UNIVERSITY FOR DEVELOPMENT STUDIES

EVALUATION OF CHICKEN MANURE AND AMMONIUM SULPHATE FERTILIZER ON YIELD AND YIELD COMPONENTS OF MAIZE (*ZEA MAYS*L.) AND *STRIGA HERMONTHICA* (DEL.) BENTH INFESTATION AND SEEDBANK

BY

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DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

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I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Striga hermonthica (Del.) Benth infests millions of hectares of land under cereals in sub-Saharan Africa, reducing production and threatening food security. A field experiment was carried out at the Savanna Agricultural Research Institute (SARI) trial farms at Nyankpala. The trial was to determine the combination of maize varieties, ammonium sulphate and chicken manure that could enhance the performance of maize in infested *Striga* field. In addition, the effect of treatments on the control of the parasite and its seed bank was also evaluated. The experiment was a 2 x 3 x 4 factorial study, laid out in a Randomized Complete Block Design with three replications. The three factors used were, ammonium sulphate at 0, 40, 80 and 120 kg/ha chicken manure at 0, 3, and 6 t/ha and maize varieties, Wang-dataa and Bihilifa.The results indicated that most of the parameters assessed such as days to 50% flowering, number of ears, grain weight, cob weight, and grain yield were significantly (p<0.05) influenced by the combination of ammonia sulphate and chicken manure. Application of 3 t/ha chicken manure plus 120 kg/ha ammonium sulphate to Wang-dataa gave highest grain yield of 3085 kg/ha and cob weight of 4716.7 kg/ha. *Striga* count was not significantly (p> 0.05) affected by variety, chichen manure and ammonium sulphate fertilizers. However the application of chicken manure at 3 t/ha combined with 80 kg/ha of ammonium sulphate reduced *striga* from 17.3/ m^2 8 WAP to 12.0/ m^2 10 WAP (Table 7). Application of chicken manure alone reduced *Striga* seed number from 3.8/ m^2 8 WAP to 25.2/ $6m^2$ 10 WAP (Table 6). Grain yield positively correlated with plant height (r=0.62**), number of ears at harvest (r=0.70**) and cob weight(r=0.93***).

DEDICATION

This work is dedicated to the Almighty Allah for the long and healthy life given me to finish the master of philosophy program. It is also dedicated to my parents, my sibling and all my friends for their prayers and support. May the Almighty Allah bless them all.

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CHAPTER ONE

Background

Maize (*Zea mays* L), is a versatile crop, cultivated across a broad range of agro ecological zones.. Every part of the maize plant has economic value, the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products. Among the developing economies, maize ranks first in Latin America and Africa but third after rice and wheat in Asia (Dowswell *et al*., 1996). The name maize is derived from the South American Indian Arawak-Carib word *mahiz*. It is also known as Indian corn or corn in America (Kochhar, 1986; Purseglove, 1992).

The total area under maize cultivation in 2005 was about 740,000 ha and production were estimated at 1,171,000 metric tons (MOFA, 2006) in Ghana. It is adapted to a wide range of environment but essentially a crop of the warm environment. According to FAO (2006), the area under production of maize in West Africa has increased from 3.2 million ha in 1961 to 8.9 million ha in 2005. Accordingly, this phenomenal expansion of land area devoted to maize resulted in increased production from 2.4 million tons to 10.6 million tons within the same period.

Maize is a major staple food in most part of Ghana, and as such is grown in all agro-ecologies in the country. It has virtually replaced sorghum and millet in northern Ghana where these cereals were previously more important. Maize is not only consumed by human beings in the form of food grain but also used as feed for livestock and poultry, being a good forage crop as the grain contains about 72 % starch, 10 % protein, 4.8 % oil, 5.8 % fiber, 3.0 % sugar and 1.7 % ash (Chaudhary, 1993). It is sometimes produced for animal feed and industrial uses such as starch, flour, ethanol, cooking syrup and crisp (Izge *et al.*, 2009). Among the cereal crops of the world, it ranks third to wheat and rice in terms of production (Ochse *et al*.,1996).

Problemstatement

Several production constraints, among which is poor and erratic rainfall, *Striga hermonthica* infestation, nutrient depletion and low soil organic matter. *S. hermonthica* (Del.) Benth is a parasitic weed that attacks cereal crops; maize, sorghum, rice, finger millet and other native and exotic grasses throughout Africa, and elsewhere in the tropics (Odhiambo and Woomer, 2005). *Striga hermonthica* is observed in most maize growing areas of northern Ghana. Control of *Striga* has become a difficult task considering the seed production rate of 10,000 – 100,000 seed per plant (Ikie *et al.,* 2006), longevity of the seed bank (Bebawi *et al.,* 1987), and complicated mode of parasitism (Ejeta and Gressel, 2007). Inherent low soil fertility and mono cropping have increased the *Striga* seed bank and infestation. *Striga* control methods such as N application, use of trap crops, chemicals, cultural, use of resistant/tolerant varieties and biological control could not by itself effectively control *Striga* (Lagoke *et al.*, 1988). *Striga* causes severe yield losses; sometimes the farmers lose 100 % of their harvest (Berner *et al.*, 1995). However, the low maize grain yield (1–2 t/ha) recorded in the West African savannas (Fakorede *et al*., 2003) indicates the limited use of fertilizer and the inadequacy of the other croping strategies. Farmers often apply an amount of fertilizer suboptimal for yield to their farms because of its high cost and limited availability as well as their low purchasing power (Kling *et al*., 1997; Ba¨ Nziger *et al*.,1999).

Therefore, *Striga* infestation and seed bank has a major economic impact on the small holders' farm level production and significantly decreases farmer income. The parasitic weed also lowers the food supply for many households as it causes major damages on the staple food and affects families whose food consumption is dependent on the harvest, so called subsistence farmers.

Striga species are widely distributed in the savannah regions of Africa. It is the largest biological constraint to food production in Africa. It is reported to infest an estimated 20 to 40 million hectares of farmlands cultivated by farmers throughout sub-Saharan Africa (CIMMYT, 2000). In Ghana the witch weeds occur in both the coastal and guinea savannah zones (Laing, 1984, cited by Aflakpui *et al*., 1997). According to Kroschel *et al*. (1999) *Striga* infestation is widespread in Northern Ghana and none of the districts is being free of *Striga*. The most widespread species is *S. hermonthica* with infestation levels are as high as 98 %. Annually *Striga* damage to crops accounts for an estimated US $7 billion in sub-Saharan Africa, and affects the welfare and livelihood of over 100 million people (CIMMYT, 2004). Apart from the direct yield losses, other socio-economic losses include relocating of fields from nearby farms to far from the farmer's residence, abandonment of farms or change of cropping pattern.

Justification

Several *Striga* control measures have been suggested that include hand pulling, crop rotation, fallowing, intercropping and nitrogen fertilization. Among these control strategies, the use of *Striga* resistant maize cultivars is thought to be the most effective and offer an economically feasible and culturally sustainable technology for the African resource-poor farmer, since it does not require extra inputs such as labour and fertilizers (DeVries, 2000; Sallah and Obeng-Antwi, 2002). Integrated nutrient management approaches, in which both manure and inorganic fertilizers are used, have been widely suggested as the most viable approach to maintain higher maize crop productivity in the *Striga* infested field (Ayoola and Makinde, 2009).

Objectives

The objectives of the study were:

1. Determine the combined effect of variety, ammonium sulphate and chicken manure on maize yield and yieldcomponents,

2. Evaluate the combined effect of variety, ammonium sulphate and chicken manure on *Striga hermonthica*infestation,

Researchquestions

The study has the following question:

Would ammonium sulphate fertilizer, chicken manure and maize varieties combination enhance the competitive ability of maize with *Striga*?

Would the interactive effect of ammonium sulphate, chicken manure and maize variety reduce *Striga* effect?

Would the interaction effect increase maize yield?

Which variety (Wang-dataa and Bihilifa) would yield more?

CHAPTER TWO

LITERATUREREVIEW

Production of Maize inGhana

Maize ranks third to wheat and rice among the cereal crops of the world in terms of production (Ochse *et al.*, 1996). Among the developing economies, it ranks first in Latin America and Africa but third after rice and wheat in Asia (Dowswell *et al.*, 1996). Globally about 140 million hectares of maize is grown with a production of 600 million tons (CIMMYT, 2000). Asia plants almost half of the developing world's maize crop and in sub-Saharan Africa, maize accounts for more than 40 % of total cereal production (IDRC, 2005). In Ghana, maize is the most important cereal in terms of production and consumption (PPMED, 1992) and one of the most popular food crop on the domesticmarket.

Maize cultivation is very high in the Brong Ahafo, Ashanti and Northern region of Ghana (Angelucci, 2012). Maize is cultivated twice in the Brong Ahafo and Ashanti region where they experience two rainfall patterns but once in a year in the Northern region. In Ghana, maize is produce predominantly by small -holder resource poor farmers under rain-fed conditions (SARI, 1996).

Maize is the primary staple in the areas of production and constitutes the basis of several local food preparations and the main feedstuff for poultry and other livestock, and an important raw material in the brewery industry. Maize is grown in all the ecological zones of the country, from the coastal belt across the forest transition, Guinea savannah to the north-eastern corners of the country. It the seventh largest agricultural commodity in terms of production value over the period from 2005-2010 accounting for 3.3 % of total agricultural production value globally (FAO, 2012). The crop is cultivated by 1.75 million (64 %) of the 2.74 million households operating farms in Ghana (FASDEP, 2002). Total area put under maize cultivation is about 713,000 hectares with production levels averaging 1.5 metric tons (mt) per hectare even though 5.0 mt/ha is the achievable yield (FASDEP, 2002). This production level is inadequate for human and animal consumption. In the northern region total area put under maize cultivation rose from 98,500 ha in 2000 to about 157,020 ha in 2002, with average yields falling from 0.8 mt/ha in 2000 to 0.75 mt/ha in 2002 (MOFA, SRID,2003).

2.2 Economic Importance of Maize

Maize is the most important cereal crop produced in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO,2008). Current world maize is about 10.14 billion metric tons (De Groote *et al.*, 2013). Technological progress and improvement in economic efficiency are key to improving agricultural productivity especially in developing countries agriculture, where inputs are inadequate and opportunities for introducing and using improved technologies have currently began falling (Okoboi, 2011; Kuwornu *et al.*, 2012). The United States (US) is the largest producer, producing over 30 % followed by China 21 % and Brazil 7.9 %. Africa produces around 7 % of the total world production. Two-thirds of all Africa maize come from eastern and southern Africa (Verheye, 2010; FAOSTAT, 2014). It is a basic stable for large population groups particularly in developing countries (FAO and ILO, 1997). Maize contributes significantly to consumer diets (Tahirou *et al.*,2009) as it is nutritious containing 80 % carbohydrate, 10 % protein, 3.5 % fiber and 2 % mineral (IITA, 2001; Khawar *et al.*, 2007). The planted land of maize and grain production have increased significantly across regions in SSA since 1961 (FAOSTAT, 2015). In many countries including Ghana, maize has become a major cereal staple and an important component of animal and human diets. Its importance is ever increasing as the source of foodfor rural masses, animal feed and raw material for the industries (Godbharle *et al*., 2010). The stalk is used for animal feed and further stalk is also used for construction of houses and fences, and as fuel wood (MoFA, 2010). Wikipedia (2006), reported that maize is hydrolyzed and enzymatically treated to produce syrups, particularly high fructose corn syrup, a sweetener and in some cases fermented and distilled to produce grain alcohol which is traditionally the source of bourbon whisky. It was considered to be the third most important cereal crop in the world after wheat and rice up to the end of the 1980s (Sleper and Poehlman, 2006). It accounts for 70 % of the food consumed in sub-Saharan Africa (FAO, 2007). The recent volatile food market and rising prices for most food crops may increase the importance of maize production. In addition, because of its productivity and wide adaptation, maize remains an important source of food with great potential to improve the livelihoods of most poor famers in developing countries (FAO, 2011). Currently, maize ranks second in production among the major grain cereals worldwide but due to a shift in cereal demand, maize is expected to be the leading cereal surpassing both wheat and rice (Pingali, 2001).

Maize is a rich source of food, fodder, and feed that provide raw materials for the industry. It has become the number one staple and cash crop for a great number of farmers (Manyong *et al.*, 2000). For over nine hundred million poor people and over one-third of all malnourished children, maize is the number one staple. Added to this is the fact that the demand for maize in developing countries was projected to increase by 72 % between 1997 and 2020. This increase in demand represented 213 million metric tonnes of maize for the period (James, 2003). Also by 2025, maize was projected to become the crop with the greatest production volume worldwide (CIMMYT and IITA, 2010). In developing countries, maizeisoftengrownasafoodcropforhumanconsumption,aswellasforthemarket,butitis increasingly being used as animal feed (WABS, 2008). Maize is high yielding, easy to process, readily digested, and cheaper than other cereals (Valencia J.A. *et al.*, 1999). The per capital consumption of maize was 943000 Mt in 2006. Hussan *et al.* (2003) noted that maize was the most important cereal fodder and grain crop grown under both irrigated and rain-fed agricultural systems in the semi-arid and arid tropics. Maize and other cereals constitute important source of carbohydrates, protein, vitamin B and minerals (Iken *et al.*, 2002). Maize grains have great nutritional value as the contain72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983).

Constraints of MaizeProduction

Major constraints to maize production include insect pests, diseases, weeds, rodents, fungi, pathogens, and viruses. Maize is attacked by many insect pests during all stages of growth from seedling to storage (Shiferaw *et al.*, 2011). Insects and other pests are a major threat to maize production (Ak'habuhaya, and Lodenius, 1988) and responsible for direct and indirect losses of maize on the farm and storage (Bankole and Mabekoje, 2004). According to Mihale *et al*. (2009) insects are responsible for 15-100 % and 10-60 % of the pre and post-harvest losses of grains in developingcountries.

Availability of adequate rainfall is by far the most limiting factor in maize production in sub Saharan Africa (CIMMYT, 1988). Kamara *et al.* (2005) added that intermittent drought is implicated among the major constraints limiting the production of maize in the Guinea Savanna of West Africa. Drought at flowering and grain filling period may cause loses of 40-90 % (Menkir and Akintunde, 2001). Low soil fertility is also among the major constraints limiting the production of maize in the Guinea Savanna of West Africa (Kamara *et al*., 2005).

Although maize is of economic important in Ghana, its production is hindered by several factors. Some of the important limiting factors to maize production in Ghana are poor inherent soil fertility, diseases and pest attack, poor storage facilities and inefficiency of resource utilization in Ghana.

Mycotoxins are toxic secondary metabolites of fungi that frequently contaminate the maize in the field and/or during storage (Smith *et al*., 2012). Mycotoxins contamination of maize poses a health risk to humans and domesticated animals (Mboya *et al.*, 2012; Suleiman *et al.*, 2013). The most important mycotoxins in maize are the Aflatoxins, Fumonisins, Deoxynivalenol, and Ochratoxin (Kimanya *et al*., 2012). Aflatoxin is a group of mycotoxin produced as secondary metabolites by the spoilage of two fungi species *Aspergillus flavus* and *A. parasitic us* (Marin *et al*., 2013). Grain export like the maize has a significant driving force for overall economic growth, increase farmers' income and poverty reduction (Diao *et al*., 2013). However, maize in most parts of the country are contaminated with mycotoxins well above acceptable levels (TFDA, 2012), thus, posse's greater economic losses and risk to agricultural export andtrade.

Mycotoxins are a heterogeneous group of toxic secondary metabolites that are produced by several fungal genera and exert toxic effects (mycotoxicosis) on human and domesticated animals (Peraica, 1999). Contaminate a range of agricultural commodities such as grains and their derived processed products (Njumbe *et al*., 2014). Mycotoxins contamination are unavoidable and unpredictable can occur throughout the food chain from the field or pre-harvest, during harvest, drying, during processing and storage (Lopez-Garcia *et al.*, 1999). Which make it an enormous challenge to manage and control, particularly in developing countries (Anukul *et al*., 2013). The production of mycotoxins depends on variousfactors, such as the commodity, poor agricultural and harvesting practices, improper drying, handling, storage conditions, climatic conditions and seasonal variations (Marin *et al.*, 2013; Leslie *et al.*, 2008) often times most factors are beyond human control (Hussein and Brasel, 2001). Mycotoxins contamination attracts worldwide attention due to the huge economic losses incurred and their impact on human, domestic animals and trade (Wu, 2006; Chilaka, *et al.*, 2012). Maybe detrimental to the health of humans and animals. Dietary exposure mycotoxins can result in serious health affect both acute and chronic. Ranging from sudden death to deleterious effects upon the central nervous, induction of hepatocellular carcinoma, effects on the cardiovascular, reproductive, pulmonary, and gastrointestinal systems to mention few (Burger *et al*., 2013; Suleiman *et al*.,2013).

Weeds are plants that grow where they are not wanted or is a plant that is hazardous to crop, peoples and animals (Bubl, 2010). Weed competes with the crops for water, soil nutrients, CO2, space and light (Rajcan and Swanton, 2001). Besides direct competes with plant for nutrients, weeds also cause indirect damage by harboring insect pests, rodents, diseases, and crop pathogens, as well as reduce wildlife habitat and crop quality (Bubl, 2010). Likewise, weeds increase the cost of crop production and interfering during harvest and cleaning or the separation of crops (Tesfay *et al*.,2014).

