بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Genotypic variability in cowpea with respect to production of the germinatoin stimulants of the purple witchweed (*Striga hermonthica* (Del.) Benth.

التباين الجيني بين أصناف اللوبيا الحلو في إنتاج منشطات انبات طفيل البودا الغرموزية

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

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الآية

قال تعالى :

(وَهُوَ الَّذِي أَنْزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجْنَا بِهِ نَبَاتَ كُلِّ شَيْءٍ فَأَخْرَجْنَا مِنْهُ خَضِرًا نُخْرِجُ مِنْهُ حَبًّا مُتَرَاكِبًا وَمِنَ النَّخْلِ مِنْ طَلْعِهَا قِنْوَانٌ دَانِيَةٌ وَجَنَّاتٍ مِنْ أَعْنَابٍ وَالزَّيْتُونَ وَالرُّمَّانَ مُشْتَبِهًا وَغَيْرَ مُتَشَابِهٍ انْظُرُوا إِلَى ثَمَرِهِ إِذَا أَثْمَرَ وَيَنْعِهِ إِنَّ فِي ذَلِكُمْ لَآيَاتٍ لِقَوْمٍ يُؤْمِنُونَ)

سورة الأنعام لآية (99)

DEDICATION

I would like to dedicate this work to:-

My dear father

My lovely mother

My sweets sisters

My brother

My Husband

Finally, to all my teachers in the Department of Plant Protection

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Abstract

The present investigation was undertaken at the College of Agricultural Studies, Sudan University of Science and Technology to select cowpea genotypes that could be used as mulch, trap crops or intercrops with sorghum or millet to combat the root parasitic weed *Striga hermonthica* and improve growth and yield of sorghum. Twenty four cowpea genotypes, obtained from the International Institute of Tropical Agriculture (IITA) Ibedan Nigeria, were subjected to series of laboratory, greenhouse and field experiments. The genotypes were grown in a field, harvested, severed into roots, stems and leaves, air dried and powdered and tested for germination inducing activity (GIA) and effects on radicle extension (RE). Three genotypes B301, T100K-901-6 and T198K-317-2 were selected for further studies on GIA of their root exudates and influence on RE. The genotypes B301 and T100K-901-6, selected for prostrate growth habit, were subjected to further laboratory evaluation for GIA, influence on RE and chromatographic behaviour of the stimulatory substances in root exudates as compared to sorghum. Further laboratory studies on effects of pH on GIA were undertaken. Moreover, Based on high GIA TK100-901-6, was selected for studying *in-situ* GIA and subsequent development of the parasite using the rhizotron technique. Greenhouse experiments and a field trial were, accordingly, conducted. In the field experiment intercropping was integrated with inoculation with *Rhizobium leguminosarum* TAL1399 and a phosphorus releasing bacterium **(***Bcillus megatherium var phosphaticum***)**. The laboratory results revealed that the GIA of powder from cowpea, revealed by germination of *S. hermonthica*, sorghum and millet strains, increased with increasing amount of powder and subsequently declined on raising powder amount. Root powder displayed higher GIA than stem and leaves powders. Powder samples showing GIA > 80% were higher for *Striga* millet strain than the sorghum congener. Cowpea powder, irrespective of genotype or *Striga* strain reduced radicle extension in a concentration dependent manner. GIA of roots exudates from hydroponically grown plants, irrespective of genotype, progressively increased with time and was negligible at 72 h, maximal at 216 h and subsequently declined. Moreover, for each sampling date GIA and RE progressively decreassed with increasing volume of root exudates for *Striga* sorghum strain. For *Striga*, millet strain, variations in GIA with time

were similar to those for the sorghum strain, however, both GIA and RE increased with exudates volume. The GIA of the root exudates for *Striga* millet strain for a given sampling date, in contrast to the sorghum congener, increased with exudates volume. Radicle extension of *Striga* germilings consistently decreased with exudates volume for the *Striga* sorghum strain, but increased with volume for the millet strain. GIA of root exudates was, invariably, maximal at pH 7. Column chromatography showed polar and non-polar germination stimulants in sorghum and cowpea genotype B301 root exudates, however, for cowpea genotype T100k-901-6 only the polar fractions were active. The results were further confirmed by HPLC. *In-situ* germination and attachment using cowpea genotype T100K-906-1-6, *Striga* sorghum strain and employing the rhizotron technique showed high germination (76.6%) and high attachment (47.2%) with no further development. In the greenhouse experiment, irrespective of intercropping, *Striga* emergence progressively increased with seed bank size. Intercropping with cowpea, significantly, reduced *Striga* emergence and dry weight. Leaf area, sorghum height and dry weight, invariably, decreased with increasing seed bank size. Intercropped sorghum, invariably, displayed better growth than sole sorghum. In the field experiment intercropping sorghum with cowpea, the seeds of which were previously dressed with *R. leguminosarum* TAL1399, *B. megaterium* or their combination delayed and reduced *Striga* emergence. Furthermore, the treatments improved sorghum growth. Cowpea genotypes dressed with the bacterial combination, invariably achieved the highest reductions in *Striga* emergence and the highest increase in the measured sorghum growth attributes. In conclusion, cowpea, genotypes B301 and T100K-901-6 could be used as mulch, trap crops or intercrops to combat *S. hermonthica* in sorghum and increase growth and yield. Similar studies with millet are imperative.

الملخص

أجريت الدراسة في كلية الدراسات الزراعية، بجامعة السودان للعلوم والتكنولوجيا وذلك لإختيار سلالات من اللوبيا الحلو التي يمكن أن تستخدم كمحاصيل تغطية او محاصيل صائدة أو كمحاصيل تحميل مع الذرة أو الدخن لمكافحة طفيل البوده وتحسين نمو و إنتاجية الذرة الرفيعة. تم الحصول علي 24 سلاله من اللوبيا، من المركز الدولي للزراعة المدارية (IITA)– ابيدان نيجيريا. عرضت السلالات إلى سلسلة من الاختبارات من خلال المعمل، والمشتل والتجارب الحقلية. تمت زراعة السلالات في الحقل ثم حصدت وفصلت إلي جذور وسيقان وأوراق وتم تجفيفها هوائياً. تم استخدام بودرةالاجزاء المفصولة في إختبار فاعلية تحفيز إنبات بذور البودا، وتأثيرها علي إمتداد الجذير. تم اختيار ثلاثة أصناف **B301** و **T100K-901-6** و T198K-317-2 لمزيد من الدراسات على فاعلية تحفيز الإنبات من الإفرازات الجذرية وتأثيرها على تمدد جذير الطفيل. تم إختيار السلالتين **B301** و **T100K-901-6** **اللتان تتصفان** بالنمو الزاحف وأخضعتا لمزيد من التقييم المعملي لتحفيز الإنبات والتأثير على إمتداد الجذير والسلوك الكروماتوغرافي للمواد المحفزة من إفرازات الجذر مقارنة بإفرازات جزور الذرة. أجريت دراسات معملية أخرى على تأثير درجة الحموضة علي تحفيز الإنبات. تم إختيار السلاله **T100K-901-6**بناءا علي زيادة إفرازت جزورة في تحفيز الإنبات لدراسة متتالية للمعدنة تطور الطفيل وذلك بإستخدام تقنية الرايزوترون. وفقاً لذلك تم إجراء تجارب تحميل مشتلية و حقلية. في التجربة الحقلية، تم تكاملها مع تلقيح اللوبيا الحلو بواسطة بكتريا العقد الجزرية (*Rhizobium leguminosarum* TAL1399) و البكتريا المزيبة للفسفور .(*Bacillus megatherium var phosphaticum*). أوضحت نتائج التجارب المعملية بأن نشاط تحفيز الإنبات من بودرة اللوبيا لبذور سلالات بودة الذرة والدخن تزيد بزيادة كمية البودرة من 5 الي 10 ملجم ويلي ذلك إنخفاض بزيادة البودرة الي 15 ملجم. أعطت بودرة الجذور أعلي تحفيز للإنبات مقارنة ببودرة الاوراق والساق. اعطت عينات البودرة نسبة تحفيز إنبات أعلي من 80% الدخن وكان أعلي إنبات في بودة الدخن مقارنة ببودة الذرة. بودرة اللوبيا، بغض النظر عن سلالة البوده او اللوبيا, تعمل علي خفض إمتداد الجذير ويعتمد ذلك على التركيز.إنبات البوده من

إفرازات جذور نباتات اللوبيا التي زرعت مائياً، بغض النظر عن السلاله تزيد تدريجياً مع الزمن ، الإنبات كان بسيطا في ال72 ساعة وبلغ زروته في 216 ساعة وإنخفض بعد ذلك.انخفض انبات بذور بوده الذره وطول الجزير بزيادة حجم افراز جزور اللوبيا ويحدث العكس تماما في حالة بذور الدخن . حقق افراز جزور اللوبيا اعلي نشاط عند الاس الهيدروجيني 7. اوضحت الدراسات الكروما توغرافيه احتوا افرازت جزور اللوبيا السلاله B301 والذرة علي مركبات قطبيه ولا قطبيه نشطه وانحصارها علي المركبات الاقطبيه في حاله السلاله **T100K-901-6**.كما اوضحت تقنية الرايزوترون ان جزور السلاله **T100K-901-6**حققت نسبة انبات والتصاق 76.2% و47.2% علي التوالي لبودة الذره .في التجارب المشتلية وبغض النظر عن الزراعة التحميلية يزداد إنبثاق البوده بزيادة مخزون البذور. الزراعة التحميلية للذرة مع اللوبيا الحلو ادت لانخفاض، معنويً في إنبثاق البوده, وزنها الجاف, و مساحة الورقة, طول الذرة و وزنة الجاف انخفض بشكل تدريجي مع زيادة حجم مخزون بذور الطفيل.أعطت الذرة التي زرعت متداخلة مع اللوبيا أفضل نمو مقارنة مع الذرة التي زرعت منفردة. أظهرت تجربة الحقل التي تم إجرائها بتحميل محصول الذرة باللوبيا ، أن معاملة بذور اللوبيا الحلو بالبكتريا العقد الجزرية (*R. leguminosarum* TAL 1399) أو بالبكتريا المذيبه للفسفور (*B. megatherium*) او خليطهما، أدت إلي تأخير وتقليل إنبثاق البوده. بالإضافة إلي ذلك أدت المعاملة إلي زيادة في نمو الذرة. سلالات اللوبيا الحلو التي تمت معاملتها بخليط من البكتريا حققت أعلي إنخفاض في إنبثاق البوده وزيادة أكثر في قياسات نمو الذرة. خلصت الدراسة بأن سلالتي اللوبيا الحلو B 301 و T100K-901-6 يمكن إستعمالها كمحاصيل تغطية أو محاصيل صائدة او متداخلة لمكافحة البوده في الذرة مما يؤدي لزيادة النمو والإنتاجية. ومن هذه الدراسة أصبح من الضروري إجراء دراسة مشابهة لمحصول الدخن.

Table of contents

List of Abbreviation

AIOE	after initiation of experiment
ARC	Agricultural Research Corporation
B	Bacillus
Bmp	*Bacillus megatherium var phosphaticum*
a	About
CAS	College of Agricultural Studies
CC	Column Chromatography
Cm	Centimeter
UV	Ultra violet
DAS	Days after sowing
et al	And others
ENDRI	Envirnment Natural Desertification Resarch Insittute
Fig.	Figure
G	Gram
GFFP	Glass fiber filter papers
GIA	Germination inducing activity
GR24	Synthetic *Striga* germination stimulant
h	hours
HPLC	High Performance Liquid Chromatography

IITA	International Institute of Tropical Agriculture
i.d.	Internal diameter
L	Litre
mg	Milligram
Min	Minute
NCR	National Centre Research
ppm	Part per million
R	Rhizobium
RE	Radicle extension
RES	Rothamsted Experimental Station
Rt	Retention time
SE	Standard error
Spp	Speices
SUST	Sudan University of Science and Technology
TLC	Thin layer chromatographys
UV	Ultra violet
µl	Micro litre
µM	Micro molar
%	Percent
^{o}C	Degree centigrade

List of Figures

List of Tables

List of Appendices

List of plates

CHAPTER ONE
INTORDUCTION

Sorghum [*Sorghum bicolor* (L.) Moench], a crop that provides food, feed, fiber, fuel and biofuel, is of vital importance to subsistent farmers in sub-Saharan Africa, where the prevailing drought often limits crop choice to only a few (Babiker, 2007). Under such conditions sorghum, millet {*Pennisetum glaucum* (L) R. BR.} and sesame (*Sesamum indicum* L.) are the corps of choice. In central Sudan where agriculture is confined, mainly to the central clay plains, sorghum is the most dominant, sesame is subsidiary and millet is occasional. In western Sudan, where soil is pre-dominantly sandy, millet is dominant and sorghum is the second dominant, particularly in localized areas where clay soils, locally, named Gardoods, predominate. Sorghum and millet are often planted in monocultures on soils of low fertility (Oswald, 2005).

Traditional African farming based on low inputs, was sustained through prolonged fallows (Ejeta, et al., 1993). However, population pressure and market demands have led to intensification of sorghum and millet planting and the replacement of traditional low yielding local land races by improved high yielding cultivars (Parker and Riches, 1993). Nevertheless, yields are, comparatively, low. The low yields are attributable to several factors among which heavy infestations by the root parasitic weed *Striga hermonthica* is of paramount significance. It was estimated that over 21 million ha-1 of arable land in Africa are infested by *Striga* resulting in losses amounting to 4.1 million tons of grain per year (Moboob, 1986). In monetary terms the losses

were estimated to exceed US$ 7 billion in value (Rubials *et al*., 2009; Timko, Huang and Lis, 2012).

The parasite produces thousands of minute seeds with prolonged viability and special germination requirements. Copious seed production by *S. hermonthica*, prolonged seed viability and consequently the buildup of a huge seed bank, shortly after initiation of infestation, coupled with the subterranean nature of the early developmental stages makes the parasite a difficult weed to control. High illiteracy among farmers, lack of awareness of the parasite life cycle and the unavoidable low crop productivity arising from the damage the parasite inflicts while subterranean, make farmers reluctant to accept and/or adopt post-emergence control measures (Babiker, 2007). Depletion of the soil seed bank by suicidal germination, which involves germination of the seeds in absence of or away from the host roots, is a potential control option and has been strongly advocated by several authors (Parker and Riches, 1993; Kgosi., 2012). Suicidal germination could be achieved by synthetic germination stimulants or by natural ones through intercropping, catch and/or trap cropping (Parker and Riches, 1993).

Planting sorghum or millet in rotation with cowpea or intercropping with cowpea are common practices in western Sudan. In the region cowpea is planted as sole crop or as a companion crop with millet and sorghum. The plant has been regarded as an efficient nitrogen fixer and is commonly used as an intercrop with sorghum and millet to reduce *Striga* infestation and damage. However, competition between cowpea and sorghum often leads to low crop yields (Hmad Elniel, 2012).

Striga hermonthica is characterized by high transpiration rate and its stomata remain open in darkness and are less susceptible to changes in abscisic acid (ABA) (Parker and Riches, 1993). The high transpiration rate enhances transfer of host xylem sap into the parasite. Intercropping shades the soil and lowers the temperature. Furthermore, it creates a high humidity micro-environment and hence cuts down transpiration of the parasite and subsequently decreased influx of nutrients and assimilates from the host (Babiker, 2002).

The present study, comprising laboratory, greenhouse and field experiments, was undertaken at the College of Agricultural studies (CAS) Sudan University of Science and Technology (SUST). The laboratory experiments were conducted to i) To screen air-dry powders of leaves, stems and roots, of 24 cowpea genotypes obtained from the International Institute of Tropical Agriculture (IITA) for germination inducing activity (GIA) in *S. hermonthica* seeds collected from under sorghum and millet, ii) To select, based on morphology, growth rate and habit, promising cowpea lines for detailed studies including a) effects of time after cowpea germination on ability of root exudates to induce germination of *S.hermonthica*, b) ability of cowpea root to induce *in-situ* germination of *S. hermonthica* seeds and iii) chromatographic behavior of the germination stimulant(s) from cowpea root exudates. The greenhouse experiment was conducted to study the effects of intercropping of selected cowpea genotypes on *Striga hermonthica* parasitism and sorghum growth, while the field experiment was

undertaken to assess the suppressive effects of cowpea lines inoculated with *Rhizobium leguminosarum* strain TAL 1399 and a phosphorus releasing bacterium, *Bacillus megaterium var phosphaticum* (Bmp), on *Striga* parasitism and sorghum growth under field conditions.

CHAPTER TWO

Literature Review

2.1. Parasitic plants

Over 4100 species, belonging to 19 families of flowering plants, are able to directly invade and parasitize others plants (Nickrent and Musselman, 2004). However, though, very few parasitize cultivated plants, nevertheless, weedy parasites pose a tremendous threat to the world economy, mainly, because they are almost uncontrollable (Parker and Riches, 1993, Gressel *et al*., 2004). Among parasitic weeds those of the Orobanchaceae received considerable attention because of relevance to world agriculture. The family is of interest for evolutionary studies, as it encompasses closely related species with vast difference in host range ((Parker and Riches, 1993). Of the genera constituting the family Orobanchaceae *Striga* is the most important. The genus *Striga*, predominant in Africa, includes 36 species, which are parasitic by nature (Parker and Riches 1993). *Striga* compensates for its rudimentary root system by penetrating the roots of other plants and diverting essential nutrients (Press and Graves, 1995). Among the *Striga* species *S. asiatica* (L.) and *S. hermonthica*, mainly on sorghum, millet and maize (*Zea mays* L.), are the most important (Oswald, 2005). Considerable areas under cereal crops in Africa, are infested by *Striga* and yield may be reduced by up to 100% (Ciotola, *et al*., 1995). Heavy *Striga* infection causes land abandonment, leading to rural exodus with associated socio-economic and demographic problems.

2.1.1. Origin and Distribution

Striga hermonthica was thought to have originated in the vast tropical areas of the savannah between the Semen Mountains of Ethiopia and the Nubian hills of the Sudan (Musselman, 1987). The same region was postulated as the center 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 the Americas. Economically important *Striga* species have broad distribution, setting conditions for genetically structured populations based on geographic locations (Mohamed *et al*., 2007).

2.1.2. Economic Importance

Parasitic plants, in general, lead to losses in productivity of their hosts. However, few of them are considered as agricultural pests. Of all parasitic plants those of the family Orobanchaceae are the most important. Of the Orobancaceae *Striga* spp. have been a serious problem on cereals and leguminous corps in sub-Saharan Africa (Babiker, 2007). The effects of the parasite on crops ranges from stunted growth through wilting, yellowing, and scorching of leaves, to lower yields and death of the infected plant. According to Gressel *et al*., (2004) among the 26.43 million hectares of all cereal corps in Africa 21.9 million hectares of the sorghum and millet fields are affected by *Striga*.

Striga. hermonthica affects 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). *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 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.

The 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 the host by its high transpiration rate and by reducing the stomatal conductance of the host plant (Inoue, *et al.*, 2000).

2.1.3. *Striga* strains:

S. hermonthica, the most important parasitic flowering plants in Africa, is reported to have several strains and physiological variants (Bebawi, 1987). However, only millet and sorghum strains are well recognized and documented. Wilson-Jones (1955) was the first to demonstrate the existence of the two strains in the Sudan. The two strains differ in ability to attack sorghum and millet. Parker and Reid (1979) have since confirmed the existence, of the two distinct strains in West Africa. Wilson-Jones (1955) attributed the observed host specificity to different germination requirements. The root exudates of either host fails to stimulate the strain of the other. It is possible that the specific germination requirements of each strain are re -inforced by an inability to develop on the alternative host even

after germination. Several other crops including finger millet {*Eleusine coracana (*L.) Geartn.}, rice (*Oryza sativa* L.} and sugarcane (*Saccharum officinarum* L.) are attacked, but there is no evidence for distinct strains of the weed being specific to these crops (ICRISAT, 1986).

2.1.4. Life cycle of *Striga*

Striga spp. are obligate hemi-parasitic plants that's attach to the roots of their hosts to obtain water, nutrients and carbohydrate (Parker and Riches 1993). *Striga* species have a very complex life cycle (Plate 2.1). The seeds of *S. hermonthica* are small and dust like (0.2 to 0.4 mm) (Parker and Riches, 1993). Energy reserves in the small seeds are limited and insufficient for a long period of autonomous growth (Doggett, 1965). *Striga* is completely dependent on its host for survival, and its life cycle is closely cued to that of the host plant (Haussmann *et al*., 2000). The life cycle of *Striga* is divided into a non-parasitic or vegetative phase and a parasitic mode (Mohamed *et al*., 1998). The non-parasitic mode includes the processes of after-ripening, conditioning and germination. The parasitic mode, on the other hand, starts on the initiation of the 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 environmental conditions under which the seeds were produced (Bebawi *et al*.,1984).

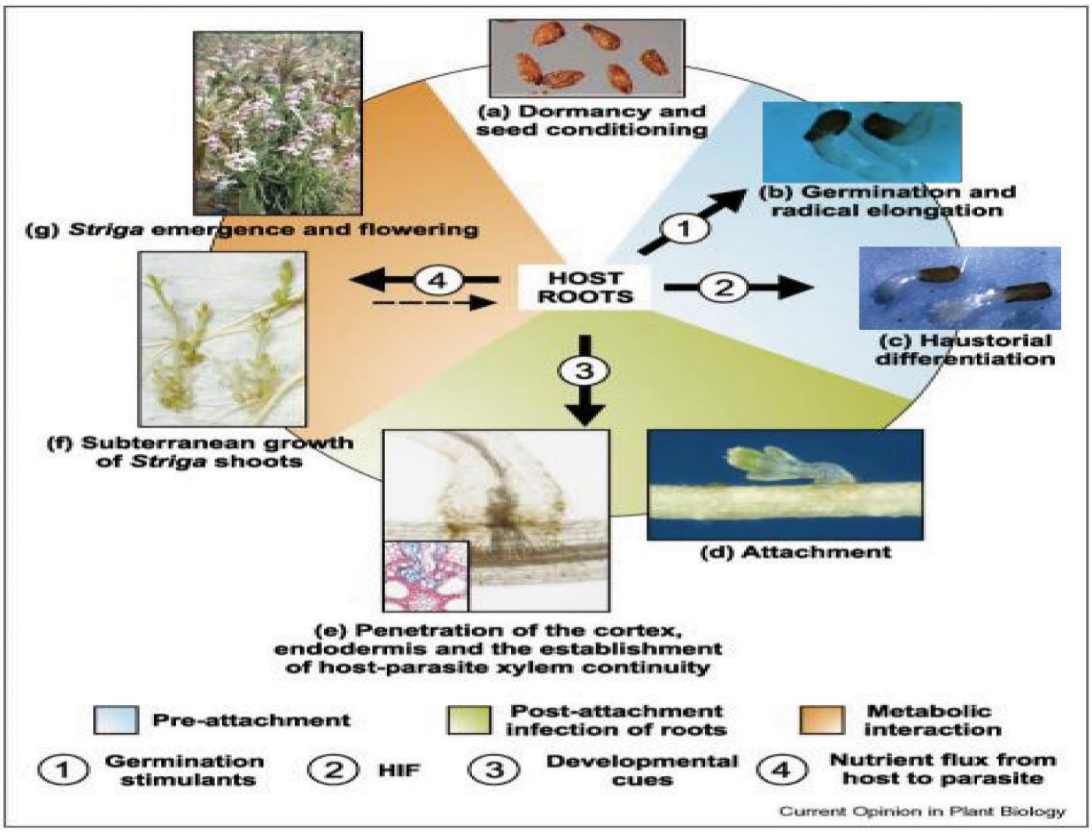

Plate: 2. 1. The life cycle of *Striga* adapted with modifications from Scholes and Press (2008)

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 pre-conditioning (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 33ºC (Parker and Riches, 1993). The biochemical changes that occur during conditioning are not well acertained (Kust, 1964, Babiker, 2007).

A chemical stimulus is needed in order to trigger the germination of *Striga* spp. (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. Babiker *et al.*, (2000) reported

conditioning is a pre-requisite for ethylene production by the seeds in response to germination stimulants. Babiker *et al.*,(2000) attributed increased ethylene production with conditioning to removal of inhibitors and/or build up of effectors. In a later work Babiker *et al.*, (2000) showed that conditioning is associated with increased respiration of the seeds and release of CO_2 which is a co-factor of ACC-oxidase, the enzyme that converts ACC into ethylene. The latter is the actual germination inducer of the parasite. Once triggered to germinate *Striga* radicle elongates and when in close proximity of the host roots a second stimulant, the haustorium factor, is received. Subsequent to the perception of the stimulant the tip of the radicle swells and produces a specialized organ, the haustorium, by which the parasite attaches to the host roots. Germlings survive only if they succeed to attach to the host root within five days following germination (Ejeta *et al*.,1993). Subsequent to attachment the haustorium penetrates the host root and establishes connection with the host xylem. Fllowing connection with the xylem, the parasite withdraws water, mineral nutrients, carbohydrates and amino acids from the host and consequently causes stunted shoot growth, leaf chlorosis and reduced photosynthesis in the host. After several weeks of underground development (6-8) *Striga* shoots emerge above the soil surface, set flowers 4 weeks after emergence and the seeds mature 4 weeks later (Babiker, 2007). The parasite produces a large number of seeds (100,000 seeds /plant) that remain viable for a long period, estimated to be 20 years (Kroschel and Muller-stover, 2004). Pre-conditioned seeds, not exposed to germination stimulants, enter a period of wet-dormancy and revert to their original none dormant conditions on

drying. This survival mechanism rapidly leads to buildup of huge seed banks after the initial infestation (Ejeta *et al*., 1993).

2.2. Control Methods

Compared with non-parasitic weeds, control of parasitic weeds has proved to be exceptionally difficult (Parker and Riche, 1993, Babiker, 2007). The ability of the parasites to produce a tremendously high number of seeds, with prolonged viability and 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, cultural biological and chemical measures. So far these methods, however, have only limited impact on the parasites and up to-date there is no single control method that can effectively solve the problem and the need for an integrated approach is imperative (Ejeta,1993).

2.2.1. Preventive methods

One of the most important control methods is to prevent the introduction and distribution of the parasite seeds form one field to another and from infested to uninfected areas. Different mechanisms are responsible for the dissemination and spread of the parasite seeds. National and international trade of crop seeds contributes to the parasite seed dispersal over long distances. *S. asiatica* infestation in the US was associated with wool shipments from South Africa (Babiker, 2007). Contaminated crops seeds were reported to be the main vehicle for long distances transport of *Striga hermonthica* (Berner *et al*., 1995). Farm equipment and machinery should be cleaned prior to their use in *Striga* free field. *Striga* shoots should be burned

or disposed of properly (Abu-lrmaileh, 2008). Other methods of prevention of seed dispersal are to prohibit animals from feeding on parasitic weeds and reduce their movements from infested to the parasite free areas.

2.2.2. 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.

2.2.2.1. 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 often have poor grain qualities, poor yield and/or poor agronomic characteristics (Parker and Riches, 1993).

2.2.2.2. 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 and small fields with low to moderate levels of infestation and 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 however, it curtails replenishment of seed reserves in soil, and if repeated, may lead to their virtual depletion.

2.2.2.3. Intercropping

Intercropping with a false host crop that stimulates *Striga* seeds 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). Several reports showed the severity of *S. hermonthica* attack was significantly reduced by intercropping. Intercropping sorghum with groundnuts (*Arachis hypoguaea* L.), cowpea (*Vigna unguiculata Wlad* Vatice), and dolichos beans (*Lablab purpurous* L.) reduced population density of *S. hermonthica* (Babiker *et al.,* 2000).

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

2.2.2.4. Crop rotations:

Traditional African agriculture was based on long fallow periods (Ejeta, *et al.,* 1993). Prolonged fallowing allows soil to regain fertility and leads to demise of *Striga* seed reserves in soil. However, with increased population pressures this option is now limited to very few areas and the length of the fallow period is rarely sufficient to allow adequate decline in infestation (Parker and Riches, 1993). The situation is further exacerbated by prolonged longevity (20 years or more) of *Striga* seed in soil (Bebawi *et al.*, 1984). Rotation of *Striga* infested land into a non-susceptible crop or into a fallow is theoretically the simplest solution. A rotational scheme must be long enough for a significant demise of the parasite seed bank through natural attrition or by induction of suicidal germination by false host crops. A rotational scheme involving a leguminous crop, 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 the subsequent cereals crop (Ahonsi *et al*., 2002). Many legumes *viz* soybeans (*Glycine max Merr*), groundnut, pigenpea. (*Cajanus cajan Mill*) have been reported to stimulate suicidal germination of *Striga* (Parker and Riches, 1993). However some reports indicated that the 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 condition (Babiker, 2007).

2.2.2.5. Catch cropping

Catch cropping is another mean of depleting *Striga* seed reserves in soil. 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 seed setting by the parasite. The catch crop, when ploughed under is equivalent to green manuring and restores, at least in part, 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 center 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 thereby killing attached *Striga* seedling. *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/or damage and deplete seed reserves (Dawoud, 1995).

2.2.2.6. Fertilizers

Striga infestation is invariably associated with poor soil fertility. Of all nutrients nitrogen and phosphorus have been claimed to be the most important. Research in the last century showed that nitrogen and phosphorus lower both *Striga* parasitism and production of germination stimulants (Parker and Riches, 1993). Recent work corroborated the early findings and indicated that the germination stimulants, sorgolactones, are the mycorrhiza branching factor and that the latter down regulates stimulants production (Babiker, 2007).

2.2.2.6.1. Nitrogen

Parasitic plants have acquired the ability to obtain nutrition from host plants 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* incidence (Parker and Riches, 1993). This variation, which may be associated with intrinsic soil or crop variety characteristics, makes recommendation of nitrogen as a sole treatment for *Striga* control difficult and fraught with an element of risk.

Nitrogen is believed to reduce stimulant production. Root exudates from sorghum grown in hydroponic cultures were 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 lgbinnosa *et al.*, (1998).

2.2.2.6.2. Phosphorus

Phosphorus deficiency has been claimed to be a major factor that intensifies *Striga* infestation and debilitating effects on susceptible crops, however, fertilization with phosphorus often showed inconsistent effects (Parker and Riches, 1993). Failure of phosphorus to positively impact *Striga* parasitism may be attributed to rapid fixation particularly in alkaline calcareous soils (Babiker, 2007).

2.3. Chemical Control

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

2.3.1. 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 parquet, 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 (Last, 1960, 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, 2000). 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 synthase (ALS) inhibiting herbicides nicosulfuron, a sulfonylurea, and imazaquin, an imidazolinone. Combining seed treatment with ALS-inhibiting herbicides and ALS-modified maize with XA-17 gene may offer a practical solution to African maize growers.

2.3.2. 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* L. 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 is not yet ascertained.

