بسم الله الرحمن الرحيم

# Sudan University of Science and Technology

# College of Graduate Studies

## Susceptibility of Selected Wheat Cultivars and *Sorghum bicolor* (cv.Abusabeen) to *Striga hermonthica (*Del.) Benth.

دراسة مقارنة على قابلية أصناف مختارة من القمح وصنف الذرة أبوسبعين للإصابة بطفيل البودا

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

By: *Sahar Adil Shams Aldein Abd Alwahab*

**B.Sc. Agronomy, Sudan University of Science and Technology (2009).**

**Supervisor:**

Dr: *Amani Hamad Eltayeb Hamad*

**Department of Agronomy**

**College of Agricultural Studies**

**March, 2014**

# الآية

قال تعالى :

الأْ َرْضِ وَ( اخْ تِلاَ فِ اللَّيْلِ وَ النَّهَ ارِ وَ الْفُلْكِ الَّتِي تجَْ رِي
س وَفِي مَ الْبأَنْجُ لِ اللَّهُ مِنَ السَّمَ اءِ مِنْ مَ اءٍ فَأَحْ يَ ا بِهِ
ثَّ فِيهَ ا مِنْ كُلِّ دَ ابَّةٍ وَ تَصْ رِيفِ الرِّيَ احِ وَ السَّحَ ابِ
َاءِ وَ الأْ َرْضِ لآَ يَ اتٍ لِقَوْ مٍ يَ عْقِلُونَ )

سورة البقرة الآية (164)

# DEDICATION

*I would like to dedicate this work to:-*

*My dear father*

*My lovely mother*

*My sweets sisters*

*My lonely brother*

*My fiancé*

*Finally, to all my teachers in department of Agronomy.*

# ACKNOWLEDGEMENTS

*First my all thanks and pries is due to almightily 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 Dr. Amani Hamad Eltayeb who supervised the work throughout the study. The study broader my knowledge and I came to know about many techniques. Special thanks to Prof. Abd Elgabar Altayeb Babiker and Dr Tilal Sayd Abd Elhaliem who help a lot. I am really thankful to them. Secondly I would also like to thank my parents and friends, who helped me a lot in finishing this project within the limited time.*

# Abstract

*Striga hermonthica*, (Del.) Benth an obligate root parasitic plant, causes serious yield losses in cereals in Sub-Sahara Africa, threat to agriculture and food security. Maize, sorghum, millet, rice and sugar cane are the traditional hosts, however, recently wheat was reported susceptible to the parasite. Green house and Laboratory experiments were undertaken at the College of Agricultural Studies (CAS), Sudan University of Science and Technology (SUST) at Shambat in 2012 - 2013 to determine i) reactions of local wheat cultivars to the parasite and their ability to sustain successful parasitism and ii) ability of air dried of the wheat residues to induce germination of the parasite. Laboratory experiments showed that wheat residues, irrespective of cultivars, plant parts and amount of powder, induced both germination and haustorium initiation (8.7-75.5%) and (22.9-100%), respectively in *S. hermonthica.* Germination varied with the amount of powder and the cultivar used. Elnelien cultivar displayed the highest germination, followed in descending order by Wadi-Elniel, Emam and Napta. Germilings from seeds induced to germinate by wheat residues showed pre-mature haustoria and shorter radicle length than those stimulated by GR24. Wheat residues, irrespective of cultivars, plant parts and amount of powder induced haustorium initiation (22.9 – 100%), and reduced radicle length by 67- 82%, as compared to the control. Seeds placed in vicinity of Abusabeen roots for 6, 9 and 12 days displayed 21.0, 37.0 and 37.7% germination, respectively. Of the resulting *Striga* germilings 30.0- 61.9% were attached to sorghum (Abusabeen). Of the *Striga* germilings 2.2- 42.9 % died prior to attachment and 0.7- 1.6% died after attachment. At 9 days seeds placed in proximity of Elnelien, Napta, Wadi-Elnile and Emam roots displayed 22.8, 12.4, 7.8 and 5.5% germination, respectively. Of the resulting germilings 63.8, 25.0, 32.0 and 38.8% achieved attachment to Elnelien, Emam, Napta and Wadi-Elnile

roots and 63.2, 75.0, 68.0 and 61.2. % germilings failed to attach, respectively. About 6.3 and 2.1% of the germilings attached to Elnelien and Napta died. Seeds placed for 12 days in vicinity of Elnelien, Napta, Wadi-Elnile and Emam roots showed 79.4, 32.4, 22.7and 15.0% germination, respectively. Attachment was 25.3, 39.4, 35.3 and 49.0% on Elnelien, Emam, Napta and Wadi-Elnile roots, respectively and about 74.7, 60.6, 46.7 and 51.0% of the germilings was failed to attachment. *S. hermonthica* emergence, irrespective of seed bank size was influenced by host species and cultivar. *Striga* emergence on sorghum (cv. Abusabeen) displayed a progressive increase with seed bank size. *Striga* emergence on wheat was lower than on sorghum and showed dependence on time and cultivar. On sorghum *Striga* emergence was evident 45 DAS. However, on wheat *Striga* emergence was noticed 60 DAS on Emam, Elnelien and Wadi-Elnile, while emergence was delayed to 75 DAS on Napta. *S. hermonthica*, irrespective of seed bank size on wheat cultivar reduced tillering and biomass producing in wheat. However, the magnitude of the reduction varied with cultivars and *Striga* seed bank size. In general, the observed reduction, with few exceptions, increased with increasing *Striga* seed bank size and was highest (61.8%) on Napta and lowest (4.2%) on Emam. The experiment showed that wheat is susceptible to *S. hermonthica* and was able to support germination, attachment, and subsequent development of *Striga*.

# الملخص

تعتبر البودا (*S. hermonthica*) من الحشائش التي تتطفل علي الجذور وتسبب خسائر في إنتاجية كثير من محاصيل الحبوب في أفريقيا جنوب الصحراء الكبرى مما يشكل تهديداً للزراعة والأمن الغذائي. تعتبر الذرة الشاميه، الذرة الرفيعة، الدخن، الأرز ومحصول قصب السكر من العوائل التقليدية، وحديثاً وجد أن القمح عرضة للأصابة بالبودا. تم إجراء تجارب مشتلية ومعملية في كلية الدراسات الزراعية (شمبات) بجامعة السودان للعلوم والتكنولوجيا في موسم 2012–2013 وذلك لتحديد (i) قابلية بعض الأصناف المحلية للقمح للإصابة بطفيل البودا ، وقدرتها على الحفاظ على التطفل الناجح (ii) ومعرفة مقدرة أجزاء أصناف القمح المجففة هوائياً في تشجيع إنبات الطفيل . أظهرت التجارب المعملية أن بقايا القمح، بغض النظر عن الأصناف، أجزاء النبات وكمية البودرة، تعمل علي تشجيع إنبات بذور البودا وذلك بنسبة تتراوح مابين 8.7_75.5% وتكوين الممصات بنسبة تتراوح بين 22.9-100%، وجد أن الإنبات يختلف بأختلاف كمية البودرة والصنف المستخدم. حيث أظهر الصنف النيلين أعلي متوسط للإنبات،يليه تنازلياً وادي النيل، إمام ونبته. إنبات بذور الطفيل بواسطة أجزاء أصناف القمح أظهرت تكوين ممصات، وقصر في طول الجزير مقارنة مع التي تم إنباتها بواسطة محفز الإنبات GR24 ، أجزاء نبات القمح، بغض النظر عن أجزاء أصناف النبات وكمية البودرة أدت إلي تشجيع تكوين الممصات بنسبة تتراوح ما بين 22.9 – 100٪، وكذلك قصر في طول الجزير بنسبة تتراوح ما بين 67–82 ٪، وذلك مقارنة مع الشاهد. أعطت بذور البودا التي تم وضعها بالقرب من جذور الذرة (أبوسبعين) لمدة 6، 9، 12 يوم نسبة إنبات 21.0، 37.0، 37.7 %، على التوالي , إستطاع منها حوالي 30.0-61.9 % الإتصال بجذور الذرة 2.2– 42.9 % ماتت قبل الإتصال وحوالي 0.7– 1.6 % ماتت بعد الإتصال. أعطت البذور التي وضعت بالقرب من جذور النيلين، نبته، وادي النيل وا ٍمام لمدة 9 أيام نسبة 22.8، 12.4، 7.8، 5.5 % إنبات، على التوالي. البذور التي نبتت من النتائج السابقةحققت إتصال بجذور النيلين وا ٍمام و نبته ووادي

النيل بنسبة 63.2، 25.0 ، 32.0 ،38.8% على التوالي وكانت نسبة الفشل في الإتصال 63.2 ،75.0، 68.0 ، 61.2 %، علي التوالي. ومات حوالي 6.3 و2.1% بعد إتصالها بجذور النيلين ونبته . البذور التي وضعت لمدة 12 يوم بالقرب من جذور النيلين، نبته،وادي النيل وا ٍمام أظهرت نسبة إنبات 79.4، 32.4، 22.7، 15.0 %، على التوالي ، وكانت نسبة الإتصال بالجذور 25.3، 39.4، 35.3، 40.0 % للنيلين وا ٍمام ونبته ووادي النيل، على التوالي وفشل منها في الإتصال بالجذور 74.7، 60.6 ، 51.0 % . يتأثر إنبثاق البودا، بغض النظر عن المخزون من بذورها بأنواع العوائل والاصناف المختلفة . إنبثاق البودا على الذرة أظهر زيادة مطردة مع زيادة مخزون البذور, وكان إنبثاق البذور على القمح أقل من الذرة معتمداً ذلك على الوقت والأصناف, أنبثقت البودا على الذرة بعد 45 يوم من الزراعة، بينما في القمح لوحظ ظهورها في 60 يوم من الزراعة على الأصناف، إمام، النيلين ووادي النيل , أما في الصنف نبته فقد تأخر إنبثاقها الى 75 يوم من الزراعة. بغض النظر عن مخزون بذور البودا على أصناف القمح أدت إلى خفض الخلف والوزن الرطب والجاف في القمح , حيث تفاوت حجم الخفض بإختلاف الأصناف ومخزون بذور البودا. بصفة عامة، مع وجود بعض الإستثناءات الإنخفاض الملاحظ يزداد مع زيادة مخزون بذور البودا، حيث أعطى نبتة أعلى معدل خفض (61.8%) وكان أقل معدل في الصنف إمام (4.2%) أظهرت التجربة أن القمح قابل للإصابة بالبودا وله المقدرة على دعم الإنبات، الإتصال ومن ثم تطور البودا.

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# List of Abbreviations

| | |
|---|---|
| % | Percent |
| ºC | Degree centigrade |
| µM | Micro molar |
| mM | Mille molar |
| Cm | Centimeter |
| Fig. | Figure |
| GR24 | *Striga* Synthetic germination stimulant |
| ppm | Part per million |
| g | gram |
| mg | Milligram |
| L | Litre |
| SE | Standard error |
| h | hours |
| ha | Hectare |
| CV | Coefficient of variation |
| Min | Minute |
| GFFP | Glass fiber filter papers |
| *et al* | And others |
| DAS | Days after sowing |
| DAP | Days after placement |
| DASP | Days after seed placement |
| No. | Number |

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# CHAPTER ONE

# INTRODUCTION

Wheat (*Triticum aestivum* L.) a Poaceae, is a cereal grain, its center of origin by the Levant region of the Near East and Ethiopian Highlands. However, at present it is cultivated worldwide. Cereal grains are a major source of energy, protein, and dietary fiber in human nutrition (Belderok *et al*., 2000). It is also a major source of protein compared with other food as it contributes more than 25 % of the protein in the human diet. Wheat has become the most important source of carbohydrate in the majority of countries in the temperate zone. Wheat straw is used as excellent feed for livestock in under developing countries (Rathore, 2005). In 2010, world production of wheat was 651 million tons, making it the third most-produced cereal after maize (844 million tons) and rice (672 million tons) (Belderok *et al*., 2000).

In Sudan, wheat is becoming the staple food of both urban and rural populations. It constitutes the second food grain in the Sudan after sorghum. It is planted in the fertile alluvial soils of the Nile in the Northern and River Nile States where winter is relatively longer and cooler. Since the 1960s, however, wheat production has moved south wards and the crop is now cultivated in the Gezira, White Nile, Gedarif, Kassala and Darfur States. The recent construction of the Hamadab Dam has also lead to an expansion of the area under wheat. Demand for wheat in the past was not very high, <100 thousand tons per annum, because the diet of the majority of the Sudanese population was based on sorghum (Ibrahim *et al.*, 2008). At present, wheat consumption has increased to over one million tons. In 2008, wheat was grown in more than 300.000 ha, with an average productivity of 1.9 million / ha (FAO, 2010).

