بسم الله الرحمن الرحيم

Sudan University of Science and Technology
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Effects of Intercropping Pearl Millet with Some Legumes on *Striga hermonthica* Emergence and Millet Growth

تأثير زراعة تحميل الدخن مع بعض البقوليات علي ظهور البودا ونمو الدخن

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

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الآيـة

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قال تعالى:
(أَوَلَمْ يَرَوْا أَنَّا نَسُوقُ الْمَاءَ إِلَى الْأَرْضِ الْجُرُزِ فَنُخْرِجُ بِهِ زَرْعًا تَأْكُلُ مِنْهُ
أَنْعَامُهُمْ وَأَنْفُسُهُمْ ۖ أَفَلَا يُبْصِرُونَ)

السجدة 27

Dedication

To the Fountain of happiness and peace, which was a symbol of fulfillment and Tenderness by bringing out herself and her love, will come joy in myself.

My Mother

Oh symbol of giving and fulfilling to you my sincere invitation deeds

My Father

To who planted the love and intimacy between our hearts and struggled for the sake of science and knowledge.

My sisters

My brother

My *Son*

My friends

To all my teachers in department of Agronomy.

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Abstract

Striga spp, pose a severe problem to agriculture. They impose significant losses in yields of staple food crops in sub-Saharan Africa and thus a genuine threat to food security. Furthermore, they are difficult to control by conventional methods. Green house experiment was undertaken during the season 2015/2016, at the College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Khartoum North to determine the effects of intercropping pearl millet (Sudan Brawn and Wad-Elbashir cv.) with cowpea, green gram, and cluster bean on *Striga* millet strain incidence and pearl millet growth. Treatments were arranged in Complete Randomized Block Design (CRBD) with three replicates. The results showed that *Striga* emergence on millet cultivars displayed a progressive increase with seed bank size. *Striga* number was generally lower in the intercrops than in the sole millet. Sole millet displayed highest *Striga* number. Cowpea intercropped with millet cultivars (Wad–Elbashir and Sudan Brown) at seed bank size of 32 and 64mg/pot, reduced *Striga* emergence by 57.1 -100%. Intercrops cluster bean with millet cultivars at *Striga* seed bank size of 32 mg/pot completely suppressed *Striga emergence* throughout the experiment. However, at *Striga* seed bank size of 64 mg/pot intercropping cluster bean with millet decreased *Striga* number by 28.3-70.9%. Green gram intercropped with millet cultivars, irrespective of seed bank size caused considerable reductions of *Striga* number (14.8-76.7%). All intercrops reduced *Striga* dry weight, in comparison to the sole millet. Cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size and millet cultivars reduced *Striga* dry weight by (70.4-72.6%), (40.9-82.1%) and (36.4-81.2%), respectively.

At 90 DAS, intercropping cowpea with Wad-Elbashir cultivar, at *Striga* seed bank size of 32mg/pot increased significantly millet height by 82.4%, as compared to the sole millet. Intercropped Sudan Brown cultivar with cowpea and cluster bean at *Striga* seed bank size of 32mg/pot increased millet height by 35.7 and 35.1%, respectively. Intercropped Wad-Elbashir cultivar with cowpea, irrespective of *Striga* seed bank size, increased number of leaves (32.3-72.0%). At *Striga* seed bank size of 32mg/pot number of leaves in Sudan Brown cultivar increased significantly when intercropped with cowpea by192.8%, as compared to the sole millet. However, intercropping with cluster bean at *Striga* seed bank size of 64mg/pot, the number of leaves increased (46.7%), but not significantly. Intercropping with cowpea and cluster bean, irrespective of *Striga* seed bank size and millet cultivars, decreased number of tillers, but not significantly, as comparison to the sole millet. However, intercropping millet cultivars with green gram displayed complete reduction in number of tillers. All intercrops did not reduce stem diameter of millet cultivars, as compared to the sole crop. Intercropping Wad–Elbashir with cluster bean, at *Striga* seed bank size of 64mg/pot, decreased chlorophyll content significantly (34.4%), as compared to the corresponding control. All intercrops reduced Sudan Brown chlorophyll content, but not significantly. At *Striga* seed bank size of 32mg/pot, intercropping Wad-Elbashir cultivar with cowpea and cluster bean increased millet dry weight by 31.3 and 62.5%, respectively, as compared to the sole millet. However, at *Striga* seed bank size of 64/pot, Wad-Elbashir dry weight increment by 54.1 and 41.6% when intercropped with cowpea and green gram, respectively. Intercropping Sudan Brown cultivar with cowpea, cluster bean and green gram, at *Striga* seed bank size of 32 and 64 mg/pot, displayed non-significant reductions in millet dry weight and the observed reductions were (19.0-31.7), (22.4-27.6) and (32.8-39.7%), respectively, in comparison to the un-infested control.

الملخص

تشكل البودا مشكلة خطيرة للزراعة وتسبب خسائر معنوية في انتاج المحاصيل الغذائية الأساسية في أفريقيا جنوب الصحراء، وهي بالتالي تعتبر مهدداً رئيسياً للأمن الغذائي. بالإضافة إلي ذلك، فهي تصعب السيطرة عليها بالطرق التقليدية. أجريت تجربة مشتلية بجامعة السودان للعلوم والتكنولوجيا، كلية الدراسات الزراعية بشمبات- شمال الخرطوم خلال موسم (2016/2015م). وذلك لمعرفة أثر زراعة التحميل ما بين أصناف الدخن (ودالبشير وسودان براون) مع اللوبيا حلو، اللوبيا الذهبية والقوار علي إنبثاق بودة سلالة الدخن ونمو الدخن. تم إستخدام القطاعات العشوائية الكاملة بثلاثة مكررات. أظهرت النتائج أن إنبثاق البودا علي أصناف الدخن يزداد بزيادة مخزون البذور. بصفة عامة تقل أعداد البودا عند زراعة التحميل وذلك مقارنة بزراعة الدخن منفرداً، حيث أعطي الدخن منفرداً أعلي عدد من البودا. أدت زراعة التحميل مابين أصناف الدخن (ودالبشير وسودان براون) مع اللوبيا حلو عند مخزون البذور 32 و64 ملجرام/ الأصيص إلي خفض إنبثاق البودا بنسبة 57.1-100%. تسببت زراعة التحميل مابين القوار وأصناف الدخن عند مخزون البذور 32 ملجرام/الأصيص في منع ظهور البودا تماماً خلال التجربة. بينما كان مخزون البذور 64 ملجرام/الأصيص، أدت زراعة التحميل مابين القوار وأصناف الدخن إلي تقليل أعداد البودا بنسبة 28.3-70.9%. أدت زراعة التحميل مابين اللوبيا الذهبية وأصناف الدخن، بغض النظر عن مخزون بذور البودا إلي خفض مقدر في أعداد البودا (14.8-76.7%). أدت كل محاصيل التحميل إلي تقليل الوزن الجاف للبودا وذلك مقارنة بزراعة الدخن منفرداً. أدت زراعة التحميل مابين اللوبيا حلو، القوار واللوبيا الذهبية مع أصناف الدخن إلي خفض الوزن الجاف للبودا بنسب (70.4-72.6%)، (40.9-82.1) و (36.4-81.2%)، علي التوالي. بعد 90 يوم من الزراعة أدت زراعة التحميل مابين اللوبيا حلو وصنف ودالبشير، عندما كان مخزون بذور البودا 32 ملجرام/الأصيص إلي زيادة

معنوية في طول الدخن بنسبة 82.4% وذلك عند مقارنتها بالدخن منفرداً. أعطت زراعة التحميل مابين صنف سودان براون مع اللوبيا حلو والقوار، عندما كان مخزون البذور 64 ملجرام/الأصيص إلي زيادة في طول النبات بنسب 35.7 و 35.1%، علي التوالي. نتج عن زراعة التحميل مابين صنف ودالبشير مع اللوبيا حلو، بغض النظر عن مخزون البذور إلي زيادة في عدد الأوراق (32.3-72.0%). عندما كان مخزون البذور 32 ملجرام/الأصيص، إزداد عدد أوراق صنف سودان براون زيادة معنوية بعد زراعة التحميل مع اللوبيا حلو وذلك بنسبة 192.8%، وذلك عند مقارنتها بالدخن منفرداً. بينما أدت زراعة التحميل مع القوار عند مخزون البذور 64 ملجرام/الأصيص إلي زيادة غير معنوية (46.7%). أدت زراعة التحميل مع اللوبيا حلو والقوار، بغض النظر عن مخزون بذور البودا واصناف الدخن الي خفض عدد الخلف، لكن بصورة غير معنوية. بينما نتج عن زراعة التحميل ما بين اصناف الدخن واللوبيا الذهبية خفض كامل في عدد الخلف. لم تؤدي كل محاصيل التحميل إلي تقليل قطر ساق أصناف الدخن، مقارنة بالدخن منفردا. زراعة التحميل مع القوار، عند مخزون بذور البودا 64 ملجرام /الأصيص أدت إلي خفض محتوي الكلورفيل معنوياً (34.3%)، وذلك مقارنة بالشاهد. أدت كل محاصيل التحميل إلي خفض محتوي الكلورفيل في سودان براون ولكن بصورة غير معنوية. عندما كان مخزون البذور 32 ملجرام /الاصيص، نتج عن زراعة التحميل ما بين صنف ود البشير مع اللوبيا الحلو والقوار زيادة في الوزن الجاف للدخن بنسب 31.3 و62.5%، علي التوالي، وذلك مقارنة بالدخن منفرداً. بينما كان مخزون بذور البودا 64 ملجرام /الأصيص، إزداد وزن ود البشير الجاف بنسب 54.1 و 41.6% عند زراعته مع اللوبيا الحلو واللوبيا الذهبية، علي التوالي. أدت زراعة التحميل ما بين صنف سودان براون مع اللوبيا حلو، القوار واللوبيا الذهبية، عندما كان مخزون بذور البودا 32 و64 ملجرام /الأصيص إلي خفض غير معنوي في الوزن الجاف للدخن، وكان ذلك بنسب (19.3- 31.7)، (22.4 -27.6) و (32.8 - 39.7)، علي التوالي وذلك مقارنة بالشاهد الخالي من البودا.