2.3.3. Germination Stimulants

Seeds of the parasitic plants *Orobanche* and *Striga* only germinate in the presence of chemical compounds that, in nature, are exuded from the roots of hosts and some non-host plant species (Babiker, 2002). Several investigators have attempted to isolate, characterize and/or identify the stimulant from many

host and non-host plants (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, strigolactones and sesquiterpene lactones (Sun, 2008). Several strigolactones, 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 stimulant 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 Sorgolactones 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. Integrated Management

From the above review it is apparent that 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 resistant or the most tolerant cultivars that are available, in addition to potential preventive measures. Cultural methods such as manipulating seeding rate, planting date, water harvest and intercropping with

leguminous crops may help in reducing infestations. A combination employing a resistant or a tolerant crop, intercropping with a legume and treatment with an ALS inhibitor is theoretically feasible. Chlorsulfuron, an ALS inhibitor, have been reported to reduce *S. hermonthica* infestation and improve sorghum growth and yield (Babiker, 2000). Emerged *Striga* plants which escape the herbicide may be removed by hand or sprayed with 2, 4-D prior to and /or at flowering. Herbicides application could be carried out by trained farmers. The aim of integrated management is to constantly reduce the parasite population leading to reduction of the soil seed bank (Abu-Irmaileh, 2008).

CHAPTER THREE

Material and Methods

3.1. General

Series of laboratory, greenhouse and field experiments were undertaken at the College of Agricultural Studies, Sudan University of Science and Technology at Shambat. The trials were undertaken with the primary objective of development of an integrated *Striga* management strategy which resides on intercropping of sorghum with cowpea.

3.1.1. Laboratory experiments

A Series of laboratory experiments was undertaken to study i) the *Striga* germination inducing activity (GIA) and influence on radicle extension (RE) of residues from 24 cowpea genotypes using sorghum and millet strains of the parasite, ii) GIA and influence on RE of root exudates from 3 cowpea genotypes selected according to their growth habit in the field (Appendiex 2), iii) effects of time on production of *Striga* germination stimulants by cowpea as influenced by genotype, vi) chromatographic behavior of the stimulant(s) from cowpea genotypes, v) *in-situ Striga* germination attachment and parasitism, of cowpea line T100K-901-6 by *S. hermonthica*, sorghum strain using, the rhizotron technique.

3.1.1.1. Materials

3.1.1.1.1. Plant materials

Twenty four cowpea genotypes were obtained from the International Institute of Tropical Agriculture (IITA) Ibadan Nigeria (Appendix 1). Two Sorghum cultivars (Abu Sabeen and Wad Ahmed), were obtained from the

Agricultural Research Corporation (ARC) Wad Medani Sudan. *Striga* seeds were obtained from plants grown under sorghum from the Gdarief State and from plants growing under millet from Kordfan State, henceforth designated as sorghum and millet strains, respectively.

3.1.1.1.2. Chemicals

3.1.1.1.2.1. GR24

The synthetic *Striga* germination stimulant GR24 was obtained from Professor Zewannenberg University of Rhobard Nijmein, The Netherlands. A stock solution of the synthetic *Striga* germination stimulants GR24 (Fig.1) was prepared by dissolving 1mg in acetone (1ml) and completion to volume (100 ml) with sterilized distilled water to obtain the desired concentration (10 ppm)

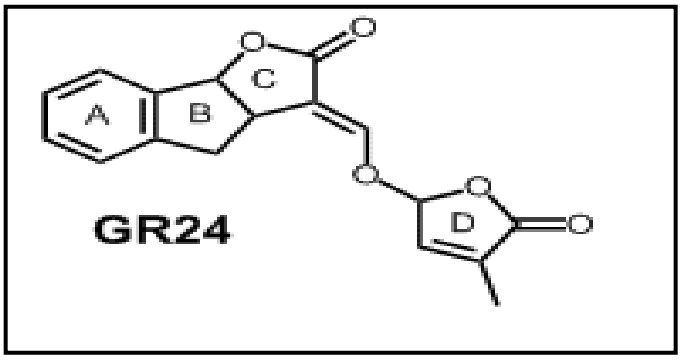

Fig.3.1. Chemical structure of the synthetic *Striga* germination Stimulants GR24

3.1.1.1.2.2. Agar

Nutrient less low melting agar was purchased from Nacalai Tesque Japan.

3.1.1.2.1. Seeds cleaning, surface disinfection

3.1.1.2.1.1. *Striga* seed cleaning, surface disinfection and conditioning:

Striga seeds (0.5-1g) were poured into a measuring cylinder (1000 ml) filled with tap water to which Tween 20 (0.5-1 ml) was added. The measuring cylinder was occasionally swirled. The seeds were allowed to settle and water containing debris and light seeds were decanted. The heavy seeds, separated from sand by repeated flotation and decantation, were subsequently transferred to a fine sieve (70 µm) and washed with tap water several times to remove traces of the detergent.

For surface disinfection *Striga* seeds were, immersed for 3 min in 70% ethanol followed by washing with sterilized distilled water and a subsequent immersion for 1 min in NaOCl solution (1%). The sodium hypochlorite was drained off, and the seeds were washed, under suction with sterilized distilled water several times, until the yellow color disappeared. The seeds, plotted dry on Whatman No.1 filter papers, were air-dried under a laminar flow cabinet and subsequently stored at ambient temperature till used.

Surface disinfected *Striga* seeds were sprinkled on 8 mm glass fiber filter papers (GFA) discs (*Ca* 25-30 seeds/disc), placed on glass fiber filter papers in Petri-dishes, and moistened with 5 ml of distilled water. The, Petri-dishes, sealed with parafilm, were wrapped in black polythene and incubated in the dark at 30°C for 14 days.

. 3.1.1.2.1.2. Surface disinfection of cowpea and sorghum seeds

Cowpea and sorghum seeds were surface-sterilized by immersion in 1% sodium hypochlorite obtained by dilution of the respective amount of commercial bleach solution (NaOCl) for 5 min. Subsequently the seeds were thoroughly washed with sterilized distilled water air dried in a laminar flow cabinet and stored at ambient temperature, till used.

3.1.1.2 Methods:

3.1.1.2.2. Effects of powder from cowpea on germination and radicle extension.

A total of 24 cowpea genotypes, grown in pots in a greenhouse for 10 days, were harvested by washing the root carefully to remove soil particles. The plants were severed into stems, leaves, and roots and subsequently dried under ambient conditions and powdered. The dried powder [0, 5, 10, 15 mg] was assayed for germination inducing activity using the Sandwich method (Fujii, *et al*., 2003) and employing conditioned *Striga* seeds. The sandwich method resides on diffusion of germination stimulants, into agar. Briefly, agar, nutrient-less (3g) was added to 1000 ml of distilled water and autoclaved for 20 min at 15 bars and 121 °C. The agar was allowed to cool in a water bath set at 40 °C prior to use. The agar was pipetted into multi-well plates (5 ml/well), and allowed to solidify prior to placement of the test sample on top. Another 5 ml of agar were placed on top, allowed to solidify, and subsequently discs containing conditioned S. *harmonthica*, millet or sorghum strain, were placed on top. The discs were gently pressed to ensure contact with the agar. The multi-well plates, cover in place, sealed with parafilm and wrapped in aluminum foil, were incubated at 30 °C in the dark for 48 h prior to examination for germination and measurement of radicle

length using a stereomicroscope. Controls without test samples were included for comparison. Germination, expressed as percentage, was taken as a measure of germination inducing activity of the powder on scale where 0-49, 50-59, 60-69, 70-79 and 80-100% indicated poor, moderate, satisfactory, good and excellent germination inducing activity, respectively. Radicle extension measuring 0.1-4.9×10^{-2}mm, 5-9.9×10^{-2} mm, 10-14.9×10^{-2} mm and ≥15×10^{-2} mm was considered very short, short, medium and long, respectively.

3.1.1.2.3. Comparative study on the effects of root exudates of sorghum and cowpea on germination and radicle extension of *S. hermonthica*

3.1.1.2.3.1. Germination and radicle extension

Sorghum (cv. Abu Sabeen), cowpea B301 and T 100K-901-6 genotypes, germinated on filter papers in Petri-dishes were transferred to 50 ml glass tubes containing 40% Long Ashton nutrient solution for 35 days. The solution was brought to volume every two days. Two hundred ml of the exudates was extracted with ethylacetate (100 X 3). The ethylacetate extracts were allowed to stand overnight at 4°C on anhydrous sodium sulphate. The extracts was subsequently evaporated to dryness at 40°C using a rotary evaporator. The residues were re-dissolved, each in 2 ml ethylacetate. Aliquots (5-30µl) were applied to glass fiber discs and allowed to stand for 2h in a laminar flow to ensure evaporation of ethylacetate. The treated discs were overlaid by discs containing conditioned *Striga* seeds (the double disc technique) (Babiker and Hamdoun, 1983). Each pair of discs was moistened with 40 µl distilled water. The seeds were re-incubated in the dark at 30°C and examined for germination and radicle extension as in 3.1.1.2.2. 24h later.

3.1.1.2.3.2. Effects of time and cowpea genotype on production of *Striga* germination stimulants

Seeds of cowpea genotype B301, T100K-901-6 and T198K-317-2 were surface disinfectet, germinated and the seedlings were transferred to glass tubes as above and allowed to grow hydroponically in 40% long Ashton solution for 4 days, subsequently transferred to tap water in glass tubes (100 ml capacity), wrapped with aluminum foil to exclude light and incubated for 4 days prior to sampling. The water volume in the tubes was allowed to drop to 50 ml or adjusted to 50 ml prior to sampling. Samplings were made daily over a 10 days period. The samples (2 ml from each tube) were subsequently tested for germination inducing activity. Aliquots (20µl each) were applied, each, to an 8 mm glass fiber disc containing conditioned *Striga* seeds, placed in Petri dishes. The seeds were re-incubated and examined for germination and radicle extension as in 3.1.1.2.2. Seeds treated with GR24 or distilled water were included as controls for comparison.

3.1.1.2.3.3. *In-situ* germination and development of *S. hermonthica* on cowpea

Reaction of cowpea genotype T100K-901-6 to *S. hermonthica* was investigated using the Rhizotron technique as described by Vasey, *et al*., (2005). Surface disinfected cowpea seeds were germinated on filter paper for 3 days at 30°C. The Seedlings were subsequently 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 allowed to grow for 10 days in a controlled environment with 12 h photoperiod and a temperature at 30°C. The rihzotron comprises of 150 mm diameter Petri-

dishes filled with Rockwool overlaid by a glass fiber filter paper. The rhizotron was opened at the top to allow for shoot growth (Plate 3.1).

Plate 3.1. A **cowpea seedling in a rhizotron**

Conditioned *Striga* seeds (*Ca*-mg) were sprinkled in close proximity of the roots. The rhizotrons, placed in polythene jackets were incubated in the dark at 30 °C prior to examination, at 7 and 14 days, for *in-situ* germination and further development of the parasite by randomly selecting 400 seeds in each. The developmental stages were recorded as described by Vasey *et al* (2005).

3.1.1.2.3.4. Chromatographic behavior of root exudates from sorghum and cowpea:

The chromatographic behavior of germination stimulants from cowpea genotypes, B301 and T100K-901-6, and sorghum was investigated using ethylacetate extract of root exudates obtained as in 3. 1.1. 2.2.

The extracts, unless mentioned otherwise, were subjected to Thin Layer (TLC), column and high performance liquid chromatography (HPLC) analyses.

3.1.1.2.3.4.1. Thin layer chromatography:

Aliquots (*Ca* 50µl) of the concentrated ethylacetate extracts were spotted onto aluminum plates (3.5× 8) coated with silica Gel 60 F254. The plates were developed using hexane/ethyl acetate (1:1). Subsequent to development the plates were examined under UV light (254nm). The plates were subsequently cut into 1cm pieces, placed in Petri-dishes and directly assayed for germination inducing activity using conditioned *S. hermonthica* seeds, sorghum strain. Germination was assayed as in 3.1.1.2.2.

3.1.1.2.3.4.2. Column chromatography:-

A glass chromatographic column (34×3cm) was packed to 15 cm with silica gel (100-200 mech) obtained from s.d. fiNE-CHEM liMiTEd. The extract in ethylacetate (*Ca*-0.5 ml) was loaded into the column. The column was eluted with hexane (10 ml) followed in sequence by hexane: ethyactate mixtures (9:1, 7:3, 1:1, 3:2, 3:7,1:4, 1:8, 0:10, and 0:1v/v)10 ml each. Fractions were collected at 5 min intervals and evaporated to dryness. The residue, of each fraction, was dissolved in ethylacetate (1ml). Aliquot (20µl) of each of the ethylactate solutions were applied each to an 8 mm glass fiber disc. The discs were allowed to stand in a laminar flow cabinet for 2 h and subsequently assayed for germination inducing activity using the double disc technique (Babiker and Humdoun, 1983). Samples were assayed for germination as in3.1.1.2.2.

3.1.1.2.3.4.3. High Performance Liquid Chromatography

Subsequent to column chromatography samples showing the highest germination inducing activity were further subjected to HPLC analysis. The HPLC machine was equipped with a develosil column (4.6×150 mm) and a UV detector (254 nm). Column temperature was adjusted to 30°C, column

pressure was 9.4 mPa. Methanol: water (7:3) was employed as mobile phase. The flow rate was set to 1ml/min^{-1}. The sample for analysis (60µl) was injected. The column effluent, passed throng a UV (254 nm) detector, was collected in fractions (5min each). The fraction, evaporated on a rotary evaporator to dryness and the residues, dissolved in ethylacetate (1ml), were assayed for germination inducing activity using the double dice technique as in 3. 1.1.2.2.

3.1.2. Greenhouse experiments.

3.1.2.1. Effects of intercropping with cowpea on *Striga* incidence and sorghum growth.

Pots (21 cm i.d.), perforated at the bottom, were filled with soil sand mix (1:1) prepared by mixing soil collected from the College farm with river sand, henceforth, referred to as soil. The soil was inoculaleted, with different levels of *Striga* seeds (1-32 mg/pot). Sorghum (cv Wad Ahmed) seeds (5 per pot) were planted at *Ca.* 2 cm soil depth. Cowpea B301 and T100K-901-6 seeds (7 per pot) were planted as companion crops.Sorghum and cowpea seedlings were thinned to 2 and 3, respectively 7 days after emergence. Sole sorghum, *Striga* infested, and *Striga* free sorghum intercropped with cowpea were included as controls for comparison. Treatments were arranged in a randomized complete block design with four replicates.

Striga count and sorghum height were determined 30, 60 and 90 days after sowing (DAS). Leaf area was estimated by multiplying the length of the second leaf from top by half of maximum width of the leaf at 30, 60 and 90 DAS. At harvest sorghum and *Striga* shoots, each, cut at ground level, were air-dried and weighed.

3.1.3. Field experiment

Microbal bioferlilizers

The bacterial strains (*Rhizobium leguminosaium* and ***B****acillus megaterium* Var. Phosphacticum (Selected on basis of their ability to suppress *striga* germination) Were obtained from ENDRI, NCR, Khartoum Sudan. Yeast extract, mannitol and meat peptone broth media were Autoclaved for 20 min at 15 bars and 121c for 20 min) and subsequently inoculated withRhizobium and Bmp, reswpcetively.

3.1.3.1. Effects of intercropping with cowpea dressed with *R.leguminosarum* and *B. megateriumon* on *Striga* incidence and sorghum growth.

The experiment was conducted in a *Srtiga* thick plot. Sorghum (cv. Wad Ahmed) was planted in 4 cm deep holes on ridges 80 cm apart at 20 cm between holes. Seeds of cowpea B301 and T100K-901-6, selected according to their prostrate habit of growth, (Plate 3.3.), dressed with *Rhizobum. Leguminosarum* L. and *Bacillus megaterium* var *phosphaticum* (Bmp), each alone and in combination, were planted (2 seeds per hole) in between the sorghum holes.

Plate: 3.2. Cowpea genotype. A) B301, B) T100K-901-6

Sorghum and cowpea seedlings were thinned to 3 and 2 plants per hole, respectively 7 days after crop emergence.Treatments were arranged in a complete randomized block design with 3 replicates. *Striga* plant, were counted 35, 50, 65, and 80 DAS. At harvest sorghum second internodes from the bottom, hundred seed weight of sorghum, sorghum head length, head sizes and plant height were measured.

3.1.4. Statistical Analyses:

Data collected from all experiments were subjected to statistical analysis using Statistix 8 statistical software, Version 2.0 (UK). Means were separated for significance using the Least Significant Difference (LSD at $p \geq 0.05$). Correlations were determined using GenStat (PC/Windows 7),VSN International Ltd., UK statistical package **(**Rothamsted Experimental Station). Graphs were drawn, when appropriate using Sigma plot version 11 and Microsoft Office Excel 2007.

CHAPTER FOUR

RESULTS

4.1. Laboratory experiments

4.1.1. Effects of powder from cowpea on germination and radicle extension.

4.1.1.1. *Striga* sorghum strain

4.1.1.1.1. Root powder

4.1.1.1.1.1. Germination

A general feature of the germination inducing activity (GIA) of powder from cowpea roots on *S. hermonthica*, sorghum strain, was an increase on raising powder level from 5 mg to 10 mg per well and a subsequent decline on a further rise in amount of powder to 15 mg (Fig.4.1.A-C and Appendix 2). GR24 at 0.1 ppm induced 77-90 % germination. Root powder at 5 mg from 2 genotypes showed poor activity (32.8 and 41% germination). Fig.4.1 A

Powder from 3 genotypes displayed moderate activity (50-59.9% germination). Powder from 14 genotypes showed satisfactory activity (60.3-69%). Powder samples from 4 genotypes exhibited good activity (70.3-74% germination). Of all powder samples tested only one displayed excellent germination inducing activity (85.5% germination). Increasing powder level to 10 mg per well increased GIA of all genotypes as none of the powder samples showed poor activity (Fig.4.1. B, Appendix 2). Of all the powder samples tested only 3 samples showed moderate activity (51.4-57% germination). Powder from 6 genotypes showed satisfactory activity (64.3-68.5% germination), while 9 samples showed good activity (70.2-78.8%

germination) and only 6 samples showed excellent germination inducing activity (80.7-86.1%) (Fig.4.1 B).

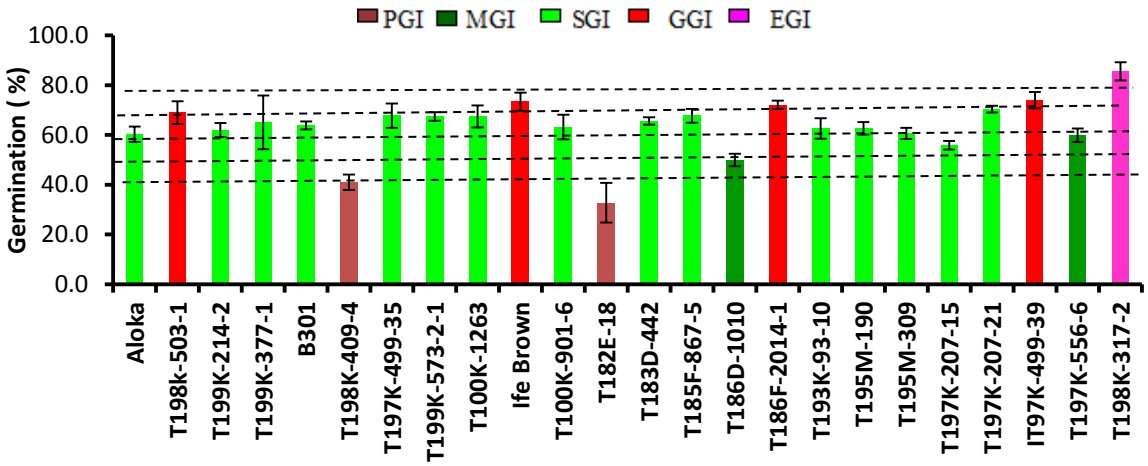

Fig.4.1 A: Germination inducing activity of cowpea genotype root powder (5 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity EGI = excellent germination inducing activity}. Vertical bars indicate standard error (SE±).

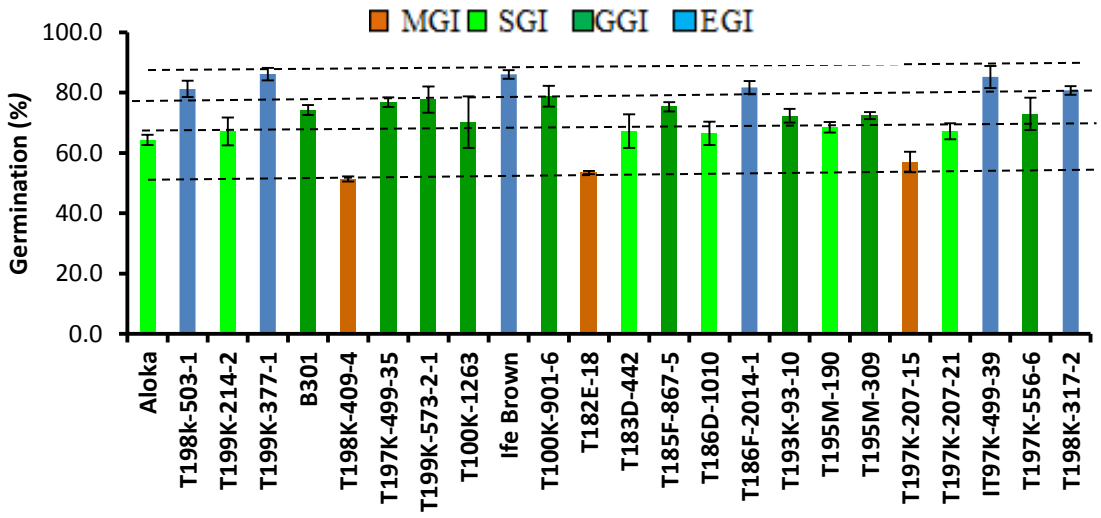

Fig.4.1 B: Germination inducing activity of cowpea genotype root powder (10 mg). {MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity, EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±).

Increasing powder to 15 mg repressed germination inducing activity of all samples (Fig. 4.1. C, Appendix 2). Four samples showed poor activity (40.9-49.9% germination), 10 displayed moderate activity (50.5-58% germination), 8 demonstrated satisfactory activity (60.1-66.9% germination) and 2 showed good (75.4 and 77.7%) activity. Considering the overall mean germination inducing activity across genotypes only one sample showed poor activity (37.4), 6 samples displayed moderate activity (50.9-59.7% germination), 12 samples displayed satisfactory activity (62.4-69.6% germination), 4 samples displayed good activity (70.6-78.3% germination), while excellent germination inducing activity (81.3%) was demonstrated by one samples (Appendix2).

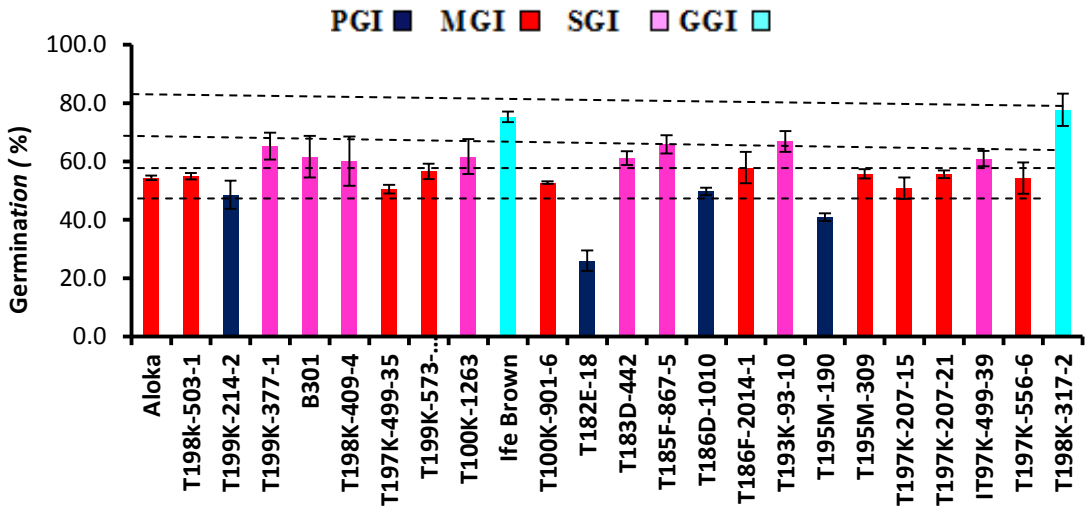

Fig.4.1 C: Germination inducing activity of cowpea genotype root powder (15mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity GGI = good germination inducing activity.Vertical bars indicate standard error (SE±).

Of all the genotypes studied and across the root powder levels T186D-1010 showed the lowest (37.4 %), and T189F-2014-1, T199K-377-1, T97K-499-

39, IFEbrown and T198K-317-2 showed the highest (7.6-81 %) germination inducing activity (Appendix 2).

4.1.1.1.1.2. Radicle extension

4.1.1.1.1.2.1. Root powder

Radicle extension of *Striga* germinlings, sorghum strain, induced to germinate by cowpea root powder, irrespective of genotypes, decreased with amount of powder used (Fig.4.2.A-C.and appendix 3). At 5 mg powder, from only one genotype effected short radicle extension (9.5×10^{-2} mm), 16 samples sustained medium radicle extension ($10.7\text{-}13.7\times10^{-2}$ mm), while only 7 sustained long radicles extension ($15.1\text{-}34.9\times10^{-2}$ mm).

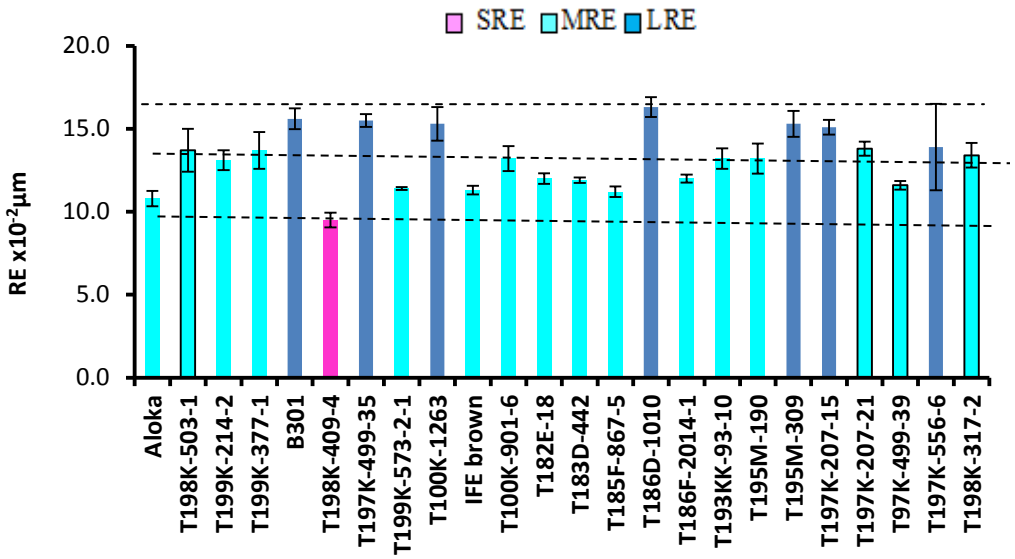

Fig.4.2 A: Effects of cowpea root powder (5 mg) on radicle extension in *S. hermonthica*. {SRE = short radicle extension. MRE = medium radicle extension, LRE = long radicle extension}Vertical bars indicate standard error (SE±).

At 10 mg 10 powder samples effected short radicle extension (7.9-9.7×10^{-2} mm) (Fig. 4.2. B. Appendix 3). While 14 samples induced medium radicle extension (10.0-14.9×10^{-2}µm).Fig. (4.2 C).

At 15 mg 19 samples effected short radicle extension (5.3-9.3×10^{-2} mm) (Fig. 4.2. C, Appendix 3), whereas 5 samples resulted in medium radicle extension (10.2-12.4×10^{-2} mm)

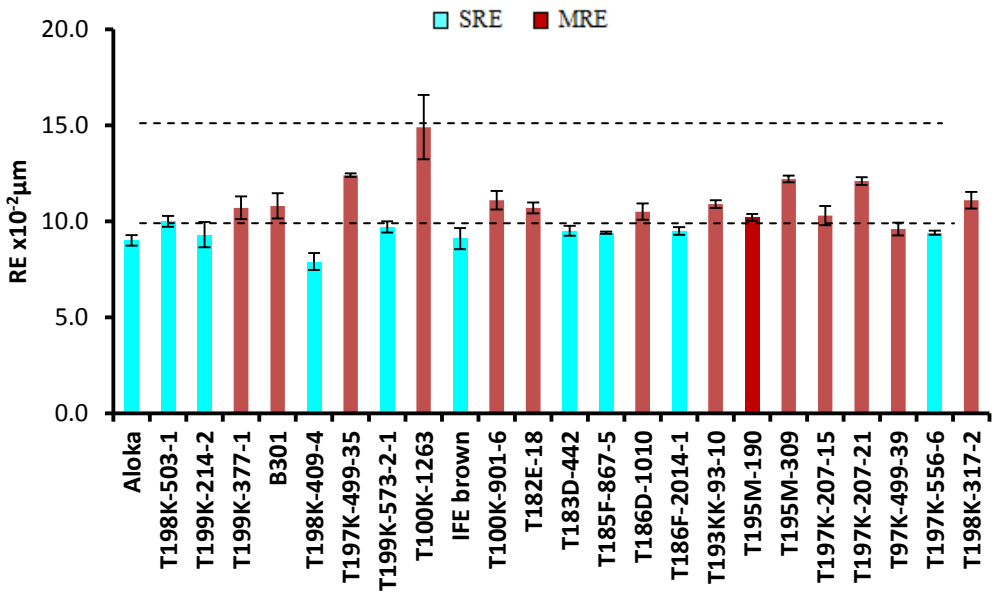

Fig.4.2 B: Effects of cowpea root powder (10 mg) on radicle extension in *S. hermonthica.* {SRE = short radicle extension. MRE = medium radicle extension}. Vertical bars indicate standard error (SE±).

Across genotypes and powder amount 9 samples resulted in germlings with short radicle length (7.6-9.7×10^{-2} mm) and 13 allowed for medium radicle (10.5-12.7) extension, while only 2 sustained long radicles (15.5 and

17.3×10^{-2} mm). Of all genotypes tested powder samples from T198K-409-4, ALOKA, Ife BROWN, IT97K-499-39 and T199K-573-2-1 resulted in the shortest radicle (7.6-9.4×10^{-2}µm) extension, and T197K-207-21, T195M-309, T197K-499-35, T100K-1263 and T197k-556-6 effected the longest radicle (12.3-17.3×10^{-2} mm) (Appendix 3).

