Season.Coating	3	995	332	0.03	0.994
Site.Coating	9	60976	6775	0.53	0.855
Contrast 1.Coating	3	32638	10879	0.84	0.472
Contrast 2.Coating	3	7646	2549	0.2	0.898
Contrast 3.Coating	3	5776	1925	0.15	0.93
Contrast 4.Coating	3	44383	14794	1.15	0.331
Contrast 5.Coating	3	27714	9238	0.72	0.543
Contrast 6.Coating	3	3795	1265	0.1	0.961
Varieties.Coating	9	95876	10653	0.83	0.593
Season.Site.Varieties	9	284495	31611	2.45	0.012
Season.Contrast 1.Varieties	3	190651	63550	4.93	0.003
Season.Contrast 2.Varieties	3	25595	8532	0.66	0.577
Season.Contrast 3.Varieties	3	20078	6693	0.52	0.67
Season.Contrast 4.Varieties	3	139681	46560	3.61	0.014
Season.Contrast 5.Varieties	3	163422	54474	4.22	0.006
Season.Site.Coating	9	49433	5493	0.43	0.92
Season.Contrast 1.Coating	3	4139	1380	0.11	0.956
Season.Contrast 2.Coating	3	19406	6469	0.5	0.682
Season.Contrast 3.Coating	3	9385	3128	0.24	0.867
Season.Contrast 4.Coating	3	24367	8122	0.63	0.597
Season.Contrast 5.Coating	3	6991	2330	0.18	0.909
Season.Varieties.Coating	9	76680	8520	0.66	0.744
Site.Varieties.Coating	27	448659	16617	1.29	0.166
Contrast 1.Varieties.Coating	9	231879	25764	2	0.041
Contrast 2.Varieties.Coating	9	87037	9671	0.75	0.663
Contrast 3.Varieties.Coating	9	68163	7574	0.59	0.807
Contrast 4.Varieties.Coating	9	208487	23165	1.8	0.071
Contrast 5.Varieties.Coating	9	252658	28073	2.18	0.025
Season.Site.Varieties.Coating	27	250443	9276	0.72	0.844
Season.Contrast 1.Varieties.Coating	9	108253	12028	0.93	0.498
Season.Contrast 2.Varieties.Coating	9	76589	8510	0.66	0.745
Season.Contrast 3.Varieties.Coating	9	43094	4788	0.37	0.948
Season.Contrast 4.Varieties.Coating	9	133130	14792	1.15	0.332
Residual	194	2502276	12898		
Total	323	21369574			