*Striga* spp., Orobanchaceae, are a serious biological constraint to food production over large parts of sub-Saharan Africa, where they affect more

than 40% of cereal crops (Ejeta, 2007; Scholes and Press, 2008). *S. hermonthica* (Del.) Benth is widely regarded as the most damaging parasitic plant species in the world causing serious damage to crops such as maize (*Zea mays* L.), Sorghum, pearl millet (*Pennisetum glaucum* L.*)* and upland rice *(Oryza sativa* L.*)*.Losses in cereals yield due to *Striga* damage vary from 10% to complete crop loss, depending on crop variety, climatic conditions and seed infestation level of the soil (Roden burg *et al*., 2005). *Striga* infestation could become so sever in all major cereal producing regions of Africa. The recent reports on susceptibility of Wheat to the parasite are rather disquieting (Vasey *et al*., 2005). In Southern and eastern Africa, where *Striga* spp. are prevalent, 5.6 million ha of wheat are farmed annually, yielding 9.3 million tons of grain. Curiously, despite the wide host ranges of most *Striga* spp. within the family Poaceae, there are only isolated field reports of *Striga* spp. infecting wheat (Vasey *et al*., 2005). This might reflect the presence of some level of resistance to *Striga* in this cereal. Alternatively, wheat might produce lower levels of the different host derived signals required for parasite development (Vasey *et al.,* 2005).

Given the lack of understanding of the nature of the interaction between *S. hermonthica* and wheat the present work was designed to **i)** determine the reaction of local wheat cultivars to *S. hermonthica* and their ability to sustain successful parasitism and **ii)** ability of air-dried parts of the wheat plant to induce germination of the parasite.

# CHAPTER TWO

# LITEATURE REVIEW

## 2.1. General

This review comprises of wheat ecology. Furthermore, the review also includes some ecological and biological aspects of parasitic weeds with emphasis on *Striga* spp.

## 2.2. Wheat ecology

Wheat is adapted to a wide range of climatic conditions, from temperate to tropical zones. The great wheat regions of the world are found in the temperature zones, between latitudes 30 – 60° N and 25 – 40° S, where the average rain-fall varies between more than 1000 mm (Porter and Gawith, 1999). The crop does not succeed in very warm and humid regions. The optimum growing temperature is 25°C, with minimum and maximum growth temperatures of 3° to 4°C and 30° to 32°C, respectively (Briggle, 1980).

## 2.3. Parasitic Plants

Over 4100 species, in approximately 19 families of flowering plants, are able to directly invade and parasitize others plants (Nickrent and Musselman, 2004; Press and Phoenix, 2005). However, only very few parasitize cultivated plants. Nevertheless, these weedy parasites pose a tremendous threat to world economy, mainly because they are at present almost uncontrollable (Parker and Riches, 1993; Gressel *et al.*, 2004). Among parasitic weeds those of the Orobanchaceae received a considerable attention because of their relevance in world agriculture. The family is of interest for evolutionary studies, and because it encompasses closely related parasites with vast difference in their host requirements (Babiker *et al*., 1993). The genus *Striga*, predominant in Africa includes 36 species, which are parasitic by nature. *Striga* compensates for its rudimentary root system by penetrating the roots of other plants and diverting essential nutrients (Press and Graves, 1995).The most economically important *Striga* spp. are *S. asiatica* (L.)

and *S. hermonthica* (Del.) mainly on sorghum, millet and maize (Oswald, 2005). Heavy *Striga* infection caused land abandonment leading to rural exodus. About 40% of cereal crops in Africa are infested by *Striga* and yield can be reduced by up to 100% (Ciotola *et al*., 1995).

### 2.3.1. *Striga*

*S. hermonthica,* the most important parasitic flowering plants in Africa is reported to have several strains and the physiological variants. However, only millet and sorghum strains are well recognized and documented. Wilson-Jones (1955) first demonstrated the existence of physiological strains of S. *hermonthica* in the Sudan, which differ in ability to attack sorghum and millet. Parker and Reid (1979) have since confirmed the existence in West Africa of distinct host-specific strains that attack either sorghum or millet, each strain being almost totally unable to parasitize the other host. The specificity could be explained by different germination requirements, the sorghum root exudates failing to stimulate the strain from millet and vice versa. 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, but this has not yet been confirmed. Several other crops are attacked in some localities, including finger millet (*Eleusine coracana* [L.] *Gaertn*.), rice and sugarcane (*Saccharum officinarum* L.) but there is no evidence for distinct strains of the weed being specific to these crops (ICRISAT, 1986).

#### 2.3.1.1. Origin and Distribution

The economically important root-parasitic weeds have their centre of origin in the old world. Africa was described as the place of origin of the agriculture important genera of the family Orobanchaceae (Ejeta, 2007). *Striga* was thought to have originated in the vast tropical areas of the savannah between the Semien Mountains of Ethiopia and the Nubian hills of Sudan (Musselman, 1987). The same region was postulated as the centre of origin of *Sorghum* (Doggett, 1965). *Striga* spp. are widely spread on light red soils of relatively low pH than on clay soils (Dawoud, 1995). The genus *Striga* comprises about 36 species; over 80% of

them are found in Africa while only four are found in Asia and America. Economically important *Striga* species have broad distribution setting conditions for genetically structured population based on geographic location (Mohamed *et al.,* 2007).

### 2.3.1.2. Economic Important of *Striga*

*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. According to Gressel *et al*., (2004), 21.9 million hectares of Sorghum and Millet fields in Africa are affected by *Striga* compared to an overall 26.43 million hectares of all cereal crops.

*S. hermonthica* can affect its host in different ways. Only part of the reduction in the growth of the host results from competition for carbon assimilates, water, mineral nutrients and amino acids (Graves *et al*., 1990). However, *Striga* does not only act as an additional sink but the parasite also has a strong 'toxic' or 'pathological' effect on the host (Press and Gurney, 2000). Parts of these effects are caused by the disturbed hormonal balance in *Striga*-infected host plants, characterized by increased levels of abscisic acid and decreased levels of cytokinins and gibberellins (Frost *et al*., 1997). By altering the host's hormonal balance, *Striga* affects host biomass allocation, resulting in the root systems of infected plants being greatly stimulated, while the shoot is stunted and reduced (Parker and Riches, 1993). The parasite also negatively affects host photosynthesis. Parasite induced reduction in host photosynthesis has been reported as the most important mechanism of growth reduction. Graves *et al*. (1989) estimated that 80% of the decrease in host growth rate can be attributed to the impact of *Striga* on host photosynthesis. Furthermore, *Striga* strongly affects the water economy of its host by its high transpiration rate and by reducing the stomatal conductance of the host plant (Grimanelli *et al*., 2000).

### 2.3.1. 3. Life cycle of *Striga*

*Striga* spp. are obligate hemi-parasitic plants that attach to the root of their host to obtain water, nutrients and carbohydrate (Parker and Riches, 1993). Most *Striga* species have a very complex life cycle. The seeds of parasitic weeds are tiny relative to those of free-living angiosperms. The seed of *S .hermonthica* are small dust like (0.2 to 0.4 mm) (Parker and Riches, 1993). Energy reserves in small seeds are limited and sufficient for short period of autonomous growth (Doggett, 1965). *Striga* is completely dependent on the host for its survival, and its life cycle is closely linked with that of the host plant (Haussmann *et al*., 2000). The life cycle of the *Striga* is divided into a non-parasite or vegetative phase and parasite mode (Mohamed *et al*., 1998). The non- parasite mode includes the processes of after-ripening, conditioning and germination. The parasite mode starts on the initiation of a haustorium followed by attachment, penetration and establishment of connection with the host xylem and further development to a mature plant that flowers and sets seeds. *Striga* seeds have an after- ripening requirement and cannot germinate in the season in which they are produced (Rich and Ejeta, 2007). After ripening may vary from 2 to 6 months depending on climatic conditions, humidity and temperature (Bebawi *et al*., 1984). During after-ripening certain internal changes, of which little is known, take place gradually inside the seed**.** After-ripened seeds will not germinate until they have passed through a preconditioning (conditioning) period. The duration and temperature optima for the conditioning period vary with the species. In *S. hermonthica* the optimum conditioning period is two weeks at 33 ºC (Parker and Reid, 1979). The biochemical changes that occur during conditioning are not well known. However, conditioning is presumed to reduce germination inhibitors within the seed (Kust, 1966). A chemical stimulus is needed in order to trigger the germination of root parasites (Press and Graves 1995; Yasuda *et al.,* 2003). However, some preparatory metabolic processes take place before the seed can react to the respective germination stimulant. These chemical compounds have been identified as sesquiterpene lactones, released in trace amount in the root

exudates (Bouwmeester *et al*., 2003). Once natural stimulant exuded by the cotton root is the strigol (Cook *et al*., 1972). Once triggered by the stimulant and a favorable temperature of 33°C, seeds germinate in 24 hours (Ramaih., 1985). On contact with a host root, the tip of the radical swells and produces a specialized haustorium by which it attaches to the host root. *Striga* seedlings survive only if they succeed to attach to the host root within five days following germination (Ejeta *et al*., 1993). Once connected, the parasite withdraws water, mineral nutrients, carbohydrates and amino acids, consequently causing stunted shoot growth, leaf chlorosis and reduced photosynthesis in the host. After several weeks of underground development the *Striga* shoots emerge above the soil surface and start to flower and produce an extremely high number of seeds (up to 100,000 seeds/plant) that can remain viable for as long as 20 years (Kroschel and Müller-Stöver, 2004). Pre-conditioned seeds, not exposed to stimulant, enter a period of wet-dormancy and revert to their original dormant condition. When dry this survival mechanism helps in building a seed bank of *Striga* in tropical soils (Ejeta *et al*., 1993).

## 2.4. Control Methods

Compared with non- parasitic weeds, control of parasitic weeds has proved to be exceptionally difficult (Parker and Riches, 1993; Babiker., 2007). The ability of the parasite to produce a tremendously high number of seeds, which remain viable in soil for more than ten years and their intimate physiological interactions with their host plants, are the main obstacles that limit the development of successful control measures that can be accepted and used by subsistence farmers (Elzein and Kroschel, 2003). However, several methods have been tried for the control of parasitic weeds, including preventive methods, mechanical and cultural methods (crop rotation, trap and catch cropping, fallowing, hand pulling, nitrogen fertilization, time and method of planting and intercropping), physical (solarization), chemical (herbicides, fertilizers, artificial seed germination stimulants and fumigants), use of resistant varieties and biological control (Parker and Riches, 1993; Joel, 2000). So far these methods, however, have only

had a limited impact on the parasites and up to-date there is no single control method that can effectively solve the problem (Joel, 2000; Ejeta, 2005).

### 2.4.1. Preventive methods

One of the most important control methods is to prevent the introduction and distribution of the parasite seeds from one field to another and from infested to uninfected areas. Control methods that affect parasite seed germination are expected to be more effective than those affecting later stage of development as they prevent parasitism prior to crop damage and could also reduce the seed bank (Sun, 2008). Different mechanisms are responsible for the dispersal of the seeds. National and international trade of crop seeds contributes to the parasite seed dispersal over long distances. Contaminated crops seeds were reported to be the main vehicle for long distance transport of *Striga hermonthica* (Berner *et al*., 1995). Farm equipment and machinery should be cleaned prior to their use in un-infested fields. *Striga* shoots should be removed prior to flower opening. The collected shoots should be burnt or disposed of properly (Abu-Irmaileh, 2008). Other methods of preventation of seed dispersal are to prevent animals from feeding on parasitic weeds.

### 2.4.2. Cultural Methods

These comprise of many of the traditional methods, including late planting, hand-pulling, intercropping, crop rotation, trap and catch cropping, and nitrogen fertilizers.

#### 2.4.2. 1. Late planting

Numerous reports showed that late sowing of susceptible crops is associated with reduced *Striga* infestation (Parker and Riches, 1993). However, the short seasons and unreliability of late season rains in most of the *Striga* endemic areas preclude adoption of this practice. Results from Kenya and Northern Cameroon (Ransom and Odhiambo, 1992) indicated that late planting of early maturing sorghum or maize genotypes, in heavily infested fields reduced *Striga* infestation and resulted in satisfactory yields. However, it is worth mentioning that most of the

early maturing sorghum genotypes have poor grain qualities and/or poor agronomic characteristics (Parker and Riches, 1993).

### 2.4.2. 2. Hand-weeding

Hand -weeding is the most common in developing countries, but is also the one that most of the farmers have rejected because of various limitations (Ogborn, 1984). The practice is logistically acceptable in case of new infestations, small field with low to moderate levels of infestation. It is always recommended as a supportive treatment (Parker and Riches, 1993). However, under heavy infestations the practice, which is labour intensive, has low cost benefit ratio (Carson and Kunjo, 1991). Hand weeding, as all measures which control *Striga* after emergence, has limited benefits to the current crop. Hand removal of *Striga* curtails replenishment of seed reserves in soil, and if repeated, may lead to their virtual depletion.

### 2.4.2. 3. Intercropping

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). There have been several reports showed that the severity of *S. hermonthica* attack was significantly reduced by intercropping. Intercropping sorghum and groundnuts (*Arachis hypoguaea* L.), sorghum and cowpea( *Vigna unguiculata*), and sorghum and dolichos beans (*Lablab purpurous* L.) reduced population density of *S. hermonthica* (Babiker *et al.,* 1996).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). Delayed planting of the intercrop reduced its effect on *Striga* emergence; however, it increased sorghum growth and yield relative to the early planted intercrop. 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 parasitc weeds *Striga* species have high transpiration rate, associated with stomata which remain open under most if not all conditions (Shah *et al*., 1987).

### 2.4.2. 4. Crop rotation

Rotation, with non-host crops in general, prevents annual buildup of *Striga* seed bank and allows for its demise through natural attrition (Eplee and Norris, 1995). 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).

