بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Effect of Hargel, Jatropha aqueous extracts and Nitrogen fertilization on *Striga* and growth and yield of Sorghum

تأثير المستخلصات المائية للحرجل، الجاتروفا والتسميد النيتروجيني على البودا ونمو وإنتاجية الذرة الرفيعة

A Thesis submitted in partial fulfillment of the requirements for the Degree of Master (M.Sc.) in Plant Protection

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الآية

قال تعالى :

(وَآيَةٌ لَهُمُ الْأَرْضُ الْمَيْتَةُ أَحْيَيْناها وَأَخْرَجْنا مِنْها حَبًّا فَمِنْهُ يَأْكُلُونَ(33)
وَجَعَلْنا فِيها جَنَّاتٍ مِنْ نَخِيلٍ وَأَعْنابٍ وَفَجَّرْنا فِيها مِنَ الْعُيُون (34)
لِيَأْكُلُوا مِنْ ثَمَرِهِ وَما عَمِلَتْهُ أَيْدِيهِمْ أَفَلا يَشْكُرُونَ (35)

صدق الله العظيم

سورة يس الآيات (33- 35)

Dedication

This research is dedicated to souls of

My Mother and Father

As well as Sisters and Brothers

Finally, to all my teaching staff of the

Plant Protection.

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First my all thanks and praises is due are Almighty Allah, the beneficent and the merciful, for giving me health and strength to accomplish this work. Further, I would like to express my special thanks and gratitude to my supervisor prof Dr. Mukhtar Abdel Aziz Mohamed who supervised the work throughout the study. Thanks are also to Dr. Yassir Ahmed Gamar and Dr. Omer Abdallah Bakheet for their great help in the statistical analysis. The study broader my knowledge and I came to know about many techniques. I am really thankful to him. Secondly I would also like to thank souls my mother and father and my friends, who helped me a lot in finishing this project within the limited time.

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List of Abbreviations

%	Percent
ºC	Degree centigrade
Cm	Centimeter
GR24	*Striga* Synthetic germination stimulant
G	Gram
Mg	Milligram
L	Liter
SE	Standard Error
H	Hours
Ha	Hectare
CV	Coefficient of variation
et al	and others
WAS	Weeks after sowing
No.	Number

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Abstract

Pots experiment was conducted, during the summer season 2018, at the College of Agricultural Studies (CAS), Shambat, Sudan University of Science and Technology (SUST), Bahri Locality, Khartoum State. The experiment was carried out to determine the effects of the Hargel *(Solenostemma argel)*, Jatropha (*Jatropha curcas)* aqueous extracts, each applied alone or in their combinations with Nitrogen 40 Ib/fed and the effect of Nitrogen applied alone on *S. hermonthica* incidence and growth and yield of Sorghum (cv.Asareca-w2). Treatments were arranged in a randomized complete block design (RCBD) with three replicates. The results of the experiment showed that, *Striga* emergence increased with increasing number of weeks from crop sowing. At 6, 10, 14 weeks after sowing (WAS), all the botanical aqueous extracts each applied alone or in their combinations with Nitrogen and Nitrogen applied alone significantly reduced *Striga* emergence by 29.1-100%. At 7 WAS, all the botanical aqueous extracts each applied alone or in their combinations with Nitrogen and Nitrogen alone significantly reduced *Striga* shoot fresh weight (g) and shoot dry weight (g) by 42.1-91.9% and 31.8% - 96.6% respectively. At 7 and 14 WAS all treatments increased plant height (cm) by 26.6-113.5. All treatments except (Hargel at 2.5%, 5% and Jatropha at 2.5% and 5%) gave plant height comparable to that obtained by *Striga* free control treatment. The medium and high concentrations of Hargel aqueous extracts and high concentration of Jatropha aqueous extract significantly increased plant shoot fresh weight (g) by 120.8, 122 and 127.8%, respectively. Hargel and Jatropha aqueous extract in combination with Nitrogen 40 Ib/fed

and all levels of Nitrogen significantly increased plant shoot fresh weight by 97.4-170%. Hargel and Jatropha at 10% and their combination with Nitrogen 40 Ib/fed and all levels of Nitrogen significantly increased plant shoot dry weight by 87.5-110%. Hargel aqueous extracts at concentrations 5% and 10% significantly increased grain yield (g)/plant and grain yield (kg)/fed by 122.9%-128.6% and 122.3 - 128.7%, respectively. All concentrations of Jatropha aqueous extracts applied alone significantly increased grain yield (g)/plant and grain yield (kg)/fed by 116.2%-138.1% and 114.1-138.2%, respectively. Hargel applied in combination with Nitrogen 40Ib/fed significantly increased grain yield (g)/plant and grain yield (kg)/fed by 142.9% - 145.7% and 143-219.2%, respectively. However, Jatropha applied in combination with Nitrogen 40Ib/fed significantly increased grain yield (g)/plant and grain yield (kg)/fed by 151.4%-179% and 137.4-178.5% respectively. Nitrogen at all levels significantly increased grain yield (g)/plant and grain yield (kg)/fed by 106.1-133.4% and 106.1-133.1%, respectively. The best treatments among the botanical aqueous extracts, each applied alone or in combination with Nitrogen 40Ib/fed were Hargel and Jatropha aqueous extracts in combination with Nitrogen, concentrations of Hargel and Jatropha at 5% and 10% and Nitrogen doses at 80 and 120 Ib/fed.

الخلاصة

أجريت تجربة الأصيص، في الموسم الصيفي 2018، في كلية الدراسات الزراعية، شمبات، جامعة السودان للعلوم والتكنولوجيا، الخرطوم بحري، ولاية الخرطوم. أجريت التجربة لتحديد تأثير المستخلصات المائية للحرجل والجاتروفا، تطبيق كل واحد منهما على حدة أو إعقابهما بإضافة النيتروجين 40 رطل/افدان و تأثير تطبيق النيتروجين منفرد على البودا ونمو وإنتاجية الذرة الرفيعة (صنف أساريكا 2). التجربة صممت بالقطاعات العشوائية الكاملة بثلاث مكررات. أظهرت نتائج التجربة أن عدد نباتات البودا المنبثقة يزداد بزيادة عدد الأسابيع بعد زراعة المحصول. بعد 6، 10 و 14 أسبوع بعد الزراعة، كل المستخلصات المائية عند تطبيقها منفردة أو التي أعقبتها إضافة النيتروجين بمعدل 40/فدان والنيتروجين منفرد خفضت إنبثاق البودا بصورة معنوية بنسبة (29.1% - 100%). في نهاية الموسم كل المستخلصات المائية للنباتين كل منهما منفرد وإعقابهما بإضافة النيتروجين 40 رطل/فدان والنيتروجين منفرد خفضت الوزن الرطب والجاف(جم) لطفيل البودا بصورة معنوية بنسبة (42.1%-91.9%) و (31.8%-96.6%)، على التوالي. بعد 7 و 14 أسبوع من الزراعة كل المعاملات زادت طول النبات بنسبة (26.6-113.%). التركيز المتوسط والعالي من المستخلص المائي للحرجل والتركيز العالي من المستخلص المائي للجاتروفا زادت بصورة معنوية الوزن الرطب للذرة الرفيعة بنسبة (120، 120.8 و127.5%)، على التوالي. المستخلصات المائية للحرجل والجاتروفا التي أعقبتها إضافة النيتروجين بمعدل 40 رطل/فدان و كل مستويات النيتروجين زادت بصورة معنوية الوزن الرطب (جم) للذرة الرفيعة بنسبة (97.4-170%). تركيزي الحرجل والجاتروفا 10% الذي أعقبه إضافة النيتروجين بمعدل 40 رطل/فدان و كل مستويات النيتروجين زادت بصورة معنوية الوزن الجاف للذرة الرفيعة بنسبة (87.5-110%). تركيزي المستخلص المائي للحرجل 5% و 10% زادا بصورة معنوية إنتاجية الحبوب (جم)/النبات و إنتاجية الحبوب (كجم)/فدان بنسبة (122.9-128.6%) و(122.3-128.7%)، على التوالي. كل تركيزات المستخلص المائي للجاتروفا منفردة أدت إلى زيادة معنوية في إنتاجية الحبوب(جم)/النبات وإنتاجية الحبوب (كجم)/فدان بنسبة (116.2-138.1%) و(143-219.2%)، على التوالي. الحرجل الذي أعقبه إضافة النيتروجين 40 رطل/فدان زاد بصورة معنوية إنتاجية الحبوب (جم)/النبات وإنتاجية الحبوب (كجم)/فدان بنسبة (142.9-145.7%) و(143-219.2%)، على التوالي. أيضا تركيزات الجاتروفا التي أعقبتها إضافة النيتروجين بمعدل 40 رطل/فدان زادت بصورة معنوية إنتاجية الحبوب (جم)/النبات وإنتاجية الحبوب

(كجم)/فدان بنسبة (151.4-179%) و(137.4-178.5%)، على التوالي. كل مستويات للنيتروجين أدت إلى زيادة معنوية في إنتاجية الحبوب (جم)/النبات وإنتاجية الحبوب (كجم)/فدان بنسبة (106.7-133.4%) و (106.7-133.4%)، على التوالي. أفضل معاملات من المستخلصات المائية للنباتين، منفردين أو عند أعقابهما بإضافة النيتروجين بمعدل 40 رطل/فدان والنيتروجين هي تركيزات الحرجل والجاتروفا التي أعقبتها إضافة النيتروجين بمعدل 40 رطل/فدان، تركيزي الحرجل والجاتروفا 5% و 10% وجرعتي النيتروجين 80 و 120 رطل/فدان.

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CHAPTER ONE

INTRODUCTION

Sorghum bicolor (L) Moench) belongs to the Poaceae family (FAO, 1995).It is a self-pollinated crop (Ideris and Mohammed, 2012). It is rank fifth cereal worldwide after Wheat (*Triticum spp*.), Rice (*Oryza spp.*), Maize (*Zea mays* L)and Barley (*Hordeum vulagdre*) in term of production (FAO, 2010). It was first domesticated in the region of North East Africa (Doggett, 1988). Ninety percent of the world's area cultivated by sorghum is in the developing countries, mainly in Africa and Asia. Major world's producers include Sudan, Nigeria, India, United States, Mexico, Ethiopia, China and Argentina (FAO, 2013). In Africa it comes second after maize in term of production (Romain and Raemaekers, 2001).In tropical Africa the Sorghum is grown for home consumption. In southern and eastern Africa malting sorghum in bear brewing has developed into a large scale commercial industry, using about 150000 tons of Sorghum grain annually, according to FAO (2010). The leaves and stem of Sorghum are also used as forage for livestock, building material and a fuel for cooking. In the industrialized countries, Sorghum grains are generally used as animal feed (Lendzemo, 2004).In Sudan the first Sorghum improvement varieties program started in mid-fifties, as conventional methods such as introduction, hybridization and selection were used. In Sudan the crop is fully utilized, the grain is ground into flour which is fermented and used for making local bread (Kissra); it is also used as porridge, soft drink called (Abrieh). Sorghum stalks are used as building material and animal feed or as fuel (Elzain and Elasha, 2005).Generally the area under crop has steadily increased over years, but yield tends have been fluctuating and by far below the international yield average. Paramount, among yield reducing factors are drought, low soil fertility and the root parasitic weed *Striga hermonthica (Del.)* Benth *(*Parker and Riches, 1993*)*.Root parasitic weeds of the genus *Striga* (Orobanchaceae) constitute a major biotic constraint to cereals production in sub-Saharan Africa, particularly for the very important food crops, maize, Sorghum and pearl millet. The most devastating to cereal production in West Africa is *Striga hermonthica* (Del.) Benth) which causes huge losses ranging from 40-90% and up to 75% of its overall damage to the hosts occurred during its subterranean stage of development (Parker and Riches, 1993; Gressel *et al*., 2004).Members of the genus *Striga* commonly known as witch weeds are obligate root parasitic weeds. The genus comprises of 28 species that occur naturally across tropical and semi tropical Africa and also in Asia and Australia. Witch weeds are characterized by bright green stems and leave and small, brightly colored flowers. *Striga* species, being obligate parasites thrive only when hosted by other plants from which they obtain water, nutrients and possibly hormones (parker and Riches, 1993). A single *S. hermonthica* plant can produce up to 500 000 seeds which can remain viable for more than 14 years (Bebawi *et al.*, 1987). This has led to the buildup of a large reserve of *Striga* seeds in contaminated soils. *Striga spp.* is prevalent in over million hectares of cereals growing area in Africa and inflicts considerable damage amounting to complete crop loss under heavy infestation (Welsh and Mohamed, 2011). *Striga* is generally native to semi-arid, tropical areas of Africa, but have been recorded in more than 40 countries (Ejeta, 2007; Vasey *et al*., 2005). *Striga* possibly originates from a region between the Semien Mountains of Ethiopia and the Nubian Hills of Sudan (Atera *et al*., 2011). This region is also the birthplace of domesticated Sorghum (*Sorghum bicolor* L). In Sudan *Striga hermonthica* is major biological constraint to the production of the crop majority, mainly Sorghum and pear millet (Ayman *et al.*, 2014). Sudan is the, one of the richest countries in its natural flora. Plants of this country, both cultivated and wild are undoubtfully an unlimited reservoir for medicinal pharmaceutical aromatic and insecticides chemicals (Adam, and Fatin, 2016). Botanical will be a promising source of pest control compounds such as *Jatropha Curcas*. The current study design to explore new environmental friendly pesticide to control weeds that to replace the highly toxic chemical. Research in Africa on the control of Striga has been going on for about 70years **(**Ahmed *et al*., 2001).Several promising *Striga* control strategies have been developed, from those that relate to soil fertility improvement to those that directly affect the parasite (Rector, 2009). This has accorded farmers with a variety of options to control the parasite, including the use of chemical herbicides, trap crops, hand-pulling, appropriate fertilizer applications, crop Rotation, intercropping, resistant crops, and biological control (Parker and Riches, 1993; Menkir and Kling, 2007; Hearne, 2009). Generally there is a lack of information on effects of nitrogen fertilizer and medicinal botanical extracts on *Striga*, thus this research was designed to investigate the effects of nitrogen fertilizer and two medicinal botanical aqueous extracts (Hargel and Jatropha) and their mixture with nitrogen on *Striga hermonthica*. We have been following this approach to exploit the effectiveness of the interaction of these control methods in a sound manner to fulfill the following objectives:

I. To determine the effects of different concentrations of aqueous extracts of argel, Jatropha and their combinations with Nitrogen on *Striga hermonthica* and growth and yield of Sorghum (cv. Asareca-w2).