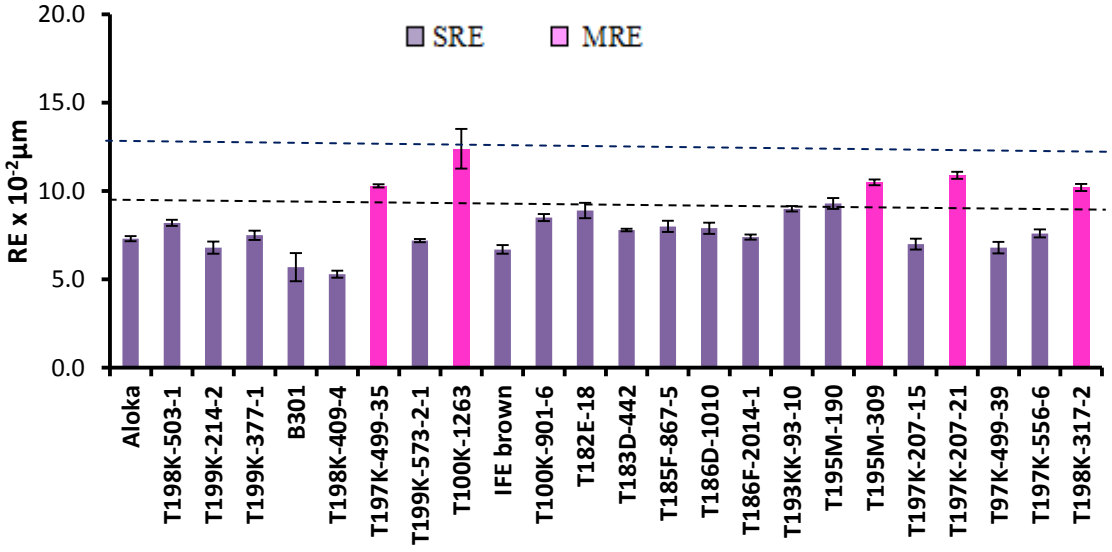

Fig.4.2 C: Effect of cowpea root powder 15 mg and radicle extension *S. hermonthica.* {SRE = short radicle extension. MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

4.1.1.1.2. Stems powder

4.1.1.1.2.1. Germination

The germination inducing activity of powder from cowpea stems showed the same trends as that of the root powder, an increase and a subsequent decline with powder amount (Fig. 4.3.A-C. and Appendix 4). GR24 at 0.1 ppm induced 77-90% germination. Stems powder at 5 mg from 8 genotypes showed poor activity (29-47.4% germination). Powder from 7 genotypes displayed moderate activity (53.8- 57.3% germination). Powder from

7genotypes showed satisfactory activity (60.-69.1%). Powder samples from 2 genotypes exhibited good activity (71 and 74.6% germination). Of all the powder samples tested none displayed excellent germination inducing activity. (Fig. 4.3 A).

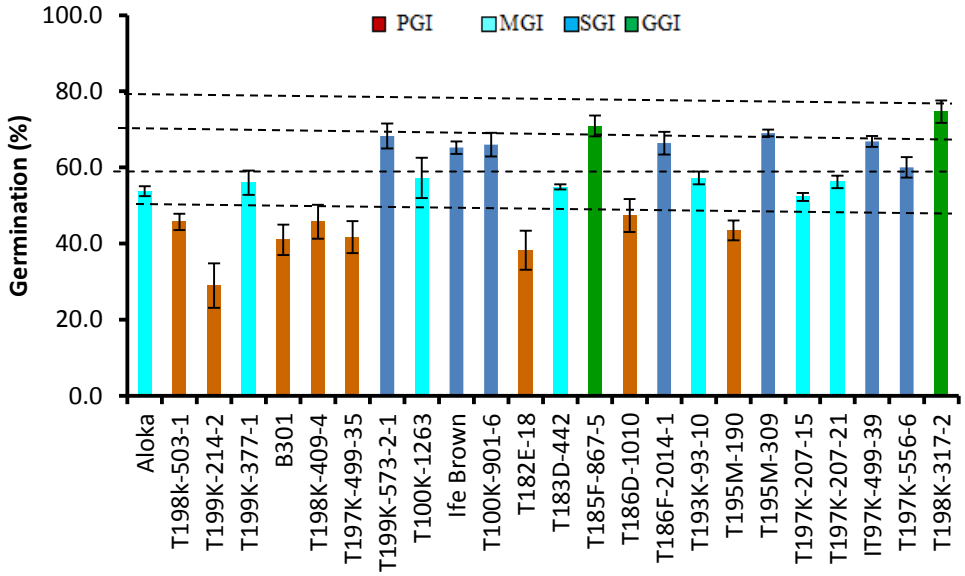

Fig.4.3 A: Germination inducing activity of cowpea genotype (stem powder 5 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity}. Vertical bars indicate standard error (SE±)

Increasing powder amount to 10 mg per well increased powder germination inducing activity of all genotypes as none of the powder samples showed poor activity (Fig. 4.3. B, Appendix 4). Of the powder samples tested only 7 sample showed moderate activity (50.9-57.7% germination). Powder from 7 genotypes showed satisfactory activity (60-69.5% germination), while 10 samples showed good activity (70.2-78.9% germination) and none of the samples showed excellent germination inducing activity.

Increasing powder level to 15 mg repressed germination inducing activity of all samples (Fig. 4.3. C, Appendix 4). Thirteen samples showed poor activity

(35.5-49.4% germination), 6 displayed moderate activity (52.3-55.8% germination) and 5 demonstrated satisfactory activities (60.1-68.2% germination).

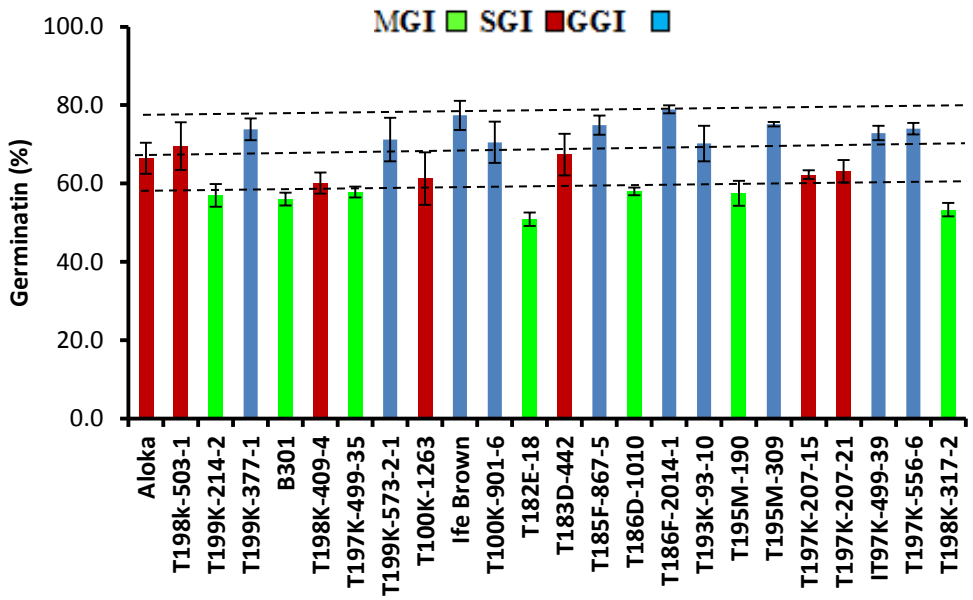

Fig.4.3 B: Germination inducing activity of cowpea genotype (stem powder 10 mg). {MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity = GGI = good germination inducing activity}.Vertical bars indicate standard error (SE±).

Considering the overall mean germination inducing activity across genotypes and powder levels 7 samples showed poor activity (40.9-49.1%), powder from 6 genotypes displayed moderate activity (53.2-58.6), 10 samples displayed satisfactory activity (60.2-69% germination), one samples displayed good activity (70.2% germination), while excellent germination inducing activity was demonstrated by none (Fig. 4.3 A-C and Appendix4). Of all the genotypes studied and across the root powder levels T199K-214-2, T182E-18, B301, T197K-499-35 and T186D-1010 showed the lowest germination inducing activity (40.9-49.1 % germination), while T199K573-

2-1, Ifebrwn, T195M-190, T1498K-317-2 and T97K499-39 showed the highest (Appendix 4).

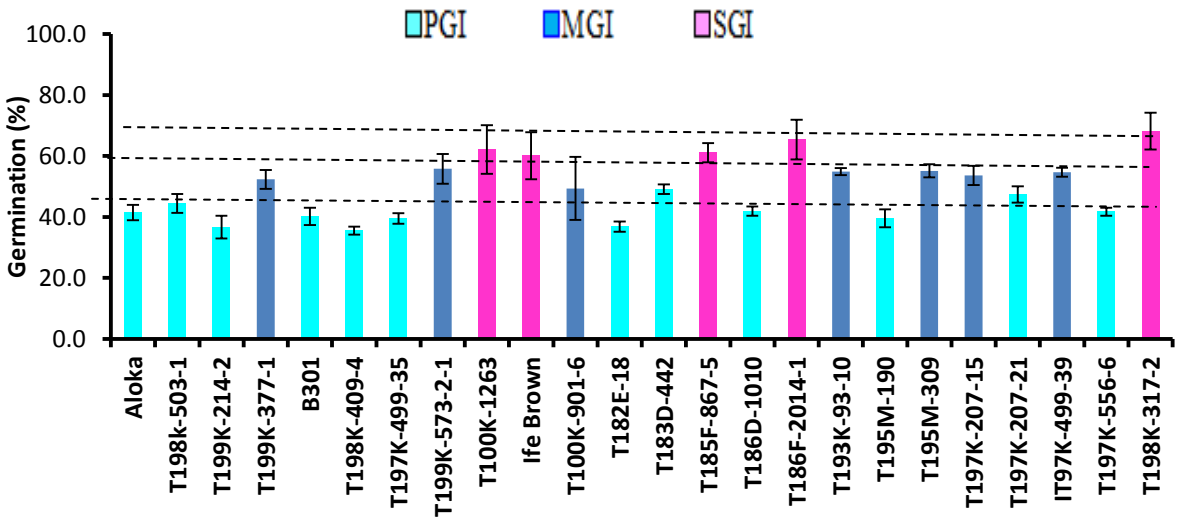

Fig.4.3 C: Germination inducing activity of cowpea genotype (stem powder 15 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity}.Vertical bars indicate standard error (SE±).

4.1.1.1.2.2. Radicle extension

Radicle extension of germinlings of *S. hermonthica*, sorghum strain, induced to germinate by cowpea stems powder, irrespective of genotype, decreased with amount of powder used (Fig. 4.4.A. and Appendix 5). At 5 mg, samples from 19 genotypes effected short radicle extension (5.5-9.9×10^{-2} mm), whereas 5 samples induced medium radicles extension (10.0-14.6×10^{-2} mm).

At 10 mg only one powder sample effected very short radicle extension (4.4×10-2 mm), (Fig. 4.4.B. Appendix 5) while 20 samples induced short radicle extension (5.0-9.9×10^{-2} mm) and 3 samples sustained medium radicle extension (10.1-11.9×10^{-2} mm)

At 15 mg 12 samples resulted in very short radicle extension (3.3-4.9×10^{-2} µm), (Fig. 4.4. C, Appendix 6) and 12 samples upheld short radicles (5.1-9.9×10^{-2} mm).

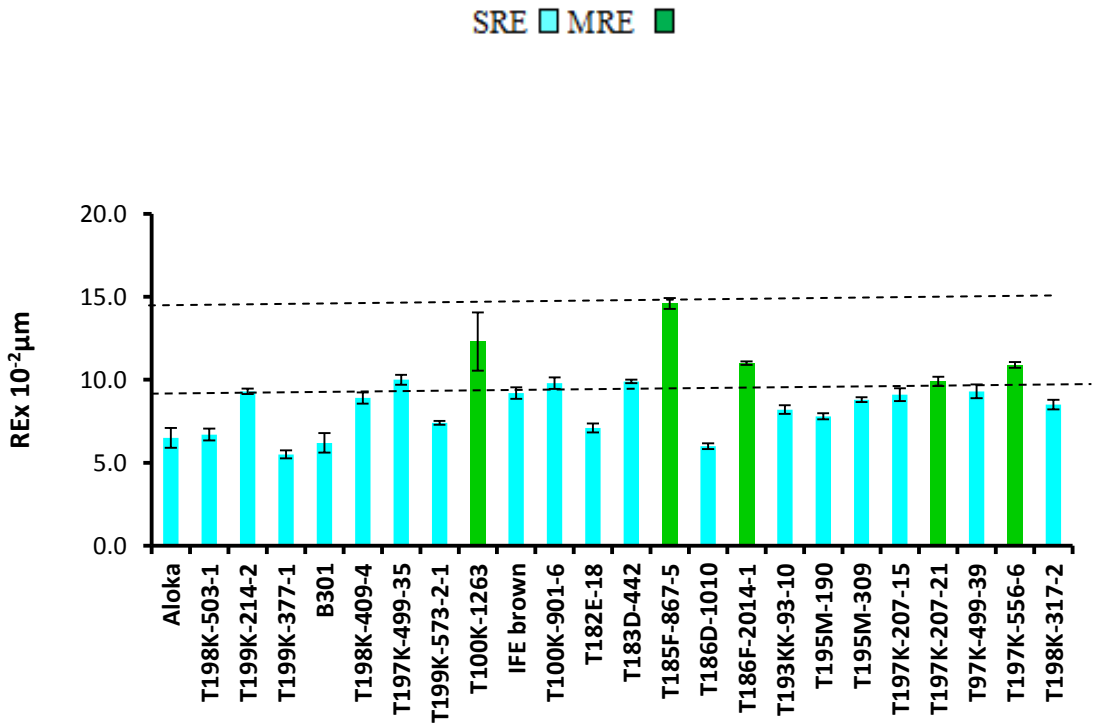

Fig.4.4 A: Effects of cowpea stem powder (5 mg) on radicle extension in *S. hermonthica.* {SRE = short radicle extension. MRE = medium radicle extension}. Vertical bars indicate standard error (SE±).

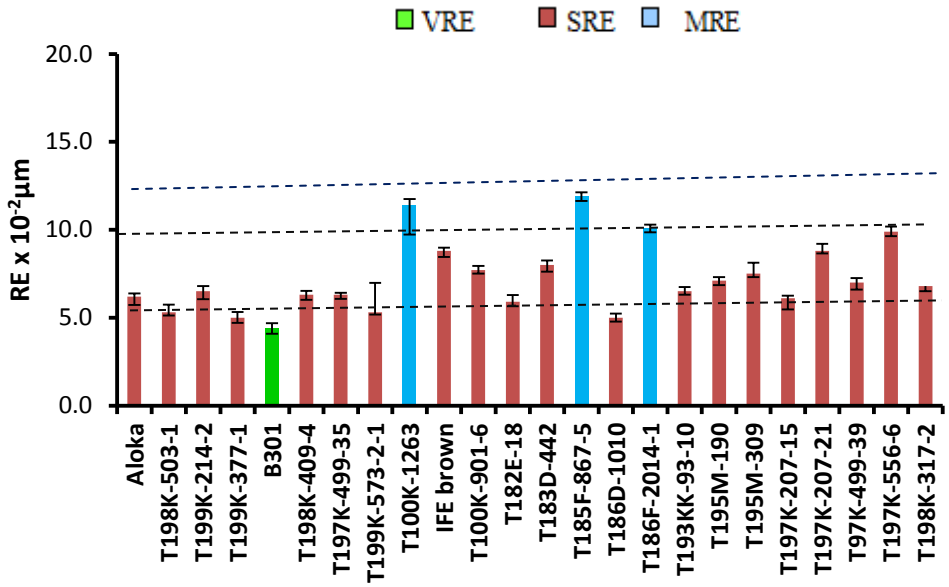

Fig.4.4 B: Effects of cowpea stem powder (10 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension. MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

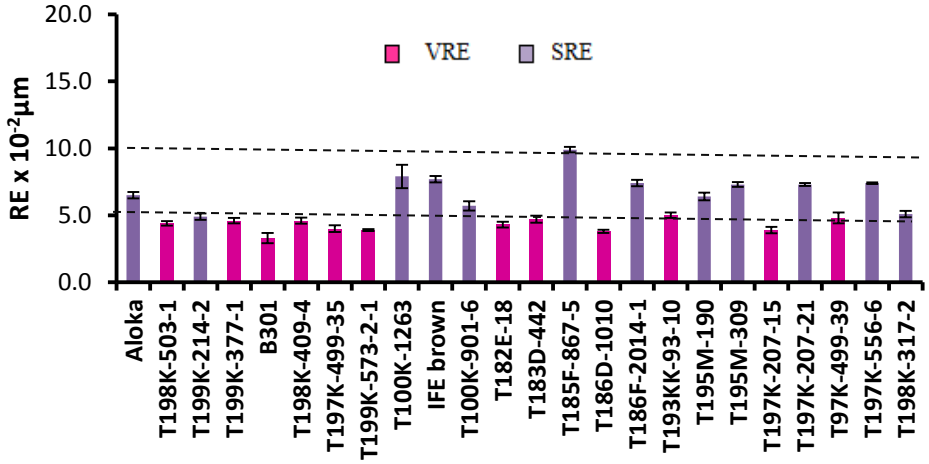

Fig.4.4 C: Effects of cowpea stem powder (15 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

Across genotypes and powder amount 2 samples sustained germlings with very short radicles (4.6-4.9×10^{-2} mm) and 20 allowed for short radicle

extension (5.5-9.59×10^{-2} mm), while 2 samples sustained medium radicle (10.5-12.1×10^{-2} mm) extension. Of all the genotype tested powder samples from B301, T186D-1010, T199K-377-1, T198K-503-1 andT199K-573-2-1 resulted in the shortest radicles (4.6-5.5×10^{-2} mm), and T195M-309, Ife, T197K-207-21, T197K-556-6 and T186F-2014-1 sustained the longest radicles (7.9-9.5×10^{-2} mm) (Appendix 5).

4.1.1.1.3. Leaves powder

4.1.1.1.3.1. Germination

The germination inducing activity of powder from cowpea leaves followed the same trends as that in 4.1.1.1.1 and 4.1.1.1.2 (Fig. 4.5 A-C).GR24 at 0.1 ppm induced 77-90% germination. At 5 mg leaves powder from 19 genotypes showed poor activity (21.1-.49.6% germination) (Fig. 4.5. A. Appendix 6). Powder from 2 genotypes displayed moderate activity (53 and 55.3% germination). Powder from 3 genotypes showed satisfactory activity (64.3-67%).

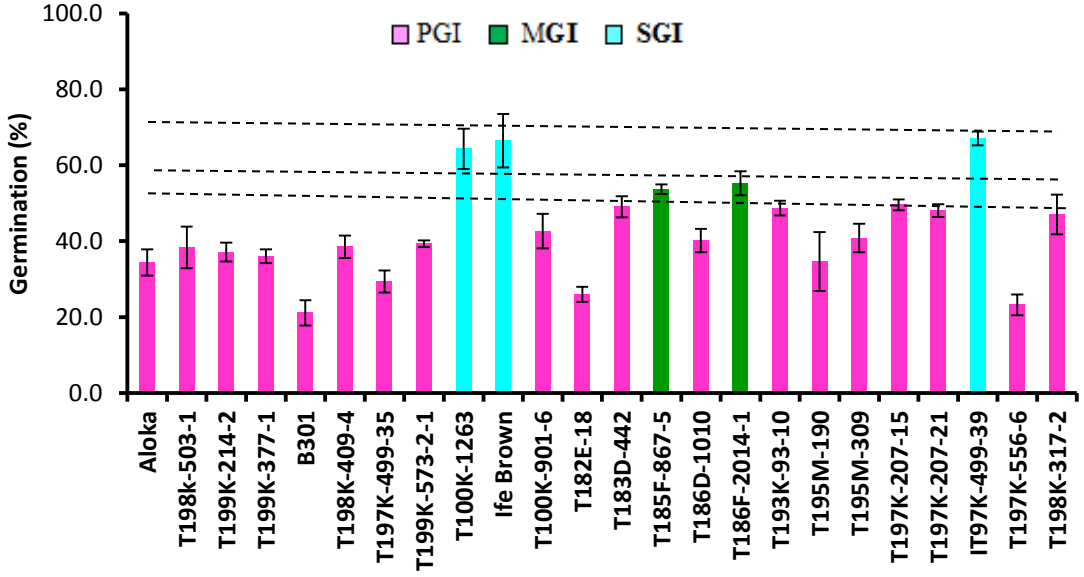

Fig.4.5 A: Germination inducing activity of cowpea genotype leaves powder (5 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity}.Vertical bars indicate standard error (SE±)

Increasing powder amount to 10 mg increased germination inducing activity of all samples. Seven samples showed poor activity (18.7-49.1), while 9 samples showed moderate activity (50.3-59.4% germination) (Fig. 4.5. B, Appendix 6). Powder from 6 genotypes showed satisfactory activity (62.5-66.8% germination), and only 2 samples showed good activity (70.7-77.6% germination).

Increasing powder to 15 mg repressed germination inducing activity (Fig. 4.5. C, Appendix 6). Of the samples tested. 21samples showed poor activity (17.6-46.7% germination), 2 displayed moderate activity (52.8 and 53.3% germination), and only one demonstrated satisfactory activity (66.5% germination).

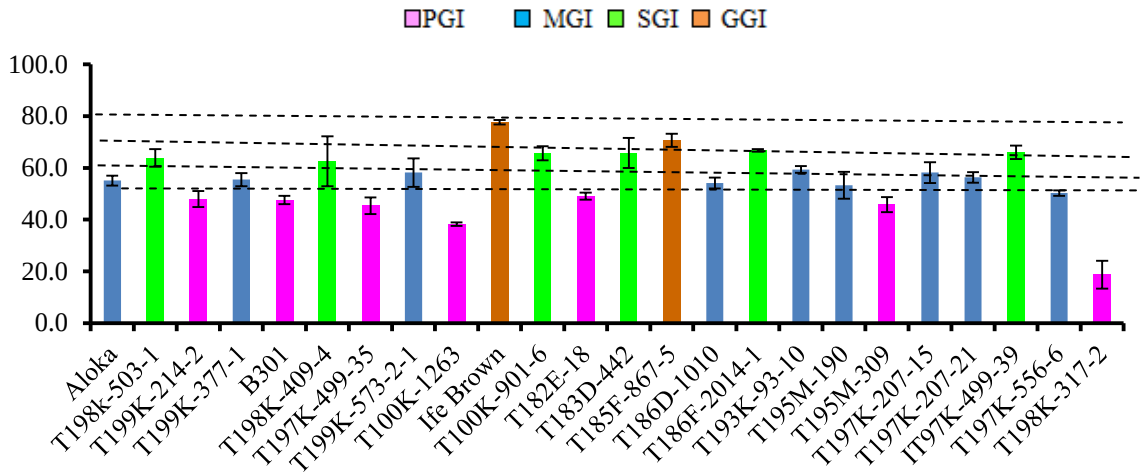

Fig.4.5 B: Germination inducing activity of cowpea genotype leave, powder (10 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity}.Vertical bars indicate standard error (SE±).

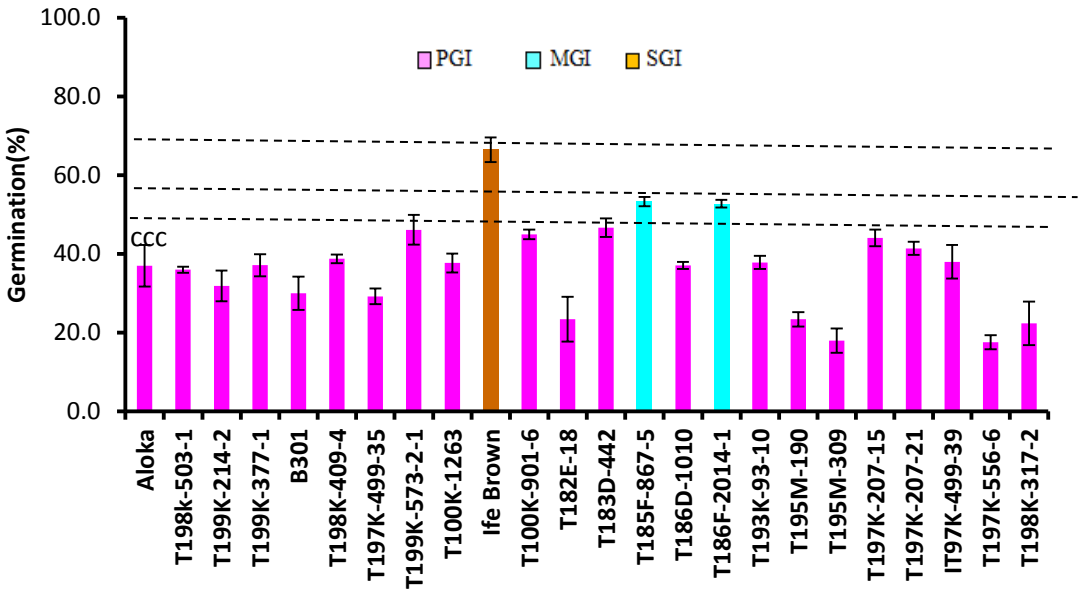

Fig.4.5 C: Germination inducing activity of cowpea genotype leave powder (15 mg). {PGI = poor Germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity}.Vertical bars indicate standard error (SE±).

Considering the overall mean germination inducing activity across genotypes and powder levels,17 samples showed poor activity (29.4-48.6), 6 samples displayed moderate activity (50.6-59.2% germination). However, none of the sample displayed satisfactory activity, while one sample exhibited good activity (70.2% germination).

Of all the genotypes studied and across leaves powder levels T198K-317-2, T197K556-6, T182E-18, T197K-499-35 and T195M-309 showed the lowest (29.4-34.8%) germination, while IFEbrowns, showed the highest (70.2%) germination inducing activity (Appendix 6).

4.1.1.1.3.2. Radicle extension

Radicle extension of germinlings of *S. hermonthica*, sorghum strain, induced to germinate by cowpea leaves powder, irrespective of genotype, decreased with the amount of powder used (Fig. 4.6. A-C,

Appendix 7). Radicle extension of germinlings from seeds induced to germinate by GR24 at 0.1 ppm was 17.3-25.7×10^{-2} mm. At 5 mg powder, samples from 7 genotypes displayed very short radicle extension (3.4-4.8×10^{-2} mm), 15 samples induced short radicles (5.2-9.9×10^{-2} mm), while only 2 sustained medium radicle extension (10.1-10.4×10^{-2} mm) (Fig. 4. 6. A).

At 10 mg 13 samples resulted in germilings displaying very short radicle extension (2.5-4.8×10^{-2} mm) (Fig. 4.6. B, Appendix 7), while 11 samples induced short radicle length (5.3-8×10^{-2} mm).

At 15 mg 18 samples effected very short radicle extension (1.7-4.5×10^{-2}µm) whereas 6 upheld short radicles (5.0-7.9×10^{-2} mm) (Fig. 4.6. C, Appendix 7).

Across genotypes and powder amount 12 samples sustained germilings with very short radicles (2.6-4.6×10^{-2} mm) and 12 supported germilings with short radicles (5.0-8.7×10^{-2} mm).

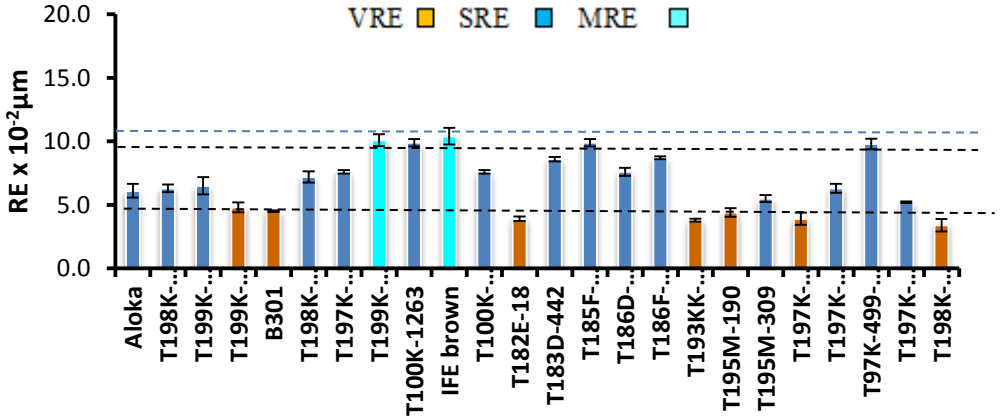

Fig.4.6 A: Effectsof cowpea leave powder (5 mg)onradicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension, MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

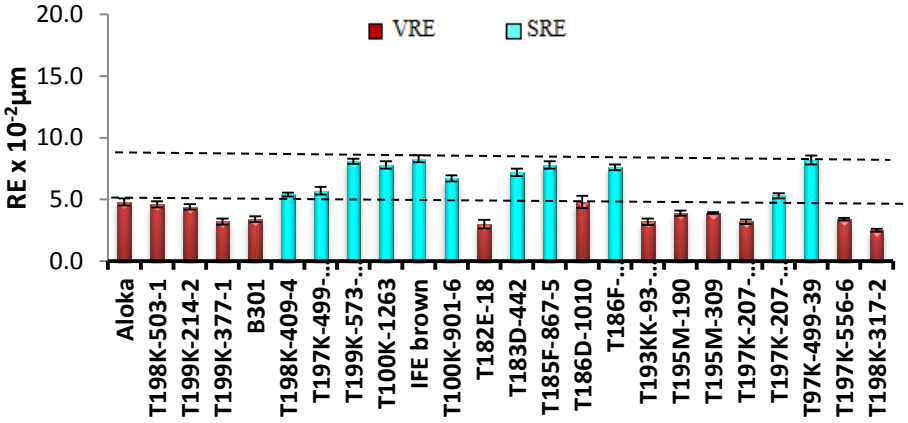

Fig.4.6 B: Effectsof cowpea leave powder (10 mg)on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±)

Of all genotype tested powder sample from T198K-317-2, T182E-18, T193K-93-10, T197K-207-15 and T199K-377-1T resulted in the shortest radicles (2.6-3.2 $\times 10^{-2}$ mm) and T185F-867-5, T100K-1263, Ife Brown, IT97K-499-39 and T199K-573-2-1 sustained the longest radicles (7.7-8.7$\times 10^{-2}$ mm) (Appendix 7).