A rotational scheme involving leguminous crops, in addition to breaking the cycle of repeated planting of a susceptible host, has the benefit of increasing soil fertility. If the legume is carefully selected, it may further enhance rapid depletion of *Striga* seed reserves in soil. In West Africa rotating *Striga* susceptible cereals with leguminous crops has been reported to decrease *Striga* seed bank and increase yield of subsequent cereal crops (Ahonsi *et al.,* 2002). Many legumes viz. soybean (*Glycine max* Merr.), groundnuts, pigonpea (*Cajanus cajan* Mill sp.) etc. have been reported to stimulate suicidal germination of *Striga* (Parker and Reid, 1979). However, recent reports indicated that different varieties of a false host differ in their capacities to induce *Striga* seed germination (Berner *et al.,* 1996). Furthermore, production of *Striga* germination stimulants and concomitantly the efficiency of the false host may be influenced by edaphic and climatic conditions (Weerasuriya *et al.,* 1993).

### 2.4.2. 5. Catch cropping

Catch cropping 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. The susceptible crop is planted at high density and then sacrificed 6-8 weeks later prior to deed setting by the parasite. The catch crop, when ploughed under is equivalent to green manuring it is restorative effects on soil fertility (Bebawi, 1987). A modified catch cropping known as serwala is traditionally practiced by farmers in Sudan, Ethiopia and Eritrea, which are

presumably the centre of origin of both sorghum and *Striga* (Kroschel, 1999). Sorghum, densely planted, is allowed to grow for 4-6 weeks and then disc-harrowed to normal stand. This technique relies on severing sorghum roots and there by killing attached *Striga* seedlings. *Striga* plants, which escape the disc-harrow, are removed by hand. The practice combines the benefits of transplanting sorghum at an advanced stage of growth and delayed planting; both practices are known to reduce *Striga* attack and debilitating effects (Dawoud, 1995).

**2.4.2. 6. Nitrogen fertilizer**

Parasitic plants have acquired the ability to obtain nutrition from host plants and have adapted to prefer less fertile soil (Abu-Irmaielh, 2008). High levels of *Striga* infestation are often associated with low soil fertility (Oswald, 2005). Several reports have shown that nitrogen at high rates suppresses *Striga* infestation, while at low rates it enhances emergence of the parasite (Bebawi, 1987; Osman *et al*., 1991). However, results of field trials across countries and locations have not been consistent in term of host crop yield or *Striga* numbers (Parker and Riches, 1993). These variations, which may be associated with intrinsic soil or crop variety characteristics, make recommendation of nitrogen as a sole treatment for *Striga* control difficult.

Nitrogen is believed to reduce stimulant production. Root exudates from sorghum grown in hydroponic cultures was considerably more active at 0 mg N/L than at 30 mg N/L. Root exudates produced at 150 mg N/L failed to induce *Striga* seed germination (Raju *et al.,* 1990). Similar results were reported by Cechin and Press*,* (1993). Furthermore, possible direct suppressive effect of high nitrogen rates on *Striga* growth was revealed by Igbinnosa *et al*., (1998).

**2.4.2. 7. Resistance varieties**

In theory resistant varieties should provide the simplest, the easiest and the cheapest method for *Striga* control. However, no absolute immunity to *Striga* has been discovered yet and resistance is defined as the ability to support less successful attachments (Ejeta *et al.,* 1993). Resistance to *Striga* has been

associated with several factors, including reduced crop root development in the upper soil layers (Hess and Ejeta, 1987), low stimulant production (Ejeta *et al*., 1993) and the direct inhibition of the infection process by development of physical and/or chemical barriers (Hood *et al.,* 1998).

Resistance to *S. hermonthica* in sorghum proved to be none durable, elusive and inconsistent (Kim *et al.,* 1987). Resistant varieties were reported to lose their resistance with time and/or location. The breakdown of resistance is attributed to the presence of several strains of the parasite as well as physiological and ecological variants (Ejeta *et al.,* 1993). The variability in *S. hermonthica* together with the paucity of resistance genes in sorghum imposes serious limitations on breeding for durable resistance (Ejeta *et al.,* 1993).The development of resistant and tolerant lines of susceptible crops constitutes an important, practical and reliable approach to controlling *Striga*. Host plant resistance is an effective means to reduce the reproduction of the parasite (Kim, 1991). Complete resistance to *Striga* by susceptible cereal crops, however, has yet to be found, though considerable variability for the level of *Striga* attack and tolerance to *Striga* parasitism has been reported both between and among the most commonly parasitized cereals. This partial resistance or tolerance has been attributed to a number of different mechanisms including: rooting patterns that allow some level of avoidance (Ransom and Odhiambo, 1995); production of reduced levels of *Striga* germination stimulants (Ejeta and Butler, 1993); increased photosynthetic rate (Gurney *et al.,* 2001) and growth and development features that delay attachment (Gurney *et al*., 1999). Cultivars with improved resistance/tolerance to *Striga* have not been widely adopted because they are low yield potential and inferior agronomic characters (Oswald and Ransom, 2004) or do not possess other traits valued by farmers such as plant height and grain characteristics (Ezeaku and Gupta, 2004).

### 2.4.3. Chemical Control

Various chemicals including herbicides, fumigants, and synthetic germination stimulants were reported as means of *Striga* control.

#### 2.4.3. 1. Herbicides

Several herbicides have been recommended for control of *Striga* on sorghum and maize (Eplee and Norris, 1987; Langston *et al*., 1991). Most of the available products viz parquat, diquat, and 2, 4-D are effective when used on *Striga* plants (Lagoke *et al.,* 1991). However, because of early crop damage post-emergence control of *Striga*, albeit reduces seed production capacity, is reluctantly accepted by farmers. Work in India and Sudan (Korwar and Friesen, 1984) showed that 2,4-D and MCPA, applied as soil directed sprays 3 to 4 weeks after crop emergence, reduced *Striga* incidence and increased crop yield. Similar results were reported with oxyfluorfen, triclopyr and chlorsulfuron (Langston and English, 1990; Babiker, 1996). These products kill the parasite during the early developmental stages and thus make evasion of crop damage possible. Dependence of herbicidal efficacy on timing of application restricts commercial use of these products to irrigated and high rainfall areas. A dry spell, following treatment could result in a substantial reduction in activity. Furthermore, most of these herbicides are either none selective to sorghum (oxyfluorfen) or has a narrow safety margin (chlorsulfuron). Accordingly, to attain maximum selectivity the products have to be applied as soil directed sprays. Directed spraying necessitates abandonment of the present system of sorghum planting, which resides on seed broadcasting followed by discing, to planting in rows. Planting in rows, albeit has several advantages involves additional costs and may not be economically feasible due to the present low yields and low prices of cereal commodities.

Berner *et al.,* (1996) reported control of *Striga* by treating maize seeds with two acetolactate synthases (ALS) inhibiting herbicides nicosulfuron, a sulfonylurea, and imazaquin, an imidazolinone. Combining seed treatment with AL S-

inhibiting herbicides and AL S-modified maize with XA-17 gene may offer a practical solution to African maize growers.

**2.4.3. 2. Fumigants**

Fumigants are chemicals that have the ability to kill most soil borne organisms including bacteria, fungi, nematodes, and weed seeds. The seeds must be physiologically active to be killed (Nandulla, 1998). Fumigation aims at eliminating the seed bank in 1-2 years. Three fumigants were reported to provide effective control of parasitic weeds. Bromomethane (methyl bromide) was reported to be highly effective on *S. asiatica* (Eplee and Langston, 1971). However, high cost, high toxicity and requirement of special skills in handling limit the use of Bromomethane to experimental plots. Jacobsohn *et al*., (1987) reported another fumigant, Vapam (Sodium methyl dithiocarbamate) to be effective on *Orbanche aegyptica*. However, the high dose requirement (600 to 1000 L/ha) makes application of this product costly and impractical. Recently, Basamid (3, 5-dimethyl-2h-1, 3, 5- thiadazine-2-thione) was reported to be effective on *S. asiatica* and other weeds (Parker and Riches, 1993). The product is easy to handle. However, its potential for controlling *Striga* in farmer`s fields remains to be determined.

**2.4.3.3. Germination Stimulants**

Seeds of the parasitic plants *Orobanche* and *Striga* only germinate in the presence of chemical compounds that are exuded from the roots of hosts and some non-host plant species. A large number of investigators have attempted to isolate, characterize and /or identify the stimulant from many host and non-host (Awad *et al*., 2006). The natural stimulants are highly active, but are present in root exudates in such an extremely low levels that their isolation, purification and identification have been difficult (Musselman, 1987). A number of different classes of secondary metabolites have been described to have germination stimulant activity including dihydrosorgoleone, the strigolactones and the sesquiterpene lactones (Sun, 2008). Several strigolactone, were found in the root exudates of various plant species (Yasuda *et al.,* 2003), and proved to stimulate

the germination of both *Orobanche* and *Striga*. Strigol was the first *Striga* germination stimulate to be identified, and was first isolated from root exudates of cotton (*Gossypium hirsutum* L.) (Cook *et al.,* 1972) and was also isolated at later stages from the root exudates of a variety of other plants including maize, millet and sorghum (Sato *et al.,* 2005). In addition to these compounds, at least 10 additional strigolactones have been detected in root exudates of different plant species (Yoneyama *et al.,* 2006). Sorgolatone was identified in the root exudates of sorghum and has high germination stimulant activity on *Striga* (Hauk *et al*., 1992; Awad *et al.,* 2006).

### 2.4.4. Integrated Management

Single methods are not sufficient to control parasitic weeds effectively in one cropping season. Therefore, combinations of control methods and their yearly application are the only solution to reduce the infestation to a tolerable level. Integrated management strategies need to combine low cost control methods that enhance crop tolerance to the parasite through improvement of soil fertility, particularly nitrogen status, utilize the most tolerant cultivars that are available, in addition to potential preventive measures. Cultural methods such as manipulating seeding rate and planting date help in reducing infestations. Herbicides application could be carried out by trained farmers. The aim of integrated management is to constantly reduce the parasite population leading to a reduction in the soil seed bank (Abu-Irmaileh, 2008).

# Chapter Three

# Material and Methods

## 3.1. General

A series of laboratory and greenhouse experiment was undertaken at the College of Agricultural Studies, Sudan University of Science and Technology (SUST) at Shambat, to **i)** determine the reaction of local wheat cultivars to *S. hermonthica* and their ability to sustain successful parasitism and **ii)** ability of air dried parts of the wheat plant to induce germination of the parasite

### 3.2. Materials

#### 3.2.1. Plant materials

Four local wheat cultivars, Emam, Napta, Wadi-Elnile, and Elnelien and Sorghum (cv. Abu sabeen), were obtained from the Agricultural Research Corporation (ARC).

#### 3.2.2. Seed cultivars sterilization

The seeds of wheat and sorghum cultivars were surface-sterilized in1% sodium hypochlorite (NaOCl) solution for 5 min. After thorough rinsing with sterilized distilled water for several times. The seeds were air dried and kept in sterile bottle till used.

#### 3.2.3. Strigol analogue (GR24) stock solution

A stock solution of the synthetic germination stimulants GR24 (Fig 3.1) was prepared by dissolving 1mg in 1ml of acetone and completion to volume (100 ml) with sterilized distilled water to obtain the desired concentration (10 ppm

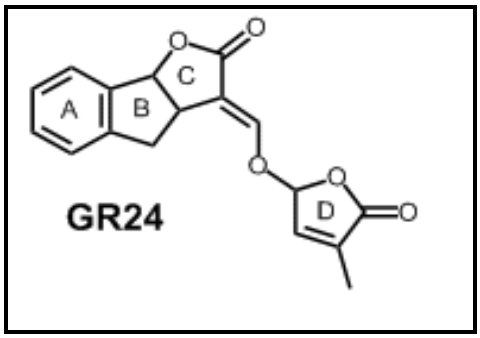



**Fig 3.1. Chemical structure of the *Striga* germination stimulants GR24**

### 3.2.4. Preparation of Agar medium

Low nutrient agar medium (gelling temperature 30-31ºC, Nacalai Tesque, Kyoto, Japan) was prepared by adding 7.5 g to one liter of distilled water and subsequent autoclaving at 15 bars and 121 ºC for 15 minutes. The autoclaved agar was cooled to room temperature.

## 3.3. Methods

### 3.3. 1. Laboratory experiments

A series of experiments was conducted at the *Striga* research laboratory, at the College of Agricultural Studies, Sudan University of Science and Technology, to determine ability of root exudates and residues of the selected wheat cultivars to induce *S. hermonthica* germination, modulate radical extension and haustorium initiation.

#### 3.3.1.1. *Striga* seeds sterilization and conditioning

*Striga* seeds were surface sterilized by immersion in 70% ethanol for 2-3 min, followed by washing 3 times with distilled sterilized water. The seeds were then immersed with swirling into a 1% sodium hypochlorite, obtained by appropriate dilution of commercial sodium hypochlorite (Bleach) for 2-3 min, followed by washing with sterilized distilled water to remove all traces of the sterilizing solution. The seeds, plotted on filter papers, were air-dried and stored till used. Glass fiber filter papers (GFFP) discs (8mm diameter) were cut, wetted thoroughly with water and placed in an oven set at 104 ºC for one hour to be sterilized before use. For pre-conditioning the sterilized discs, placed in 9 cm Petri dishes lined with a single sheet of glass fiber filter

papers, were moistened with 5 ml of distilled water. Subsequently, about 25-50, surface sterilized *Striga* seeds were sprinkled on each of the glass fiber discs. The Petri dishes sealed with Parafilm to avoid moisture loss, were wrapped with aluminum foil, and incubated in the dark at 30 ºC, for 14 days.