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List of Abbreviations

%	Percent
ºC	Degree centigrade
cm	centimeter
g	gram
mg	milligram
L	Litre
SE	Standard Error
h	hours
ha	hectare
CV	Coefficient of variation
et al	and others
DAS	Days after sowing
No.	Number

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CHAPTER ONE

Introduction

Pearl millet *Pennisetum americanum* (L.) belongs to family Poaceae, it is one of the most widely cultivated cereals in the world, ranking sixth after rice (*Oryza Sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), barley (*Hordeum vulgare* L.) and sorghum ((*Sorghum bicolor* L) in terms of area planted to these crops (Khairwal *et al*., 2007). Pearl millet originated in tropical western Africa, the greatest numbers of both wild and cultivated forms of this species occur in this region. It is a principal cereal cultivated in tropical semi-arid regions of the world primarily in Africa and Asia (Vanisha *et al*., 2011**)**. It is an important food and forage crop of Africa, Asia and America (Dakheel *et al.,* 2009; Newman *et al.,* 2010). Pearl millet is extensively used in different countries as forage of high nutritional quality (Maiti and Rodriguez, 2010). However, the use of pearl millet as a food crop is limited to the developing countries in Asia and Africa. It is estimated that over 93% of pearl millet grain is used as food, the remaining divided between animal and poultry feed (7%) (Khairwal *et al*., 2007). Pearl millet is a source of energy, protein, vitamins and minerals for millions of poorest people in the regions where it is cultivated. It generally has 9 to13% proteins, but large variation among genotypes ranging from 6 to 21% (Khairwal *et al*., 2007).

Pearl millet is a climate hardly crop which is grown in harsh conditions, but as a subsistence crop. Currently this crop is cultivated on about 18 million hectares in Africa, which is 56% of the 32 million hectares of the world pearl millet growing area (FAO, 2011). Total millet production in Africa during 2011 was 11 million tons with an average yield of about 0.6 t ha^{-1}, much lower than its potential yield of 3.5 t/ ha^{-1}.

Millet is the second most important cereal crop, following sorghum, with about 12.4% share in total annual cereal production in the Sudan (FAO-SIFSIA, 2010), but the third most important in terms of total availability and consumption (FEWS NET, 2015). On average, over 90 percent of millet production is grown in traditional production systems (FSTS, 2014). Pearl millet is the preferred staple food for the majority of inhabitants in Western Sudan (Kordofan and Darfur regions). A large share of local millet production is also believed to be used as horse feed, particularly in urban areas (FEWS NET, 2015).

Pearl millet yield is by far below the international average (Babiker, 2007). Paramount, among yield reducing factors, is poor soil fertility, low inputs and heavy infestations by root parasitic weed *Striga hermonthica* (Del.) Benth. are of paramount importance (Babiker, 2007). *Striga* spp. are prevalent in over 50 million hectares of the cereals growing areas in Africa and inflict considerable damage amounting to complete crop loss under heavy infestations (Welsh and Mohamed, 2011). In Sudan *S. hermonthica* is a major biological constraint to the production of the staple crops of the majority, mainly sorghum and pearl millet (Ayman *et al*., 2014). *S. hermonthica*, well adapted to its environment and tolerant to a wide range of temperature and soil moisture stress, has developed two distinct strains. The first, specific to pearl millet, is predominant in the drier northern regions of sub-Saharan Africa, while the second attacks sorghum and is found farther south in the wetter regions (Welsh and Mohamed, 2011). *S. hermonthica* sorghum and millet strains differ in their response to natural germination stimulants (Parker and Riches, 1993). The sorghum strain is more responsive to the strigol-type SLs, while the millet strain is less responsive to the strigol type (Parker and Reid, 1979; Cardoso *et al*., 2014).

Many potential control methods were developed against the parasite including physical, cultural, chemical, and biological. However, so far these methods have only a limited impact on controlling *Striga* and today there is no single control method that can effectively solve this problem. Cost effective alternative control methods that are acceptable to small-scale farmer are needed. The roots of several legumes are known to induce suicidal germination of Striga seeds. The potentials of cereal-legume intercropping and rotation to manage *Striga* infestation in cereals has been demonstrated under controlled, researcher managed conditions. The effectiveness of cereal/legume intercropping to influence *Striga* germination depends on the effectiveness of the produced stimulant/inhibitors, root development, fertility improvement, shading effect and its compatibility to *Striga* species because the response of *Striga* to management options is specific (Mbwaga *et al*., 2001).

The objective of this study is to determine the effects of intercropping pearl millet cultivars (Sudan Braun and Wad-Elbashir cv.) with different legumes via cowpea (*Vigna ungiculata* (L.) Walp), green gram (*Vigna radiata* L.), and cluster bean (*Cyamopsis tetragonoloba* L.) on suppression of *S. hermonthica* mille strain parasitism and pearl millet growth.

CHAPTER TWO

LITERATURE REVIEW

2-1. Millet

Millets are small-seeded cereals having excellent nutritional quality. They are comparable or superior to some commonly consumed cereals like wheat and rice (Ragaee *et al*., 2006). It plays a major role in the food security and economy of many less developed countries in the world. They are commonly cultivated in India, Africa and China. Millets ranks as the sixth most important cereal and feeds one third of the total world population (Saleh *et al*., 2013). They are easy to cultivate, inherently bio-diverse and can be grown together with varied crops (Dendy 1995). Another attributes of millets that make them a preferred choice in areas where they are cultivated, are their short harvest period (45-65 days) (Bukhari *et al*., 2011).

Millet refers to a number of different species, all of which are small-grained, annual cereal grasses (Macrae *et al*., 1993). Pearl millet is the most widely grown type of millet. Because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature, it can be grown in areas where other cereal crops, such as maize or wheat, would not survive. Pearl millet production is concentrated in the developing countries which account for over 95% of the production and acreage (Basavaraj *et al*., 2010). India is the largest producer of pearl millet in Asia and is mainly grown in northwestern parts (Dendy 1995; Obilana, 2003). In Africa, pearl millet production is concentrated in Sahara and drier areas of northern and eastern Africa (Obilana, 2003).

In Sudan, Pearl millet, locally known as "Dukhun", is one of the important cereal crops, coming as the second most-important cereal crop, after sorghum, in both area and total production. It is the preferred staple food crop for the majority of the inhabitants of western Sudan (Kordofan and Darfur States). The average total area annually planted in the country is about 6 million feddans (2.5 million ha). About 95% of this area is found in Western Sudan. The grain is consumed as human food mainly in the form of porridge, called "aseeda" or in the form of a thin pancake called "kisra". The stalks can be used as feed for animals but they are mostly used as building material or fuel. A large share of local millet production is also believed to be used as horse feed, particularly in urban areas.

2-2. *Striga*

Striga species, so-called witchweeds, are obligate root hemi-parasites belonging to the family Orobanchaceae, and represent the biggest weed threat to agriculture of sub-Saharan Africa. *Striga* possibly originates from a region between the Semien Mountains of Ethiopia and the Nubian Hills of Sudan (Atera and Itoh, 2011). *Striga hermonthica* and *Striga asiatica*, which infect sorghum, maize, millet, and upland rice cause considerable yield losses (Ejeta, 2007). Crops such as wheat previously unaffected by *Striga* are now showing serious infestation in Sahel (Ejeta, 2007). During the last 20-30 years, it has attained devastating proportions due to cereal mono-cropping (Oswald, 2005). Cereal yield losses due to *Striga* attack vary from about 10% to complete crop loss and total abandonment of cereal production in severely infested fields (Gressel *et al*., 2004). Most of the yield loss (about 75%) occurs before *Striga* emergence (Parker and Riches, 1993). These losses largely depend on *Striga* density, host species and genotype, land use system, soil nutritional status and rainfall patterns (Atera *et al*., 2012). The most affected are the poor subsistence farmers, who are not aware of the threat that *Striga* poses to their land quality and food security as the weed continues to increase its soil seed bank and spreading to new areas.

2-2-1. *Striga hermonthica* strains:

S. hermonthica, the most important parasitic flowering plants in Africa, is reported to have several strains and physiological variants (Bebawi, 1987). This species has developed strains specific to sorghum and millet (Wilson-

Jones, 1955). These are morphological similar but have consistent floral variations. The millet-strain has smaller dull pink corolla and the sorghum strain has a larger pink corolla (Mohamed and Musselman, 2008). The two strains differ in ability to attack sorghum and millet. *S. hermonthica* in Sudan, where inter-species specificity for sorghum and pearl millet was previously found (Wilson-Jones, 1955), changes in the region growing pearl millet in the 1980s resulted in the gradual appearance of *S. hermonthica* virulent on pearl millet, where previously there had been specificity for sorghum (Ejeta, 2007). This phenomenon suggests that *Striga* host specificity can be based on regional separation of crop cultivation, which can break down when these patterns are disrupted, suggesting that *S. hermonthica* adaptations to host species may change on a scale of years rather than tens of years. However, in the western Eritrea region of Ethiopia, sorghum and pearl millet are grown in the same areas, but *Striga* is reportedly not currently parasitic on pearl millet (Ejeta, 2007); this may be due to the suggested lag phase for *S. hermonthica* populations switching between sorghum and pearl millet (Parker and Riches, 1993), suggesting that adapting to both species simultaneously may also take time (Estep *et al.*, 2011).

Parker and Reid (1979) have since confirmed the existences, of the two distinct strains in West Africa. Wilson-Jones (1955) attributed the observed host specificity to different germination requirements. The root exudates of either host fails to stimulate the strain of the other. It is possible that the specific germination requirements of each strain are rein-forced by an in ability to develop on the alternative host even after germination.

