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EVALUATION OF SORGHUM (*Sorghum bicolor*) VARIETIES FOR RESISTANCE TO STRIGA (*Striga hermonthica*) IN NORTHERN GUINEA SAVANNA OF GHANA

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(INGENIEUR AGRONOMIE)

AUGUST, 2015

EVALUATION OF SORGHUM (*Sorghum bicolor*) VARIETIES FOR RESISTANCE TO STRIGA (*Striga hermonthica*) IN NORTHERN GUINEA SAVANNA OF GHANA

A Thesis presented to the Department of Crop and Soil Sciences, Faculty ofAgriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, in partial fulfillment of the requirement for the award of the Degree of MPHIL/ PLANT BREEDING.

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DECLARATION

I, Issa TRAORE hereby declare that this submission is my own work toward the degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Sorghum is an important food crop in Ghana and its production is mainly concentrated in the three northern regions (Upper East, Upper West, Northern regions). Its production is negatively influenced by Striga. In the objective to increase sorghum production in these areas fourteen progenies was assessed for their resistance to striga.The resistance study was carried out in infested field and pots at Savana Agricultural Research Institute (SARI) in northern Ghana. The experiment was Randomized complete Block Design (RCBD) with 3 replication. Data collection was done on: plant height, days to 50% flowering, striga counting on each experimental unit. GNSTAT 2013 version 12 was used for data analysis and LSD at 5% to compare different means. In the infected field mean data of the sorghum progenies across the two parents (Framida, SRN 39) were presented since analysis of variance revealed significant differences for somes of the traits studied. Sorghum progenies under striga infestation showed reduced plant height, 50% flowering, panicle length, and grain yield by 9%, 8%, 9%, 13% respectively. Analysis of variance showed that for 50% flowering there were highly significant differences among the sorghum F4 ($p < 001$) and the two parents. The first early maturing genotype (70 days) was SRN 39. Analysis of variance showed that there were significant differences among sorghum F4 and two parents for striga emergence. The first germination of striga was observed in Framida plot (61 DAP) and the last germination of striga (73 DAP) was observed in the plot of 013-KE-F3T-208 (G8). Analysis of striga counts showed that there were significant, highly significant differences among sorghum F4 and the two parents at the fourth and fifth counts respectively. The lowest means (1.36, 1.04) were recorded respectively for 013-KE-F3T-208 (G8) at the fourth count and Framida for the fifth count. Plant height showed significant differences ($P < 0.05$) among sorghum F4 and two parents, 013-KE-F3T-205-P2 (G6) was recorded as the tallest (2.25 m) and SRN 39 the shortest (1.25 m). For grain yield one of sorghum progenies 013-BE-F3P-219-P2 (G3) recorded the heigher grain yield (1324Kg/ha) than the resistant parents Framida and SRN 39 which recorded 1320 and 1030 Kg/ha respectively. Sorghum progenies G3 recorded highly resistant to *Striga hermonthica.* The yield was negatively correlated to striga damage rate (SDR) and different striga weekly counts. Some of the sorghum F4 progenies (013-BE-F3P-194 (G1), 013-KE-F3T-205-P3 (G7), 013-KE-F3T-235-P1 (G11), 013-KE-F3T-235-P2 (G12)) that showed appreciable levels of tolerance to Striga also recorded a excellent grain quality.

DEDICATION

I dedicate this thesis to my father Bourama TRAORE who died two days before my first examination at KNUST.

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CHAPTER ONE

1.0 INTRODUCTION

Sorghum bicolor (L) Moench is a viable food grain for many of the world's most food insecure people who live in marginal areas with poor soil fertility and erratic rains. It is a staple food crop for millions of people in Africa, South Asia and Central America. Worldwide, sorghum is the fourth major cereal crop in terms of production, after maize (*Zea mays* L), wheat (*Triticum aestivum* L) and rice (*Oryza sativa* L) (FAO 1998). Sorghum is the most important cereal grown in the entire region of the Guinea Savana Zone of West Africa, where it is considered as the most staple food both to humans and to livestock. It is also a very important food source in India and China (Doggett, 1988). In terms of tonnage, in Africa, sorghum is the second most important cereal where production has increased steadily over the past 40 years from nearly 10 million metric tons to 26 million metric tons from approximately 25 million hectares (Mbwika *et al*., 2011). In Sub-Sahara Africa (SSA) sorghum production is estimated at 24 million MT with Nigeria being the highest producing country followed by Mali (Mbwika *et al*., 2011). Globally, Nigeria occupies the second place and Mali sixth after the USA. In Mali, sorghum production has increased from 711.645 MT in 1995 to 907.966MT in 2007 and occupies more than 25% of the arable land (FAO, 1998).

A considerable amount of sorghum produced is consumed as human food in form of porridge, tuo zaafi, and fried dumphing (maasa) (Obilana, 1995). Also, sorghum is an important food in Ghana.The leaves provide folder for farm animals whilst the stalks are used in fencing, weaving baskets, mats and fuel wood. Relative to other cereals, sorghum is utilized mainly in brewing an opaque beer known as (pito), an important cottage industry in Northern Ghana which is as old as the cultivation sorghum itself (Atokple *et al*., 1998).

Sorghum yield; range between 500 and 800 kg/ha in the Northern Region and slightly higher (700 and 900 kg/ha) in the Upper Region. These low yields are due to the cultivation of indigenous land-race varieties with inherent low yield potentials, lack of wide diversity of new improved varieties and hybrids, little or no use of fertilizer and low planting densities characteristic of traditional mixed cropping systems (Schipprack and Mercer-Quashie, 1984; Atokple *et al*., 1999)

The crop, being an indigenous crop of Africa, is adapted to varying climatic conditions both in terms of drought resistance and tolerance to periods of water logging.

According to Ogborn (1972), grain yield losses due to *Striga hermonthica* infestation can range from 10 to 91% in sorghum. The increasing threat of *Striga hermontica* to sorghum production can mainly be attributed to a change in the cropping system of the people in the affected region of West Africa, where monocropping has played a great role in eroding the soil fertility and fallow periods have decreased due to population pressure which encourages intensive use of land under poor soil managements, resulting in increasing severe attack of *S. hermonthica* which survives well under poor soil conditions. Other cereals such as millet (*Pennisetum americanum* L.) and maize (*Zea mays* L.) are seriously being attacked by *S. hermonthica* too.

The control of *S. hermonthica* has not been easy at all. Several control measures have been tried which include agronomical/cultural (Ramaiah, 1984); chemicals

(Hosmani, 1978) and integrated approach (Gworgwor and Weber, 1991), but there has not been any effective and proper method developed to combat this weed.The struggle, however, still continues with some local successes here and there. Striga is found to be one of the major factors limiting the production and productivity of sorghum in the sub-region. Therefore, in order to have sustainable increase in production, lot of efforts needs to be focused on the evaluation of varieties for resistance/tolerance against striga. The use of sorghum tolerant/resistant varieties against *Striga hermonthica* can be a factor to improve sorghum production and productivity in Africa particularly in Ghana. The method of backcrossing sorghum resistant varieties (Framida, SRN 39) by different varieties wich have higher grain yield, better grain quality and proceed the evaluation at F4 generation can achieve this objective.

1.1 JUSTIFICATION OF THE STUDY

In northern Ghana, sorghum is cultivated throughout the savannah agro-ecological zones, covering about 41% of the total land area of the region (Galley, 2013). The crop is consumed in the form of stiff porridge (tuo zaafi), thin porridge (koko) or fried dumpling (maasa) and brewing local opaque beer (pito) (Atokple *et al.*, 1998). Sorghum is primarily a smallholder crop grown for household food security. Commercialization of the crop is rather limited and its value chain is under development. However, the crop is gaining commercial significance especially in the malting and brewing industries. Improvement in production, availability of products, storage facilities, utilization and consumption of sorghum will significantly contribute to the household food security and nutrition of the inhabitants of these areas of Ghana facing those constraints in particular and to the world level in general.

Sorghum production is however, negatively influenced by abiotic stresses such as heat, drought and low soil fertility and biotic stresses (diseases, insects and weeds). (Atokple *et al*.,1999).

Striga remains a major constraint not only to sorghum production but also to other cereals and other crops (including sugarcane). In Ethiopia for instance, striga affects all cereal crops and unlike other countries such as Kenya, where striga is a problem in areas where the soils are largely infertile. It is also found in the highlands where soils are fertile. Annual sorghum production losses due to striga in SSA are estimated to be on average 29% with 25% in Ethiopia, 35% in Nigeria and 40% in Mali. In terms of monetary value, the annual cereal losses due to striga is estimated at US $ 75 million (Mbwika *et al*., 2011). Various methods such as hand weeding and planting of trap crops, chemical/herbicide treatments are used for the control of striga in sorghum. The application of herbicide is frequently used by farmers to control striga but continuous use of these chemicals could have negative effects on both the operator and the environment. Hand pulling or weeding is another control method commonly used but this is found to be time consuming and not very effective. Framida and SRN-39 are resistant to striga but there are not accepted by farmers because of their grain quality (red color). The crossing between the two resistant varieties and suceptibles varieties (97-SB-F5DT-150 and 97-SB-F5DT-154) but accepted by farmers due to their grain quality and higher yield gave different progenies combining these two traits (resistant to striga, higher grain quality). These best performing lines can be improved for release to farmers. Testing for the performance of these progenies is therefore necessary in that it will help in coming out with the best of them in terms of both striga resistance and grain quality.

Therefore, planting of tolerant/ resistant varieties can serve as best alternative in attaining sustainable yield increase in the sub-region.

1.2 General Objective

Increase sorghum production and productivity through the development of better performing lines that combine high grain yield, good grain quality, and good resistance to Striga.

1.3 Specific objective

(1) To evaluate the level of resistance/tolerance of different sorghum varieties (progenies) against striga.

(2) To identify best performing lines with high yield potential and resistant to striga.

CHAPTER TWO

2.0 LITERATURE REVIEW

Sorghum is the major cereal crop cultivated in arid and semi arid tropics of the world. The crop yields are very low in these tracts owing to vagaries of monsoon and other factors. *Striga* poses a serious threat to successful cultivation of sorghum. In field where *Striga* infestation is very severe, the host crop fails to heads and produce any yield. So some of the physical (like handweeding, pulling and burning) and chemical methods are adopted to prevent the *Striga* from flowering and seeding but, no single method is effective, hence integrated *Striga* management approach like use higher levels of farmyard manure, nitrogen and trap crops and use of tolerant varieties are effective in controlling *Striga* (Rao *et al*., 1996).

2.1 Origin and Distribution of Different Races of Sorghum

In world sorghum is a tropical grass which is particularly grown in Africa, India and Asia. In these differents country sorghum is an important staple food (FAO, 1998).

According to Harlan and De Wet (1972), sorghum is in the family of Poaceae and tribe of Andropogoneae, and there are three species of sorghum: *Sorghum bicolor, Sorghum halepense*, *Sorghum propinqum.*

Acording to Harlan and De Wet (1972), there are seven races of sorghum which are cultivated in the world :

1- Race Kafir (Southern Africa)

2- Race Durra (East Africa, Middle East and India)

3- Race Milo-Caudatums (East Africa)

4- Race Feteria-Guineas (Sudan)

5- Race Hegari (Sudan)

6- Race Koaliang (China)

7- Race Sballu(India).

2.2 Domestication of Sorghum

Acording to Reddy *et al*, (2002) after its domestication 3.000 BC in Africa sorghum was expended in Arabia, India and China. Acording to Onwueme and Sinha, (1999) sorghum became important in USA in 1950's trough introduction of sorghum hybrids. It is also used like animal feed (dwarf type) as forage. The grain is also used as human food.

2.3 *Morphology* of Sorghum

Sorghum is a herbaceous plant with a height at maturity of between 0.5 to 6 m depending on the variety.

Aboubacar (2005) reported that the root system of sorghum is fasciculé, well-branched and very powerful and can have 2 m deep in the ground. The stem (culm) is cylindrical, erect, solid. It is composed of node along its length. And at the end of the rod forms the inflorescence.

According to Diallo (2003), the leaves are alternate on the stem along and can reach 50 to 80 cm length. And the number of sheets can range from 7 to 24 according to the humidity and cultivars.

Aboubacar (2005), reported that sorghum inflorescence is a panicle and it has different shape and variable size depending on the variety and can measure 25 to 80 cm long and 10-15 cm wide. Panicle, consisting of a central rachis with secondary and tertiary branching, spikelets usually have two florets with one being sterile.

Sorghum is self- pollinating crop with 6% outcrossing, but some fodder sorghums and some Guinea race may have up to 30% outcrossing (Reddy *et al*., 2002).