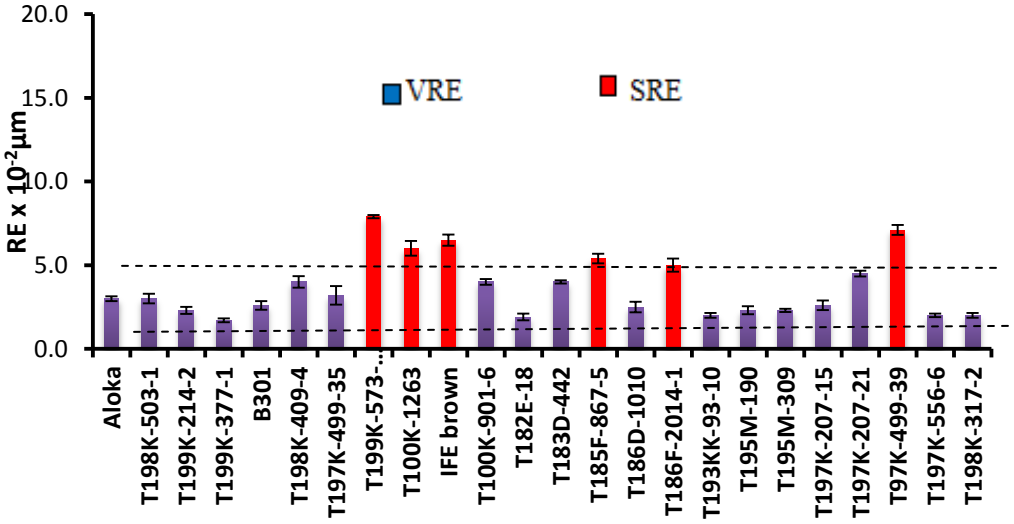

Fig.4.6 C: Effects of cowpea leave powder (15 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension, SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

4.1.1.2. *Striga* millet strain

4.1.1.2.1. Root powder

4.1.1.2.1. 1. Germination

A general feature of the germination inducing activity of powder from cowpea roots, on *S. hermonthica*, millet strain followed the same trends as those noticed for the sorghum strain (4.1.1.1.1, 4.1.1.1.2 and 4.1.1.1.3). Germination increased on raising powder level from 5 mg to 10 mg per well and subsequently declined on a further rise in amount of powder to 15 mg. Seeds treated with GR24 at 0.1 ppm displayed 55-72.8% germination. At 5 mg root powder from one genotype showed poor activity (45.6% germination). Powder from 6 genotypes displayed moderate activity (52.1-59.9% germination). Powder from 10 genotypes showed satisfactory activity (60.4-68.7%). Powder samples from six genotypes exhibited good activity (71.1-78.4% germination), and 1 sample showed excellent germination inducing activity (94.7% germination) (Fig. 4.7. A. Appendix 8).

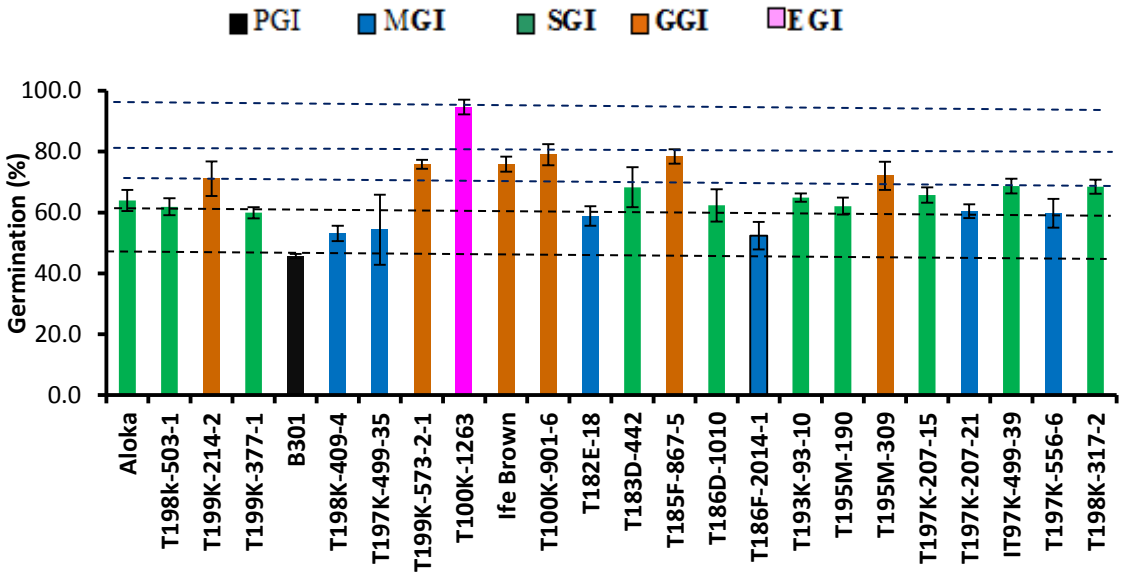

Fig.4.7 A: Germination inducing activity of cowpea genotype (root powder 5 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity = GGI = good germination inducing activity EGI = excellent germination inducing activity}. Vertical bars indicate standard error (SE±).

Increasing powder level to 10 mg increased germination inducing activity as none of the powder samples showed poor activity (Fig. 4.7. B, Appendix 8). Of all the powder samples tested only one sample showed moderate activity (59.7% germination). Powder from 9 genotypes showed satisfactory activity (60.7-68.8% germination), while 9 samples showed good activity (70.1-78.6% germination) and only 5 samples showed excellent germination inducing activity (80.4-95.1%) (Fig. 4.7, B).

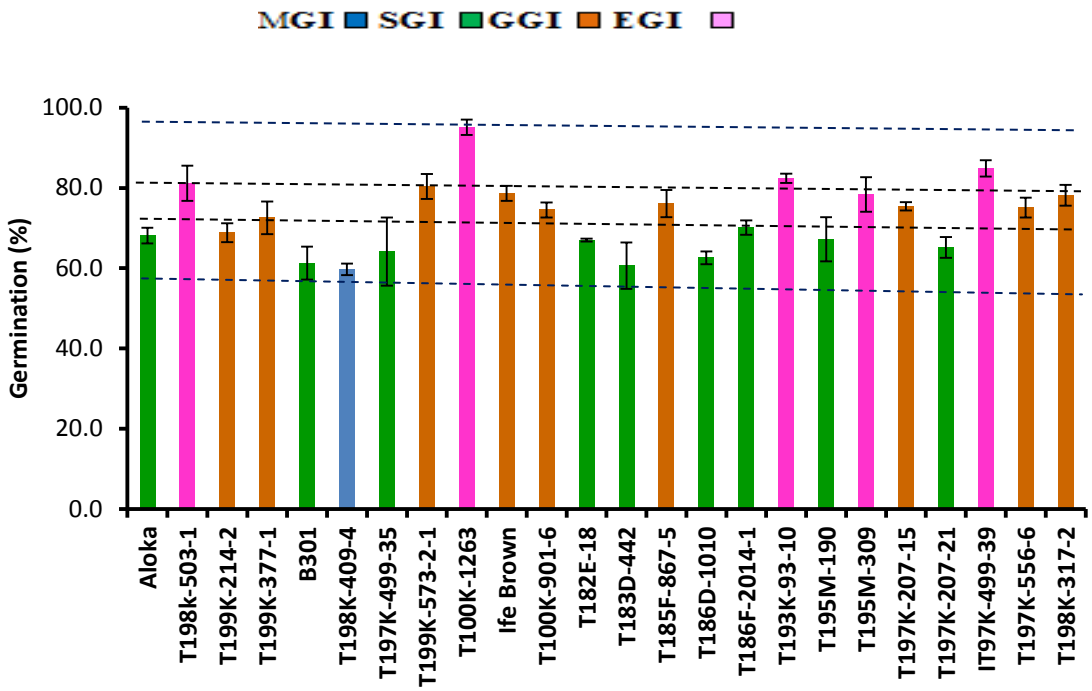

Fig.4.7 B: Germination inducing activity of cowpea genotype (root powder 10 mg). {MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity EGI = excellent germination inducing activity. Vertical bars indicate standard error (SE±).

Increasing powder to 15 mg repressed germination inducing activity of all the samples tested 7 showed poor activity (33.4-49.1% germination), (Fig. 4.7. C, Appendix 8) 10 samples displayed moderate activity (55-59% germination), 5 demonstrated satisfactory activity (62.9-65.5% germination), while good (72.2%) and excellent (94.7%) germination inducing activity was displayed, each, by one sample.

Considering the overall mean germination inducing activity across genotypes and powder levels only one sample displayed poor activity (46.8% germination), 6 samples displayed moderate activity (51.7-59.5% germination), 10 samples showed satisfactory activity (60.2-69.8% germination), 6 samples displayed good activity (70.2-72.9%germination), while excellent germination inducing activity (94.8%) was demonstrated by one sample.

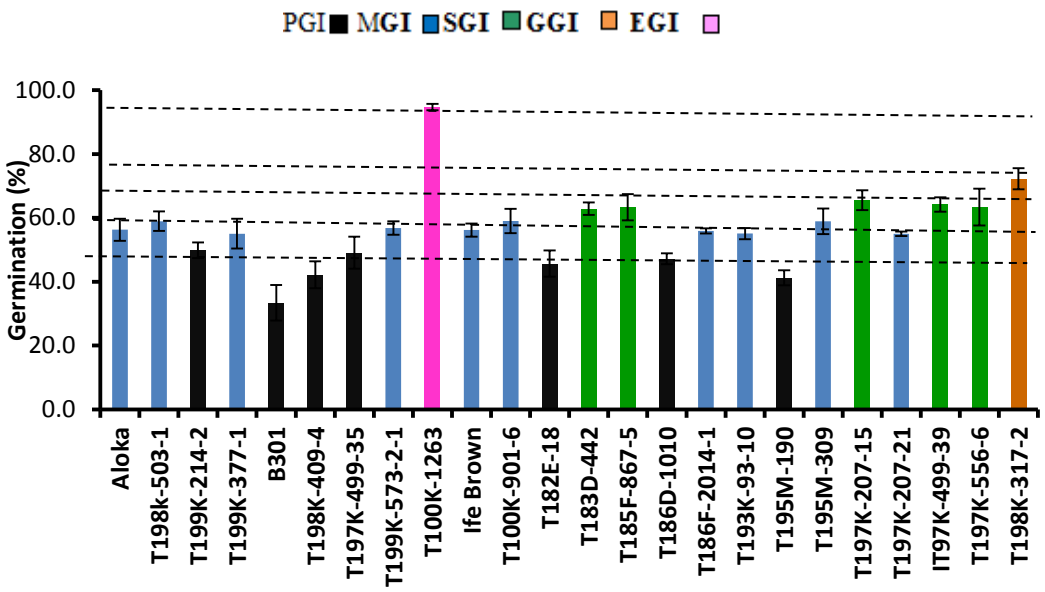

Fig.4.7 C: Germination inducing activity of cowpea genotype root powder (15 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity, EGI = excellent germination inducing activity}Vertical bars indicate standard error (SE±).

Of all the genotypes studied and across the root powder levels B301 showed the lowest germination inducing activity (46.8 % germination), while IFEbrown, T100K-901-6,T97K-499-39,T198K-317-2 and T100K-1263 showed the highest (70.8-94.8%germination) (Appendix 8).

4.1.1.2.1. 2. Radicle extension

Radicle extension of germilings of *S. hermonthica*, millet strain, from seeds induced to germinate by cowpea root powder, irrespective of genotype, decreased with amount of powder used (Fig. 4.8. A- C, Appendix9). At 5 mg, powder from 5 genotypes effected short radicle extension (7.8-9.9×10^{-2} mm), 14 samples induced medium radicle extension (10.0-14.7×10^{-2} mm), while 5 sustained long radicle extension (15.2-17.6×10^{-2} mm) (Fig. 4.8. A, Appendix 9).

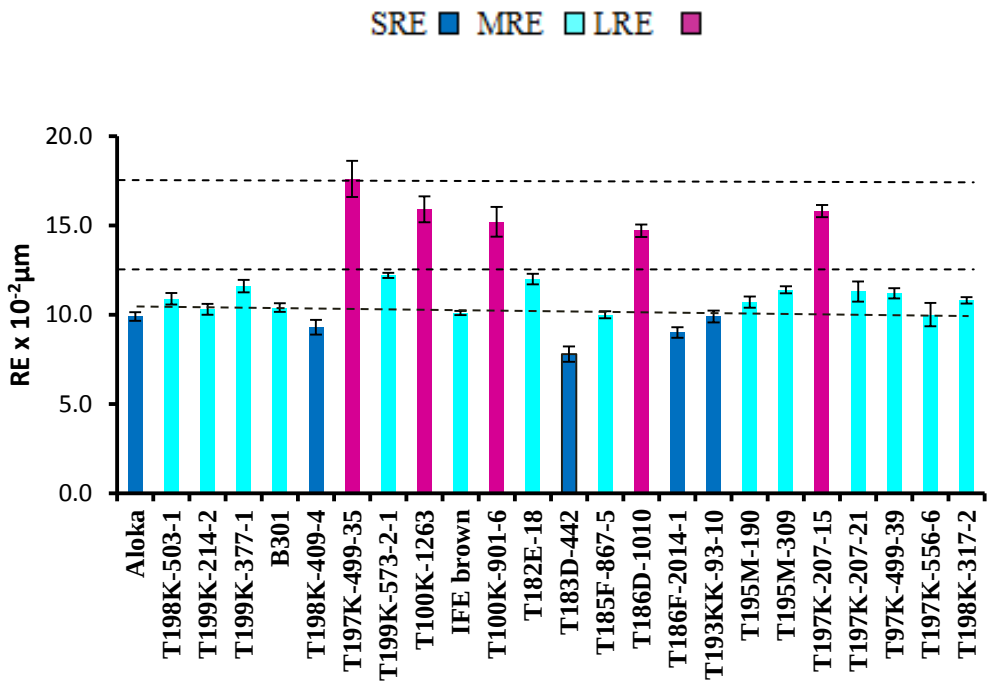

Fig.4.8 A: Effects of cowpea root powder (5 mg) on radicle extension *S. hemonthica*. {SRE = short radicle extension. MRE = medium radicle extension, LRE = long radicle extension} Vertical bars indicate standard error (SE±).

At 10 mg 18 powder samples effected short radicle extension (5.4-9.9×10^{-2} mm), (Fig. 4.8. B, Appendix9), while 6 samples induced medium radicle extension (10.0-13.0×10^{-2} mm).

At 15 mg one sample effected very short radicle extension (3.9×10^{-2} mm), 21 samples effected short radicle extension (5.3-9.5×10^{-2} mm), (Fig. 4.8. C, Appendix 9), while 2 samples sustained moderate radicle extension (10.6 and 11.6×10^{-2} mm).

Across genotype and powder amount, 17 samples sustained germilings with short radicle extension (5.7-9.6×10^{-2} mm) and 7 allowed for medium radicle extension. Of all genotype tested powder samples from T183D-442, T186F-2014-1, T198K-409-4, B301 and T199K-214-2 resulted in the shortest radicle extension (5.7-8.3 ×10^{-2} mm), and T182E-18, T197K-499-35,

T100K-901-6, T197K-207-15 and T100K-1263 sustained the longest radicles extension (10.8-13.5 $\times 10^{-2}$ mm). (Appendix 9).

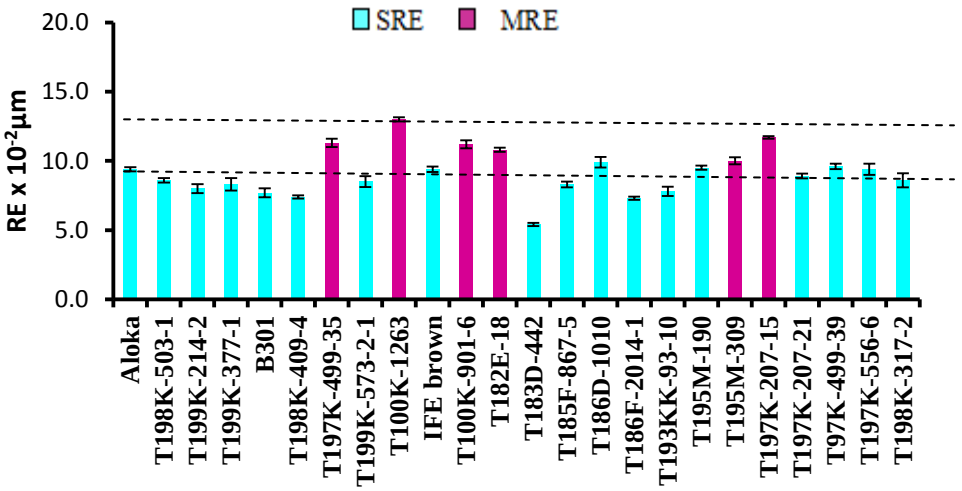

Fig.4.8 B: Effects of cowpea root powder (10 mg) on radicle extension *S. hermonthica.* {SRE = short radicle extension. MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

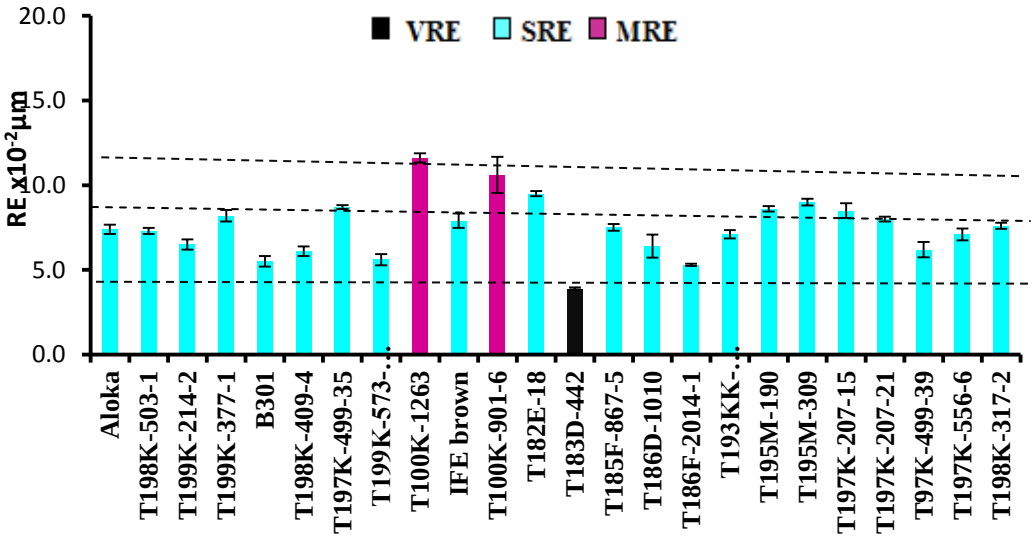

Fig.4.8 C: Effects of cowpea root powder (15 mg) on radicle extension *S. hermonthica*. {VRE = very short radicle extension, SRE = short radicle extension. MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

4.1.1.2.2. Stems powder

4.1.1.2.2.1. Germination

A general feature of the germination inducing activity of powder from cowpea stems on *S. hermonthica*, millet strain, was an increase on raising powder level from 5 to 10 mg per well and a subsequent decline on a further rise in amount of powder to 15 mg. (Fig. 4.9. A-C Appendix 10). GR24 at 0.1 ppm induced 55-68.1% germination. At 5 mg stem powder poor (27.5-45.7% germination) and moderate (52.1- 58.4% germination) germination inducing activity were dispayed, each by 7 samples (Fig. 4.9. A. Appendix 10).

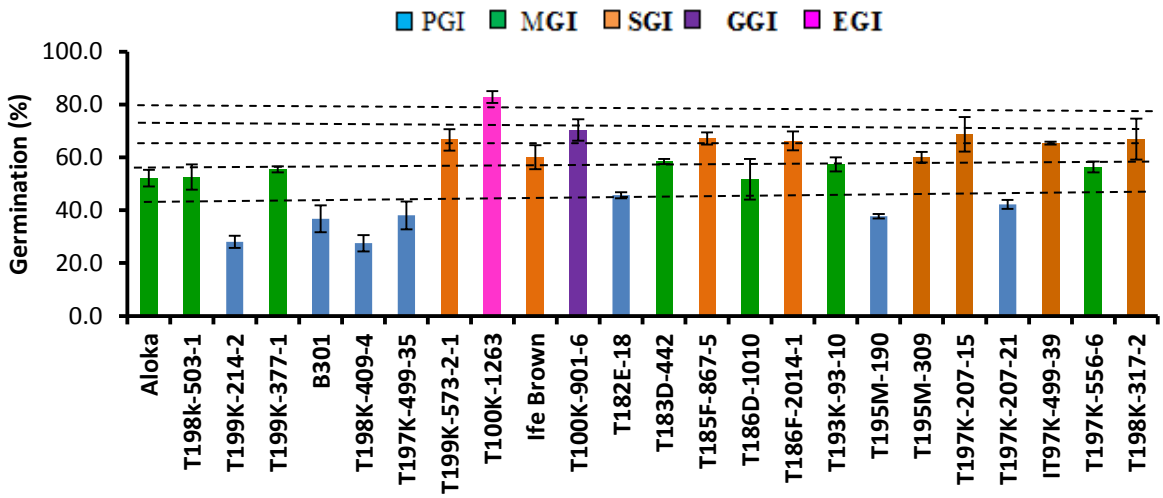

Fig.4.9 A: Germination inducing activity of cowpea genotype stems powder (5 mg). {PGI = poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity = GGI = good germination inducing activity EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±)

Powder from 8 genotypes showed satisfactory activity (60.1-68.7%) and only one each, of the powder samples exhibited good (70.3%) and excellent (82.8%) germination inducing activity.

Increasing powder level to 10 mg per well increased germination inducing activity as only one of the powder samples showed poor activity (47.8%) (Fig. 4.9.B. Appendix 10). Seven samples showed moderate activity (50.4-58.9%). Powder from 6 genotypes showed satisfactory activity (60.3-69.4%), while 9 samples showed good activity (70.2-79.8%) and only one sample showed excellent germination inducing activity (89.3%).

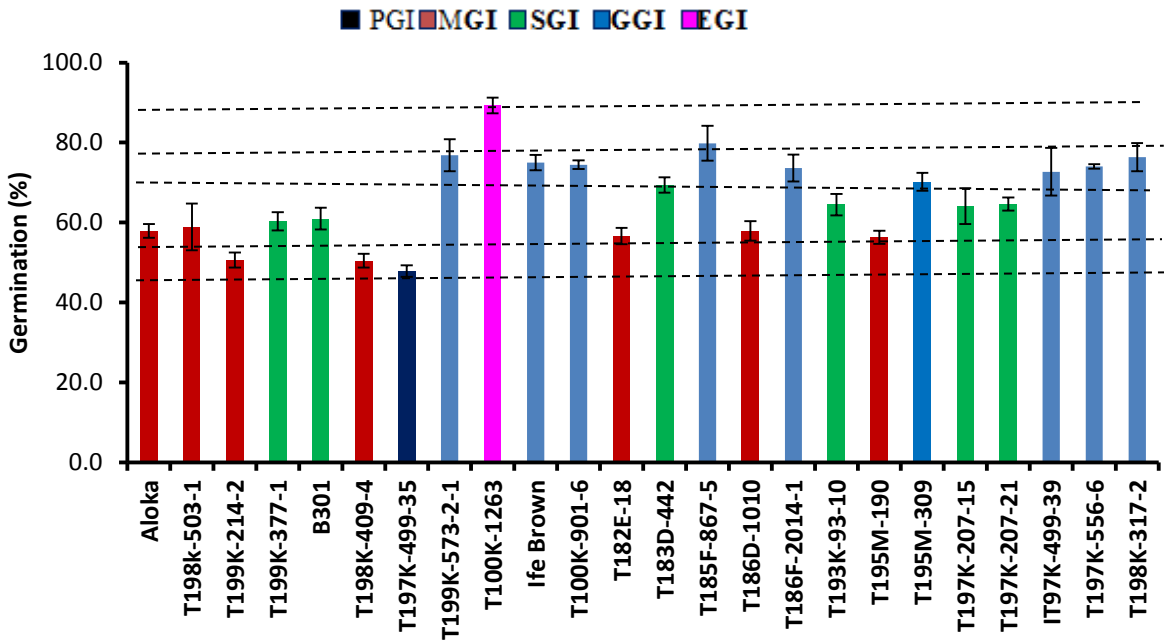

Fig.4.9 B: Germination inducing activity of cowpea genotypestem powder (10 mg). {PGI = Poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±)

Increasing powder to 15 mg repressed germination inducing activity of all samples (Fig. 4.9. C. Appendix 10). Twelve samples showed poor activity (32.7-47.2% germination), 7 samples displayed moderate activity (50.8-59.3% germination), 4 demonstrated satisfactory activity (61-66.7%

germination), and only one sample, displayed excellent (92.4%) germination inducing activity.

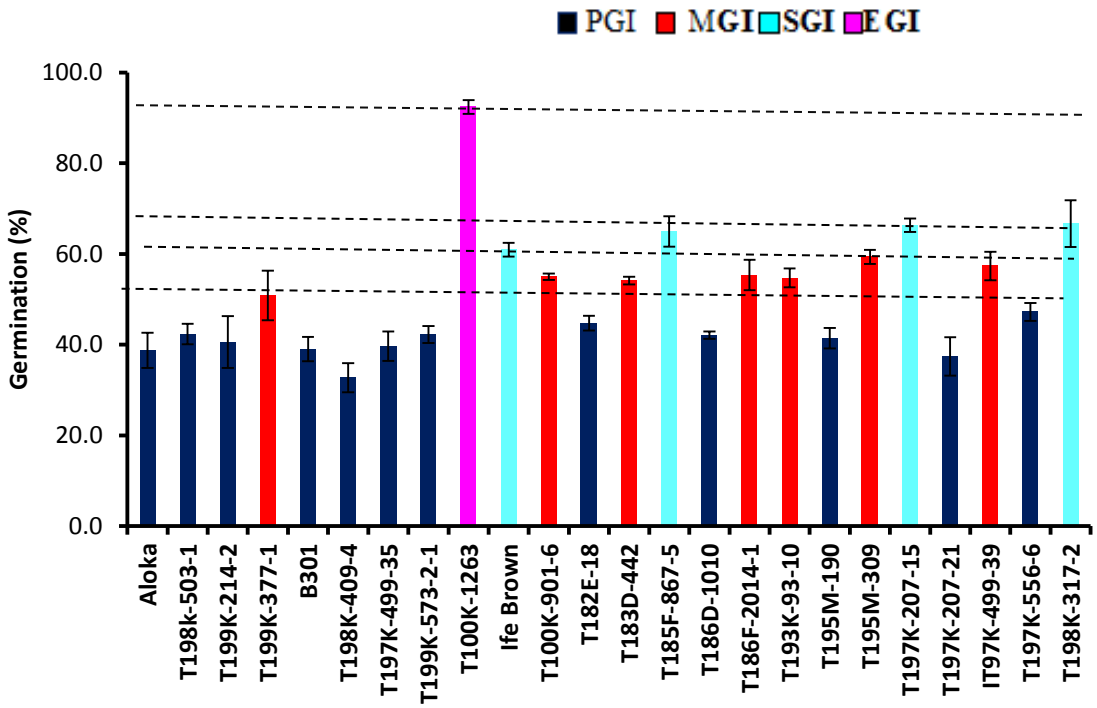

Fig.4.9 C: Germination inducing activity of cowpea genotype (stem powder 15 mg). {PGI = Poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±).

Considering the overall mean germination inducing activity across genotypes and powder levels 8 samples displayed poor activity (36.9-49.6%) 5 samples displayed moderate activity (50.6-59.2% germination), 8 samples displayed satisfactory activity (60.6-66.6% germination), 2 samples displayed good activity (70 and 70.6%germination), while excellent germination inducing activity (88.2%) was demonstrated by one sample.

Of all the genotypes studied and across the stem powder levels T198K-409-4, T199K-214-2, T197K-499-35, T195M-190and B301 showed the lowest

germination inducing activity (36.6-45.6 % germination), while T198K-317-2, T185F-867-5 and T100K-1263 showed the highest (Appendix10)

4.1.1.2.2. 2. Radicle extension

Radicle extension of *Striga* (millet strain) germilings from seeds induced to germinate by cowpea stem powder, irrespective of genotype, decreased with amount of powder used (Fig4.10. A-C, Appendix11). Germilings from seeds induced to germinate by GR24 at 0.1 ppm displayed 9.4-19.0×10^{-2} mm radicle extension. At 5 mg samples from 23 genotypes effected short radicles (5.4-9.8×10^{-2} mm) extension, while only one sample induced medium radicle extension (10.6×10^{-2} mm) (Fig4.10. A)

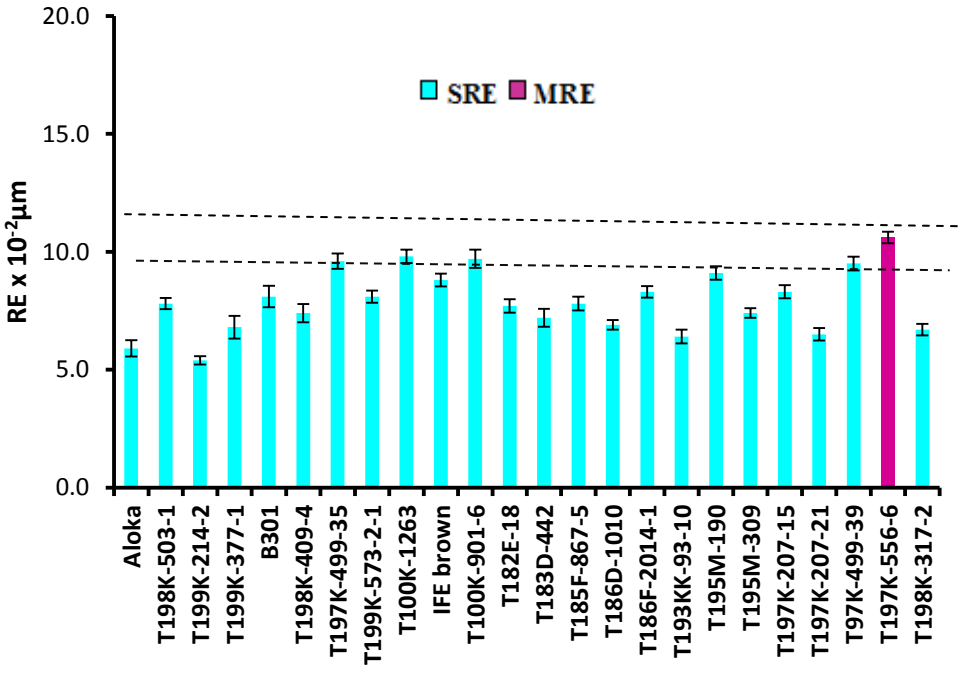

Fig.4.10 A: Effects of cowpea stem powder (5 mg) on radicle extension in *S. hermonthica*. { SRE = short radicle extension. MRE = medium radicle extension}.Vertical bars indicate standard error (SE±).

At 10 mg, 4 powder samples effected very short radicle length (4.0-4.8×10^{-2} mm), (Fig. 4.10.B. Appendix 11), while 20 samples induced short radicle extension (5.2-9.0×10^{-2} mm).