2-2-2. *Striga* life cycle

Striga spp. have a very complex life cycle, which is intimately tied to that of its host and that follows a series of developmental stages from seed to seed producing plants (Plate 2.1). *Striga* species produce thousands of tiny seeds that remain viable in the soil for several decades. These dust-like seeds are easily dispersed by wind, crop seeds, water and people. In addition, *Striga* seeds can survive for more than 10 years before germination (Atera and Itoh, 2011). *S. hermonthica* seeds are very small (0.2 × 0.3 mm), light weight (0.4–0.5 × 10^{-2}mg) and one plant can produce up to 200,000 seeds (Parker and Riches, 1993). Normally seeds mature and are shed onto soil towards the end of the rainy season. Freshly harvested seeds remain dormant for several months depending on the species, strains and environmental conditions under which the seeds were produced (Ejeta *et al.*, 1993). This period is referred to as after –ripening. *Striga* seeds remain dormant until they are exposed to host-derived germination stimulants called strigolactones (Shen *et al.*, 2006). Strigolactones had been known to induce germination in certain parasitic plants for around 25 years before it was discovered that this class of chemicals was also involved in plant shoot branching, and in inducing the branching of mycorrhizal fungi in the soil (Yoder and Scholes, 2010). However, before the parasite seeds can respond to these stimuli and germinate they require a pre-treatment at a suitable temperature (25-35 °C) under moist conditions, for 7–14 days, a treatment known as preconditioning (Joel *et al.*, 1995). After the conditioning period, the parasite seeds will germinate only if exposed to sufficiently high concentrations of germination stimulants hence assuring that germination only occurs in close vicinity of the host root. Exogenous germination stimulants (strigolactones) are produced by the host root and also by some non-host (usually referred to as trap crops) roots. A germinated *Striga* seedling forms a specialized attachment and penetration organ called a haustorium in response to host-derived haustorium induction factors, which include various phenolic acids, quinones, and flavonoids (Yoder, 2001). When the seed have been germinated the seedling can live for 3 to 7 days without a host. After that it will die if it is not attached to a root and there has been able to create a parasitic link to that particular root. A xylem-xylem connection is created between the haustorium and the host plant, in that way the seedling can withdraw water and nutrients from the host plant (Cardoso *et al*., 2010). After successful attachment and penetration of a host root, the parasite will develop a so-called tubercle that helps to accumulate nutrients. At a certain stage it forms a shoot, emerges above the soil, flowers and produces seeds after which the lifecycle can start again (Plate 2.1) (Sun, 2008).

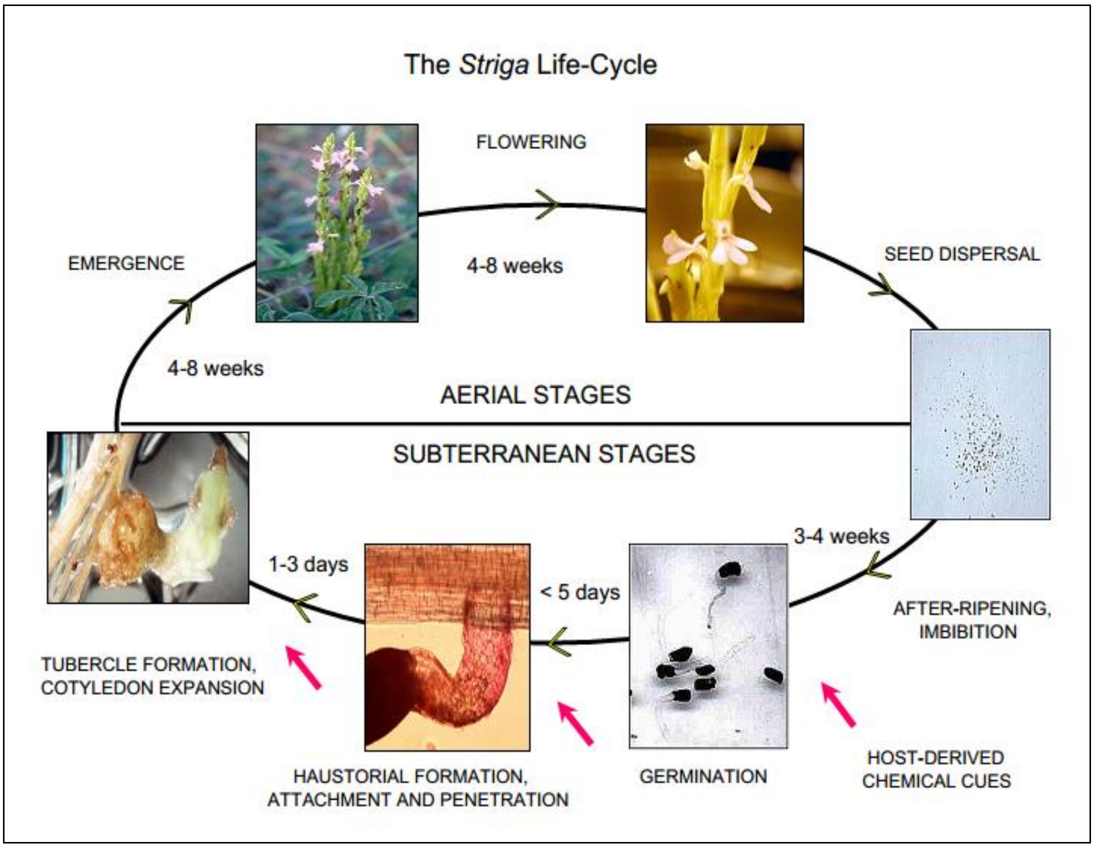

Plate 2.1. *Striga* life cycle (F*aculty.virginia.edu/timko*)

2-2-3. Impact of *S. hermonthica* on the host

Striga spp. has marked effects on growth and yield of their hosts. The parasite is more damaging and debilitating under drought and low soil fertility conditions (Oswald, 2005). The common name witchweed, synonymous with the Latin name *Striga*, befits the debilitating and bewitching effects the parasite inflicts on its hosts even before it emerges and becomes visible above the ground (Parker and Riches, 1993). Grain yield losses even can reach 100% in susceptible cultivars under a high infestation level and drought conditions (Haussmann *et al.*, 2000). According to estimated by Gressel *et al*., (2004), 17.2 million hectares (64% of the total area) of sorghum and pearl millet production in West African are infested with *Striga*. The magnitude of the loss in yield due to the parasite is determined by the level of *Striga* infestation, soil fertility, agro-climatic conditions, land use system, the plant species and the host genotype (Oswald and Ransom, 2004). Symptoms displayed by infected hosts include stunting, reduction in internodes expansion, wilting, chlorosis, increased root to shoot ratio, reduced photosynthetic rate, increased photorespiration and decreased growth and yield (Parker and Riches, 1993). The impact of *Striga* on infected cereals is only partly attributable to competition between host and parasite for resources.

2-2-3. *Striga* control and management

The tremendous impact of parasitic plants on world agriculture has prompted much research aimed at preventing infestation. Many potential control methods were developed against the parasite problem including physical, cultural, chemical and biological (Joel, 2000). So far these methods however have only had a limited impact on controlling the menace of the parasites and today there is no single control method that can effectively solve this problem (Ejeta, 2005). In Sudan, a number of control measures for *Striga* have been adopted by the farmers such as cultural practices, fertilizers, herbicides, germination stimulants, resistant varieties and biological control. Cultural practices include hand pulling, sowing date, planting method, intercropping, catch cropping and crop rotation with emphasis on trap crops. However, it has been proved to be difficult to find selective products to control the parasite and each of them has one or more limitations that have led to low farmer adoption (Ahmed and Alamun, 2010). *Striga* seeds can easily be transferred from one field to another by cultivation, and also by water, wind, and animals. However, the most significant seed transfer agents are people, transportation vehicles, and farming machines, which easily transfer seeds and contaminated soil. Once a field is infested with parasitic weeds, controlling its seed production is very difficult. Extermination of seeds before their spread to new fields and regions is a crucial component in parasitic weed prevention program (Panetta and Lawes, 2005). Preventing the movement of parasitic weeds from infested into un-infested areas is a crucial component of control. Both sanitation and quarantine are required in order to prevent the dispersal of seeds.

2-2-3-1. Cultural practices:-

Striga cultural control strategies should maintain or increase grain yield, reduce the parasite soil seed bank and reduced parasitism. The cultural methods of control include, hand-pulling, crop rotation, trap-crops, catch-crops and intercropping.

2-2-3-1-1. Hand weeding

Hand weeding can only be recommended in cases of limited infestation to prevent any further increase in the parasite population and to reduce the seed bank in the soil. The removal of mature plants prevents the increase of the parasitic weed seed bank. However, when the parasite emerges from the soil, most of the damage to the host crop has already occurred. However, even when hand weeding is still commonly used in some countries where no other feasible means of control are available and the wages for labor are cheap, it is only practical in preventing build-up of parasite seeds in slightly infested soils (Rubiales and Aparicio, 2012).

2-2-3-1-2. Crop rotation

Rotation of infested land into non-susceptible crops or into a fallow is theoretically the simplest of all solutions. Rotating *Striga* susceptible crops with those that stimulate *Striga* germination without being parasitized (trap crops), has long been advocated as an efficient measure for reducing *Striga* seed bank (Joel *et al*., 2007; Parker and Riches, 1993). Ahonsi *et al.* (2002) reported that in West

Africa, rotating *Striga* susceptible cereals with leguminous crops has been decrease *Striga* seed bank and increase yield of subsequent cereal crops. Several legumes via soybean (*Glycine max* Merr.), groundnuts (*Arachis hypogaea* L.), pigonpea (*Cajanus cajan* Mill sp.) have been reported to stimulate suicidal germination of *Striga* (Parker and Reid, 1979). The increase in yield due to millet-cowpea rotation was 37% as compared to three or five year's continuous millet cropping (Samak, 2003).