**3.3.1.2. Effects of wheat residues on *Striga* seeds germination**

The present investigation was undertaken to study the effects of dried wheat cultivars residues (leaves, stem, and roots) on *S. hermonthica* seed germination, radicle length and haustorium initiation. Micro-multi-well plastic plates were used. Aliquots of autoclaved agar (5ml) as previously described in 3.2.4, were pipette into each well of a multi-well plate. Subsequent to gelatinization samples of wheat parts powder (0, 5, 10, 15, 20, 25 and 30 mg) were added and distributed evenly by hand. Another 5ml Agar was added to each well on top of the sample, and allowed to solidify. This method is known as the sandwich method (Fujii *et al*., 2004). Glass fiber discs containing conditioned *Striga* seeds (4/well) were placed on top of the second agar layer. Discs containing conditioned *Striga* seeds, placed on the top of agar, treated with GR24 at 0.1 ppm or distilled water, were included as control for comparison.

The multi-well-plates were sealed with Parafilm, wrapped with aluminum foil and incubated in the dark at 30 ºC for 48 h. The seeds were subsequently examined for germination, radicle length, and haustorium initiation using a binocular stereo-microscope. Treatments were arranged in a Complete Randomized Design (CRD) with 4 replicates.

**3.3.1.3. In-situ germination and attachment of *S. hermonthica* to sorghum and wheat:-**

Reaction of wheat cultivars and sorghum to *S. hermonthica* was investigated using the Rhizotron technique previously described by Vasey *et al*., (2005). Wheat seeds were germinated on filter paper for 3 days at 20 ºC. Seedlings were transferred to glass test-tubes filled with 40% Long Ashton solution. The tubes were wrapped with aluminum foil to exclude light from the roots.

Plants were maintained in a controlled environment with a 12 h photoperiod and photon flux density of 200 umolm$^{-2}$s$^{-1}$, at day and night temperatures of 20 and 18 ºC, respectively. After 10 days wheat seedlings were transferred to 150 mm diameter Petri dishes on a 150 mm diameter glass fiber filter paper, over laying a sheet of rock wool, which filled the base of the dish. The Rhizotron contained a hole at the top through which the shoot system grew (Plate 3.1). The Petri dishes, placed in a black nylon jacket to excluded light from the roots, were wrapped with aluminum foil and incubated in light at 20 ºC. Conditioned *Striga* seeds treated or not with GR24 at 0.1 ppm, were subsequently placed adjacent to wheat roots using a brush. Germination, attachment, penetration and establishment, were examined 3, 6, 9 and 12 days after incubation, using a binocular stereo- microscope.


**Plate 3.1.Rhizotron technique**

### 3.3.2. Green house experiment

A pot experiments was conducted in a greenhouse at the College of Agriculture Studies, (CAS), at Shambat during the season 2012/2013, to compare the reaction of selected local wheat cultivars (Emam, Wadi-Elnile, Napta, and Elnelien) and sorghum (cv. abusabeen) to *S. hermonthica.* 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 (2, 4, 6, 8, and 10 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. Wheat and sorghum seeds (5/pot) were sown early November at 2 cm soil depth. The pots were immediately irrigated. Subsequent irrigations were carried out every two days. Wheat and Sorghum seedlings were thinned to three plants per pot two weeks after sowing. Treatments were arranged in a Randomized Complete Block Design (RCBD) with four replicates.

Data collected on wheat growth comprised of i) Plant heights (cm), ii) number of leaves, iii) number of tillers/plant, iv) chlorophyll content (SPAD readings), vi) shoot fresh weight (g) and vii) shoot dry weight (g). Data collected on *S. hermonthica* included *Striga* emergence.

Average of SPAD readings at 3-5 points (according to leaf size) using a chlorophyll meter (SPAD-502, Konica Minolta Sensing, Japan) was recorded for each leaf.

**3.4. Statistical analysis**

Prior to analysis of variance (ANOVA), data were checked for normality using Shapiro-Wilks-W-Test. Data on percentage germination of *S. hermonthica* seeds were arcsine square root transformed to fulfill ANOVA requirements. The data were subsequently subjected to ANOVA using SAS 9.1 statistical package (SAS Ins.). Mean separation was made by Tukey honestly significance difference test at $P > 5\%$.

# CHPTER FOUR

# RESULTS

## 4.1. Laboratory experiments

### 4.1.1. Effects of wheat powder on *S. hermonthica*

#### 4.1.1.1. Effects on seed germination

In all experiments, *S. hermonthica* conditioned in water and subsequently treated with distilled water displayed no germination. However, seeds treated with GR24 at 0.1 ppm displayed high germination (90%). Germilings Wheat residues, irrespective of cultivars, plant parts and amount of powder, induced germination of *S. hermonthica*. Seeds conditioned in distilled water displayed an average germination of 36.2% in response to wheat root powder at 5mg/well. An increase in powder level to 10mg/well increased germination to 40.6%. A further increase of root powder to 20, 25, and 30 mg/well increased germination to 41.8, 47.2 and 50.4%, respectively (Table 4.1). Among the wheat cultivars Elnelien root powder gave the highest germination (63.7%). Powder from Wadi-Elnile, Emam and Napta induced 53.3, 31.5 and 23.9% germination, respectively.

Wheat stem powder at 5mg/well induced 41% germination. However, at 10mg/well the germination increased, albeit not significantly. A further increase in stem powder to 25 mg/well increased germination to 48.8%. However, increasing stem powder to 30 mg/well reduced germination slightly (Table 4.1). Among the cultivars tested, Elnelien stem powder displayed the highest germination (59.6%), followed in descending order by Wadi-Elnile (56.0%), Napta (28.8%) and Emam (27.1 %).

Wheat leaves powder at 5mg/well induced about 35.7% germination. An increase in leaf powder to 10 and 15mg/well increased germination to 36.9 and 47.1%, respectively. A further increase of leaf powder to 20 mg/ well or

more reduced germination, albeit not significantly (Table 4.1). Wadi-Elnile leaf powder induced about 60.8%, while, Elnelien, Napta and Emam displayed 54.6, 20.5 and 19.6% germination, respectively.

**Table 4.1. Effects of wheat residues on *S. hermonthica* germination**

| Plant parts | | | | | |
|---|---|---|---|---|---|
| **Roots** | | | | | |
| **Powder amount (mg)** | **Cultivars** | | | | **Mean** |
| | **Elnelien** | **Emam** | **Napta** | **Wadi-Elnile** | |
| **5** | 61.1 (±4.1)[1] | 26.1 (±2.9) | 18.4 (±4.3) | 39.3 (±4.7) | **36.2c** |
| **10** | 62.9 (±6.4) | 36.1 (±5.1) | 22.2 (±2.9) | 41.2 (±4.9) | **40.6bc** |
| **15** | 65.6 (±6.8) | 40.5 (±3.9) | 27.9 (±2.8) | 35.2 (±1.7) | **42.3abc** |
| **20** | 54.0 (±4.8) | 28.2 (±5.2) | 28.8 (±4.2) | 56.1 (±5.3) | **41.8bc**[2] |
| **25** | 68.7 (±5.3) | 25.7 (±0.8) | 22.5 (±2.9) | 72.1 (±3.5) | **47.2ab** |
| **30** | 69.9 (±4.1) | 32.5 (±3.3) | 23.4 (±1.7) | 75.7 (±7.1) | **50.4a** |
| **Mean** | **63.7a** | **31.5c** | **23.9c** | **53.3b** | |
| **Stem** | | | | | |
| **5** | 63.4 (±2.7) | 16.8 (±3.9) | 31.7 (±3.2) | 52.2 (±2.1) | **41.0 a** |
| **10** | 56.6 (±2.6) | 25.3 (±2.7) | 32.3 (±6.6) | 51.4 (±1.9) | **41.4 a** |
| **15** | 56.5 (±6.8) | 25.0 (±3.8) | 15.4 (±1.8) | 52.5 (±2.3) | **37.3 a** |
| **20** | 60.3 (±3.1) | 30.6 (±3.2) | 28.8 (±3.6) | 53.0 (±2.4) | **43.2 a** |
| **25** | 62.9 (±3.4) | 38.0 (±3.7) | 33.5 (±3.5) | 60.8 (±2.6) | **48.8 a** |
| **30** | 57.8 (±5.3) | 26.9 (±3.4) | 31.3 (±3.5) | 66.3 (±4.0) | **45.6 a** |
| **Mean** | **59.6** | **27.1** | **28.8** | **56.0** | |
| **Leaves** | | | | | |
| **5** | 44.5 (±3.7) | 18.0 (±7.4) | 12.3 (±4.0) | 68.0 (±11.4) | **35.7 a** |
| **10** | 51.9 (±3.9) | 29.2 (±5.3) | 21.6 (±5.4) | 44.9 (±6.1) | **36.9 a** |
| **15** | 60.2 (±5.7) | 32.9 (±9.1) | 28.1 (±10.1) | 67.4 (±5.0) | **47.1 a** |
| **20** | 48.8 (±2.7) | 8.7 (±1.7) | 19.3 (±7.0) | 62.8 (±7.6) | **34.9 a** |
| **25** | 58.2 (±4.8) | 16.8 (±4.9) | 24.5 (±5.4) | 59.3 (±7.2) | **39.7 a** |
| **30** | 64.0 (±6.4) | 12.4 (±3.7) | 17.3 (±3.6) | 62.5 (±9.0) | **39.0 a** |
| **Mean** | **54.6** | **19.6** | **20.5** | **60.8** | |
| **Three-Way ANOVA** | | | | | |
| **Cultivars, C** | | | 213.9*** | | |
| **Plant part, PP** | | | 3.6*** | | |
| **Plant levels, Pl** | | | 4.4*** | | |
| **C*PP** | | | 4.6*** | | |
| **C*Pl** | | | 2.8** | | |
| **PP*Pl** | | | 2.5** | | |
| **C*PP*Pl** | | | 2.2** | | |
| **CV%** | | | 26 | | |

*= P≤ 0.5, **= P ≤ 0.01, ***= P ≤ 0.001.

[1]Data between parentheses are the standard errors of means.

[2]Means in rows and colum's each followed by the same letter(s) were not significantly different at P≤ 0.5 (Tukey-Test).

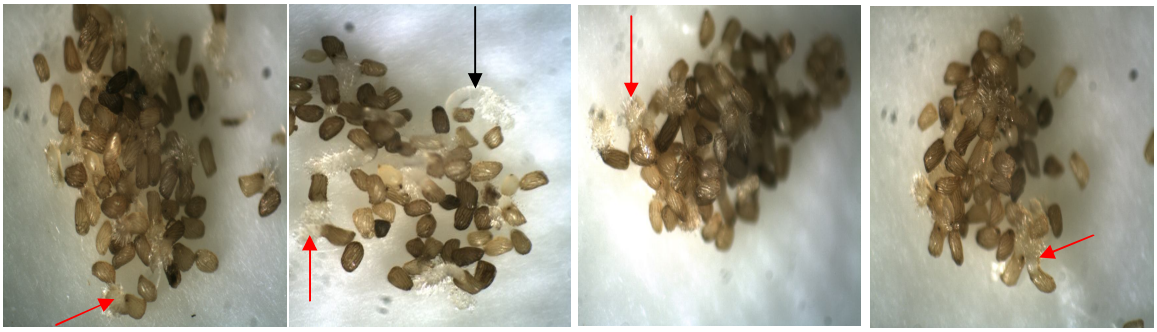
#### 4.1.1.2. Effects on haustorium initiation

Germilings from seeds induced to germination by wheat, irrespective of cultivars and plant parts showed pre-mature haustoria (Plate 4.1).

Wheat root powder at 5, 10 and 15mg/well induced 86.6, 80.7 and 86.5% haustoria initiation, respectively, irrespective to cultivar. A further increase in amount of wheat root powder to 20mg/well or more reduced haustorium formation significantly 82.1- 75%. Among the cultivars studied Elnelien and Napta showed highest and comparable average haustorium initiation (100%), followed by Wadi-Elnile (86.3%), while Emam sustained the lowest 40.1% (Table 4.2).

Wheat stem powder at 5, 10 and 15mg/well induced 100% haustorium initiation. Increasing stem powder to 20, 25 and 30mg/well decreased haustorium formation to 68.4, 56.2 and 67.1%, respectively, irrespective to cultivar (Table 4. 2). Wadi-Elnile stem displayed highest haustorium initiation (92.1%), followed by Napta (86.2%), Elnelien (75.1%) and Emam (74.3%).

Wheat leaves powder was induced considerable number of haustoria. At 5mg/well average haustorium initiation 100%. An increase in leaf powder to 10 and 15mg/well reduced haustorium initiation to 97.5 and 95.2%, respectively. A further increase in powder amount to 20mg/well or more decreased haustorium initiation significantly (Table 4.2). Emam and Wadi-Elnile showed highest haustorium initiation (100%), followed in descending order by Napta (95.1%) and Elnelien (78.2%).