According to FAO, worldwide, 13 % loss of agricultural production is credited to weeds. In Africa, more than 50 % of crop losses are due to weeds (Sibuga, 1997). Sibuga (1997) revealed that weeds are the most important crop pests in SSA. Chikoye *et al.* (2005) also noted that a significant amount of crop production cost (40 % – 80 %) in SSA is used for weed management. In addition, over 50 % of the farming time is devoted to weeds management (Tesfay *et al.*, 2014). The estimated loss due to weeds is higher than thesum of the potential losses due to insect, pathogens, and viruses (Oerke, 2006). A research conducted in Tanzania shows that weeds deny over 1.7 million metric tons of maize production per year (Kitabu, 2013). Weed management is an important aspect in crop production.Itreducescropyields and can lead to total crop failures if uncontrolled (Steiner and Twomlow (2003). Weed competition greatly reduces crop yields. It is often a greater problem in a single crop or in simple crop associations than in the multi-crop associations. Some report of yield losses in maize due to weeds range between 20 to 100 % (Tadious and Bogale, 1994). Furthermore, it was reported by Chikoye *et al*. (2005) that in West Africa weeds contribute to maize yield losses to about 50 % to 90 %. Tesfay *et al*. (2014) observed that proper control of weeds in maize could increase yield up to 96%.

In Ghana, crop response to nitrogen on depleted soil that have been continuously cropped can be twice as high as those with high natural fertility that have laid fallow for a number of years (Edmeades *et al*., 1991). FAO (2005) noted that fertilizer nutrient application in Ghana is approximately 8 kg/ha whiles depletion rates range from about 40 to 60 kg/ha/yr of nitrogen, phosphorus, and potassium.

Effects of Sulphate of ammonia performance onmaize

Sulphate of ammonia is the type of inorganic fertilizer that contains N. It contains ammonium (NH_4) in the form of a 21 % nitrogen (N) and sulphate (SO_4) in the form of a 24 % sulphur (S) containing fertilizer. Sulphate of ammonia supply the ammonium (NH_4) contents to the plants in the form of nitrogen (N), which is the most limiting nutrient in maize production in the savannas of West Africa (WA) (Carsky and Iwuafor, 1995). It is estimated that annual loss of maize yield due to low-N stress varies from 10 to 50 % (Wolfe *et al*., 1988). Nitrogen deficiency in West Africa is caused by several factors including the leaching of soil N below the root zone due to torrential rainfall (Bennett *et al.*, 1989) poor weed control in farmers' fields (Lafitte and Edmeades, 1994) and the application of sub-optimal levels of inorganic fertilizer due to high prices (Smith *et al*., 1997) and non-availability of fertilizer. In most cases, less than 20 kg Nha^{-1} is applied to maize crops. Kamara *et al.* (2005) and Kamara *et al*. (2009) reported severe yield losses in maize in Nigerian savannas when no nitrogen was applied.

Maize is nitro positive and needs relatively higher quantities of nitrogen for good yield. It is therefore, imperative to use an optimum amount of N through a suitable and efficient source. Nitrogen plays a very significant role in crop development because it is not only an integral part of structural and functional proteins, chlorophyll and nucleic acids (RNA and DNA) but also it is very essential for the proper utilization of carbohydrate (Tisdale *et al*., 1990). Leaf area index, leaf area duration, rate of leaf expansion, photosynthetic rate, radiation interception and radiation use efficiency also increase with increased in the supply of N (Tisdale *et al*., 1990; Muchow and Davis, 1988 and Sinclair and Horie, 1989). Crude protein concentration is also improved by proper Nitrogen supply (Tisdale *et al*., 1990). Increasing level of nitrogen has increased yield components of maize during different research studies (Bangarwa *et al*., 1988) resulting in remarkable increase in grain yield.

Effects of chicken manure on performance ofmaize

Chicken manure is the feces of chicken used as organic fertilizer, especially for soils with low nitrogen. Chicken manure contains all 13 of the essential plant nutrients that are used by plants. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo). It contains 0.8 % potassium, 0.4 % to 0.5 % phosphorus and 0.9 % to 1.5 % nitrogen of the three most essential elements.

The numerous uses of maize notwithstanding, yield in Africa has continuously declined to as low as 1 t/ha due to rapid reduction in soil fertility and negligence of soil amendment materials. (Olakojo, 1993, Kim, 1997, DIPA, 2006, Enujeke, 2013). Sonetra (2002) suggested that subsistence farmers should apply organic manure directly to the soil as a natural means of recycling nutrients in order to improve soil fertility and yield ofcrops.

Manures and fertilizers are the life wire of improved technology contributing about 50 to 60 % increase in productivity of food grains in many parts of the world, irrespective of soil and agro-ecological zone (DIPA, 2006).

Reijnties *et al.* (1992) and Adepetu (1997) remarked that the downward trend in food production should prompt farmers to amend the soil with different materials in order to enhance growth and yield of crops. Poultry dropping have been recommended to subsistence farmers in West Africa as soil amendments for increasing crop yield.

Sobulo and Babalola (1992) reported that poultry dropping and cattle dung increased root growth of maize and the crop extracted soil water more efficiently for increased grainyield.

Among the different sources of organic manure which have been used in crop production, chicken manure was found to be the most concentrated in terms of nutrient content (Lombin *et al.*, 1992). Kostchi *et al.* (1989) observed that application of chicken manure improved the availability of some minerals in the soil, and especially the transfer of nutrients from rangeland to the crop plant. Izunobi (2002) reported that chicken manure, especially those produced in deep litter or battery cage house are the richest known farmyard manure supplying greater amounts of absorbable plantnutrient.

Amujoyegbe *et al.* (2007) reported that chicken manure increased the leaf area total chlorophyll content and grain yield of maize and sorghum. According to Brady and Weil (1999), chicken manure mineralizes faster than other animal manure such as cattle or pig dung; hence it releases its nutrients for plant uptake and utilization rapidly.

Sharply and Smith (1991) reported that chicken manure contains basic nutrients required for enhancing growth and yield of crops. Application of chicken manure increases carbon content, water holding capacity, aggregation of soil, and decreases bulk density (Egerszegi, 1990). It also increases the water soluble and exchangeable potassium and magnesium which enhance crop yield (Jackson *et al.*, 1999). Ibeawuchi *et al.* (2007) reported that 8 t/ha of chicken manure resulted in significantly higher grain yield, dry matter and increased leaf area of maize.

Biology of Strigahermonthica

Striga is a root parasitic plant, which has 35 species exist globally (Berner *et al.*, 1995), is an obligate plant weeds infesting the roots of the host plants especially of *Graminae (grass)* family. It survives by siphoning water and nutrients required for its growth from maize and other cereals (Sserumag, 2015). About 80% of these species can be found in Africa but not all of them affect the farming conditions. *Striga* flowers and shed seeds within the life cycle of its host. The seeds are tiny (< 0.3 mm) and a single plant can produce up to 50,000 seeds, which mature at different times and can remain dormant and viable in the soil for up to 20 years (Lagoke *et al.*, 1988; CIMMYT, 2004).

Germination of *Striga* is temperature dependent, with 30^0 C as the minimum threshold and 35^0 C as the optimum (Carson, 1986). Chemical exudates from young host roots triggers germination under optimum soil temperature and moisture conditions (Sallah *et al.*, 2002). Immediately the host plants establish, germination initiates and only seeds exposed to the chemical stimulant of the host roots germinate (Kroschel *et al*., 1999). The majority of the seed population is not reached by the stimulants and stays viable in the ground until the next growing season. The radicle of the *Striga* seedling, in contact with the host root, is transformed into a haustorium followed by penetration and attachment to the host root and, finally, emergence from the soil (Sallah *et al*., 2002). Thus, the parasitic nature of *Striga* also involves dependency on the host for developmental signals. The necessity of such a signal ensures that a suitable host is available and close enough to be reached by a germ tube and formation of the haustorium. Haustorium formation and host finding are thus very sensitive stages in *Striga* development. Like all parasitic seed plants, the haustorium represents the physical and morphological contact between the host and the *Striga*. Its primary task is the supply of water and nutrients (Kroschel *et al*., 1999). Haustoria penetrate the host tissue until they reach the vascular system in order to have access to nutrients, water and organic substances. Attachment may occur as early as two weeks after germination of maize, depending on the size of the *Striga* seed bank in the soil and the exudation of germination stimulant by maize roots in the vicinity of *Striga* seeds (CIMMYT, 2004).

Distribution of *Strigahermonthica*

Striga hermonthica is found mainly in the tropical arid and semi-arid zones of Africa, Europe and Asia, with an annual rainfall of 400 – 1000 mm and where the dominant vegetation is natural savannah or grassland.

Striga spread exclusively by seed. The seeds being very small (about 3µm), they are easily carried on different items including shoes clothes, field tools, livestock, run-offs and or eroded soil; but the major means of dispersal is through human activities such as field preparation (machinery/ tools) and through planting contaminated seeds (Sserumag, 2015). *Striga* *hermonthica*is the most widespread species, occurring in Africa, Asia, Australia and New Zealand (Bharathalakshmi and Jayachandra, 1979) and in the United States of America (Eplee, 1981, 1982 and Eplee and Herbaugh, 1979). *Striga hermonthica* lowers the food supply for many households as it causes major damages on the staple food and affects families of subsistence farms whose food consumption is dependent on their harvest. *Striga* species are widely distributed in the savannah regions of Africa. Out of the 30 *Striga* species listed by Musselman (1987) only four species are found in Asia and America while 23 species are found in Africa, of which 16 occur in West Africa (Kroschel, 1999). According to Badu-Apraku and Fakorede (2001), three species of *Striga* affect maize in Western and Central Africa, namely, *S. hermonthica. Asiatica* and *S. aspera, S. hermonthica* being the most important. Reports from an investigation carried out in eleven regional development organisations in Burkina Faso indicate that *Striga* infestations occurred throughout the country – both on research and farmers' fields (Ouedraogo 1986). In Benin, Guinea, Mali, Cote d'lvoire, Senegal and Nigeria, 20 % to 80 % of lands used for cereal and legumes grain cultivation are reported to carry *Striga* infestation (Lagoke *et al*., 1988).

In Ghana *Striga* is important in the northern savannah, which has a single rainy season and annual rainfall ranging from 800 mm to 1200 mm (Nyarko, 1986). It is reported to be a serious problem in this part of the country, covering approximately all areas above latitude $9^0 30^{|}$ Nwhich represents approximately 57 % of the total land area (Nyarko,1986).

Striga is known to seriously affect two-thirds of the 73 million hectares devoted to cereal crop production in Africa (Lagoke, 1988). They flower and shed seeds within the life cycle of its host. This species is thought to originate from the Nuba Mountains of Sudan and adjacent areas of Ethiopia, which are widely recognized as centres of origin based on its common occurrence there on wild grass hosts (Musselman and Hepper, 1986). The extent to which *Striga* reduces the growth of its host is highly variable and depends on factors such as host plant genotype, parasite infestation level, and environment (van Ast *et al.*, 2005).

Striga hermonthica infestation and damages

Abdul *et al*. (2012) stated that most important species of *Striga* are *S.asiatica*, *S. hermonthica* and *S. forbesii* which are mainly found in cereals such as maize, sorghum, pearl millet and rice. The parasitic weed *Striga hermonthica (Del.) Benth*, has become a serious constraint for cereal production in various parts of Africa, including the moist and dry savannas of West Africa. Recently, *Striga* has become a major constraint to maize production causing economic loss in northern Guinea savanna and some parts of the derived and southern Guinea savanna (Ogunbodede and Olakojo, 2001). The Food and Agriculture Organisation (FAO) has estimated that two-thirds of cultivated savannah areas are infested with *S. hermonthica* that can cripple cereal production (maize, sorghum and millet) by taking over whole fields of the crop (IITA, 1993). In addition to draining minerals, water and photosynthates, *Striga* does most of its damage to its host through phytotoxins before it emerges from the soil (CIMMYT, 2004). *Striga* infected maize is characterized by symptoms including leaf chlorosis, blotching, wilting, scorching, stunting, and reduction in tassel and ear size (Kim, 1991; IITA, 1991). Usually, *Striga* seed overwinters in the soil but the presence of maize not exudates triggers its germination. The suppressive effects of N on *Striga* infestation were attributed to delayed germination; reduced radical elongation, reduced stimulants production and reduction of seeds response to the stimulants (Hassan *et al*., 2009). On germination *Striga* develops haustoria which penetrates and subsequently colonize the maize root cells. After colonizing the maize plant, *Striga* remain undergroundwhereitmayspend4-7weeksbeforeemergence.Onemerging.Itrapidlygrowsto flowering and seed production, shortly before drying. Each *Striga* plant is capable of producing up to 200,000 seeds in order to develop a sustainable control strategy. Yield losses in staple cereal crops damage by *Striga* from a few percentages up to complete crop failure depending on factors such as crop species, level of infestation rainfall pattern and soil degradation (Weber *et al*., 1995). The grain production in Africa is potentially at risk on 44 million hectares of land (Sauerborn, 1991). *Striga hermonthica* has a potential of invading 48 million hectares of arable land in Africa alone (Watson and Kroschel, 1998). The Food and Agriculture Organisation (FAO) has estimated that two-thirds of cultivated savannah areas are infested with *S. hermonthica* that can cripple cereal production (maize, sorghum and millet) by taking over whole fields of the crop (IITA,1993).

Studies have shown that *Striga* can reduce the yield to almost zero (Hassan *et al*., 1995), which may lead to the farmer abandoning the fields when they are no longer productive (Berner *et al*., 1995) and some studies claim that problems caused by *Striga* continue due to loss of soil fertility since low soil fertility would benefit *Striga* (Parker, 2008). According to Parker (2008) problems with *Striga* are generally caused by low economic resources, poor soil fertility, newly infested areas due to unclean sowing material and cropping of host crops.

How to reduce *Striga hermonthica* seed bank

Prevention of seed input to the seed bank of *Striga hermonthica*-infested fields is an important objective of *Striga* management. *Striga hermonthica* (Del) Benth) infests more than 50 million hectares of farmland with intensifying dissemination in Sub-Saharan Africa, which makes it one of the gravest threats to food security in this region (Parker, 2012). *Striga* seed bank density had a significant effect on*Striga* seed production. Higher seed bank density resulted in more

*Striga*plants, which led to increased intra-specific competition and consequently a reduced level of reproduction per plant (Rodenburg *et al*., 2006).

Control of *S. hermonthica* remains challenging due to its very high seed production per plant, with seed survival rates in soils of more than ten years (Parker and Riches, 1993; Van Mourik, 2007). Since *Striga* seeds can remain viable in the soil for up to 10-20 years, therefore *Striga* control measures should aim at avoiding addition of new seed while at the same time reducing the seed bank from the infested soils. Several measures could be executed in order to reduce *Striga* seed bank from the soil and they include; planting herbicide treated (imazapyr-resistance) maize seed, adoption of push-pull technology, use of *Striga* maize resistance varieties, trap cropping, and good agricultural practices such as fertilization, crop rotation, intercropping and physical removal of S*triga* (Sserumag, 2015). Rodenburg *et al.* (2006) noted that the use of genotypes which support fewer emerged *Striga* plants is important to reduce parasite infection and reproduction rates and thereby lower parasite pressure in the following growingseason.

It has been widely accepted that a single control method is not effective against *S. hermonthica*, hence, integrated approach was postulated as control strategies (Menkir and Kling, 2007; Hearne, 2009; Atera *et al*., 2012). Among these control strategies, the use of *Striga* resistant/tolerant maize cultivars is thought to be an effective and offer an economically feasible and culturally sustainable technology for the African resource-poor farmer, since it does not require extra inputs such as labour and fertilizers, (DeVries, 2000; Sallah and Obeng-Antwi, 2002). Riches (1998) reported that timing of fertilizer applications even in small doses was effective on the plant's ability to cope with the parasite. Van Mourik (2007) also reported that application of 2 ton/ha, organic manure did not have significant effect on *Striga* seed production andlong-termeffecton*Striga*seedbank.However,onestudyofasinglefertilizertypecannot also be used to generalize the influence of fertilizers on *Striga* reproduction and long-term effect on seed bank. Nowadays, an integrated approach to *Striga* management is gaining popularity and generally favoured over the use of any single control method (Van Mourik, 2007).

Striga ControlMethods

The control of *Striga* species is particularly different from ordinary weeds because much of the damage to the host crop occurs while the parasite is still underground (Parker and Riches, 1993). In order to be effective, *Striga* control strategies must ensure good yield from the planted crop and reduction in *Striga* seed reserves in the soil (Adetimirin and Kim, 1997). Consequently, control methods that act before or during *Striga* attachment will be the most effective in preventing the damaging effects of the parasite. In the African resource-poor farmer's context, the method must also be at a minimal cost, sustainable, easily adoptable and fit well into his peasant croppingsystem.

Control strategies developed for the control of *Striga* in maize and other cereals include, land preparation, hand pulling and hoe weeding, rotation with non-host crops, land fallowing, and the use of trap and catch crops, fertilizer, chemicals, resistant/tolerant varieties (Kim, 1991a; Lagoke *et al*., 1991; Kroschel *et al*., 1999; CIMMYT, 2004). Among these control strategies, the use of *Striga* resistant maize cultivars is thought to be the most effective and offer an economically feasible and culturally sustainable technology for the African resource-poor farmer, since it does not require extra inputs such as labour and fertilizers, (DeVries, 2000; Sallah and Obeng-Antwi, 2002).