2-2-3-1-3. Trap crops

Trap crops are commercially valuable crops that are able to reduce the seed bank of parasitic plants. The use of trap crops, which induce the germination of *Striga* seeds but without being parasitized, is one of the most promising methods and culturally acceptable (Botanga *et al*., 2003). Certainly, the trap cropping induces suicidal germination and leads to depleted *Striga* seed bank. Trap crops as a control technique should be included in the regular rotation and fallow management of infested fields and integrated with other control measures. Common cultivated trap crops include cotton (*Gossypium barbadense*), groundnut, soybean, pigeonpea, green or black gram (*Vigna mungo*), lucerne (*Medicago sativa*), sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*) (Babiker, 2007). Trap crops cannot be expected to eliminate the seed bank in the soil immediately (Fernández-Aparicio *et al*., 2011). Work in Western Kenya showed that 4 years of continuous cropping with cowpea or cotton did not reduce *Striga* infestation below damaging levels (Odhiambo and Ransom, 1996).

2-2-3-1-4. Catch cropping

Catch crops are rotational crops, which are susceptible to attack by parasite and usually have economic disadvantage, but have sometimes been technically more successful than trap crops (Parker and Riches, 1993). It is another mean of depleting *Striga* seed reserves in soils. Catch crops are planted to stimulate a high germination percentage of the parasite seeds but are destroyed or harvested before the parasite can produce the seeds (Teka, 2014).

2-2-3-1-5. Nitrogen fertilization

Low fertility of soil is considered to be an important factor associated with severe infestation of fields by weedy root parasites. Good soil management practices involving the use of crop residues, organic manure, and nitrogen or phosphorus application can contribute to an effective control of parasitic weeds (Jain and Foy, 1992; Etagegnehu and Rungsit, 2004). The application of phosphate or nitrogen to deficient soil has been reported to reduce *S. hermonthica* on sorghum (Ayongwa *et al*., 2006). The use of nitrogen to suppress *Striga* has been demonstrated in the East and Central African highlands (Esilaba *et al*., 2000; Gacheru and Rao, 2001). Mumera and Below (1993) found that *Striga* infection generally declined with increasing N availability, the impact was partially dependent on the severity of infestation. Application of high dosage of nitrogen fertilizer is generally beneficial in delaying *Striga* emergence and obtaining stronger crop growth (Dugie *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).

2-2-3-1- 6. Resistance crop varieties

Resistant varieties should provide the simplest, the easiest and the cheapest method for *Striga* control. Resistance is the process by which host withstand the parasite attack in a manner that prevent parasite establishment and growth, whereas tolerance involves the ability to endure damage inflicted by the parasite (Eizenberg *et al*., 2013). Full immunity of host plants to *Striga* or *Orobanche* has not yet been found. Crop cultivars with resistance to *Striga* have long been suggested as a cost-effective method of reducing *Striga* related losses that would be combatable with the low input farming system predominant in sub-Saharan Africa (Joel *et al*., 2007). Several resistant crop varieties are used nowadays in various parts of Africa, Europe and Asia. Genetic variation for low *Striga* germination stimulant production in sorghum is used to breed for *Striga*-

resistant varieties and introduce them into high yielding sorghum cultivars in several African countries (Ejeta, 2007). Some host genotypes, particularly wild relatives of sorghum (Rich *et al*., 2004), have a reduced ability to initiate haustoria. In the latter case, this is likely to be due to production of low amount of haustorial inducing factor (Gurney *et al*., 2003). In other cases low haustorial initiation may be due to the production of inhibitors, but this is a little researched area at present (Rich *et al*., 2004). Few pearl millet cultivars have been reported as partially resistant or tolerant to *Striga*, and resistance (or at least a lower level of susceptibility) in certain pearl millet materials was shown to be dominant (Ramaiah, 1987). Lack of precise and validated information about *Striga* resistance in pearl millet may be partially due to the fact that the pearl millet/*S. hermonthica* pathosystem is particularly complex. Both host and parasite are highly out-crossing species, which results in each plant in a pearl millet landrace, improved open-pollinated variety or genepool population having a different genotype and therefore carrying potentially different alleles for *Striga* resistance or susceptibility. Similarly, each S. *hermonthica* plant in a natural population carries potentially different alleles for virulence. Partial quantitative resistance to *S. hermonthica* was reported in wild pearl millet relatives from Africa (Wilson *et al*., 2000, 2004).

2-2-3-1-7. Intercropping

Intercropping as agriculture practice and cultivation of two crops or more in the same space and at the same time. Accordingly, intercropping promotes the interaction between the different plants (Sullivan , 2003). Intercropping increases yield per unit of land by more efficiently using natural resources and increases to labor and spreads labor bottlenecks. It also improves control of diseases, pests, and weeds, and reduces soil erosion and water runoff (Andrews, 1987).

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). Intercropping with a false host crop that stimulates *Striga* seed germination without being itself attacked or parasitized, has been thought as a method for depletion of *Striga* seed reserves in soil (Parker and Riches, 1993). The roots of several legumes are known to induce suicidal germination of *Striga* seeds, and this feature has become incorporated into *Striga* suppression strategies involving cereal-legume rotation or intercropping. Intercropping cereals with legumes and other crops is a common practice in most area of Africa, and has been reported as influencing *Striga* infestation (Teka, 2014).

Khan *et al*. (2008) discovered a new and highly effective intervention against *Striga* spp. in cereals, which involves intercropping with the fodder legumes, *Desmodium* spp. Root exudates of *D. uncinatum* (Jacq.) DC. contain novel flavonoid compounds, some of which stimulate germination of *S. hermonthica* and others dramatically inhibit its subsequent development, including radicle extension. *Desmodium* spp. have been developed as intercrops for maize, sorghum and millet (Khan *et al.*, 2008). *Desmodium* suppress *Striga*, not only by producing a germination stimulant, but also by producing chemicals that interfere with the development of haustoria (Khan *et al.*, 2002). Intercropping cereal with cowpea in the same row gave the highest yield in Cameroon and in Ethiopia (Mbwaga *et al*., 2001). The effectiveness of cereal/legume intercropping to influence *Striga* germination depends on the effectiveness of the produced stimulants/inhibitors, root development, fertility improvement, shading effect and its compatibility to *Striga* species (Mbwaga *et al*., 2001).

Intercropping sorghum with *Lablab purpurpeus* (L) reduced *Striga* infestation, dry weight, number of capsules and increased sorghum yield and yield components (Babiker, 2002). Delayed planting of the intercrop reduced the efficiency of *Striga* control. Abunyewa and Padi (2003) provided evidence that introduction of food legume on farmlands with high *S.*

hermonthica infestation as an alternative to bush fallow system could help achieve sustainable crop production in the Sudan savannah zones. Soybean was more effective in reducing *Striga* infestation and also gave higher maize grain yield than cowpea (Kureh *et al*., 2006). Tenebe and Kamara (2002) showed evidence that performance of intercropped sorghum was significantly better than that of the monoculture in terms of plant height, dry matter, leaf number and leaf area index. Reda *et al*. (2005) illustrated that ten food legume and oilseed crop species were compared in inter-row arrangement with sorghum under non-fertilized conditions. He concluded that there was a positive significant impact of intercropping on sorghum growth and development. However, contrasting results were reported by Esilaba (2006) where cereal crop yields were significantly reduced by intercropping. De-Groote *et al*. (2010) found that soybean trigger suicidal germination of *Striga* and reduces the *Striga* seed bank in the soil when intercropped with maize.

Work in Sudan showed that 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).

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).

CHAPTER THREE

Material and methods

3-1. General

A series of greenhouse experiment was undertaken at the College of Agricultural Studies, Sudan University of Science and Technology (SUST) at Shambat. The goal of study was to determine the effects of intercropping Pearl millet cultivars (Sudan Braun and Wad-Elbashir) with cowpea, green gram, and cluster bean on *S. hermonthica* millet strain incidence and pearl millet growth.

3-2. Materials

3-2-1. Plant materials

S. hermonthica, pearl millet strain, seeds were collected in 2012 from under pearl millet in Kordofan State Western Sudan. Seeds of two local Pearl millet cultivars (Sudan Braun and Wad-Elbashir), were obtained from the Agriculture Research Corporation (ARC), Wad-Medani, Sudan.

3-3-2. Green house experiment

Pot experiment was conducted in a greenhouse at the College of Agriculture Studies, (CAS), at Shambat during the season 2015/2016. The experiment was conducted under artificial *S. hermonthica* infestation. Artificial infestation of soil was achieved by mixing 2g of *Striga* seeds with 1kg soil, followed by subsequent dilution with *Striga* free soil to give the required infestation level (32 and 64 mg /pot). *Striga* free or infested soil was placed in plastic pots (9 cm i .d) with perforations at the bottoms. Pots filled with *Striga* free soil (0 mg) were included as control for comparison. Pearl Millet cultivars (Sudan Braun and Wad-Elbashir cv.) were sown as sole crop or intercropped with cowpea, green gram, and cluster bean. Pearl millet, cowpea, green gram, and cluster bean seeds (5/pot) were sown at 2 cm soil depth. The pots were immediately irrigated. Subsequent irrigations were carried out every two days. Pearl millet, cowpea, green gram, and cluster bean seedlings were thinned to three plants per pot two weeks after sowing. Treatments were laid out in Randomized Complete Block Design (RCBD) with three replicates.

3-3. Data Collection

3-3-1. *Striga*

Treatments effects, unless mentioned otherwise, were assessed by determining i) number of *Striga* emergence per pot at 45, 60 and 90 days after sowing (DAS) and ii) *Striga* dry weight per pot at harvest (g).