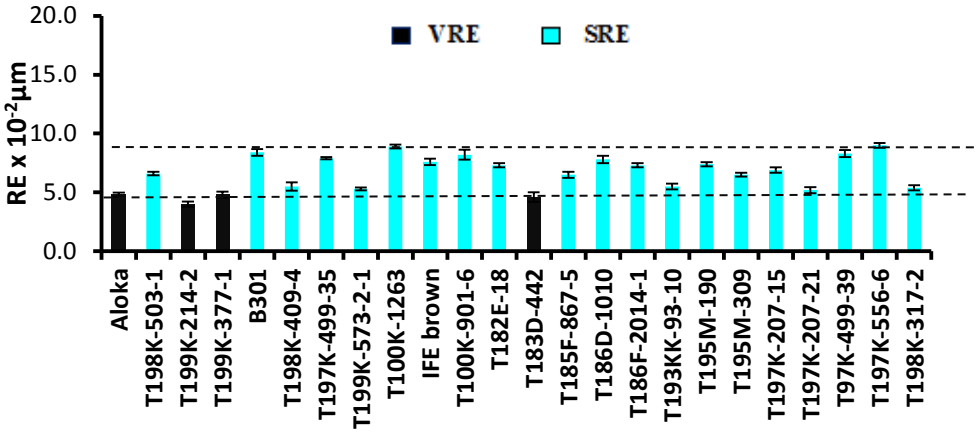

Fig.4.10 B: Effects of cowpea stem powder (10 mg) on radicle extension in *S. hermonthica*. VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

At 15 mg 10 sample effected very short radicle extension (2.9-4.8×10^{-2} mm), and 14 samples upheld short radicle extension (5.1-8.1×10^{-2}µm). (Fig. 4.10. C, Appendix 11).

Across genotypes and powder amount 3 samples supported germilings with very short radicle extension (4.5-4.9×10^{-2} mm) and 21 allowed for short radicles (5.2-9.0×10^{-2} mm) extension. Of all genotype tested powder samples from T199K-214-2, ALOKA, T183D-442, T197K-207-21 and T199K-377-1 resulted in the shortest radicle extension (4.5-5.2×10^{-2} mm), and T195M-190, T197K-499-35, T100K-901-6, T100K-1263 and T197K-556-6 sustained the longest radicles (8.0-9.×10^{-2} mm) (Appendix 11).

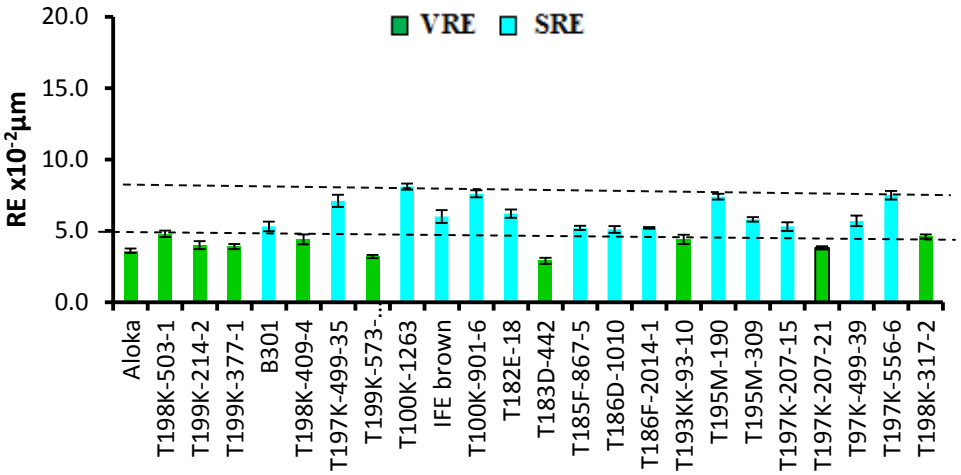

Fig.4.10 C: Effects of cowpea stem powder (15 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

4.1.1.2.3. Leaves powder

4.1.1.2.3. 1. Germination

GR24 at 0.1 ppm induced 55-68.1% germination. Leaves powder at 5 mg from 18 genotypes showed poor activity (8-48.7% germination) (Fig. 4.11.A Appendix 12). Powder from 2 genotypes displayed moderate activity (52.9 and 57.8% germination). Powder from 2 genotypes showed satisfactory activity (60.6 and 67.2%). A powder sample from one genotype exhibited good activity (72.6% germination) and one sample displayed excellent activity (86.7% germination).

Increasing powder level to 10 mg per well increased germination inducing activity of all samples as only 9 of the powder samples showed poor activity (12.5-49.0% germination) and only 8 sample showed moderate activity (50.4-59.4% germination) (Fig. 4.11. B, Appendix 12). Powders from 5 genotypes showed satisfactory activity (63.-66.4% germination), while one

sample showed good activity (70.9% germination) and only one sample showed excellent germination activity (93.4%).

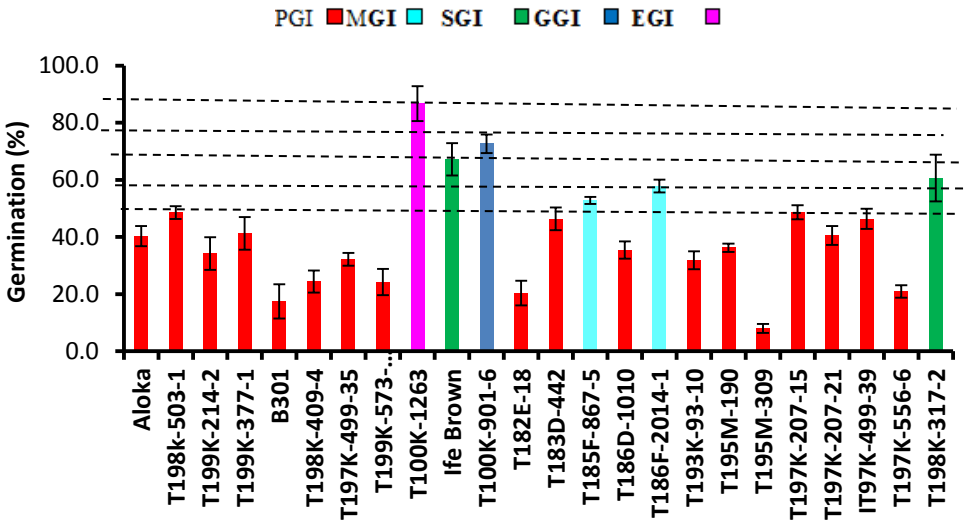

Fig.4.11 A: Germination inducing activity of cowpea genotype (leave powder 5 mg). {PGI = Poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±).

Increasing powder to 15 mg repressed germination inducing activity of all the samples. Of the tested, samples 19 showed poor activity (10.6-48.8% germination) (Fig. 4.11. C, Appendix 12), 4 displayed moderate activity (51-56.8% germination) and only one displayed excellent (84.5%) germination inducing activity.

Considering the overall mean germination inducing activity, across genotypes and powder levels, 15 powder samples displayed poor activity (15.61-45.8% germination), 6 samples displayed moderate activity (50-58% germination), 2 samples displayed satisfactory activity (60 and 66% germination).

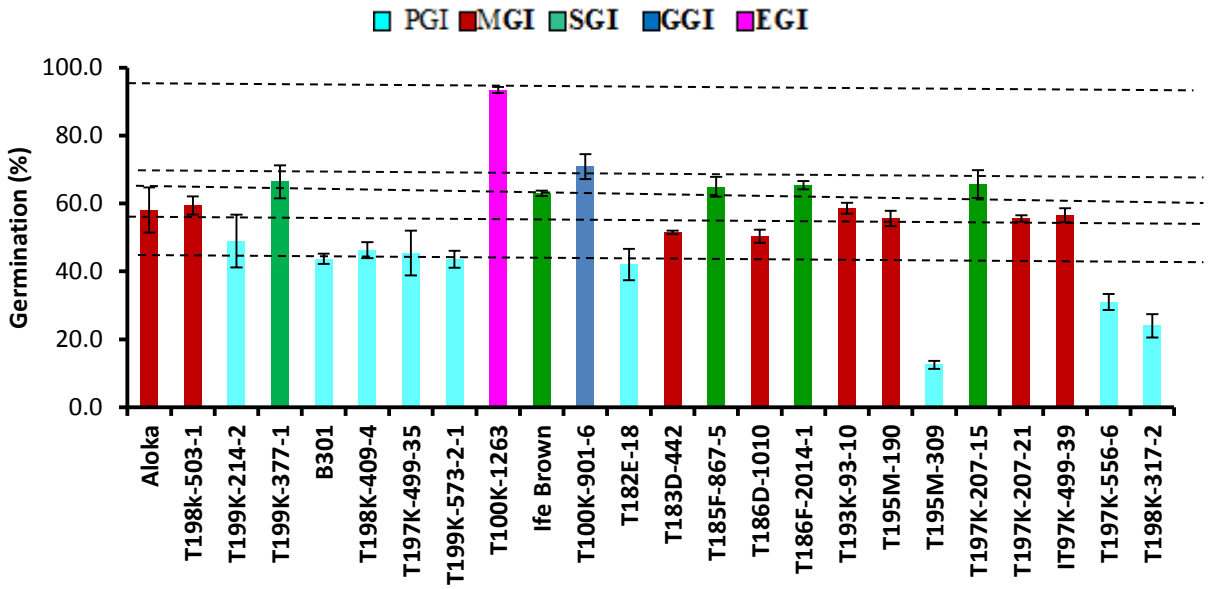

Fig.4.11 B: Germination inducing activity of cowpea genotype (leave powder 10 mg). {PGI = Poor germination inducing activity, MGI = moderate germination inducing activity, SGI = satisfactory germination inducing activity, GGI = good germination inducing activity EGI = excellent germination inducing activity}.Vertical bars indicate standard error (SE±).

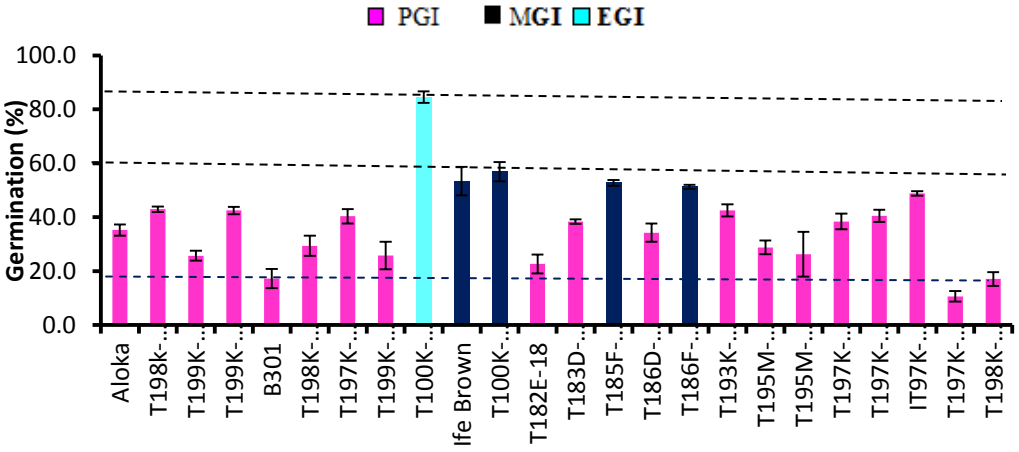

Fig.4.11 C: Germination inducing activity of cowpea genotype leave powder (15 mg). {PGI = Poor germination inducing activity, MGI = moderate germination inducing activity, EGI = excellent germination inducing activity}. Vertical bars indicate standard error (SE±).

None of the samples displayed good activity, while excellent germination inducing activity (88.2%) was demonstrated by one sample. Of all the genotypes studied and across powder levels T195M-309, T197K-556-6,

B301, T182E-18 and T199K-573-2-1 showed the lowest germination inducing activity (15.61- 31.2 %), while IFEbrown, T100K-901-6 and T100K-1263 showed the highest. (Appendex 12).

4.1.1.2.3.2. Radicle extension

Radicle extension of germilings of *S. hermonthica*, millet strain, from seeds induced to germinate by cowpea leaves powder, irrespective of genotype, decreased with the amount of powder used (Fig 4.12 and A-C. Appendix13). At 5 mg, powder from 10 genotypes affected very short radicle extension (3.0-4.8×10^{-2}µm) and 14 samples induced short radicles (5.6-9×10^{-2}µm) (Fig 4.12. A and Appendix 13).

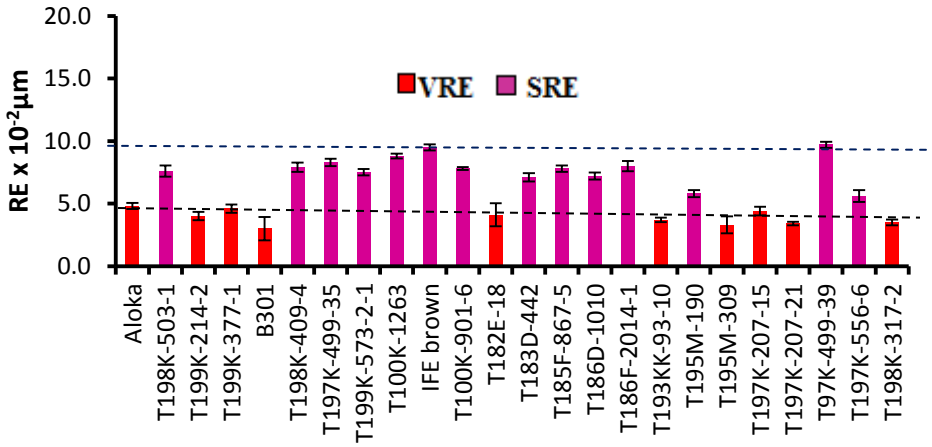

Fig.4.12 A: Effecst of cowpea leave powder (5 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

At 10 mg 12 powder samples affected very short radicles (2.3-3.7×10^{-2} mm), while 12 samples induced short radicles (5.0-8.1×10^{-2}µm) (Fig. 4.11. B, Appendix 13).

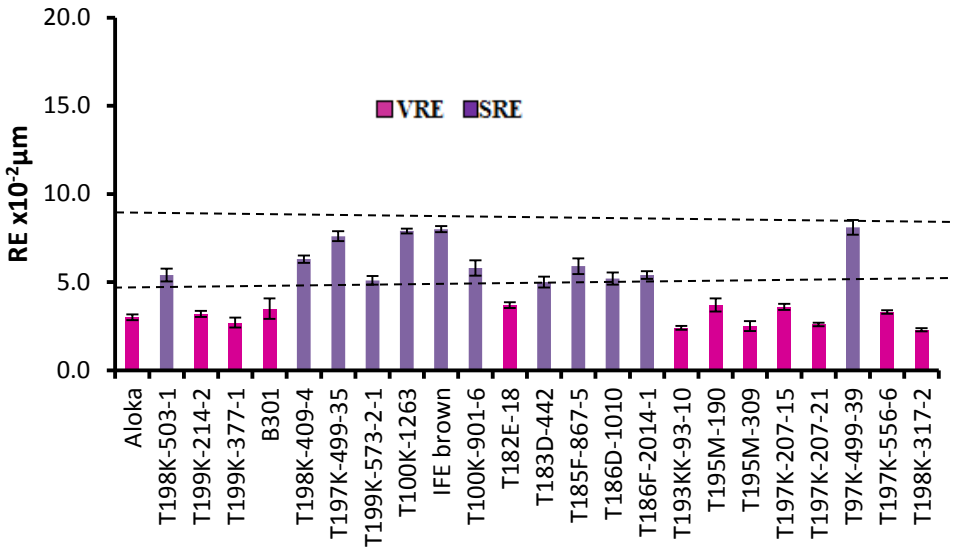

Fig.4.12 B: Effects of cowpea leave powder (10 mg) on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±)

At 15 mg 21 samples resulted in very short radicles (1.5-4.6×10^{-2} mm) and 3 samples upheld short radicles (5.8-6.4×10^{-2} mm) (Fig. 4.11. C, Appendix 13).

Across genotypes and powder amount 12 samples resulted in germlings displaying very short radicle extension (2.4-3.8×10^{-2} mm) and 12 supported germilings with short radicle length (5.1-7.9×10^{-2} mm). Of all genotype tested powder sample from T1995M-309, T198K-317-2, T193K-93-10, T197K-207-21 and B301 resulted in the shortest radicles (2.4-2.9, 10^{-2} × mm), while T198K-409-4, T197K-499-35, T100K-1263, IFE Brown and IT97K-499-39 sustained the longest radicles (6.3-7.9×10^{-2} mm) (Appendix 13).

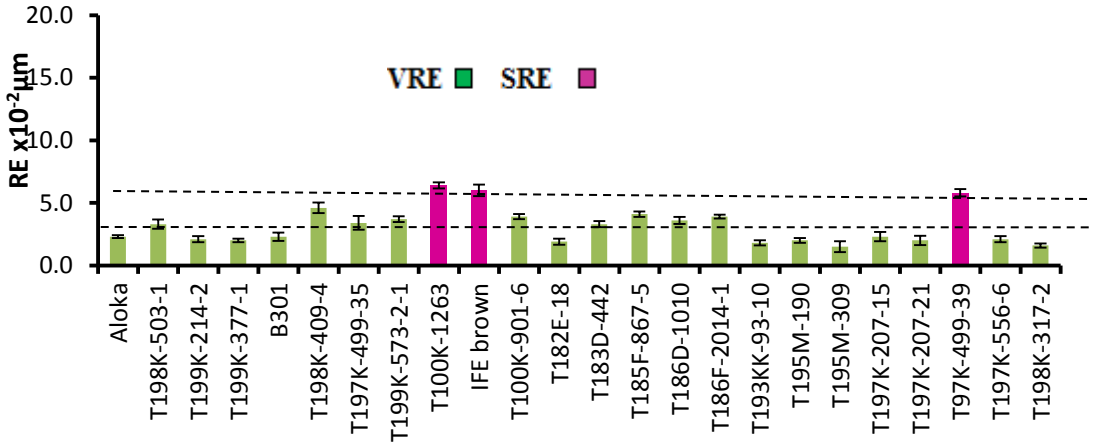

Fig.4.12 C: Effectsof cowpea leave powder(15 mg)on radicle extension in *S. hermonthica.* {VRE = very short radicle extension SRE = short radicle extension}.Vertical bars indicate standard error (SE±).

4.1.2. Effects of cowpea root exudates on germination and radicle extension of *S. hermonthica* as influenced by time and genotype.

4.1.2.1. *Striga* sorghum strain

4.1.2.1.1. Germination

Generally *Striga* germination inducing activity, irrespective of genotype, increased with time and decreased with concentration (Table 4.1a-c). At 5µl root exudates from cowpea B301 induced negligible to little germination (0.0-1.7%) up to 72 h after initiation of the experiment (AIOE) (Table 4.1 a). Root exudates collected 96 and 120 h induced 10.4 and 15.2% germination, respectively. Root exudates collected 144 h AIOE displayed significant increase in activity (41.5% germination). At 168 h a non-significant increase in germination inducing activity was displayed. Samples taken at 216 h and 240 h AIOE showed, significantly higher germination inducing activity.

Table 4.1. Effects of cowpea root exudates on *S. hermonthica* germination as influenced by time and genotype (Sorghum strain).

	Germination% **Exudate volume(µL of original)**			
Time(h)	5	**10**	20	**Mean**
a-cow B301				
24	0.0 (±0.0) e	0.0 (±0.0) d	0.0 (±0.0) f	**0.0 e**
48	0.7 (±0.7) e	0.0 (±0.0) d	0.8 (±0.8) f	**0.5 e**
72	1.7 (±0.8) e	1.8 (±0.8) d	0.8 (±0.8) f	**1.4 e**
96	10.4 (±2.0) d	9.1 (±1.8) c	6.4 (±1.2) e	**8.6 d**
120	15.2 (±2.9) d	14.2 (±1.9) c	12.5 (±0.8) d	**14.0 c**
144	41.5 (±2.8) c	30.9 (±3.2) b	28.9 (±2.8) c	**33.8 b**
168	43.0 (±5.0) bc	40.3 (±3.6) a	41.0 (±1.2) a	**41.5 a**
192	49.3 (±1.6) ab	41.7 (±3.0) a	33.9 (±1.0) b	**41.6 a**
216	54.0 (±1.3) a	45.1 (±1.2) a	35.8 (±1.0) b	**45.0 a**
240	51.2 (±2.2) a	39.9 (±1.5) a	32.9 (±4.0) bc	**41.3 a**
Mean	**26.7 a**	**22.3 a**	**19.3 a**	
b- cowpea T100K-901-6				
24	0.0 (±0.0) e	0.0 (±0.0) d	0.0 (±0.0) d	**0 e**
48	0.0 (±0.0) e	0.0 (±0.0) d	0.0 (±0.0) d	**0 e**
72	2.1 (±0.9) e	4.1 (±1.2) d	5.3 (±1.5) cd	**3.8 d**
96	2.3 (±1.0) e	5.3 (±2.5) d	4.0 (±2.2) cd	**3.8 d**
120	9.6 (±2.1) d	6.0 (±1.2) d	4.5 (±1.2) cd	**6.7 d**
144	27.1 (±2.6) c	18.5 (±3.5) c	7.9 (±1.5) c	**17.9 c**
168	41.0 (±2.0) b	31.9 (±2.5) b	21.0 (±2.6) b	**31.5 b**
192	49.5 (±2.7)a	39.9 (±1.0) a	33.8 (±3.5) a	**41.1 a**
216	52.1 (±1.5) a	43.0 (±1.5) a	30.5 (±4.9) a	**41.9 a**
240	48.6 (±1.2) a	44.8 (±3.7) a	31.4 (±1.5) a	**41.6 a**
Mean	**23.3 a**	**19.3 ab**	**13.9 b**	
c- cowpea T198K-317-2				
24	0.0 (±0.0) f	0.0 (±0.0) d	0.0 (±0.0) e	**0 g**
48	1.3 (±1.3) f	0.0 (±0.0) d	0.0 (±0.0) e	**0.4 g**
72	1.7 (±1.1) f	2.9 (±1.4) d	3.9 (±2.1) de	**2.8 g**
96	10.8 (±0.8) e	6.2 (±1.5) d	4.7 (±1.1) de	**7.3 f**
120	12.8 (±1.7) e	13.5 (±4.6) c	7.7 (±1.8) d	**11.3 e**
144	25.1 (±1.8) d	18.1 (±2.3) c	15.7 (±1.9) c	**19.6 d**
168	33.0 (±4.2) c	27.7 (±4.5) b	22.0 (±4.0) c	**27.6 c**
192	37.8 (±1.9) c	36.7 (±3.0) a	33.2 (±3.4) ab	**35.9 b**
216	55.7 (±1.9) a	42.3 (±1.3) a	37.8 (±3.3) a	**45.3 a**
240	49.5 (±1.0) b	40.3 (±1.4) a	28.5 (±1.0) b	**39.4 b**
Mean	**22.8 a**	**18.8 ab**	**15.4 b**	**19.0**

At 10µl negligible (0.0%) to little (14.2%) germination was displayed up to 120 h after initiation of the experiment. A further increase of sampling period to 144 h increased germination inducing activity significantly. Root exudates collected at 168 h AIOE or more showed a further significant increase in germination. Increasing exudates volume to 20µl showed a progressive increase in germination inducing activity reaching apeak (41%germination) at 168 h and subsequently declined and was 31.4% on extension of the sampling period to 240 h. Across time the lowest exudates concentration (5µl) exhibited the highest germination, albeit not significantly (Table 4.1. a).

Cowpea T100K-901-6 root exudates showed similar trends in germination inducing activity (Table 4.1. b). At 5µl Samples made 24 and 48 h AIOE induced no germination. Samples made 72-120h showed negligible to little (2.1-9.6% germination) activity. At 120h germination at 5µl decreased to 6 and 4.5% on raising the exudates volume to 10 and 20µl, respectively. Asample made 144 h AIOE showed significantly higher germination inducing activity. Exudate at 5, 10 and 20µl induced 27.1, 18.5 and 7.9 germination, respectively. Increasing sampling time to 168 h AIOE resulted in significant increase in germination inducing activity. A further increase in sampling time to 192 h AIOE or more resulted in a further significance increase in germination inducing activity. Across time the lowest exudates volume (5µl) displayed significantly higher germination than the highest volume (20µl)

Root exudates from cowpea T198K-317-2 showed similar patterns of germination inducing activity (Table 4.1 c). The germination inducing activity across concentrations was negligible (0%) to low (10.8%) up to 96 h

AIOE. Samples made 120 h AIOE showed, significantly, higher activity at 5 and 10 µl, but not at 20µl. However, samples made 144 h AIOE showed significantly higher activity, irrespective of exudatesvolume. Increasing sampling time to 168 h AIOE significantly increased the germination inducing activity at the lowest (5µl) and middle concentration (10µl), but not at the highest concentrations (20µl). Increasing the sampling time to 192 and 216 h AIOE increased the germination inducing activity considerably at 5µl and significantly at 10 and 20µl exudates volume. However, a further increase in sampling time to 240 h resulted, in a drop in germination significant at the lowest and highest exudates volume (5µl) but not the middle concentration. Across time germination was invariably higher at the lowest concentration (5µl).

4.1.2.1.2. Radicle extension

In general radicle extension in *Striga* germilings induced to germinate by cowpea root exudates progressively increased with time and decreased with concentration (Table 4.2 a-c). Germilings from seeds induced to germinate by GR24 at 0.1 ppm displayed 9.2-14.3×10^{-2}µm radicle extension. Cowpea root exudates collected 24 and 48h AIOE, irrespective of genotype or concentration, elicited little germination and very short germilings radicle extension was displayed.

Germilings induced to germinate with root exudates from cowpea B301 collected 72 h AIOE displayed negligible radicle extension (5.1-6.9×10^{-2}µm) (Table 4.2 a). Extending time of collection to 96 h resulted in a significant increase in radicle extension. Increasing collection time to 120 and 144 h increased radicle extension considerably, albeit not significantly.

Table 4.2. Effects of cowpea root exudates on *S. hermonthica* radicle extension as influenced by time and genotype (*Striga* sorghum strain)

	Radicle extension ($\times\mu m10^{-2}$) Exudate volume (µL)			
Time(h)	**5**	**10**	**20**	**Mean**
a-cowpeB301				
24	0.0 (±0.0) f	0.0 (±0.0) e	0.0 (±0.0) e	**0 g**
48	0.1 (±0.1) f	0.0 (±0.0) e	0.0 (±0.0) e	**0.03 fg**
72	0.4 (±0.2) f	0.1 (±0.1) e	0.5 (±0.2) e	**0.3 f**
96	6.9 (±0.2) c	6.9 (±0.2) d	5.1 (±0.1) d	**6.3 e**
120	7.1 (±0.1) d	6.6 (±0.2) d	5.5 (±0.3) d	**6.6 d**
144	8.9 (±0.5) c	6.4 (±0.2) d	5.3 (±0.2) d	**6.9 d**
168	9.9 (±0.3) b	7.7 (±0.2) c	6.7 (±0.2) c	**8.1 c**
192	10.1 (±0.2) b	8.6 (±0.1) b	7.3 (±0.2) b	**8.7 b**
216	10.8 (±0.2) a	8.7 (±0.2) b	7.3 (±0.2) ab	**8.9 b**
240	11.3 (±0.2) a	9.7 (±0.1) a	7.8 (±0.3) a	**9.6 a**
Mean	**6.6 a**	**5.5 ab**	**4.6 b**	
b- cowpeaT100K-901-6				
24	0.0 (±0.0) e	0.0 (±0.0) g	0.0 (±0.0) f	**0 h**
48	0.0 (±0.0) e	0.2 (±0.2) fg	0.0 (±0.0) f	**0.1 h**
72	0.7 (±0.2) e	0.7 (±0.3) f	1.1 (±0.3) e	**0.8 g**
96	2.4 (±0.6) d	3.7 (±0.1) e	3.9 (±0.3) d	**3.4 f**
120	7.3 (±0.5) c	5.0 (±0.2) d	4.2 (±0.2) d	**5.5 e**
144	7.8 (±0.4) c	5.9 (±0.2) c	4.4 (±0.2) cd	**6.1 d**
168	9.8 (±0.3) ab	7.8 (±0.2) ab	6.1 (±0.2) a	**7.9 ab**
192	9.8 (±0.2) ab	7.8 (±0.3) ab	5.4 (±0.2) b	**7.6 bc**
216	10.5 (±0.2) a	8.1 (±0.2) a	6.4 (±0.2) a	**8.3 a**
240	9.4 (±0.1) b	7.4 (±0.2) b	4.9 (±0.2) bc	**7.2 c**
Mean	**5.8 a**	**4.7 ab**	**3.6 b**	
c- cowpeaT198K-317-2				
24	0.0 (±0.0) e	0.0 (±0.0) f	0.0 (±0.0) h	**0 h**
48	0.0 (±0.0) e	0.0 (±0.0) f	0.3 (±0.3) gh	**0.1 h**
72	0.2 (±0.1) e	0.7 (±0.4) f	1.0 (±0.5) g	**0.6 g**
96	2.6 (±0.6) d	2.9 (±0.4) e	1.8 (±0.4) f	**2.5 f**
120	7.2 (±0.1) c	6.0 (±0.1) d	4.5 (±0.1) e	**5.9 e**
144	8.9 (±0.2) b	6.7 (±0.2) c	5.1 (±0.2) de	**6.9 d**
168	9.1 (±0.5) b	7.6 (±0.3) b	6.1 (±0.2) bc	**7.6 c**
192	9.7 (±0.3) b	7.1 (±0.3) bc	5.4 (±0.2) cd	**7.4 c**
216	10.9 (±0.2) a	7.7 (±0.2) b	6.5 (±0.2) ab	**8.3 b**
240	11.3 (±0.3) a	9.0 (±0.2) a	7.2 (±0.1) a	**9.1 a**
Mean	**6.0 a**	**4.8 ab**	**3.8 b**	

A further increase in collection time to 168 and 192 h resulted in a significant increase in radicle extension at the lowest exudate volume (5µl), but not at the higher volumes (10 and 20µl). Exudates collectedat 216 h AIOE or more, when applied at the lowest volume (5µl) increased radicle length significantly. Increasing exudates volume to 10 and 20µl reduced radicle extension. Across time radicle length consistently decreased with increasing exudates concentration.

Germilings from seeds induced to germinate by root exudates collected from cowpea T100K-901-6 showed more or less the same trend in radical extension (Table 4.2 b). Root exudates collected 24 and 48 h AIOE induced no radicle protrusion. Samples collected 72-96h AIOE showed a progressive increase in radicle extension.

Increasing sampling time to 120-216 h resulted in significant increase in radicle extension with time and a decrease in radicle extension with increasing exudates concentration. However, a further increase in sampling time to 240h resulted in a significant decline in radicle extension.