II. To determine effects of different doses of Nitrogen on *Striga* and growth and yield of Sorghum (cv. Asareca-w2).

CHAPTER TWO

LITERATURE REVEIEW

2.1. *Sorghum bicolor* (L) Monech):

Sorghum bicolor belongs to family Poaceae, It is a self-pollinated crop cultivated for its edible grains, commonly called sorghum and also known as durra in Sudan. Sorghum genetically is considered as a drought tolerant crop and has evolved various eco types that withstand an array of biotic factor. It is considered more tolerant to many stresses, including heat, drought, and salinity and flooding as compared to other cereal crops (Ali *et al*., 2011). However, the crop grown in rain-fed areas is highly affected by drought stress (Kebede *et al*., 2001). The crop is crucially important to food security in Africa as it is exclusively drought resistant and can withstand periods of high temperature (Taylor, 2006).

In Sudan, Sorghum is most important cereal crops in terms of production and consumption (Ibrahim *et al.,* 1995). It is cultivation all over the country, either under rain fed or under supplementary irrigation. The amount and rainfall patterns of and length of rainy seasons as in Sub-Sahara Africa is fluctuating. These climatic changes adversely affect traditionally Sorghum growing areas of North Gadarif, Gezira, Sennar, White Nile State and North Kordofan. The dominant varieties grown are the traditional Feterita types e.g. Arfa Gadmek, Abdalla Mustafa and Korolo. Tetron and Dabar are grown on a limited scale. Some pioneer farmers in south Gadarif grow the improved varieties, Wad Ahmed and Tabat. Sorghum grown in this region is used for commercialization purposes and is sold mainly in the local markets, with some of it for export (Babiker, 2002).

2.2. Parasitic plants:

Parasitism is a coexistence of two different organisms of which one (the parasite) lives at the expense of the other (host). Parasitic higher plants are the most destructive agricultural pests known (Parker and Riches, 1993; Sauerborn, 1991). Today, about 4,100 species of parasitic plants belong to 19families have been recognized as serious pests causing considerable economic damage (Nickrent and Musselman, 2004). According to Yoder (1997) they can be classified into two main types depending on the presence or absence of chlorophyll. Holoparasites do not contain chlorophyll and depend completely on their host for the supply of assimilates. Hemiparasites contain some chlorophyll and can perform photosynthesis to some extent. Some of these hemiparasites can live either as a parasite or on their own roots, and these are called facultative parasites (Joel *et al*., 1995). Parasitic plants can attach to their host on several different organs (shoots, roots or branches). Parasitic weeds adopt different forms to invade host plants. Some (dodders and mistletoes) invade aerial parts, whereas others invade the underground roots (*Orobanche* and *Striga*). Root parasites are more common and are found in diverse taxonomic groups. Some of the most economically important root pathogens are in the broomrape family, Orobanchaceae. This family includes the largest number of genera (85) and species (ca. 1650) of all the families of parasitic flowering plants (Nickrent and Musselman, 2004). The genus *Striga* contains about 41 species that are found on the African continent and parts of Asia; Africa is the presumed region of origin (Wolfe *et al*., 2005). Mohamed *et al*. (2001) described 28 species and six subspecies from Africa. Of these 22 species of *Striga* are endemic. The most important of 11 species that attack crops are *Striga asiatica* (L.) Kuntze and *Striga hermonthica* (Del.) Benth) .Parasitizing cereals and *Striga gesnerioides* (Willd.) Vatke parasitizing cowpea and other wild legumes.

2.2.1. *Striga*:

Striga spp. (Witch weeds) are pernicious, root attaching parasitic plants, a genus of 42 currently described species in the world of which 28 species occur naturally in Africa (Barker, 1990; Cochrane and Press, 1997).The parasites does not have its own roots and therefore it compensates by penetrating the roots of host plant to siphon the essential nutrients for growth (Watson *et al*., 1998). The host plants are stagnated and sometimes die from phytotoxic effects within days of attachment (Frost *et al*., 1997; Khan *et al*., 2007).A small parasite biomass attachment to the host plant can result in a large reduction in height, biomass and grain yield (Gurney et al., 1999; Rodenburg *et al*., 2006). The parasite attack the host plant underground and by the time the flowering stem of the parasite appears above the ground damage has been caused (Westerman *et al*., 2007).

Most witch weeds are characterized by bright-green stems and leave and small, brightly colored flowers. A mature Striga plant has high reproductive capacity, and is capable of producing 10,000 to 200,000 tiny seeds per plant that can survive in the soil for more than 10 years (Van Ast and Bastiaans, 2006; Hearne, 2009).After germination, the parasite must find the host plant for attachment within 4 days if not it will die (Gurney *et al*, 2006). *Striga* has been a serious problem of cereal and legume crops among farmers in sub-Saharan Africa. Its effects on crops range from stunted growth, through wilting, yellowing, and scorching of leaves, to lowered yields and death of many affected plants. Farmers have reported losses between 20% and 80%, and are eventually forced to abandon highly infested fields (Atera and Itoh, 2011). Grain yield losses even can reach 100% in susceptible cultivars under a high infestation level and drought conditions (Haussmann *et al.*, 2000). According to (Gressel *et al*., 2004), estimated 17.2 million hectares (64% of the total area) of sorghum and pearl millet production in West African are infested with

Striga. Most of the yield loss (about 75%) occurs before *Striga* emergence (Parker and Riches, 1993).

2.2.2. *Striga* life cycle:

The life cycle of *Striga* is complex and it is tied to development stages of the host plant from seed to seed. The most important step in the life cycle is germination of *Striga* seed which involves: - pre-conditioning of the seeds which requires humid and warm conditions, radical growth to the host root, haustorium formation and attachment to the host root (Spallek *et al*., 2013). However, pre-conditioning of *Striga* seeds also requires secondary metabolites derived from host plants and non-host plants to induce germination (Yoder, 2001; Gurney *et al*., 2006; Hooper *et al*., 2009). These germination stimulants are exuded at the tip of roots of host plants (Parker and Riches, 1993; Yoder, 1999). After germination, the parasite must find the host plant for attachment within 4 days if not it will die (Gurney *et al*., 2006).

The parasitic seedling grows underground totally depending on the host for growth and development for about 3 to 6 weeks (Gurney *et al*., 2006). After emergence Striga seedling forms the stem and leaves with chlorophyll but becomes hemi-parasite that produces assimilates, partially depending on the host for Striga nutrients, water and minerals. Within one month after emergence, plant initiates flowers and seeds. The plant produces many seeds which enable the parasite to build its soil seed bank (Gbehounou *et al*., 2003).

S. hermonthica and *S. asiatica* are the most widespread and dangerous species parasiting on cereal crops such as sorghum (*Sorghum bicolor* (L.)Moench), pearl millet (*Pennisetum glaucum* (L.)R. Br.), maize (*Zea mays* L.) and uplandrice (both *Oryza glaberrima* (Steud.) and *O. sativa*L.), whereas S. gesnerioides (Willd.) Vatke attacks crops such as cowpea (*Vigna unguiculata* (L.) Walp) and peanut (*Arachis hypogaea*L.) (Parker, 1991 and Oswald, 2005). In the recent years, crops such as wheat (*Triticum aestivum* L.) that were previously unaffected by the parasite are now showing serious infestation (Vasey *et al*., 2005).And areas of productive agriculture have been abandoned because of this scourge. *Striga* is therefore, a pandemic of serious proportion because of its vast geographical infection, its economic impact and possess a potential threat to smallholder livelihoods.

2.3. *Striga* control methods:

The tremendous impact of parasitic plant on world agriculture has prompted much research aimed at preventing infestation. Many potential control methods were developed against the parasite problem physical, cultural, chemical, and biological (Jole, 2002). Control of *S. hermonthica* in cereals has so far proven elusive. Economically feasible and effective technologies are still to be developed for the cash strapped subsistence farmers in most of the *Striga*-stricken areas (Debrah, 1994). The control of *S. hermonthica* has also been made very difficult due to the biology of this weed. It is very prodigious as far as seed production is concerned.

2.3.1. Cultural control methods:

A number of cultural practices have been recommended for *Striga* control such as crop rotation (Oswald and Ransom, 2001); intercropping (Udom *et al*., 2007); transplanting (Oswald *et al*., 2001); soil and water management (Fasil and Verkleij, 2007); use of fertilizers (Jamil *et al*., 2011); and hand weeding (Ransom, 2000) to reduce the production of further Striga seed. These methods should also reduce the density of Striga seeds already in the soil seed bank (Fasil and Verkleij, 2007).

2.3.1.1 Hand- weeding and sanitation:

Today the most used control method against *Striga* is hand weeding. It is recommended to prevent seed set and seed dispersal. Weeding the small *Striga* plants is a tedious task and may not increase the yield of already infected plants, it is necessary to prevent seed production and reinfestation of the soil

(Teka, 2014). Due to high labour costs in repeated hand-pulling of *Striga*, it is recommended that hand-pulling should not begin until 2-3 weeks after *S. hermonthica* begins to flower to prevent seeding (Parker and Riches, 1993). Hand-pulling will usually need to be continued for 3-4 years and is most economical on the least infested fields. It is always recommended as a supportive treatment (Parker and Riches, 1993).

2.3.1.2 Crop Rotation:

Crop rotation of infested land with non-susceptible crops or fallowing is theoretically the simplest solution. Rotation with non-host crops interrupts further production of Striga seed and leads to decline in the seed population in the soil. The practical limitation of this technique is required more than three years for rotation. The choice of rotational crop should therefore be based 1st on its suitability to the local conditions and only secondarily on its potential as a trap crop (Parker and Riches, 1993 and Teka, 2014),to reduce parasite seeds (Esilaba and Ransom, 1997). *Pasture legumes; Mucuna gigantica, Stylosanthes guyanensi*s and *,Desmodium spp*. were investigated for their ability to induce germination of conditioned *S. hermonthica* seed, for their effect on *Striga* attachment and on *Striga* shoot emergence. Laboratory experiments showed that, the root exudates of the legumes stimulated up to 70% more *Striga* seeds to germinate than exudates of maize. Maize-Mucuna combination had the highest number of attachments while all other combinations and maize planted in pure stand had lower numbers of attached. Cowpea varieties, cv. Black eye bean and cv. TVU 1977 OD, produced potent exudates, which were highly compatible with sorghum as intercrops in field trials (Fasil, 2002). In other research findings also reported the effectiveness of the combined use of trap-cropping, fertilization and host plant resistance to control *S. hermonthica* (IITA, 2002; Tesso, *et al*., 2007).

2.3.1.3. Trap and Catch crops:

Trap crops: Trap-crops cause suicidal germination of the weed, which reduces the seed bank in the soil. Some varieties of cowpea, groundnut and soybean have potential to cause suicidal germination of *S*. *hermonthica* and improve soil fertility (Carsky *et al*; 2000; Schulz *et al*., 2003).The use of trap crops such as soybean causes suicidal germination of the *Striga* seedlings which do not attack the soybean consequently; the *Striga* is ploughed off before flowering there by reducing the seed density of *Striga* in the soil (Umba *et al*., 1999). In IITA, about 40 lines of soybean were screened for their ability to induce Striga hermonthica seeds to germinate using the cut roots of soybean plants. The results showed variability among the soybean lines in their ability to stimulate seed germination. Hess and Dodo (2003) also found that the use of leguminous trap crops that include varieties of groundnut (*Arachis hypogaea*), soybean (*Glycine max*), cowpea (*Vigna unguiculata*) and sesame (*Sesamum indicum*) stimulate the suicidal germination of *Striga* is another technology to control *Striga* (De Groote *et al*., 2010).

Catch crops: Catch crops are planted to stimulate a high percentage of the parasite seeds to germinate but are destroyed or harvested before the parasite can reproduce.It is another mean of depleting *Striga* seed reserves in soils. Contrary to trap cropping, which relies on false hosts, catch cropping employs true hosts of the parasite. A thick planting of Sudan grass at 20-25 kg seed per hectare should be sown and either ploughed in or harvested for forage at 6-8 weeks before *Striga* seeds. The main crop could then be planted during the main rains (Parker and Riches, 1993and Teka2014). The catch crop, when ploughed under is equivalent to green manuring, it is restorative effects on soil fertility (Bebawi, 1987). Catch crops are considered to be less economically favoured than trap crops because of the lack of direct financial returns.

2.3.1.4. Intercropping:

Intercropping cereals with legumes and other crops is a common practice in most areas of Africa, and has been reported as influencing *Striga* infestation (Teka, 2014). Intercropping is a potentially viable, low-cost technology, which would enable to address the two important and interrelated problems of low soil fertility and *Striga* (Fasil, 2002). Growing of Sorghum in association with cowpea and haricot bean was effective against *S. hermonthica* and produced significantly improved yield per unit area in preliminary trials in Ethiopia. Intercropping had rather detrimental effect on yield performance of sorghum and showed two cowpea varieties - cv. TVU 1977 OD and cv. Black eye bean produced the highest supplemental yield of up to 329 and 623 kg ha–1 grain and 608 and 1173 kg ha–1 biomass at Adibakel and Sheraro (Tigray, Ethiopia) in 1999 and 2000, respectively (Fasil, 2002).Also recent result shows that intercropping maize with cowpea and sweet potato can significantly reduce the emergence of Striga in Kenya (Oswald *et al*., 2002).In Sudan intercropping is a valuable cheap and effective method for suppressing localized infestations of the parasite on relatively small farms (Babiker, 2002). Intra-row planting of hyacinth bean (*Lablab purpureus*) with sorghum, reduced *S. hermonthica* emergence by 48-93%, dry weight by 83-97%, number of seed capsules by 52-100% and increased Sorghum grain yield by several fold in comparison with the sole crop (Babiker, 2002). Intercropped fodder legumes (*Desmodium uncinatum* and *D. intortum*) with maize reduced *Striga* infestation in Kenya (Khan *et al*., 2000). The effect was significantly greater than that on other legumes such as cowpeas, as were the concomitant yield increases. The mechanism by which *D. uncinatum* reduce *Striga* infestation in intercropping was found to be the allelopathic effect inhibiting the development of haustoria of *Striga* (Khan *et al*., 2001). Identification of the compounds released from *D. uncinatum* involved in the suppression of the parasite may give more exploitation for developing reliable intercropping strategies, as well as new approaches for molecular biology in *S. hermonthica* (Gressel, 2000).