3-3-2. Pearl Millet

Data collected on Pearl millet growth attributes were taken 30, 60 and 90 DAS. The data comprised of i) Plant height (cm), ii) number of leaves per plant, iii) number of tillers per plant, iv) stem diameter (cm), v) chlorophyll content (SPAD reading) and vi) shoot dry weight (g).

Average of SPAD readings at 3 points using a chlorophyll meter (SPAD-502, Konica Minolta Sensing, Japan) was recorded for each leaf

3-4. Statistical analysis

Data on millet growth and yield attributes and *S. hermonthica* millet strain were subjected to analysis of variance (ANOVA) and means were separated for significance by the Least significance Differences (LSD) at P> 5% using Statistic 8, statistical software, Version 2.0 (UK).

CHAPTER FOUR

Results

4-1: Effects of intercropping on *S. hermonthica* millet strain

4-1-1: *Striga* millet strain

4-1-1-1: *Striga* emergence

Statistical analysis showed significant differences at ($P < 0.05$) in number of *Striga* per pot between *Striga* seed bank size and also between intercrops (Appendix 1). *Striga* count made 60 and 90 DAS showed that *Striga* emergence on millet cultivars display a progressive increase with seed bank size (Table 4.1). At 60 DAS, average *Striga* emergence on sole millet Wad–Elbashir and Sudan Brown cultivars at seed bank size of 32 mg/pot was 2.7 and 4.3 plant /pot, respectively. However, increasing *Striga* seed bank size to 64mg/pot increased *Striga* emergence, however, the observed increase was not significant (Table 4.1).

60 DAS, at *Striga* seed bank size of 32 mg/pot, intercropping millet (Wad–Elbashir cv.) with cowpea and cluster bean resulted, no *Striga* emergence. However, intercropped Wad–Elbashir with green gram reduced *Striga* emergence by 11.8%, but not significantly. At seed bank size of 64 mg/pot, intercropping Wad–Elbashir with cowpea, cluster bean and green gram reduced *Striga* emergence by 72.3, 29.8 and 21.3%, respectively, albeit not significantly, as compared to the sole millet (Table 4.1). At 60 DAS, Sudan Brown intercropped with cowpea and green gram at *Striga* seed bank size of 32 mg/pot reduced number of *Striga* per pot, but not significantly and the observed reductions were considerable (62.8 -76.7 %). However, intercropped Sudan Brown with cluster bean shows no *Striga* emergence was observed (Table 4.1). Intercropped Sudan Brown with cowpea at *Striga* seed bank size of 64 mg/pot suppression *Striga* emergence by 57.1%, but not significantly. However, intercropped Sudan Brown with cluster bean and green gram

reduced *Striga* number significantly, as compared to the corresponding sole millet (Table 4.1).The observed reductions were considerable (62.9- 71.%).

Table 4.1. Effects of intercropping on *Striga* (millet strain) emergence

Number of *Striga* emergence/pot				
Pearl millet cultivars				
Days After Sowing (DAS)				
Treatments	**60 DAS**		**90 DAS**	
	Wad-Elbashir	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S32 (sole millet)	2.7 bc	4.3 ab	4.0 bc	5.0 abc
S64 (sole millet)	4.7 ab	7.0 a	7.0 ab	10.3 a
S32+cowpea	0.0 c	1.7 bc	0.0 c	2.0 bc
S32+ cluster bean	0.0 c	0.0 c	0.0 c	0.0 c
S32+ green gram	2.3 bc	1.0 bc	4.0 bc	1.3 bc
S64+cowpea	1.3 bc	3.0 abc	2.7 bc	4.0 bc
S64+ Cluster bean	3.3 abc	2.7 bc	5.0 abc	3.0 bc
S64+ green gram	3.7 abc	2.0 bc	5.3 abc	2.7 bc
LSD	2.11		2.96	
Standard error (±)	4.31		6.05	

*S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test.

At 90 DAS, the parasite, irrespective of millet cultivar displayed an average of 4-5 plants /pot at the lowest seed bank size (32 mg/pot). Increasing seed bank size to 64 mg/pot increased *Striga* emergence to 7 and 10.3 plants /pot, on Wad–Elbashir and Sudan Brown, respectively (Table 4.1). Intercropped Wad–Elbashir with cowpea and cluster bean at *Striga* seed bank size of 32 mg/pot exhibited negligible *Striga* emergence. Wad–Elbashir intercropped with cowpea, cluster bean and green gram at *Striga* seed bank size of 64mg/pot reduced *Striga* emergence by 62.9, 28.6 and 24.3% respectively, but not significantly, in comparison to the sole crop (Table 4.1). At *Striga* seed bank size of 32 mg/pot intercropping Sudan Brown with cowpea and green gram decreased number of *Striga* per pot, but not significantly and the observed reductions was considerable (60-74%). However, no *Striga* emergence was observed after intercropped with cluster bean. Intercropped Sudan Brown with cowpea, cluster bean and green gram at *Striga* seed bank size of 64 mg/pot, reduced *Striga* emergence significantly by 61.2, 70.9 and 73.8 %, respectively, in comparison to the sole millet (Table 4.1).

4-1-1-2: *Striga* dry weight

Statistical analysis showed significant difference in *Striga* dry weight between intercropping, *Striga* seed bank size, and showed non- significant differences across the millet cultivars (Appendix 1). *Striga* dry weight on sole millet cultivars progressively increased with *Striga* seed bank size. At the lowest seed bank size (32 mg/pot) the parasite displayed an average dry weight of 3.7-5.4 g/pot on sole millet (Wad-Elbashir and Sudan-Brown cv). However, increasing *Striga* seed bank size to 64 mg /pot increased *Striga* dry weight to 8.8 and 11.7g /pot on Wad-Elbashir and Sudan Brown, respectively. However, the observed increased was significant only in Sudan Brown, in comparison to the lowest seed bank size (Table 4.2). At *Striga* seed bank size of 32 mg/pot intercropping Wad-Elbashir with green gram did not reduced *Striga* dry weight. Wad-Elbashir intercropped with cluster bean and green gram at *Striga* seed bank size of 64 mg/pot, reduced *Striga* dry weight by 36.4 and 40.9%, respectively, in comparison to the sole millet. However, the reduction was not significant (Table 4.2). However, intercropped Wad-Elbashir with cowpea reduced *Striga* dry weight significantly and the observed reduction was considerable (73.9%).

At *Striga* seed bank size of 32 mg/pot intercropping millet (Sudan Brown cv.) with cowpea and green gram reduced *Striga* dry weight, but not significantly. However, the observed reduction was considerable (70.4-87%). Intercropped Sudan Brown with cowpea, cluster bean and green gram at *Striga* seed bank size of 64 mg/pot, reduced *Striga* dry weight significantly by 72.6, 81.2 and 82.1 %, respectively, in comparison to the corresponding sole millet (Table 4.2).

Table 4.2. Effects of intercropping on *Striga* dry weight

	Striga dry weight (g)/pot	
	Pearl millet cultivars	
Treatments	Wad-Elbashir	Sudan Brown
S32 (sole millet)	3.7 bc	5.4 bc
S64 (sole millet)	8.8 ab	11.7 a
S32+cowpea	0.0 c	1.6 c
S32+ cluster bean	0.0 c	0.0 c
S32+ green gram	3.5 bc	0.7 c
S64+cowpea	2.3 c	3.2 bc
S64+ Cluster bean	5.6 bc	2.2 c
S64+ green gram	5.2 bc	2.1 c
LSD	2.94	
Standard error (±)	6.01	

*S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test.

4-1: Effects of intercropping on millet cultivars

4-2-1: Plant height

The results show that plant height at 30 DAS was similar, across millet cultivars. *Striga* millet strain, irrespective of seed bank size did not reduce Wad-Elbashir height, in comparison to un-infested control (Table 4.3). *Striga* free Sudan Brown displayed the highest height (13.5 cm). *Striga* at seed bank size of 32 and 64 mg/pot reduced Sudan Brown height significantly by 43.7 %, as compared to the corresponding control (Table 4.3). Intercropping with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size did not reduce Wad-Elbashir height, in comparison to un-infested control and sole millet (Table 4.3). However, Sudan Brown height, irrespective of seed bank size reduce significantly after intercropped with cowpea, cluster bean and green gram, the observed reductions, increment with increasing *Striga* seed bank size by (31.9-34.1), (30.4-46.7) and (22.2-30.4%), as compared to un-infested control (Table 4.3).

At 60 DAS, *Striga* at seed bank of 32 and 64 mg/pot inflicted in-significant decrease in sole Wad-Elbashir height (9.1-13.1%). However, height of sole

Sudan Brown reduced significantly at *Striga* seed bank size of 32 and 64 mg/pot by 57.0 and 41.4%, respectively, as compared to the un-infested control (Table 4.3). Intercropped Wad-Elbashir with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size reduced millet height, but not significantly, in comparison to the un-infested control and corresponding sole millet (Table 4.3). Sudan Brown intercropped with cowpea, cluster bean and green gram show a significant reduction in height at *Striga* seed bank size of 32 and 64 mg per pot in comparison to the corresponding *Striga* free control (Table 4.3). The observed reduction was considerable (23.7- 41.2%). Intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size increased millet height, in comparison to the sole millet. The observed increment was considerable (28.6 - 67.3%).

At 90 DAS, *Striga* free millet, irrespective of cultivars displayed the highest height (57.9-65.5 cm). At the lowest *Striga* seed bank size (32mg /pot) Wad-Elbashir and Sudan Brown height was reduced by 54.7 and 44.4%, respectively, in comparison to the corresponding *Striga* free control (Table 4.3). Increasing seed bank size to 64mg/pot reduced Sudan Brown height significantly and the observed reduction was 37.5%. At *Striga* seed bank size of 32 and 64 mg/pot, Wad-Elbashir intercropped with cluster bean and green gram exhibited significant reductions in height in comparison to the un-infested control (Table 4.3). The observed reductions were considerable (40.2-61.7%). Intercropping cowpea with Wad-Elbashir at *Striga* seed bank size of 32mg/pot increased millet height significantly (82.4%), as compared to the sole millet. However, cowpea intercrops with Sudan Brown increased millet height, but not significantly, as compared to the sole millet (Table 4.3). At *Striga* seed bank size of 32 mg/pot, green gram intercropped Sudan Brown displayed significant reduction in height (42.0%). Intercropped Sudan Brown with cluster bean and green gram at *Striga* seed bank size of 64mg/pot reduced height significantly by 40.4 and 35.6%, respectively (Table 4.3).