The fruit is called caryopsis and are round or ovoid. The fruit sorghum stripped of its husk is called grain and weighs about 20 to 30 mg.

2.4 Ecology and Physiology of Sorghum

According to House (1987), sorghum grows on very different soils. The most favorable soils are sandy-clay texture to clay-sand containing more than 20% clay, a little humus, neutral PH or slightly acidic (6.5) and well-drained. Many varieties of sorghum are photosensitive and short days with a level between 12 and 13 hours for tropical varieties. The root system well developed sorghum allows it to withstand extreme humidity conditions.

According to Touré, (1999), the optimum temperature for growth and development of sorghum is 30 ° C. Flowering and seed formation normally occur at 40-43 ° C.

2.5 Sorghum Production

Sorghum is the fifth most important cereal crop in the world, and the 2nd in Africa after maize and is grown on about 42 million hectares worldwide. Average annual production from 1997-2010 was 60 million metric tons. About 90% of the world crop is grown in developing countries. They are 80% of farmers who produced sorghum like subsistence crop and often used local landraces that provide low yield. (FAO, 2014).

In Ghana the sorghum production in 2006 to 2013 is less than 2 tonnes per ha showing in the folowing table (Table 2.1) acording to FAOSTAT (2014).

Table 2.1 : Sorghum production in Ghana in 2006-2013

years	2006	2007	2008	2009	2010	2011	2012	2013
Harvested area (ha)	320000	208470	275860	267210	252555	243482	230841	230000
Production (tonnes)	315000	154830	330950	350550	324422	287069	279983	277000

Source : FAOSTAT (2014)

2.6 Sorghum Production Constraints

Sorghum is the most favored plant as a host for insect pest.Numerous lists have been produced cataloging well over 150 species as pests and potential pests of sorghum (Teetes, 1982). The most important diseases are, coals, ergot, grain mold and mildew. Insects that cause the most damage are the stem borer and shoot fly. Sorghum maturity, is also very damaged by oiseaux. In some areas, weeds, especially striga, is a serious constraint for sorghum production. Other low production are due to low soil fertility, drought, insufficient varieties resistant to different diseases and lack of post-harvest technology (Nyabyenda, 2006).

2.6.1 Sorghum Midge *Stenodiplosis sorghicola*

Sorghum midge is one of the most damaging in many areas of sub-Saharan Africa and it is observed in some areas in the world where the crop is grown, except

Southeast Asia (Teetes, 1982). The larve of sorghum midge feed on the ovary and causing grain yield loss . (Teetes, 1982).

2.6.2 Sorghum Grain Mold

According to Leslie (2008), Sorghum grain mold disease caused by several species of Fusarium and is the most important disease on the worldwide.The infection takes place at an early stage and the presence or absence of a testa probably has little effect on initial colonization. Grain mold fungi may cause the formation of false or premature black layer which forms 10- 16 days before maturity and results in the development of small seed. Significant losses caused by the weather due to the prolonged period of moiture that exist follow the physiological maturity of the grain.

2.6.3 Bird Damage

One of the most serious pest in Africa which is causing more sorghum damage is the bird species Quelea quelea (L). They root and nest communally, usually on different sites and on trees. The estimation of Quelea damage in Africa is over one million ton of grain yield lost per year (Doggett, 1972).

2.7 Some Resistant Varieties to *Striga hermonthica*

According to Bourama (1996), Varietal resistance has emerged as the main method of fight against Striga. The use of resistant varieties is a particularly attractive solution (cheap, undemanding implementing and technical force). Indeed, these varieties do not allow the removal of large number of Striga and provide a good return. The replacement of susceptible varieties grown by farmers easily solves the problem. Several resistant varieties have been tested in different countries. Some have been abandoned because of the quality of grain. Those currently available are:

- Burkina Faso: Framida, Sariaso 14 ICSV 1049 F2-20
- Niger: SRN 39
- Mali: Wassa, Séguetanna CZ, WTDC 39, WTDC 45, Seguifa (Malisor 92-1) Soumalenba
- Senegal: F2-20, CE 145-66, -33 180 CE, 151-262 CE 25

Many local varieties have also shown good adaptations to *S. hermonthica* in their growing areas. The tolerance of a host plant is not so popular because it does not limit the proliferation of the parasite. So it is convenient to distinguish the case of resistance where the host plant can complete its entire life cycle, case where satisfactory crop tolerance is achieved despite the development of the parasite.(Bourama, 1996).

2.8 Botany and Distribution of Striga

According Obilanan (1984), there are 30 Striga species in the world. Of these, 23 occur in Africa (Obilanan, 1984), with 16 species present in West Africa; Riches and Parker (1993) reported that six species occurring in southern Africa. In parts of Africa, the continent where these evil parasitic herbs are endemic profusion of striga has a serious impact on the socio -economic life of farmers, especially in the subjects of the poor drought resource production systems. Heavy infestation by these pests have caused notable farms abandoned. In catastrophic cases migrations of farming communities have been reported (Riches and Parker, 1993).

In terms of yield loss grain sorghum Dogget (1965) reported an estimate of 59% Obilana (1984) reported 45-95 % and Ramaiah (1987) 10-35 %.

Acording to Abdalla *et al*. (2010) striga (Striga sp.) is a harmful parasite herb of many plants, which causes considerable damage to crops in semi- arid tropics.

Although a number of control measures have been suggested, breeding crops that are resistant to attack is the most feasible and effective method of control. However, breeding efforts have been hampered by the lack of adequate laboratory techniques to discover the host -parasite critical interactions, which occur naturally in the soil. Germination stimulating the production is the only mechanism of Striga resistance in sorghum [Sorghum *bicolor* (L) Moench] that has been widely studied and used for breeding. Striga is distributed in arid and semi arid regions of the world, mainly in Africa, USA and India (Jogalekar *et al*., 1959).

Parker (1965) reported that the longevity of the seeds of *Striga asiatica* in the ground could be even up to 20 years. Hosmani *et al*. (1971) observed that Striga mile produce half a million seeds per plant and seeds are about 0.4 mm long and 0.2 mm wide.

Doggett (1965) indicated that Striga seeds which are in the immediate vicinity of the root of the host to be at a distance of 10 mm from the root of the host may be stimulated and contact root.The host with Striga germination has two distinct phases ie. Preconditioning and stimulation. During the pre-conditioning phase, the seeds must be exposed to a temperature regime and adequate moisture above 20 ° C for a period of 10-14 days (Parker (1965). After the appropriate pre-conditioning the seeds need a stimulus to germination. The stimulant was reported to contain purines (Worsham et al, 1959), coumarin (Worsham *et al*., 1962), ethylene (Egley and Dale, 1970) and strigol (Worsham *et al*., 1959). On the contrary Yoshikawa *et al*. (1978) found that the germination even not preconditioned *Striga asiatica* seeds kinetin can be obtained by concentration of 2.32 x 10-4M.

Ogborn (1972) showed that the main environmental factors causing variation in the emergence of Striga seems to be the micro-climate soil, saturated seeds experience a dormant state and are unable to germinate until dried. Sorghum infestation does not develop normally until the end of peak rainfall and if the infestation developed before the onset of heavy rains raised the dead plants naturally during the rainy season. In dry soils, seeds are viable for longer periods than in soils that are generally wet (Robinson, 1960).

Reda *et al*. (2007), reported that the reduction and delay in the striga emergence can be attributed to the reduced germination, reduced haustorium initiation and attachment.

Hosmani (1978) reported that Striga infestation become more severe after the large-scale cultivation of hybrid sorghum since 1964, Striga is known to parasitize pearlmillet, sugar cane and rice, besides sorghum.

The germination of Striga seeds with different cultures root exudates was studied by Prabhakarasetty (1980) and the results indicated that germination was highest in the three days after application of root exudates.

A plant Striga individual produces thousands of tiny dust like seeds that can remain dormant in the soil for 15-20 years (Ramaiah *et al*., 1983).

Tchemi (1989) stated that the Striga species infest more than half of the cultivated area of maize, sorghum and millet (*Pennisetum americanum*) and have been reported to reduce yields of 30 to 80 percent. Similarly, Sauerborn (1991) reported that yield losses depend on Striga density, nutritional status soil, agro-climatic conditions, plant species and genotype grown. Losses range from 15 percent in more favorable conditions to 100 percent.

Bekker *et al*. (2003) observed that germination depends on the distance of Striga seeds in the roots of the host plant which is known for producing exciting exudates. Depletion was greater for Striga seeds located in the plants between the crop rows.

The literature on botany and distribution of Striga indicated that Striga is distributed in arid and semi arid regions of the world, mainly in Africa, USA and India, four Striga species have been known to occur as *Striga asiatica, Striga densiflora, Striga angustifolia* and *gesnerioides*. Many workers indicated that Striga produces thousand to half a million seeds per plant and seed longevity in soil was even 20 years. It acts as root parasitic partial in cereals.

2.9 Effect of Moisture on Striga

Haussaman *et al*., (2001) reported that sorghum entires as resistant when they supported significantly fewer emerged Striga plants.

Roger and Nelson (1962) observed that there was a continuous movement of carbohydrates, water and nutrients from the host plant parasites, even after the lifting of the Striga to soil surface.

Osman *et al*. (1991) reported that irrigation treatments are not significant effects on seed germination of Striga and sustainability, but a slightly higher number of plants emerged at the irrigation of 60 mm from the 30 mm and Striga seeds in warm, moist environments would rapidly deteriorate and die. The rate of deterioration depended on soil moisture, soil type and duration of exposure and the intensity of the temperature. Some low lying land in Somalia and Sudan, which have been the flodded occasion, were free to Striga, while the better-drained soils were heavily infested.

The germination and longevity of purple witchweed (*Striga hermonthica*) seeds stored in nylon gauze bags in the soil were tested in Northern Benin, Lawrence, USA during rainy season. The results of the experiment indicated that viability and germination of purple witchweed seed declined in moist soil treatment (Gbehounou *et al.*, 2003).

Frost *et al*. (1997), indicated that in dry soils, the seeds were viable for longer period than in soils which were usually wet.

Gbehounou *et al.* (2004) noticed that when sorghum sowing was delayed for 30 days, crops were 3.5 – 5 times less infested as compared to early sowing. It may be caused by the combined effect of dying off process of the seeds and excess soil moisture. On the contrary early sown sorghum crop yielded more than late sown one, despite higher *Striga* infestation in early sown crops (Mbwaga, 1996).

Oliver, 2013 reported that the environmental condition can affect the growth and development of *striga hermonthica*.

2.10 METHODS OF STRIGA CONTROL

2.10.1 Use of compost (organics)

The decomposition of organic matter results in humus formation. Humin as the fraction of organic matter contains purine complex phenolic polymers (Broadbent *et al.*, 1957). Worsham *et al.* (1959) reported that purines stimulate the germination of *Striga* seed in the absence of root exudate of host plants. Kinetin 6-(2-furfuryl) amino purine and certain other 6substituted amino purines were found to stimulate the germination of *Striga asiatica*. Optimum concentration for most active compound was in the range of 5 to 25 mg per litre.

Coumarin derivatives also stimulated the *Striga* seeds to germinate in the absence of host root exudates. About 40 coumarin derivatives were tested to find out their effect on germination and seedling growth of *Striga asiatica*, a coumarin derivative has stimulated *Striga* seeds to germinate at 10 and 20 ppm, while 4-hydroxy coumarine at 10 ppm stimulated germination (Worsham *et al.*, 1962).

A survey in 56 maize and 26 sorghum fields was carried out during February-March 1994 in order to collect data on *Striga* control in Shinyanga region of Tanzania. A sample of 140 farmers were interviewed to determine their indigenous farming practices, the most likely adopted control measures were rotation with trap crops such as cotton (96% farmers), the use of fertilizer in the form of cow manure (82%) and regular hand pulling (54%) (Reichmann *et al.*, 1995).

Marley *et al.* (2004a) conducted experiment in screen house and field conditions in Nigeria and observed under screen house evaluation of the plant materials that neem seed powder was the most effective with only 16.5 per cent of *Striga hermonthica* emergence. This was followed by Parkia fruit powder and Parkia fruit peel powder with 29.1 per cent and 38.8 per cent *Striga* emergence, respectively. And in the field, all the plant materials significantly reduced *Striga hermonthica* emergence. The lowest number of emerged *Striga hermonthica* plants was observed on plots treated with neem seed powder (with 1.7 emerged *Striga hermonthica* per 3 m^2, while the control plots had 30.3 emerged *Striga* per 3m) and hence there was significant increase in grain yield.