Chemical controlmethod

The principle of *Striga* control using herbicides lies in the fact that the maize variety has to be resistant to the herbicide, so that once the seed is coated with the chemical (Imazapyr), the maize survives, while *Striga* is killed during the initial stages of attachment to the root (before it can damage the host plant).

Striga seed bank is reduced due to direct action of herbicide on the seeds. Sserumag (2015) reported that a dose of 30 g/ha of Imazapyr is required for effective *Striga* control in maize (30 g of Imazapyr coated on 25 kg of seed). Imazapyr-resistant maize technology was a novel approach based on a natural form of herbicide resistance found in maize, which is widely referred to as IR maize. In addition, Imazapyr that was not absorbed by the maize seedling diffuses into the surrounding soil and kills ungerminated *Striga* seeds (CIMMYT, 2004). According to Lagoke *et al.* (1991), farmers in Sokoto State of Nigeria reported that soaking host seed in brine or an extract of *Parkia filicoides* reduces *Striga*infestation.

Ethylene was found to induce suicidal germination of *Striga* in the USA and it was reported to be the primary tool for reducing *Striga* seed banks in the witch weed eradication program in the Carolinas (Ransom, 1999). Studies have revealed that herbicides such as Dicamba, 2, 4-D and MCPA are effective in the selective control of *Striga* (Lagoke *et al.*, 1991; Odhiambo and Ransom, 1993). According to Odhiambo and Ransom (1993), Dicamba (a post-emergent herbicide) was shown to control *Striga* when applied soon after attachment, timing being critical to maximizing its effectiveness both in terms of *Striga* control and safety of the host crop. However, they indicated that the added yield from the application of Dicamba was usually not sufficienttoallowthetreatmenttobeeconomical.However,on-farmtrialsshowedthattheuse of IR maize technology enables farmers to increase harvest from a paltry average of 500 kg/ha to over 1,500 kg/ha Sserumag (2015).

IR-maize (Imazapyr resistant maize) is coated with the herbicide imidazolinones. The roots of maize first absorbed the herbicide which it was resistant against and then later released it as it kills *Striga* seedling and seeds (Kanampiu *et al*., 2002). Imazapyr is absorbed quickly through plant tissue and can be taken up by roots. IR-maize is used as a control method against *Striga* and to improve the yields in *Striga* infested areas. Studies showed that traditional mono-cropping with no use of fertilizer, IR-maize increased the yields compared to the use of local varieties from 0.5 tons per hectares to 1.0 tons perhectares.

Cultural controlpractise

The cultural control practices are those *Striga* management procedures that farmers can easily carry out without necessarily applying chemicals. They include practices like crop rotation, trap-cropping, timely planting, use of fertilizers, hand weeding among others.

Hand pulling andhoeing

Weeding using a hand-hoe is the most popular method of *Striga* management in maize production especially under subsistence scale. It is often done in combination with hand pulling *Striga* and other weeds in proximity with the maize plants. It is most commonly used by small holder farmers in most developing countries (Lagoke *et al*., 1991) and in Ghana (Nyarko, 1986). Even though widely recognised and most commonly used by smallholder farmers, hand pulling and hoeing are very tedious, labour-intensive and expensive operations (Lagoke *et al*., 1991; Kroschel *et al*., 1999). Hand pulling could only be effective in *Striga* control when infestations are light (Pieterse, 1985). However, these methods do not reduce damage to any significantlevel, since*Striga* inflicts most damages on the crop before it emerges from the soil (Lagoke *et al*., 1991), but could prevent flowering and production of seed. It is a long term improvement of controlling the weed by preventing an increase of *Striga* seed bank in the field.

Even though widely recognised and most commonly used by smallholder farmers, hand pulling and hoeing are very tedious, labour-intensive and expensive operations (Lagoke *et al*., 1991; Kroschel *et al*., 1999). Hand pulling could only be effective in *Striga* control when infestations are light (Pieterse, 1985). However, these methods do not reduce damage to any significant level, since *Striga* inflicts most damages on the crop before it emerges from the soil (Lagoke *et al*., 1991), but could prevent flowering and production of seed.

Use of fertilizers (sulphate of ammonia and chicken manure as nitrogen source) Applying commercial fertilizers or adapting other soil fertility amendment practices enhances maize growth vigour, thereby rendering the plants more versatile to withstand *Striga*attack.

Nitrogen increases maize production in the Savannah Ecological Zone of Nigeria (Singh *et al*., 2001, EL-Gizawy and Saleem, 2010 and Sharifai, 2011). Stefan (2003) indicated that fresh poultry dropping contain 70 % water, 1.4 % N, 1.1 % P_2O_5 and 0.5 % K_2O whilst dried chicken manure contains 13 % water, 3.6 % N, 3.5 % P_2O_5 and 1.6 % K_2O. Ammonium sulphate (SA) contains 21 % of nitrogen and 24 % sulphur available for plants. Chicken manure alone or in combination with nitrogen is effective in reducing and delaying *Striga* growth and early infestation compared with zero application.

Interaction between nitrogen, host and *Striga* are not well understood (Press 1995; Pageau *et al*., 2003) but some studies have documented the effect of Nitrogen fertilizer on *Striga* emergence and population and their resultant effect on cereal grain yield (Kim *et al*., 1997; Aflakpui *et al.*, 2002; Showemimo *et al*., 2002; Oswald and Ransom 2004; Godwin *et al.*, 2005). Kaudi and Abdul salam (2008) reported that *Striga* spreads rapidly in areas of low fertility and decreasing plant diversity, conditions often experienced by poor farmers in dry land zones. Lagoke and Isah, (2010) reported that the application of nitrogen fertilizer increases the performance of cereal crops under *Striga* infestation. This is due to the fact that nitrogen reduces the severity of *Striga* attack while simultaneously increasing the host performance. They also noted that the effectiveness of N in suppressing *Striga* depended on the responsiveness of maize to N levels and the *Striga* infestation. On the other hand, Kim and Adetimirin (1997) reported that N fertilizer applied to maize at 60 and 120 kg ha^{-1} did not affect *Striga*emergence.

Kim *et al.,* (1997) reported that N fertilizer applied at the rate of 120 and 150 kg/ha reduced emergence significantly. Aflakpui *et al.,* (2002), found no major effect of N on the relative growth response of maize to *Striga.* As noted by Kim and Adetimirin (1997) and Mumera and Below (1993) sources of *Striga* infestation may be responsible for the inconsistencies observed in most studies that are carried out under artificial infestation with either very high or low inoculums pressure. The conditions prevailing under artificial infestation may not be representative of what obtained under natural conditions. There is therefore a need to assess N effect on *Striga* infestation and damage under natural field conditions. The extent to which *Striga* reduces the growth of its host is highly variable and depends on factors such as host plant genotype, parasite infestation level, and environment (van Ast *et al.*, 2005). Limited studies have shown the importance of integrating resistant or tolerant crop varieties with N fertilization in *Striga* control on sorghum and maize (Kim and Adetimirin 1997; Showemimo *et al.,*2002).

The fact that N reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and Isah, 2010). The application of nitrogen fertilizer to cereals on soils of low fertility also reduces crop damage caused by *Striga.* Although *Striga* abundance is favoured by low soil fertility, (Weber *et al*., 1995; Debrah *et al.*, 1998), the mechanisms by which nitrogen reduces *Striga* damage are not well understood, and high levels of nitrogen application, above 120 $kgNha^{-1}$, would be required to achieve a significant reduction in *Striga* emergence (Kim *et al.*, 1997). Olakojo *et al*. (2001) also reported that the use of NPK and urea fertilizers as effective means of controlling *S. hermonthica* in maize field. Also, another effective way of controlling *striga* using fertilizers includes increasing soil N and other nutrients, replenishing the soil organic matter and increasing soil moisture holding capacity (Ikie *et al*.,2006).

Use of *Striga* resistantvarieties

Striga hermonthica is a threat to increased maize production in Ghana particularly in the high – yield potential savanna zone. *S. hermonthica* could be controlled by using resistant variety on farms which had long been abandoned due to *Striga* infestation (Parker and Riches, 1993). Scientists have identified some inbreeds and hybrids that have consistently demonstrated tolerance to *S. hermonthica* under heavy infestation (Kim *et al*., 1984; Olakojo and Kogbe, 1999; Ogunbodede and Olakojo, 2001).

However, studies with conventional maize hybrids (Chevalier and Schrader, 1977; Pe´rez Leroux and Long, 1994) have shown that maize genotypes vary in their response to N availability, reflecting variations in their relative abilities to absorb nitrogen fertilizer from the soil (N uptake efficiency), and in their relative efficiencies in using acquired nitrogen to produce yield components (N use efficiency) (Chevalier and Schrader, 1977; Moll *et al.*, 1982). Therefore, there is the need to evaluate these new *Striga* resistant maize hybrids at different rate of nitrogen application under natural condition. Host plant resistance would probably be the most feasible andpotentialmethodforparasiticweedcontrol(Ejeta*etal*.,2000;Haussmann*etal*.,2000;

Omanya, 2001). A resistant plant stimulates germination of *Striga* but it does not allow it to attach to the root. In *Striga* infested areas cultivation with resistant crops results in fewer *Striga* plants and higher crop yield than a non-resistant genotype of the cultivated plant would do (Rodenburg *et al.*, 2006).

A tolerant crop does not affect *Striga* in any way, however it has a higher stover, grain production and is less damaged than a non-tolerant crop (Kim, 1994). Trap crops induce germination of *Striga* seeds but do not host the parasitic weed and therefore result in suicidal germination since the seedlings die (Botanga *et al*., 2003). In *Striga* research, tolerance is the ability of the host plant to withstand the effects of the parasites that are already attached whereas resistance denotes the ability of the host plant to prevent attachment of the parasite to its roots (Kim, 1994).

However, adoption of different control methods to reduce *Striga* infestation has been limited. The average farmer cannot afford external inputs or they do not consider it suitable in their cropping system (Ransom, 2000). Tolerant genotypes have the disadvantage of encouraging the build-up of *Striga* seeds in fields over time (Kim, 1991) whilst resistant cultivars have the distinct advantage of not requiring expensive inputs from the farmer and depleting the seed bank. Indeed, resistant varieties are seen as the most practical, cheap and durable tool that can be effectively used by subsistence farmers to control *Striga*. *Striga* resistance is the ability of the host root to stimulate *Striga* germination but at the same time prevent attachment of the seedlings to its roots or to kill the seedlings when attached (Kim, 1994). When screening for *Striga* resistance the most important traits are host plant damage, few *Striga* plants attached to the crop plant and high grain yield (Badu-Aprakuet *et al.*, 1999). The rate of *Striga* damage is an index of tolerance while emerged *Striga* is an index of resistance (Rao, 1985). Host plant resistancewould probably be the most feasible and potential method for parasitic weed control (Ejeta *et al*., 2000; Haussmann *et al*., 2000; Omanya, 2001).

Use of trap and catchcrop

Trap- and catch crops are used to stimulate the germination of *Striga*. Catch crops are however parasitized and need to be destroyed as soon as they are infected. On the other hand, trap-crops are non-host crops and only induce the germination of *Striga* but do not sustain their growth for them to emerge to the surface (Kroschel *et al*., 1999).

Rotating host crops with trap crops, especially leguminous trap crops, have been used as an intervention for the successful control of *Striga*. Rotating susceptible cereal crops with leguminous trap crops is reported to reduce *Striga* seed banks, or clean *Striga* infested fields, to enhance cereal production (Berner *et al*., 1995). Soybean, groundnut, bambara groundnut and *Sesbania sesban* have been used as trap-crops in inter-cropping systems or rotated with susceptible host to successfully induce abortive germination of *Striga* seeds, with a consequent reduction in infestation in the savannah zones of sub-Saharan Africa (Carson, 1985; Tchemi, 1986; Parkinson *et al*., 1986). *Sesbania sesban* has been found to be very promising since its establishment and removal later from the field are both very easy (ICRAF, 1996). In Nigeria, Parkinson *et al*. (1986) reported a reduction in infestation, through abortive germination of the parasite, using soybean, cotton and bambara groundnut in rotation or as intercrop with susceptible hosts. Eplee and Norris (1990) reported a 90 % reduction of *S. asiatica* seed by cotton in artificial infestationtrials.

Croprotation

This involves cultivation of maize on the same piece of land in sequence with other crops especially leguminous crops such as beans, cowpeas, groundnuts, pigeon pea, soybean, lablab, mucuna and bambara nuts, or with trap crops like sunflower. Once legumes or other trap crops are grown in rotation with maize they will induce *Striga* germination; but since *Striga* is not adapted to their root system it dies shortly after germination.

This practice reduces *Striga* seed bank in the soil. *Striga* research in Africa has a long history and a range of effective component control technologies has been identified (Parker and Riches, 1993). Examples of control options for *S. hermonthica* range from the use of leguminous trap-crops to stimulate suicidal germination of *Striga* seeds and therefore reduce the seed bank and improve soil fertility, to the use of resistant host-crop cultivars. Schulz *et al.* (2003) found that resistant maize following a soybean trap-crop yielded 1.58 t ha^{-1} of grain and out yielded farmers' maize variety following traditional practices by more than 80 %. The effectiveness of leguminous trap-crops in reducing the *Striga* seed bank was demonstrated by Sauerborn (1999) in field experiments in Ghana where annual double cropping of trap-crops (soybean, sunflower and cotton) reduced the seed bank by about 30 % each year. Similarly, Schulz *et al.* (2003) achieved 50 % seed bank reduction after one year's rotation with soybean and cowpea under farmer-managedconditions.

Carsky *et al.* (2000) reported that *S. hermonthica* incidence in maize after soybean, compared to maize after sorghum, was significantly reduced from 3.2 to 1.3 emerged plants per maize plant, resulting in greatly improved grain yields. The use of grain legumes can contribute to soil N (Carsky and Iwuafor, 1999). Estimates of fertilizer replacement values in a monomodal savannazoneofWestAfricawere20kgN/hafromsoybeanand45kgN/hafromcowpea

(Kaleem, 1993; Carsky *et al.*, 1997). Sanginga *et al.* (2001) reported that the grain yield of maize grown after soybean was increased by an average of 25 % across two locations. They attributed this to enhanced N availability following soybean and other rotation effects, such as the reduction of soil-borne diseases. Good rotational sequence for maize should include crops that are capable of suppressing growth of a number of other weed species in addition to *Striga*. According to a study by De Groote (2010), crop rotation with maize-soybean and maize-crotalaria did not lead to a significant reduction in *Striga* seed bank, even though the maize yield was higher during the crop rotation. Many DT and NUE varieties are being scaled-up in eastern, southern and West African countries, with significant present and potential impacts (Alene *et al*., 2009; Kostandini *et al*.,2015).

Similarly, under the Integrated *Striga* Management for Africa (ISMA) project, IITA, CIMMYT and partners in Kenya and Nigeria came together to develop and deploy *Striga* tolerant improved maize varieties. Some of the projects have also developed improved crop management practices, including cereal-legume rotation to control *Striga* and to improve soil fertility (Kamara *et al*., 2008). When fallows with *Sesbania*, member of the family *Fabaceae*, were included in the crop rotation, grain production of maize were higher in comparison with unfertilized continuous maize cropping (Sjögren,2009).

Integrated *Striga*management

This approach entails deploying more than one complementary *Striga* control options. It may involve integrating measures aimed at reducing the amount of *Striga* seeds already in the soil with those aimed at avoiding addition of new seeds to the soil and or those aimed at avoiding

Striga introduction into new areas. It is a more sustainable way of enhancing maize productivity in areas prone to *Striga* infestation.

The interaction between N and resistant varieties in reducing infestation under natural populations of *Striga* has not been extensively studied. The potential for reducing *Striga* infestation in maize from its present level can be realized by integrating appropriate resistant and tolerant maize varieties with adequate N fertilization. Farmers themselves have also developed a range of coping strategies to the problem of *Striga*. In a survey in northern Nigeria, farmers mentioned hand pulling and hoe weeding, application of inorganic fertilizer, manure or ash, crop rotations, fallowing and early planting as some of the measures adopted to reduce the menace of *Striga* (Emechebe *et al*., 2004). A direct relationship between N fertilization rate and maize plant growth and grain yield was widely demonstrated (Zhang *et al*., 1993; Jokela and Randall, 1989; McCullough *et al*.,1994).

CHAPTER THREE

MATERIALS ANDMETHODS

Description of experimental site

The experiment was conducted at the experimental site of CSIR-SARI Nyankpala (about 16 km west of Tamale) in the Northern Region of Ghana during the 2018 farming season to determine the best combination of maize variety, ammonium sulphate and chicken manure that would enhance the performance of maize in a *Striga* infested field in Northern Ghana.

The area lies within the Guinea savanna zone of Ghana which falls on latitude $09^0 25^{''}$N, longitude 0^0 $58^{''}$W and at an altitude of 183 m above sea level. The area is characterized with natural vegetation dominated by grasses with few shrubs. The climate is warm, semi-arid with a total annual mean rainfall of about 1022 mm which falls mainly between May and September each year following a pronounced dry season between October and April. The area has an average minimum temperature of 25^0 C and a maximum average temperature of 35^0 C. The soil is brown in colour, moderately derived from voltaian sandstone and classified as Nyankpala series (plinthicAcrisol)

Description of the experimental treatment

The experimental design was 2 x 4 x 3 factorial study laid out in a Randomized Complete Block Design (RCBD) with three replications. A plot size of 4.0m x 1.5m with an alley of 0.75 m and 2 m separating plots and replication respectively. The treatments of the experiment were maiz variety (Wang-dataa and Bihilifa), chicken manure (0 ton/ha, 3 ton/ha and 6 ton/ha) and ammonium sulphate at (0 kg/ha, 40 kg/ha, 80 kg/ha and 120 kg/ha) applied as basal and topdressing at 2 WAP and 6 WAP respectively.