Parker and Riches (1993) attributed the suppressive effects of intercropping to several factors, including its action as a trap-crop, interference with production of germination stimulants, exudation of germination inhibitors and/or reduction of the parasite transpiration, through decreasing air temperature and increasing humidity. In common with most parasitic weeds *Striga* species have high transpiration rate, associated with stomata which remain open under most if not all conditions (Shah *et al*., 1987).

2.3.1.5. Soil fertility:

Nitrogen and phosphorus are applied in sufficient quantities (Adagba *et al*., 2002 and Teka, 2014). Fertilizer application had significant effect on height, vigour score, reaction score of Sorghum as well as shoot count, days to emergence, dry matter of production and dry weight of Striga. The application of high nitrogen (N) increases the performance of cereal crops under Striga infestation. This is due to the fact of that nitrogen reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and Isah, 2010).

Application of high dosage of nitrogen fertilizer is generally beneficial in delaying emergence and obtaining stronger crop growth (Dugje *et al.,* 2008). Also other advantageous effects of fertilizers include increasing soil nitrogen and other nutrients, replenishing the organic matter of the soil and increasing soil moisture holding capacity (Ikie *et al*., 2006).

2.3.2.Host plant resistance:

Host plant resistance would in all probability be the most feasible and potential method for parasitic weed control. Using biotechnological approaches (including biochemistry, tissue culture, plant genetics and breeding, and molecular biology) significant progress has been made in developing screening methodologies and new laboratory assays, leading to the identification of better sources of parasitic weed host resistance (Ejeta *et al*., 2000).). It is potentially an acceptable Striga control option to resource-poor farmers (Gurney *et al*., 2003; Rich *et al*., 2004). However, dependence on host resistance alone is not ideal because so far complete resistance against *Striga* cannot be attained through breeding (Gurney *et al*., 2002), and usually the newly developed varieties may not fulfill farmers preference traits (Adugna, 2007).Full resistance of host plants to *Striga* or *Orobanche* has not until now been found. However, several resistant crop varieties are used now a days in various parts of Africa, Europe and Asia. As the reported resistant or tolerant cultivars are often not accepted by farmers because of their low yield, low seed and storing quality, poor adaptation to a large range of agro-ecological zones and their sensitivity to pest and diseases, the recently developed techniques significantly contribute to overcoming these problems by permitting transfer of resistance genes into adapted cultivars with high-yielding potential. This will lead to a lower parasite infestation and to a higher crop yield (Elzein and Krosche, 2003).

2.3.3. Chemical control methods:

2.3.3.1. Germination stimulants:

Definite chemicals such as ethylen ‹ethephon, strigol and strigol analogues can induce germination of *Striga* seeds in the absence of a suitable host and therefore seed reserves in the soil (Esilaba and Ransom, 1997). In dicotyledonous plant species there is evidence that the production of strigolactone by the host plant could be reduced if sufficient minerals are available (Lopez-Raez *et al*., 2008).

2.3.3.2. Pre emergence herbicides

Technology currently being deployed as a complement to *Striga* resistance in maize involves use of herbicide as a seed coating. The parasite competes with its host for resources; changes host plant architecture and reduce the photosynthetic rate and the water use efficiency of the host (Watling and Press, 2001).This has led to the emergence of a new technology known as imazapyr-resistant maize (IRM) which has proven to be efficient for *Striga* control (Kanampiu *et al*., 2006; De Groote *et al*., 2006). Research on-farm trials in Kenya and Tanzania indicate that seed dressing with Imazapyr and Pyrithiobac offers good *Striga* control and increased maize yields (Kanampiu *et al*., 2004).

2.3.3.3. Post emergence herbicides

Post emergence herbicides used for the selective control of *Striga* generally acts through the foliage, although some have soil residual effects. Among the herbicides tested, 2, 4-D has been the most selective and is the cheapest. 2-methyl-4-chlorophenoxyacetic acid (MCPA), a compound closely related to 2, 4-D, has also been effective especially when mixed with bromoxynil (Ejeta *et al*., 1996). Post emergence application of 2,4-D (1 L product/ha), Glufosinate (2 L product/ha) and Oxyflourfen (1 L product/ha) was effective in preventing the top growth of *Striga*. Unfortunately, most of those products had narrow window of application and the only safe treatment for the crop was targeted spray of 2,4-D (Fasil, 2004). Babiker *et al*. (1996) reported that a combination of urea and dicamba effectively controlled *Striga* between 62-92% on sorghum, while chlorsulfuron in combination with dicamba controlled *Striga* as much as 77-100% on sorghum.

2.3.4. Biological control methods:

The objective of weed biological control is not the eradication of weeds but the reduction and establishment of a weed population to a level below the economic threshold (Rajni and Mukerji, 2000). Means of biological control of weeds comprise herbivorous insects, microorganisms (especially fungi), and smother plants (Sauerborn and Kroschel, 1996). The method, involves importation, colonization, and establishment of exotic natural enemies, which include predators and parasitoids. Efforts to manage weeds using biological control have been gaining momentum throughout the world, especially in the recent past (Delfosse, 2004).Biological control is considered as a potential cost-effective, safe and environmentally beneficial alternative means of reducing weed populations in crops, forests or rangelands (Charudattan, 2001). Disadvantages of weed biological control includes it will usually require a long period (5 to 10) years of research and a high initial investment of capital and human resources (Culliney, 2005). Biological control is unattractive as a private entrepreneurial effort (Hill and Greathead, 2000 and Coombs *et al*., 2004).

2.3.4.1. Biological control by using insect:

The insects that attack *Striga* can be classified according to their damage as defoliators such as Junonia spp., gall forming as *Smicrony spp*. (Coleoptera: Curculionidae) in India and Africa; shoot borers as *Apanteles sp*., miners as *Ophiomyia strigalis*, Spencer (Diptera: Agromyzidae) in East Africa; inflorescence feeders as *Stenoptilode staprobanes* and fruit feeders as *Eulocastra spp*. (Lepidoptera: Noctuiidae) in India; (Kroschel *et al*., 1999).

Kroschel *et al*. (1999) have been concluded that, the use of herbivorous insects could play a role in an integrated control package, lowering the Striga population by reducing its reproduction capabilities and spread.

However, the augmentation of native insect populations through in undative releases is not applicable in the third world, mainly due to the infeasibility of mass rearing.

2.3.4.2. Biological control by using pathogen:

Most organisms have natural enemies that balance their populations, avoiding excessive abundance (Templeton, 1982). Biological control of *S. hermonthica* using *Fusarium oxysporum* is considered as one of the novel management strategies (Sauerborn *etal*., 2007).Fungi are preferred to other microorganisms as bio-herbicides because they are usually host specific, highly aggressive, and easy to mass produce and are genetically diverse (Ciotola *etal*., 2000). Field and laboratory tests showed that *F. oxysporum* is highly effective in hindering germination, growth and development of *Striga* and thus may lead to reduction of Striga seed bank in the soil (Ciotola *et al*., 2003).Various *Fusariumspp*. and vesicular arbuscular mycorrhizal(VAM) fungi have been found which can reduce *Striga* infestations significantly on sorghum and maize when used together with resistant host (Ciotola *et al*., 2000; Lendzemo *et al*., 2005 and Franke *et al*., 2006).

2.3.5. Integrated Management

Different control methods (e.g., hand-pulling, hoe-weeding, trap- and catch cropping) have been tried out with no conclusive and consistent results for the subsistence farmer. This may partly be due to the difficulty to deplete huge amounts of seeds that have accumulated and continue to accumulate in the seed bank over the years. *S. hermonthica* problem may be too widespread and too severe to control using a single approach. Management of the hemi-parasite needs an integrated approach that includes host plant resistance, cultural practices, and chemical treatments. Within targeted management, it is important to understand the interaction of the host plant, Sorghum, with the biotic and a biotic environment (Lendzemo, 2004).Several integrated techniques for the control of *Striga* have been developed and tested. Mumera (1983) investigated the efficacy of three herbicides with N fertilizer on maize and sorghum cultivars. Odhambo and Ransom (1994) recommended that maintenance of soil fertility (fertiliser and crop residues) and the removal of *Striga* before seed set would restore the productivity of lands infested with *Striga*. However, the best solution in the control of *Striga* is an integrated approach that includes a combination of methods that are affordable and acceptable by farmers.

2. 3. 6. Fertilizer and botanical extracts used in this investigation:

2. 3. 6. 1. Nitrogen fertilizer:

2. 3. 6. 2. Botanical extracts:

2. 3. 6. 2. 1. *Jatropha curcas*: *Jatropha Curcas* L. is a small, perennial shrub that grows 3-5 meters in height, it belongs to family Euphorbiaceae, that is native to the American tropics, most likely Mexico and Central America. It is cultivated in tropical and subtropical regions around the world.

In Sudan can be found in many regions like the Blue Nile, South Kordufan, Kassala, South Darfur and others states (Adam, and Fatin 2016).

2. 3. 6. 2. 2. Hargel {*Solenostemma argel* (Del.) Hayne}:

The plant *Solenostemma argel* is an erect herbaceous perennial plant that grows up to 60-100 cm tall, with several vigorous stems, belong to family Asclepiadaceae is a desert plant indigenous to Africa, used in traditional medicine worldwide, particularly in African countries (Sudan, Libya, Chad, Egypt and Algeria), Saudi Arabia and Palestine (Elkamali, and Khalid, 1996; Ahmed ,2007; Shayoub *et al*.,2013).This plant is regarded as the richest source in Sudan and locally called Hargel, it is indigenous in the northern region (Orange, 1982), widely spread in the places between Dongola and Barber, particularly around Abu Hamad area (Elkamali, and Khalid, 1996)

CHAPTER THREE

MATERIALS AND METHODS

3.1. General:

The experiment was conducted at the Demonstration Farm of College of Agricultural Studies, Shambat, Sudan University of Sciences and Technology (SUST), to evaluate two botanical water extracts(Hargel leaves, Jatropha seeds) and Nitrogen, each one alone and in combination on *Striga hermonthica* incidence and growth and yield of Sorghum.

3.2. *Striga* hermonthica seeds:

S. hermonthica seeds were harvested in (2015) from a sorghum filed at the National Center for Research, Khartoum, Sudan, air dried and stored at ambient temperature (30°C).

3.3. Plant materials:

Hargel leaves were collected from local market in Khartoum Bahri and a Jatropha seeds were collected from National Tree seeds Center-Agricultural Research Corporation. The plant materials were washed and dried at room temperature and were separately ground into fine powder (<1mm) and stored until use.

3.4. Plant aqueous extracts:

Aqueous extracts at 10% concentration were obtained by pickling at room temperature. Ten grams of powdered part of plant material were placed in a 250ml glass beaker with 100ml of sterile distilled water for 24hours and each suspension was then filtered through two tools, the first (nylon cloth)served to move big debris and the second(filter paper) to set an homogeneous solution, other concentrations (5%and 2.5%) were obtained from 10% concentration (Yonli *etal*., 2010).

3.5. Crop seeds treatment:

The sorghum seeds were placed in six beakers (three concentrations of the Hargel water extract and three concentrations of the Jatropha water extract), the beakers were placed at room temperature for eight (8) hours before planting. The seeds of controls were placed in beaker containing sterile distilled water.

3.6. Pots experiment:

A Pots experiment was conducted during the summer season (2018)at the demonstration farm, College of Agricultural Studies, (CAS), Shambat, Sudan University of Science and Technology, Khartoum Bahri Locality, Khartoum State, Sudan (Latitude15° 40` N and Longitude 32° 23` E,).

Sorghum cultivar (Asareca-w2) was obtained from Elobied Research Station, Agricultural Research Corporation. The experiment was conducted under artificial *S. hermonthica* infestation. Artificial infestation of soil was achieved by mixing two (2) grams of *Striga* seeds with 1kg soil. The required level of *Striga* seeds (20 mg/pot) was obtained by taking 10 grams of mixed of soil and *Striga* seeds. *Striga* seed soil mixture was added to *S. hermonthica* free soil thoroughly mixed by hand. Sorghum cultivar Asareca-w2 seeds which were treated by three concentrations of Argel and three concentrations of Jatropha aqueous extracts were sown on15th July in 2 cm soil depth, five seeds /pot, later thinned to two plants per pot at three weeks after sowing. Two botanical extracts, Hargel and Jatropha and nitrogen in the form of urea were used at different single doses and mixtures doses. Nitrogen fertilizer in the form of urea was applied at40, 80 and 120 lbs/fed (½ dose at thinning stage and (½ dose when the plants were knee high), in addition to two controls, the first was negative control treatment which was contained (0mg) *Striga* seeds, the second was positive control treatment which was contained (20 mg) *Striga* seeds, both controls were used for comparison. Irrigation was applied immediately after crop seed sowing and frequently two to three days interval according to temperature and other environmental conditions. This experiment includes 17 treatments arranged in a randomized complete block design (RCBD), with three replicates as follow:

1- Hargel, 2.5%, 5.0% and 10%.

2- Jatropha, 2.5%, 5.0% and 10%.

3- Nitrogen at (40, 80 and 120 Ibs /fed), in the form of urea.

4- Each concentrations of Hargel mixed with 40 Ib of Nitrogen/fed in the form of urea (H 2.5%+40Ib N, H 5%+40IbN and H 10%+40IbN).

5- Each concentrations of Jatropha mixed with 40 Ibs of Nitrogen/fed in the form of urea (J2.5%+40Ib N, J5%+40IbN and J10%+40IbN).