2.10.2 Use of trap crops

Studies carried out by Yaduraju (1975) revealed that there was significant difference in the emergence of *Striga* both at 65 and 85 days after sowing of sorghum grown after harvest of different false hosts. Fallow (control) recorded highest emergence of *Striga*. *Striga* population was significantly low in treatments where false hosts such as cotton, cowpea, groundnut and linseed were grown, while sunflower and castor had no effect on *Striga* emergence. However, all these crops decreased the incidence of *Striga* in the succeeding sorghum crop. Cowpea, groundnut, linseed and cotton reduced the incidence of *Striga* by 46, 39, 35 and 36 per cent, respectively at 85 days after sowing of sorghum and this was significant as compared to control.

An experiment conducted by Ejeta and Butler (1993) observed that the trap crops such as cowpea induced *Striga asiatica* seed germination but did not support its subsequent growth and development. In the absence of a suitable host, the *Striga asiatica* seedling died within four days from germination.

Trap crops offer an excellent scope to control *Striga* because they not only reduced the *Striga* seed reservoir but also enhanced soil fertility through N fixation and thus led to increased grain yields of subsequent cereal crops (Odhiambo and Ransom, 1994).

In clay loam soils (30-40% clay) Carsky *et al.* (1994) observed that alternate rows of cowpea did not reduce *Striga* density but planting cowpea and sorghum in the same row or in the same or alternating hills reduced *Striga* density and number of *Striga* per sorghum stand. Yields of sorghum grain in the same row planting treatments were non-significant. Similarly, Mbwaga (1996) observed that sorghum or maize intercropped with cowpea (spreading type) in the same row resulted in the least

Striga emergence and the highest cereal yield was obtained from this treatment.

An integrated control strategy was developed in northern region of Ghana during 1993-95 to control *Striga hermonthica* in two infested sorghum fields. The integrated system combined cotton and soybean as trap crops, a fallow period, a *Striga* resistant cultivar (cv. SRN 39) with higher nitrogen fertilization (30 kg ha^{-1}) and hand pulling of emerged *Striga* plants was practised. The results emphasized that the *Striga* seed bank in the soil decreased by 48 per cent after the combined cropping system, by 33 per cent after cotton, by 34 per cent after soybean and by 22 per cent after fallow (Jost, 1997). Similarly, Delft *et al.* (1997) observed that by keeping field fallow for a year, the level of *Striga hermonthica* infestation had decreased by 62 per cent from 280 seeds m ^{2} to 125 seeds m ^{2}.

Oswald *et al.* (1997) studied on intercropping of Sudan grass (*Sorghum sudanense*) with maize as a *Striga* catch crop and uprooted after 30 or 50 days after sowing which resulted in stimulating the germination of high numbers of *Striga* seeds.

A pot culture experiment was conducted at the Research and Teaching farm of the faculty of Agriculture, University of Maiduguri, Nigeria, during the months of April-July 1997. The results reported that *Striga hermonthica* counts were significantly affected by sorghum varieties and trap crop treatments at 12 weeks after sowing. ICSV 1007 supported significantly lower number of *Striga hermonthica* (8.5 plants/pot) than the other varieties (9.9 to 29.0 plants/pot). Sesame and bambara groundnut trap crops had significantly lower number of *Striga hermonthica* (5.3 and 5.9 respectively) plants than either sorghum or any other trap crop treatments (Hudu and Gworgwor, 1998).

Tenebe and Kamara (2002) recorded the performance of sorghum intercropped with groundnut varieties (RMP-12, Yarkasa and Ex-Dakar), was significantly better than that of the monoculture in terms of plant height, dry matter, leaf number and leaf area index. Intercropping of sorghum with RMP-12 resulted in a significant suppression of *Striga* as compared to other groundnut varieties.

Bekker *et al.* (2003) noticed that by including one year cotton trap crop *Striga* seed bank depletion in soil was 46 per cent with unfertilized continuous sorghum and combining this with the common practice of allowing seed shedding increased the seed bank by 270 per cent.

The above information may be concluded as trap crops were known to reduce *Striga* population by acting as false host. This false host stimulated germination of *Striga* seeds and did not support the seedling for further establishment. Hence, crop rotation or intercropping (eg. Cowpea, greengram, horsegram, groundnut and cotton) with these false hosts is of practical importance which reduced the *Striga* seed reserves from the soil.

2.10.3 Effect of nitrogen on *Striga* (inorganics)

Last (1960) reported that application of 80 kg N ha in the form of urea or ammonium sulphate at sowing increased the grain yield of severely infested sorghum crop by eight times (from 180 kg/ ha to 1505 kg/ ha) and three times (1140 kg/ ha to 3830 kg/ ha) in less severely infested crop. Studies made with witchweed laboratory, North Carolina, indicated that very high rates of N (100 to 300 kg/ ha) were required to control *Striga asiatica* completely for the entire growing season, but these rates were toxic to corn (Shaw *et al.*, 1962). On the contrary, the studies made by Mathur and

Mathur (1967) on sandy soils of Rajasthan revealed that N, P2O5 and K2O each at 22 kg/ ha, either singly or in combinations did not control *Striga asiatica* on bajra. Kim *et al.* (1997) observed that, by continuous cropping of maize and high N application (>120 kg/ N ha) reduced *Striga* infestation significantly within five years, and low N application (<30 kg/ ha) sustained high *Striga* infestation. Among the four levels of nitrogen fertilizer (0, 40, 80 and 120 kg N/ ha in the form of urea) the minimum *Striga* emergence was noticed with the application of 120 kg N/ ha (Esilaba *et al.*, 2000).

Abunyewa and Padi (2003) stated that total nitrogen content at initial sampling showed significant negative correlation with the number of *Striga* seeds in the plough layer.

The results of the trials conducted elsewhere were indicated that nitrogen not only provides good protection to the host from the parasite but also improved the performance of the infected crop. Many workers reported that high rates of N (100 to 300 kg/ha) were required to control *Striga*.

2.11 Effect of Striga on Growth Parameters

2.11.1 Effect of *Striga* on plant height

Frost *et al.* (1997) noticed that within four days of parasite attachment to the host roots, infected plants of both cultivars (CSH-1 and Ochuti) were significantly shorter than uninfected control.

Greenhouse experiments revealed that during flowering and grain filling periods there was significant reduction in stem height due to *Striga* infestation (Gebremedhin *et al.*, 2000).

Sineba and Drennon (2001) noticed that during *Striga* infestation there was reduced sorghum stem height and weight by 22 and 25 per cent at 38 days after sowing and by 34 and 36 per cent at 64 days after sowing respectively.

Showemimo (2002) conducted experiment on eight genetically diverse elite sorghum lines, sorghum lines SSV-3 and KSV-4 possessed partial resistance, with low damage score (3.0%, SSV-3 and 2.7%, KSV-4), reduced height (13.7%, SSV-3 and 16.8%, KSV-4) and grain yield reduction (17.9%, SSV-3 and 18.2%, KSV-4). Line KSV-8 was resistant to *Striga hermonthica*, line SSV-3, KSV-4 and KSV-8 were considered as potential sources of *Striga hermonthica* resistance.

Khan *et al.* (2007) conducted field trials during the long (March-August) and short (October-January) rainy seasons of 2003 and 2004 at the International Centre of Insect Physiology and Ecology (ICIPE) in Kenya on intercroping system, the results indicated that the greenleaf desmodium intercropping significantly enhanced plant height in maize (95.6%) and sorghum (11.8%).

2.11.2 Effect of *Striga* on leaf

Frost *et al.* (1997) recorded that at 55 days, infested plants of both cultivars (CSH-1 and Ochuti) had significantly less shoot and root biomass and significantly smaller leaf area than uninfected control.

Greenhouse experiments revealed that leaf number was unaffected due to *Striga* infestation in the course of crop development in susceptible (IS 9302) and resistant (SRN 39) sorghum cultivars. However, leaf area index (LAI) of IS 9302 *Striga* infested plants was significantly lower during panicle initiation and flowering, but in SRN 39 reduction in leaf area index was delayed considerably and was significant only at peak flowering and at harvesting stages (Gebremedhin *et al.*, 2000).

2.11.3 Effect of *Striga* on dry matter

Ast *et al.* (2000) recorded that the root dry weight in Tiemarifing (tolerant sorghum landrace) was found to be three times greater than that of CK60-B (Sensitive sorghum cultivar). CK60-B had much higher total root biomass (approximately 46%) concentrated in the upper 6 cm of the soil layer. The large differences were observed between the genotypes in root weight and overall root length in the lower soil layers.

Gworgwor and Weber (2003) conducted experiment in a controlled growth chamber and results indicated that, there was increased root: shoot ratio as compared to the control treatment. The per cent reduction of *Striga hermonthica* emergence after VAM fungi inoculation was 62 per cent and resulted in about 30 per cent increase in total dry matter yield of sorghum over control, while the total loss in dry matter yield of sorghum due to *Striga hermonthica* infestation was 36 per cent. Similar experiment was also conducted by Lendzemo *et al.* (2005) in North Cameroon, Africa to control *Striga hermonthica* during the cropping seasons (June-October) of 2000 for maize and 2001 and 2002 for sorghum. He observed that there was significant reduction (30% and more than 50%, number of *Striga* shoots on maize and sorghum respectively) in the number of *Striga hermonthica* shoots. Similar trend was noticed on dry weight of *Striga* (40% reduction in *Striga* dry weight in maize, 46 and 23% reduction in *Striga* dry weight in sorghum during 2001 and 2002, respectively).

The literature collected may be summarized as parasitic weed such as *Striga* is a noxious root parasite having a broad range of hosts including many important graminoaceous crops (sorghum, pearlmillet, sugarcane and maize). The results of many workers stated that, at 55 days, infested plant had significantly lower shoot and root biomass and significantly smaller leaf area than uninfected plant.

2.12 EFFECT OF *STRIGA* ON YIELD

Shawemimo (2006), repoerted that *Striga* infestation reduced plant height, panicle length, panicle weight, 1000 grain weight and grain yield by 13.7, 35.9, 52.9, 64.5 and 52.6%, respectively. The yield and yield components were quantitatively heritable. *Striga* stress on pre-flowering traits resulted in between 14 and 50% reduction in seedling vigor and delayed flowering from 2 to 9%, while post-flowering traits of panicle weight and grain yield were reduced from 8 to 37% and 5 to 45%, respectively.

In Andhra Pradesh both *Striga asiatica* and *Striga densiflora* were known to attack sorghum and the yield loss may range from 15 to 75 per cent depending upon severity of infestation (Sreeramulu, 1959). Similar results were obtained by Nagur *et al.* (1962) and Venkateshwara Rao *et al.* (1967).

Yield of corn was reduced to an extent of 80 per cent due to *Striga asiatica* in North and South Carolina of USA (Shaw *et al.*, 1962).

Striga hermonthica (Del.) Benth, is the most destructive parasitic weed on cereals in western Africa, (Sauerborn, 1991). Grain losses on a regional scale average 5 - 15%, however, Striga can exert a more impact in certain locally, sometimes resulting in total crop failure (Doggette, 1988). Up to 5% and 95% yield losses have been recorded for resistant and susceptible sorghum hybrids, respectively (Obilana, 1984).

Shamugasundaram and Venkataraman (1964) from Tamil Nadu reported 50 per cent grain yield loss in sorghum. Doggett (1965) reported that the large populations of *Striga* caused enormous yield losses over 95 per cent in some seasons in East Africa. Porwal (1968) observed the yield of bajra in Rajasthan were reduced by 25 to 85 per cent due to *Striga* infestation. Rao *et al.* (1989a) quoted the yield losses in rainfed crops varied from 30 to 80 per cent depending upon the severity of infestation.

Experiments were conducted at 6 locations in India and in some locations over 3 years, the results indicated that the mean grain yield loss estimates ranged from 9.2 to 27.6 per cent of the potential yield between locations with an average loss of 17.5 per cent in the rainy season and in the post rainy season, the average loss was 25.2 per cent with a range of 20.1 to 39.6 per cent across years. Potential loss estimates indicated the possibility of up to 98.6 per cent crop loss at some locations in some years (Rao *et al.*, 1989b).

Press and Graves (1991) noticed that *Striga hermonthica* reduced the growth of millet, sorghum and maize by 28, 33 and 28 per cent, respectively and *Striga gesnerioides* reduced the growth of cowpea by 72 per cent and there was a significant reduction in grain and bean yields (ranging from 81% in millet to 100% in maize).

Kroschel *et al.* (1996) reported that two isolates of *Fusarium oxysporum* and *Fusarium solani* reduced the emergence of *Striga hermonthica* by 88 and 76 per cent, respectively. Sorghum yield was increased by 26 per cent. In contrast, there was no yield in control treatment.