Table 4. 3. Effects of intercropping on plant height in Millet

	Plant height (cm)					
	Days After Sowing (DAS)					
	30 DAS		60 DAS		90 DAS	
	Pearl millet cultivars					
Treatments	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	7.7 cd	13.5 a	17.6 bcd	26.3 a	65.5 a	57.9 ab
S32 (sole millet)	9.0 cd	7.6 cd	15.3 bcde	11.3 de	29.7 f	32.2 ef
S64 (sole millet)	11.1 abc	7.6 cd	16.0 bcde	15.4 bcde	51.1 abcd	36.2 cdef
S32+cowpea	8.4 cd	9.2 cd	13.8 bcde	15.4 bcde	54.1 abc	43.7 bcdef
S32+ Cluster bean	9.7 bcd	9.4 cd	12.5 cde	18.2 bc	33.9 def	43.5 bcdef
S32+ green gram	11.0 abc	10.5 abcd	15.3 bcde	18.9 b	29.2 f	33.6 def
S64+cowpea	13.4 ab	8.9 cd	14.6 bcde	19.8 b	50.6 abcde	42.4 bcdef
S64+ Cluster bean	7.6 cd	7.2 d	11.1 e	16.4 bcde	25.1 f	34.5 def
S64+ green gram	8.1 cd	9.4 cd	11.4 de	20.0 ab	39.2 bcdef	37.3 cdef
LSD	**3.75**		**6.37**		**18.79**	
Standard error (±)	**1.85**		**3.13**		**9.25**	
F- value	**2.52***		**2.71***		**0.92**^{ns}	

S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. *=P<0.05, Ns= non- significant

4-2-2: Number of leaves

Number of leaves at 30 and 60 DAS was similar between millet cultivars and differences between treatments were not significant (Table 4.4). At 30 DAS, *S. hermonthica* millet strain, irrespective of seed bank size had no significant effect in number of leaves on millet cultivars, in comparison with the *Striga* free control. *Striga* at seed bank size of 32 and 64 mg/pot reduced number of leaves in Wad-Elbashir, but not significantly and the observed reductions were 37.6 and 33.5%, respectively (Table 4.4). Intercropping Wad-Elbashir with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size reduced number of leaves per plant, but not significantly, in comparison to un-infested control (Table 4.4). The observed reductions were considerable (29.4-42.9%). However, intercropped millet (Sudan Brown cv.) with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size increased number of leaves per plant (10-33%), thought it's not significantly, in comparison to *Striga* free control (Table 4.4).

At 60 DAS, *S. hermonthica* millet strain, irrespective of seed bank size and millet cultivars reduced number of leaves in millet, albeit not significantly. In Wad-Elbashir non- significant reductions in number of leaves by 28.5 and 50% were attained at *Striga* seed bank size of 32 and 64 mg per pot, respectively. However, in Sudan Brown the reduction only observed at *Striga* seed bank size of 32mg/pot (Table 4.4). In Wad-Elbashir all intercrops, irrespective of *Striga* seed bank size decreased number of leaves, albeit not significantly, in comparison to the un-infested control (13.8-51.6%). Intercropping Sudan Brown with cowpea at *Striga* seed bank size of 32 mg/pot displayed highest number of leaves (143%), over the control. At *Striga* seed bank size of 64 mg/pot, intercropped Sudan Brown with cluster bean increased number of leaves, in comparison to the un-infested control (Table 4.4) and the observed increment was considerable (70%).

Table 4.4. Effects of intercropping on number of leaves in Millet

	Number of leaves/plant			
	Days After Sowing (DAS)			
	30 DAS		60 DAS	
	Pearl millet cultivars			
Treatments	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	17.0 a	10.0ab	18.6 ab	10.0 ab
S32 (sole millet)	10.6 ab	10.0 ab	13.3 ab	8.3 b
S64 (sole millet)	11.3 ab	11.6 ab	9.3 ab	11.6 ab
S32+cowpea	9.6 ab	9.6 ab	9.0 b	24.3 a
S32+ Cluster bean	11.3 ab	12.3 ab	11.3 ab	8.3 b
S32+ green gram	12.0 ab	13.0 ab	11.0 ab	10.0 ab
S64+cowpea	12.0 ab	11.0 ab	16.0 a	10.3 ab
S64+ Cluster bean	9.3ab	13.3 ab	8.0 b	17.0 ab
S64+ green gram	12.0 ab	13.0 ab	9.3 ab	8.6 b
LSD	**7.70**		**15.27**	
Standard error (±)	**3.79**		**7.51**	
F- value	**0.73** ^{ns}		**1.03** ^{ns}	

S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant

4-2-3: Number of tillers

Statistical analysis showed that differences between millet cultivars in number of tillers/ plant were not significant at 30 and 90 DAS. However, at 60 DAS significant differences were observed between the cultivars (Table 4.5). At 30 DAS, the number of tillers per plant of sole millet cultivars (Wad-Elbashir and Sudan Brown) showed a considerable increase in comparison to the un-infested control (25-60%). In Wad-Elbashir, *Striga* at seed bank size of 64mg/pot reduced number of tillers per plant (50%), but not significantly. Intercropping Wad-Elbashir with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size decreased number of tillers per plant, but not significantly (34.6-50%). However, in Sudan Brown all intercrops, irrespective of *Striga* seed bank size increased number of tillers (30-170%), over the un-infested control (Table 4.5).

At 60 DAS, *Striga* millet strain at seed bank of 32 and 64mg/pot, irrespective of millet cultivars caused significant reductions in number of tillers and the observed reductions were 70 and 75% (Table 4.5). In Wad-Elbashir, all intercrops, irrespective of *Striga* seed bank size reduced number of tillers significantly and the observed reductions were considerable (42.5-100%). Intercropped Sudan Brown with cluster bean increased number of tillers by 30%, thought it's not significantly; in comparison to the un-infested control (Table 4.5). However, the number of tillers decreased significantly (100%) when intercropped Sudan Brown with cluster bean at *Striga* seed bank size of 64 mg/pot (Table 4.5).

In sole Wad-Elbashir at 90 DAS, *Striga* seed bank at 32 and 64mg/pot caused significant decrease (100%) in number of tillers. However, in sole Sudan Brown *Striga* at seed bank size of 32 and 64 mg/pot reduced number of tillers by 100 and 69.7%, respectively. At *Striga* seed bank of 32 and 64mg/pot, irrespective of millet cultivars, intercropped with cowpea and cluster bean decreased number of tillers, but not significantly, as comparison to the sole millet (Table 4.5). However, intercropped millet cultivars with green gram displayed complete reduction in number of tillers.

4-2-4: Stem diameter

Analysis of variance showed that differences between millet cultivars in stem diameter were significant at 30, 60 and 90 DAS (Appendix2). Wad-Elbashir displayed highest stem diameter and Sudan Brown sustained the lowest (Table 4.6). In general, *S. hermonthica* millet strain, irrespective of seed bank size, millet cultivars and date of observation, with few exceptions decreased stem diameter of millet, but not significantly, as compared to un-infested control (Table 4.6). The observed reductions were 6.9-30.6%.

At 30, 60 and 90 DAS, intercropped Wad-Elbashir with cowpea, cluster bean and green gram at *Striga* seed bank size of 32 mg/pot reduced stem diameter, albeit not significantly (6.7-28.9%), as compared to the *Striga* free control (Table 4.6). At 30 and 90 DAS, intercropping Wad-Elbashir with cowpea, at seed bank size of 64 mg/pot increased stem diameter by 14.3 and 13.3%, respectively and the observed increment was not significant. At *Striga* seed bank size of 64 mg/pot, cluster bean and green gram intercropped Wad-Elbashir, irrespective of DAD, displayed in-significant reduction in stem diameter (Table 4.6).

At 30 DAS, at *Striga* seed bank size of 32 and 64mg/pot, intercropped Sudan Brown with cowpea, increased stem diameter by 13.3 and 40%, respectively over the un-infested control and also increment by 30.8 and 50%, respectively, as compared to the corresponding sole millet (Table 4.6). At *Striga* seed bank size of 64 mg/pot, stem diameter, irrespective of date of observation increased (10.3-26.7%), when intercropped Sudan Brown with cluster bean, albeit not significantly. At 30, 60 and 90 DAS, intercropped Sudan Brown with green gram at *Striga* seed bank size of 64 mg/pot decreased stem diameter by 33.3, 20.8 and 17.2%, respectively, in comparison to the corresponding control (Table 4.6).