6- Negative control treatment (*Striga* free).

7- Positive control treatment (20 mg of *Striga* seeds).

3.7 Data Collection:

3.7.1 The parasite:

Striga growth components such as number of *Striga* emergence were carried out at 6, 10 and 14 weeks after sowing (WAS). At harvest *Striga* plants collected from each treatment were harvested, weighted to determine fresh weight and air-dried and weighted to determine dry weight.

3.7.2. The crop:

3.7.2.1. Vegetative growth components:

Two plants were taken at flowering from each pot. Growth analysis including, plant height (cm), shoot fresh weight (g)/plant, shoot dry weight(g)/plant, number of leaves/plant and days to 50% flowering were measured in each pot.

3.7.2..1.1. Plant height (cm):

Plant height was measured from the soil surface (at the base of the plant) to the base of the flower, in each plant, and then the mean height was obtained.

3.7.2.1.2. Plant shoot fresh weight (g)/plant:

The same plants were used to determine the shoot fresh weight/plant in each pot. Roots were detached, then the shoots were weighed by using sensitive balance, then the mean weight was computed as was done by (Mukhtar, 2006).

3.7.2.1.3. Plant shoot dry weight (g)/plant:

The same plants were used to determine the shoot dry weight (g)/plant in each pot. Roots were detached, then the shoots were dried in an oven at 80 °c for 72 hours and then weighed by using sensitive balance, then the mean weight was computed as was done by (Mukhtar, 2006).

3.7.2.1.4. Number of leaves/plant:

The same plants were used to determine the number of leaves/plant in each pot, and then the mean number was obtained.

3.7.2.1.5. Days to 50% flowering:

The days to 50% flowering, the number of days from planting until the date on which 50% of the plants in a pot have shed pollens was recorded.

No severe pest and diseases were noticed during the experiment

3.7.2.2. Yield components parameters:

At the final harvest each pot was harvested, then heads of the two plants in each treatment were cut and air dried and used for determination of yield characters including, number of heads/plant, head weight (g), 100 seed weight (g), grain yield (g/plant), and total grain yield (kg/fed) as follows:

3.7.2.2.1. Number of heads/plant:

Estimated as the mean of number of heads from the same two plants.

3.7.2.2.2. Head weight (g):

Estimated as the mean head weight from the heads of the same two plants in each pot.

3.7.2.2.3. Grain yield (g)/plant:

The harvested heads of the same two plants were air dried and threshed in bulk, weighed and the average seed yield per plant was then calculated.

3.7.2.2.4. Total grain yield (kg/fed):

The harvested heads in each pot were air dried and threshed in bulk, then weighed and the total seed yield was calculated according to the following formula (Mukhtar, 2006).

Total seed yield (kg/fed) = Plant grain yield (kg) x number of plants/fed.

3.8 Statistical Analysis:

The experiment was arranged in randomized complete block design (RCBD) with three replications. Analysis of variance (ANOVA) was carried out on data obtained using the statistical analysis system Statistix 8 User Guide Version 2.0 computer package to detect significant effects among the treatments and populations compared. Mean squares for treatments or populations were calculated. Simple statistics including mean, standard deviation, standard error and coefficient of variation (C. V. %) were also calculated.

CHAPTER FOUR

Results

4.1 Pots experiment

4.1.1 Effects of Hargel, Jatropha aqueous extracts and their combination with Nitrogen and Nitrogen alone on *Striga* and growth and yield of Sorghum.

4.1.1.1. Effects on *Striga:*

4.1.1.1.1. *Striga* emergence:

Striga count made at 6, 10 and 14 weeks after sowing (WAS) showed that, *Striga* emergence increased with increasing of the weeks.

Statistical analysis showed significant differences between treatments (Table.1). At 6 WAS, Hargel at 2.5%, 5% and 10% significantly reduced number of *Striga* emergence by 84.1%, 91% and 100%, respectively as compared to *Striga* control treatment (Table 1).

Jatropha at 2.5%, 5% and 10% significantly reduced *Striga* emergence by 84.1%, 100% and 100%, respectively as compared to *Striga* control treatment.

Nitrogen at 40, 8O and 120 Ib/fed significantly reduced *Striga* emergence by 100%, 100% and 100%, respectively as compared to *Striga* control treatment.

Hargel at concentrations 2.5%, 5% and 10% plus Nitrogen 40 Ib /fed significantly reduced *Striga* emergence by 100%, 100% and 100%, respectively as compared to *Striga* control treatment. However, Jatropha concentrations 2.5%, 5% and 10% plus dose of Nitrogen 40 Ib/fed significantly reduced *Striga* emergence by 86.4%, 91% and 100%, respectively as compared to *Striga* control (Table 1). At 10 WAS, Hargel at 2.5, 5% and 10% significantly reduced *Striga* emergence by 40%, 53.4% and 60%, respectively as compared to *Striga* control treatment (Table 4.1). Jatropha at 2.5%, 5% and

10% significantly reduced *Striga* emergence by 42%, 29% and 57.4%, respectively as compared to *Striga* control treatment (Table 1).

Nitrogen at 40, 80, and 120 Ib/fed significantly reduced *Striga* emergence by 70.7%, 73.4% and 97.4%, respectively as compared to *Striga* control treatment (Table 1).

Hargel concentrations plus Nitrogen 40 Ib/fed (2.5%+40) , (5%+40) and (10% +40) significantly reduced *Striga* emergence by 84%, 86% and 57%, respectively as compared to the *Striga* control treatment (Table 1).However, Jatropha concentrations plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10%+40) significantly reduced *Striga* emergence by 64%, 35.4 and 64%, respectively as compared to the *Striga* control (Table 1).

At 14 WAS, Hargel at 2.5%, 5% and 10% significantly reduced *Striga* emergence by 52.3%, 53.8% and 58.6%, respectively as compared to *Striga* control treatment (Table 1). Also Jatropha concentrations at 2.5%, 5% and 10%significantly reduced *Striga* emergence by 58.6%, 44.3 and 64.8%, respectively as compared to *Striga* control (Table 1). Nitrogen at 40, 80, and 120 Ib/fed significantly reduced *Striga* emergence by 72.9%, 64.8% and 77.6%, respectively in comparison to *Striga* control (Table 1).Hargel at three concentrations plus Nitrogen 40 Ib/fed (2.5+40), (5+40) and (10%+40) significantly reduced *Striga* emergence by 77.6%, 87.2% and 64.8%, respectively in comparison to the *Striga* control treatment (Table 1). However, Three Jatropha concentrations plus Nitrogen 40 Ib (2.5%+40), (5% +40) and (10%+40) significantly reduced *Striga* emergence by 69.5%, 50.5% and 71.4%, respectively in comparison to *Striga* control treatment (Table 1).

Table1: Effects of Hargel, Jatropha aqueous extracts and Nitrogen concentrations and their combination on *Striga* emergence (plants/pot)

Number of *Striga* emerged/pot			
Treatments	**6 (WAS)**	**10 (WAS)**	**14 (WAS)**
H 2.5%	0.7b	9bcd	10bcd
H 5%	0.4bc	7bcdef	9.7bcd
H 10%	0.0c	6def	8.7bcde
J 2.5%	0.7b	8.7bcde	8.7bcde
J 5%	0.0c	10.7b	11.7b
J 10%	0.0c	6.4def	7.4cdef
N40 Ib/fed	0.0c	4.4fgh	7.4efg
N80 Ib/fed	0.0c	4fgh	5.7cdef
N120 Ib/fed	0.0c	0.4i	4.7fg
H 2.5%+N40 Ib/fed	0.0c	2.4ghi	4.7fg
H 5%+N40 Ib/fed	0.0c	2.0hi	2.7g
H 10%+N40 Ib/fed	0.0c	6.4def	7.4cdef
J 2.5%+N40 Ib/fed	0.6bc	5.4fg	6.4defg
J 5%+N40 Ib/fed	0.4bc	9.7bc	10.4bc
J 10%+N40 Ib/fed	0.0c	5.4fg	6 cdef
Striga control	4.4a	15a	21a
C.V%	26.4	25.3	24.8
F-Value	10.4***	5.4***	6***
SE±	1.1	0.2	1.3

WAS=Weeks after sowing, H=Hargel, J= Jatropha, N= Nitrogen,

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001

4.1.2. *Striga* shoot fresh Weight (g)/plant:

Statistical analysis showed significant differences in *Striga* fresh weight between the treatments (Table 2). Hargel at 2.5%, 5% and 10% significantly reduced *Striga* fresh weight by 46%, 52.3% and 58.6%, respectively as compare to the *Striga* control treatment (Table 2). However, *Jatropha* at 2.5%, 5% and 10% significantly reduced *Striga* fresh weight by 42.1%, 49.8% and 78.1%, respectively as compared to *Striga* control treatment (Table 2).

Nitrogen at 40, 80 and 120 Ib/fed significantly reduced *Striga* fresh weight by 77.2%, 83.4% and 91.9%, respectively as compared to *Striga* control treatment (Table 2). Hargel concentrations plus Nitrogen 40 Ib/fed (2.5+40) ,)5+40) and (10% +40) significantly reduced *Striga* fresh weight by 72.3%, 75.5% and 79.3%, respectively as compare to *Striga* control treatment (Table 2). However, Jatropha concentrations plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly reduced *Striga* fresh weight by 67.9%, 73% and 87%, respectively as compared to *Striga* control treatment (Table 2).

4.1.2. *Striga* shoot dry weight (g)/plant:

Statistical analysis showed that, there are significant differences in *Striga* dry weight between the treatments (Table 4.2). Hargel at 2.5%, 5% and 10% significantly reduced *Striga* dry weight by 31.8%, 58% and 73.3%, respectively as compared to *Striga* control treatment (Table 2).*Jatropha* at 2.5% insignificantly reduced *Striga* dry weight by 39.2%,while at 5% and 10% significantly reduced *Striga* dry weight by 61.9% and 77.8%, respectively as compared to *Striga* control (Table 2).Nitrogen at 40, 80 and 120 Ib/fed significantly reduced *Striga* dry weight by 77.3%, 83% and 96.6% respectively as compared to *Striga* control (Table 2). Hargel concentrations plus Nitrogen 40 Ib 2.5+40) , (5+40) and (10% +40) significantly reduced *Striga* dry weight by 56.3%, 72.2% and 77.3%, respectively as compared to *Striga* control (Table 2). However, *Jatropha* concentrations plus Nitrogen 40 Ib (2.5%+40), (5%

+40) and 10%+40) significantly reduced *Striga* dry weight by 69.3%, 71.6% and 92%, respectively as compared to *Striga* control (Table 2).

Table 2: Effects of Hargel, Jatropha aqueous extracts and Nitrogen and their combination on *Striga* shoot fresh and dry weight (g)/plant

Treatments	*Striga* shoot fresh weight (g)	*Striga* shoot dry weight (g)
H 2.5%	30.8bc	12.0b
H 5%	27.2bc	7.4d
H 10%	23.6cd	4.7def
J 2.5%	33.0b	10.7bc
J 5%	28.6bc	6.7de
J 10%	12.5efgh	3.9efg
N40 Ib/fed	13efgh	4.0efg
N80 Ib/fed	9.5fgh	3.0fgh
N120 Ib/fed	4.6h	0.6h
H 2.5%+N40 Ib/fed	15.8def	7.7cd
H 5%+N40 Ib/fed	14.odef	4.9def
H 10%+N40 Ib/fed	11.8efgh	4.0efg
J 2.5%+N40 Ib/fed	18.3de	5.4def
J 5%+N40 Ib/fed	15.4ef	5.0def
J 10%+N40 Ib/fed	7.4gh	1.4gh
Striga control	57.0a	17.6
C.V%	23.7	30
F-Value	22.8***	15.5***
SE±	2.7	1

*S_X= H=Hargel, J= Jatropha, N= Nitrogen, WAS= Weeks after sowing

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001.

4.2. Effects on Sorghum:

4.2.1. Sorghum height (cm):

At 7 WAS significant differentials were observed between the treatments in plant height (Table 3).*Striga* free control treatment significantly increased plant height by 104% as compared to *Striga* control treatment (Table 3).

Hargel at 2.5% and 5% increased plant height by 44.3% and 61.4%, respectively as compared to *Striga* control treatment. However at 10% significantly increased plant height by 98.4% as compared to *Striga* control treatment (Table 4.3). Also *Jatropha* at 2.5% and 5% increased plant height by 26.6% and 44.7%, respectively. At 10% significantly increased plant height by 110% as compared to *Striga* control treatment (Table 3).

Nitrogen at 40, 80 and 120 Ib/fed significantly increased plant height by72.2%, 86.4% and 93.3, respectively as compared to *Striga* control treatment (Table 3). Hargel concentrations plus Nitrogen 40 Ib/fed(2.5%+40) , (5%+40) and (10% +40) significantly increased plant height by 73.6%, 90.3% and 95.9% respectively as compared to *Striga* control (Table 4.3). However, Jatropha concentrations plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased plant height by 64.4%, 70.5% and 88.8%, respectively as compared to *Striga* control (Table 3). All treatments except (Hargel at 2.5%, 5% and Jatropha 2.5%, 5%) gave plant height comparable to that obtained by *Striga* free control treatment (Table 3).

At 14 WAS, Hargel at 2.5% increased plant height by 50.3% as compared to *Striga* control treatment, while at 5% and10% significantly increased plant height by 57.7% and 91% as compared to *Striga* control treatment (Table 3). Also *Jatropha* at 2.5% increased plant height by 44.4%, while at 5% and 10% significantly increased plant height by 54.6% and 113.5%, respectively as compared to *Striga* control treatment (Table 3).

Nitrogen at 40, 80 and 120 Ib/fed significantly increased plant height by 69%, 76.5% and 91.5, respectively as compared to *Striga* control treatment (Table 3).

Hargel concentrations plus Nitrogen 40 Ib/fed(2.5%+40) , (5%+40) and (10% +40) significantly increased plant height by 75%, 98% and 82.5% respectively as compared to *Striga* control treatment (Table 3). However, The three *Jatropha* concentrations plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and 10%+40) significantly increased plant height by 60.3%, 77.3% and 90.1%, respectively as compared to *Striga* control treatment (Table 3). However, all treatments except (Hargel at 2.5%, 5% and Jatropha 2.5%, 5%)gave plant height comparable to that obtained by *Striga* free control treatment (Table 3).