Jean- Baptiste *et al*. (2012) reported, in pots and in field, results showed that soghum cultivars differed significantly with respect to number of emerged Striga plants.

Under high and uniform infestation, three promising varieties namely S35, CS54 and Défé Gala constantly recorded low number of parasite plants and low host damage score. Mature plant resistance was also expressed by delay of parasite emergence and inhibition of its development, low reduction in sorghum growth and production (dry matter and grain yield) in comparison with susceptible varieties. Globally, in pot trials, Striga infestation reduced sorghum height, panicle weight and grain yield by 36.6%, 33.7% and 56.5% respectively in comparison with uninfected control.

Ten genetically diverse but homozygote sorghum cultivars adopted to northern Guinea, Savanna zone of Nigeria were grown in *Striga* sick field for two years (1994 and 1995). The results of correlated response indicated that selecting for bigger stem girth, high root, good plant vigour and shoot weight and taller plants under *Striga* infestation will lead to corresponding increase of 1.1, 1.4, 2.7, 7.8 and 14.9 per cent, respectively on grain yield, while 52.4 per cent reduction in grain yield was observed by selecting *Striga* encouraging traits (Showemimo, 2003).

Lendzemo *et al.* (2005) conducted experiment on maize in North Cameroon, and observed that infestation of maize by *Striga hermonthica* resulted in a significant reduction in cob yield to an extent of 20 per cent.

Grain losses of sorghum due to *Striga hermonthica* are difficult to estimate, however, Doggett (1988) reported 59% estimated loss. Ramaiah (1987) reported 10-35% loss and an African regional scale average loss of between 5 and 15% (Riches and Parker, 1993).

The above information may be concluded as *Striga* is established directly on the vascular system of the host plant, it drains water and nutrients from host. Further, reduced grain yield (15 to 75%) and all the yield components considerably, depending on the extent of infestation. If *Striga* infestation is very severe, the crop may fail to bear ears resulting in complete loss of yield.

2.13 Use of Host Plant Resistant to Striga

Hess and Lenné (1999) reported that SRN 39 and Framida are resistant to striga based on many year results at different research sites of ICRISAT.

Hess and Lenné (1999) have confirmed the stability of resistance in Framida red across locations and years.

Hess et al. (1992) reported that the mechanism of host plant resistance to striga was also attributed to low germination stimulant production.

According to Hess and Lenné (1999), Framida and SRN 39 were selected as a better source parents for improvements of the sorghum elite varieties because of their stable resistance to *Striga hermonthica*.

Hess and Lenné (1999), noted that striga tolerant genotypes permit and supports as many striga plants as susceptible genotypes but do not show a concomitant reduction in grain production or overall productivity. Hess and Lenné (1999), suggest that SRN 39 is a better donor parent for Striga resistance than IS 9830. ICSV 00090 NG, a cross between ICSV 111 and SRN 39 gave the highest grain yield of 2.02 t/ha in a replicated trial compared to the two parents, ICSV 111 (1.11 t/ha) and SRN 39 (0.86 t/ha). This variety combines potential for high yield and resistance to Striga.

Oliver, 2013 reported as yet, no crop cultivar, or wild relative, with full resistance (i.e. immunity) to any Striga species has been found. However, tolerant cultivars of maize, sorghum and rice have been identified (Scholes and Press, 2008); and novel types of post-attachment resistance have been described in rice (Gurney *et al*., 2006), sorghum (Mohamed *et al*., 2003), and in a wild relative of maize (Gurney *et al*., 2003). Progress has been made in breeding complex traits underlying broad-spectrum resistance in sorghum into farmer-preferred or locally-adapted cultivars; these cultivars, with high levels of resistance and high yields, are now starting to have a positive impact in several African countries (Ejeta, 2007). The objective of the current study was to evaluate and select striga tolerant progenies cross between two known resistant parents of sorghum for adoption in Ghana.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The experiment was conducted to evaluat sorghum (*Sorghum bicolor*) varieties for resistance to striga (*Striga hermonthica*) in SARI/Nyankpala (Ghana). The details of materials used and methodology adopted are presented in this chapter.

3.1 Materials

3.1.1 Experimental Site

The study was conducted both at the experimental field and in pots at Savanna Agricultural Research Institute (SARI) in Nyankpala, Tolon district of the Northern Ghana from July to November 2014. The field was naturally infested with striga before the commencement of the experiment.

Nyankpala lies within the Savannah zone which is characterized by large area of grassland interspersed with trees. It is located on latitude 9° 25N and longitude 00.58. The rainfall was about 1043 mm with a monthly means of 88 mm compare to 83.5 mm in 2014 (Table 3.1). A higher mean of rainfall was observed in August and September then it stopped in October.the reparation of ranfall was normaly done in time (Figure 3.1). The area records a minimum temperature of about 15° C occurring in January when the weather is under the influence of North East (Harmattan) winds where as maximum temperature of about 42° C occurs at the end of the dry season in March and April. Wet season temperatures ranges between 20-35° C with an annual mean temperature of 28° C. The soil is an alfisol under the USDA classification and Savanna Ochrosol under Ghanaian system of classification (Galley, 2013).

3.1.2 Climatic condition

Table 3.1: Means of rainfall, temperature, and relative humidity for last 10 years

Years / parameters	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Rain fall (mm)	63,7	68,1	82,6	109	113	112	89,7	85,9	90	83,5
Temperature (°c)	28.9	28.2	28.5	28.1	29.3	28.8	28.9	28.3	28.3	29.5
Relative humidity(%)	66	67	66	68	71	71	67	69	68	67

Nyankpala meterologycal station data 2014

A higher mean of rainfall was observed in August and September and it stop in October. The repartiton was good in the time. (Figure 3.1).

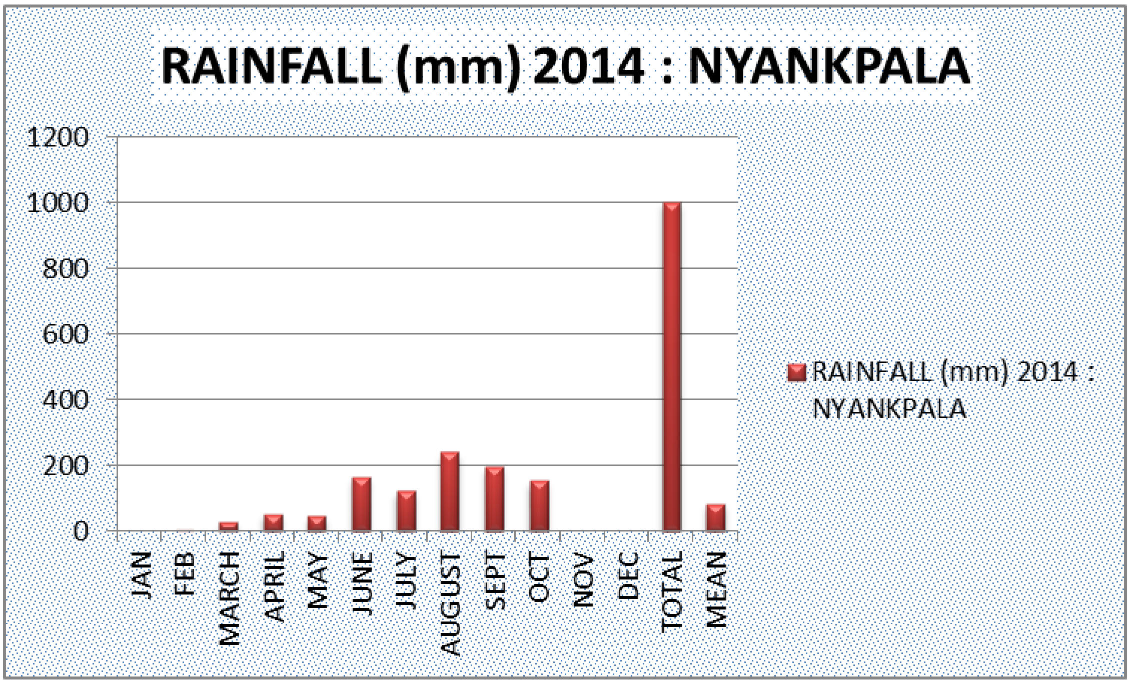

Figure 3.1 rainfall mean of Nyankpala in 2014

3.1.3 Experimental design and layout

A field experiment was laid in Randomized Complet Block Design (RCBD) with 14 treatments with one level of striga. Table 3.2 shows the planting materials and their origin.

3.1.4 Planting material

Twelve (12) F3 sorghum progenies and two (2) parents were tested for their resistance/tolerance against striga. Both progenies and parents were obtained from Mali. These F3 sorghum progenies were coming from the bacrossing between Framida, SRN 39, 97-SB-F5DT-150 and 97-SB-F5DT-154. (Table 3.2).

Table 3.2 : Register of seed material

Progenies	**Generation**	**Origin**
013-BE-F3P-194	F4	Mali
013-BE-F3P-219-P1	F4	Mali
013-BE-F3P-219-P2	F4	Mali
013-BE-F3P-239	F4	Mali
013-KE-F3T-205-P1	F4	Mali
013-KE-F3T-205-P2	F4	Mali
013-KE-F3T-205-P3	F4	Mali
013-KE-F3T-208	F4	Mali
013-KE-F3T-223	F4	Mali
013-KE-F3T-231	F4	Mali
013-KE-F3T-235-P1	F4	Mali
013-KE-F3T-235-P2	F4	Mali
Framida	Parent	Mali
SRN-39	Parent	Mali

3.2 METHODOLOGIES

3.2.1 Experiment in the field

The field was found to be naturally infested by striga hermonthica. The land was ploughed at 20 cm deep by tractor when the soil was wet. After ploughing, the land was harrowed followed by construction of ridges. The plots in the field were delimited by pegs. Each plot composed of 3 ridges of 5 m length, and one empty ridge between different plots.

Before planting, sand was mixed with the striga seed to have an infested soil. At the end of this process; holes of 30 cm were made using a dibbler. Some amount of striga inoculants were placed in each hole using a pince followed by sowing of sorghum seeds. The sorghum seeds were planted at 2 seeds per hill at spacing of 30 between plants and 75 cm between rows.

3.2.1.1 Weed control

The first weeding was carried out one month after planting using hand hoe. The second weed control was done two weeks after the first weeding using hand pulling.

3.2.1.2 Fertilizer application

Compound fertilizer, NPK 15-15-15 was applied at the rate of 250 kg/ha at twenty-eight days after planting. A weight of 281.25 grams of fertilizer was applied in each plot through placement at the base of each plant. . At one month after basal application (NPK 15-15-15) sulphate of Amonia was applied at the rate of 150 kg/ha through the same method.

3.2.1.3 Data collection

The data was collected on all the plants in the three rows (experimental unit).Observations were done on different parameters as in Table 3.3.

3.2.1.3.1 Seedling emergence

Seedling emergence is the number of sorghum plant hills germinated in the plot at one weeck after planting.

3.2.1.3.2 Plant vigor

Is the visual observation of the turgidity of seedlings at three weeks after emergence of the sorghum plants and scored on scale of 1 to 5.

3.2.1.3.3 Striga emergence

Is the date at which striga started to emerge in the plot. The observatoion of the striga emergence was done in the field at eight weeks after planting.

3.2.1.3.4 Number of striga per plot

The number of striga was counted weekly in each plot.

3.2.1.3.5 Plants stands

Plant stands was the number of plant of sorghum standing in the plot one and two week after thinning.

3.2.1.3.6 Date of 50% heading/flowering

The recording of date of 50% heading was carried on the day at which 50% of the plant in the experimental unit started to have panicles from the boot. This data was taken early in the morning.

The date of 50% flowering was recorded on the day at which 50% of the plant in the experimental unit started flowering. It was also taken 1-2 days in the morning.

3.2.1.3.7 Striga damage rate

Striga damage rate is different level of striga damage in the field. It is scored at 1 to 9. 1= very low, 2= very low to low, 3= low, 4= low to intermediate, 5= intermediate, 6= intermediate to high, 7= high, 8= high to very high, 9= very high.

3.2.1.3.8 Plant height

Plant height was measured from the base of the plant to the tip of the panicule at maturity. This data was taken at the maturity three plants per experimental unit. The average of three plant heights was taken per plot.

3.2.1.3.8 Grain appreciation on the field (score grain)

This was an observation on the panicle form and size, grain color and size. The data was scored on the scale of 1 to 5 where 5 is worst and 1 the best.

3.2.1.3.9 Number of harvested hill per plot

This was the number of hillsof sorghum plants present at the day of harverst in the experimental unit. The data was collected by counting the plant hills.