Table 1 shows the combinations of the treatments used on the field.

Table 1: Description of the experimental treatments

Code	Treatments	Treatments descriptions
101	$M_0N_{40}V_2$	0t/ha of poultry manure + 40kg/ha of sulphate of ammonia with variety 2
102	$M_3N_{120}V_1$	3t/ha of poultry manure + 120kg/ha of sulphate of ammonia with var.1
103	$M_6N_{40}V_2$	6t/ha of poultry manure +40kg/ha of sulphate of ammonia with var.2
104	$M_6N_{120}V_2$	6t/ha of poultry manure + 120kg/ha of sulphate of ammonia with var.2
105	$M_6N_0V_2$	6t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.2
106	$M_3N_0V_1$	3t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.1
107	$M_6N_{80}V_1$	6t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.1
108	$M_6N_{40}V_1$	6t/ha of poultry manure + 40kg/ha of sulphate of ammonia with var.1
109	$M_0N_{80}V_1$	0t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.1
110	$M_3N_{40}V_2$	3t/ha of poultry manure + 40kg/ha of sulphate of ammonia with var.2
111	$M_3N_{80}V_2$	3t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.2
112	$M_6N_{120}V_1$	6t/ha of poultry manure + 120kg/ha of sulphate of ammonia with var.1
113	$M_6N_{80}V_2$	6t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.2
114	$M_0N_{80}V_2$	0t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.2

115	$M_0N_{120}V_1$	0t/ha of poultry manure + 120kg/ha of sulphate of ammonia with var.1
116	$M_3N_{120}V_2$	3t/ha of poultry manure + 120kg/ha of sulphate of ammonia with var.1
117	$M_6N_0V_1$	6t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.1
118	$M_0N_0V_2$	0t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.2
119	$M_0N_{40}V_1$	0t/ha of poultry manure + 40kg/ha of sulphate of ammonia with var.1
120	$M_0N_0V_1$	0t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.1
121	$M_3N_0V_2$	3t/ha of poultry manure +0kg/ha of sulphate of ammonia with var.2
122	$M_3N_{40}V_1$	3t/ha of poultry manure + 40kg/ha of sulphate of ammonia with var.1
123	$M_0N_{120}V_2$	0t/h of poultry manure + 120kg/ha of sulphate of ammonia with var.2
124	$M_3N_{80}V_1$	3t/ha of poultry manure + 80kg/ha of sulphate of ammonia with var.1

M = Represents Chicken manure, N = Ammonium sulphate, V_1 = Wang- dataa, V_2 = Bihilifa

Collection and preservation of *Striga hermonthica*seed

Striga hermonthica infested areas identified in the Tolon District of Northern Ghana were monitored during the months of October and November 2017, when the seed had not yet matured. These fields were inspected regularly until the floral heads of the *striga* had matured. A floral head was considered matured if all florets had completed flowering, with no visible flowers at the uppermost parts. Healthy and intact matured capsules were harvested into paper bagsandputinlargeplasticbagstopreventtheseedsfromdroppingbeforetheyweresenttoa drying point for further drying. The capsules were removed daily for exposure to sunlight in a well-ventilated shed for adequate drying of the seeds.

When the seeds were thoroughly dried, small amounts of the harvested heads were successively spread on polythene sheeting and gently beaten with a stick until all the capsules were completely shattered and the seeds shed. The seed together with the smaller trash was passed through three sieves – 250, 180 and 150 micrometre (m) mesh sizes. Only the material collected on the 150 m sieve was collected as seed. The seed lot was then dried for four days under dry conditions until they were used to infest the maizefield.

Land preparation and planting of seeds

The vegetation was cleared, tractor was used to plough and ridges made across the slope followed by pegging to layout the experimental plots. Germination test of maize seed was done to ascertain their viability above 80 % before planting. The maize was sown at a spacing of 0.75 m between ridges and 0.45 m between plants, and the total land size was 288 m^2. Maize were sown at a depth of 3 cm. A maximum of three seeds were planted per hole and seedlings thinned to two plants per hole two weeks after emergence. Empty hills wererefilled.

Striga seeds were counted and weighed and mixed thoroughly with a quantity of soil, and then planted in the holes before the maize on the same day. The chicken manure was incorporated withtheplotsatthreedifferentlevelsof(0,3and6t/ha),twoweeksbeforeplanting.About50

% of the ammonium fertilizer were applied as basal at two weeks after planting (2 WAP) and the remaining 50 % of the ammonium sulphate were used to top dress four weeks after the basal application respectively.

Weedmanagement

Soon after planting, glyphosate (non-selective) herbicide was applied to kill all weeds to avoid early competition. All subsequence weedings were done by hand. The first weeding was done three weeks after planting (3 WAP) and the second was done six weeks after plating (6 WAP).

Soil sampling andanalysis

Soil samples for determination of soil available N and P were obtained from the upper soil surface layer (0-15 cm) using a 1m soil auger. The soil samples were collected prior to planting at random. Six soil samples were taken using the soil augur in every replication and the soil bulked together to get one composite sample to determine the initial soil properties Table 2. Soil analysis was also carried out for the various treatments after harvesting. Three samples were taken for each treatment in each replication and bulk for the post-harvest soilanalysis.

Table 2: Initial physico-chemical properties of Akukayilli soil in 2017

Soil Depth (cm)			**0-15**
pH (Soil:H_20) 1:2.5			4.87
O.M (%)			**0.403**
O.C (%)			**0.234**
N (%)			**0.0219**
P (Mg/kg)			**4.73**
K(Mg/kg)			**76**
Ca (Cmol+/kg)			**2**
Mg (Cmol+/kg)			**1.3**
TEXTURE			
SAND(%)	SILT (%)	CLAY (%)	TEXTURAL CLASS
66.2	22.44	11.36	SANDY LOAM

Determination of soil physico-chemicalproperties

Determination of soil pH

The pH of the soil was determined using the method by Lierop and Mackenzie (1977) and Narayana (2020).The apparatus used in determining the pH included pH meter, glass electrode, 50 ml beakers, stirring rod, spatula and distilled water.

The soil pH was determined in the ratio of 1:2.5 (soil: water) in deionized water. 10 g of air-dried soil was weighed and kept into a 50 ml beaker. 25 ml of the deionized water was added to the soil in the beaker. The suspension was then being stirred vigorously for about 20 minutes and later allowed to stand for about 30 minutes where most of the clay particles had settled down the suspension. pH meter was calibrated with two standardized solutions at 4 and 7 respectively. The electrode of the pH meter was then inserted into a partially settled solution. The pH values were then read andrecorded.

Determination of total organic carbon (C)

The total organic carbon was dertermined using the method by Fung *et al*. (1996). 2.0 g of fine air-dried soil sample was weighed into a 250 ml Erlenmeyer flask. 10 ml of 1.0 N potassium dichromate was then added to the solution followed by 20 ml of concentrated sulfuric acid. The mixture was then swirled to ensure that the solution was in contact with all the soil particles. The flask content was then allowed to cool on an asbestos sheet for about 30 minutes. 100 ml of distilled water and 10 ml of orthophosphoric acid was then added to the solution. 2 to 3 drops of diphenylamine indicator was then added and titrated with 1.0 N ferrous sulfate solution until the color changed to blue and then to green as the endpoint. The titre value was then recorded and corrected for the blank solution.

Determination of total nitrogen

Total nitrogen was determined using the Kjeldahl method which has been used by other researchers including Babu (2015). A known weight of the soil sample was poured into a digestion flask followed by the addition of 5 ml of Kjeldahl digestion mixture (concentrated sulfuric acid with selenium as catalyst). The soil was then digested in the mixture by heating at 360 to 410℃ until the mixture became clear and colorless. The flask was allowed to cool and then the mixture was totally transferred into 100 ml volumetric flask and then topped up with distilled water. 20 ml of the aliquot was then transferred into the Kjeldahl distillation apparatus and then 20 ml of 40% NaOH was added. 75 ml of distillate was then collected over 10 ml of 4% Boric acid in a 100 ml conical flask. The collected distillate was titrated with 0.1 N HCl till light green color changed to pink.

Determination of availablephosphorous

Available phosphorus of the soil was determined using the method of Watanabe and Olsen (1965). Available phosphorus was determined by weighing 5 g of the air-dried soil into shaking bottles followed by the addition of 35 ml of BRAY 1 solution (0.025 normal HCl and 0.03 normal NH_4F) and then shaken on a mechanical shaker for about 8 minutes at 3000 rpm and filtered using the Whatman No. 42 filter paper to obtain a clear solution. 1 ml of the standard solution was then pipetted into a set of clean test tubes and topped up with distilled water and mixed thoroughly. 2 ml of blue color reagent and 1 ml of ascorbic acid was then added to the mixture and mixed well. Using a visible range UV/VIS spectrophotometer the color was measured at 650 nm after six minutes. Absorbance versus P concentration (ppm) was plotted and then unknown samples were read, while ppm p was obtained by interpolation on the graph plotted.

Determination of exchangeable cations (calcium, magnesium, potassium) Exchangeable cations were determined using the procedure adopted by Gillman (1979). 5 g of 2 mm sieved air-dried soil was weighed into a 100 ml shaking bottle. 50 ml of 1.0 ammonium acetate solution was then added to it and cocked and shaken on a mechanical shaker for 2 hours. The shaken mixture was then filtered using the Whatman N0. 42 paper to obtain a clean and clear filtrate. Potassium from the filtrate was then measured using the flame photometer. Calcium and magnesium were measured from the filtrate using the atomic absorption spectrophotometer

.3.7.6 Determination of particle size distribution

The particle size distribution of the soil was determined by the modified Bouyoucous hydrometer method described by Day (1965). 51 g of air-dried soil was weighed and transferred into a 250 ml beaker. 50 ml of prepared calgon solution and 100 ml of distilled water were then dispensed into the soil and shaken on a mechanical shaker overnight to soak and disperse soil particles, the mixture was then transferred into a sedimentation cylinder and topped up with 1-liter deionized water. A blank of sodium hexametaphosphate was then made and treated similarly as the sample. The particle sizes were then measured by, placing the cylinders on a flat surface. A hydrometer was immediately placed into the suspension and slide slowly into the suspension until it was floating. The first reading on the hydrometer was taken at 40 seconds after the cylinder was set down (H1). The hydrometer was then removed and the temperature of the suspension taken with a thermometer (T1 in ˚C). The next hydrometer reading was taken after 5 hours (H2) and then the temperature taken in that order (T2 in˚C).

Field preparation and agronomicpractices

The field was ploughed, harrowed and ridged before planting. A two-row plots of 4 m long represented each entry. Between rows were 0.75 m apart and between plants were 0.40 m apart. The plots were artificially inoculated with the *S. hermonthica* seeds collected from the infested areas in the Tolon District of Northern Ghana during the months of October and November 2017. This was accomplished by mixing 1 g pure *Striga* seed containing approximately 1500 germinable seeds in each planting hole. These were thoroughly mixed with soil before placing maize seed in the hole. Three maize seeds were sown per hill and were thinned to two plants per hill at three weeks after planting to obtain a target population of 1,800 plants ha^{-1}. Pre-emergence chemical weed control was practiced and consisted of an application of a combination of Pendimethalin. Hand weeding was also practiced two days prior to *Striga* count to clear all unwanted weeds in the field to keep the field clean for accurate *Striga* count.

The sulphate of ammonia were calculated in grams (g) and divided in to levels as (0, 28.6, 57.2, and 85.7 g/ha), for basal and top dressing respectively. The organic fertilizer (chicken manure) was also calculated and applied at the rate of 0, 0.0018 and 0.0036 t/ha respectively.

Data Collection andMeasurements

Days to 50 %tasseling

The days to 50 % tasseling was taking from the net plot; by counting the the number of days to when 50 % of the plants produced tassel.

Days to 50 %silking

The number of days it takes from planting to when 50 % of the plants had formed silks was recorded for days to 50 % silking.

Plant height(cm)

Plant height at 10 weeks after planting (10WAP) was measured for the five randomly tagged plants in each plot from the ground to the stem tip using a tape measure, and the mean calculated for each plot.

Ear height(cm)

Ear height was measured from the base of the plant to the node bearing the uppermost ear at harvest using plant height measurement pole.

Leaf area

The leaf area (LA) was measured in centimeters by measuring the length and breadth of the five-tagged plant leaves multiplied by a constant figure 0.75 (Adeoye *et al.*, 2011).

Leaf area index (LAI)

Was determined from LA using instantaneous approach. This was done by calculating the number of plants per each plot and the leaf area index was deduced using the equation below.

$$LA = \text{Leaf length} \times \text{Leaf breath} \times 0.75(cm^2) \quad \ldots\ldots 1$$

$$LAI = LAPP \times Pm^{-2} \quad \ldots\ldots 2$$

Where,

LA- leaf area, LAPP- leaf area plant^{-1}, LP^{-1}- leafs plant^{-1}, Pm^{-1}- plants m^{-1}, LAPP = LA× LP^{-1}

Number earsharvested

Ears harvested is the total number of ears (cobs) harvested from each plot.

Cob weight

Cob weight was the weight of cobs harvested per plot recorded in **(kg/ ha)**

Stalk lodged

The actual number of plants whose stalks had broken below the ear was recorded per plot by rating them from 1-9 in order of its damage rate.

Earaspect

The ear aspect was taken by observing the ear structure and rate them with a range from 1-10.

Host plant damage ratings(HDR)

Visible damage symptoms on host plants were taken at 10 weeks after planting. Diseased plants were rated on a scale of 1 to 9 (1= no visible symptoms and 9 = all plants dead or dying).

Grain yield(kg/ha)

All plants in the net plot were harvested to determine grain yield per plot and the yield was converted to tons per hectare bases and adjusted to 12.5 % moisture level.

$$GYLD = \frac{(fldwt-0.8)}{6} \frac{(100-moist)}{84} 10000$$

Where: *fldwt* is the weight of maize harvested per plot, assuming 80 % shelled grain weight and the effective plot size of 6 m^2; *moist* is the moisture of the grains at harvest (Kang, 1994).

Striga emergence count(m^2)

The number of emerged *Striga* plant in each plot was noted at 8, and 10 weeks after planting (WAP). Even though *striga* emergence were observed in the seventh week after planting.

Stover weight(kg/ha)

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

Choosing a suitablevariety

In an effort to identify suitable variety to be used for commercial production, a rank sum was calculated by ranking the grain yield, *Striga* count, 100 grains weight, plant height, ear height, days to silking and days to anthesis. The best variety was selected based on the rank sum values calculated by summing the ranks of each genotype.

Harvesting

Harvesting was carried out after 90 days when the cobs were fully matured and was ready for harvesting. The whole plants of each entry were harvested; the harvested maize was dried, bagged and labeled according to the replications and treatment.

Correlations amongtraits

The degree of relationship between traits were determined by Pearson correlation coefficients using MSTATIC 2. After determining the linear associations between two traits, partial correlation was used to determine whether or not the association between any two traits was real holding the third trait constant. Correlation coefficients range in value from -1 (a perfect negative relationship) to +1 (a perfect positive relationship).

Dataanalysis

Data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT statistical software version 12. Significant differences among treatments were determined using Least Significance Difference (LSD) at 5 % level of probability. All count data (i.e. *Striga* count) were transformed logarithmically (Kihara *et al.,* 2011) before being subjected to ANOVA to normalize thedata.

CHAPTER FOUR

RESULTS

Days to 50%tasseling

There were no significant (p>0.05) differences in primary and secondary interaction among treatments on this parameter except for the significant effects of variety (p<0.05) and chicken manure (p<0.001) on this parameter. Wang-dataa tasselled earlier (55 days) than Bihilifa 56 days (Figure 1). Moreover, the application of 6 t/ha of chicken manure recorded the earliest days of 53 (Figure 2). The application of 3 t/ha of chicken manure recorded 54 days, and the late days 57 were recorded by zero application of chicken manure.

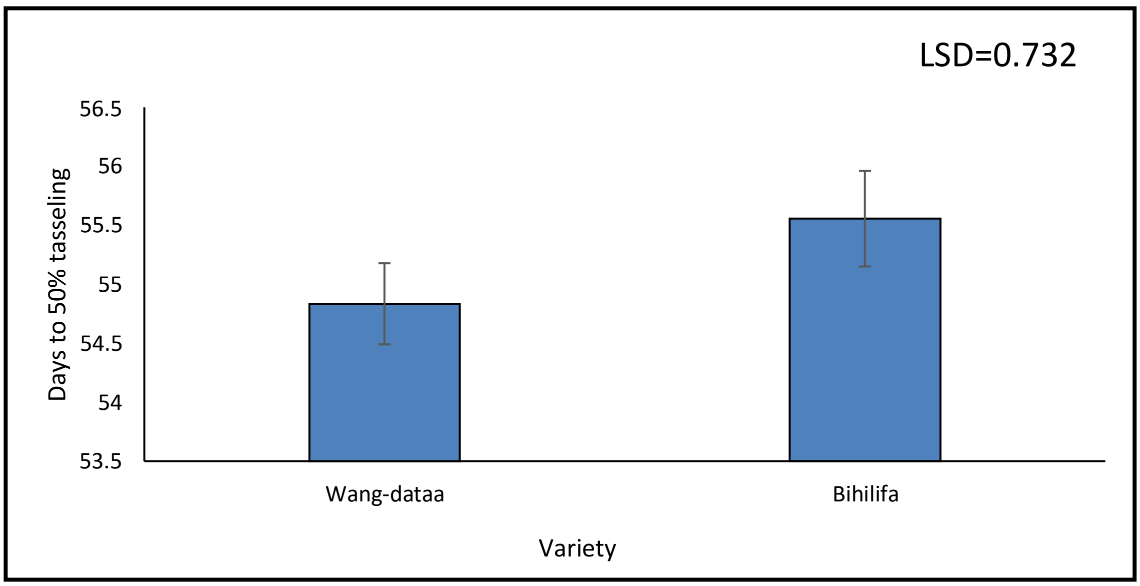

Figure 1: Influence of variety on days to 50% tasseling. Bars represent SEM.