Table 3: Effects of Hargel, Jatropha aqueous extracts and Nitrogen and their combination on Sorghum height (cm)

Treatments	7 WAS	14 WAS
H 2.5%	73.3bcd	86.7cde
H 5%	82abcd	91bcd
H 10%	100.8ab	110.2abcd
J 2.5%	64.3cd	83.3de
J 5%	73.5bcd	89.2bcd
J 10%	106.7a	123.2a
N40 Ib/fed	87.5abc	97.5abcd
N80 Ib/fed	94.7abc	101.8abcd
N120 Ib/fed	98.2ab	110.5abcd
H 2.5%+N40 Ib/fed	88.2abc	101abcd
H 5%+N40 Ib/fed	96.7ab	114.2abc
H 10%+N40 Ib/fed	99.5ab	105.3abcd
J 2.5%+N40 Ib/fed	83.5abc	92.5bcd
J 5%+N40 Ib/fed	86.6abc	102.3abcd
J 10%+N40 Ib/fed	95.9abc	109.7abcd
Striga free control	103.8a	116.2ab
Striga control	50.8d	57.7e
C.V%	22.1	17.5
F-Value	1.8*	2.4*
SE±	11	10

H=Hargel, J= Jatropha, N= Nitrogen, WAS= Weeks after sowing

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001.

4.2.2. Sorghum shoot fresh weight (g)/plant:

Statistical analysis showed significant differences in Sorghum fresh weight among the treatments and *Striga* control reduced plant shoot fresh weight by 65% as compared to *Striga* free control treatment (Table 4). *Striga* free control significantly increased fresh weight by 185.4% as compared to the *Striga* control treatment (Table 4). Hargel at 2.5% not significantly increased fresh weight by 36.8%, while at5% and 10% significantly increased fresh weight by 120.8%, and 122 %, respectively as compared to the *Striga* control treatment (Table 4). However, *Jatropha* at 2.5% and 5% not significantly increased fresh weight by 82.8% and 51.4%, respectively. At 10% significantly increased fresh weight by 127.8% as compared to the *Striga* control treatment (Table 4).

Nitrogen at 40 Ib/fed not significantly increased fresh weight by 69.4%, while at 80 and 120 Ib/fed significantly increased fresh weight by 97.4%, and 141.8%, respectively as compared to *Striga* control treatment (Table 4).

The three concentrations of Hargel plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10% +40) significantly increased Sorghum fresh weight by 98.4%, 127.8% and 170%, respectively as compared to *Striga* control treatment (Table 4). However, the three concentrations of Jatropha plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased fresh weight by 117%, 102% and 114%, respectively as compared to *Striga* control treatment (Table 4). All treatments except (Hargel at 2.5%, and Jatropha 2.5%, 5% and N40 Ib/fed) gave fresh weight comparable to that obtained by *Striga* free control treatment (Table 4).

4.2.3. Sorghum shoot dry weight (g)/plant:

Statistical analysis showed significant differences in Sorghum dry weight between the treatments (Table 4). *Striga* free control significantly increased dry weight by 121.4% as compared to the Striga control (Table 4). Hargel at 2.5%, 5% not significantly increased dry weight by 49.3%, 47.5%, respectively, while at 10% significantly increased dry weight by 87.1%, as compared to *Striga* control treatment (Table 4.4). However, Jatropha at 2.5% and 5% not significantly increased dry weight by 54.3% and 46.4%, respectively, while at 10% significantly increased dry weight by 88.6% as compared to *Striga* control treatment (Table 4).

Nitrogen at 40, 80 and 120 Ib/fed significantly increased dry weight by 88.2%, 97.1 and 104.6%, respectively as compared to *Striga* control treatment (Table 4).

The three Hargel concentrations plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10% +40) significantly increased dry weight by 94.3%, 98.6% and 110%, respectively as compared to the *Striga* control treatment (Table 4). However, The three concentrations of Jatropha plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased shoot dry weight by 91.1%, 80% and 85.7%, respectively as compared to *Striga* control treatment (Table 4). However, all treatments except (Hargel at 2.5%, 5% and Jatropha 2.5%, 5%) gave dry weight comparable to that obtained by *Striga* free control treatment (Table 4).

Table 4: Effects of Hargel, Jatropha aqueous extracts and Nitrogen each alone and their mixtures on Sorghum fresh and dry weight (g)

Treatments	Fresh weight(g)	Dry weight(g)
H 2.5%	68.4de	41.8cde
H 5%	110.4abcd	41.3de
H 10%	111abcd	52.4abcd
J 2.5%	91.4bcde	43.2bcde
J 5%	75.7cde	41de
J 10%	1 13.9abcd	52.8abcd
N40 Ib/fed	84.7cde	52.7abcd
N80 Ib/fed	98.7abcd	55.2abcd
N120 Ib/fed	120.9abc	57.3abc
H 2.5%+N40 Ib/fed	99.2abcd	54.4abcd
H 5%+N40 Ib/fed	13.9abcd	55.6abcd
H 10%+N40 Ib/fed	135ab	58.8ab
J 2.5%+N40 Ib/fed	108.5abcd	53.5abcd
J 5%+N40 Ib/fed	101abcd	50.4abcd
J 10%+N40 Ib/fed	107abcd	52abcd
Striga free control	142.7a	62ab
Striga control	50e	28e
C.V%	27.8	19.2
F-Value	2*	2.3*
SE±	16	5.5

H=Hargel, J= Jatropha, N= Nitrogen, WAS= Weeks after sowing

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001

4.2.4. Number of leave per plant:

Number of leave ranged between 10-13.4 leave per plant. *Striga* free control increased number of leave by 22.3% as compared to *Striga* control treatment (Table 5). Hargel at 2.5% and 50%not significantly increased number of leave by 11.2% and 37.8%, respectively, while 10% significantly increased number of leave by 44.5% as compared to *Striga* control treatment (Table 5). However *Jatropha* at 2.5%, 5% and 10% not significantly increased number of leave by 15.6%, 18.9% and 33.4%, respectively as compared to *Striga* control treatment (Table 5).

Nitrogen at 40, 80 and 120 Ib/fed increased number of leave by 18.9%, 30% and 18.9%, respectively but not significantly as compared to *Striga* control treatment (Table 5).

Hargel concentrations plus Nitrogen 40 Ib (2.5+40) and (5+40) not significantly increased number of leave by 37.8%, 41.2% and 33.4%, respectively as compare to *Striga* control (Table 5). However, *Jatropha* concentrations plus Nitrogen 40 Ib (5%+40) and (10% +40) not significantly increased number of leave by 30% and 11.2%, respectively but at 2.5% significantly increased number of leave by 48.8% as compared to *Striga* control (Table 5). All treatments gave number of leave comparable to that obtained by *Striga* free control treatment (Table 5).

4.2.4. Days to 50% flowering:

Statistical analysis showed significant differences in Sorghum 50% flowering between the treatments (Table 5). *Striga* free control significantly reduced Sorghum 50% flowering by 8.8% as compared to *Striga* control treatment (Table 5). Hargel concentrations significantly reduced Sorghum 50% flowering by 4.4-7.5% as compared to *Striga* control treatment (Table 5). However *Jatropha* at three levels significantly reduced Sorghum 50% flowering by 5.3-7.5% as compared to *Striga* control treatment (Table 5).

Hargel concentrations plus Nitrogen 40 Ib (2.5%+40), (5%+40) and (10% +40) significantly reduced days to 50% flowering by 8.8%, 7% and9.3%, respectively as compare to *Striga* control treatment (Table 4.5). However, Jatropha concentrations plus Nitrogen 40 Ib (2.5%+40), (5% +40) and (10%+40) significantly reduced Sorghum 50% flowering by 7%, 7.5% and 8.8%, respectively as compared to *Striga* control (Table 4.5). All treatments gave Sorghum 50% flowering comparable to that obtained by *Striga* free control treatment (Table 5).

Table4 5: Effects of Hargel, Jatropha aqueous extracts and Nitrogen and their combination on Sorghum number of leave and days to 50% flowering:

Treatments	Number of leave	Days to50% flowering
H 2.5%	10ab	72.4b
H 5%	12.4ab	70bc
H 10%	13a	70.7bc
J 2.5%	10.4ab	70.7bc
J 5%	10.7ab	70bc
J 10%	12ab	71.7bc
N 40Ib/fed	10.7ab	68.7c
N 80Ib/fed	11.7ab	69c
N 120Ib/fed	10.7ab	70bc
H 2.5%+N40Ib/fed	12.4ab	69c
H 5%+N40Ib/fed	12.7ab	70.4bc
H10%+N40Ib/fed	12ab	68.7c
J 2.5%+N40Ib/fed	13.4a	70.4bc
J 5%+N40Ib/fed	11.7ab	70bc
J 10%+N40Ib/fed	10ab	69c
Striga free control	11ab	69c
Striga control	9b	75.7a
C.V%	21.07	2.6
F-Value	0.80Ns	2.6*
SE±	1.3	1

H=Hargel, J= Jatropha, N= Nitrogen, WAS=Weeks after sowing

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001

4.2.5. Head weight (g)/plant:

Statistical analysis showed differences in head weight among the treatments (Table 6). *Striga* free control significantly increased head weight by 125.7% as compared to the *Striga* control treatment (Table 6). Hargel at 2.5%, 5% and 10% increased head weight by 22.8%, 49.7 and 55.7, respectively as compared to the *Striga* control treatment (Table 6). However, Jatropha at 2.5%, 5% and 10% increased head weight by 47.9%, 55.7% and 61.7%, respectively as compared to the *Striga* control treatment (Table 6).

Nitrogen at 40, 80 and 120 Ib/fed increased head weight by 41.9%, 53.9 and 58.7%, respectively as compared to the *Striga* control treatment (Table .6).

The three concentrations of Hargel mixed with Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10% +40) significantly increased head weight by 66.5%, 66.5% and 112.6%, respectively as compared to the *Striga* control treatment (Table 6). However, The three concentrations of Hargel mixed with Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased head weight by 65.9%, 70.1% and 89.2%, respectively as compared to the *Striga* control treatment (Table 6). The three concentrations of Hargel plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10%+40) and The three concentrations of Jatropha plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10%+40) gave head weight comparable to that obtained by the *Striga* free control treatment (Table 6).

4.2.6. Grain yield (g)/plant:

Statistical analysis showed significantly differences in yield (g)/plant among the treatments (Table 6). *Striga* free control significantly increased Sorghum grain yield (g)/plant by 218.1% as compared to the *Striga* control treatment (Table 6). Hargel at 2.5% increased grain yield (g)/plant by 76.2%, while 5% and 10% significantly increased grain yield (g)/plant by 122.9and 128.6

respectively as compared to the *Striga* control treatment (Table 6).Jatropha at 2.5%, 5% and 10% significantly increased grain yield (g)/plant by 116.2%, 128.6% and 138.1%, respectively as compared to the *Striga* control treatment (Table 6).

Nitrogen at 40, 80 and 120 Ib/fed significantly increased grain yield (g)/plant by 106.7%, 125.7 and 133.4%, respectively as compared to the *Striga* control treatment (Table 6).

The three concentrations of Hargel plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10% +40) significantly increased grain yield(g)/plant by 142.9%, 145.7% and 219%, respectively as compared to the *Striga* control treatment (Table 6). The three concentrations of Jatropha plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased grain yield(g)/plant by 151.4%, 151.4% and 179%, respectively as compared to the *Striga* control treatment (Table 6). All treatments except (H2.5%, J2.5% and N40 Ib/fed) gave grain yield (g)/plant comparable to that obtained by *Striga* free control treatment (Table 6).

4.2.6. Grain yield (kg)/fed:

Statistical analysis showed significantly differences in grain yield (kg)/fed among the treatments (Table 6). The *Striga* free control treatment significantly increased grain yield (kg)/fed by 217.6% (Table 6). Hargel at 2.5% increased grain yield (kg)/fed by 75.6%, while at 5% and 10% significantly increased yield (kg)/fed by 122.3 and 128.7, respectively as compared to the *Striga* control treatment (Table 6). However, Jatropha at 2.5%, 5% and 10% increased grain yield (kg)/fed by 114.1%, 128.7% and 138.2%, respectively as compared to the *Striga* control treatment (Table 6).

Nitrogen at 40, 80 and 120 Ib/fed significantly increased grain yield/fed by 106.1%, 125.5 and 133.1%, respectively as compared to *Striga* control treatment (Table 6).

Each of the three concentrations of Hargel plus Nitrogen 40 Ib/fed (2.5%+40), (5%+40) and (10% +40) significantly increased grain yield(kg)/fed by 143%, 145.8% and 219.2%, respectively as compared to the *Striga* control treatment (Table 4.6). However, Each of the three concentrations of Jatropha plus Nitrogen 40 Ib/fed (2.5%+40), (5% +40) and (10%+40) significantly increased grain yield(kg)/fed by 137.4%, 150.9% and 178.5%, respectively as compared to the *Striga* control treatment (Table 6). All treatments except (H2.5%, J2.5% and N40 Ib/fed) gave grain yield (kg)/fed comparable to that obtained by the *Striga* free control treatment (Table 6).