3.2.1.3.10 Number of harvested panicles per plot

The number of panicles harvested was obtained through counting the number of productive panicles in the experimental unit.

3.2.1.3.11 Panicules weight per plot

Panicle weight was the total dry weight of harvested panicle from the experimatal plots. After harvest the panicles were exposed to sun light for drying after which weights per plot were taken.

3.2.1.3.12 Grains weight per plot

Grain weight was the total weight of grain obtained after threshing the harvested panicles.Grain weight permet to determine grain yield and yield loss.

Grain yield was calculated by formular:

Grain yield = Grain weight per plot X 10000 / surface area for one plot

Grain yield loss = [(YC- YS) / YC] X 100

YC: yield of control resistance one

YS: yield of under striga infestation

3.2.2 Experiment in the Pots

The experiment was carried out in an open place using pots (20L). The experimental design was a Randomized Complete Design (CRD) with 2 factors: striga (one level), and varieties (14 levels). Each of the experimental unit was repeated in 3 replications. The different treatments in pots were positioned at random. The pots were arranged in rows with a space of 50cm between pots as footpath, and 1m between replications. The experiment composed of a total of 84 pots, 2 pots was allocated to each variety. The soil from the field was use to fill the pots and transported to the greenhouse. Ten kilograms of soil (10kg) was put in each pot before planting. The striga seeds were mixed with dried sand to make an inoculum. Then two hanfull of the inoculum was mixed with the soil in each pot. The soil was levelled in each pot and sorghum seeds were planted at a depth of 5cm. Four seeds were sown in each pot and thinned to one plant per pot at 2 weeks after emergence. Water was applied in each pot every three days.

Table 3.3: differents experimental data

	Experimental in the pots	**Experimental in the field**	**Description**
1	Striga emergence	Striga emergence	Days
2	Plant stand	Plants stand	Number
3	Sorghum emergence	Sorghum emrgence	Number
4	Seedling vigor	Seedling vigor	Score
5	Number of Striga plants	Number of Striga plants	Weeckely
6	Days to flowering in each pot	Days to flowering in each plot	Date when 50% of plant flower in the plot
7	Number of harvested panicles per pot	Plant height (PH1,PH2,PH3)	
8	plant height at harvested per pot	Number of hills harvested	
9	Panicles weight per plot	Number of panicles harvested	
10	Grain yield per plant (g)	Panicles weight per plot	
11	Grain yield per hectare	Grain weight per plot	

CHAPTER FOUR

4.0 RESULTS

The experiment in pot failed due to striga seed dormance. Different results were taken on the field trial. Before analysis sorghum 013-KE-F3T-231 (G10) was eliminated due to its poor germination in the field and in the pot experiment.

4.1 Days to 50% flowering

As shown in Table 4.1, the days to 50% flowering recorded on the different varieties varied from 94 to 72 days. The highest number of days to 50% flowering was observed in 013-KE-F3T-235-P1 (G11) (94 days), while the lowest was recorded on SRN-39 (72 days).

Analysis of Variance shows that there were highly significant differences among the sorghum F4 ($p < 0.01$) and the two parents Framida and SRN 39. There were significant differences betweent Framida and SRN-39 and rest of the varieties, however, they were not significantly different from each other at $P<0.05$. No significant differences were observed between 013-BE-F3P-219-P1 (G2), 013-KE-F3T-205-P1 (G5), 013-KE-F3T-205-P2 (G6), 013-KE-F3T-205-P3 (G7), 013-KE-F3T-208 (G8), 013-KE-F3T-223 (G9) and 013-KE-F3T-235-P1 (G11) at $P<0.05$.

4.2 Striga Emergence

Analysis of variance showed that there were significant differences among sorghum F4 and two parents for striga emergence.The first germination of striga was observed in Framida plot (61 DAP) and the last germination of striga (73 DAP) was observed in the plot of 013-KE-F3T-208 (G8) (Table 4.1).

Table 4.1: Striga emergence and days to 50% flowering

Progenies	**SGE**	**FL5**
013-BE-F3P-194	66	89
013-BE-F3P-219-P1	68	92
013-BE-F3P-219-P2	69	87
013-BE-F3P-239	64	84
013-KE-F3T-205-P1	67	92
013-KE-F3T-205-P2	69	92
013-KE-F3T-205-P3	69	90
013-KE-F3T-208	73	92
013-KE-F3T-223	63	84
013-KE-F3T-235-P1	69	94
013-KE-F3T-235-P2	70	92
Framida	61	76
SRN-39	66	72
Means	67	87
LSD (5%)	8.46	5.51
CV %	7.5	3.7

SGE : Striga emergence ; FL5 : days to 50% flowering

4.3 Striga Damage Rate

After analysis of variance, there was no significant differences ($P \geq 0.05$) among sorghum F4 and the two resistant parents for striga damage, the mean was 3.59 (Table 4.2).

Analysis of seedling vigor showed that there were highly significant differences (P< 0.01) among sorghum F4 and the two parents. The highest vigor was Framida and the smaller vigor (1.67) for 013-KE-F3T-205-P3 (G7) (Table 4.2).

Table 4.2: Means of seedling vigor and striga damage

Progenies	**Seedling vigor**	**Striga damage rate**
013-BE-F3P-194	3.00	5.00
013-BE-F3P-219-P1	3.00	5.33
013-BE-F3P-219-P2	4.00	3.67
013-BE-F3P-239	4.00	5.67
013-KE-F3T-205-P1	3.00	3.00
013-KE-F3T-205-P2	2.33	2.33
013-KE-F3T-205-P3	**1.67**	3.33
013-KE-F3T-208	3.00	1.67
013-KE-F3T-223	2.67	6.00
013-KE-F3T-235-P1	1.67	1.33
013-KE-F3T-235-P2	2.33	4.00
Framida	**5.00**	3.33
SRN-39	4.67	2.00
Means	3.10	3.59
LSD (5%)	1.270	3.239
CV %	24.3	53.5

4.4 : Striga Counting

Analysis of variance revealed that there were no significant differences among sorghum F4 at the first, second, third and sixth striga counting, but there were significant differences at the fourth and highly significant differences at the fith striga counting (Table 4.3).

Among differents means of striga counting (1.11, 1.19, 1.40, 1.53, 1.52, 1.15) the highest mean of striga was recorded at fourth week counting after planting (Table 4.3).

At the fourth counting the heighest mean (1.72) was recorded for 013-KE-F3T-223 (G9) and the lowest (1.36) for 013-KE-F3T-235- P1 (G11) (Table 4.3). And at the fifth week after planting the heighest number (1.75) of striga was recorded for 013-BE-F3P-219-P1 (G2) and the lowest mean (1.04) was recorded for Framida (Table 4.3).

Table 4.3: Number of striga at different counting per weeck.

Progenies	**1WAP**	**2WAP**	**3WAP**	**4WAP**	**5WAP**	**6WAP**
013-BE-F3P-194	1.21	1.27	1.57	1.64	1.70	1.21
013-BE-F3P-219-P1	1.05	1.37	1.55	1.71	**1.75**	1.20
013-BE-F3P-219-P2	1.04	1.22	1.42	1.55	1.63	1.21
013-BE-F3P-239	1.20	1.30	1.54	1.70	1.71	1.14
013-KE-F3T-205-P1	1.08	1.20	1.27	1.50	1.55	1.22
013-KE-F3T-205-P2	1.08	1.13	1.35	1.40	1.43	1.14
013-KE-F3T-205-P3	1.08	1.11	1.36	1.43	1.44	1.10
013-KE-F3T-208	1.04	1.10	1.28	1.37	1.40	1.11
013-KE-F3T-223	1.11	1.16	1.56	**1.72**	1.72	1.15
013-KE-F3T-235-P1	1.08	1.11	1.24	**1.36**	1.54	1.12
013-KE-F3T-235-P2	1.04	1.13	1.40	1.55	1.59	1.21
Framida	1.16	1.20	1.41	1.53	1.26	1.05
SRN-39	1.11	1.11	1.27	1.38	**1.04**	1.05
Means	1.11	1.19	1.40	1.53	1.52	1.15
LSD (5%)	0.0742	0.0856	0.1329	0.1222	0.1575	0.0849
CV %	8.20	8.84	11.59	9.79	12.67	9.07

WAP : week after planting

4.5 Plant Height (PH)

With 1.89 m mean, plant height of sorghum F4 progenies was between 1.41 to 2.30 m while the two parents Framida and SRN 39 mesured respectively 1.92 and 1.27 m.

Plant height at the maturity showed significantily differences ($P < 0.05$) among sorghum F4 progenies and two parents. 013-KE-F3T-205-P2 (G6) was the tallest (2.25 m) and the shortest was SRN 39 with 1.27 m (Table 4.4).

4.6 Panicle Length

Analysis of variance for panicle length showed highly significant differences among sorghum F4 and resistant parents. Sorghum 013-BE-F3P-239 (G4) and 013-KE-F3T-205-P2 (G6) had the heighest panicle length (38 cm), and Framida (G13) had the shortest panicle (27 cm), (Table 4.4).

4.7 Grain Yield

There were highly significant differences among sorghum F4 and the two resistance parents.The sorghum progenie 013-BE-F3P-219-P2 (G3) recorded the highest grain yield (1324 Kg/ha), followed by the two parents Framida and SRN 39 respectively 1320 and 1030 Kg/ha. 013-KE-F3T-205-P1 (G5) recorded the lowest grain yield (323Kg/ha), (Table 4.4).

Table 4.4: Different means of plant height, grain yield and panicle lenght

Progenies	PH(m)	Pan lenght (cm)	Yield (Kg/ha)
013-BE-F3P-194	2,103	31	602
013-BE-F3P-219-P1	1,597	31	671
013-BE-F3P-219-P2	2,123	37	**1324**
013-BE-F3P-239	1,413	38	538
013-KE-F3T-205-P1	2,267	33	**323**
013-KE-F3T-205-P2	2,3	38	445
013-KE-F3T-205-P3	2,17	36	499
013-KE-F3T-208	2,083	33	776
013-KE-F3T-223	2,037	29	576
013-KE-F3T-235-P1	1,637	35	763
013-KE-F3T-235-P2	1,68	35	947
Framida	1,92	27	1320
SRN-39	1,27	30	1030
Means	1.89	33.36	755
LSD(%)	0.221	4.30	275.9
CV%	6.9	7.7	21.7

4.8 Grain Yield, Yield Lost and level of resistance to striga

Even though there were significant differences (P< 0.05) among sorghum progenies for grain yield, base on the grain yield mean, sorghum progenies could be classified in four groups for resistance to striga:

- The progenie 013-BE-F3P-219-P2 (G3) recorded the higher grain yield (1324Kg/ha) than the two resistant parents and it was demonstrated highly resstant to striga.

- Sorghum progenies 013-KE-F3T-235-P2 (G12), 013-KE-F3T-208 (G8), and 013-KE-F3T-235-P1 (G11) recorded moderate resistant due to their higher grain yield than the mean grain yield.
- Tolerant group: 013-BE-F3P-219-P1 (G2), G1, G9, G4) and Susceptible group like (G5), their grain yield recorded smaller than the mean grain yield. (Table 4.5).

The grain yield lost was ranged from 8 to 69% that confirm different level of resistance of different sorghum progenies against *Striga hermonthica* in this study (Table 4.5).

The higher grain yield lost (69%) was recorded on 013-KE-F3T-205-P1 (G5) and the smaller grain yield lost (0%) was recorded on 013-BE-F3P-219-P2 (G3), Framida and SRN-39 (Table 4.5).

Table 4.5 : Variation in grain yield, yield lost and resistance to striga

Genotypes	Yield (Kg/ha)	Yield lost (%)	Remarks
013-BE-F3P-219-P2	1324	0	Highly resistant
Framida	1320	0	Highly resistant
SRN-39	1030	0	Highly resistant
013-KE-F3T-235-P2	947	8	Moderate resistant
013-KE-F3T-208	776	25	Moderate resistant
013-KE-F3T-235-P1	763	26	Moderate resistant
013-BE-F3P-219-P1	671	35	Tolerant
013-BE-F3P-194	602	42	Tolerant
013-KE-F3T-223	576	44	Tolerant
013-BE-F3P-239	538	48	Tolerant
013-KE-F3T-205-P3	499	52	Susceptible
013-KE-F3T-205-P2	445	57	Susceptible
013-KE-F3T-205-P1	323	69	Susceptible
Mean	755		
LSD (5%)	275.9		
CV%	21.7		

4.9 Grain Appreciation (Score Grain)

Analysis of variance showed that there were highly significant differences (P< 0.01) among sorghum F4 and there resistant parents for the grain apreciation

We recorded the excellent score (1) for 013-BE-F3P-194 (G1), 013-KE-F3T-205-P3 (G7), 013-KE-F3T-235-P1 (G11), 013-KE-F3T-235-P2 (G12), good score(2) for all the other progenies but Framida(G13) and SRN 39(G14) recorded the bad score (3 to 4) grain (Figure 4.1).