Table 4.5. Effects of intercropping on number of tillers in Millet

	Number of tillers/plant					
	Days After Sowing (DAS)					
	30 DAS		60 DAS		90 DAS	
	Pearl millet cultivars					
Treatments	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	2.7 a	1.0 ab	4.0 a	1.0 bc	3.7 ab	3.3 ab
S32 (sole millet)	3.0 a	1.7 ab	1.0 bc	0.3 bc	0.0 c	0.0 c
S64 (sole millet)	1.3 ab	1.3 ab	1.0 bc	0.3 bc	0.0 c	1.0 abc
S32+cowpea	1.7 ab	1.7 ab	1.3 bc	1.0 bc	2.0 abc	0.7 bc
S32+ Cluster bean	2.7 a	1.0 ab	1.3 bc	1.3 bc	1.7 abc	0.0 c
S32+ green gram	1.3 ab	2.7 a	0.0 c	0.3 bc	0.0 c	0.0 c
S64+cowpea	1.7 ab	1.3 ab	2.3 ab	1.0 bc	3.0 abc	3.0 abc
S64+ Cluster bean	0.0 b	1.7 ab	0.3 bc	1.3 bc	0.7 bc	0.7 bc
S64+ green gram	2.7 a	2.7 a	1.3 bc	0.0 c	0.0 c	0.0 c
LSD	**2.05**		**2.33**		**3.23**	
Standard error (±)	**1.00**		**1.15**		**1.59**	
F- value	**1.42^{ns}**		**1.01^{ns}**		**0.46^{ns}**	

S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant

Table 4. 6. Effects of intercropping on stem diameter in Millet

	Stem diameter(cm)					
	Days After Sowing (DAS)					
	30 DAS		60 DAS		90 DAS	
	Pearl millet cultivars					
Treatments	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	2.1 ab	1.5 abc	3.6 a	2.4 bcd	3.8 abc	2.9 cdef
S32 (sole millet)	1.9 abc	1.3 bc	2.5 bcd	2.0 cd	2.9 cdef	2.3 f
S64 (sole millet)	2.1 ab	1.4 bc	3.6 a	2.3 bcd	4.2 ab	2.7 def
S32+cowpea	1.9 abc	1.7 abc	2.9 abc	2.7 abcd	3.3 abcde	3.0 cdef
S32+ Cluster bean	1.9 abc	1.4 bc	2.6 bcd	2.4 bcd	3.0 cdef	2.9 cdef
S32+ green gram	2.0 abc	1.3 abc	2.5 bcd	1.9 d	2.7 def	2.3 f
S64+cowpea	2.4 a	2.1 ab	3.6 a	2.9 abc	4.3 a	3.3 abcde
S64+ Cluster bean	1.7 abc	1.9 abc	3.2 ab	2.7 abcd	3.7 abcd	3.2 bcdef
S64+ green gram	1.6 abc	1.0 c	3.0 abc	1.9 d	3.3 abcd	2.4 ef
LSD	**1.01**		**1.0**		**1.03**	
Standard error (±)	**0.49**		**0.49**		**0.50**	
F- value	**0.38^{ns}**		**0.76^{ns}**		**0.62^{ns}**	

S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant

4-2-5: Chlorophyll content

In general, the chlorophyll content was relatively high at the early stage of growth (30 and 60 DAS). However, a progressive decline in chlorophyll content occurred at 90 DAS (Table 4.7). Chlorophyll content, irrespective of millet cultivars and DAS, was not influenced by *Striga* seed bank size (Table 4.7). At 30 and 60 DAS, millet cultivars displayed comparable chlorophyll content, however, at 90 DAS Wad-Elbashir sustained heights chlorophyll content and Sudan Brown displayed the lowest.

At 30 DAS, sole millet, invariably, showed a progressive decline in chlorophyll content with *Striga* seed bank size, in comparison to the *Striga* free control. *Striga* at a seed bank size of 64 mg/pot reduced chlorophyll content in Wad-Elbashir and Sudan Brown by 27.1 and 41.7%, respectively, but not significantly (Table 4.7). At 30 DAS, irrespective of *Striga* seed bank size, chlorophyll content reduced in Wad-Elbashir intercropped with cowpea and cluster bean. However, at *Striga* seed bank size of 32 and 64 mg/pot, intercrops with green gram increased Wad-Elbashir chlorophyll content and the observed increment was not significant, in comparison to the un-infested control (Table 4.7). In Sudan Brown, irrespective of *Striga* seed bank size, all intercrops reduced chlorophyll content (1.3-45.8%), but not significantly.

At 60 DAS, *Striga* millet strain, irrespective of seed bank size and millet cultivars decreased millet chlorophyll content, but not significantly. The observed reductions were 10.8-33.1%. Intercropped Wad-Elbashir with green gram at *Striga* seed bank size of 32mg/pot increased chlorophyll content by 63.4%, in comparison to the sole millet. At seed bank size of 64 mg/pot, intercropped Sudan Brown with cluster bean increased chlorophyll content by 44.6%, in comparison to the sole millet (Table 4.7). However, all intercrops, irrespective of *Striga* infestation and millet cultivars with few exceptions reduced chlorophyll content (2-45.9%), but not significantly, in comparison to the un-infested control and sole millet (Table 4.7).

Table 4.7. Effects of intercropping on Chlorophyll content in Millet

	Chlorophyll content /plant					
	Days After Sowing (DAS)					
	30 DAS		60 DAS		90 DAS	
	Pearl millet cultivars					
Treatments	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	32.3 a	39.8 a	40.8 ab	40.3 abc	19.2 bcde	22.1 abcd
S32 (sole millet)	31.6 a	35.8 a	27.3 bcd	30.6 abcd	20.4 abcde	19.3 bcde
S64 (sole millet)	24.0 a	23.2 a	36.4 abcd	27.6 bcd	23.5 ab	18.1 bcde
S32+cowpea	32.8 a	39.3 a	25.8 bcd	25.1cd	19.3 bcde	15.5 cde
S32+ Cluster bean	28.7 a	21.7 a	26.0 bcd	25.8 bcd	18.8 bcde	14.6 de
S32+ green gram	37.8 a	22.9 a	44.7 a	23.1 d	23.0 abc	18.4 bcde
S64+cowpea	23.9 a	24.1 a	40.0 ab	21.8 d	27.8 a	15.0 de
S64+ Cluster bean	27.4 a	24.2 a	24.8 cd	34.8 abcd	15.4 de	13.4 e
S64+ green gram	33.8 a	23.8 a	27.5 bcd	21.8 d	17.5 bcde	14.1 e
LSD	**20.66**		**15.54**		**7.59**	
Standard error (±)	**10.17**		**7.65**		**3.74**	
F- value	**0.56^{ns}**		**1.74^{ns}**		**1.26^{ns}**	

S_X=*Striga* seed bank size (mg/pot).

Means within a column and/or row followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant

At 90 DAS, *Striga* infestation did not reduced sole Wad-Elbashir chlorophyll content. *Striga* at seed bank size of 32 and 64mg/pot, decreased Sudan Brown chlorophyll content by 12.7 and 18.1%, respectively (Table 4.7). Intercropped Wad-Elbashir with cowpea, cluster bean and green gram, irrespective of *Striga* infestation displayed in-significant increased in chlorophyll content (26.2-92.6%), but only at the highest *Striga* seed bank size (64mg/pot) effected a significant increased when intercropped with cowpea. The observed increment was considerable (127%), over the un-infested control (Table 4.7). Intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* infestation, displayed insignificant decreased in chlorophyll content (16.7-39.4%), in comparison to the un-infested control (Table 4.7).

4-2-6: Millet dry weight

Statistical analysis showed that highly significant differences ($P<0.01$) in plant dry weight between millet cultivars (Appendix 2).Wad-Elbashir sustained the highest dry weight (99.8 g), while Sudan Brown displayed the lowest one (73.6g). In Wad-Elbashir, *Striga* free control displayed a dry weight of 95.0 g. At *Striga* seed bank size of 32 and 64 mg/pot, sole Wad-Elbashir displayed slight non-significant (15.8%) decrease in dry weight, in comparison to the *Striga* free control (Table 4.8). Intercropped Wad-Elbashir with cowpea at *Striga* seed bank size of 32 and 64 mg/pot, increased millet dry weight by 29.8 – 36.8% and 54.1- 62.5%, respectively, in comparison to the *Striga* free control and sole millet (Table 4.8). At *Striga* seed bank size of 32mg/pot, intercropped Wad-Elbashir with cluster bean increased millet dry weight by 10.5-31.3%, albeit not significantly, as compared to the un-infested control and sole millet. However, increasing *Striga* seed bank size to 64mg/pot resulted non- significant reduction in Wad-Elbashir dry weight and the observed reductions were 16.3-29.8 % (Table 4.8).

Wad-Elbashir intercropped with green gram at *Striga* seed bank size of 32mg/pot showed not significant reduction in dry weight (15.8%), as compared to the un-infested control (Table 4.8). At *Striga* seed bank size of 64mg/pot, Wad-Elbashir intercropped with green gram resulted slight non-significant (19.3-41.6%) increment in millet dry weight, in comparison to the un-infested control and sole millet (Table 4.8).

In Sudan Brown, *Striga* free control displayed highest dry weight (96.7g). *Striga* seed bank size of 32 and 64 mg/pot, reduced Sudan Brown dry weight by 31.0 and 10.3%, respectively, in comparison to the un-infested control (Table 4.8). Intercropped Sudan Brown with cowpea, cluster bean and green gram, at *Striga* seed bank size of 32 and 64 mg/pot, showed non- significant reductions in millet dry weight and the observed reductions were (19.0-31.7), (22.4-27.6) and (32.8-39.7%), respectively, in comparison to the un-infested control (Table 4.8).

Table 4.8. Effects of intercropping on Millet dry weight

Millet dry weight (g)/pot		
Pearl millet cultivars		
Treatments	**Wad-Elbashir**	**Sudan Brown**
S0 (Un-infested control)	95.0 abcd	96.7 abcd
S32 (sole millet)	80.0 abcd	66.7 cd
S64 (sole millet)	80.0 abcd	86.7 abcd
S32+cowpea	130.0 a	66.0 cd
S32+ cluster bean	105.0 abcd	70.0 cd
S32+ green gram	80.0 abcd	58.3 d
S64+cowpea	123.3 ab	78.3 bcd
S64+ Cluster bean	66.7 cd	75.0 bcd
S64+ green gram	113.3 abc	65.0 cd
LSD	**50.72**	
Standard error (±)	**24.96**	
F- value	**0.71^{ns}**	

*S_X=*Striga* seed bank size (mg/pot).