Radicles from germilings induced to germinate by root exudates from cowpea genotype T198K-317-2 showed similar trends (Table 4.2 d). Excaudate collected 24 and 48 h AIOE induced negligible germination. In general, radicle extension of germilings induced to germinate by exudates collected 72 h AIOE or later progressively increased with time and decreased with rising concentration of the exudates. Germilings from seeds induced to germination by the lowest concentration (5µl) collected 96 h AIOE displayed low radicle extension ($2\text{-}6\times10^{-2}$µm). Exudates collected 120 h AIOE increased radicle extension significantly. A further increase of collection time to144 h AIOE increased radicle extension significantly. An,

increase in collection time to168-240 h resulted in a further significant increase in radicle extension,

4.1.2.2. *Striga* millet strain

4.1.2.2.1. Germination

Root exudates, irrespective of genotype and concentration, showed little germination inducing activity in the first 72 h AIOE. However at 96 h or more a significant increase in activity with time and concentration was displayed (Table. 4.3 a-c). At 96 h Root exudates from cowpea B301 showed little germination inducing activity at the lower volumes (5 and 10 µl). However, at 20 µl a substantial activity (35.4%germination) was displayed (Table 4.3. a). Exudate obtained at 120 h AIOE, irrespective of volume displayed substantial activity (24.7-31.9% germination). Root exudates sampled 144 h, AIOE displayed high germination inducing activity. Further extension of the collection time to 240 h increased germination, albeit not significantly. Across time germination increased with exudates volume.

Root exudates from cowpea T100K-901-6 sampled 96 h AIOE induced negligible germination (5.0%) at the lowest concentration (5 µl) (Table 4.3 b). Increasing volume of the exudates to 10 and 20 µl increased germination to 13.6 and 16.4%, respectively. Exudates sampled 120 h AIOE induced 25.6, 28.7 and 34.8% germination at the lowest, middle and highest volume[s], respectively. Samples made 144 h AIOE displayed significantly, high germination inducing activity. Germination inducing activity progressively increased with time up to 192 h AIOE and subsequently declined, at the lower exudates volumes (5 and 10) on further extension of the collection time to 240 h.

Table 4.3. Effects of cowpea root exudates on *S. hermonthica* Germination as influenced by time and genotype.

Time (h	Germination% Exudate volume (µl of original)			
	5	**10**	**20**	**Mean**
a-cowpeaB301				
24	0.0 (±0.0)d	0.0 (±0.0) e	0.0 (±0.0) d	**0.0 e**
48	0.7 (±0.7) d	0.0 (±0.0) e	0.0 (±0.0) d	**0.2 e**
72	2.8 (±1.2) d	0.9 (±0.9) e	2.7 (±1.3) d	**2.1 e**
96	16.2 (±2.2) c	15.6 (±2.5) d	35.4 (±1.9) c	**22.3 d**
120	24.7 (±3.4) b	29.2 (±1.5) c	31.9 (±1.8) c	**28.5 c**
144	41.8 (±2.2) a	52.3 (±1.5) b	53.4 (±0.9) b	**49.1 ab**
168	40.9 (±2.5) a	47.6 (±1.2) ab	54.9 (±3.5) ab	**47.7 b**
192	45.2 (±2.2) a	50.2 (±1.3) a	53.2 (±0.5) b	**49.5 ab**
216	43.8 (±1.4) a	52.7 (±0.4) a	61.4 (±6.4) a	**52.6 a**
240	44.2 (±0.7) a	52.9 (±1.1) a	56.2 (±1.7) ab	**51.1 ab**
Mean	**26.0 b**	**30.1 ab**	**34.9 a**	
b- cowpeaT100K-901-6				
24	0.0 (±0.0) d	0.0 (±0.0) f	0.0 (±0.0) e	**0 g**
48	0.0 (±0.0) d	1.7 (±1.7) f	0.0 (±0.0) e	**0.6 g**
72	2.6 (±1.3) d	4.4 (±2.1) f	7.8 (±2.7) d	**4.9 f**
96	5.0 (±1.6) d	13.6 (±0.5) e	16.4 (±3.1) c	**11.6 e**
120	25.6 (±1.9) c	28.7 (±3.4) d	34.8 (±4.4) b	**29.7 d**
144	31.1 (±3.6) bc	37.1 (±2.1) c	49.0 (±1.5) a	**39. c**
168	33.5 (±2.4) b	47.8 (±0.8) a	49.7 (±1.5) a	**43.7 b**
192	43.6 (±4.4) a	48.7 (±1.0) a	52.8 (±1.2) a	**48.4 a**
216	32.2 (±2.4) b	42.2 (±1.5) b	49.4 (±3.2) a	**41. bc**
240	30.0 (±0.6) bc	39.9 (±1.8) bc	53.1 (±1.3) a	**41. bc**
Mean	**20.4 b**	**26.4 ab**	**31.3 a**	
c- cowpea T198K-317-2				
24	0.0 (±0.0) f	0.0 (±0.0) e	0.0 (±0.0) g	**0 f**
48	0.0 (±0.0) f	0.0 (±0.0) e	1.4 (±1.4) g	**0.5 f**
72	1.4 (±0.9) f	2.3 (±1.2) e	4.1 (±1.2) g	**2.6 f**
96	9.6 (±2.5) e	11.0 (±2.7) d	12.1 (±3.1) f	**10.9 e**
120	18.0 (±3.0) d	22.1 (±4.9) c	28.5 (±4.6) e	**22.9 d**
144	31.6 (±2.5) c	49.0 (±2.9) ab	51.9 (±1.2) cd	**44.2 c**
168	41.4 (±1.5) b	44.1 (±3.0) b	45.6 (±3.0) d	**43.7 c**
192	45.4 (±2.9) b	47.5 (±2.3) ab	53.9 (±1.6) bc	**48.9 b**
216	52.0 (±1.4) a	53.6 (±4.4) a	65.0 (±2.4) a	**56.9 a**
240	51.9 (±1.6) a	53.1 (±2.1) a	59.4 (±1.5) ab	**54.8 a**
Mean	**25.1 a**	**28.3 a**	**32.2 a**	

Cowpea T198K-317-2 root exudates sampled 24-96 h elicited negligible to little germination (Table 4.3. c). A sample made at 120 h AIOE showed 18, 22.1 and 28.5% germination at the lowest (5µl) middle (10µl) and the highest (20µl) concentration, respectively. A sample made at 144 h AIOE showed relatively high germination inducing activity. Germination inducing activity, irrespective of exudates volume, was invariably the heighest for exudates collected 216 h AIOE with no further significant change with time.

4.1.2.2.2. Radicle extension.

In general radicle extension of germilings of *S. hermonthica*, millet strain, from seeds induced to germinate by cowpea root exudates, irrespective of the latter genotype, progressively increased with concentration of the exudates and time of collection (Table 4.4 a-c). In general germilings from seeds induced to germinate by exudates collected up to 72 h AIOE displayed negligible and inconsistent germination and radicle extension. Increasing collection time to 96 h AIOE resulted in significant increase in radicle extension.

Germilings from seeds induced to germinate by root exudates collected 96 h AIOE, from cowpea B301, at its lowest concentration (5µl/disc) displayed an average radicle extension of 0.7×10^{-2}µm (Table 4.4 a). Radicle extension steadily increased with exudate collection time reached peaked (5.1×10^{-2}µm) at 192 and 216 h AIOE and subsequently declined, significantly, on further increase of the collection time to 240 h. Radicle extension of germilings induced to germinate by higher concentrations of root exudates (10 and 20µl) followed more or less the same trend, a progressive increase with time, reaching a peak at 216 h followed by a significant decline on extension of collection time to 240h.

Table. 4.4. Effects of cowpea root exudates on *S. hermonthica* radicle extension as influenced by time and genotype (*Striga* millet strain).

Time (h)	Radicle extension($\times 10^{-2}$ µm)			
	Exudate volume (µL of original)			
	5	**10**	**20**	**Mean**
a-cowpeaB301				
24	0.0 (±0.0) e	0.0 (±0.0) g	0.0 (±0.0) g	**0.0 G**
48	0.1 (±0.1) e	0.0 (±0.0) g	0.0 (±0.0) g	**0.0 F**
72	0.3 (±0.1) e	0.3 (±0.1) g	0.1 (±0.1) g	**0.2 e**
96	1.7 (±0.3) d	1.6 (±0.3) g f	0.7 (±0.2) f	**1.3 d**
120	2.8 (±0.2) c	4.4 (±0.2) d	5.3 (±0.1) e	**4.2 c**
144	2.7 (±0.2) c	3.8 (±0.1) e	5.3 (±0.1) e	**4.0 c**
168	3.8 (±0.2) b	5.1 (±0.1) c	6.0 (±0.2) d	**5.0 b**
192	5.1 (±0.2) a	6.6 (±0.1) a	7.4 (±0.2) c	**6.4 a**
216	5.1 (±0.2) a	6.8 (±0.1) a	8.6 (±0.2) a	**6.8 a**
240	4.2 (±0.4) b	5.8 (±0.1) b	7.9 (±0.3) b	**6.0 a**
Mean	**2.6 b**	**3.5 ab**	**4.1 a**	
b-cowpeaT100K-901-6				
24	0.0 (±0.0) f	0.0 (±0.0) e	0.0 (±0.0) f	**0.0 f**
48	0.0 (±0.0) f	0.0 (±0.0) e	0.0 (±0.0) f	**0.0 f**
72	0.4 (±0.2) ef	0.8 (±0.3) d	0.8 (±0.3) e	**0.7 e**
96	0.7 (±0.4) e	0.8 (±0.4) d	0.9 (±0.3) de	**0.8 e**
120	2.5 (±0.4) d	2.7 (±0.5) c	1.5 (±0.4) d	**2.2 d**
144	3.3 (±0.1) c	5.0 (±0.2) b	5.7 (±0.2) c	**4.7 c**
168	3.5 (±0.1) c	4.4 (±0.3) b	6.0 (±0.1) c	**4.6 c**
192	4.6 (±0.3) ab	5.9 (±0.2) a	7.3 (±0.1) ab	**5.9 b**
216	4.5 (±0.2) b	5.9 (±0.2) a	7.2 (±0.2) b	**5.8 b**
240	5.2 (±0.2) a	6.5 (±0.2) a	7.9 (±0.2) a	**6.5 a**
	2.5 b	**3.2 ab**	**3.8 a**	
c-cowpeaT198K-317-2				
24	0.0 (±0.0) g	0.0 (±0.0) g	0.0 (±0.0) e	**0.0 h**
48	0.1 (±0.1) g	0.0 (±0.0) g	0.0 (±0.0) e	**0.0gh**
72	0.2 (±0.1) g	0.5 (±0.2) g	0.7 (±0.4) e	**0.5 g**
96	2.2 (±0.2) f	2.0 (±0.4) f	2.6 (±0.5) d	**2.3 f**
120	2.8 (±0.1) e	2.6 (±0.2) e	2.9 (±0.6) d	**2.8 e**
144	3.1 (±0.2) e	4.0 (±0.2) d	4.8 (±0.2) c	**4.0 d**
168	3.6 (±0.1) d	4.5 (±0.1) cd	5.7 (±0.2) b	**4.6 c**
192	4.1 (±0.2) c	4.7 (±0.2) c	5.6 (±0.1) bc	**4.8 c**
216	5.7 (±0.2) a	6.5 (±0.2) a	7.9 (±0.2) a	**6.7 a**
240	5.1 (±0.1) b	5.9 (±0.2) b	7.8 (±0.2) a	**6.3 b**
Mean	**2.7 b**	**3.1 ab**	**3.8 a**	

Root exudates from cowpea T100K-901-6 collected 24 and 48 h AIOE did not induce germination (Table 4.4 b). Germilings from seeds induced to germinate by the lowest concentration (5µl) of root exudates collected 72 and 96 h AIOE displayed limited radicle extension (0.4-0.9×10-2µm). Radicle extension showed progressive increase with collection time. Furthermore, increasing concentration of the exudates to 2- and 4- fold increased radical extension.

Root exudates from cowpea genotype T1198K-317-2 induced negligible germination 24 and 48 h AIOE. Radicle length of germilings from seeds induced to germinate with root exudates collected at 72 h was 0.2×10^{-2}µm at the lowest concentration (5µl), but was 0.5×10^{-2} µm and 0.7×10^{-2} µm at 10 and 20µl, respectively. A progressive and significant increase in radicle extension, irrespective of exudates concentration, was realized on increasing the collection time to 96 h or more. Radicle extension in germilings from seeds induced to germinate by root exudates collected 96 h AIOE was 4-11-fold the corresponding radicle extension affected by exudates collected 72h AIOE. Radicle extension progressively and significantly increased with collection time, reached a maximum at 216 h and subsequently declined at 240 h.

4.1.3. Effects of pH on germination inducing activity of cowpea root exudates.

Germination inducing activity of cowpea root exudates showed differential activity with pH and was dependent on genotype and *Striga* strain (Table 4.5). Activity of root exudates from cowpea B301 at 5µl on *S. hermonthica* sorghum strain, was low (17.1-25.4%) and no significant differences in activity were observed between pH levels (Table 4.5). At pH 10 exudates

volume at 10 and 15 µl showed significantly higher activity (21.4 and 14.2%) in comparison to lower pH levels (4 and 7). Across the volumes used GIA, invariably, decreased with exudates volume. For the millet strain, the GIA was, invariably, higher than that for the *Striga* sorghum strain. At the lowest exudates volume (5 µl) the GIA was significantly the highest (35%) at pH 10. Increasing exudates volume to 10 and 15 µl increased GIA, however, differences between pH levels were not significant.

Table 4.5. Effects of pH on germination inducing activity of cowpea root exudates.

	Germination (%)							
	***Striga* strain**							
a-CowpeaB 301	Sorghum				Millet			
	Exudates volume (µl)							
	5	10	15	mean	5	10	15	Mean
4	24.7 a	16.7 b	13.3 b	**18.3 a**	32.1 c	41.1 b	53.3 a	**42.2 a**
7	25.4 a	17.8 b	12.0 c	**18.4 a**	34.0 c	41.9 b	51.1 a	**42.4 a**
10	17.1 a	21.4 a	14.2 a	**17.6 a**	35.0 b	38.2 b	54.1 a	**42.5 a**
mean	**22.4 a**	**18.7 a**	**13.2 b**		**33.8 c**	**40.4 b**	**52.0 a**	
b)T100K-901-6								
4	31.7 a	21.1 b	19.3 b	**24.1 b**	35.2 c	42.3 b	48.2 a	**42.0 b**
7	35.8 a	30.9 b	25.7 c	**30.8a**	42.3 b	52.2 a	54.3 a	**49.6 a**
10	25.5 a	24.2 a	23.7 a	**24.5 b**	36.2 b	40.9b	51.1 a	**42.8 b**
mean	**31.1 a**	**25.5 b**	**22.9 b**		**37.9 c**	**45.1 b**	**51.2 a**	

Root exudates from cowpea T100K-901-6, irrespective of *Striga* strain or volume used, displayed the highest activity at pH 7. GIA on *Striga*, sorghum strain consistently decreased with volume while on the millet strain it increased with exudates volume. The GIA of exudates, irrespective of cowpea genotype was invariably higher on the millet strain.

4.1.4. Comparative study on germination inducing activity of Sorghum (cv Abusabeen) and Cowpea B301, T100K-901-6.

Germination inducing activity of root exudates from sorghum cv Abusabeen collected at 23 days AIOE increased in a concentration dependent manner (Table. 4.6.). At the lowest concentration (5µl) the exudates showed minimal activity (13.3%germination). A surge in activity occurred on increasing concentration by 2-fold (10 µl). A further increase in concentration to 3-and 6 fold, the initial concentration, did not increase germination significantly. However, the maximum germination (66.2%) was attained at the highest concentration (30µl) B301.

Table. 4.6. Germination inducing activity of roots exudates from sorghum, cowpea B301 and cowpea T100K-901-6

	Germination (%) **Plant species**			
	Sorghum	**CowpeaB301**	**CowpeaT100K-901-6**	**Mean**
5	13.3 (±3.5) c	19 (±2.1) d	67.6 (±1.7) ab	**33.4 c**
10	56.4 (±5.8) ab	45.4 (±3.2) c	62.8 (±2.6) b	**55.0 b**
15	58.8 (±1.7) ab	51.2 (±2.4) bc	71.8 (±4.5) ab	**Mean**
20	54 (±3.8) b	58.8 (±3.4) ab	65.8 (±4.3) b	**59.6 b**
25	64.6 (±4.3) ab	66.6 (±3.1) a	77.6 (±3.0) a	**69.4 a**
30	66.2 (±1.8) a	67.2 (±2.9) a	67.8 (±4.1) ab	**67.0 a**
Mean	**52.2 b**	**51.4 b**	**68.9 a**	

Germination inducing activity of root exudates from cowpea genotype B301 progressively increased with increasing concentration (Table 4.6). At the lowest rate (5µl) low germination (19%) was achieved. Increasing concentration of the exudates to 2-fold (10µl) increased germination

significantly. A further increase in concentration to 3-fold increased germination, albeit not significantly. However, a significant increase in germination was attained on increasing concentration to 4-fold. Further increase in exudates concentration to 5- and 6-fold did not increase germination significantly

Root exudates from cowpea genotype T100k-901-6 displayed high germination (67.6%) at the lowest concentration (5µl). However, germination did not increase significantly on increasing exudates to 6-fold (Table 4.6).

Across species and genotype root exudate from cowpea T100K-901-6 displayed the highest germination inducing activity, whereas root exudate from sorghum and cowpea T100K-901-6 displayed comparable activity.

4.1.5 Chromatographic behavior of germination stimulants from cowpea B301 and cowpeaT100K-901-6sorghum.

Root exudates from cowpea B301 and T100K-901-6 were subjected to Thin Layer Chromatography. For comparative studies the root exudates of the two cowpea genotypes and sorghum were further analyzed by column and high performance liquid chromatography.

4.1.5.1. Thin Layer Chromatography (TLC)

On thin layer chromatography root exudates from both cowpea genotypes displayed considerable germination inducing activity (40 and 55%) at Rf 0.57 and 0.71. At Rf 0.86. Both genotypes showed low (5 and15%) germination inducing activity (Fig. 4.13).

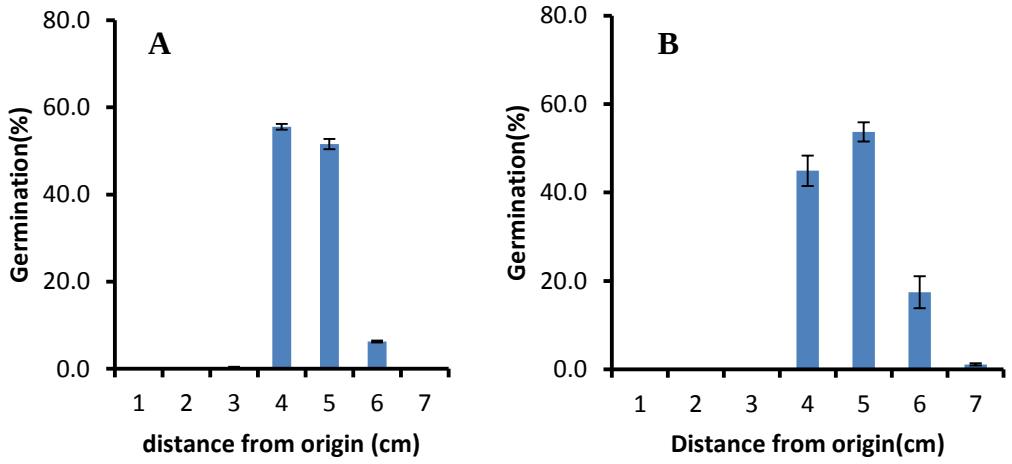

Fig. 4.13: Chromatographic behavior of root exudates from cowpea genotypes.A) B301, B) T100K-901-6.(TLC).Vertical bars indicate standard error (SE±).

4.1.5.2. Chromatographic behavior of sorghum and cowpea root exudates.

4.1.5.2.1. Column chromatography

4.1.5.2.1.1. Sorghum

Hexane eluate (H) of root exudates showed negligible germination inducing activity (4%germination) (Fig. 4.14). Germination inducing activity of the column effluent increased with increasing proportion of ethylacetate in the solvent mix. At 10% ethylacetate the eluate induced 14% germination.

Increasing the proportion of ethylactate to 30% increased germination to 54%. However, a further increase of ethylacetate concentration to 50 and 60% resulted in low activity (6 and 10% germination). The activity of the column effluent showed a surge (58% germination) on increasing ethylacetate proportion to 70% (Fig. 4.15). The activity of the column effluent progressively decreased with further increase in the ethylacetate proportion to 80% or more.

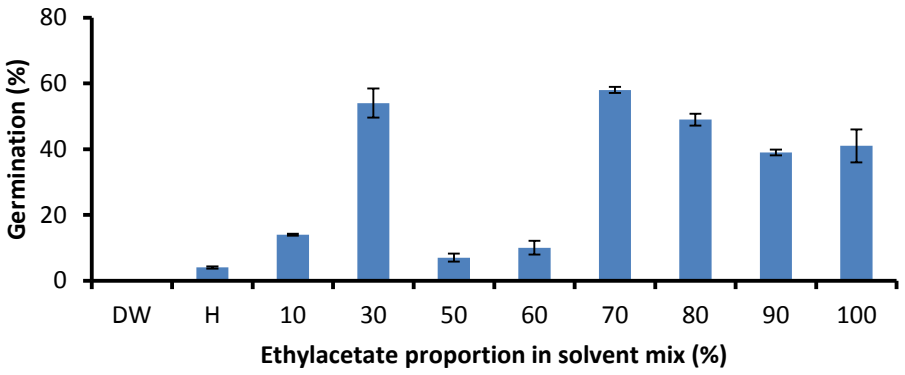

Fig.4.14. Chromatographic behavior of sorghum root exudates (Column chromatography).H = hexane. Vertical bars indicate standard error (SE±).

4.1.5.2.1.2. Cowpea B301

Hexane eluate of cowpea B301 root exudates showed no germination inducing activity (Fig. 4.15.). Elution of the column with the solvent mix showed negligible to little (6-14% germination) activity on raising the proportion of ethylacetate from 10 to 60% (Fig 4.15). However, a surge in germination inducing activity (58%) was observed on increasing the proportion of ethylacetate to 70% where germination was maximal. Germination progressively decreased on increasing the proportion of ethyl-acetate to 80% or more.

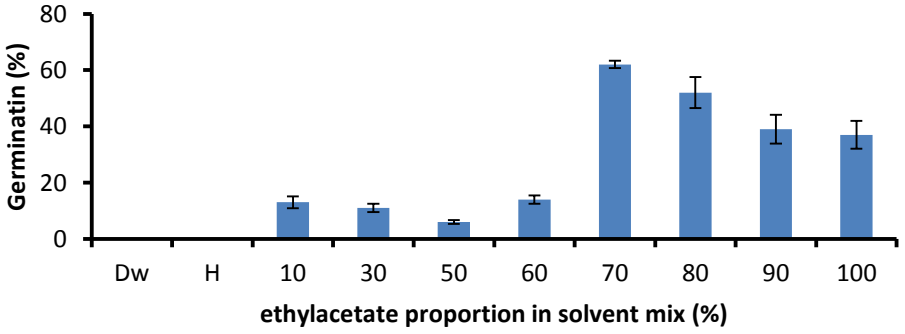

Fig.4.15. Chromatographic behavior of Cowpea genotype (B301) roots exudates (Column chromatography). H =hexane. Vertical bars indicate standard error.

4.1.5.2.1.3. Cowpea T100K-901-6

The hexane column eluate and the solvent mix up to 50% ethyacatate showed no germination inducing activity (Fig. 4.16.). However, increasing the proportion of ethylacetate to 60 % resulted in considerable germination (26%). A further increase in proportion of the ethylacetate to 70% further increased the germination inducing activity (58% germination). A further increase in proportion of ethyl acetate in the solvent mix up to 100% did not alter activity of the column effluent signifcantly.

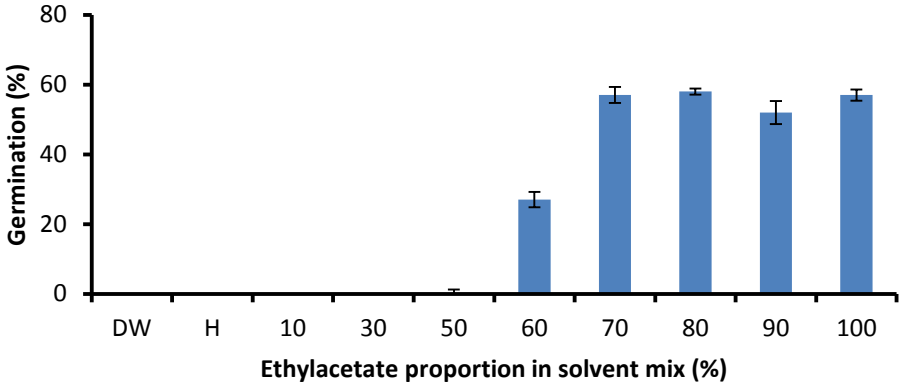

Fig. 4.16. Chromatographic behavior of Cowpea genotype (T100K-901-6) roots exudates (Column chromatography). H =hexane. Vertical bars indicate standard error (SE±)..

4.1.5.3. High Performance Liquid Chromatography

4.1.5.3.1. Sorghum

On HPLC root exudates from Sorghum showed limited germination inducing activity (10-17%) in fractions with retention time (Rt) 5-10, 10-15, and 15-20 min (Fig. 4.17)

4.1.5.3.2. Cowpea B301.

For cowpea B301 germination inducing activity was displayed by fractions of Rt 5-10, 10-15 and 20-25 min (Fig. 4.18).

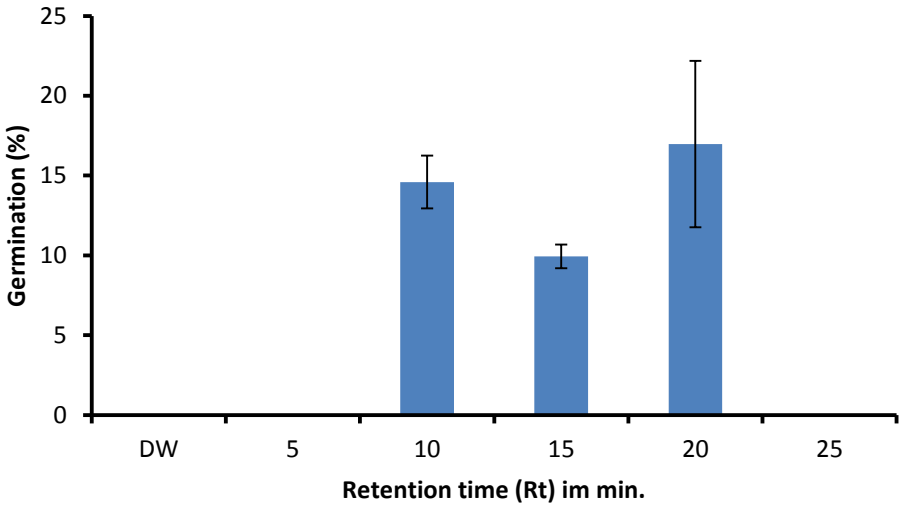

Fig. 4.17. HPLC Profile of germination inducing activity of root exudates from sorghum. (cv Abusbeen). Vertical bars represent standand error (SE±)

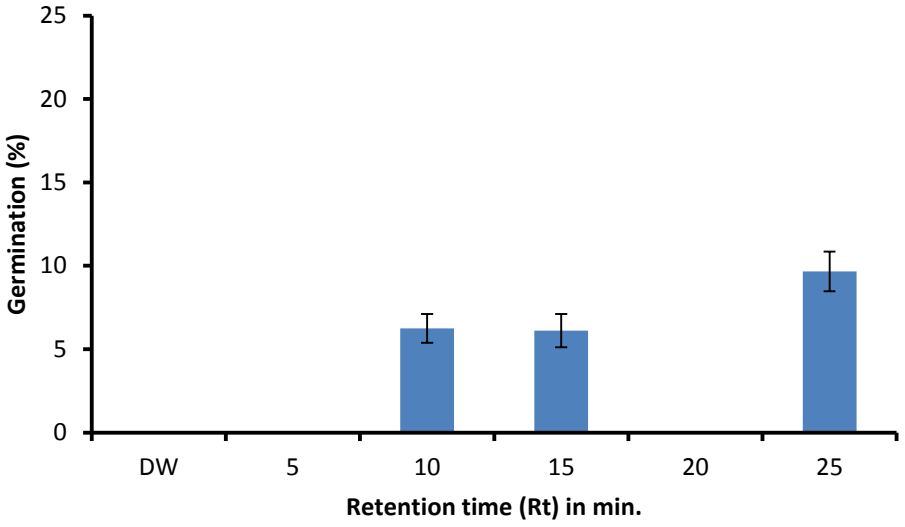

Fig. 4.18. HPLC Profile of germination inducing activity of root exudates from cowpea B301. Vertical barsrepresent standand error (SE±)

4.1.5.3.3. Cowpea T100K-901-6.

For cowpea T100K-901-6 germination inducing activity was displayed by fractions with Rt 0-5, 5-10, 10-15, 15-20 and 20-25 min (Fig.4.19).

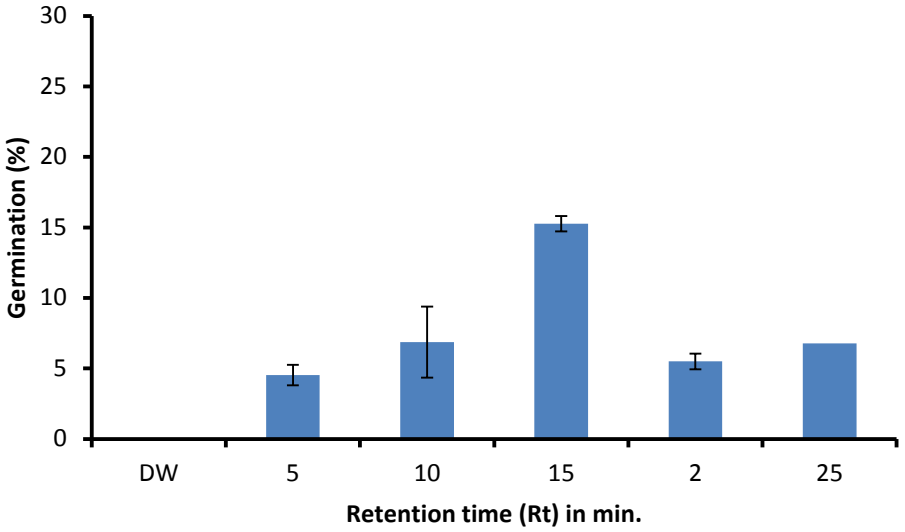

Fig. 4.19. HPLC Profile of germination inducing activity of root exudates from Cowpea T100K-901-6. Vertical barsrepresent standand error (SE±)

4.1.6. *In–situ* germination and further development of *S. hermonthica* on cowpea.