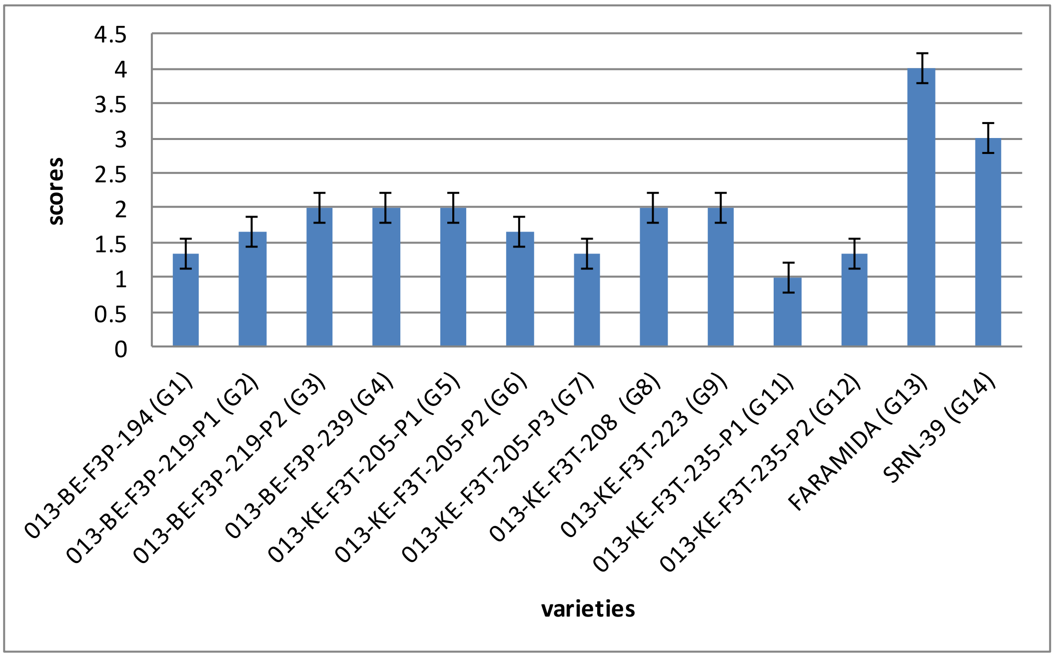

Figure 4.1: Score grain for 13 varieties of sorghum

4.10 Stay Green (STGR)

After analysis of variance it observed that there were no significant differences (P≥ 0.05) among sorghum F4 and the two resistant parents concerning green leaves at maturity (Fig 4.2).

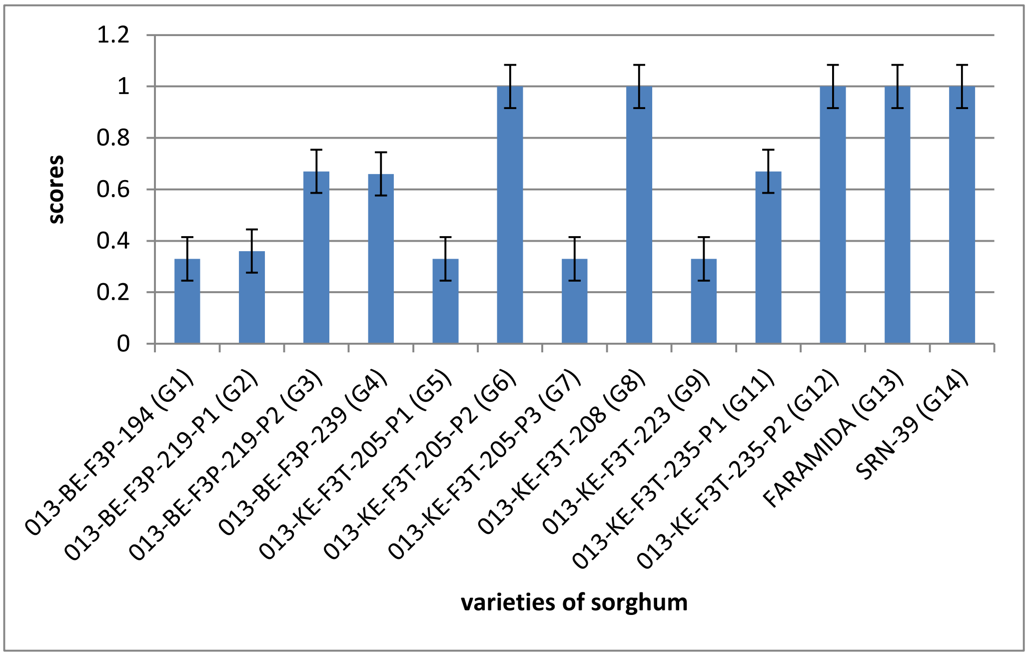

Figure 4.2: Stay green of 13 sorghum genotypes at maturity.

4.11 Correlation Betwen Different Parameters

Analysis of correlation showed that grain yield was negatively correlated to all parameters apart from striga emergence (Table 4.6). The plant height was negatively correlated to striga damage rate, different number of striga after planting (WAP), but it is positively correlated to panicle length. Striga damage rate (SDR) affected negatively and it reduced days to 50% flowering, plant height, panicle length and grain yield (Table 4.6).

Table 4.6 : correlation betwen different parameters

	Fl5	**PH**	**Panl**	**SDR**	**SGE**	**Yield**	**4WAP**	**5WAP**
Fl5	0							
PH	0.3553	0						
Panl	0.3368	0.1077	0					
SDR	-0.0294	-0.1244	-0.1298	0				
SGE	0.3820	0.1994	0.3781	-0.5471	0			
Yield	-0.5408	-0.1720	-0.0920	-0.2521	0.0494	0		
4WAP	0.0179	-0.1612	-0.1427	0	-0.5330	-0.2918	0	
5WAP	0.3222	-0.0232	0.0182	0	-0.3748	-0.3733	0	0

Fl5: days to 50% flowering, **PH**: plant height, **Panl**: panicle length, **SDR**: striga damage rate, **SGE**: days to striga emergence, **WAP**: week after planting.

CHAPTER FIVE

5.0 DISCUSSION

Sorghum is one of the important staple foods in northern Ghana, but its production is affected by biotic and abiotic stresses. One of the biotic factors is the S*triga hermonthica*. Striga hermonthica is the most destructive parasitic weed on cereals in Western Africa reported by Sauerborn (1991). Ogborn; (1972) said that various environmental factors influence the growth and development of Striga. Growing sorghum in artificially infested soil in pots investigator more control over the experimental environment than is possible in the field (Ogborn 1972). The effect of *Striga hermonthica* on sorghum progenies was tested in the infected field and in pot experiment.

5.1 Experiment in Pot

No striga emergence was recorded in any pot for the following reasons: the germination of striga seed, was delayed as a result of dormancy and the planting system (Striga seed and sorghum seed were planted the same day). Striga seed should have been planted one or two days and watered copiously before planting the sorghum seed in the pot. There were also the weather condition, the temperature was hot at the time of planting the pot experiment. That was demonstrated by Osman *et al*. (1991), who observed that in high moisture and hot environements, striga seeds would rapidly deteriorate and subsequently die, such deterioration and rate depended on soil type, soil moisture, and intensity of temperature. All these factors affected the germination of striga. Frost *et al*. (1997), indicated that in dry soils, the seeds were viable for longer period than in soils which were usually wet. The sorghum progenies tested in the study showed resistance to striga in the field so no emergence of striga was recorded in the pot.

5.2 Experiment in the Field

Sorghum progenies from the crossing between Framida, SRN-39, 97-SB-F5DT-150 and 97-SB-F5DT-154 recorded higher variation for grain yield, days to 50% flowering, some Striga counts per plot, panicle lenght, score grain, and plant height. That was confirmed by Hess and Lenné (1999), reported that Framida and SRN-39 were selected as a better source parents for improvements of sorghum elite varieties because of their stable resistance to *Striga hermonthica*. This variability among sorghum progenies indicated:

- Differences in Striga seed distribution in the field under natural conditions that mean the distribution of striga seed in the field was so heterogeneous in different plots in different replications.

- Differences in genotypes resistances levels: all the sorghum genotypes had different levels in terms of resistance to *Striga hermonthica*. This genetique variability of resistance of striga can also affect Striga seed germination in the soil.

- In the field the variability of severity of striga infestation was not the same as was reported by Ramaiah (1984).

5.2.1 Striga Damage Rate (SDR)

Among the fourten varietys the number of striga plants in the plot were low that was due to low stimulus produced by roots of different sorghum plants in the field. It has been reported that there is a continued movement of carbohydrates, water and nutrients from sorghum plant to Striga even after emergence of the striga from the soil surface (Roger and Nelson (1962). During the different stages of sorghum development, some dead striga plants were recorded, that were due to the effect of resistance factors probably acting as allelo chemicals released from the sorghum progenies to striga. Haussamann *et al*. (2001) identified those sorghum entries as resistant to striga when they supported significantly fewer emerged striga plants. This was a clear indication of the damage during the striga sub-terranean stage of development as was reported by Parker (1965). Low SDR scores were exhibited from most of sorghum F4 progenies. This showed that the sorghum F4 progenies were resistant to striga infestation, which is an effective way of reducing Striga damage.

5.2.2 Effect of striga on 50% flowering

Highly significant differences were recorded among sorghum progenies and parents for days to 50% flowering. This reduction of days to flowering could be attributed to the higher level of striga effect on physiology of sorghum plants during susceptible vegetative phase up to flowering initiation. The number of days to 50% flowering recorded on the varieties ranged from 72 to 94. Franke et al., (2006) did a similar experiment and recorded days to 50% anthesis ranging from 58 to 94 and the mean was 70. The higher mean value recorded in the current study may be due to differences in genotypes used and the variation in levels of Striga infestation. Rao *et al.* (1996), also reported days to flowering of sorghum ranged from 42 to 129 days during post rainy season and 33 to 180 days during the rainy season which indicated day- length sensitivity. Early maturity is one attribute to avoid striga infestation that was demonstreted by Framida and SRN 39 which flowered earlier than all sorghum progenies.The nutrient uptake by host plant (sorghum) was reduced by the Striga and could be a factor to affect the flowering and reduced sorghum production. Gebremedhin *et al*. (2000), made similar observation that during sorghum flowering and grain filling periods there was significant reduction in stem height due to striga infestation.

5.2.3 Effet of Striga on Plant Height

There were variability between sorghum F4 progenies and the two resistant parents. In general, higher plant heights were observed within the F4 progenies compared to the parents. This is inline with Hesse and Lenné (1999) who stated that variability of plant height among the tested varieties was attributed to the genetique variation of differents sorghum progenies. The reduction in sorghum plant height was 34% at 64 days after sowing in other study by Sineba and Drennon (2001). The low fertility of the soil and the nutrients from the applied fertilizer were used by Striga as the parasite on the sorghum plant and affected its growth and hence the plant height. Frost *et al*. (1997) reported that the attachement of Striga on the root system affected and reduced the plant height of host plant by taking the substantial amount of nutrients from the host plant.

5.2.4 Effect of striga on grain yield

The grain yield was highly significant between sorghum progenies and the two resistant parents. This could be due to striga effect on sorghum plants during vegetative physiological phase. This is agreement with Shawemimo (2006) who reported 52.6% grain yield reduction was observed on sorghum due to striga infestation. The grain yield loss depend on Striga density, soil fertility, agro-climatic conditions, and the plant species, as reported by Sauerborn (1991). Grain yield loss can be used to classify the level of resistance by the host plant to Striga (Obilana

,1984). The levels recorded in the current study showed that four sorghum progenies were resistant to *Striga hermonthica* to a degree. These progenies can be regarded as resistant or tolerant because of their higher grain yield and lower Striga infestation levels, as was observed by Dogget (1988). Rao *et al.* (1989a) reported that the yield lost in rainfed crops varied from 30 to 80 per cent depending upon the severity of infestation.

CHAPTER SIX

6.**0 CONCLUSION AND RECOMMENDATION**

6.1 Conclusion

The research was conducted in Northern Region of Ghana, sorghum progenies F4 and two resistant varieties (Framida, SRN 39) all from Mali were used to test their resistance to *striga hermonthica*.The study was carry out on station field (infected field) and in pots at Savana Agricultural Research Institute (SARI). The objective of the study was to increase sorghum production and productivity through the development of better performing lines that combine high grain yield, good grain quality, and good resistance to Striga in Northern Region of Ghana. The design was Randomized complete Bloc (RCBD) with three replications. Data were collected and subjected to analysis, using the Genstat 2013 version 12.