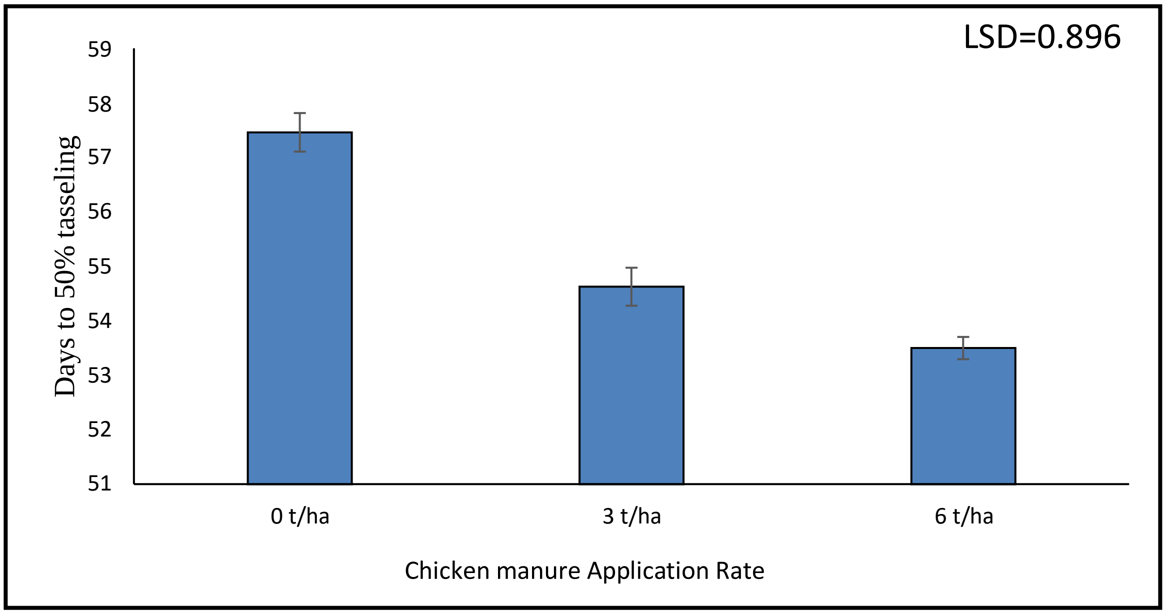

Figure 2: Influence of chicken manure on days to 50% tasseling. Bars represent SEM.

Days to 50%silking

There was no significant (*p*>0.05) difference among treatments in secondary interaction except for the significant (*p*<0.05) effect of variety and inorganic fertilizer, and significant (*p*<0.001) effect by organic fertilizeron this parameter. The earliest days value of 57.11 was given by Wang-dataa variety in combination with the application of ammonium sulphate at 80 kg/ha (Figure 3a). This value was statistically identical to the values 57.33 and 57.44 of the same variety in combination with ammonium sulphate applied at 0 and 120 kg/ha respectively. The late day of 58.56 was recorded by Bihilifa plus the application of ammonium sulphate at 80 kg/ha.

Also, the earliest days of 56 were recorded by the application of 6 t/ha of chicken manure (Figure 3b). The control supported the late days of 60.

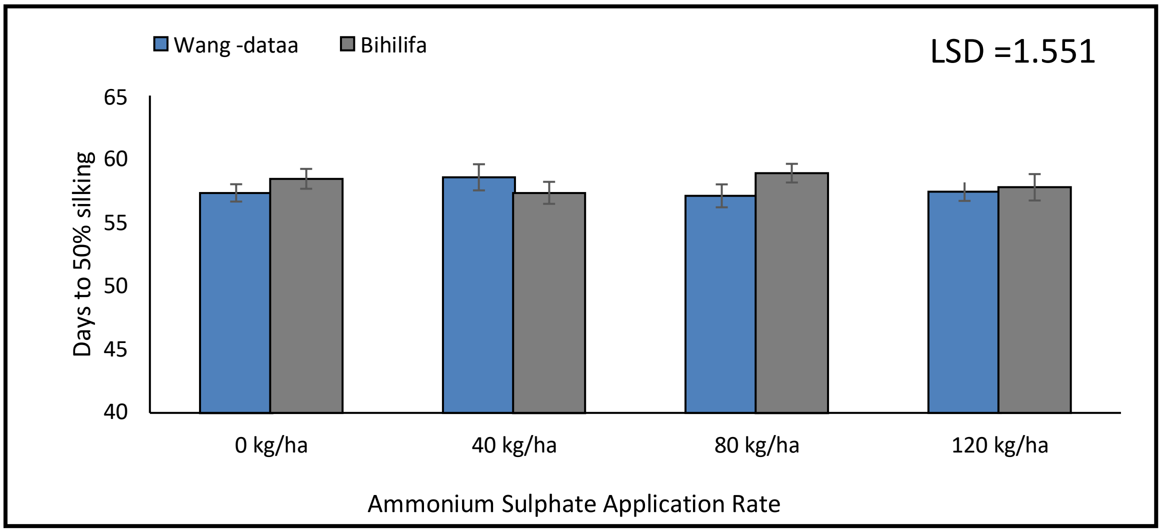

Figure 3a: Influence of variety by ammonium sulphate on days to 50% silking. Bars represent SEM.

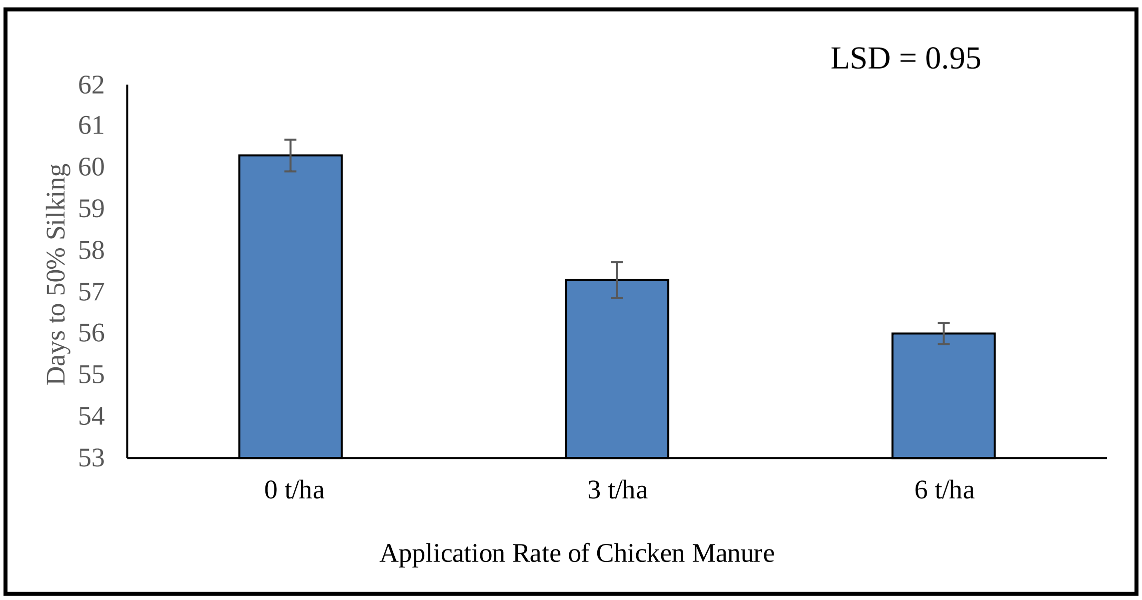

Figure 3b: Influence of chicken manure on days to 50% silking. Bars represent SEM.

Plant height at maturity (cm)

There were no significant (*p*>0.05) differences among treatments in main effects and secondary interaction on plant height except for the significant (*p*<0.001) influence of organic fertilizer. Application of chicken manure at 6t/ha gave the optimum height value of 136 cm (Figure 4). The lowest height of 107 cm was supported by the control.

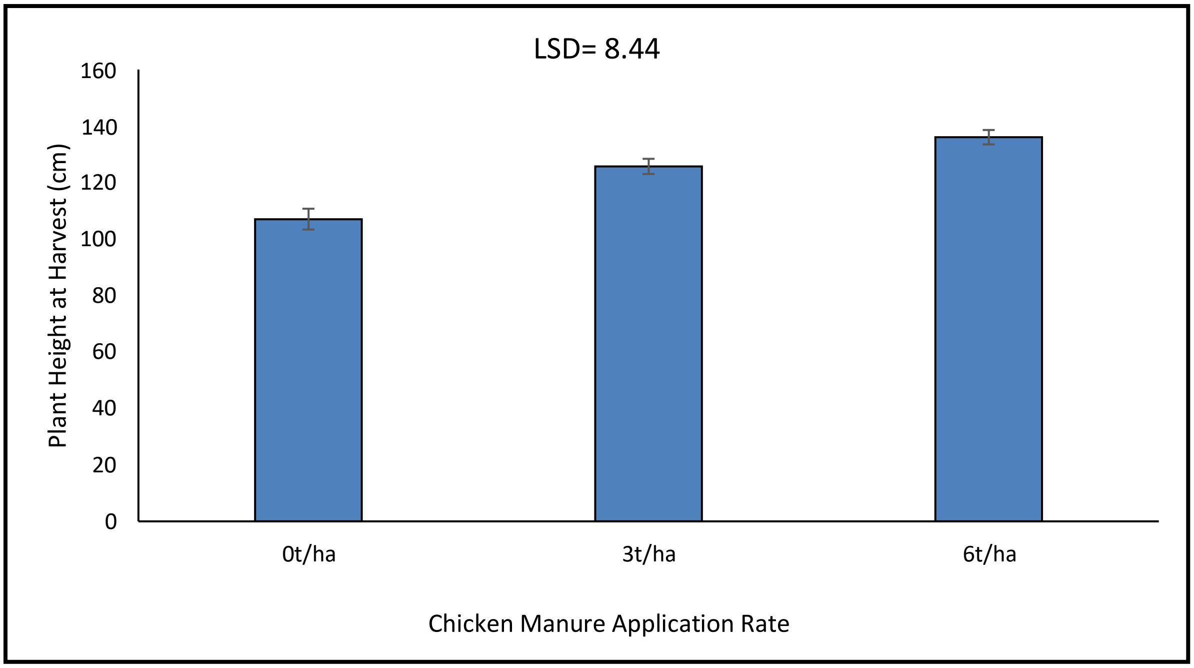

Figure 4: Influence of chicken manure on plant height at maturity. Bars represent SEM.

Ear height(cm)

There were no significant (*p*>0.05) differences among treatments in primary and secondary interaction except for the significant (*p*<0.001) effect by organic fertilizer on this parameter. The application of 6t/ha of chicken manure recorded the highest ear height value of 60.8 cm (Figure 5). The lowest value 43.3 cm was supported by the control.

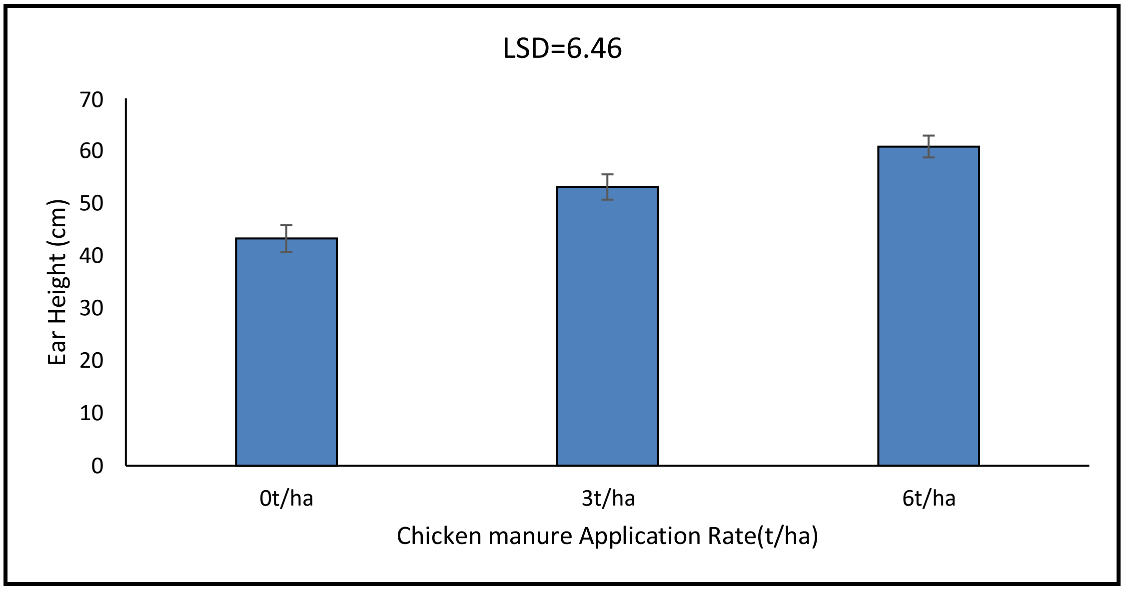

Figure 5: Influence of chicken manure on ear height damage score. Bars represent SEM.

Leaf area index (LAI)

There were no significant (p>0.05) differences among treatments in main effects and secondary interaction except for thesignificant (p<0.01) effect on leaf area index by organic andinorganic fertilizers.The application of 6 t/ha of chicken manure combined with ammonium sulphate at 40 kg/ha recorded the highest value of 31.68 (Figure 6). The minimum value 16.3 was supported by zerochicken manure plus ammonium sulphate at 40 kg/ha.

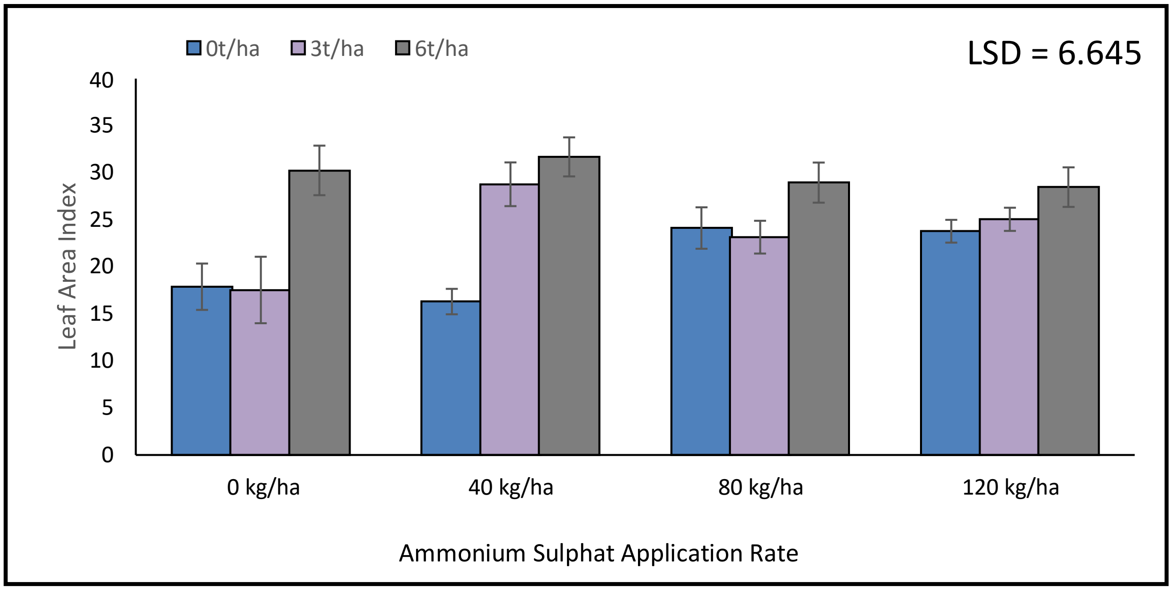

Figure 6: Influence of chicken manure by ammonium sulphate on leaf area index (LAI). Bars represent SEM.

Number of ears at harvest(m^2)

There was no significant (p>0.05) effect by primary interaction on this parameter, except for the significant (p>0.001) and (p<0.05) differences among treatments in main effect and secondary interaction. Wang-dataa gave the best number ears per hectar when 6 t/ha of poultry manure and 120 kg/ha of ammonium sulphate were applied. However the application of 3 t/ha of poultry and either 40 kg/ha or 80 kg/ha or 120 kg/ha of ammonium sulphate to Wang-dataa gave similar results to the best obtained for the trial. Also Bihilifa treated with 3 t/ha of poultry manure plus 40 kg/ha of ammonium sulphate or 6 t/ha poultry manure plus 80 kg/ha ammonium sulphate gave the similar results to the best ear number in thistrial.