An observation made one week after inoculation with conditioned seeds showed that germination induced by cowpea roots was 76.9%. Of the resulting germilings only47.2%were attached (Table. 4.7.). GR24 treated seeds displayed 100% germination and of the resulting germilings only 52.8 were attached.

Table 4.7. *In–situ* germination and further development of *S. hermonthica* on cowpea.

	Germination (%)	Attach ment
CowpeaT100K-901-6	76.9 (±7.9)	47.2 (±3.8)
GR241PPm	100 (±3.0)	52.8 (±3.6)

The second and third observations made 2 and 3 weeks later showed no further germination or attachment. In all observations the attached germilings did not develop further and the seed coat in all germilings remained intact (Plate 4. 1).

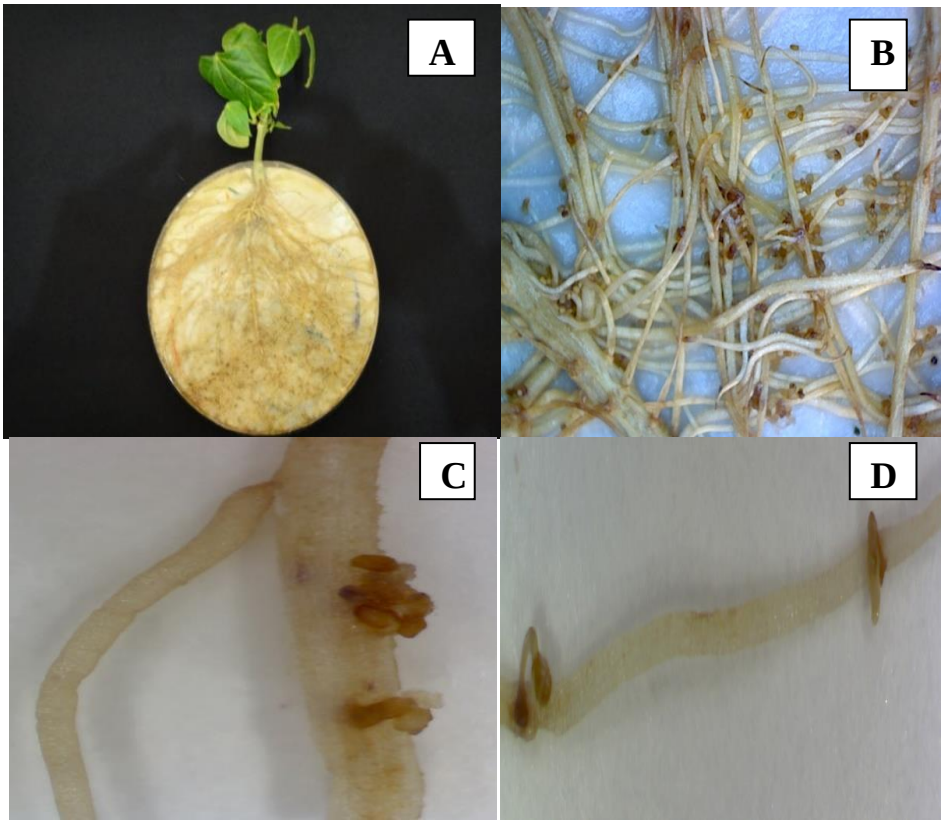

Plate 4.1. *In–situ* germination and further development of *S. hermonthica* on cowpea. A) Rhiztron unit, B) Cowpea roots with *Striga* seeds, C) Attached *Striga* germiling and D) attached dead *Striga* germilings. Arrow showed *Striga* seeds.

4.2. Greenhouse experiments:

4.2.1. Effects on *Striga*

4.2.1.1. Emergence*:*

Striga emergence, on sorghum, irrespective of intercropping, increased with time and seed bank size (Table. 4.8). At 30 DAS, average *Striga* emergence on sole sorghum at the lowest seed bank size was 3 plants per pot (Table 4.8

a). Increasing seed bank size to 2 mg per pot increased *Striga* emergence by more than 1-fold; however the observed increase was not significant. At a seed bank of 4 mg/pot *Striga* emergence showed a significant increase. Increasing *Striga* seed bank to 8 and 16 mg/pot futher increased emergence, albeit not significantly. At the highest seed bank size (32mg/pot) *Striga* emergence increased significantly (Table 4.8 a).

Table. 4.8. Effects of seedbank size and intercropping with cowpea on *Striga* infestation and sorghum growth (*Striga* emergence)

	***Striga* emergence (plant/pot)** **Time after crop sowing (Days)**			
	30	**60**	**90**	**Mean**
a-Sole sorghum				
1	3.0 (±1.1) c	7.0 (±1.6) d	13.3 (±1.9) d	**7.8 d**
2	6.5 (±0.6) bc	12.0 (±1.5) c	17.5 (±1.0) cd	**12.0 c**
4	7.5 (±0.6) b	13.5 (±0.6) bc	21.3 (±0.9) abc	**14.1 bc**
8	9.5 (±0.6) b	15.0 (±0.4) bc	20.0 (±1.1) bc	**14.8 b**
16	10.0 (±2.7) b	16.3 (±1.3) ab	23.0 (±1.6) ab	**16.4 b**
32	14.3 (±0.9) a	18.5 (±0.6) a	25.0 (±1.8) a	**19.3 a**
Mean	**8.5 c**	**13.7 b**	**20.0 a**	
b-cowpea B301		B301		**Mean**
1	0.3 (±0.3) d	0.5 (±0.3) d	0.5 (±0.3) d	**0.4 e**
2	0.8 (±0.5) cd	1.5 (±0.6) d	1.8 (±0.6) cd	**1.3de**
4	1.5 (±1.0) cd	2.3 (±0.9) cd	2.5 (±0.9) cd	**2.1 d**
8	3.3 (±0.5) c	4.5 (±1.6) c	5.5 (±1.3) c	**4.4 c**
16	6.8 (±0.9) b	8.8 (±0.9) b	11.8 (±1.5) b	**9.1 b**
32	13.0 (±1.5) a	16.8 (±1.0) a	24.8 (±2.5) a	**18.2 a**
Mean	**3.6 a**	**4.9 a**	**6.7 a**	
ccowpeaT100K901-6				
1	0.0 (±0.0) c	0.5 (±0.5) c	0.5 (±0.5) c	**0.3 d**
2	0.8 (±0.5) bc	1.3 (±0.8) c	1.0 (±0.4) c	**1.0 d**
4	1.8 (±0.8) bc	2.3 (±1.1) c	2.5 (±1.3) c	**2.2 cd**
8	3.3 (±1.8) bc	4.0 (±1.5) c	4.5 (±1.7) c	**3.9 c**
16	5.3 (±1.3) b	9.0 (±0.8) b	9.5 (±1.6) b	**7.9 b**
32	10.0 (±3.1) a	17.0 (±2.2) a	19.0 (±2.4) a	**15.3 a**
Mean	**3.0 a**	**4.9 a**	**5.3 a**	

At 60 DAS *Striga* emergence, irrespective of seed bank size, showed considerable increase in comparison to that recorded at 30 DAS (Table 4.8 a). *Striga* emergence at the lowest seed bank size was 7 plants per pot. Increasing seed bank size to 2 mg per pot increased *Striga* emergence significantly. An increase in *Striga* seed bank to 4, 8 and 16 mg per pot increased the parasite emergence, albeit not significantly. A further increase in *Striga* seed bank to 32 mg per pot increased emergence, significantly.

At 90 DAS *Striga* emergence showed a similar trend. The average *Striga* emergence at the lowest and highest seed bank was 13.3 and 25 plants per pot, respectively (Table 4.8 a).

At 30 DAS *Striga* on sorghum intercropped with cowpea B301 at the lowest seed bank size (1mg per pot) displayed the lowest emergence (Table. 4.8 b). Increasing seed bank size to 2 and 4 mg per pot increased *Striga* emergence, albeit not significantly. Increasing *Striga* seed bank size to 8 mg per pot increased *Striga* emergence significantly in comparison to the lowest seed bank size. Increasing *Striga* emergence to 16 mg per pot increased emergence by more than 1-fold. At a seed bank of 32 mg per pot *Striga* displayed the highest emergence (13 plants per pot).

At 60 DAS *Striga* emergence was higher than at 30DAS and it followed more or less the same trends. Emergence of the parasite was lowest (0.5 plant/pot) at the lowest seed bank size (1mg/pot). However, a progressive, albeit non- significant increase in emergence was observed up to a seed bank of 8 mg/pot. A further increase in *Striga* seed bank to 16 and 32 mg/pot, further increased the parasite emergence by about 1-and, 3-fold, respectively (Table. 4.8 b).

At 90 DAS *Striga* emergence was lowest at the lowest seed bank size (Table 4.8 b). Increasing *Striga* seed bank size to 2 and 4 mg per pot increased *Striga* emergence, albeit not significantly. Increasing *Striga* seed bank size to 8 mg per pot increased *Striga* emergence significantly in comparison to the lowest seed bank size. However, the emergence, albeit higher, was comparable to that at seed banks of 2 and 4 mg per pot. Increasing *Striga* seed bank size to 16 and 32mg per pot further increased *Striga* emergence by more than 2-to-4-fold, respectively (Table 4.8 b).

Striga emergence on sorghum intercropped with cowpeaT100K-901-6 showed a similar trend to that observed on sorghum intercropped with B301 (Table 4.8 c). At 30 DAS and at the lowest seed bank size no *Striga* emergence was observed. A further increase in *Striga* seed bank size to 2, 4 and 8 mg per pot did not result in a significant increase in emergence. However, increasing *Striga* seed bank to 16 mg per pot increased *Striga* emergence significantly. Asurge in *Striga* emergence was observed on further increase of *Striga* seed bank to 32 mg per pot (Table 4.8 c).

At 60 DAS *Striga* emergence at the lowest *Striga* seed bank was very low (0.5 plants/pot). Increasing *Striga* seed bank up to 8 mg/pot increased *Striga* emergence, albeit not significantly. A further increase in *Striga* seed bank size to 16 and 32 mg per pot increased *striga* emergence by 2-to-4-fold in comparison to emergence of the parasite at the seed bank of 4 mg per pot.

At 90 DAS *Striga* emergence showed no further increase and displayed the same pattern and intensity as at 60 DAS.

4.2.1.2. Dry weight.

Striga dry weight, irrespective of intercropping, progressively increased with increasing seed bank size (Table 4.9). On sole sorghum *Striga* dry weight

progressively increased with seed bank size. *Striga* dry weight at the lowest seed bank size was 24.3 g. Increasing *Striga* seed bank to 2 mg per pot increased *Striga* dry weight by 74.9%. However, the observed increase was not significant.

Table. 4.9. Effects of seedbank size and intercropping with cowpea on *Striga* infestation and sorghum growth (*Striga* dry weight)

	***Striga* dry weight (g)**			
***Striga* seed**	**Sole Sorghum**	**B301**	**T100K-901-6**	**Mean**
1	24.3 (±2.4) d	30.5 (±2.3) c	19.0 (±2.3) c	**24.6 d**
2	42.5 (±6.2) cd	32.0 (±0.9) c	21.8 (±1.5) bc	**32.1 cd**
4	56.8 (±7.4) bc	34.5 (±5.0) bc	23.0 (±3.1) bc	**38.1 bc**
8	76.8 (±15.9) ab	40.8 (±4.2) abc	29.0 (±3.5) ab	**48.8 ab**
16	86.8 (±2.5) a	44.0 (±5.3) ab	33.3 (±4.7) a	**54.7 a**
32	91.3 (±2.4) a	46.3 (±3.1) a	35.0 (±) a	**57.5 a**
Mean	**63.0 a**	**38.0 b**	**26.8 c**	**42.6**

On sole sorghum increasing *Striga* seed bank to 4 mg or more increased *Striga* dry weight significantly in comparison to the lowest seed bank size. At *Striga* seed bank size of 4, 8, 16 and 32 mg per pot the increase in *Striga* dry weight in comparison to the lowest seed bank size was 133.7, 216, 257, and 275.7% respectively (Table 4.9).

Striga dry weight on sorghum intercropped with cowpea B301, albeit progressively increased with seed bank however, differences between treatments were not significant up to a seed bank of 8 mg per pot (Table 4.9). Increasing seeds bank size, to 16 and 32 mg per pot resuled in significant increase in dry weight. The respective increase in the parasite dry weight at a seed bank of 16 and 32 mg per pot was 44.3 and 51.8% in comparison to the lowest seed bank size.

Striga on sorghum intercropped with cowpea T10K-901-6 displayed a dry weight of 19 g per pot at the lowest *Striga* seed bank size. Increasing *Striga* seed bank size to 2 and 4 mg per pot increased *Striga* dry weight, albeit not significantly and the observed increase in *Striga* dry weight was 14.7 and 21%, respectively (Table 4.9). A Further increased in seed bank size to 8, 16 and 32 mg per pot increased *Striga* dry weight by 52.6, 75.3 and 84%.

Across the seed bank size sole sorghum sustained the highest mean average *Striga* dry weight followed in descending order by sorghum intercropped with cowpea B301 and T100K-901-6 (Table 4.9).

4.2.2. Effects on sorghum.

4.2.2.1. Height

In all treatments sorghum height progressively decreased with *Striga* seed bank size and increased with time (Table. 4.10). In general sorghum intercropped with cowpea, irrespective of the latter genotype or *Striga* seed bank size, displayed better growth than sole sorghum. *Striga* free sorghum when intercropped with cowpea, irrespective of genotype or date of observation, displayed an increase in height of 27.7-64.5% in comparison to the corresponding sole sorghum treatment.

In sole sorghum at 30 DAS *Striga* seed bank at 1-8mg/pot inflicted insignificant (5.1-20.9%) decrease in height (Table. 4.10). Increasing *Striga* seed bank size to 16 and 32 mg per pot reduced sorghum height significantly (27.2and39.9%), (Table. 4.10). Sorghum height, irrespective of bservation date, was negatively and significantly correlated with *Striga* emergence at 30 DAS (r=-0.492--0.654) and *Striga* dry weight at harvest (r=-0.486 (Appendix 14).

Table. 4.10. Effects of seedbank size and intercropping with cowpea on *Striga* infestation and sorghum growth (sorghum height)

	Sorghum height (cm) Time after sowing (Days)			
	30	**60**	**90**	**Mean**
a- Sole sorghum				
0	15.8 (±1.8) a	19.0 (±2.0) a	24.5 (±2.6) ab	**19. a**
1	15.0 (±2.2) ab	18.8 (±1.9) a	26.3 (±1.8) a	**20 a**
2	14.0 (±0.9) ab	18.8 (±1.5) a	24.0 (±1.6) abc	**18.9 ab**
4	15.5 (±1.0)a	18.3 (±1.3) a	20.3 (±1.3) bcd	**18 ab**
8	12.5 (±1.0) abc	16.5 (±0.6) ab	19.8 (±0.9) cde	**16. abc**
16	11.5 (±0.6) bc	15.8 (±0.5) ab	18.5 (±0.6) de	**15. bc**
32	9.5 (±1.0) c	13.3 (±0.9) b	15.5 (±0.6) e	**12. c**
Mean	**13.4 c**	**17.2 b**	**21.3 a**	
b-cowpeaB301				
0	24.8 (±2.9) a	27.8 (±3.4) a	31.3(±2.4) a	**27.9 a**
1	22.8 (±3.1) ab	24.3 (±3.0) ab	30.5 (±1.7) a	**25.8 ab**
2	18.8 (±1.1) abc	22.3 (±2.1) abc	26.5 (±2.5) ab	**22.5 bc**
4	20.5 (±1.3) bc	21.8 (±1.4) bc	24.5 (±1.8) bc	**22.25 bc**
8	18.3 (±0.9) bc	19.3 (±0.5) bc	22.3 (±1.1) bc	**19.9 c**
16	17.5 (±0.6) bc	19.0 (±0.7) bc	21.5 (±1.3) bc	**19.3 c**
32	**15.3 (±0.9) c**	**17.5 (±0.6) c**	**20.0 (±0.7) c**	**17.6 c**
Mean	**19.8 b**	**21.7 b**	**25.2 a**	
c- T100K-901-6				
0	26.0 (±1.5) a	30.3 (±1.3) a	34.5 (±1.7) a	**30.3 a**
1	24.3 (±3.1) ab	29.3 (±1.5) ab	30.5 (±1.6) ab	**28.0 ab**
2	21.0 (±1.5) bc	28.3 (±1.2) ab	29.0 (±0.7) ab	**26.1 abc**
4	20.0 (±1.1) bc	27.0 (±3.0) abc	27.5 (±3.3) b	**24.8 bc**
8	19.3 (±0.8) c	23.8(±2.7) bcd	25.0 (±2.6)bc	**22.7 cd**
16	18.0 (±1.1) c	21.5 (±2.6) cd	24.3 (±2.1) bc	**21.3 cd**
32	**16.5 (±0.6) c**	**19.0 (±1.7) d**	**19.0 (±2.4) c**	**18.2 d**
Mean	**20.7 a**	**25.6 a**	**27.1 a**	

At 60 DAS reductions in sorghum height followed more less similar trends. *Striga* seed bank up to 16 mg/pot did not inflict significant reductions in sorghum height. However, increasing *Striga* seed bank to 32 mg per pot decreased sorghum height significantly. Sorghum height, consistently,

showed negative correlations with *Striga* emergence at 60DAS (r=-0.55) (Appendix 14).

At 90 DAS *Striga* seed bank size at 2 and 4 mg per pot reduced sorghum height by 2 and 17.1%, respectively. Increasing *Striga* seed bank size to 8 mg per pot or more, reduced sorghum height significantly and the observed reductions were 24.5-36.7%. Sorghum height was negatively correlated with *Striga* emergence (r=-0.434- -0.566) and *Striga* dry weight (r=-0.797). (Appendix 14).

At 30 DAS *Striga* free sorghum intercropped with cowpea B031 displayed a height of 24.8 cm. *Striga* seed bank 1 and 2 mg per pot reduced sorghum height, albeit not significantly. Increasing *Striga* seed bank size to 4 mg per pot or more resulted in significant reductions in sorghum height. Sorghum height was consistently and significantly correlated with *Striga* emergence (r=-0.527- -0.532) and *Striga* dry weight (r=-0.498) (Appendix 15).

At 60 DAS *Striga* seed bank at 1 and 2 mg per pot reduced sorghum height, albeit not significantly. Increasing *Striga* seed bank to 4 mg per pot or more reduced sorghum height significantly. The highest reduction (38.3%) was observed at the highest seed bank size (32mg/pot). Sorghum height was consistently and significantly correlated with *Striga* emergence (r=-0.517--0.494) and *Striga* dry weight (r=-0.587) (Appendix 15).

At 90 DAS *Striga* seed bank at 1 and 2 mg reduced sorghum height, albeit not significantly. A further increase in seed bank size to 4 mg per pot or more resulted in significant reductions. The highest reduction (31.7%) was observed at the highest seed bank size (Table. 4.10.b) Sorghum height was consistently and significantly correlated with *Striga* emergence (r=-652- -0.632) and *Striga* dry weight(r=-0.611) (Appendix 15).

At 30 DAS sorghum intercropped with cowpea T100K-901-6 did not show a significant reduction in height at *Striga* seed bank size of 1 mg per pot. However, increasing *Striga* seed bank size to 2 or more per pot reduced sorghum height significantly in comparison to the corresponding *Striga* free control. The highest reduction (36.5%) was observed at the highest *Striga* seed bank (Table 4.10). Sorghum height was consistently and significantly correlated with *Striga* emergence (r=-515- -0.557) and *Striga* dry weight(r=-0.622) (Appendix 16).

At 60 DAS *Striga* seed bank of 1 and 2 mg per pot did not cause significant reductions in sorghum height. However, increasing seed bank size to 4 mg per pot or more resulted in significant reduction[s]. The highest reduction in sorghum height (36.3%) was attained at the highest seed bank size. Sorghum height was consistently and significantly negatively correlated with *Striga* emergence (r=-453- -0.625) and *Striga* dry weight(r=-0.587) (Appendix 16).

At 90 DAS *Striga* seed bank size up to 2 mg per pot did not inflict significant reductions in sorghum height in comparison to the corresponding *Striga* free control. However, increasing *Striga* seed bank size to 4 mg/pot or more resulted in significant reductions. The highest reduction attained at the highest seed bank size was 45%. Sorghum height was negatively correlated with *Striga* emergence (r=-538--0.578) and *Striga* dry weight(r=-0.616) (Appendix 16).

4.2.2.2. Leaf area

Leaf area, irrespective of intercropping or time, decreased with increasing *Striga* seed bank size (Table 4.11). At 30 DAS sole sorghum, invariably, showed a progressive decline in leaf area with *Striga* seed bank size in

comparison to the *Striga* free control (Table 4.11). However, significant reductions in leaf area were realized only at a seed bank of 8 mg per pot or more. The reductions in leaf area at *Striga* seed bank of 8, 16 and 32% were 47.8, 54.9, and 66.4%, respectively. The leaf area was negativity correlated with *Striga* emergence (r=-0.68--0.634) and *Striga* dry weight(r=-0.661) (Appendix 14).

At 60 DAS the leaf area of sole sorghum showed a progressive increase in comparison to the records made at 30 DAS, irrespective of *Striga* seed bank size (Table 4.11). However, a gradual decrease with *Striga* seed bank size was realized in comparison to the *Striga* free control and only the highest *Striga* seed bank size (32mg/pot) effected a significant reduction (56.7%). The leaf area was negativity correlated with *Striga* emergence (r=-0.521--0.463) and *Striga* dry weight (r=-0.493) (Appendix 14).

At 90 DAS leaf area showed more or less the same trend, a progressive decline with *Striga* seed bank size. However, significant reductions (31.2 and 51%) were only attained at seed bank size of 16 and 32 mg per pot. The leaf area was negativity correlated with *Striga* emergence (r= -0.605--0.522) and *Striga* dry weight(r=-0.592) (Appendix 14).

The overall effect across time showed a significant increase in sorghum leaf area. However, the overall effect across *Striga* seed bank levels was a progressive decline with increasing seed bank size with, significant reductions attained at the highest *Striga* infestation levels (16 and 32 mg/pot).

Intercropping with cowpea B301 and T100K-901-6, irrespective of *Striga* infestation increased sorghum leaf area in comparison to sole sorghum

(Table 4.11). A consistent progressive decline in leaf area was invariably affected with increasing *Striga* seed bank size.

Table 4.11. Effects of seedbank size and intercropping with cowpea on *Striga* infestation and sorghum growth (Leaf area)

	Leaf area(cm^2) Time after sowing (DayS)			
a-Sole sorghum				
0	45.0 (±6.1) a	53.3 (±5.3) a	73.6 (±6.7) a	**57.3 a**
1	38.1 (±5.9) ab	54.0 (±9.3) a	69.9 (±6.4) ab	**54.0 ab**
2	32.9 (±7.6) abc	46.0 (±11.0) ab	60.7 (±10.8) ab	**46.5 ab**
4	28.1 (±7.5) abcd	43.2 (±9.6) ab	58.1 (±9.4) abc	**43.1 abc**
8	23.5 (±5.3) bcd	39.2 (±8.4) ab	55.8 (±7.9) abc	**39.5 abc**
16	20.3 (±4.2) cd	37.4 (±6.7) ab	50.7 (±4.8) bc	**36.1 bc**
32	15.1 (±2.4) d	23.1 (±2.8) b	36.1 (±4.0) c	**24.8 c**
Mean	**29.0 c**	**42.3 b**	**57.8 a**	
b-B301				
0	141.8 (±30.3) a	170.4 (±27.1) a	176.8 (±19.0) a	**163.0 a**
1	130.1 (±15.0) a	160.0 (±8.7) ab	173.5 (±31.3) a	**154.5 ab7**
2	123.4 (±14.6) a	143.8 (±12.5) abc	166.1 (±16.7) a	**144.4 abc**
4	117.5 (±15.3) a	139.6 (±7.3) abc	149.4 (±25.1) a	**135.5 abc**
8	114.6 (±13.9) a	130.4 (±10.4) abc	134.1 (±21.0) a	**126.4 abc**
16	104.1 (±15.1) a	126.6 (±12.4) bc	118.4 (±17.8) a	**116.3 bc**
32	95.6 (±13.4) a	106.8 (±12.7) c	116.4 (±18.6) a	**106.0 c**
Mean	**118.1b**	**139.6 a**	**147.8 a**	
c-T100K-901-6				
0	157.4 (±19.8) a	171.8 (±11.5) a	182.9 (±13.2) a	**170.7 a**
1	154.3 (±17.4) a	157.6 (±9.2) a	163.5 (±17.5) a	**158.5 ab**
2	142.0 (±14.0) a	150.7 (±9.9) a	155.6 (±16.8) a	**149.4 ab**
4	138.2 (±29.4) a	148.1 (±20.2) a	155.2 (±26.3) a	**147.1 ab**
8	124.2 (±18.4) a	144.6 (±16.1) a	144.9 (±21.9) a	**137.9 ab**
16	118.7 (±21.7) a	131.7 (±7.2) a	142.1 (±11.7) a	**130.8b**
32	104.2 (±23.4) a	128.3 (±31.1) a	138.3 (±24.0) a	**123.6 b**
Mean	**134.1b**	**147.5 ab**	**154.6 a**	

At 30 DAS sorghum intercropped with cowpea B301 did not show significant reductions in leaf area, irrespective of the parasite seed bank size. However, though not significant, the leaf area showed a negative correlation

with *Striga* emergence (r= -0.416--0.363)) and *Striga* dry weight (r=-0.319) (Appendix 15).

. At 60 DAS the sorghum leaf area declined with increasing seed bank. However, significant reductions (24.7 and 36.34%) were only attained at the highest levels of *Striga* seed bank (16 and 32) The leaf area was negativity correlated with *Striga* emergence (r= -0.593--0.463) and *Striga* dry weight (r=-0.3039) (Appendix 15).

. At 90 DAS sorghum leaf area declined with *Striga* seed bank, but the observed reductions were only significant at the highest seed bank size (16 and 32 mg/pot) (Table. 4.11.b). The leaf area was negativity correlated with *Striga* emergence (r= -0.652--0.632) and *Striga* dry weight (r=-0.71) (Appendix 15).

Sorghum intercropped with cowpea T100K-901-6, irrespective of time, showed a consistent decline in leaf area with *Striga* seed bank size (Table 4.11). However, the observed reductions were, invariably, not significant**.**

4.2.2.3. Dry weight.

Sorghum dry weight irrespective of intercropping decreased with increasing *Striga* seed bank size. (Table 4.12). *Striga* free sole sorghum showed a shoot dry weight of 67.5 g per pot. *Striga* seed bank size at 1and 2 mg per pot reduced sorghum dry weight by 7.7 and 22.5% respectively, and the reductions were not significant. Increasing *Striga* seed bank size to 4, 8, 16 and 32 mg per pot reduced sorghum dry weight by 31.9, 39.3, 54.8 and 60.7 %, respectively and the observed reductions were significant in comparison to the respective *Striga* free control.

Table. 4.12. Effects of seedbank size and intercropping with cowpea on *Strigs* infestation and sorghum growth (sorghum dry weight)

	Sorghum dry weight(g)			
***Striga*seedbank(g/pot)**	**Sole sorghum**	**B301**	**T100K-901-6**	**Mean**
0	67.5 (±11.2) a	134.8 (±19.4) a	150.0 (±16.6) a	**117.4 a**
1	62.3 (±7.6) ab	131.8 (12.7) a	144.0 (±13.5) ab	**112.7 a**
2	52.3 (±4.9) abc	104.8 (±11.6) ab	116.3 (±12.2) bc	**91.1 b**
4	46.0 (±8.9) bcd	73.0 (±18.1) bc	84.3 (±13.0) cd	**67.8 c**
8	40.3 (±4.8) cd	53.0 (±8.3) c	63.5 (±8.8) de	**52.3 cd**
16	30.5 (±1.4) d	52.5 (±4.3) c	58.0 (±3.4) de	**47.0 cd**
32	26.5 (±3.5) d	40.0 (8.4) c	49.0 (±4.3) e	**38.5 d**
Mean	**46.5 b**	**84.3 a**	**95.0 a**	

Intercropped sorghum invariably showed significantly higher dry weight than the sole crop (Table. 4.12). However, it showed more or less the same trends in reduction with *Striga* seed bank as sole sorghum in comparison to the respective *Striga* free control (Table. 4.12) *Striga* free sorghum intercropped with cowpea B301 displayed a dry weight of 134.8 g (Table. 4.12). *Striga* seed bank of at 1, and 2 mg per pot reduced sorghum dry weight by 2.2 and 22.3% respectively and the attained reductions were not significant. Increasing *Srtiga* seed bank to 4, 8, 16 and 32 mg per pot decreased sorghum dry weight by 45.8, 60.7, 61.1 and 70.3 %, respectively and the observed reductions were significant.

Sorghum intercropped with cowpeaT100K-901-6 displayed a dry weight of 150 g per pot. *Striga* at the lowest seed bank reduced sorghum dry weight by 4 % and the observed reduction was not significant (Table 4.12 c). Increasing *Striga* seed bank to 2 and 4 mg per pot decreased sorghum dry weight significantly. A further increase in *Striga* seed bank to 8 mg per pot or more caused further significant reductions in sorghum dry weight. The

reductions in sorghum dry weight inflicted by the parasite at seed bank of 8, 16 and 32 were 57.7, 61.3 and 67.3%, respectively.

4.3. Field experiments

Effects of intercropping with cowpea, previously dressed with *Bacillus megatherium var phosphaticum* and *Rhizobium leguminosarum*, on *Striga* incidence and sorghum growth.

4.3.1. *Striga* incidece

All treatments decreased *Striga* emergence considerably in comparison to the control (Table. 4.13). Furthermore, *striga* emergence progressively increased with time.

At 35 DAS, *Striga* emergence was maximal on sole sorghum (6.3 plants/m^2). Intercropping with cowpea B301 dressed with Bmp, Rhizobium and their combination reduced *Striga* emergence by 79.4, 83.1and 100% compared to the control (Table. 4.13). Intercropping with cowpea T100K-901-6 dressed with Bmp, Rhizobium and their combination reduced *Striga* emergence by 73, 95.2 and 100%, respectively.

At 50 DAS, cowpea B301 dressed with Bmp, Rhizobium and their combination reduced *Striga* emergence by 67.9, 73.3 and 82.4%, respectively (Table. 4.13). Cowpea T100K-901-6 dressed with Bmp and Rhizobium or their combination, on the other hand, reduced *Striga* emergence by 71.7, 82.3 and 93%, respectively.

At 65 DAS, the corresponding reductions in *Striga* emergence caused by intercropping with cowpea B301 dressed with Bmp, *Rhizobium* and their combination were 68, 78.8 and 84%, respectively in comparison to the control (Table. 4.13).