Table4.5: Effects of Hargel, Jatropha aqueous extracts and Nitrogen each alone and their combination on Sorghum Head weight, Yield (g)/plant and Yield (kg)/fed:

Treatments	Head weight (g)/plant	Yield (g)/plant	Yield (kg)/fed
H 2.5%	20.5de	18.5cd	866.4cd
H 5%	25bcde	23.4abc	1096.7abc
H 10%	26bcde	24abc	1128abc
J 2.5%	24.7cde	22.7bc	1056.3bc
J 5%	26bcde	24abc	1128abc
J 10%	27abcde	25abc	1175abc
N40 Ib/fed	23.7cde	21.7bc	1016.8bc
N80 Ib/fed	25.7bcde	23.7abc	1112.3abc
N120 Ib/fed	26.5bcde	24.5abc	1149.9abc
H 2.5%+N40 Ib/fed	27.8abcd	25.5abc	1198.5abc
H 5%+N40 Ib/fed	27.8abcd	25.8abc	1212.6abc
H 10%+N40 Ib/fed	35.5ab	33.5a	1574.5a
J 2.5%+N40 Ib/fed	27.7abcd	26.4abc	1171abc
J 5%+N40 Ib/fed	28.4abcd	26.4abc	1237.7abc
J 10%+N40 Ib/fed	31.6abc	29.3ab	1374ab
Striga free control	37.7a	33.4a	1566.7a
Striga control	16.7d	10.5d	493.3d
C.V%	24	25.5	25.5
F-Value	1.7Ns	2.3*	2.1*
SE±	2	3.6	4.1

H=Hargel, J= Jatropha, N= Nitrogen.

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. *P≤0.05, ***= P≤0.001

CHAPTER FIVE

Discussion

Recent approaches to control crop parasites are oriented towards exploring news alternative sources of herbicides less hazardous and inexpensive. Researchers have indicated that, the plant kingdom is characterized by the presence of chemical substances, in the form of natural products that are used to combat parasitic weeds attack by eliciting strong physiological responses in various stages of parasite life cycle. Botanical herbicides might be a promising source of parasites control compounds such as *Jatropha curcas*. The current study aimed at exploring new environmental friendly herbicides to control *Striga* on Sorghum.

The result indicated that there is significant reduction on *Striga* emergence at 6, 10 and 14 weeks after sowing (WAS) by 52.3-100%, when the water extract of Hargel (2.5%, 5% and 10%), and their combinations with Nitrogen 40 Ib/fed were used. Similar result was found by Wegdan (2016) who reported that used Hargel extracts above the concentration 0.2% effect germination and growth of some weeds. Possible reason for this, the presence allelopathic effects of concentrations, might be attributed to the hormone –like properties of allelo-chemicals of plants extracts such argelin and argelosid, choline, flavonoids, monoterpenes, pregane glucoside, sitosterol, and a triterpenoid saponin. However, high concentrations of the Hargel and their combinations with Nitrogen fertilization have highly impact on controlling *Striga*.

The result indicated that there is significant reduction in number of *Striga* emergence at 6, 10 and 14 WAS by 29-100%, when the extracts of Jatropha (2.5%, 5% and 10%) and their combination with Nitrogen 40 Ib/fed were used. The same result was found by Asif ullah *et al*. (2017) who reported that the different concentrations of aqueous extracts of *Jatropha curcas* significantly reduced germination and growth of some weeds. Possible reason for this the presence of phenolics compounds in aqueous extracts of *Jatropha curcas* (Khattak *et al*., 2015). Phenolics are a group of compounds have allelopathic potential in the ecosystem. They have a hydroxyl group (-OH) which is bonded to an aromatic hydrocarbon group (Li *et al*., 2010). Haustorium of *Striga* is very sensitive indicator of phytotoxic activity. In addition Phenolic allelochemicals effect *Striga* seeds germination and effect haustorium growth. These findings are consistent with those obtained by Asif ullah *et al*. (2017) who reported that, the *Jatropha curcas* aqueous extracts contain allelochemicals phenolic compounds and high concentration contains high Phenolic compound. This phenolic compound decreased germination and growth of this parasite.

The levels of the Nitrogen fertilizer (40, 80, and 120 lb/fed) when were applied, significantly reduced number of *Striga* emergence at 6, 10 and 14 WAS by 58.2-100%. Possible reason for this could be due to *Striga* seeds cannot germinate in the absence of a chemical stimulant, because Nitrogen decreases stimulant production by the host plant. This result is in agreement with that obtained by Lagoke and Isah (2010); Poornima *et al*. (2008); Buah and Mwinkara (2009); Hugaretal (2010) and Rashida *et al*. (2017) who reported that, Nitrogen reduced the severity of *S. hermonthica*.

At harvest time all concentrations of Hargel aqueous extract and their combination with Nitrogen 40 Ib/fed significantly reduced *Striga* shoot fresh and dry weights by 46-79.3% and 31.8-77.3% respectively. This means the botanical extract has effect on the vegetative growth of *Striga* plant, which is expected to have impact on number of *Striga* seeds produced, this will definitely affected the *Striga* seed bank. Also all concentrations of Jatropha aqueous extracts and their combination with Nitrogen 40 Ib/fed significantly reduced *Striga* shoot fresh and dry weights at harvesting time by 42.1-87% and

39.2-92% respectively. This means this botanical extract has effect on the vegetative growth of *Striga* plant, which is expected to have impact on number of *Striga* seeds produced, this will definitely affected the *Striga* seed bank.

At harvest time all Nitrogen doses significantly reduced *Striga* fresh and dry weights by77.2-91.9% and 77.3-96.6% respectively. This means the Nitrogen has effect on the vegetative growth of *Striga* plant, which is expected to have impact on number of *Striga* seeds produced; this will definitely affected the *Striga* seed bank. This result might be due to negative effect of N on growth and development of the *Striga*. This is due to the fact of that nitrogen reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and Isah, 2010). This result agrees with the findings of Hassan *et al*. (2009) who reported that Nitrogen reduced *Striga* infestation, reduced stimulants production, delayed germination, and reduction of *Striga* seeds response to the stimulants.

Also the result indicated that there is significant increase in plant height at 7 and 14 WAS, when the all extracts of Hargel alone or in combination with Nitrogen 40 Ib/fed used by 73.6-98.4%, except (H 2.5% and H 5% not significant). This means the botanical extract has positive effect on the vegetative growth of plant. Possible reason for this the presence of high amount of the hormone –like argelin and argelosid, choline, flavonoids, monoterpenes, pregane glucoside, sitosterol, and a triterpenoid saponin (Suleiman *et al*., 2009).

The result indicated that there is significant increase in plant height at 7 and 14 WAS, when the all extracts of Jatropha alone or in combination with Nitrogen 40 Ib/fed used by 64.4-113.5%, except (J 2.5% and J 5% not significant). This means the botanical extract has positive effect on the vegetative growth of plant.

The result indicated that there is significant increase on plant height at 7 and 14 WAS by 72.2-93.3%, when the application of the Nitrogen fertilizer (40, 80 and 120 lb/fed) was used. This means the Nitrogen has positive effect on the vegetative growth of plant, which is expected to have impact on *Striga* plants number, this will definitely reduce number of *Striga* plants which compete Sorghum plants. Similar findings on positive effect of increased rate of N was mentioned by Adagba *et al*. (2002); Lagoke and Isah (2010); Teka (2014) who reported that, fertilizer application had significant effect on height, vigour score, reaction score of sorghum as well as shoot count, days to emergence, dry matter of production and dry weight of *Striga*. The application of high nitrogen (N) increases the performance of cereal crops under *Striga* infestation. This is due to the fact of that nitrogen reduced the severity of *Striga* attack while simultaneously increasingly the host performance.

Also at harvesting time the result indicated all concentrations of Hargel aqueous extracts alone or in combination with Nitrogen 40 Ib/fed except (H 2.5%) significantly increased plant shoot fresh weight by 98.4-170%. Possible reason for this Hargel aqueous extracts containing a cylated phenolic glycosides, namely argelin and argelosid, choline, flavonoids, monoterpenes, and pregane glucoside, all this components as promoting ingredient to Sorghum growth. This result is in line of that reported by Idris *et al*. (2011) who reported that, Hargel dry leaves can be used as growth promoting ingredients to enhance the growth of crops.

The concentrations of Jatropha aqueous extracts (2.5% and 5%) have an effect on plant fresh at harvesting time but not significantly. However, the high concentration (10%) has significant effect on plant fresh weight. This means this botanical extract has effect on the vegetative growth of plant growth, which is expected to have impact on number of *Striga* plant emerged; this will definitely affected the plant growth.

The application dose of Nitrogen 40 Ib/fed has an effect on plant shoot fresh at harvesting time but not significant. However, the medium and high doses (80 and 120 Ib/fed) have significant effect on plant fresh weight. This means the Nitrogen has effect on the vegetative growth of plant, which is expected to have impact on number of *Striga* plant emerged; this will definitely affected the plant growth. This result contradicts findings of Bilal *et al*. (2000) and Rashida *et al*. (2017) who reported that plant height increased progressively up to harvest over control with the application of nitrogen fertilizers.

The result indicated that there is an effect on plant fresh weight at harvest time, when the extract of Hargel (2.5%) was used but not significant. However, medium and high concentrations of the Hargel (5% and 10%) have significant effect on plant fresh weight .This means this botanical extract has positive effect on the vegetative growth of plant and negative effect on *Striga* plant. Possible reason for this Hargel aqueous extracts containing acylated phenolic glycosides, namely argelin and argelosid, choline, flavonoids, monoterpenes, and pregane glucoside, all this components as promoting ingredient to Sorghum growth. This result is in line of that reported by Idris *et al*. (2011) who reported Hargel dry leaves can be used as growth promoting ingredients to enhance the growth of crops.

The different concentrations of Hargel in combination with Nitrogen 40 Ib/fed significantly increased plant fresh weight at harvest time. This means this botanical extract in combination with Nitrogen 40 Ib/fed have positive effect on the vegetative growth of plant and negative effect on *Striga* plant, which is expected to have impact on number of *Striga* plants, this will definitely reduce number of *Striga* plants which compete Sorghum plants.

The concentrations of Jatropha (2.5% and 5%) have effect on plant fresh weight at harvest time but not significantly, while the high concentration (10%) has significant effect on plant fresh weight. This means this botanical extracts have positive effect on the vegetative growth of plant and negative effect on *Striga* plant, which is expected to have impact on number of *Striga* plants, this will definitely reduce number of *Striga* plants which compete Sorghum plants.

The different concentrations of *Jatropha* in combination with Nitrogen 40 Ib/fed have significant effect on plant fresh weight at harvest time. This means this botanical extracts in combination with Nitrogen 40 Ib/fed have positive effect on the vegetative growth of plant and negative effect on *Striga* plant, which is expected to have impact on number of *Striga* plants, this will definitely reduce number of *Striga* plants which compete Sorghum plants.

The result indicated that there is an effect on plant shoot fresh weight at harvest, when the application of the Nitrogen (40 lb/fed) fertilizer was used but not significantly. However, medium and high doses of the Nitrogen (80 and 120 Ib/fed) have high positive effect on plant fresh weight. Similar findings on positive effect of increased rate of N was supported by Lagoke and Isah (2010) and Rashida *et al*. (2017). The application of high nitrogen (N) increases the performance of cereal crops under *Striga* infestation. This is due to the fact of that nitrogen reduced the severity of *Striga* attack while simultaneously increase the host performance.

The result indicated that there was a significant increase on plant dry weight at harvest time, when the extract of Hargel (10%) was used by 87.1% while, not significantly at (2.5% and 5%) by 49.3 and 47.5%, respectively. Also all concentrations of Hargel in combination with Nitrogen significantly increased plant shoot dry weight by 94.3-110%.

The result indicated that there was a significant increase on plant shoot dry weight at harvest time, when the extract of Jatropha (10%) was used by 88.6% while, not significantly at (2.5% and 5%) by 54.3 and 46.4%, respectively. Also all concentrations of Jatropha in combination with Nitrogen significantly increased plant shoot dry weight by 80-91.1%.

The result indicated that there was a significant increase on plant dry weight at harvest time, when the Nitrogen used at (40, 80 and 120 Ib/fed) by 88.2-104.6.

The result indicated that there was significant reduction on days to 50% flowering by 4.4-9.3, when the water extracts of Hargel (2.5%, 5% and 10%), and their combinations with Nitrogen 40 Ib/fed were used. These findings are in line with those obtained by Awad *et al*. (2012) who reported that, Hargel dry leaves can be used (either as growth promoting ingredients or botanical pesticide) enhanced the flowering and yield palm tree (a dry date cultivar) in the Northern State, Sudan. Also application of all Nitrogen doses significantly reduced days to 50% flowering by 7.5-9%. This result agrees that obtained by Zerihun (2016) who reported that, delay in days to 50% flowering with application of higher level of N might link to nitrogen increased vegetative period and it delays reproductive period. This could be related to the vigorous growth that resulted in higher number of days for flowering and maturity.

The result indicated that Hargel aqueous extracts at concentrations 5% and 10% significantly increased grain yield (g)/plant and grain yield (kg)/fed by 122.9%-128.6% and 122.3 - 128.7%, respectively. Also Hargel applied in combination with Nitrogen 40Ib/fed significantly increased grain yield (g)/plant and grain yield (kg)/fed by 142.9% - 145.7% and 143-219.2%, respectively. Possible reason for this is the presence of allelo-chemicals that effect *Striga* growth and that enhance plant growth and yield by decreased number of Striga that compete the Sorghum plants. This is in line with the previous work of. Idris et al. (2011) who reported that, Hargel leaves can be used as growth promoting ingredients or botanical enhanced the flowering and yield palm tree in the Northern State, Sudan. The result indicated that there was significant increased on grain yield (g)/plant and grain yield (kg)/fed, by 116.2%-138.1% and 114.1-138.2%, respectively when the Jatropha aqueous extracts used. However, the result indicated that Jatropha applied in combination with Nitrogen 40Ib/fed significantly increased grain yield (g)/plant and grain yield (kg)/fed by 151.4%-179% and 137.4-178.5% respectively.

The three levels of Nitrogen (40, 80 and 120 Ib/fed) significantly increased grain yield (g)/plant and grain yield (kg)/fed by 106.1-133.4% and 106.1-133.1% respectively, and applied high level of Nitrogen more effective on grain yield. The grain yield increased when the level of N increased. This result might be due to the increase up of grain yield attributing characters and nutrient uptake of the crop under these levels as well as reduced *Striga* infestation at high application levels. This result is in agreement with that obtained by Hugar *et al*. (2010); Zerihun (2016) and Rashida *et al*. (2017) who reported that, the grain yield increased when the level of N increased.