Application of Wang-dataa with 3 t/ha of poultry manure plus 40 kg/ha of ammonium sulphate and also Bihilifa with 3 t/ha with 3 t/ha of poultry manure plus 40 kg/ha of ammonium sulphate were adequate to produce the best ear number per hectar.

Table 3: Number of ears at harvest as affected interaction by variety by organic fertilizer and inorganic fertilizer.

Variety	Organicfertilizer	Inorganic fertilizer			
	Applicationrate(t/ha)	Application rate (kg/ha)			
		0	40	80	120
Wang-dataa	0	2.8[defghi]	1.8[hi]	3.1[defghi]	3.3[cdefgh]
	3	3.7[cdefg]	3.9[abcdef]	4.8[abc]	4.2[abcde]
	6	2.2[ghi]	4.3[abcd]	5.4[ab]	5.5[a]
Bihilifa	0	1.7[hi]	1.5[i]	2.4[fghi]	2.9[defghi]
	3	2.6[efghi]	4.1[abcde]	3.6[cdefg]	3.2[cdefgh]
	6	3.8[bcdefg]	3.7[cdefg]	4.4[abcd]	3.1[cdefghi]

Grand mean: 3.4

LSD(5%)=1.4 **CV (%) =4.2**

Means followed by similar letters are not significantly different at 5% level of probability.

4.7Cob weight (kg/ha)

Cob weight was significantly (*p*<0.05) influenced by the interaction among variety, organic fertilizer and inorganic fertilizer.The outstanding value 4716.7 kg/ha was given by wang-data variety with the application of chicken manure at 6 t/ha plus ammonium sulphateat 120 kg/ha (Table 4). However application of 6 t/ha of poultry manure and 80 kg/ha of ammonium sulphate to Wang-dataa gave a similar results to the best obtained for the trial. The lowest value 2166.7

kg/ha was obtained for the application of Bihilifa variety withzero chicken manure plus ammonium sulphate at 40 kg/ha.

Table 4: Cob weight as affected by variety, organic fertilizer and inorganicfertilizer

Variety	Organicfertilizer	Inorganic fertilizer			
	Rate of application(t/ha)	Rate of application (kg/ha)			
		0	40	80	120
Wang-dataa	0	2383^{efgh}	2383^{efgh}	2433^{efgh}	15300^{defgh}
	3	2833^{cdefgh}	3216^{cdef}	3550^{bc}	3450^{cd}
	6	2500^{efgh}	3216^{cdef}	4283.3^{ab}	4716^{a}
Bihilifa	0	3283^{cde}	2166^{h}	2216.7^{h}	2616^{defgh}
	3	2333^{efgh}	3116^{cdefg}	2883.3^{defgh}	3116^{cdefg}
	6	2666^{cdefgh}	3166^{cdef}	3116.7^{cdefg}	2883^{cdefg}

Grand mean: 2966

LSD(5%)=766 **CV (%) =26333**

Means followed by similar letters are not significantly different at 5% level of probability

Stalklodge

There was no significant (p>0.05) differences among treatments in primary and secondary interaction except for the significant (p<0.01) effect by variety on this parameter.The higherstalk lodged value 1.528 was recorded by Bihilifa (Figure 6), with Wang-dataa supporting the lower value of 1.194.

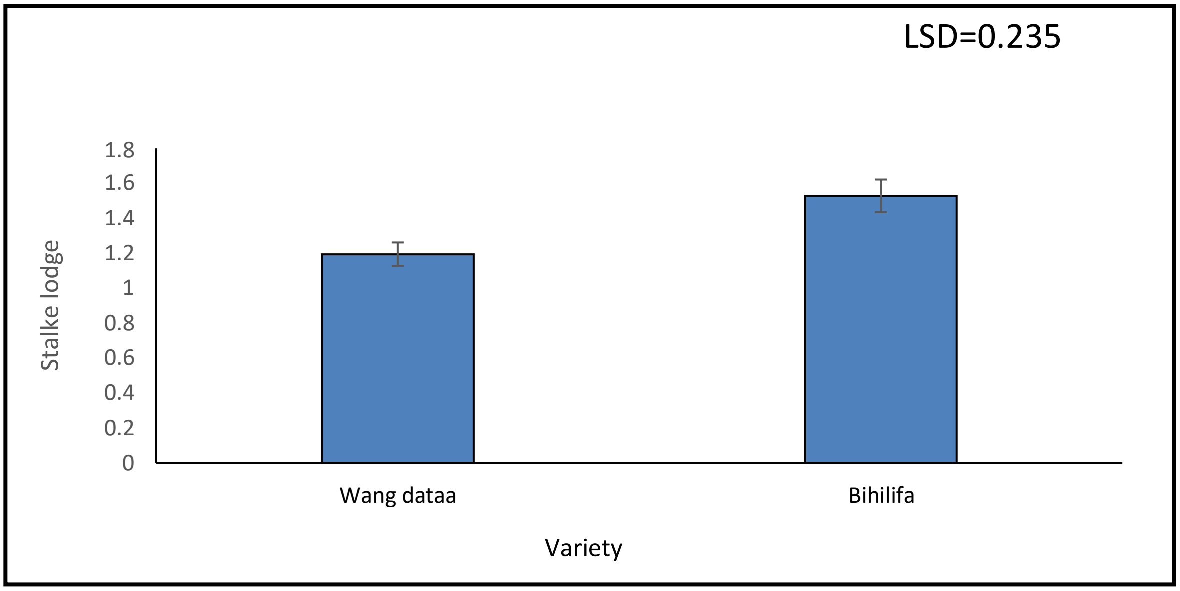

Figure 7: Influence of variety on stalk lodge. Bars represent SEM.

Ear appearancescore

There was significant effect by variety ($p<0.05$), organic fertilizer ($P < 0.001$), and inorganic fertilizer ($p<0.001$) on ear appearance score. There was no significant ($p<0.05$) effect in primary and secondary interaction. Wang-dataa gave a better ear appearance score value of 4.58, followed by good Bihilifa score of 5 (Figure8).

Moreover, the best score 4.25 were recorded for the application of 6t/ha of chicken manure. (Figure 9). The good score 5.63 was recorded by the control

With the inorganic fertilizer, the best score 4.27 was recorded for the application of ammonium sulphate at 80kg/ha (Figure 10). The control supported good score of 5.33.

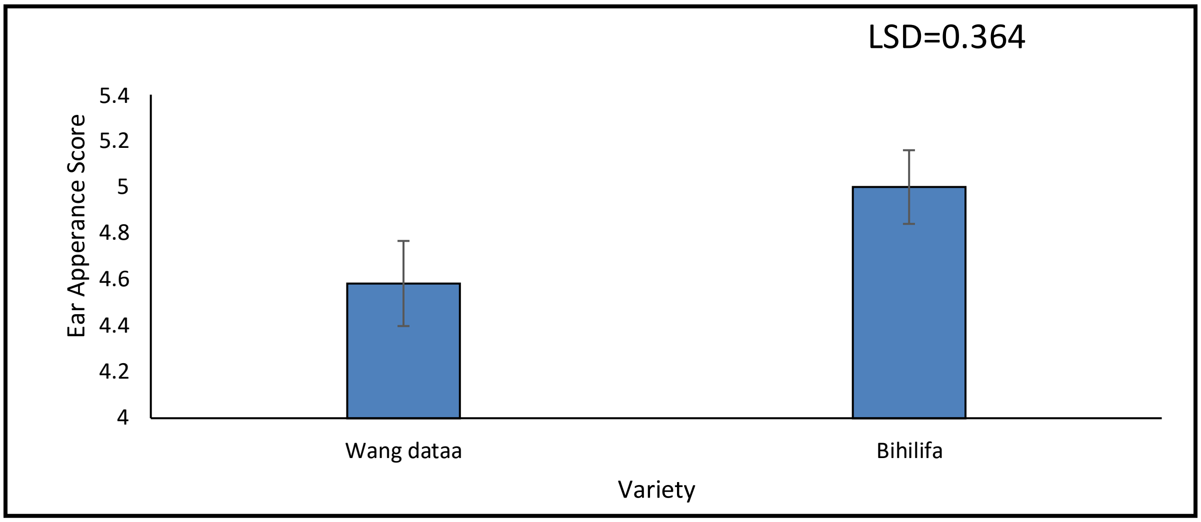

Figure 8: Influence of variety on ears damage score. Bars represent SEM.

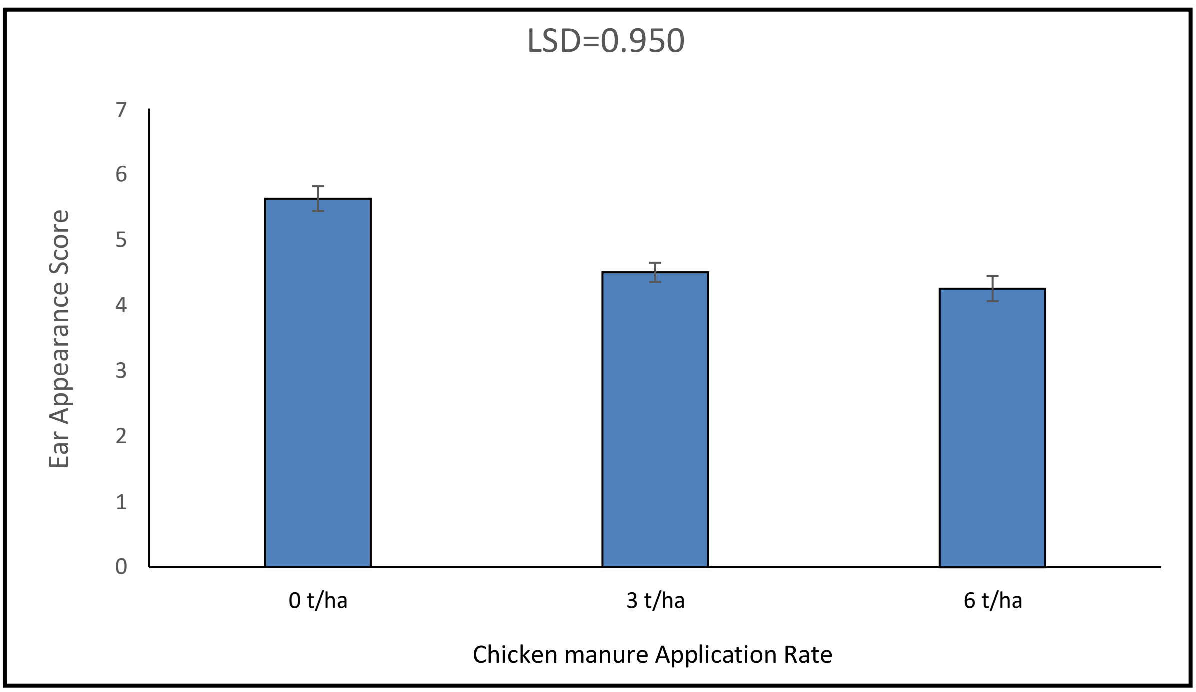

figure 9: Influence of chicken manure on ears damage score. Bars represent SEM.

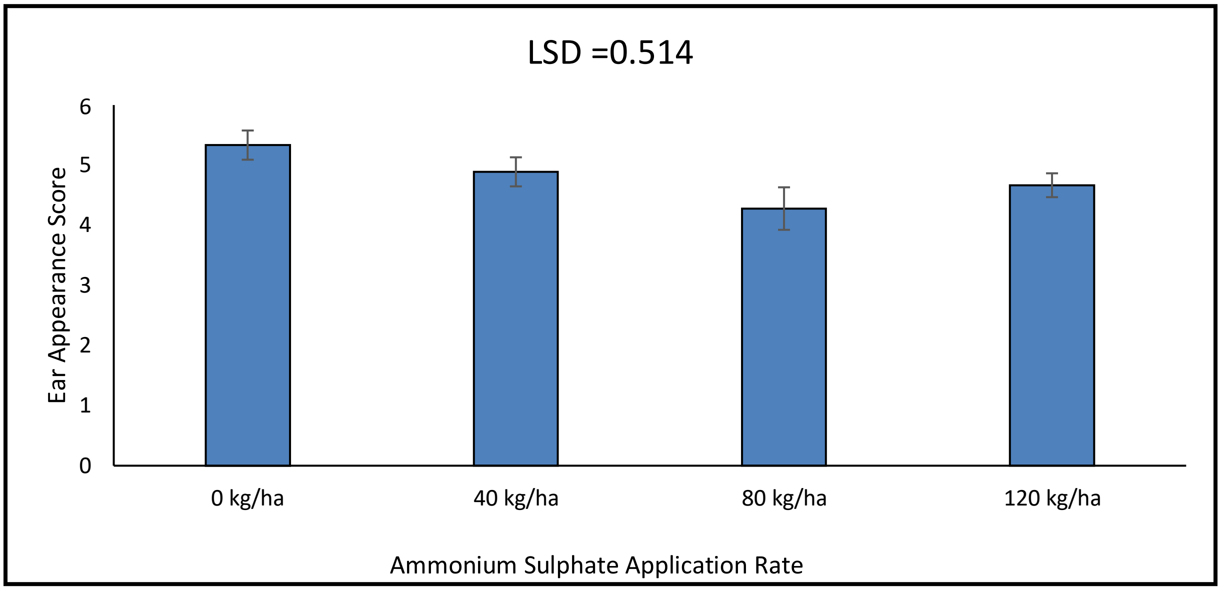

Figure 10: Influence of ammonium sulphate on ears damage score. Bars represent SEM.

Host plantdamage

There was significant (p<0.05) effect by organic and variety, and significant (p<0.05) effect of variety by inorganic fertilizer on this parameter. The combined influence between Wang-dataa variety applied with chicken manure at 6 t/ha gave the minimum damage values 2.83 (Figure 11). Wang-dataa combined with chicken manure at 0 t/ha gave the highest value of3.67.

Similarly, the highest values 4 and 3.56 were given by Bihilifa variety plus the application of ammonium sulphate at (80 and 0) kg/ha (Figure 12). The least damage value 2.67 was supported under Wang-dataa plus the application of ammonium sulphate at 80 kg/ha.

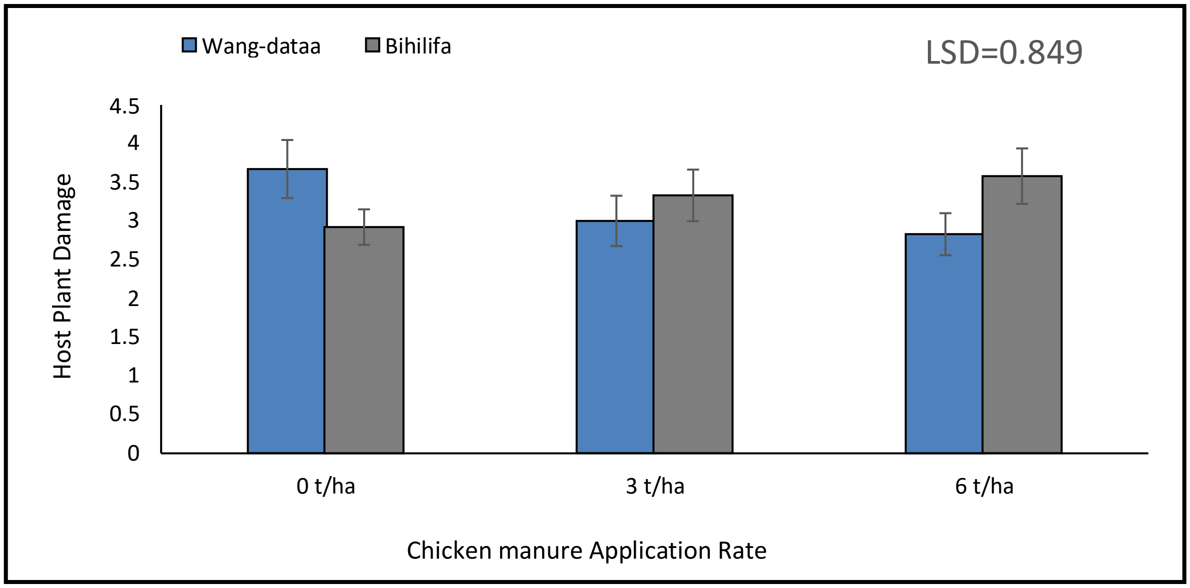

Figure 11: Influence of variety by chicken manure on *striga* infestation damage. Bars representSEM.

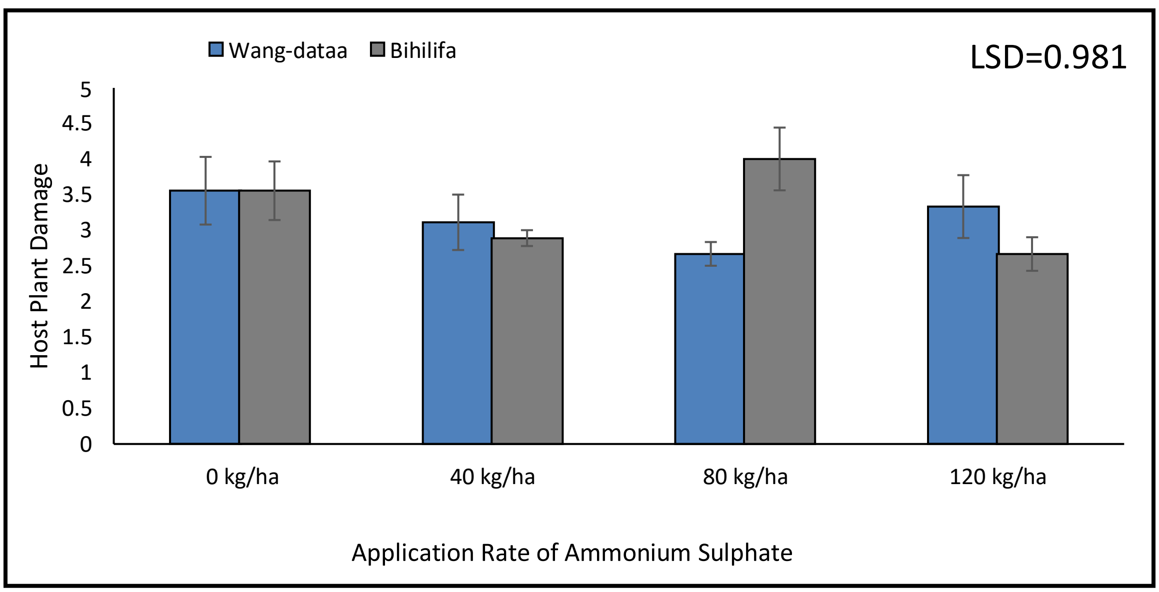

figure 12: Influence of variety by ammonium sulphate on *striga* infestation damage. Bars representSEM.