**Elnelien** **Wadi-Elnile** **Napta** **Emam**

**Plate 4.1. *S. hermonthica* induced to germinate by wheat cultivars. Black and red arrows show radicle and haustoria, respectively.**

**Table 4.2. Effects of wheat residues on *S. hermonthica* haustorium initiation**

| Powder amount (mg) | Cultivars | | | | Mean |
|---|---|---|---|---|---|
| | **Elnelien** | **Emam** | **Napta** | **Wadi-Elnile** | |
| **Plant parts** | | | | | |
| **Roots** | | | | | |
| **5** | 100.0 (±0.0)[1] | 46.4 (±18.0) | 100.0 (±0.0) | 100.0 (±0.0) | **86.6a** |
| **10** | 100.0 (±0.0) | 22.9 (±1.6) | 100.0 (±0.0) | 100.0 (±0.0) | **80.7ab** |
| **15** | 100.0 (±0.0) | 45.9 (±11.5) | 100.0 (±0.0) | 100.0 (±0.0) | **86.5a** |
| **20** | 100.0 (±0.0) | 53.2 (±7.3) | 100.0 (±0.0) | 75.1 (±2.1) | **82.1bc** |
| **25** | 100.0 (±0.0) | 36.0 (±8.3) | 100.0 (±0.0) | 75.6 (±2.7) | **77.9bc** |
| **30** | 100.0 (±0.0) | 36.3 (±5.0) | 100.0 (±0.0) | 67.2 (±2.1) | **75.9c** |
| **Mean** | **100.0a** | **40.1c** | **100.0a** | **86.3b** | |
| **Stem** | | | | | |
| **5** | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **100.0a**[2] |
| **10** | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **100.0a** |
| **15** | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **100.0a** |
| **20** | 52.4 (±2.9) | 51.5 (±9.2) | 87.3 (±11.3) | 82.3 (±6.1) | **68.4b** |
| **25** | 35.2 (±7.6) | 44.5 (±3.6) | 59.3 (±9.7) | 86.0 (±2.3) | **56.2b** |
| **30** | 63.1 (±4.5) | 49.9 (±8.0) | 70.8 (±10.2) | 84.6 (±5.0) | **67.1b** |
| **Mean** | **75.1b** | **74.3b** | **86.2a** | **92.1a** | |
| **Leaves** | | | | | |
| **5** | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **100.0a** |
| **10** | 100.0 (±0.0) | 100.0 (±0.0) | 90.0 (±10.0) | 100.0 (±0.0) | **97.5ab** |
| **15** | 80.7 (±12.1) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **95.2ab** |
| **20** | 54.4 (±6.0) | 100.0 (±0.0) | 100.0 (±0.0) | 100.0 (±0.0) | **88.6b** |
| **25** | 66.9 (±13.5) | 100.0 (±0.0) | 92.2 (±5.9) | 100.0 (±0.0) | **89.8b** |
| **30** | 67.1 (±13.2) | 100.0 (±0.0) | 91.4 (±5.1) | 100.0 (±0.0) | **89.6b** |
| **Mean** | **78.2b** | **100.0a** | **95.6a** | **100.0a** | |
| **Three-Way ANOVA** | | | | | |
| **Cultivars, C** | | | 61.2*** | | |
| **Plant part, PP** | | | 56.5*** | | |
| **Plant levels, Pl** | | | 70.0*** | | |
| **C*PP** | | | 90.8*** | | |
| **C*Pl** | | | 2.7** | | |
| **PP*Pl** | | | 20.1*** | | |
| **C*PP*Pl** | | | 5.4*** | | |
| **CV%** | | | 14.8 | | |

*= P≤ 0.5, **= P ≤ 0.01, ***= P ≤ 0.001.

[1]Data between parentheses are the standard errors of means.

[2]Means in rows and colum's each followed by the same letter(s) were not significantly different at P≤ 0.5 (Tukey-Test).

### 4.2.1.3. Effects on Radicle length

Germilings resulting from seeds stimulated by wheat powder, irrespective of cultivars and plant parts employed, displayed shorter radical length than those stimulated by GR24 (Table 4.3). Germilings from seeds induced to germinate with GR24 at 0.1ppm displayed a mean radical length of 7.2μm$10^{-2}$. *Striga* germilings from seeds induced to germinate by wheat root powder at 5, 10, 15, 20, 25 and 30mg/well showed an average radical length of 2.0-2.3 μm$10^{-2}$. Wheat root powder reduced radical extension by 67-70%, in comparison to the control. *Striga* germilings from seeds induced to germinate by Elnelien, Emam, Napta and Wadi-Elnile displayed radical length of 2.0, 3.3, 1.4 and 2.1μm$10^{-2}$, respectively (Table 4.3).

Wheat stem, irrespective of amount of powder reduced radical length by 84.7-68.0%, as compared to the control. *Striga* germilings from seeds induced to germinate by wheat stem at 5, 10, 15, 20, 25 and 30 mg/well displayed an average radical length of 1.6-1.9 μm$10^{-2}$, Elnelien, Emam, Napta and Wadi-Elnile, irrespective of amount of powder reduced radical length to 2.3, 1.6, 1.1 and 1.8 μm$10^{-2}$, respectively (Table 4.3).

Wheat leaves powder reduced radical length by 70.8-86.1%, as compared to control. Radical length was reduced to 2.1, 1.6, 1.4, 1.3, 1.2 and 1.3μm$10^{-2}$, respectively in germilings from seeds induced to germinate by wheat leaves at 5, 10, 15, 20, 25 and 30 mg/well, respectively (Table 4.3). Elnelien, Emam, Napta and Wadi-Elnile reduced radical length to 1.2, 1.7, 1.0 and 2.1μm$10^{-2}$.

**Table 4.3. Effects of wheat residues on *S. hermonthica* radicle length (mμ$10^{-2}$)**

| Plant parts | | | | | |
|---|---|---|---|---|---|
| **Roots** | | | | | |
| | **Cultivars** | | | | |
| **Powder amount (mg)** | **Elnelien** | **Emam** | **Napta** | **Wadi-Elnile** | **Mean** |
| 5 | 1.8 (±0.1)[1] | 4.0 (±0.5) | 1.6 (±0.2) | 2.1 (±0.2) | **2.1** |
| 10 | 2.1 (±0.2) | 3.7 (±0.2) | 1.2 (±0.2) | 1.1 (±0.0) | **2.0** |
| 15 | 1.9 (±0.2) | 3.1 (±0.2) | 1.4 (±0.2) | 2.2 (±0.2) | **2.1** |
| 20 | 1.9 (±0.2) | 3.6 (±0.2) | 1.6 (±0.2) | 2.2 (±0.2) | **2.3** |
| 25 | 2.2 (±0.2) | 2.6 (±0.3) | 1.3 (±0.2) | 2.3 (±0.2) | **2.1** |
| 30 | 1.9 (±0.1) | 3.2 (±0.3) | 1.5 (±0.2) | 2.5 (±0.2) | **2.3** |
| **Mean** | **2.0b** | **3.2a** | **1.4c** | **2.1b** | |
| **Stem** | | | | | |
| 5 | 2.3 (±0.1) | 1.5 (±0.2) | 1.1 (±0.0) | 1.8 (±0.0) | **1.6b**[2] |
| 10 | 2.4 (±0.1) | 1.6 (±0.2) | 1.1 (±0.0) | 1.6 (±0.1) | **1.6b** |
| 15 | 2.3 (±0.2) | 1.6 (±0.2) | 1.1 (±0.0) | 1.6 (±0.1) | **1.6b** |
| 20 | 2.5 (±0.1) | 1.4 (±0.1) | 1.1 (±0.2) | 1.7 (±0.1) | **1.7ab** |
| 25 | 2.5 (±0.0) | 1.8 (±0.0) | 1.1 (±0.2) | 1.9 (±0.2) | **1.8ab** |
| 30 | 2.2 (±0.2) | 1.8 (±0.1) | 1.1 (±0.1) | 2.4 (±0.1) | **1.9a** |
| **Mean** | **2.3a** | **1.6c** | **1.1d** | **1.8b** | |
| **Leaves** | | | | | |
| 5 | 1.0 (±0.1) | 3.2 (±0.2) | 1.1 (±0.0) | 3.2 (±0.3) | **2.1a** |
| 10 | 1.2 (±0.2) | 1.8 (±0.1) | 1.1 (±0.0) | 2.5 (±0.3) | **1.6b** |
| 15 | 1.1 (±0.2) | 1.7 (±0.1) | 1.0 (±0.2) | 1.9 (±0.2) | **1.4bc** |
| 20 | 1.3 (±0.2) | 1.2 (±0.1) | 1.0 (±0.1) | 1.8 (±0.1) | **1.3bc** |
| 25 | 1.1 (±0.2) | 1.1 (±0.1) | 1.0 (±0.1) | 1.8 (±0.1) | **1.2c** |
| 30 | 1.5 (±0.1) | 1.2 (±0.2) | 1.1 (±0.0) | 1.5 (±0.2) | **1.3bc** |
| **Mean** | **1.2c** | **1.7b** | **1.0c** | **2.1a** | |
| **Three-Way ANOVA** | | | | | |
| **Cultivars, C** | | | 114.5*** | | |
| **Plant part, PP** | | | 93.0*** | | |
| **Plant levels, Pl** | | | 3.0* | | |
| **C*PP** | | | 50.7*** | | |
| **C*Pl** | | | 3.4* | | |
| **PP*Pl** | | | 7.4*** | | |
| **C*PP*Pl** | | | 4.7** | | |
| **CV%** | | | 19.0 | | |

*= P≤ 0.5, **= P ≤ 0.01, ***= P ≤ 0.001.

[1]Data between parentheses are the standard errors of means.

[2]Means in rows and colum's each followed by the same letter(s) were not significantly different at P≤ 0.5 (Tukey-Test).

### 4. 1.2. *In-situ* germination, haustorium and attachment of *S. hermonthica* to sorghum and wheat.

Seeds placed in vicinity of Abusabeen roots displayed 21.0, 21.4 and 37.7% germination at 6, 9 and 12 days after placement (DAP), respectively. Seeds placed in vicinity of wheat roots, irrespective of cultivars, showed no germination at 6 days after placement (Fig 4.1 A). However, at 9 and 12 DAP placed in proximity of Elnelien roots displayed 22.8 and 79.4% germination, respectively, seeds placed for 9 days near Napta, Wadi-Elnile and Emam roots displayed 12.4, 7.8 and 5.5% germination, respectively. Seeds placed for 12 days in vicinity of Napta, Wadi-Elnile and Emam roots showed 32.4, 22.7and 15.0% germination, respectively. Of the resulting *Striga* germilings 30.0, 54.2 and 61.9% were attached to sorghum (Abusabeen) roots 6, 9 and 12 days after seeds placement (DASP) respectively (Fig 4.1 B). At 9DASP in vicinity of wheat roots 63.8, 25.0, 32.0 and 38.8% of the germilings achieved attachment to Elnelien, Emam, Napta and Wadi-Elnile roots (Plate 4.2). At 12 DASP attachments was 25.3, 39.4, 35.3 and 49.0% on Elnelien, Emam, Napta and Wadi-Elnile roots, respectively. Of the germilings, induced to germinate by Abusabeen 2.2, 42.9 and 7.3% died prior to attachment 6, 9 and 12 (DASP). However, on wheat at 9 DASP 69.7, 71.3, 52.4 and 80.4% germilings failed to attach to Elnelien, Emam, Napta and Wadi-Elnile, respectively (Fig 4.1C). At 12 DASP 63.0, 8.7, 16.0 and 9.8% of the germilings failed to attach to Elnelien, Emam, Napta and Wadi-Elnile, respectively. Of the *Striga* germilings attached to Abusabeen 1.6 and 0.7% died at 9 and 12 DASP, however, on wheat at 9 days 6.3 and 2.1% of the germilings attached to Elnelien and Napta died, however, germilings death was respectively lower on Emam, Napta and Wadi-Elnile 0, 7.1 and 4.5% (Fig 4.1 D and Plate 4.3).