Conclusions and Recommendations

Conclusions

- Hargel and Jatropha aqueous extracts each one alone reduced *Striga* emergence and *Striga* fresh and dry weight this means the two botanicals have effect on *Striga* emergence and growth.
- Hargel and Jatropha aqueous extracts in combination with Nitrogen reduced *Striga* emergence and *Striga* fresh and dry weight this means the two botanicals and Nitrogen have effect on *Striga* emergence and growth
- Nitrogen alone effectively reduced emergence and suppressed *Striga* emergence.
- Effectiveness of botanicals increased by increasing concentration, add Nitrogen to the botanicals concentrations and increased Nitrogen levels

Recommendations

- Use Hargel aqueous extracts at 5% and 10% to control *Striga hermonthica* and decreased their effect on Sorghum growth and yield.
- Use Jatropha aqueous extracts at 2.5% 5% and 10% in to control *Striga hermonthica* and decreased their effect on Sorghum growth and yield.
- Use Hargel and Jatropha aqueous extracts at 2.5% 5% and 10% in combination with nitrogen 40 Ib/fed to control *Striga hermonthica* and decreased their effect on Sorghum growth and yield.
- To control *Striga hermonthica* on Sorghum can be applied Nitrogen at 80 and 120 Ib/fed.
- *Striga* management requires integrated practices comprising different components such as use resistance variety such as cultivar (Asareca-w2) and Hargel or Jatropha aqueous extracts in combinations with nitrogen 40 Ib/fed.

References

Adagba, M. A.; Lagoke, S. T. and Imolehin, E. D. (2002).Nitrogen effect on the incidence of *Striga hermonthica* (Del.) Benth in upland rice. *Agron. Hungarica. 50:145-150.*

Adam, A. I. M. and Fatin, A. O. (2016). Efficacy of *Jatropha curcas* leave and bark Powder against *Trogoderma granarium* (Evert's) (Coleoptera: Dermestidae). *M. Sc., thesis, Al Zaiem AL-Azhari University, Sudan.*

Adugna, A (2007). The role of introduced sorghum and millets in Ethiopian Agriculture. *SAT Journal.3. ICRISAT, India*.

Ahmed N. E., Sugimoto, Y.; Babiker, A. G.; Mohamed, O. E.; Inanaga, S. and Nakajima, H. (2001). Effects of *Fusarium solani* isolates and metabolites on *Striga* germination. *Weed Sci. 49: 354–358.*

Ahmed, M. A. (2007). The efficacy of four systemic insecticides using two methods of application against the green date palm pit scale insect (*Asterolicanium phoenicis* Rao) (Homoptera: Asterolicaniidae) in northern Sudan. Acta Horticulturae, 736:369-389.

Ali, M. A.; Abbas, A. S.; Awan, I.; Jaban, K. and Gardezi, S. D. A. (2011).Correlated response of various morpho-physiological characters with grain yield in *Sorghum* landraces at different growth phases. *The Journal. Animal. Plant Science, 21* ***4****: 671- 679.*

Asif ullah, K.; Faizan Ullah.; Sultan, M.; Muhammad, I. and F. Ullah (2017).Alellopathic effects of Jatropha curcas L. leaf aqueous extract on early seedling growth of *Parthenium hysterophorus. Pakistan J. Agric.30 (1) 45-54*.

Atera, E. A.; Itoh, K. and Onyango, J. C. (2011). Evaluation of ecologies and severity of *Striga* weed on rice in sub-Saharan Africa. Agr.and Biol. *J. of N. America, 2: 752-760.*

Awad, K. T; Khalid, O. A.; Tagelsir, I.M. and Sidahmed, O. (2012). Argel (*Solennostemma argel* Del. Hayenne) applications for control of the date palm green scale insect (*Asterolicanium phoenicis* Rao) and yield enhancement. *ARPN J. of Agri Bio Sci, 7: 6*.

Ayman, A. A.; Dafalla, D. A.; Hassan, Y. R. and Lubna, E. K. (2014).Effects of Some Formulations of Chlorsulfuron, On *Striga* Control and *Sorghum* Yield. *International Journal of Life Sciences Research, **2**: 185-188.*

Babiker, H. H. (2002). Overview of Sorghum and millet in Sudan.Ministry of Science and Technology, Agricultural Research Corporation, Food Research Centre.

Babiker, A.G.T. Butler, L. and Ejeta, G. (1996).Integrated use of *Striga* resistant *Sorghum* varieties with cultural and chemical control. In: *The International Conference on Genetic Improvement of sorghum and Pearl Millet*. Taxas A and M University Research and Extension Centre, Luubbock, USA.pp517-524.

Barker, W. R. (1990).New taxa, names and combinations in Lindernia, Peplidiuni, stemodia and Striga (Scrophulariaccae) mainly in the Kimbcrlcy region, Western Australia*. J. of Adelaide Bot. Gardens, 13: 79-94.*

Bebawi, F. F.; Eplee, R. E., Harris; C. E. and Norris, R. S. (1987). Longevity of witch weed (*Striga asiatica*) seed. *Weed Science, **32**: 494-497.*

Bilal, M.Q.; and Sarwar, M. (2000). Effect of varying levels of nitrogen and farm yard manure application on tillering and height of Mott grass. *International Journal of Agriculture and Biology, 2: 21-23*.

Buah, S. S. J. and Mwinkaara, S. (2009). Response of Sorghum to nitrogen fertilizer and plant density in the Guinea Savanna Zone. *Journal of Agronomy, 8 (4): 124-130*.

Carsky, R. J.; Berner, D. K.; Oyewole, B. D.; Dashiell, K.and Schulz, S. (2000). Reduction of *Strigahermonthica* parasitism on maize using soyabean rotation, Int. *J. Pest Manag, 46: 115-120.*

Charudattan, R. (2001). Biological control of weeds by means of plant pathogens: Significance for integrated weed management in modern agro-ecology. *Bio Contr. 46: 229-260.*

Ciotola, M.; Watson, A. K. and Hallett, S. G. (2003). Impacts of *Fusarium oxysporum* isolate M12-4A up on seed germination of *Striga hermonthica* in vitro. In: Moreno, M. T., Cubero, J. I., and Parker, C., (eds). *Proceedings of Advances in Parasitic Plant Research, Canada. pp. 871-878.*

Ciotola, M. A.; Ditommaso, A. and Watson, A. K. (2000). Chlamydo spores production, inoculation, methods and pathongenicity of F. oxysporum M12-4A, a biocontrol for *Strigahermonthica. Biocontrol Science and Technology, 10: 129-145.*

Cochrane, V. and Press, M. (1997).Geographical distribution and aspects of the ecology of the hemiparasitic angiosperm *Striga asiatica* (L.) Kuntze: a herbarium study. *J. of Trop. Ecol., 13: 371-380.*

Coombs, E M.; Clark, H. K.; Piper, G. L. and Cofrancesco, A. F. (2004).Biological control of invasive plants in the United States.*Corvallis OR: Oregon State University Press, 467pp.*

Culliney, T. W. (2005). Benefits of classical biological control for managing invasive plants, Crit. Rev. *Plant Sci., 24: 131-150.*

De-Groote, H.; Rutto, E.; Odhiamb, O. G.; Kanampiu, F.; Khan, Z.; Coe.; R. and Vanlauw, B. (2010). Participatory evaluation of integrated pest and soil fertility management options using ordered categorical data analysis. *Ag.Sys. dio:10.1016/J.agsy.2009.12.005. (Accessed at October 13/ 2015 at 11 pm.*

Debrah, S. K. (1994). Socio-economic constraints to the adoption of weed control techniques: the case of *Striga* control in the West African semi-arid tropics. *International journal of pest management* ***40****: 153-158.*

Delfosse, E. S. (2004). Introduction. In biological control of invasive plants in the United States, ed. Coombs, E.M.; Clark, J.K., Piper, G.L., Cofrancesco, A.F., and Corrallis, *J. R. O. R., Oregon State. University Press, pp. 1-11.*

Dogett, H. (1988). The Sorghum crop.In Sorghum (2nded).*Longm group U. K. Limited. London, U. K. Pp368-404.*

Dugje, I. Y.; Kamara, A. Y. and Omoigui, L. O. (2008). Influence of farmers' crop management practices on *Striga hermonthica* infestation and grain yield of maize (Zea mays L.) in the Savanna zones of northeast Nigeria*. J. Agron. 7(1): 3340.*

Ejeta, G. (2007). The *Striga* scourge in Africa: a growing pandemic. In: Ejeta, G. and Gressel, J. (eds.). Integrating new technologies for *Striga control*: Towards ending the *witch-hunt,pp.3-16.*

Ejeta, G.; Babiker, A.G.; and Mohamed, A. (1996). Chemical control of Striga hermonthica on sorghum. In: Moreno,M. (eds). Advances in Parasitic Plant research. Proceedings of the 6th International Symposium on Parasitic. Pp. 769-773.

Ejeta, G., Mohammed, A., Rich, P., Melakeberhan, A., Housley, T.and Hess, D. (2000). Selection for specific mechanisms of resistance to *Striga* in sorghum. *p. 29-40*.

Elzain, I. N. and Elasha, A. E. (2005).Sorghum grown under irrigated and rain-fed conditions in Sudan.*ARC. Pp4.*

Elzein, A. Eand Kroschel, J. (2003). Progress on management of parasitic weeds.In: Labrada, R. (ed.). *FAO Plant Production and Protection.*

Weed Management for Developing Countries. Paper 120 Addendum 1, Food and Agriculture Organization of the United Nations, Rome. pp 109-144.

Elkamali, H. H. and Khalid, S. A. (1996).The most common herbal remidies in Dongola Province, Northern Sudan. *Fitoterapia*; (*69):118-121*.

Esilaba, A. O. and Ransom, J. K. (1997). *Striga* in the Eastern and Central African countries: A Literature review.Technical report series, No. *1. African highlands initiative, ICRAF, Nairobi. 39pp.*

FAO, (1995).Sorghum and Millets in Human Nutrition.FAO Food and Nutrition Series; No.27, ISBN 92-5-10331-1.

FAO, (2010).Food and Agriculture Organization of the United Nations.*Rome, Italy. Tc/A0416E/1/2.06/300. FAOState 2010*.

FAO, (2013).Food and Agriculture Organization of the United Nations Crop Prospects and food situation.

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

Fasil, R. (2002).*Striga hermonthica* in Tigray *(Northern Ethiopia) prospect for control and improvement of crop productivity through mixed cropping.*Ph.D. thesis, Vrije University, Amsterdam, the Netherlands.

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

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

Gacheru, E. and Rao, M.R. (2001). Managing *Striga* infestation on maize using organic and inorganic nutrient sources in Western Kenya. *International journal of pest management 47:233-239.*

Gbehounou, G.; Pieterse, A. H. and. Verkleij, J. A. C. (2003). Longevity of *Striga* seeds reconsidered: results of a field study on purple witch weed (*Striga hermonthica*) in Benin. Weed Sci. 51: 940–946.

Gressel, J. (2000). Molecular biology for weed control. *Transgenic Research, **9**:355-382.*

Gressel, J.; Hanafi A., Head, G.; Marasas, W. and Obilana, A.B. (2004).Major heretofore intractable biotic constraints to African food security that may be amenable to novel biotechnological solutions. *Crop Prot., 23: 661-689.*

Gurney, A. L., Press, M. C. and Scholes, J. D. (1999). Infection time and density influence the response of sorghum to the parasitic angiosperm *Striga hermonthica*. *New phytol, 143: 573-580.*

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

Gurney, A.L.; Grimanelli, D.; Kanampiu, F.K.; Hoisington, D.; Scholes, J.D.; and Press, M.C. (2003). Novel sources of resistance to *Strigahermonthica* in Tripsicum dactyloides, a wild relative of maize. *New Phytol.160:557-568.*

Gurney, A.L.; Taylor, A.; Mbwaga, A. ; Scholes, J.D.; and Press, M.C. (2002).Do maize cultivars demonstrate tolerance to the parasitic weed *Striga asiatica* . *Weed Res. 42:299-306.*

Hassan, M. M.; Abdelgain, M. E. and Babiker, A.G. T. (2009). Potential of bacterial strains and nitrogen in reduction of *Striga hermonthica* (Del.) Benth. Infesting Sorghum, America- Eurasian. *Journal of sustainable agriculture, 3(1): 1-9.*

Haussmann, B. I.; Geiger, H. H.; Hess, D. E., Hash, C. T. and Bramel, P. (2000).Application of molecular markers in plant breeding. Training manual for a seminar held at IITA. *International Crop Research Institute for the Semi-Arid Tropics* (ICRISAT). *Patancheru 502324, Andhra paradesh, India.*

Hearne, S. J. (2009). Control –the *Striga* conundrum. *Pest manage. Sci. 65: 603–614.*

Hess, D. E. and Dodo, H. (2003). Potential of sesame to contribute to integrated control of *Striga hermonthica* in the West African Sahel. *Crop Protect, 23:515-522.*

Hugar, A. Y.; Jayadeva, H. M.; Rangaswamy, B. R.; Shivanna, S. and Handrappa, H. (2010). Assessing the effect of nitrogen and harvesting stages on yield and yield attributes of sweet sorghum genotypes. *Agricultural Science, 30 (2): 139 – 141.*

Hill, G. and Greathead, D. (2000).Economic evaluation in classical biological control. In: The Economics of biological invasions, ed. Perrings, C.; Williamson, M., and Dalmazzone, S.; Cheltenham, UK: *Edward Elgar Publishing, pp.208-223.*

Hooper, A. M.; Hassanali, A.; Chamberlain, K.; Khan, Z. and Pickett, J. A. (2009).New genetic opportunities from legume intercrops for controlling *Striga spp.,* parasitic weeds. *Pest Manage. Sci.65: 546–552.*

Ibrahim, H. E.; Ahmed, A. T.; Omer, M. E.; Hamdoun, A. M.; Babiker, A. E. and Boreng, p.(1995). Status of sorghum production, technology generation, transfer and Adoptions farmer, in Sudan. In: Proceeding of a workshop on Sorghum and millet research in Eastern and Central Africa., Kampala, Uganda, pp. 157-166.