Grain yield(kg/ha)

Grain yield was significantly (*p*<0.01) affected by the interaction between variety and organic fertilizer by inorganic fertilizer. The synergy between Wang-dataa variety with the application of chicken manure at 6 t/ha plus ammonium sulphateat 120 kg/ha gave the outstanding yield of 3085 kg/ha (Table 5). Wang-dataa with 6 t/ha of chicken manure with 80 kg/ha of sulphate of ammonia gave 2818 kg/ha was statistically similar. The minimum value 1555 kg/ha was obtained for the application of Bihilifa variety plus chicken manure at 0 t/ha plus ammonium sulphateat 40kg/ha.

Table 5: Grain yield as affected by variety, organic fertilizer and inorganicfertilizer

Variety	Organicfertilizer	Inorganicfertilizer			
	Application rate(t/ha)	Application rate(kg/ha)			
		0	40	80	120
Wang-dataa	0	1692[gh]	1679[gh]	1721[fgh]	1788[efgh]
	3	1952[defgh]	2186[cde]	2391[cd]	2322[cd]
	6	1756[efgh]	2186[cde]	2818[ab]	3085[a]
Bihilifa	0	1820[efgh]	1555[h]	1592[h]	1822[efgh]
	3	1750[efgh]	2116[cdefg]	1988[defgh]	2458[bc]
	6	1853[efgh]	2153[cdef]	2122[cdefg]	1987[defgh]

Grand mean: 2033

LSD(5%)=377 **CV (%) =11**

Means followed by similar letters are not significantly different at 5% level of probability.

***Striga* count at 8 and10WAP**

Striga count at 8 WAP was significantly influenced by variety and organic fertilizer (*p*<0.01), and organic fertilizer by inorganic fertilizer (*p*<0.01).At 10WAP, there wassignificant differences of (p<0.01) and (p<0.05) among variety and organic fertilizer, and organic fertilizer by inorganic fertilizer respectively. The application of Bihilifa plus chicken manure at 6 t/ha recorded the highest *Striga* infestation value 14.5/ m^2 at 8 WAP, which was however, reduced to 9.9/ m^2 at 10 WAP (Table 6).

Moreover, the application of 6 t/ha ofchicken manure combined with zero ammonium sulphate recorded the highest *Striga* infestation value 17.3/ m^2 at 8 WAP, which was however reduced to 12.0/ m^2 at 10 WAP (Table 7). The application of chicken manure at 3 t/ha combined with 80 kg/ha of ammonium sulphate recorded the least value of 3.8/ m^2 at 10 WAP.

Table 6: Influence of variety by chicken manure on *striga* count at 8 and 10WAP.

Variety *x*	**Chicken manure(t/ha)**	***Striga* count**	
		8WAP	**10WAP**
Wang-dataa	0	31.8[d]	29.4[b]
	3	69.9[ab]	41.3[ab]
	6	61.4[bc]	39.3[b]
Bihilifa	0	45.3[cd]	41.8[ab]
	3	44.7[cd]	25.2[b]
	6	14.5[a]	9.9[a]
Grand mean:	**9.4**	**Grand mean: 6.6**	
LSD (5%):	**3.6**	**LSD(5%):**	**9**
CV (%):	**7.7**	**CV(%):**	**2.9**

Means followed by similar letters are not significantly different at 5% level of probability

Table 7:Influenceof chicken manure by ammonium sulphate on *Striga* count at 8 and 10WAP.

Organic	**Inorganic**							
	***Striga* count**							
	8WAP				**10WAP**			
	0	**40**	**80**	**120**	**0**	**40**	**80**	**120**
0	4.8^{b}	6.2^{b}	10.0^{ab}	4.7^{b}	4.6^{b}	5.3^{ab}	8.8^{ab}	4.6^{b}
3	10.7^{ab}	9.1^{ab}	5.8^{b}	12.5^{ab}	7.8^{ab}	4.2^{b}	3.8^{b}	6.3^{ab}
6	17.3^{a}	11.5^{ab}	10.2^{ab}	10.5^{ab}	12.0^{a}	7.8^{ab}	6.3^{ab}	6.8^{ab}
Grand mean:	**9.4**				**Grand mean: 6.6**			
LSD (5%):	**5.1**				**LSD(5%):**	**4.1**		
CV (%):	**7.8**				**CV(%):**	**9.0**		

Means followed by similar letters are not significantly different at 5% level of probability.

Stover weight(kg/ha)

There was no significant (*p*>0.05) differences among treatments in main effect, primary and secondary interactions.

Table 8: Stover weightas affected by variety, organic fertilizer and inorganic fertilizer

Variety	Organicfertilizer Application rate(t /ha)	Inorganic fertilizer Application rate(kg/ha) 0	40	80	120
Wang-dataa	0	0.24[b]	0.16[b]	0.13[b]	0.20[b]
	3	0.23[b]	0.20b[a]	0.43[b]	0.16[b]
	6	0.05[b]	0.23[b]	0.40[b]	0.97[a]
Bihilifa	0	0.27[b]	0.57[b]	0.16[b]	0.57[b]
	3	0.48[b]	0.43[b]	0.08[b]	0.10[b]
	6	0.02[b]	0.23[b]	0.33[b]	0.05[b]

Grand mean: 0.93

LSD (5%)= 9.590 **CV (%) = 133.4**

Means followed by similar letters are not significantly different at 5% level of probability.

Correlationanalysis

The correlation analysis indicated that most of the growth parameters and grain yield had positive relation with each other (Table 13). The analysis regarding the yield and other major yield related parameters indicated that grain yield had positively correlated with plant height (r=0.65**), number of ears at harvest (r=0.70**), and cob weight(r=0.92***)

Table 9: Correlation coefficients (r) between yield components and grain yield

	50%P	50%S	LAI	NE	PH	CW	GY
50%P							
50%S	0.8847***	-					
LAI	-0.4862*	-0.4903*	-				
NE	-0.6644	-0.6040	0.5449**	-			
PH	-0.7346	-0.7549	0.6437**	0.6195**	-		
CW	-0.6173	-0.5973	0.4273*	0.6789**	0.6519**		
GY	-0.5911	-0.5688	0.4587*	0.7023**	0.6193**	0.9273***	-

***** Highly significant at ($P < 0.001$), **Moderately Significant at ($P < 0.01$) and Significant at ($P < 0.05$)**

GY= grain yield, NE= number of ears at harvest, CW= Cob weight, PH=Plant height, LAI=leaf area index, 50%S =days to 50% silking, 50%P =days to 50% Pollen.

CHAPTER FIVE

RESULTSDISCUSSION

Days to 50 % tasseling andsilking

The study indicated that earlier flowering of 54 days after planting was promoted by 6 t/ha of chicken manure over control, indicating positive effect of the treatment (Figure 2).

For days to 50 % silking the earliest day's value of 57.11 were given by Wang-dataa variety in combination with the application of ammonium sulphate at 80 kg/ha (Figure 3).

Tasseling begun immediately after knee height growth which generally occurred at 35 to 45 days after emergence. As the tassels opened, spikelet's (bearing anthers) were pushed out by elongating filaments and pollen grains were emptied from the extruded anthers (Sleper and Poehlman, 2006).

The earlier days to 50 % pollen as demonstrated by Wang-dataa might be as a result of the environmental conditions that favored its performance. This result is confirmed by Strahler and Strahler (2005), who revealed that it is important to choose the best adapted resistant cultivar for every location as resistance is often regional and also performance depends on environmental conditions. The outstanding result of Wang-dataa could also be due to its genetic makeup. The present study suggested that there is indeed the existence of genetic differences among the maize varieties because the genetic materials belong to different pool. Similar results had been reported by Raouf *et al.* (2009), where significant days to 50 % silking differences among maize cultivars. In conformity with this result, Konuskan (2000), and Gozubenli *et al*. (2001) reported a considerable varietal variation for plant height of maize cultivars. The earliest days to 50 % pollen of 6 t/ha of chicken manure could be due to the higher rate that enhanced this growth variable. This is confirmed by the finding of Uzoma *et al.* (2011) who observed that only organic amended soils resulted in better crop establishment and positively increased crop growth rate.

: Plant height(cm)

Application of 6 t/ha of chicken manure resulted in plant height of 136 cm over the control (Figure 4). This output could be probably due to the timely and adequate release of nutrient to support its growth as plant height is a key indicator of plant growth and is linked to nitrogen nutrition status during vegetative development of maize (Yin *et al*., 2011). Provision of adequate organic fertilizers in split application extends vegetative growth period of maize and this increases the photosynthesis duration and partitioning of photo assimilates to stems which in turn positively impacts on maize plant heights (Amanullah *et al*., 2009). This observation is supported by the finding of Echarte *et al.* (2008) who observed that higher nitrogen uptake triggered higher vegetative growths and subsequently higher dry matter accumulation. Also, nitrogen management practices that make nitrogen available to crops in the right quantity and at the appropriate time promote development of early and larger surface leaf area which enhances biomass production and partitioning into grains (Gadalla *et al*., 2007). Obi and Ebo (1995) noted significant improved average maize height upon application of chicken manure to a severely degraded ultisol in southern Nigeria. Fagimi and Odebode (2007) who also reported increased plant height and number of leaves of maize plant resulting from application of higher rate of chicken manure. Efthimiadou *et al.* (2010); Masulili *et al*. (2010); Nwaiwu *et al.* (2010) also observed that organic manure used alone ensured increment in growth ofcrop.

leaf area index(LAI)

The analysis indicated that the application of 6 t/ha of chicken manure combined with ammonium sulphate at 40 kg/ha recorded the highest value of 31.68 (Figure 5). This performance could be due to the sufficient nutrient supply that enhancedLAI.

This result is supported by the finding of Amanullah *et al*. (2007) and Amanullah *et al*. (2009) who reported that nitrogen application on N deficient soil increased number of leaf per maize plant that resulted in a higher LAI as well as total dry matter. The increase in N level increased LAI (Amanullah *et al*., 2007) and showed positive relationship with increase crop growth rate and light interception (Amanullah *et al*., 2009). Dry matter produced by maize crops is dependent on the amount of radiation absorbed by the canopy which also depends on green leaf area. Light interception by crop canopy is a function of dry matter productivity where leaf contributes more than 80 %. Leaf area development is therefore an important parameter that affects maize grain yield and yield components (Akmal *et al.*, 2010). Leaf area influences the interception and utilization of solar radiation and consequently drive dry matter accumulation and grain yield (Valentinuz and Tollenaar, 2006). Leaf area development and photosynthetic rate are highly responsive to N fertilization (Tajul *et al*., 2013). Amanullah *et al*. (2009) reported that increased nitrogen uptake by maize plants led to increased photosynthesis and partitioning of more dry matter to leaves and thus, resulted in higher leaf area per plant. Maize grain yield is determined by many factors, among them, green leaf area and LAI which determines the photosynthetic capability of the plant, crop growth rate and dry matter production and partitioning to kernels at harvest (Cirilo *et al*.,2009).

Number of ears harvested per plot (m^2)

The results indicated that the combined effect of Wang-dataa variety with the application of chicken manure at 6 t/ha plus ammonium sulphate at 120 kg/ha gave the outstanding number of ears per plot 33.00 (Table 2).

The best output obtained under higher rate of both organic and inorganic fertilizers could be as a result of timely supply of nutrients in sufficient quantity, which mineralized rapidly for plant uptake and use. This phenomenon coupled with the genetic make-up of the Wang-dataa variety could also suppress most plant diseases or other soil-borne diseases which may otherwise decline yield. This finding is confirmed by DIPA, 2006, which revealed that manures and fertilizers are the life wire of improved technology contributing about 50 to 60 % increase in productivity of food grains in many parts of the world, irrespective of soil and agro-ecological zone, because more nutrients will be released which mineralized rapidly for plant uptake and utilization. It could also suppress most plant diseases or other soil-borne diseases which depress yield, or to increased microbial activities which favour yield increases as reported by Gopinath *et al*. (2008), Olanikan (2006) and Enujeke *et al*. (2013). These reports are generally in harmony with the work and recommendations of Brady and Weils, (1999), DIPA, (2006), sharply and Smith, (1991), and Fagimi and Odebode, (2007). Reijnties *et al*. (1992) and Adepetu (1997) remarked that the downward trend in food production should prompt farmers to amend the soil with different materials in order to enhance growth and yield ofcrops.

Cob weight(kg/ha)

The combined effect of the organic fertilizer and the inorganic fertilizer resulted in higher cob weight compared to the sole treatments (Figure 5). The outstanding value of 0.43 kg/ m^2 cob weightwasgiven by Wang-dataa variety with 6 t/ha ofchicken manure plus 120kg/ha of ammonium sulphate (Table 3). Higher nitrogen level and other nutrients obtained from the organic materials and inorganic fertilizer could have resulted in heavy cobs. Similar trend was observed by Khan *et al.* (2008) who detected that lower nitrogen level in the soil resulted in lighter grain weight due to less available nitrogen for the optimum plant growth. Yadav *et al*. (2000) also reported that integration of organic manure and inorganic fertilizer resulted in higher sustainable yield index compared with application of either alone.

Earaspect

Wang-dataa gave a better ear appearance score value of 4.58, followed by Bihilifa score of 5 (Figure 9). With the inorganic fertilizer, the best score of 4.27 was recorded under the application of ammonium sulphate at 80 kg/ha (Figure 11). This might be as a result of environmental factors or timely supply of nutrients in a sufficientquantity.

Both ammonium sulphate and chicken manure are sources of nitrogen, which is general needed by plants for higher productions and fight against *Striga* in cereal production. When N supply is insufficient, carbohydrates will be deposited in vegetative cells, which will cause the plants to thicken (Sasseville and Mills, 1979; Marti and Mills, 1991; Mills and Jones, 1996). When N supplies are adequate, and conditions are favorable for growth, proteins are formed from the manufactured carbohydrates, less carbohydrate is thus deposited in the vegetative cells and more protein is formed, and because protoplasm is highly hydrated, a more succulent plant results.

Host plantdamage

The results revealed that the combined influence between Wang-dataa variety applied with chicken manure at 6 t/ha gave the minimum damage score 2.8 (Figure 7). This may be due to the nitrogen content in chicken manure that might reduce the damage cause by *Striga*.

Both ammonium sulphate and chicken manure are sources of nitrogen, which is general needed by plants for higher productions and resistance against *Striga* in cereal production. When N supply is insufficient, carbohydrates will be deposited in vegetative cells, which will cause the plants to thicken (Sasseville and Mills, 1979; Marti and Mills, 1991; Mills and Jones, 1996). When N supplies are adequate, and conditions are favorable for growth, proteins are formed from the manufactured carbohydrates, less carbohydrate is thus deposited in the vegetative cells and more protein is formed, and because protoplasm is highly hydrated, a more succulent plant result.

Grain yield(kg/ha)

The synergy between Wang-dataa variety with 6 t/ha application of chicken manure plus120 kg/ha of ammonium sulphate gave the outstanding yield of 3085 kg/ha (Table 5). Wang-dataa with 6 t/ha of chicken manure with 80 kg/ha of sulphate of ammonia gave 2818 kg/ha grain yield, which was the same statistically as 3085 kg/ha. So the question is which treatment will you recommend?? Because of the lower rate of 80 kg/ha SA, your best bet is Wang-dataa plus 6 t/ha chicken manure plus 80 kg/ha ofSA.

(Yadav *et al*., 2000; Nyamangara *et al*., 2005). Chivenge *et al*. (2011) reported that whilst application of sole organic and sole inorganic N fertilizers increased maize yield by 60 % and84 % respectively over the control, combined application of organic and inorganic N fertilizer increased maize yield by 114 % over the control, and 33 % and 17 % over the sole organic and inorganic fertilizers, respectively. Nitrogen use efficiency (NUE) in maize is often defined as grain produced per unit of fertilizer nitrogen applied. The NUE concept commonly provides a quantitativemeasureoftheeffectivenessofplantstotakeupandconvertavailableNintograin yield within a cropping system (Ciampitti and Vyn, 2011). Nitrogen deficiency promotes a reduction in maize crop growth rate and subsequently reduces grain yield (Andrade *et al.*, 2002).