**Plate 4.2. Attachment of *S. hermonthica* on sorghum and wheat cultivars**

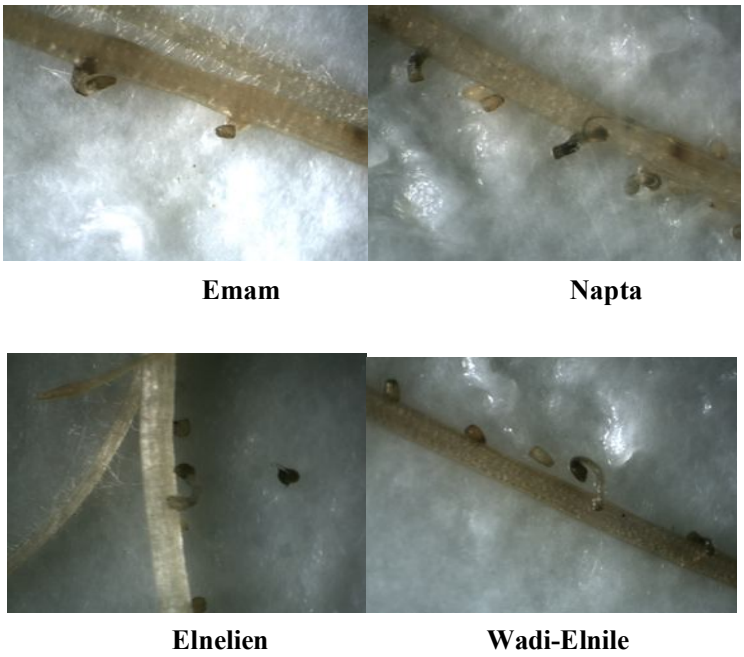



**Plate 4.3. Death of *S. hermonthica* germilings after attachment on wheat cultivars**

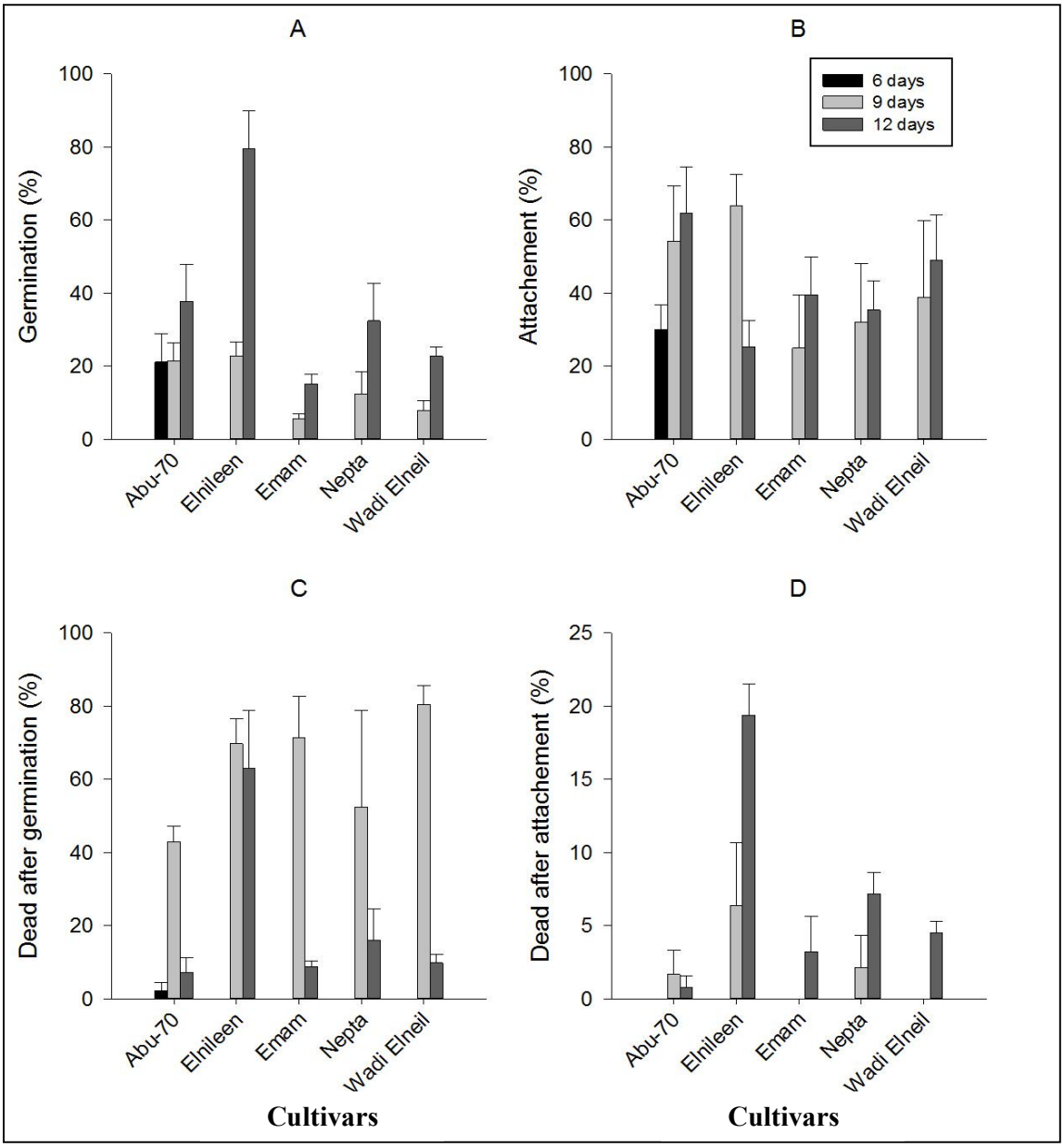



**Fig 4.1. *In Situ* germination, attachment and development of *S. hermonthicca* on sorghum and wheat. Vertical bars represent standard error of means (SE±).**

Keys:-
A: germination
B: Attachment
C: Dead after germination
D: Dead after attachment

## 4.2. Green house Experiment:

### 4.2.1. Effects on *Striga*

#### 4.2.1.1. *Striga* emergence

*S. hermonthica* emergence, irrespective of seed bank size, was influenced by host species. *Striga* emergence on Sorghum (Abusabeen) displayed a progressive increase with seed bank size. At 45, 60 and 75 DAS *Striga* emergence on Abusabeen was 4.4, 9.8 and 10.8 plants/pot, respectively (Table 4.4). *S. hermonthica* emergence on wheat showed dependence on time and was influenced by cultivars (Table 4.4). At 45 DAS *Striga* showed no emergence, irrespective of cultivar. *Striga* started to emerge 60 DAS on Emam, Elnelien and Wadi-Elnile, while emergence was delayed to 75 DAS on Napta (Table 4.1). *Striga* emergence on wheat was significantly lower than that on sorghum (Abusabeen) (Table 4.4). At 60 DAS and a seed bank of 4 mg/pot *Striga* emergence was 0.3, 0.5 and 0 on Emam, Elnelien, and Wadi-Elnile, respectively. At a seed bank of 8 mg/pot *Striga* emergence was 0.3, 0.5 and 3.3/pot on Emam, Elnelien and Wadi-Elnile, respectively. At 75 DAS, and the lowest seed bank size (2 mg/pot) *Striga* emergence was 0.3, 0, 0.5 and 0 on Emam, Napta, Elnelien and Wadi-Elnile, respectively. A further increase in *Striga* level to 8 mg/pot increased emergence to 0.8, 0.3, 0.5 and 3.3 on Emam, Napta, Elnelien and Wadi-Elnile, respectively (Table 4.4).

### 4.2.2. Effects on wheat

#### 4.2.2.1. Effects on plant height

Plant height at 45 DAS was similar, across cultivars (Table 4.5). At 60 DAS differences in height, between cultivars, were significant. Among cultivars Emam displayed the maximum height followed in descending order by Wadi-Elnile, Elnelien and Napta. At 75 DAS all cultivars displayed comparable height (Table 4.5).

**Table 4.4. Effects of *Striga* seed bank size on *Striga* emergence**

| | Days after sowing | | | | | |
|---|---|---|---|---|---|---|
| | 45 DAS | | | | | |
| | *Striga* seed-bank size/ pot (mg) | | | | | |
| **Cultivars** | **2** | **4** | **6** | **8** | **10** | **Mean** |
| **Abusabeen** | 0.5 | 2.5 | 6.5 | 6.0 | 6.5 | **4.4 a** |
| **Emam** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0 b** |
| **Napta** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0 b** |
| **Elnelien** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0 b** |
| **Wadi-Elnile** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0 b** |
| **Mean** | **0.1 a** | **0.5 a** | **1.3 a** | **1.2 a** | **1.3 a** | |
| | | | **60 DAS** | | | |
| **Abusabeen** | 3.5 | 4.0 | 14.3 | 13.5 | 13.8 | **9.8 a** |
| **Emam** | 0.0 | 0.3 | 0.0 | 0.3 | 0.5 | **0.2 b** |
| **Napta** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0 b** |
| **Elnelien** | 0.0 | 0.5 | 0.0 | 0.5 | 1.0 | **0.4 b** |
| **Wadi-Elnile** | 0.0 | 0.0 | 0.3 | 3.3 | 0.0 | **0.7 b** |
| **Mean** | **0.7 b** | **1.0 ab** | **2.9 ab** | **3.5 a** | **3.1 ab** | |
| | | | **75 DAS** | | | |
| **Abusabeen** | 5.8 | 5.8 | 14.3 | 14.0 | 14.3 | **10.8 a** |
| **Emam** | 0.3 | 0.8 | 0.3 | 0.8 | 0.8 | **0.6 b** |
| **Napta** | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | **0.1 b** |
| **Elnelien** | 0.5 | 0.5 | 0.0 | 0.5 | 1.0 | **0.5 b** |
| **Wadi-Elnile** | 0.0 | 0.0 | 0.5 | 3.3 | 0.0 | **0.8 b** |
| **Mean** | **1.3 a** | **1.4 a** | **3.0 a** | **3.8 a** | **3.2 a** | |

Means within a column and/or row followed by the same letter(s) are not significantly different at P≤ 0.5 (Tukey-Test).

#### 4.2.2.2. Effects on number of leaves

At 45 and 60 DAS all wheat cultivars, irrespective of *Striga* seed bank, displayed comparable number of leaves (Table 4.4). At 75 DAS, *S. hermonthica*, irrespective of seed bank size or cultivars, reduced number of leaves, as compared to the control. However, inter varietal differences were significant where Emam had the highest number of leaves, while Napta and Wadi-Elnile showed lowest and comparable number of leaves (Table 4.6).

#### 4.2.2.3. Effects on number of tillers

Number of tillers at 45 DAS varied significantly with cultivars (Table 4.7). Among the cultivars Elnelien had the highest number of tillers, while Emam had the lowest. However, at 60 and 75 DAS differences in number of tillers between cultivars were not significant. At 75 DAS *S. hermonthica*, irrespective of cultivar, reduced the number of tillers. In general, at the lowest *Striga* seed bank size (2 mg/pot) number of tillers was reduced by 21.4%. An increase in seed bank size to 4 mg/pot reduced number of tillers significantly, in comparison to the control. A further increase in *Striga* seed bank to (6-10 mg /pot) did not result in a further significant decrease in number of tillers (Table 4.7).

#### 4.2.2.4. Effects on chlorophyll index

Chlorophyll index, irrespective of cultivars and DAS, was not influenced by *Striga* seed bank size (Table 4.8). In general, the chlorophyll content was relatively high at the early stage of growth (45 and 60 DAS). However, a progressive decline in chlorophyll content occurred at 75 DAS (Table 4.8). At 75 DAS, the different cultivars displayed differential response to *Striga* seed bank size. Napta displayed the highest chlorophyll content, followed in descending order by Wadi-Elnile, Elnelien and Emam (Table 4.8).

**Table 4.5. Effects of *Striga* seed bank size on plant height in wheat**

| Days after Sowing (DAS) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 45 DAS | | | | | | |
| | | *Striga* seed-bank size/pot (mg) | | | | | |
| **Cultivars** | **Control** | **2** | **4** | **6** | **8** | **10** | **Mean** |
| **Emam** | 26.1 (±1.8) | 24.5 (±1.9) | 26.6 (±1.7) | 29.1 (±1.6) | 25.3 (±1.1) | 26.3 (±1.5) | **26.3 a** |
| **Napta** | 24.8 (±1.1) | 24.8 (±2.3) | 24.1 (±1.9) | 23.9 (±1.0) | 21.5 (±1.6) | 25.1 (±0.8) | **24.0 a** |
| **Elnelien** | 25.8 (±2.2) | 25.4 (±0.1) | 28.4 (±1.6) | 26.0 (±0.8) | 26.5 (±2.9) | 29.8 (±1.0) | **27.0 a** |
| **Wadi-Elnile** | 26.4 (±1.3) | 24.5 (±1.1) | 22.0 (±0.8) | 18.0 (±6.1) | 18.6 (±6.3) | 23.9 (±0.7) | **22.2 a** |
| **Mean** | **25.7** | **24.8** | **25.2** | **24.2** | **22.9** | **26.2** | |
| | | | **60 DAS** | | | | |
| **Emam** | 46.4 (±2.8) | 48.0 (±2.6) | 42.1 (±3.2) | 42.5 (±1.3) | 40.8 (±2.0) | 42.0 (±1.9) | **43.6a** |
| **Napta** | 39.6 (±1.5) | 28.6 (±9.8) | 35.0 (±5.1) | 38.5 (±2.1) | 37.8 (±2.5) | 38.6 (±0.9) | **36.4b** |
| **Elnelien** | 41.4 (±3.0) | 37.6 (±2.1) | 37.9 ( ±3.0) | 40.6 (±1.1) | 37.1 (±1.6) | 38.3 (±0.8) | **38.8ab** |
| **Wadi-Elnile** | 44.3 (±0.8) | 38.5 (±2.0) | 42.0 (±3.4) | 37.5 (±6.4) | 41.9 (±0.9) | 37.0 (±8.0) | **40.2ab** |
| **Mean** | **42.9** | **38.1** | **39.2** | **39.7** | **39.4** | **38.9** | |
| | | | **75 DAS** | | | | |
| **Emam** | 44.0 (±0.8) | 39.1 (±2.2) | 42.4 (±2.6) | 39.9 (±3.0) | 41.5 (±4.3) | 39.6 (±3.4) | **41.1a** |
| **Napta** | 35.5 (±3.2) | 27.5 (±9.5) | 36.1 (±0.6) | 39.0 (±3.1) | 37.9 (±1.0) | 35.8 (±4.5) | **35.3ab**[1] |
| **Elnelien** | 35.8 (±2.3) | 33.8 (±1.9) | 33.4 (±1.7) | 41.1 (±2.7) | 34.8 (±2.6) | 35.6 (±3.4) | **35.7ab** |
| **Wadi-Elnile** | 32.6 (±7.0) | 34.9 (±3.1) | 32.8 (±6.6) | 43.5 (±2.4) | 33.8 (±1.8) | 35.9 (±3.2) | **35.6a** |
| **Mean** | **36.9** | **33.8** | **36.1** | **40.8** | **37.0** | **36.7** | |

± = Standard error of means.