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test. Ns= non- significant

CHAPTER FIVE

Discussion

Cereal legume intercropping is a predominant cropping system in Sub-Sahara African countries where it is used for maximizing use of limited farmlands, food security and improving soil fertility. Use of legume trap crops is an important low cost method for depletion of *Striga* seed bank in the soil.

Striga counts at 60 and 90 DAS were generally lower in the intercrops than in the control pots of sole millet. The results showed that sole millet sustained highest *Striga* emergence. This is in agreement with the findings of Aliyu and Emechebe (2006) who reported higher number of *Striga* in sole sorghum as compared to sorghum when intercropped with cowpea. At *Striga* seed bank size of 32 and 64 mg/pot, cowpea intercropped with millet cultivars (Wad–Elbashir and Sudan Brown cv.) reduced *Striga* emergence by 57.1 -100% (Table 4.1). The results revealed that intercrops cluster bean with millet cultivars at *Striga* seed bank size of 32 mg/pot completely suppressed *Striga* emergence throughout the experiment (Table 4.1). However, at *Striga* seed bank size of 64 mg/pot intercropping cluster bean with millet decreased *Striga* number by 28.3-70.9%, as compared to the sole millet. Suppression of *Striga* emergence by intercropping with different legumes is consistent with several reports, Khan *et al*., (2002) who found that mixed cropping of cereals and cowpea reduce *Striga* infestation significantly. Mbwaga *et al*. (2001) also observed that intercropping cereals and cowpea has been observed to reduce *Striga* infestation significantly. Intercropping of sorghum with soybean and groundnut has significantly reduced the *Striga* counts per plot as compared to sole sorghum (Merkeb *et al*., 2016). Similarly, Chivinge *et al*. (2001) reported that cowpea cultivars reduced *Striga* emergence by 40%. This reduction may be due to shading effects from the cowpea canopy that created unfavorable conditions for *Striga* germination (Kureh *et al*., 2006).

Intercropped millet cultivars (Wad–Elbashir and Sudan Brown cv.) with green gram at seed bank size of 32mg/pot displayed suppression of *Striga* emergence by 14.8-76.7%, as compared to the sole millet (Table 4.1). At *Striga* seed bank size of 64 mg/pot green gram intercrops with millet cultivars with few exception, significantly reduced *Striga* number and the observed reductions were considerable (21.3-74.8%). This result is consistent with the report of Khan *et al.* (2007) who observed that in pooled analysis across seasons that intercropping sorghum with green gram, cowpea and crotalaria, and maize with crotalaria significantly reduced *Striga* populations. Florahk, (2014) also found that intercropping maize with green gram had significantly lower *Striga* counts when compared with maize that was artificially infested with *Striga*. The green gram provides a good ground cover to the soil thus reducing the emerging *Striga* and other weeds. The reduced *Striga* counts during intercropping could be attributed to smothering of emerging *Striga* by the spreading vegetation of the non-host crops, low soil temperatures (Kureh *et al*., 2000) and the exudates could be inhibiting attachment. Increased humidity and lowered temperatures under the intercrops reduced the growth of emerging *Striga* (Parker and Riches, 1993). Intercropping with legumes also improves soil fertility through fixation of atmospheric nitrogen. Addition of nitrogen to the soil is generally considered to alleviate the effects of *Striga* and to lower the amount of *Striga* supported by the host.

All intercrops reduced *Striga* dry weight, in comparison to the sole millet. Cowpea, cluster bean and green gram intercropped with millet cultivars, irrespective of *Striga* seed bank size reduced *Striga* dry weight by (70.4-72.6%), (40.9-82.1%) and (36.4-81.2%), respectively (Table 4.2). The reduction in *Striga* dry weight is consistent with the reductions in emergence caused by intercropping with different legumes (cowpea, cluster bean and green gram). These results corroborate the findings of Yonli *et al.* (2012) who reported integrated *Striga* management controls based on intercropping system, *Fusarium*-inoculum or both in combination significantly reduced *Striga* dry biomass. Yonli *et al.* (2012) reported that when the cowpea plants covered the soil, the temperature decreased while the air humidity increased under cowpea leaves and stalks. The interaction of these environmental factors may create a micro-climate that would affect the emergence and the growth of *Striga* plants and then *Striga* biomass should be significantly reduced.

At 30 DAS, intercropping with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size did not reduce Wad-Elbashir height, in comparison to un-infested control and sole millet. However, at 60 and 90 DAS, Wad-Elbashir height reduced when intercropped with different legumes. At 30, 60 and 90 DAS, all intercrops, irrespective of *Striga* seed bank size reduce Sudan Brown height, in comparison to un-infested control (Table 4.3) and this could be attributed to the competition between the intercrops in growth resources and also due to the effect of *Striga*. This is probably because *Striga* affects cell elongation as it takes photosynthesis away from the millet crop leading to shorter millet internodes and stunted growth. At 60 DAS, intercropped Sudan Brown with cowpea, cluster bean and green gram, irrespective of *Striga* seed bank size increased millet height, in comparison to the sole millet and the observed increment was considerable (28.6 - 67.3%). Similar results was obtained by **(**Merkeb *et al*., 2016), who found that sorghum height increased in all treatments of intercropping with groundnut and soybean. Desmodium intercrops that significantly enhanced plant height in maize and sorghum (Khan *et al*., 2007).

At 30 and 60 DAS, irrespective of *Striga* seed bank and millet cultivars all intercrops with few exceptions reduced number of leaves/ plant, as compared to the un-infested control. At 90 DAS, all intercrops, irrespective of *Striga* seed bank size and millet cultivars did not reduced stem diameter per plant, but decreased number of tillers per plant, as compared to the sole millet

(Tables 4.4, 4.5 and 4.6). This is probably due to competition between millet and the legumes for growth factors such as soil moisture and nutrients.

At 30, all intercrops, irrespective of *Striga* seed bank size and millet cultivars did not reduced chlorophyll content, as compared to sole millet. At 60 and 90 DAS, all intercrops, irrespective of *Striga* infestation and millet cultivars with few exceptions reduced chlorophyll content, but not significantly, in comparison to the un-infested control and sole millet (Table 4.7).This is probably the legumes intercrop that affected the partitioning of photosynthesis to the sink.

Intercropping Wad-Elbashir with cowpea, irrespective of *Striga* seed bank size, increased millet dry weight, in comparison to the *Striga* free control and sole millet (Table 4.8). Intercropping Wad-Elbashir with cluster bean at *Striga* seed bank size of 32mg/pot, increased millet dry weight by 10.5-31.3%, albeit not significantly, as compared to the un-infested control and sole millet. At *Striga* seed bank size of 64mg/pot, Wad-Elbashir intercropped with green gram resulted in slight non-significant (19.3-41.6%) increment in millet dry weight, in comparison to the un-infested control and sole millet (Table 4.8). A similar result was obtained by Rezig (2016) and Musyoka (2014). Intercropping Sudan Brown with cowpea, cluster bean and green gram, at *Striga* seed bank size of 32 and 64 mg/pot, showed non- significant reductions in millet dry weight, as compared to the un-infested control (Table 4.8). This was is in agreement with the findings of Hamad-Elneel (2011), who reported a decline in dry weight of cowpea intercropped sorghum, irrespective of *Striga* infestation. This could be attributed by lower number of plant leaves and stunted growth of millet due to the negative impact of *Striga* and also due to the intercrops system.

Conclusions and Recommendations

Conclusions

1. Intercropping millet with different legumes (cowpea, cluster bean and green gram) was effective in suppressing *Striga* emergence.

2. Millet cultivars differed considerably in their support to *Striga* numbers.

3. Intercropping with these legumes therefore showed some assure as a suitable component of an integrated *Striga* management approach for the small holder farmers, but this would need to be combined with other cultural methods such as hand weeding of emerged *Striga* to avoid replenishment of *Striga* seed bank in the soil.

Recommendations

1. Future studies on the cost benefit of intercropping millet and different legumes to reduce the effect of *Striga* parasitism on millet.
2. Pre-screening of available cowpea, green gram and cluster bean cultivars for *Striga* germination stimulation and testing further intercropping and rotation.

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APPENDICES

Appendix 1. Three way ANOVA and F- values for number of *Striga* emergence and *Striga* dry weight

Source of variation	Number of *Striga*/pot (60DAS)	Number of *Striga*/pot (75DAS)	*Striga* dry weight/pot
Cultivars, C	0.9ns	0.38^{ns}	0.0^{ns}
***Striga* seed bank, Ssb**	9.92**	6.89*	7.96**
Intercrops, I	6.45**	4.04*	4.11*
C*Ssb	0.14ns	0.0^{ns}	0.0^{ns}
C*I	1.4ns	1.2^{ns}	1.18^{ns}
Ssb*I	0.84ns	0.34^{ns}	0.42^{ns}
C*Ssb*I	0.21ns	0.04^{ns}	0.19^{ns}

*=P<0.05, **=P<0.01, ***=P<0.001, ^{ns}=non-significant.

Appendix 2. F- Value between millet cultivars

Parameters	F-value
Plant height (30 DAS)	0.23^{ns}
Plant height (60 DAS)	13.21***
Plant height (90 DAS)	0.37^{ns}
Number of leaves/plant (30 DAS)	0.2^{ns}
Number of leaves/plant (60 DAS)	0.01^{ns}
Number of leaves/plant (90 DAS)	7.99**
Number of tillers/plant (30 DAS)	0.44^{ns}
Number of tillers/plant (60 DAS)	3.04*
Number of tillers/plant (90 DAS)	2.81^{ns}
Stem diameter (30 DAS)	6.52*
Stem diameter (60 DAS)	18.00***
Stem diameter (90 DAS)	15.97***
Chlorophyll content (30 DAS)	0.31^{ns}
Chlorophyll content (60 DAS)	3.40*
Chlorophyll content (90 DAS)	9.47**
Millet dry weight	9.91**

*=P<0.05, **=P<0.01, ***=P<0.001, ^{ns}=non-significant.

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