The immediate short-term effects of applied fertilizers are often emphasized to the neglect of residual effects. Yet when farming is continued on the same site for several years, residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently crop yield (Enwezor *et al*., 1989). Cooke (1970) showed that when soil contains residues of inorganic nitrogen, larger maximum yields are possible than may be obtained from soil without residues. Increased nitrogen availability promotes greater yield responses with high yielding than with low yielding maize varieties (Ciampitti and Vyn, 2011). Manure nutrients are stored for a longer time in the soil, thereby supporting better root development, leading to higher soil microbial biomass and increased crop yields (AbouEl-Magd *et al*., 2006). High levels of production were obtained by Gomes *et al.* (2007), who divided nitrogen fertilization at maize seed sowing and side dressing. According to them, the average grain weight of 182 g per ear was obtained when nitrogen fertilization was applied only in side dressing, 30th days after shoot emergence. Leaf area influences the interception and utilization of solar radiation which consequently drive dry matter accumulation and grain yield (Valentinuz and Tollenaar,2006).

***Striga* emergence count**

The analysis showed that the fertilizer (sulphate of ammonia and chicken manure) had significantly effects on the *Striga* emergence count on the maize varieties. The results revealed that the application of Bihilifa plus chicken manure at 6 t/ha recorded the highest *Striga* infestation value of 86.7 at 8 WAP, which was however, reduced to 59.2 at 10 WAP (Table 5). Moreover, the application of 6 t/ha of chicken manure combined with zero ammonium sulphate recorded the highest *Striga* infestation value 103.5 at 8 WAP, which was however reduced to

72.0 at 10 WAP (Table 6). The greater *Striga* content might be due to initial *Striga* seed bank variations at the site and the more the seed bank the more seeds will germinate with suitable hosts, therefore, translating to greater *Striga* emergence. The reduction in the *Striga* may also be due to the nitrogen content in chicken manure that might reduce the *Striga* number at 10 WAP.

Significant difference for *Striga* emergence count at the end of the 10 WAP might be due to the influence of the resistant/tolerant maize varieties and the treatments used. The high *Striga* numbers in some of the treatments might be attributed to high initial *Striga* seed bank at the site. The higher number of *Striga* in some of the plots might also be due to variation in soil fertility where some plots might have low soil fertility. Though *Striga* emerged on all plots, but some treatments did not show any *Striga* symptoms, which implies that these treatments had more tolerance level to S. *hermonthica* infestation. This result agrees with Gurney *et al*. (1999) who observed that highest *Striga* infestation did not necessarily translate into the least yield with resistant varieties. *Striga* thrives well in less fertile soils as supported by Cardoso *et al*. (2010) who reported that one of the witch weed most contributing factors for development is low soil fertility and cropping systems in SSA with no external inputs. Reduced emergence of *Striga* in some of the treatments in the current study implies that, reduced germination of *Striga* or reduced attachment of germinated *Striga* to roots of the host plant, or both. Because *Striga* is an obligate parasite, interactions between *Striga* and its host plays a crucial role in survival of the parasite. Differences in production of *Striga* stimulants are known to occur between crop cultivars (Hesse *et al.,* 1992), and that may be the cause for reduced *Striga* emergence in some of the treatments in the current study. The low number of *Striga* plants in some of the treatments couldbeduetotheirabilitytoshowsomelevelsofresistancetotheparasiticweed,which reduced the extent of severity of *Striga* infestation. Lagoke and Isah (2010) also reported that nitrogen reduced the severity of S. hermonthica.

Stover weight(kg/ha)

The results revealed that there was no significant difference among treatments on this parameter (Table 2). The results were not in line with the finding of Patil (1974) who reported that application of farm yard manure alone or in combination with chemical fertilizers significantly increased the dry matter, grain and stover yield of maize over control. The organic materials improved crop growth as exhibited in increase plant and dry biomass (Thomsen, 2005; Masulili *et al*., 2010) due to nutrients availability especially nitrogen (Khan *et al.*, 2011). Amanullah *et al*. (2011) also reported that all foliar application of various N-sources (urea, CAN, and AS) had significantly produced higher biomass yield total dry matter than control (water spray only). Amanullah *et al*. (2007) reported again that the higher LAI in maize intercepted more light and increased the biomass inmaize.

Combined application of manure and chemical N fertilizer significantly increased maize crop biomass and total nitrogen concentration in the plant organs, thereby improving the nitrogen fertilizer utilization (Hou *et al.*, 2012). Ziadi *et al*. (2008) reported that maize shoot biomass generally increased with increasing nitrogen fertilization. Rajcan and Tollenaar (1999) also reported that increase in nitrogen rate increased leaf longevity and photosynthesis in maize which resulted in higher dry matter production. Amanullah and Shah (2011) also reported significant effect of rates and times of nitrogen application on maize leaf and stem dry weights at silking and physiological maturity stages. Vasanthi & Kumaraswamy (2000) who reported that poultry manure plus one-half rate of the chemical fertilizer rate yielded significantly greater amount of green fodder of corn than the full rate of NPK alone.

: Soil physico-chemicalproperties

The results of the analysis indicated that there was increase in fertility of the soil which reduces the *striga* effects and increases the yield. The organic manure improves the soil texture, increases organic carbon content and the major plant nutrients due to the organic fertilizer applied. Sharpley and Smith (1991) reported that chicken manure contains basic nutrients required for enhancing growth and yield of crops. Tualar *et al*. (2012) observed that the interaction between the application of organic fertilizer and inorganic fertilizers (nitrogen, phosphorus and potassium) affected organic carbon content and soil cation exchangecapacity.

CHAPTER SIX

6.0: CONCLUSION AND RECOMMENDATION

Theexperimentwasconductedtodeterminethebesttreatmentcombinationofmaizevariety, sulphateofammoniaandchickenmanurethatcouldoptimizetheproductioncropandreduce *Striga hermonthica* infestation and seed bank in the savanna zone.

The study revealed that;

- The application of 6 t/ha chicken manure plus 120 kg/ha of ammonium sulphate gave the maximum yield of 3085 kg/ha, which was statistically identical to the value of 2818 kg/ha of Wang-dataa with 6 t/ha of chicken manure plus 80 kg/ha of sulphate of ammonia.

- The application of chicken manure at 3 t/ha combined with 80 kg/ha of ammonium sulphate recorded the minimum *Striga* count value of 3.83m^{-2}

- TheBihilifapluschickenmanureat3t/harecordedtheleast*Striga*infestationvalueof 2.45m^{-2}

It is therefore recommended that:

- Farmers whose fields are infested with *Striga hermonthica* could use 6 t/ha of chicken manure and 80 kg/ha of ammonium sulphate to optimize maizeyield.

- Farmers should apply chicken manure at 3 t/ha combined with 80 kg/ha of ammonium sulphate to reduce *Striga*infestation

- Farmers should use Bihilifa plus chicken manure at 3 t/ha to manage S*triga* in heavy infestedareas.

- More maize varietal testing in combination with newly developed fertilizers used by farmers is required to illicidate farmer friendly techniques for management of *Striga hermonthica*.

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APPENDIX

Appendix 1: Days to 50% tasseling

Sourceofvariation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	5.861	2.931	1.23	
REP.*Units* stratum					
Variety	1	9.389	9.389	3.95	0.053
Organic_Fert	2	199.694	99.847	41.96	<.001
Inorganic_fert	3	2.500	0.833	0.35	0.789
Variety. Organic_Fert	2	1.194	0.597	0.25	0.779
variety.Inorganic_fert	3	3.611	1.204	0.51	0.680
Organic_Fert.Inorganic_fert					
	6	27.417	4.569	1.92	0.098
Variety. Organic_Fert.Inorganic_fert					
	6	6.139	1.023	0.43	0.855
Residual	46	109.472	2.380		
Total	71	365.278			

Appendix 2: Days to 50% silking

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	17.028	8.514	3.18	
REP.*Units* stratum					
Variety	1	4.500	4.500	1.68	0.201
Organic_Fert	2	232.694	116.347	43.52	<.001
Inorganic_fert	3	1.611	0.537	0.20	0.895
Variety. Organic_Fert	2	14.083	7.042	2.63	0.083
variety.Inorganic_fert	3	22.500	7.500	2.81	0.050
Organic_Fert.Inorganic_fert	6	33.306	5.551	2.08	0.074
Variety. Organic_Fert.Inorganic_fert	6	1.917	0.319	0.12	0.994
Residual	46	122.972	2.673		
Total	71	450.611			

Appendix 3: Plant height at maturity

Sourceofvariation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	2282.0	1141.0	5.41	
REP.*Units* stratum					
Variety	1	136.1	136.1	0.65	0.426
Organic_Fert	2	10412.9	5206.4	24.70	<.001
Inorganic_fert	3	435.6	145.2	0.69	0.564
Variety. Organic_Fert	2	209.2	104.6	0.50	0.612
variety.Inorganic_fert	3	612.4	204.1	0.97	0.416
Organic_Fert.Inorganic_fert					
	6	1096.7	182.8	0.87	0.526
Variety. Organic_Fert.Inorganic_fert					
	6	636.8	106.1	0.50	0.802
Residual	46	9696.6	210.8		
Total	71	25518.3			

Appendix 4: Ear height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1003.5	501.8	4.06	
REP.*Units* stratum					
variety	1	39.0	39.0	0.32	0.577
Organic_Fert	2	3693.8	1846.9	14.95	<.001
Inorganic_fert	3	181.5	60.5	0.49	0.691
variety.Organic_Fert	2	238.8	119.4	0.97	0.388
variety.Inorganic_fert	3	379.7	126.6	1.02	0.391
Organic_Fert.Inorganic_fert					
	6	1597.6	266.3	2.15	0.065
variety.Organic_Fert.Inorganic_fert					
	6	523.0	87.2	0.71	0.647
Residual	46	5684.5	123.6		
Total	71	13341.3			

Appendix 5: Leaf area index (cm)

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	41.13	20.56	0.67	
REP.*Units* stratum					
Variety	1	13.09	13.09	0.43	0.517
Organic_Fert	2	1080.25	540.13	17.56	<.001
Inorganic_fert	3	187.29	62.43	2.03	0.123
Variety. Organic_Fert	2	11.36	5.68	0.18	0.832
variety.Inorganic_fert	3	11.85	3.95	0.13	0.943
Organic_Fert.Inorganic_fert					
	6	536.73	89.45	2.91	0.017
Variety. Organic_Fert.Inorganic_fert					
	6	213.74	35.62	1.16	0.345
Residual	46	1414.56	30.75		
Total	71	3510.00			

Appendix 6: Number of ears at harvest

Sourceofvariation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	24.33	12.17	0.47	
REP.*Units* stratum					
Variety	1	288.00	288.00	11.02	0.002
Organic_Fert	2	1261.75	630.88	24.14	<.001
Inorganic_fert	3	505.00	168.33	6.44	<.001
Variety. Organic_Fert	2	5.08	2.54	0.10	0.908
variety.Inorganic_fert	3	137.44	45.81	1.75	0.169
Organic_Fert.Inorganic_fert					
	6	307.58	51.26	1.96	0.091
Variety. Organic_Fert.Inorganic_fert					
	6	398.47	66.41	2.54	0.033
Residual	46	1202.33	26.14		
Total	71	4130.00			

Appendix 7: Cob weight (kg)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.24111	0.12056	1.52	
REP.*Units* stratum					
Variety	1	0.72000	0.72000	9.10	0.004
Organic_Fert	2	2.98028	1.49014	18.84	<.001
Inorganic_fert	3	1.14333	0.38111	4.82	0.005
Variety. Organic_Fert	2	0.79083	0.39542	5.00	0.011
variety.Inorganic_fert	3	0.92556	0.30852	3.90	0.015
Organic_Fert.Inorganic_fert					
	6	1.97083	0.32847	4.15	0.002
Variety. Organic_Fert.Inorganic_fert					
	6	1.05361	0.17560	2.22	0.05
Residual	46	3.63889	0.07911		
Total	71	13.46444			

Appendix 8: stalk loge

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.0278	0.0139	0.06	
REP.*Units* stratum					
Variety	1	2.0000	2.0000	8.14	0.006
Organic_Fert	2	1.4444	0.7222	2.94	0.063
Inorganic_fert	3	1.5000	0.5000	2.03	0.122
Variety. Organic_Fert	2	0.3333	0.1667	0.68	0.513
variety.Inorganic_fert	3	0.4444	0.1481	0.60	0.617
Organic_Fert.Inorganic_fert					
	6	1.0000	0.1667	0.68	0.668
Variety. Organic_Fert.Inorganic_fert					
	6	0.5556	0.0926	0.38	0.890
Residual	46	11.3056	0.2458		
Total	71	18.6111			

Appendix 9: Ears aspect

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	0.3333	0.1667	0.28	
REP.*Units* stratum					
variety	1	3.1250	3.1250	5.32	0.026
Organic_Fert	2	25.7500	12.8750	21.94	<.001
Inorganic_fert	3	10.4861	3.4954	5.96	0.002
variety.Organic_Fert	2	1.7500	0.8750	1.49	0.236
variety.Inorganic_fert	3	1.3750	0.4583	0.78	0.511
Organic_Fert.Inorganic_fert					
	6	6.1389	1.0231	1.74	0.132
variety.Organic_Fert.Inorganic_fert					
	6	1.9167	0.3194	0.54	0.772
Residual	46	27.0000	0.5870		
Total	71	77.8750			

Appendix 10: Host plant damage

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	3.528	1.764	1.65	
REP.*Units* stratum					
Variety	1	0.222	0.222	0.21	0.650
Organic_Fert	2	0.194	0.097	0.09	0.913
Inorganic_fert	3	4.000	1.333	1.25	0.303
Variety. Organic_Fert	2	7.194	3.597	3.37	0.043
variety.Inorganic_fert	3	10.000	3.333	3.12	0.035
Organic_Fert.Inorganic_fert	6	8.917	1.486	1.39	0.238
Variety. Organic_Fert.Inorganic_fert	6	5.250	0.875	0.82	0.561
Residual	46	49.139	1.068		
Total	71	88.444			

Appendix 11: Grain yield (kg/ha)

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	148980.	74490.	1.41	
REP.*Units* stratum					
Variety	1	696787.	696787.	13.23	<.001
Organic_Fert	2	3907835.	1953918.	37.09	<.001
Inorganic_fert	3	1889968.	629989.	11.96	<.001
Variety. Organic_Fert	2	537831.	268915.	5.10	0.010
variety.Inorganic_fert	3	513421.	171140.	3.25	0.030
Organic_Fert.Inorganic_fert					
	6	1145760.	190960.	3.62	0.005
Variety. Organic_Fert.Inorganic_fert					
	6	1218389.	203065.	3.85	0.003
Residual	46	2423477.	52684.		
Total	71	12482449			

Appendix 12: Striga count 8WAP

Sourceofvariation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	4545.1	2272.5	3.31	
REP.*Units* stratum					
Variety	1	369.0	369.0	0.54	0.467
Organic_Fert	2	15139.0	7569.5	11.02	<.001
Inorganic_fert	3	1990.2	663.4	0.97	0.417
Variety. Organic_Fert	2	8388.8	4194.4	6.11	0.004
variety.Inorganic_fert	3	1668.4	556.1	0.81	0.495
Organic_Fert.Inorganic_fert					
	6	14427.2	2404.5	3.50	0.006
Variety. Organic_Fert.Inorganic_fert					
	6	7687.0	1281.2	1.86	0.107
Residual	46	31602.2	687.0		
Total	71	85816.9			

Appendix 13: Striga count 10WAP

Sourceofvariation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	702.6	351.3	0.78	
REP.*Units* stratum					
Variety	1	517.3	517.3	1.14	0.290
Organic_Fert	2	3578.3	1789.1	3.96	0.026
Inorganic_fert	3	2185.9	728.6	1.61	0.199
Variety. Organic_Fert	2	4336.0	2168.0	4.80	0.013
variety.Inorganic_fert	3	279.4	93.1	0.21	0.892
Organic_Fert.Inorganic_fert					
	6	7013.2	1168.9	2.59	0.030
Variety. Organic_Fert.Inorganic_fert					
	6	5839.4	973.2	2.15	0.065
Residual	46	20784.8	451.8		
Total	71	45236.9			

Appendix 14: Plant_aspect

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	4.361	2.181	0.91	
REP.*Units* stratum					
variety	1	4.014	4.014	1.68	0.201
Organic_Fert	2	40.444	20.222	8.48	<.001
Inorganic_fert	3	24.931	8.310	3.49	0.023
variety.Organic_Fert	2	8.778	4.389	1.84	0.170
variety.Inorganic_fert	3	12.042	4.014	1.68	0.184
Organic_Fert.Inorganic_fert					
	6	25.444	4.241	1.78	0.124
variety.Organic_Fert.Inorganic_fert					
	6	9.333	1.556	0.65	0.688
Residual	46	109.639	2.383		
Total	71	238.986			

Appendix 15: Stover_weight_kg/ha

Sourceof variation	d.f.	s.s.	m.s.	v.r.	Fpr.
REP stratum	2	73.83	36.91	1.08	
REP.*Units* stratum					
variety	1	34.69	34.69	1.02	0.318
Organic_Fert	2	64.71	32.36	0.95	0.394
Inorganic_fert	3	103.54	34.51	1.01	0.395
variety.Organic_Fert	2	75.71	37.86	1.11	0.338
variety.Inorganic_fert	3	103.42	34.47	1.01	0.396
Organic_Fert.Inorganic_fert					
	6	208.41	34.73	1.02	0.424
variety.Organic_Fert.Inorganic_fert					
	6	216.07	36.01	1.06	0.401
Residual	46	1566.09	34.05		
Total	71	2446.48			