[1]Means within a column and/or row followed by the same letter(s) are not significantly different at P≤ 0.5 (Tukey-Test).

**Table 4.6. Effects of *Striga* seed bank size on number of leaves in wheat**

| | Days after Sowing (DAS) | | | | | |
|---|---|---|---|---|---|---|
| | 45 DAS | | | | | |
| | *Striga* seed-bank size/pot (mg) | | | | | |
| **Cultivars** | **Control** | **2** | **4** | **6** | **8** | |
| **Emam** | 27.9 (±3.1) | 24.3 (±3.2) | 25.8 (±2.9) | 32.4 (±4.0) | 29.4 (±6.3) | 29.4 |
| **Napta** | 27.3 (±2.0) | 19.1 (±4.0) | 20.4 (±4.0) | 30.3 (±3.2) | 25.1 (±5.9) | 26.4 |
| **Elnelien** | 32.8 (±6.7) | 30.8 (±3.3) | 28.6 (±5.7) | 24.1 (±3.7) | 19.9 (±1.2) | 31.6 |
| **Wadi-Elnile** | 25.0 (±2.8) | 25.6 (±2.6) | 20.6 (±1.2) | 19.5 (±7.9) | 25.3 (±8.8) | 33.1 |
| **Mean** | **28.2** | **24.9** | **23.8** | **26.5** | **24.9** | **3** |
| | **60 DAS** | | | | | |
| **Emam** | 19.5 (±4.1) | 23.8 (±4.7) | 25.3 (±4.7) | 26.1 (±3.5) | 27.9 (±6.8) | 31.1 |
| **Napta** | 28.6 (±1.2) | 30.0 (±7.0) | 29.4 (±5.0) | 29.6 (±3.8) | 18.5 (±3.5) | 27.9 |
| **Elnelien** | 26.5 (±3.1) | 28.0 (±3.2) | 22.9 (±3.6) | 21.0 (±2.1) | 21.5 (±4.7) | 39.0 |
| **Wadi-Elnile** | 29.9 (±5.8) | 20.6 (±5.6) | 22.4 (±2.7) | 15.8 (±4.1) | 21.9 (±5.0) | 20.8 |
| **Mean** | **26.1** | **25.6** | **25.0** | **23.1** | **22.4** | **2** |
| | **75 DAS** | | | | | |
| **Emam** | 27.3 (±1.9) | 26.6 (±3.8) | 28.8 (±2.2) | 22.8 (±3.7) | 37.0 (±4.0) | 23.0 |
| **Napta** | 22.1 (±1.7) | 22.0 (±2.5) | 20.5 (±3.0) | 16.1 (±3.7) | 19.9 (±0.8) | 19.3 |
| **Elnelien** | 29.3 (±5.9) | 20.0 ±2.9) | 26.4 ±2.9) | 22.0 (±4.0) | 27.8 (±3.3) | 16.9 |
| **Wadi-Elnile** | 26.0 (±2.6) | 17.0 (±4.9) | 23.6 (±7.1) | 18.9 (±1.8) | 13.6 (±2.2) | 21.0 |
| **Mean** | **26.1a** | **21.4ab** | **24.8b** | **19.9ab** | **24.5b** | **20** |

± = Standard error of means.

[1]Means within a column and/or row followed by the same letter(s) are not significantly different at P≤ 0.5 (Tukey-Test).

**Table 4.7. Effects of *Striga* seed bank size on number of tillers in wheat**

| | Days after Sowing (DAS) | | | | | |
|---|---|---|---|---|---|---|
| | 45DAS | | | | | |
| | *Striga* seed-bank size/pot (mg) | | | | | |
| **Cultivars** | **Control** | **2** | **4** | **6** | **8** | **10** |
| **Emam** | 4.8 (±0.7) | 3.8 (±0.3) | 3.6 (±0.1) | 3.9 (±0.1) | 3.6 (±0.6) | 3.0 (± |
| **Napta** | 4.8 (±0.8) | 5.3 (±0.9) | 4.3 (±1.1) | 5.3 (±1.1) | 3.4 (±1.2) | 3.4 (± |
| **Elnelien** | 7.9 (±1.7) | 5.9 (±1.0) | 4.9 (±0.9) | 5.1 (±1.0) | 4.1 (±0.1) | 6.4 (± |
| **Wadi-Elnile** | 5.6 (±0.7) | 5.0 (±0.7) | 4.0 (±0.2) | 5.3 (±1.0) | 7.1 (±1.1) | 5.4 (± |
| **Mean** | **5.8** | **5.0** | **4.2** | **4.9** | **4.6** | **4.** |
| | | | **60 DAS** | | | |
| **Emam** | 4.3 (±0.4) | 3.6 (±0.2) | 3.0 ( 0.4) | 3.8 (±0.6) | 3.8 (±0.9) | 3.6 (± |
| **Napta** | 4.3 (±0.6) | 4.1 (±0.4) | 3.6 (±0.7) | 3.0 (±0.7) | 3.3 (±0.4) | 4.0 (± |
| **Elnelien** | 4.3 (±1.1) | 3.3 ( 0.6) | 2.6 (±0.3) | 2.6 (±0.6) | 2.8 (±1.0) | 5.4 (± |
| **Wadi-Elnile** | 4.1 (±0.5) | 3.1 ( 0.8) | 2.8 (±0.1) | 2.5 (±0.2) | 2.5 (±1.0) | 4.0 (± |
| **Mean** | **4.2** | **3.5** | **3.0** | **3.0** | **3.1** | **4.** |
| | | | **75 DAS** | | | |
| **Emam** | 3.8 (±0.5) | 3.5 (±0.2) | 3.1 (±1.0) | 5.0 (±0.8) | 3.3 (±0.7) | 4.3 (± |
| **Napta** | 3.6 (±0.4) | 3.6 (±0.4) | 2.6 (±0.6) | 2.8 (±0.4) | 2.8 (±0.6) | 3.3 (± |
| **Elnelien** | 5.8 (±1.7) | 3.4 (±0.6) | 2.6 (±0.3) | 4.1 (±0.6) | 2.6 (±0.6) | 4.0 (± |
| **Wadi-Elnile** | 3.6 (±0.5) | 2.9 (±0.8) | 2.5 (±0.2) | 2.1 (±0.6) | 3.8 (±0.6) | 4.0 (± |
| **Mean** | **4.2a** | **3.3ab** | **2.7b** | **3.5ab** | **3.1ab** | **3.9** |

± = Standard error of means.

[1]Means within a column and/or row followed by the same letter(s) are not significantly different at P≤ 0.5 (Tukey-Test).

**Table 4.8. Effects of *Striga* seed bank size on chlorophyll index in wheat**

| | Days after Sowing (DAS) | | | | | |
|---|---|---|---|---|---|---|
| | 45 DAS | | | | | |
| | *Striga* seed-bank size/pot (mg) | | | | | |
| **Cultivars** | **Control** | **2** | **4** | **6** | **8** | |
| **Emam** | 32.7 (±3.8) | 31.0 (±4.1) | 32.9 (±1.7) | 36.5 (±2.3) | 28.7 (±1.7) | 32 |
| **Napta** | 37.1 (±3.3) | 35.5 (±4.0) | 35.8 (±2.8) | 33.0 (±2.4) | 30.4 (±1.2) | 34 |
| **Elnelien** | 33.5 (±1.2) | 32.9 (±0.9) | 40.8 (±1.1) | 31.0 (±5.2) | 30.7 (±2.0) | 37 |
| **Wadi-Elnile** | 38.2 (±3.0) | 36.4 (±2.6) | 32.9 (±0.4) | 29.9 (±2.6) | 33.1 (±2.0) | 35 |
| **Mean** | **35.3** | **33.9** | **35.6** | **32.7** | **30.7** | |
| | **60 DAS** | | | | | |
| **Emam** | 36.8 (±0.4) | 34.9 (±2.4) | 31.0 (±0.2) | 29.1 (±0.5) | 28.0 (1.7) | 33 |
| **Napta** | 28.3 (±4.5) | 32.4 (±5.3) | 41.0 (±1.2) | 33.2 (±2.7) | 37.2 (±2.0) | 36 |
| **Elnelien** | 34.9 (±3.7) | 36.6 (±2.5) | 29.0 (±3.3) | 27.6 (±2.4) | 34.4 (±2.1) | 38 |
| **Wadi-Elnile** | 37.6 (±3.3) | 36.8 (±1.0) | 35.5 (1.5) | 33.2 (±4.6) | 38.6 (±0.5) | 27 |
| **Mean** | **34.4** | **35.1** | **34.1** | **30.7** | **34.6** | |
| | **75 DAS** | | | | | |
| **Emam** | 15.8 (±1.4) | 13.5 (±0.4) | 16.4 (±1.0) | 16.0 (±1.1) | 14.5 (±0.4) | 14 |
| **Napta** | 27.1 (±2.5) | 15.6 (±0.7) | 26.6 (±2.6) | 25.1 (±2.6) | 18.0 (±0.7) | 19 |
| **Elnelien** | 15.9 (±0.6) | 16.2 (±0.7) | 15.3 (±0.6) | 14.5 (±0.7) | 15.3 (±0.9) | 13 |
| **Wadi-Elnile** | 15.8 (±0.4) | 16.4 (±0.5) | 14.5 (±1.0) | 13.4 (±0.6) | 21.1 (±4.8) | |
| **Mean** | **18.6** | **15.4** | **18.2** | **17.2** | **17.2** | |

± = Standard error of means.

#### 4.2.2.5. Effects on fresh and dry weight

*S. hermonthica*, infestation invariably, reduced both wheat fresh and dry weight in all cultivars (Table 4.9). However, the magnitude of the reduction varied with cultivars and *Striga* seed bank size. In general, the observed reduction, with few exceptions, increased with increasing *Striga* seed bank size and differences between cultivars were significant. Elnelien displayed the highest fresh and dry weight, followed in descending order by Emam, Wadi-Elnile and Napta (Table 4.9).

*Striga* free Emam displayed a fresh weight of 23.5g/pot. At the lowest *Striga* seed bank size (2 mg/ pot) Emam fresh weight decreased, albeit not significantly (20.8g/pot). A further increase in *Striga* seed bank to 4mg/pot decreased fresh weight significantly and the observed reduction was 46.8% in comparison to the *Striga* free control (Table 4.9). A further increase in *Striga* seed bank to 6-8mg/pot did not cause further reductions.

*Striga* free Napta displayed a fresh weight of 20.0g/pot. At the lowest seed bank size (2 mg/pot) the cultivars displayed a considerable reduction (30%), but- not significant loss in fresh weight, as comparison to control (Table 4.9). At seed bank of 4 and 6mg/pot Wadi-Elnile showed a non- significant decrease in fresh weight. However, increasing seed bank size to 8 and 10mg/pot decreased wheat fresh weight by 43.5 and 52.5%, respectively (Table 4.9).

In Elnelien the reductions in fresh weight, irrespective of *Striga* seed bank size, was not significant. *Striga* reduced fresh weight in Wadi-Elnile and the observed reduction progressively increased with increasing seed bank size (Table 4.9). The observed reductions were 23, 25, 39 and 32% at *Striga* seed bank size of 4, 6, 8 and 10 mg/pot, respectively.

*S. hermonthica*, irrespective of seed bank size reduced dry weight of all cultivars. However, the different cultivars showed differential response (Table 4.9).

In Emam significant reduction (51.6%) was only, observed at *Striga* seed bank size of 4 mg/pot. In Napta *Striga* seed bank size at its lowest levels (2 and 4mg/pot) resulted in 29.8 and 16.8% reductions in dry weight as comparison to the control. Increasing the parasite seed bank to 8mg/pot or more resulted in further reductions (46.6-16.8%). In Elnelien the reduction in dry weight, irrespective of *Striga* seed bank size, was not significant. In Wadi-Elnile *Striga* at the lowest seed bank size (2 mg/pot) did not inflict significant reduction on dry weight. However, increasing seed bank size to 4 mg/pot or more reduced dry weight by 21.5-38%, in comparison to the *Striga* free control (Table 4.9).

**Table 4.9.Effects of *Striga* seed bank size on fresh and dry weight in wheat**

| | **Plant fresh weight (g)** | | | | |
|---|---|---|---|---|---|
| | **Cultivars** | | | | |
| ***Striga* seed bank size(mg)** | **Emam** | **Napta** | **Elnelien** | **Wadi-Elnile** | **Mean** |
| **0** | 23.5 (±2.1) | 20.0 (±2.1) | 29.0 (±6.3) | 25.8 (±5.0) | **32.8 a** |
| **2** | 20.8 (±4.4) | 14.0 (±2.9) | 24.8 (±3.9) | 27.3 (±7.6) | **27.9 a** |
| **4** | 12.5 (±2.9) | 18.3 (±2.8) | 35.5 (±7.8) | 19.8 (±7.6) | **28.0 a** |
| **6** | 29.5 (±6.3) | 22.0 (±9.7) | 23.8 (±2.2) | 19.3 (±11.7) | **24.2 a** |
| **8** | 26.8 (±4.7) | 9.5 (±1.0) | 27.0 (±3.3) | 15.8 (±5.9) | **20.1 a** |
| **10** | 22.5 (±3.0) | 11.3 (±3.0) | 35.0 (±10.4) | 17.5 (±7.1) | **22.2 a** |
| **Mean** | **22.6ab** | **15.8b** | **29.2a** | **20.9ab** | |
| | **Plant dry weight (g)** | | | | |
| **0** | 22.3 (±1.7) | 17.8 (±2.0) | 26.3 (±5.6) | 22.3 (±4.3) | **29.2 a** |
| **2** | 18.5 (±3.8) | 12.5 (±2.7) | 22.3 (±3.7) | 25.0 (±7.0) | **25.0 a** |
| **4** | 10.8 (±3.1) | 14.8 (±3.1) | 32.8 (±7.6) | 17.0 (±7.1) | **24.8 a** |
| **6** | 26.0 (±4.9) | 16.8 (±5.4) | 21.5 (±2.3) | 17.5 (±10.8) | **23.2 a** |
| **8** | 24.0 (±3.4) | 6.8 (±1.0) | 24.3 (±3.2) | 13.8 (±5.3) | **20.1 a** |
| **10** | 19.0 (±3.0) | 9.5 (±2.7) | 29.0 (±7.6) | 16.3 (±6.7) | **20.4 a** |
| **Mean** | **20.1ab**[1] | **13.0b** | **26.0a** | **18.6ab** | |

± = Standard error of means.