The results of study indicated that considerable variability existed among the sorghum F4 and the two resistant parents to Striga in terms of days to 50% flowering, plant height, striga emergence, grain yield.

Sorghum progenies 013-BE-F3P-219-P2 G3 were highly resistant to striga due to its grain yield (1324Kg/ha) and yield lost (0%).Sorghum progenies 013-BE-F3P-219-P2 (G3) and 013-KE-F3T-235-P2 (G12) were the best performing lines due to there higher yield, 1324 and 947 Kg/ha respectively. Four sorghum progenies (013-BE-F3P-194 (G1), 013-KE-F3T-205-P3 (G7), 013-KE-F3T-235-P1 (G11) and 013-KE-F3T-235-P2 (G12)) recorded the excellent grain quality and apart form Framida and SRN 39 the rest progenies recorded the good grain quality.

Four sorghum progenies (G3, G12, G8, and G11) were resistant to *Striga hermonthica* in this study. There was an improvement in the performance of sorghum varieties when *Striga* was inoculated in the soil.

It is evident that new sources for Striga resistance can be exploited by the performance of the progenies under Striga infestation. These progenies can be used in the sorghum breeding program to develop inbred lines with resistance to Striga infestation.

Different results indicate that the sorghum elite varieties for this trial like 013-BE-F3P-219-P2 (G3) can be improved for Striga resistance using pedigree breeding.

6.2 Recommendation

It is recommended that the continuation of this trial next year at F5 generation to confirm the resistance to Striga. In the pot the striga seed should be planted and watered one or two week before planting sorghum seed. And the trial should be at two level in the field (no infected field and infected field by Striga) to observe the reel differnce.

REFERENCES

Abdalla, H. M., Housley, T.L., and Gebisa, E. (2010). An vitro Technique for studying specific striga resistance mechanisms in sorghum; Pp: 12-56.

Aboubacar, A. (2005). Résistance aux punaises des panicules de sorgho [*Sorghum bicolor* (L) Moench]: Etude des descendances F3 du croisement de Malisor 84-7. Pp : 1- 6.

Abunyewa, A.A. and Padi, F.K. (2003). Changes in soil fertility and *Striga hermonthica* prevalence associated with legume and cereal cultivation in the Sudan Savannah Zone of Ghana. *Land Deg. Dev.*, 14(3): 335-343.

Ast, A.V., Bastiaans, L. and Kropff, M.J. (2000). A comparative study on *Striga hermonthica* interaction with a sensitive and a tolerant sorghum cultivar. *Weed Res. Oxford*, 40(6): 479-493.

Atokple, I.D.K., Clottey, V.A., Gyasi, O., Manful, J.T., Quaye, W., Kwafo, A., Johonson, P., Bruce, J.,Andah, A.and Ayireko,P. (1999). Increasing Sorghum Productivity in Ghana : Study on the Production System of Sorghum Pp :62.

Atokple, I.D.K Murty, D.S.C.C. Nwasike. (1998). « Registration of ICSV 111 Sorghum cultivar. » Crop science 35.6 (1998).

Bekker, R.M., Forcella, F., Grundy, A.C., Jones, N.E., Marshall, E.J.P. and Murdoch, A.J. (2003). Depletion of natural soil seed banks of *Striga hermonthica* in West Africa under different integrated management regimes. *Aspects of Appl. Biol.*, 69: 261-
268.

Bourama, D. (1996). Lutte contre le *Striga hermonthica* sur le sorgho et le mil en zones soudano saheliennes. Sotuba. Mali. Pp : 2- 5.

Broadbent, F.E., Tyler, K.B. and Hill, G.N. (1957). The stimulant involved in the germination of *Striga hermonthica* Benth. *Hillgardia*, 27: 247.

Carsky, R.J., Singh, L. and Ndikawa, R. (1994). Suppression of *Striga hermonthica* on sorghum using a cowpea intercrop. *Expt. Agric.*, 30: 349-358.

Delft, G.J.V., Graves, J.D., Fitter, A.H. and Pruiksma, M.A. (1997). Spatial distribution and population dynamics of *Striga hermonthica* seeds in naturally infested farm soils. *Plant and Soil*, 195(1): 1-15.

Diallo, C. (2003). Etude de l'effet hétérosis chez quelques hybrides de type guinea et dérivés guinea. Mémoire de Fin d'Etudes, cycle Ingénieur Agronome. Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou. Mali.Pp: 3-5.

Doggett, H. (1965). *Striga hermonthica* on sorghum in East Africa. *East African Agric. J.*, 18: 155-159.

Doggett, H. (1972). The improvement of sorghum in East Africa. Pp 10.

Doggett, H. (1988). Sorghum 2nd ed. Longman Scientific and Technical, Essex, England.Pp 25-50.

Egley, G.H. and Dale, J.E. (1970). Ethylene, 2-chloroethyl phosphonic acid and witchweed germination. *Weed Sci.*, 18: 586-589.

Ejeta, G. and Butler, L.G. (1993). Host parasite interactions throughout the *Striga* life cycle and their contributions to *Striga* resistance. *African Crop Sci., J.*, 1(2): 75-80.

Ejeta, G. (2007). Breeding for Striga resistance in sorghum: exploitation of an intricate host- parasite biology. Crop Science 47:216-227.

Esilaba, A.O., Reda, F., Ransom, J.K., Bayu, W., Woldewahid, G. and Zemichael, B.

(2000). Integrated nutrient management strategies for soil fertility improvement and *striga* control in Northern Ethiopia. *African Crop Sci., J.*, 8(4): 403-410.

FAO. (1998). Sorghum and millet production in the world and in Africa, www.fao.org/docrep

FAO. (2014). Sorghum production in Ghana 2006-2013, www.faostat.org.

Franke, A.C., Elis, J. J., Tarawali, G., Schulz, S., Hussaini, M.A., Kureh, I., White, R., Chikoye, D., Douthwaite, B., Oyewole, B.D., Olanvewaju, A.S. (2006). Evaluating and scalingup integrated *Striga hermonthica* control technologies among farmers in Northern Nigeria crop protect. 25 : 868-878.

Frost, D.L., Gurney, A.L., Press, M.C. and Scholes, J.D. (1997). *Striga hermonthica* reduces photosynthesis in sorghum: the importance of stomatal limitations and a potential role for ABA. *Plant, Cell and Env.*, 20(4): 483-492.

Galley, S.S. (2013). Evaluation of sorghum hybrids in Northern Ghana, Thesis, UDS Nyankpala. Pp : 6- 7.

Gbehounou, G., Adango, E., Hinvi, J.C. and Nonfon, R. (2004). Sowing date or transplanting as components for integrated *Striga hermonthica* control in grain cereal crops. *Crop Prot.*, 23(5): 379-386.

Gbehounou, G., Pieterse, A.H. and Verkleij, J.A.C. (2003). Longevity of *striga* seeds reconsidered: results of a field study on purple witchweed in Benin. *Weed Sci.*, 51(6): 940-946.

Gebremedhin, W., Goudriaan, J. and Naber, H. (2000). Morphological, phenological and water use dynamics of sorghum varieties (*Sorghum bicolor*) under *Striga hermonthica* infestation. *Crop Prot.*, 19(1): 61-68.

Gurney, A.L., Grimanelli, D., Kanampiu, F. (2003). Novel sources of resistance to *Striga hermonthica* in Tripsacum dactyloides, a wild relative of maize. New Phytologist, 160, 557–568.

Gurney, A.L., Slate, J., Press, M.C., Scholes, J.D. (2006). A novel form of resistance in rice to the angiosperm parasite *Striga hermonthica*. New Phytologist, 169, 199–208.

Gworgwor, N.A. and Weber, H.C. (1991). Effect of N-application on sorghum growth, *Striga* infestation and the osmotic pressure of the parasite in relation to the host. *J. Pl. Phy.*, 139(2): 194-198.

Gworgwor, N.A. and Weber, H.C. (2003). Arbuscular mycorrhizal fungi parasite host interaction for the control of *Striga hermonthica* (Del.) Benth. in sorghum (*sorghum bicolor* (L.) Moench). *Mycorrh.*, 13(5): 277-281.

Harlan, J.R. and De Wet, J.M. (1972). A simplified classificationof cultivated sorghum. The study supported by a grant from the Rockefeller Foundation and the Ilinois Agricultural Experiment station crop 172-176.

Haussamann, B.I.G. and Hess, D.E. (2001). *Striga* control: mechanisms and strategies for promoting sustainable sorghum production in Africa with special emphasis on host plant resistance. Towards sustainable sorghum production, utilization and commercialization in west and central Africa *Proceedings of a Technical Workshop of the West and Central Africa Sorghum Research Network*, Lome, Togo, 19-22, April 1999, pp.101-119.

Hesse, D.E., Ejeta, G., and Butler, L.G. (1992). Selecting sorghum genotypes expressing a quantitative biosynthetic trait that confers resistance to *Striga*. Phytochemistry 31:494-497.

Hesse, D.E. and Lenné, J.M. (1999). Repport on ICRISAT, secto Review for *Striga* control in sorghum and millet.pp: 120-136.

Hosmani, M.M. (1978). *Striga* (A noxious root parasitic weed). Univ. Agric. Sci., Dharwad, pp.1-79.

Hosmani, M.M., Shivaraj, B. and Kurdikeri, C.B. (1971). Seed production potentialities of common weeds of Dharwad. *PANS*, 17: 237-239.

House, L. R. (1987). Manuel pour la sélection du sorgho .Deuxième édition. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Patancheru P. O. Andhra Pradesh 502324, Inde. P. 150-229.

Hudu, A.I. and Gworgwor, N.A. (1998). Preliminary results on evaluation of trap crops for *Striga hermonthica* (Del.) Benth. Control in sorghum, Internl Sorgh Mill. News. , 39: 118-121.

Jean- Baptiste, T., Noubissié, H., Yadji, T. and Issa, B. (2012). Screening Sorghum Populations for Resistance to *Striga hermonthica* (Del.) Benth in Northern Cameroon, 1 : 12- 45.

Jogalekar, R.G., Hardas, M.G. and Deshmukh, N.Y. (1959). A short note on the control of weed *Striga*. *Indian J. Agron.*, 4: 114-118.

Khan, Z.R., Midego, C.A.O., Hassanali, A., Pickett, J.A. and Wadhams, L.J. (2007). Assessment of different legumes for the control of *Striga hermonthica* in maize and sorghum. *Crop Sci.*, 47: 730-736.

Kim, S., Lagoke, S.T.O. and Thom, C. (1997). Observations on field infection by witchweed on maize in west and central Africa. *Internl. J. Pest Manag.* 43(2): 113-121.

Kroschel, J., Hundt, A., Abbasher, A.A. and Sauerborn, J. (1996). Pathogenicity of fungi collected in northern Ghana to *Striga hermonthica*. *Weed Res. Oxford*, 36(6): 515-

520.

Last, F.T. (1960). Effect of cultural treatments on incidence of *Striga hermonthica* (Del.) Benth and yield of sorghum in the Sudan field experiments, 1957-58. *Ann. App. Biol.* 40: 207-229.

Lendzemo, V.W., Kuyper, T.W., Kropff, M.J. and Ast, A.V. (2005). Field inoculation with arbuscular mycorrhizal fungi reduces *Striga hermonthica* performance on cereal crops and has the potential to contribute to integrated *Striga* management. *Field Crops Res.*, 91(1): 51-61.

Leslie, L.F. (2008). Grain molds mycotoxins and stalk rots of sorghum and millet, Kansas state University USA, pp. 75-76.

Marley, P.S., Aba, D.A., Shebayan, J.A.Y., Musa, A. and Sanni, A. (2004a). Integrated management of *Striga hermonthica* in sorghum using a mycoherbicide and host plant resistance in the Nigerian Sudano-Sahelian Savanna. *Weed Res. Oxford*, 44(3): 157-162.

. Mathur, R.L. and Mathur, B.N. (1967). Effect of fertilizers on the incidence of *Striga lutea* Lour and yield of bajra. Indian Phytopath, 20: 270-272.

Mbwaga, A.M. (1996). Status of *Striga* species in Tanzania: occurrence, distribution and on-farm control packages. Drought tolerant crops for Southern Africa *Proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop*, Gaborone, Botswana, 25-29 July, 1994, 1996, pp.195-200.