Ideris, A. E. and Mohammed, H. I. (2012). Screening and Evaluation of forage Sorghum cultivar for forage production using multicriterion decision analysis. *Advance in environmental biology, 6(3): 114-151.*

Idris, T. I. M.; Ibrahim, A. M. A. Mahdi, E. M. and Taha, A. K. (2011). Influence of argel (*Solenostemma argel* Del. Hayne) soil applications on flowering and yield of date palm (*Phoenix dactylifera*L.). Agriculture and Biol. *J. North America*, *2(3): 538-542*.

IITA (International Institute for Tropical Agriculture), (2002).*Striga* biology and control: Strategies for African farmers. IITA/DFID, Ibadan, Nigeria.(CD-ROOM).

Ikie, F. O.; Schulz, S.; Ogunyemi, S.; Emechebe, A. M.; Togun, A. O. and Berner, D. K. (2006).Effect of soil sterility on soil chemical properties and Sorghum performance under *Striga infestation*. *World J. Agric. Sci., 2(4):367-371.*

Jamil, M.; Charnikhova, T.; Cardoso, C.; Jamil, T.; Ueno, K.; Verstappen, F., Asami, T. and Bouwmeester, H. J. (2011). Quantification of the relationship between strigolactones and *Striga hermonthica* infection in rice under varying levels of nitrogen and phosphorus. *Weed Res., 51:373-385.*

Joel, D. M. (2002). The long-term approach to parasitic weeds control: manipulation of specific developmental mechanisms of the parasite. *Crop Protect., 19: 753-758.*

Joel, D. M.; Steffens, J.C. and Matthews, D. E. (1995).Germination of weedy root parasites.In seed development and germination. Edited by Kigel, J. and Galili, G. Marcel Dekker, Inc., *NewYork, pp. 567 – 597.*

Kanampiu, F., Mbogo, P and Massawe, C.(2004). Multi location testing of herbicide-resistant Maize to control *Striga*. In: Integrated approaches to higher productivity in the new millennium (Friesen, D.K. and Palmer, A.F.E. eds). *Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference. 5-11 February 2002. Nairobi, Kenya. CIMMYT (International Maize and Wheat Improvement Centre) and KARI (Kenya Agricultural Research Institute). pp. 169-172.*

Kebede, H. P.; Subudhi, K.; Rosenow, D.T. and Nguyen, H.T.(2001). Quantitative trait loci influencing drought tolerance in grain Sorghum *(Sorghum bicolor L. Moench).* Theory. *Appl. Genet,* ***103****: 266-276.*

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

Khan, Z.R.; Pickett, J. A.; Van den berg, J.; Wadhams, L. J. and Woodcock, C. M. (2000). Exploiting chemical ecology and species diversity: stem borer and *Striga* control for *maize* and *Sorghum* in Africa. *Pest management Science,* ***56****:957-962.*

Khan, Z. R.; Pickett, J. A.; Wadhams, L.J. and Muyekho, F. (2001). Habitat management strategies for the control of cereal stem borer and *Striga* in *maize* in Kenya. *Insect science* Appl., ***21****:375-380.*

Khattak, A. F.; Ullah, S. M.; Wazirand Shinwari,Z. K. (2015). Allelopathicpotential of *Jatrophacurcas* L leaf aqueous extracts on seedlinggrowth of wheat. *Pakistan. J. Bot., 47: 2449-2454*.

Kroschel, J.; Jost, A. and Sauerborn, J. (1999).Insects for *Striga* control-possibilities and constraints. In: Kroschel, J.; Mercer-Quarshie, H.; Sauerborn, J. (Eds.), Advances in parasitic weed control at On-farm Level, Vol. 1, Joint action to control *Striga* in Africa. Margraf Verlag, Weikersheim, *Germany, pp. 117-132.*

Lagoke, S. T. O. and Isah, K. M. (2010).Reaction of maize varieties to *Striga hermonthica* as influenced by food legume intercrop, spacing and split application of compound fertilizer. Nig. *J. Weed Sci., 23: 45-58.*

Lendzem, V. W. (2004). The tripartite interaction between Sorghum, *Striga hermonthica*, and arbuscular mycorrhizal fungi.*Ph.D thesis, Wageningen University, Wageningen, The Netherland*.

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

Li, Z. H.; Wang, Q.; Ruan X.; Panand, C. D. and Jiang, D. A. (2010).Phenolics and plant allelopathy. *Molecules*, *15: 8933-8952*.

Lopez-Raez, J.A.; Charnikhova, T.; Gomez Roldan, V.; Matusova, R. and Kolen, W (20080. Starvation. New phyto. 178:863-874.

Menkir, A. and Kling, J. G. (2007).Response to recurrent selection for resistance to *Striga hermonthica* (Del.) Benth in a tropical maize population. *Crop Sci., 47: 674–684.*

Mohamed, E. H. B. (2004). Effect of *Vinca rosea* and Hargel (*Solenostemma argel Del.Hayne);* powder and aqueous extract on the faba bean beetle adult *Bruchidius incarnatus Boh (Coleoptera: Bruchidae); M. Sc., Thesis, College of Agric. Studies, SUST.*

Mohamed, K. I.; Musselman, L. J. and Riches, C. R. (2001). The genus *Striga* (Scrophulariaceae) in Africa.*Annals of Missouri botanical gardens, **88**: 60–103.*

Mumera, L. (1983). *Striga* infestation in *maize* and *sorghum* relative to cultivar, herbicidal activity and nitrate. In: Proceedings, 9th East *African Weed Science Society Conference, Nairobi, 1983, pp**82**-104*

Nickrent, D. L. and Musselman, L. J. (2004).Introduction to parasitic flowering plants.The plant health instructor.*Digital Objective identification: 10.1094/ PHI-I-2004-0330-01., pp. **1**-7*

Odhambo, G.D and Ransom, J.K. (1994).Preliminary evalua- tion of long-term effects of trap cropping on *Striga*.In Biology and Management of *Orobanche.Proceedings of the Third International Conference on Orobanche and Related Striga Research. Piterse, AH, Verkleij, JAC and ter Borg ST (eds).Amsterdam,Royal Tropi- cal Institute.pp.505-512.*

Orange, R. A. (1982). Ecological and phyto-chemical studies on *Solenostemma argel* growing in Saudi Arabia. *J. of the College of Science; King Saudi University, 13(1): 17-24.*

Oswald, A, and Ransom, J. K. (2001). *Striga* control and improved farm productivity using crop rotation. *Crop Protect. 20: 113-120.*

Oswald, A., Ransom, J. K.; Kroschel, J. and Sauerborn, J. (2001). Transplanting maize (Zea mays) and Sorghum (*Sorghum bicolor*) reduces *Striga hermonthica* damage. *Weed Sci., 49: 346-353.*

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

Oswald, A. (2005). *Striga* control—technologies and their dissemination. *Crop Prot., 24: 333-342.*

Parker, C. and Riches, C. G. (1993). Parasitic weeds of the world: Biology and control. CAB International, Wallingford, U. K. pp. 332.

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

Poornima, S.; Geethalakshmi, V. and Leelamathi, R.M. (2008). Effect of sowing dates and nitrogen levels on yield and juice quality of sweet Sorghum. *Journal of agricultural biological science, 4(6): 651-654*.

Rajni, G. and Mukerji, K. G. (2000).Biological control of weeds with plant pathogens. In: Mukerji, K.G.; Chamola, B.P. (Eds.), *Crop Diseases, weeds and nematodes, Vol., 1, R. K. Updahyay, Plenum Pub Corp, US, pp. 199-206.*

Ransom, J. K. (2000). Long-term approaches for the control of *Striga* in cereals: field management options. *Crop Protect, 19; 759-763.*

Rashida, A.; Elfatih, A.; Amani, H. E. and Babiker, A. G. T. (2017). Influence of nitrogen, chlorsulfuron and triclopyr on management of *Striga hermonthica* on Sorghum. *International journal of agriculture & environmental science (IJAES)*, *6 (4): 32 – 37*.

Rector, B.G. (2009). A sterile-female technique proposed for control of *Striga hermonthica* and other intractable weeds: Advantages, shortcomings and risk management. Pest *Manage. Sci., 65: 596-602.*

Rodenburg, J.; Bastiaans, L. and Kropff, M. J. (2006).*Characterization of host tolerance of Striga hermonthica. Euphotic, 14: 353-365.*

Romain, H. and Raemaeker, S. (2001). *Director General for international cooperation, Ministry of Foreign Affairs, External Trade. Brussels (Crop production in Africa).*

Sauerborn, J. and Kroschel, J. (1996). Under rated methods of weed control, and their use in the agriculture of developing countries. In: Second International weed control congress, *Copenhagen, Denmark, pp. 611-621.*

Sauerborn, J.; Müller-Stöver, D. and Hershenhorn, J. (2007).The role of biological control in managing parasitic weeds. *Crop Prot., 26: 246-254.*

Sauerborn, J. (1991). The economic importance of the phytoparasite Orobanche and *Striga*, Nairobi, CIMMYT.

Schulz, S.; Hussaini, M. A.; Kling, J. G.; Berner, D. K., and Ikie, F. O. (2003). Evaluation of integrated Striga hermonthica control technologies under farmer management. Exp. *Agric., 39: 99-108.*

Shah, N.; Smirnoff, N., and Stewart, G. R. (1987).Photosynthesis and stomatal characteristics of *Striga hermonthica* in relation to its parasitic habit. *Physiologic plant arum*, ***69****: 699-703.*

Spallek, T.; Mutuku, J. M. and Shirasu, K. (2013). The genus *Striga*: a witch profile. *Molecular plant pathology DOI: 10.1111/mpp.12058.*

Shayoub, M.; Haj, E.; Makawy, A.; Rasha, R., and Mona, A. (2013). Adverse reaction of *Solenostemma argel* leaves, extraction and alkaloids tablets administered to patients. Global *J. Trad Med Sys*, *2(1):14-18*.

Sulieman, A. E.; Elzobair, W. M. and Abdelrahim, A. M. (2009).Antimicrobial activity of the extract of Solenostemma argel plant. *J. Sci. and Techno. 10(3): 104-115*.

Taylor, J. R. N. (2006). Overview: Importance of Sorghum in Africa. In(ed) Brink, M; Belay, G., Cereals and pulses, CTA, Wageningen, Netherlands.

Teka, H. B. (2014). Advance research on *Striga* control: A review Ethiopia Institute of Agriculture Research. *African journal of plant science, 8* (***11***)*: 492-506.*

Templeton, G. E. (1982). Status of weed control with plant pathogens. P.29-44, in: Charudattan, R. and Walker, H. L. (eds). *Biological control of weeds with plant pathogens. Wiley, New York.*

Tesso, T.; Zenbaba, G.; Aberra, D, and Ejeta, G. (2007). An integrated *Striga* management option offers effective control of in Ethiopia. In: Ejeta, G. and Gressel, J. (eds). Integrating new technologies for Striga control: towards ending the witch-hunt. *World scientific publishing Co., Singapore. pp. 199-212.*

Udom, G. N.; Babatunde, F. E. and Tenebe, V. A. (2007). Suppression of witch-weed (*Striga hermonthica*) in Sorghum: cowpea mixture as affected by cowpea varieties and planting patterns. Int. *J. Agric. Res., 2: 268-274.*

Umba, U.; Dashiell, K.; Berner, D. and Ebong, U. U. (1999).Effect of soybean cultivars on *Striga* emergence and yield of the subsequent maize crop.Proceedings of regional maize workshop, 4-7th May, 1999, IITA Cotonou, Republic of Benin., pp. 321-329.

Van Ast, A. and Bastiaans, L. (2006).The role of infection time in the differential response of Sorghum cultivars to *Striga hermonthica* infection. Weed Res., 46: 264–274.

Vasey, R. A.; Scholes, J. D. and Press, M. C. (2005). Wheat (Triticum aestivum) is susceptible to the parasitic angiosperm *Striga hermonthica*, a major cereal pathogen in Africa. *Phytopathology, 95: 1294-300.*

Watson, A. K.; Ciotola, M. and Peden, D. (1998).Controlling of the noxious *Striga* weed. International development research centre, Ottawa, Canada. *Weed Res., 35: 303-309.*

Watling, J.R. and Press, M.C. (2001). Impacts of infection by parasitic angiosperms on host photosynthesis. Pant Bio. 3:244-250

Wegdan, I. M. (2016). Allelopathic Effect of Argel (*Solenostemma argel* L.) Additives on seed germination and vigour of two snap bean (*Phaseolus vulgaris* L.) Cultivars. *M.Cs. Thesis*, *College of Agric. Studies*, *SUST*.

Welsh,A. B., and Mohamed, K. I. (2011). Genetic diversity of *Striga hermonthica* population in Ethiopia: Evaluating the role of geography and host specificity in shaping population structure. *International journal plant Sciences, 173: 773-782.*

Westerman, P. R.; Van Ast; A.; Stomph, T. J. and Van Der Werf, W. (2007). Long-term management of the parasitic weed *Striga hermonthica*: Strategy evaluation with a population model. *Crop Prot., 26: 219-227.*

Wolfe, A. D.; Randle, C. P.; Liu, L. and Steiner, K. E. (2005).Phylogeny and biogeography of Orobanchaceae.Folia Geobotanica 40, 115.

Yoder, J. I. (1997). A species specific recognition system directs haustorium development in the parasitic plant Triphysaria (Scrophulariaceae). *Planta, 202: 407-413.*

Yoder, J. I. (1999). Parasitic plant responses to host plant signals: a model for subterranean plant-plant interactions. Curr. O. *Plant Biol., 2: 65-70.*

Yoder, J. I. (2001). Host plant recognition by parasitic Scrophulariaceae.Curr. O., *in Plant Biol., 4: 359-365.*

Yonli, D.;TraoreH.; Sereme P. and Sankara P.(2010). Use of local plant aqueous extracts as potential bio-herbicides against *Striga* *hermonthica* (Del.) Benth. in Burkina Faso. *Asian journal of crop science, 2: 147-154.*

Zerihun, S. (2016).Effect of nitrogen fertilizer on Striga infestation, Yield related traits in Sorghum [(Sorghum bicolor (L.) Moench]varieties at Kile, Eastern Ethiopia. *Journal of biology*, *Agriculture and healthcare, 6(2): 2224-3208 P*.