[1]Means within a row followed by the same letter(s) are not significantly different at P≤ 0.5 (Tukey-Test).

# CHAPTER FIVE

# Discussion

*Striga* spp. are obligate root parasitic plants. They are of economic importance as they reduce crop yield and quality and present a serious threat to food security in many areas across the world (Parker and Riches, 1993). The parasites remove water, minerals and Photosynthase from the host and thus reduce the latter ability to grow and compete for nutrients, light, water and space (Joel *et al*., 2007). Crops that are parasitized usually grow more slowly and depending on severity of infestation, biomass production is lowered and the host may be killed. The most promising approach to minimize these losses is breeding of resistant genotypes. The development of reliable methods for screening large numbers of host genotypes in the field has been slow due to the complex interactions between host, parasite and environment which influence establishment on the host root and subsequent growth. Several host resistance mechanisms have also been suggested in the literature including low stimulant production by host plants, low production of the haustorial initiation factor, avoidance mechanisms, presence of physical barriers, hypersensitive response (HR) and antibiosis (Ejeta *et al*., 2000).

The results of laboratory experiment showed that wheat residues, irrespective of cultivars, plant parts and amount of powder, induced germination of *S. hermonthica* (Table 4.1). Exudates of wheat roots induced *Striga* germination, though; their ability to do so was lower than that of sorghum, suggesting that quantity or activity of stimulant produced was lower. *Striga* spp. requires the presence of multiple stimulants derived from the host to trigger germination, haustorium formation, and subsequent development. Among the wheat cultivars, Elnelien root and stem powder gave the highest germination (63.7%), followed by Wadi-Elnile, Emam and Napta, respectively. Wadi-Elnile leaf powder induced about 60.8% germination, while, Elnelien, Napta

and Emam displayed 54.6, 20.5 and 19.6% germination, respectively. The difference between the cultivars may be related to differential stimulants contents of the respective powders. Germilings from seeds induced to germinate by wheat residues, irrespective of cultivars and plant parts showed pre-mature haustoria. Wheat root powder at 5- 15mg/well induced considerable haustorium initiation (81- 87%). A further increase in wheat root powder to 20mg/well or more reduced haustorium formation significantly. Wheat stem powder, on the other hand at 5- 15mg/well induced haustorium initiation in all germilings. Increasing stem powder to 20- 30mg/well decreased haustorium formation significantly. Wheat leaves powder induced considerable number of haustoria. At 5mg/well haustorium initiation was 100%. An increase in leaf powder to 10 and 15mg/well reduced haustorium initiation to 97 and 95%, respectively. A further increase in powder amount to 20 mg/well or more decreased haustorium initiation significantly to 88% (Table 4.2). The concurrent differential increase or decrease in germination and haustorium initiation with increasing powder concentration (Tables 4.1 and 4.2) may be attributed to difference in the chemical signals involved and the cytological changes in the radicle. Germination in *Striga* involves cell extension while haustorium initiation is a differentiation process that involves cell division (Riopel *et al*., 1990) however, possible involvement of inhibitors cannot be ruled out.

Wheat root powder reduced radicle extension by 67-70%, in comparison to the control. *Striga* germilings from seeds induced to germinate by Elnelien, Emam, Napta and Wadi-Elnile displayed radicle length of 2.0, 3.3, 1.4 and 2.1$\mu m10^{-2}$, respectively (Table 4.3). The reduction in radicle could be due to initiation of pre-mature haustoria.

Seeds placed in vicinity of Abusabeen roots displayed 21.0, 21.4 and 37.7% germination, 6, 9 and 12 days after placement (DAP). Seeds placed in vicinity of wheat roots, irrespective of cultivars, showed no germination 6 days after placement (Fig 4.1A). At 9 and 12 days seeds placed in proximity of Elnelien

roots displayed 22.8 and 79.4% germination, respectively, seeds placed for 9 days near Napta, Wadi-Elnile and Emam roots displayed 12.4, 7.8 and 5.5% germination, respectively. Seeds placed for 12 days in vicinity of Napta, Wadi-Elnile and Emam roots showed 32.4, 22.7and 15.0% germination, respectively. The difference between the cultivars may be related to differential stimulant production, or differential sensitivity of the parasite. Of the germilings, induced to germinate by Abusabeen 2.2, 42.9 and 7.3% died prior to attachment 6, 9 and 12 DASP, however, on wheat at 9 DASP 69.7, 71.3, 52.4 and 80.4% germilings failed to attach to Elnelien , Emam, Napta and Wadi-Elnile, respectively (Fig 4.1C). At 12 DASP 63.0, 8.7, 16.0 and 9.8% of the germilings failed to attach to Elnelien, Emam, Napta and Wadi-Elnile, respectively. Of the *Striga* germilings attached to Abusabeen 1.6 and 0.7% died at 9 and 12 (DASP), however, on wheat at 9 days 6.3 and 2.1% of the germilings attached to Elnelien and Napta, respectively died. Germilings death was respectively lower on Emam, Napta and Wadi-Elnile (Fig 4.1D). (This may be due to differential stimulant production between the two plant species). However, presence of inhibitors and/or promoters cannot be ruled out. Subsequent to attachment *Striga* developed much slower on wheat than sorghum. Furthermore, death of the parasite seedling was more frequent on wheat than sorghum (Fig 4.1 A-D). This finding is consistent with that of Vasey *et al*., (2005). Vasey *et al*., (2005), based on rhizotron studies, concluded that the parasite developed more slowly on wheat than sorghum. This may be attributed to difficulty of obtaining nutrients and\or metabolites essential for sustaining normal growth of the parasite. A similar phenomenon was reported for Framida, on *Striga* resistant sorghum variety (Arnand *et al*., 1991, Amusan *et al*., 2008) and was attributed to blockage of translocation of assimilates and/or other host metabolites essential for growth and development of the parasite, thus leading to haustorial collapse and/or inhibition of the haustorial development culminating in death and/or slow growth of the parasite. In general the observed differences in seedlings

mortality may be attributed to difference in the ability of the hosts to supply nutrients to the parasite.

The results of green house experiment revealed that wheat is susceptible to *S. hermonthica.* Similar findings were reported by Vasey *et al*., (2005).Vasey *et al*., (2005) reported that *Striga* spp. require the presence of multiple stimulants derived from the host to trigger germination, haustorium formation, and subsequent development, and all these signals are present in wheat. *Striga* emergence, irrespective of seed bank size was influenced by host species. The number of *Striga* emergence on wheat cultivars was significantly lower than that on sorghum (Abusabeen) and this is consistent with that reported by Vasey *et al* (2005). *Striga* count made 45, 60 and 75 days after sowing (DAS) showed that *Striga* emergence across see the seed bank on Abusabeen displayed a progressive increase with seed bank size. At 45, 60 and 75DAS mean *Striga* emergence across the seed bank size on Abusabeen was 4.4, 9.8 and 10.8 plants/ pot, respectively (Table 4.4). *S. hermonthica* emergence on wheat showed dependence on time and was influenced by cultivars (Table 4.4). At 45 DAS *Striga* showed no emergence, irrespective of the cultivar employed. *Striga* started to emerge 60 DAS on Emam, Elnelien and Wadi-Elnile, while emergence was delayed to 75 DAS on Napta. The observed difference in the reactions to the *Striga s*eed bank between the cultivars may be related to differential stimulants production, differential susceptibility to the parasite. The parasite developed more slowly on wheat than on sorghum, this may be due to difficulty of obtaining nutrients and \ or metabolites essential for sustenance of the parasite growth, (Vasey *et al*., 2005). The observed increase in *Striga* emergence with seed bank size indicates the importance of the seed bank in determining the level of infestation and damage.

Chlorophyll index, irrespective of cultivars and DAS, was not influenced by *Striga* seed bank size (Table 4.8). In general, the chlorophyll content was relatively high at the early stage of growth (45 and 60 DAS) and no

significant differences were observed between treatments (Table 4.8).However, a progressive decline in chlorophyll content occurred at 60-75 DAS. That may be due to normal senesce with time. At this time, the growing points of the main shoot and tillers stop initiating new leaves and start producing reproductive structures (Zadoks *et al*., 1974). *S. hermonthica*, irrespective of seed bank size and cultivar, reduced the number of tillers of wheat, as well as the fresh and dry weight (Tables 4.7and 4.9). At 75 DAS *S. hermonthica*, irrespective of cultivar, reduced the number of tillers. In general, at the lowest *Striga* seed bank size (2 mg/pot) number of tillers was reduced by 21.4%. An increase in seed bank size to 4 mg/pot reduced number of tillers significantly, in comparison to the control. *S. hermonthica*, infestation invariably, reduced both wheat fresh and dry weight in all cultivars (Table 4.9). However, the magnitude of the reduction varied with cultivars and *Striga* seed bank size. In general, the observed reduction, with few exceptions, increased with increasing *Striga* seed bank size and differences between cultivars were significant. These findings are consistent with those obtained by Vasey *et al* (2005) who reported that *Striga* infection resulted in significant reduction in number of tillers (26%) and in growth and biomass of wheat. Similar findings were reported by Rna (2013) with *S. hermonthica* on sorghum. This is a common effect of *Striga* infection on other cereals, such as maize and sorghum. In general, *S. hermonthica* can affect its host in different ways. Only part of the reduction in growth of the host results from competition for carbon assimilates, water, mineral nutrients and amino acids (Graves *et al*., 1990). However, *Striga* does not only act as an additional sink but the parasite also has a strong 'toxic' or 'pathological' effect on the host (Press and Gurney, 2000). Parts of these effects are caused by the disturbed hormonal balance in *Striga*-infected host plants, characterized by increased levels of abscisic acid and decreased levels of cytokinins and gibberellins (Frost *et al*., 1997). By altering the host's hormonal balance *Striga* affects host biomass allocation, resulting in the root systems of infected plants being

greatly stimulated, while the shoot is stunted and reduced (Parker and Riches, 1993). The parasite also negatively affects host photosynthesis. Parasite induced reduction in host photosynthesis has been reported as the most important mechanism of growth reduction. Graves *et al*. (1989) estimated that 80% of the decrease in host growth rate can be attributed to the impact *Striga* has on host photosynthesis. Furthermore, *Striga* strongly affects the water economy of its host by its high transpiration rate and by reducing the stomatal conductance of the host plant (Grimanelli *et al*., 2000).

# Conclusions and Recommendations

## Conclusions

- Wheat is susceptible to *S. hermonthica* and was able to support the germination, attachment, and subsequent development of *Striga*.
- *S. hermonthica* emergence, irrespective of seed bank size was influenced by host species and cultivar.
- Wheat residues induced germination, haustorium initiation and reduced radicle length of *S. hermonthica.*

## Recommendations

- Further research is needed to find out whether differences exist in the onset of stimulant exudation by the roots of wheat cultivars.
- The experiment should be repeated for another year with additional treatments to confirm the results.
- More elaborate studies on the influence of wheat cultivars on *Orobanche crenata* are needed. Employment of Wheat as a trap crop for O. *crenata,* a serious pest on faba bean (*Vicia faba* L.) in the Northern and River Nile States, should be investigated.

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# Appendix

**Appendix 1**. Three way ANOVA and F values for Plant height (cm), number of leaves and tillers/plant and chlorophyll content index.

| Source of variation | Plant height (cm) | No. leaves/ plant | No. tillers/plant | Chlorophyll index |
|---|---|---|---|---|
| **Cultivars, C** | 5.3*** | 5.2*** | 2.3$^{ns}$ | 8.0*** |
| ***Striga* level, SL** | 1.0$^{ns}$ | 2.7** | 5.1*** | 2.7*** |
| **Days, D** | 126.7*** | 5.1*** | 24.4*** | 403.0*** |
| **C*SL** | 0.4$^{ns}$ | 1.7* | 1.6ns | 1.6ns |
| **C*D** | 2.4*** | 1.6$^{ns}$ | 4.1*** | 3.0*** |
| **SI*D** | 0.7$^{ns}$ | 1.0$^{ns}$ | 0.6ns | 1.5ns |
| **C*SL*D** | 1.0$^{ns}$ | 0.9$^{ns}$ | 0.6ns | 2.4** |
| **CV%** | 18.9 | 28.7 | 36.2 | 16.7 |

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