Mbwika, J.M, Odame, H. and Ngugi, E.K. (2011). Feasibility study on *Striga* control in Sorghum, Nairobi, African Agricultural Technology Fondation: 15-120.

Mohamed, A., Ellicott, A., Housley, T.L., and Ejeta, G. (2003). Hypersensitive response to Striga infection in sorghum. Crop Science 43:1320-1324.

Nagur, T., Sreeramulu, C. and Sivaramakrishnaiah, M. (1962). *Striga* resistant sorghum culture No. 109. *Andhra Agric. J.,* 9: 145-148.

Nyabyenda, O. (2006). Les plantes cultivées des Régions Tropicales d'Altitude (RTA) d'Afrique, CTA (Centre Technique de coopération Agricole et Rural). Pp 141-147.

Obilana, A.B. (1995). Inheritance of resistance to Striga (*Striga hermonthica* [Benth]) in sorghum. Protection Ecology 7:305-311.

Obilana, A.B. (1984). Inheritance of resistance to Striga (*Striga hermonthica* [Benth]) in sorghum. Protection Ecology 7:305-311.

Odhiambo, G.D. and Ransom, J.K. (1994). Long-term strategies for *Striga* control. Fourth Eastern and Southern Africa Regional Maize Conference, 28 March, 1 April, 1994, Nairobi, Kenya, pp.263-266.

Ogborn, J.E.A. (1972). The control of *Striga hermonthica* (Del.) Benth in peasant farming.

Proc. of 11th Broad Weed Cont. Conf., Brighton, 3: 1068-1077.

Oliver L. P., 2013, the genetics of host adaptation in the parasitic plant *Striga hermonthica*. Sorghum Protection, (3) : 66-98.

Onwueme, I.C. and Sinha, I.T. (1999). Field crop production in tropical Africa CTA publication Science Direct, 93; 264-272.

Osman, M.A., Raju, P.S. and Peacock, J.M. (1991). The effect of soil temperature, moisture and nitrogen on *Striga asiatica* (L.). Kuntze seed germination, viability and emergence on sorghum (*Sorghum bicolor* L. Moench) roots under field conditions. *Plant and Soil,* 131(2): 265-273.

Oswald, A., Abayo, G., Ransom, J.K., Kroschel, J. and Sauerborn, J. (1997). Catch cropping with Sudan grass – an option for *Striga* control in subsistence agriculture. Brighton crop protection conference weeds. *Proc. Internl.*

Conf., Brighton, UK, 17-20, November, 1997, 1: 227-232.

Parker, G. (1965). The *Striga* problem – a review. *PANS*, 11: 99-111.

Porwal, B.L. (1968). Studies on efficiency of various weedicides on control of *Stirga*. *Rajasthan Agric.,* 8: 79-82.

Prabhakarasetty, T.K. (1980). Studies on biology and control of *Striga asiatica* (L.) Kuntze. *Ph.D. Thesis*, Univ. Agric. Sci., Bangalore.

Press, M.C. and Graves, J.D. (1991). Carbon relations of angiosperm parasites and their hosts. Progress in orobanche research. *Proc. Internl Workshop on Orobanche Res.,* Obermarchtal, Germany, 19-22 August, pp.55-65.

Ramaiah, K.V., Parker, C., Rao, M.J. and Musselman, L.J. (1983). *Striga* identification and control handbook. Information Bulletin No. 15. *Internl. Crop Res. Inst. For the Semi-Arid Tropics*, Patancheru, Andhra Pradesh, India, pp.85-98.

Ramaiah, K.V. (1984). Patterns of Striga resistance in sorghum and millets with special emphasis on Africa. p.71-92. In: Ayensu, E.S., Doggete, H., Keynes, R.D., Marton, J.L., Musselman, L.J., Parker, C., and Pickering, A. (eds). Proceedings of the International Workshop on the Biology and Control of Striga. ICSU Press Paris, Dakar, Senegal.

Ramaiah, K.V. (1987). Breeding cereal grains for resistance to witchweed. pp.227-242. In: Musselman, L.J. (ed). Parasitic Weeds in Agriculture. CRC Press, Boca Raton, USA.

Rao, M.J.V., Chidley, V.L. and House, L.R. (1989a). Estimates of grain yield losses caused in sorghum (*Sorghum bicolor* L. Moench) by *Striga asiatica* (L.) Kuntze obtained using the regression approach. *Agric., Ecosys. Env.,* 25(2-3): 139-149.

Rao, M.R., Shetty, S.V.R., Reddy, S.L.N. and Sharma, M.M. (1989b). Weed management in improved rainfed cropping systems in semi-arid India. *Soil, Crop and Water Manag. Sys. for Rainfed Agric. in the Sudano-Sahelian Zone,* pp.303-316.

Rao, S.A., Rao, K.E.P., Mengesha, M.M. and Reddy, V.G. (1996). Morphological diversity in sorghum germplasm from India. *Gene. Res. Crop Evol.,* 43(6): 559-567.

Reda, F. and Verkleij, J.A. (2007). Cultural and cropping systems approach for Striga management-a low cost alternative option in subsistence farming. p.229-240. In: Ejeta, G. and Gressel, J. (eds). Integrating New Technologies for Striga Control: Towards Ending the Witch-hunt. World Scientific Publishing Co., Singapore.

Reddy, V.J. and Singha, M. (2002). Geographical distribution of basic and intermediate race in the world collection of sorghum germplasm in International sorghum and millet newsletter ISMN Scientific editors, pp14-17.

Reichmann, S., Kroschel, J. and Sauerborn, J. (1995). Distribution and infestation of *Striga* species in Shinyanga region of Tanzania and evaluation of control methods. Brighton crop protection conference: Weeds *Proc. Internl. Conf.,* Brighton, UK, 20-23, November, 1: 151-156.

Reud, D.C. and Parker, C. (1979). Germination requirements in *Striga* species. *Proc.2nd Internl. Symp Parasitic Weeds*, Raleigh NC: North Carolina State Univ., pp.201-210.

Riches, C.R., Parker, C. (1993). Parasitic Weeds of the world: Biology and control CAB International Walingford, UK, Pp : 332.

Robinson, E.L. (1960). Growth of witchweed (*Striga asiatica*) as affected by soil types and soil air temperatures. *Weeds*, 15: 243-245.

Roger, W.E. and Nelson, R.R. (1962). Penetration and nutrition of *Striga asiatica*. *Phytopath.,*
52: 1064-1070.

Sauerborn, J. (1991). Parasitic flowering plants – ecology and management, Weikersheim, Germany, Josef Maragraf, pp.20-25.

Schipprack, W. and Mercer-Quarshie, H. (1984). Sorghum Production and Improvement in Ghana. Pp. 95-105. In sorghum Improvement in West Africa Proceeding of the Regional workshop held at Ouagadougou, 27th to 30th November, 1984.

Scholes, J.D., Press, M.C. (2008). Striga infestation of cereal crops- an unsolved problem in resource limited agriculture. Curr. O. Plant Biol, 11: 180-186.

Shamugasundaram, A. and Venkataraman, K. (1964). Co-20 jowar stands up to *Striga*. *Indian Farm.,* 14(4): 9.

Shaw, W.C., Shepherd, D.R., Robinson, E.L. and Sand, P.F. (1962). Advances in witchweed control. *Weeds*, 10: 182-192.

Showemimo, F.A. (2002). Evaluation of sorghum lines for *Striga* resistance. *Trop. Agric.,* 79(4): 237-240.

Showemimo, F.A. (2003). Selection criteria for combining high yield and *Striga* resistance in sorghum. *Tropicul.*, 21(3): 157-159.

Sineba, W. and Drennon, D.S.H. (2001). Vegetative growth of sorghum and *Striga hermonthica* in response to nitrogen and the degree of host root infection. *European J. Pl. Path.,* 107(9): 849-860.

Tchemi, W. (1989). *Striga* in Togo. *FAO-Plant Production and Protection Paper*, 96: 92-97.

Tenebe, V.A. and Kamara, H.M. (2002). Effect of *Striga hermonthica* on the growth characteristics of sorghum intercropped with groundnut varieties. *J. Agron. Crop Sci.,* 188(6): 376-381.

Teetes, G.L. (1982). ‘‘Sorghum insect pest management’’ in House, L.R, Mughogho L.K., and 45b Peacock (eds). Sorghum in the eighties, 1: 225-235, ICRISAT, Pancheru India Pradest.

Touré, A.O. (1999). Contribution à l’amélioration du sorgho (*Sorghum bicolor*), par : la culture in vitro d’anthères, étude de l’action de la photopériode. Mémoire de fin d’études, cycle Ingénieur Agronome. Faculté des Sciences et Technologies. Université de Mostaganem. Algérie. Pp : 6- 7.

Venkateshwara, R.L., Rama R.V. and Pardhasardhy, A.V. (1967). N-13, A high yielding *Striga* resistant strain of jonna. *Andhra Agric. J.,* 14: 67-70.

Worsham, A.D., Moreland, D.E. and Klingman, G.C. (1959). Stimulation of *Striga asiatica* (Witchweed) seed germination by 6-substituted purines. *Sci.,* 130: 1654-1656.

Worsham, A.D., Moreland, D.E. and Klingman, G.C. (1962). Promotion of germination of *Striga asiatica* seed by coumarin derivatives and effects on seedling development. *Nature,* 195: 199-201.

Yaduraju, N.T. (1975). Studies on *Striga asiatica* (L.) Kuntze control in sorghum (*Sorghum bicolor* (L.) Moench). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore

Yoshikawa, F., Worsham, A.D., Moreland, D.E. and Eplee, R.E. (1978). Biochemical requirements for seed germination and shoot development of witchweed (*Striga asiatia*). *Weed Sci.,* 26: 119-122.

Appendices

Appendix 1: Analysis of variance for Seedling Vigor:

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	0.3590	0.1795	0.32	
Treatment	12	39.5897	3.2991**	5.80	<.001
Residual	24	13.6410	0.5684		
Total	38	53.5897			

Appendix 2: Analysis of variance for days to 50% flowering

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	25.59	12.79	1.19	
Treatment	12	1656.92	138.08**	12.89	<.001
Residual	24	257.08	10.71		
Total	38	1939.59			

Appendix 3: Analysis of variance for Plant height

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	0.0670	0.0335	1.95	
Treatment	12	4.0619	0.3385	19.69	<.001
Residual	24	0.4126	0.0171		
Total	38	4.5416			

Appendix 4: Analysis of variance for Panicle length

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	22.518	11.259	1.73	
Treatment	12	421.656	35.138**	5.39	<.001
Residual	24	156.532	6.522		
Total	38	600.707			

Appendix 5: Analysis of variance for Yield

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	280678	140339	5.24	
Treatment	12	3641186	303432**	11.32	<.001
Residual	24	643288	26804		
Total	38	4565151			

Appendix 6: Analysis of variance for SGE

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	57.90	28.95	1.15	
Treatment	12	347.90	28.99^{NS}	1.15	0.371
Residual	24	606.10	25.25		
Total	38	1011.90			

Appendix 7: Analysis of variance for score grain

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	2.512	1.256	4.42	
Treatment	12	22.564	1.880**	6.62	<.001
Residual	24	6.820	0.284		
Total	38	31.897			

Appendix 8: Analysis of variance for stay green

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	0.153	0.076	0.41	
Treatment	12	4.564	0.380^{NS}	2.02	0.069
Residual	24	4.512	0.188		
Total	38	9.230			

Appendix 9: Analysis of variance for first counting of striga

Source of varietion	Degree of freedom	Sum of Squares	Mean Sum of Squares	Variance Ratio	F Ratio
Rep Stratum	2	4.362	2.181	2.45	
Treatment	12	12.985	1.082^{NS}	1.22	0.329
Residual	24	21.375	0.890		
Total	38	38.722			

Apendix:10 Analysis of variance for different

Source of variation	df	Mean Sum of Squares								
		SV	**FL5**	**PH**	**PL**	**Yield**	**SGE**	**SGR**	**STGR**	**STRC**
Rep	2	0.1795	12.79	0.0335	11.259	140339	28.95	1.25	0.076	2.181
Treatment	12	3.2991**	138.08**	0.03385**	35.138**	303432**	28.99^{NS}	1.88**	0.380^{NS}	1.082^{NS}
Residual	24	0.5684	10.71	0.0171	6.522	26804	25.25	0.284	0.188	0.890
Total	38									

** Highly significative, NS : no significative

SV : Seedling Vigor ; **FL5** : days to 50% flowering ; **PH** : Plant height ; **PL** : Panicle length ; **Yield** : Grain yield ; **SGE** : Striga emergence ;

SGR : Score grain ; **STGR** : Stay green ; **STRC** : Striga first counting.