Table 4.13. Effects of intercropping with cowpea, previously dressed with *B. megatherium var phosphaticum* and *R.leguminosarum,* on *Striga* emergence

No of emerged *Striga* shoots/plant					
	Days after sowings (DAS)				
Treatments	**35**	**50**	**65**	**80**	**Mean**
B301+ Bacillus Bmp	1.3 (±1.2) b	6.0 (±2.2) b	8.0 (±3.4) b	10.3 (±3.3) b	**6.4b**
B301+ Rhizobium TAL1399	1.0 (±0.8) b	5.0 (±2.2) b	5.3 (±2.3) b	8.7 (±2.2) b	**5.0b**
B301+ Bmp+ Rhizobium	0.0 (±0.0) b	3.3 (±1.6) b	4.0 (±0.6) b	7.0 (±1.0) b	**3.6b**
T100K-901-6+*Bacillus* Bmp	1.7 (±1.2) b	5.3 (±2.7) b	6.7 (±3.2) b	9.0 (±3.1) b	**5.7b**
T100K-901-6+Rhizobium TAL1399	0.3 (±0.2) b	3.3 (±1.8) b	4.7 (±1.2) b	7.7 (±0.9) b	**4.0b**
T100K-901-6+ Bmp+ *Rhizobium*	0.0 (±0.0) b	1.3 (±0.7) b	3.0 (±0.6) b	5.7 (±0.9) b	**2.5b**
Sole sorghum	6.3 (±0.9) a	18.7 (±2.2) a	25.0 (±1.7) a	31.0 (±2.2) a	**20.3a**
Mean	**1.5c**	**6.1b**	**8.1ab**	**11.1a**	
Two-Ways ANOAVA */9					
Treatments, T	**27.1*** **				
Days, D	**27.2*** **				
T*D	**0.4^{ns}**				
CV%	**31**				

B=Bacillus R=Rhizobium

T100K-901-6 previously dressed with Bmp, *Rhizobium* or their combination reduced *Striga* emergence by 73.2, 81.2 and 88%, respectively.

At 80 DAS the intercropping with B301, previously dressed with Bmp, Rhizobium or their combination reduced *Striga* emergence by 66.7, 71.9 and 77.4%, respectively compared to the control. Cowpea T100K-901-6, previously dressed with Bmp, Rhizobium or their combination reduced *Striga* emergence by 71, 72.2 and 81.6, respectively (Table. 4.13).

4.3.2. Effects on sorghum

4.3.2.1. Height

Sorghum height, irrespective of treatment, showed progressive increase with time (Table. 4.14). However, all treatments resulted in height comparable to the control (*Striga* infested sole sorghum).

Table. 4.14. Effects of intercropping with cowpea previously dressed with *Bacillus megatherium var phosphaticum* and *Rhizobium leguminosarum* (sorghum height)

Treatment	Sorghum plant height (cm) Days after sowing (DAS)			
	30	60	90	Mean
B301+ Bacillus Bmp	42.3 (±1.3)	79.7 (±1.9)	103.0 (±1.3)	**75.0**
B301+ *Rhizobium* TAL1399	49.1 (±1.7)	80.6 (±1.5)	107.7 (±1.7)	**79.1**
B301+ Bmp+ *Rhizobium*	46.1 (±1.5)	79.8 (±2.0)	107.9 (±2.1)	**77.9**
T100K-901-6+ Bacillus Bmp	46.2 (±1.9)	81.2 (±0.8)	106.4 (±2.2)	**78.0**
T100K-901-6+*Rhizobium* TAL1399	48.2 (±1.7)	82.2 (±2.2)	107.7 (±1.7)	**79.4**
T100K-901-6+ Bmp+ *Rhizobium*	46.1 (±2.1)	83.1 (±1.7)	107.2 (±1.5)	**78.8**
Sole sorghum	47.7 (±2.1)	81.2 (±2.2)	108.4 (±2.0)	**79.1**
Mean	**46.5c**	**81.1b**	**106.9a**	
Two-Way ANOVA				
Treatments, T	**2.4^{ns}**			
Days, D	**777.0*** **			
T*D	**0.4^{ns}**			
CV%	**6.8**			

4.3.2.2. Length of the first internodes

All treatments increased length of the first internodes in comparison to the control, (Table 4.15). At 45 DAS, cowpea B301 dressed with the bacterial combination resulted in a significant increase (50%) in length of the first internode (Table. 4.15. Among other treatments sorghum intercropped with cowpea T100K-901-6, previously dressed with *Rhizobium* and the bacterial combination, displayed the highest internode length. At 90 DAS sorghum intercropped with B301 dressed with *Rhizobium* or Bacillus Bmp increased internode length over the control, albeit not significantly. However, sorghum intercropped with cowpea B301 dressed with the bacterial combination displayed, significantly, longer internode than sole sorghum.

Table. 4.15. Effects of intercropping with cowpea, previously dressed with *Bacillus megatherium var phosphaticum* and *Rhizobium,* on sorghum growth (lower internode length

	Internodes length (cm) Days after sowing (DAS)		
Treatment	**45**	**90**	**Mean**
B301+ Bacillus Bmp	4.9 (±0.6) ab	5.0 (±0.4) c	**4.9 bc**
B301+ Rhizobium TAL1399	5.7 (±0.5) ab	5.7 (±0.5) c	**5.7 abc**
B301+ Bmp+ Rhizobium	6.3 (±0.3) a	7.1 (±0.7) a	**6.7 a**
T100K-901-6+ Bacillus Bmp	4.7 (±0.4) ab	5.8 (±0.4) bc	**5.2 bc**
T100K-901-6+Rhizobium TAL1399	5.6 (±0.4) ab	6.0 (±0.5) abc	**5.8 abc**
T100K-901-6+ Bmp+ Rhizobium	5.6 (±0.6) ab	7.0 (±0.6) ab	**6.3 abc**
Sole sorghum	4.2 (±0.4) b	4.9 (±0.5) c	**4.6 c**
Mean	**5.3 a**	**5.9 a**	
Two-Way ANOVA			
Treatments, T	**2.6^{ns}**		
Days, D	**0.2^{ns}**		
T*D	**2.0^{ns}**		
CV%	**26.5**		

4.3.2.3. Head length, head size and 100 seed weight

Head length was significantly increased by all treatments in comparison to the *Striga* infested control (Table. 4.16.). Intercropping with cowpea B301 dressed with *Bacillus* Bmp, *Rhizobium* TAL1399 or their combination increased head length by 27.6, 52.8 and 61.0%, respectively over the untreated control.

Cowpea T100K-901-6 dressed with Bacillus Bmp and *Rhizobium* TAL1399 or their combination increased head length by 34.1, 39.0 and 60.2%, respectively. All treatments increased head size significantly in comparison to the untreated control (Table 4.16). Cowpea B301 dressed with *Bacillus* Bmp or *Rhizobium*TAL1399 or their combination increased head size by

33.6, 64.7 and 122.4%, respectively. The corresponding figures for cowpea genotype T100K-901-6 were 30.4, 67.0 and 94.5%, respectively.

Table. 4. 16. Effects of intercropping with cowpea previously dressed with *Bacillus megatherium var phosphaticum* and *Rhizobiumleguminosarum* on sorghum growth (head length, head size and 100 seed weight).

	Yield parameters		
Treatments	**Head length (cm)**	**Head sizes (ml)**	**100seeds/g**
B301+ Bacillus Bmp	15.7 (±0.6) a	63.2 (±6.5) bc	2.3 (±0.1) ab
B301+ *Rhizobium* TAL1399	18.8 (±0.6) a	77.9 (±9.0) a	2.6 (±0.2) a
B301+ Bmp+*Rhizobium*	19.8 (±0.6)a	105.2 (±11.2) a	3.0 (±0.3) a
T100K-901-6+ Bacillus Bmp	16.5 (±0.5) a	61.7 (±7.0) ab	2.5 (±0.1) a
T100K-901-6+*Rhizobium* TAL1399	17.1 (±0.5) a	79.0 (±10.5) ab	2.4 (±0.5) ab
T100K-901-6+ Bmp+*Rhizobium*	19.7 (±0.6) a	92.0 (±9.3) ab	2.7 (±0.2) a
Sole sorghum	12.3 (±0.5) b	47.3 (±3.8) c	1.8 (±0.1) b

All treatments increased the 100 seed weight over the control (Table 4.16) B301 dressed with *Rhizobium or* Bmp, each alone, and in combination increased the 100 seed weight by 27.8, 44.4 and 66.7. Cowpea T100K-901-6 dressed with *Rhizobium* TAL1399and Bmp, each alone and in a combination, increased the 100 seed weight by 38.9, 33.3 and 50.0%, respectively

CHAPTER FIVE

Discussion

Striga research in Africa has a long history and a range of control technologies has been identified (Parker and Riches, 1993; Babiker, 2007). However, most of the available technologies have not been largely adopted (Babiker, 2007). Lack of adoption of the improved technologies has been attributed to sophistications, expensiveness, lack of understanding, or unawareness and/or erratic performance (Babiker, 2007). Furthermore, the problem is linked to both intrinsic and extrinsic factors related to the parasite and the environment, respectively. Among the intrinsic factors the parasite, fecundity, facilitating development of a huge seed bank soon after introduction, is crucial (Parker and Riches, 1993). Furthermore, the parasite, spread, growth vigour and the damage it inflicts on its host have been closely associated with failure or unacceptability of the developed technologies. Intercropping cereals with legumes is a traditional African farming practice particularly in rainfed areas. Diversification of cropping by subsistent farmers is practiced to avoid the risk of crop failure due to rain shortage.

Cowpea is a common crop in Western Sudan and is commonly used as an intercrop with sorghum and millet. However, strip cropping is common (Parker and Riches,1993). Experience with intercropping of sorghum and millet in Sudan, where the cowpea is planted in the same hole or between holes of the cereal crop, invariably resulted in stand and yield reductions of the companion crop yield (Hamad Elneel, 2011). The observed reduction is attributed to competition for nutrient, water, space and light. Cowpea is a

legume, a nitrogen fixer, and a good source of proteins. Furthermore, it is a host of *Striga gesneriodis*. In West Africa early maturing cowpea genotypes are planted as intercrop with sorghum and millet in the rainfed sector to safe guard against crop failure and to combat *Striga hermonthica* in infested fields (Parker and Riches,1993).

Previous studies considered cowpea as a trap crop to be planted in rotation with cereals, with the primary objective of reducing *Striga* seed bank or as an intercrop with the cereal to reduce *Striga* seed bank and through decreased soil temperature represses germination of the parasite and suffocate juvenile *Striga* plant through competition and raising atmospheric humidity (Yonil, 2012).

In the present work a holistic approach was adopted with the objectives of providing information on activity of cowpea residues, root exudates and intercropping in greenhouse and field experiments where intercropping was integrated with inoculation with *R.leguminosarum* and *B. megatherium var phosphaticum***,** a phosphorus releasing bacterium

The results revealed that a general feature of GIA of cowpea residues. presented in powder from roots, stems and leaves, is an increase with increasing weight of samples followed by a subsequent decline on further increase in weight of the sample in question (Figs 4.1 A-C,4.3, A-C, 4.5 A-C, Appendices 2, 4, 6). Furthermore, GIA of cowpea residues was influenced by genotype, the source organ and the *S. hermonthica* strain (Figs 4.1 A-C,4.3, A-C, 4.5 A-C, Appendices 2, 4, 6). Based on the arbitrary scale, described in 3.1.1.2.1, the root powder displayed the highest germination followed in descending order by that of stems and leaves (Figs 4.1 A-C,4.3, A-C, 4.5 A-C, Appendices 2, 4, 6). At the lowest root powder

level (5 mg/well) 79.2% of the samples showed satisfactory to excellent GIA on *Striga* seeds, sorghum strain,. Increasing powder level to 10 mg/well increased the number to 87.5%. At a higher powder level (15 mg/well) none of the samples showed excellent GIA and the number showing satisfactory and good GIA was repressed to 41.6% (Figs. 4.1 A-CAppendix2). For the stem powder, none of the samples showed excellent GIA. At 5 mg/well 37.5% of the samples showed satisfactory and good GIA. Increasing powder level to 10 mg/well increased the number to 70.9 %. At 15 mg/well none of the samples showed good or excellent GIA and only 20.8% showed satisfactory GIA (Appendix 18). For the leaves powder at 5 mg/well none of the samples showed good or excellent GIA. Most of the samples (79.2%) showed poor GIA and 12.5% displayed satisfactory GIA. At 10 mg/well 25, and 8.3% of the samples showed satisfactory and good GIA, respectively and none showed excellent GIA (Appendix 18). At powder level of 15 mg/well none of the samples showed good or satisfactory GIA. Most of the samples (87.5%) showed poor activity and only 4.2% showed satisfactory GIA (Appendix 18).

Radicle extension also showed variations with powder source, powder amount and *Striga* strain (Figs. 4.2 A-C, 4.4-A-C, 4.6-A-C, Appendicies 3, 5 and 7). For the root powder and *Striga*, sorghum strain, radicle extension varied from short to long, however, the proportion of each varied with the amount of powder used (Fig. 4.2. A-C, Appendix 3 and 7). At the lowest concentration (5 mg) short and medium and long radicles were 4.2, 66.7 and 29.1%, respectively (Appendix 19). At 10 mg only short and medium radicle extensions were displayed with proportions of 41.7 and 58.3%, respectively (Appendix 19). Increasing powder amount to 15 mg increased the

proportions of germilings with short radicles to79.2 % of the total and decreased the proportion of germilings with medium radicle extension to 20.8%, respectively (Appendix 19).

For the stem powder at the lowest concentration only short and medium radicle extension were displayed with proportions of 79.2 and 20.8%, respectively (Fig. 4.4, Appendix 5 and 19). Increasing the amount of powder to 10 mg increased the proportions of germilings with medium and long radicle extension to 83.3 and 12.5%, respectively with only 4.2% germilings displaying very short radicle extension. Increasing the amount of powder to 15 mg resulted in further radicle shortening as the number of germilings displaying very short and short radicle extension was increased each to 50%, and 50%, respectively and no medium or long radicles were observed.

For *Striga* millet strain (Fig.4.7 A-C, Appendix 18/) 70.86% of the roots powder samples at the lowest level (5mg/well) showed satisfactory to excellent GIA. Increasing powder level to 10 mg/well increased the number to 95.8%. a further increase in powder level to 15 mg/well repressed the number to 25.1% and most of the samples (45.8%) showed moderate GIA. For the stem powder at its lowest level (5mg/well) 41.75% of the samples displayed satisfactory to excellent GIA. Increasing powder level to 10 mg/well increased the number to 66.7%. A further increase in powder level to15 mg/well resulted in 16.7 and 4.2% of the samples displaying satisfactory and excellent GIA (Fig. 4.9 and Appendix 18).

For the leaves powder (Fig. 4.11 A-C, Appendix18) at 5 mg/well only 16.7% of the samples displayed satisfactory to excellent GIA. Increasing powder to 10 mg/well increased the number to 29.2%. At 15 mg/well 4.2%

of the samples showed excellent GIA, none showed satisfactory GIA and most of the samples (79.2%) showed poor GIA.

For the *Striga,* millet strain, radicle extension followed more or less similar trends to that of sorghum (Figs. 4.2, 4.4, 4.6, 4.8, 4.10, 4.12, Appendices, 9, 11, 13 and 19). For the root powder at the lowest concentration (5 mg/well) none of the germilings displayed very short radicle extension. However, germilings displaying short, medium and long radicle extension were 20.8, 62.5 and 16.7%, respectively (Fig. 4.8 A-C, Appendix 19). Increasing the powder concentration to 10 mg/well increased the proportion of germilings with short radicles to75% and decreased the proportion of those displaying medium radicle extension to 25% (Fig. 4.8, Appendix 19). Increasing powder level to 15 mg increased the number of germilings exhibiting short radicle length to 87.5%.

For stem powder at its lowest level (5mg/well) only germilings with short (95.8%) and medium (4.2%) radicle extension were observed (Fig. 4.10 A and Appendix 19). Increasing powder amount to 10 mg/well resulted only in germilings with very short radicles (16.7%) and medium (83.3%) radicle extension (Fig. 4.10 B and Appendix 19). Increasing powder to 15 mg/well resulted in further radicle shortening. The number of germilings with very short radicles and those with short radicles was increased to 41.7 and 58.3% of the total, respectively (Fig. 4.10 C and Appendix 19).

For leaves powder radicle extension varied between very short and short. However, the proportion showed dependence on powder amount (Fig. 4.12, Appendix 19). At the lowest powder amount the proportion of germilings with very short radicles and those with short radicles were 41.7 and 58.3%, respectively (Fig. 4.12 A, Appendix 19). The corresponding figures for the

powder at 10 mg/well were 50 and 50% (Fig. 4.12 B, Appendix 19). A further increase in powder amount to 15 mg/well increased the number of germilings showing very short radicles to 87.5% (Fig. 4.12 C, Appendix 19)

It is evident from the results that powders from all parts of cowpea, irrespective of genotype, induced both germination and radicle extension at lower concentrations but were inhibitory at the highest concentration (Figs 4.12 A-C Appendix19). A reduction in germination reduces the effective incoulum pressure on the host roots. Furthermore, the reduced radicle extension may decrease successful contact with the host and thus decreases the probability of contact between the parasite radicles and the host roots. Failure of radicles to come in contact with host roots within 5 days subsequent to germination leads to death of germilings (Babiker *et al*., 2007)

Based on the lowest concentration of the root exudates, irrespective of genotype, the GIA on *Striga*, sorghum strain, was little to negligible during the first 72 h AIOE (Table 4.1). However, on further extension of sampling time to 96 h the GIA progressively increased, reached a peak at 216h AIOE and subsequently declined, albeit often not significantly. For a given sampling period, increasing root exudates concentration by 2-to-3-fold, invariably, resulted in a decrease in GIA (Table 4.1).

Variations in radicle extension with exudates concentration, sampling time and cowpea genotype, often mirrored imaged the GIA (Tables 4.1 and 4.2).The decrease in GIA and RE with concentration of the root exudates, which is in agreement with those of cowpea powder found in this study (Figs. 4.2-4.7), suggests concurrent production of both germination stimulants and inhibitors. A similar finding was reported by Wareswara *et al*.(1993) in sorghum root exudates. However, more subtle interactions

involving the stimulants as allelochemicals cannot be ruled out. Several allelochemicals and herbicides, because of feedback inhibition, were reported to be stimulatory at lower concentrations and inhibitory at higher concentrations (Babiker, 1976).

For *Striga,* millet strain, based on the lowest exudates concentration, variations in GIA and RE with time, in general, followed the same trends as noted for sorghum strain (Tables 4.1-4.4). However, the time for attainment and sustenance of the highest GIA showed some variations with genotype. Root exudates from genotype B301 attained and maintained relatively high GIA (40.9-45.2% germination) at 144-240h AIOE (Table 4.3). For genotype T100K-901-6 the highest GIA (43.6% germination) was attained 192h AIOE and then significantly declined on further extension of the sampling time to 216 h or more. For genotype T198K-317-2 maximum GIA was attained at 216 h AIOE. However, in contrast to *Striga* sorghum strain the GIA, for a given sampling time, tended to increase with exudate volume. At peak GIA for genotype B301 (216h AIOE) germination was 43.8, 52.7 and 61.4% at the lowest (5 µl), middle (10 µl) and highest (20 µl) concentration, respectively.GIA for the genotype T100K-901-6 at its peak (192 h AIOE) effected 43.6, 48.7 and 52.8% germination at the lowest (5 µl), middle (10 µl) and highest (20 µl) concentration, respectively. For genotype T198K-317-2 the corresponding germination figures were 52, 53.6 and 65%, respectively (Table 4.1)

RE in *Striga,* millet strain, mirror imaged the GIA as it consistently increased with sampling time and the amount of root exudates used (Tables 4.3 and 4.4). For genotype B301 RE showed maximum values (5.1-8.6×10^{-2} µm) at 216 h AIOE, while for the genotypes T100K-901-6 and T198K-317-

2 maximum values (5.2-7.9×10^{-2}µm and 5,7-9×10^{-2} µm) were displayed 248 and 216 h AIOE,respectively (Tables 4.3 and 4.4).

Solution pH often had no significant effects on GIA of root exudates of cowpea genotype B301, although it showed a tendency to be more active at neutral pH (pH7) (Table 4.5). The GIA of root exudates of cowpea T100K-901-6 appeared to be higher than that of B301 and showed a clear response to pH and was, invariably, significantly higher at pH7 than at the lower or higher pH levels (Table 4.5).). Furthermore, the exudate, irrespective of cowpea genotype, was more active on the millet strain than on the sorghum strain. Moreover, the GIA of the exudates decreased with concentration for the sorghum strain, whereas for the millet strain the activity increased with exudates concentration. These results when taken in conjunction with the lactonic nature of root parasitic weeds germination stimulants in plants including cowpeas (Parker and Riches, 1993) are in line with instability of strigolactones in alkaline and acidic media (Babiker and Hamdoun, 1983). However, more subtle interactions involving penetration and accumulation of the stimulants in the seeds or differential activity of certain enzymes in the seeds cannot be ruled out. Furthermore, the differential activities of the exudates on sorghum and millet strains of the parasite substantiate the results of the experiment on kinetics of stimulants production in cowpea where a tendency of higher GIA on *Striga*, millet strain was displayed (Table 4.1).

Variability in response of the two *Striga* strains to germination stimulants in root exudates of cowpea is consistent with their response to natural and synthetic germination stimulants (Parker and Riches, 1993). Resistance of sorghum to *Striga*, millet strain, and that of millet to *Striga* sorghum strain were reported to be at the germination stage (Wilson-Jones, 1954; Parker

and Riches, 1993). It is noteworthy that a plant species may produce several strigolactones which differ significantly in their germination inducing activity and that the main strigolactones from sorghum and cowpea were reported to be sorgolactone and alectrol, respectively (Matusova *et al*., 2005). It is noteworthy that stereochemistry plays a crucial role in GIA of strigolactones and in host specificity (Matusova et al., 2005).

GIA of root exudates collected from sorghum and cowpea genotypes, progressively increased with concentration (Table4.6). However, GIA from cowpea genotype T100K-901-6 showed high germination (67.6%) at the lowest concentration (5µl), with no significant change on raising exudates concentration to 30µl. However, as pointed out by Sato *et al*. (2005), it is not possible to distinguish between qualitative and quantitative differences based on bioassay. Chromatographic analyses using TLC (Figs. 13) did not show clear cut differences in composition of the root exudates of the two cowpea genotypes. Column Chromatographic (CC) and HPLC analyses (Figs. 14 -19), on the other hand, showed distinct qualitative differences. Column chromatography showed different profiles. For sorghum the column effluents revealed different fractions with different polarities. Fractions with low polarity (ethlyacetate <50%) where maximum GIA (57% germination) was displayed by the fraction eluted when ethylacetate was 30% of the developing solvent and fractions with high polarity (ethyyacetate >50%) where maximum GIA (55% germination) was displayed by the fraction eluted when ethylacetate was 70% of the developing solvent. For the cowpea B301 (Fig.4.16) both non-polar (ethylacetate < 50%) and polar fractions (ethylacetate >50%) with GIA were detected. The polar fractions were the most active and the maximum GIA (65% germination) was displayed by the

fraction eluted when ethylacetate, in the developing solvent, was raised to 70%. For cowpea genotype T100K-901-6 none of the non-polar fractions showed GIA. However, polar fractions (ethylacetate >50%) showed considerable GIA. The highest, 58 and 56 %, germination was displayed by fractions eluted when ethylacetate in the developing solvent was raised to 70 and 80%, respectively (Fig.4.16).

The qualitative difference in composition of the root exudates was further substantiated by HPLC analyses (Figs.4.18, 19, 20). For sorghum GIA was confined to fractions with Rt 10, 15 and 20 min. For cowpea B301 GIA was displayed by fractions with Rt 10, 15 and 25 min, while for cowpea T100K-901-6 GIA was confined to fractions with Rt 5, 10, 15, 20 and 25 min.

In-situ germination and attachment of *Striga*, sorghum strain, to cowpea as revealed by the rhizotron study (Table 4.7 and Plate 4. 1) showed that cowpea induced high germination and that attachment of the parasite readily occurred. However, no further development was incurred as the plumular end remained within the seed coat. Such performance indicates developmental arrest attributable to failure of haustorial hyphae or intrusive cells to establish connection with cowpea xylem. This finding is in line with that reported by Hood *et al*., (1998) for *S. asiatica* in cowpea where resistance was reported to be due arrestment of penetration in the outer cortical cells due to degeneration of the distalmost cells of the endophyte (Hood *et al*., 1998). Cowpea is not parasitized by *S. hermothica*, however, it is a host for the closely related species *S. gesneriodies*.

In the greenhouse experiment, irrespective of intercropping, *Striga* emergence progressively increased with seed bank size (Table 4.8). However, intercropping with cowpea, irrespective of time and seed bank

size delayed and repressed *Striga* emergence, significantly in comparison to sole sorghum where the reductions varied between 50 and 100% and 1and 30 % at the lowest and highest seed bank size, respectively. The reduction in the parasite emergence could be as pointed out by Parker and Riches (1993), in similar situations, due to induction of germination by the advancing cowpea roots away from those of sorghum and/or competition between cowpea roots and those of sorghum for the juvenile *Striga* germilings.

Striga dry weight, invariably, increased at a faster rate on sole than intercropped sorghum (Table. 4. 9). At the lower seed bank size *Striga*, dry weight from under sorghum intercropped with cowpea B301 increased by 25% in comparison with that from sole sorghum. However, on T100K-906-1 *Striga* dry weight was reduced by 22.8%. At *Striga* seed bank size of 2 mg/pot the parasite dry weight was reduced by 24.7 and 48.7 on intercropping with cowpea B301 and T100K-901-6, respectively. At *Striga* seed bank size of 4, 8, 16 and 32 mg/pot intercropping with cowpea B301 reduced *Striga* dry weight by 39.5, 47.0, 49.3 and 49.2.%, respectively. The corresponding figures for cowpea T100k-901-6 were 59.5. 62.2. 61.6 and 61.7%. The reduction in *Striga* dry weight is consistent with the reductions in emergence instigated by intercropping with cowpea. Furthermore reduced transpiration and photosynthesis of the parasite resulting from shading by the intercrop, as reported in similar situations (Parker and Riches, 1993, Babiker, 2007), could account, at least in part, for a considerable proportion of the loss in dry weight.

Sorghum height, irrespective of intercropping, displayed a progressive decrease with *Striga* seed bank size (Table 4.10). Early in the season (30 DAS) sole sorghum showed significant reductions in height, only, at the

highest *Striga* seed bank size. However, late in the season *Striga* seed bank size of 4 mg/pot or higher resulted in significant reductions. The intercropped sorghum appeared to display better growth than sole sorghum. However, though the experiments were undertaken in the same area at the same time, no hard and fast comparison can be made.

The crop height, irrespective of cowpea genotype, progressively declined with *Striga* seed bank size. Sorghum intercropped with cowpea B301 displayed significant reduction, irrespective of time, when *Striga* seed bank was 4 meg/pot or more. A similar trend in crop height was displayed by sorghum intercropped with cowpea T100K-901-6.

Leaf area, irrespective of intercropping, decreased with *Striga* seed bank size (Table. 4.10). Leaf area was invariably higher for intercropped sorghum. Early in the season, 30 DAS, sole sorghum displayed significant reduction in leaf area when the *Striga* seed bank size was 8 mg/pot or higher. At 60 DAS significant reduction in leaf area (56.7%) was only achieved at the highest seed bank size (32 mg/pot). At 90 DAS significant reductions in leaf area were attained at seed bank size of 16 and 32 mg/pot. The maximum reductions attained at the highest seed bank size, across time, were 66.4, 56.7 and 51%, respectively.

In sorghum intercropped with cowpea, B301 no significant reduction in sorghum leaf area was observed early in the season. However, at 60 DAS a significant reduction in leaf area was attained at *Striga* seed bank of 16 and 32 mg/pot. The highest reductions attained, across time, were 67.4, 37.3 and 34.16% at 30, 60 and 90 DAS.

In sorghum intercropped with cowpea T100K-901-6 reductions in leaf area were not significant, irrespective of *Striga* seed bank level. The maximum

reductions attained at the highest *Striga* seed bank size were 33.9, 25.3 and 24,4% at 30, 60 and 90DAS, respectively.

As indicated by the magnitude of the reduction in leaf area with time it would appear that limited recovery in leaf area occurred with time. Furthermore, sole sorghum displayed the highest reduction in leaf area. Sorghum intercropped with cowpea genotype T100K-901-6 displayed less reduction in leaf area than the one intercropped with cowpea B301.

Sorghum dry weight, irrespective of intercropping, progressively declined with *Striga* seed bank. However, dry weight of intercropped sorghum, irrespective of *Striga* seed bank size, was invariably higher than that of sole sorghum. The dry weight of intercropped *Striga* free sorghum was about 2-fold that of the respective *Striga* free sole sorghum. This finding is at variance with that of Hamad Elneiel (2012), who reported a decline in dry weight of cowpea intercropped sorghum, irrespective of *Striga* infestation. However, the results are consistent with those of Ledgard and Steele, (1992) and Musyoka (2014). Such a difference could be attributed, at least in part, to differences in the genotypes used. In the present stud cowpea genotypes with prostrate and spreading habit were employed (Plate 3.3). Furthermore, cowpea is a legume and a nitrogen fixer. Transfer of nitrogen and possibly phosphorus from legumes to neighbouring non-leguminous plants from decaying cowpea roots and nodules has been reported by several authors (Ledgard and Steele, 1992; Musyoka, 2014).

In the field experiment treatments comprising sorghum intercropped with cowpea, irrespective of genotype, dressed with *B. megatherium*, *R.leguminosarum* or their combinations sustained and maintained significantly less *Striga* emergence than sole sorghum (Table 4.13). At 30

DAS reductions in *Striga* emergence on sorghum intercropped with cowpea B301dressed with *B. megatherium***,** *R.leguminosarum* and their combination was 66.7-79%, 71.9-73.3% and 77.4-100% in comparison to that on sole sorghum, respectively (Table 4.13). The corresponding figures for sorghum intercropped with cowpea T100k-901-6 were 71-73%, 75.2-95% and 81.6-100%. It is noteworthy, albeit differences between the individual treatments were often not significant, that dressing cowpea, irrespective of genotype, with the combination *B. megatherium* and *R.leguminosarum* was the most effective in suppressing the parasite emergence These findings corroborate the results of the greenhouse experiment (Table 4.8) and are in agreement with those of Musyoka (2014) in Eastern Kenya where cowpea inoculation with a *Rhizobium* sp. together with phosphorus fertilization increased nodulation in cowpea by 1000-3277%, and phosphorus and nitrogen uptake by sorghum, a companion crop, by more than 1-fold. Similarly grain and straw yields were increased by about 2-3-fold. These findings clearly indicate that intercropping reduced *Striga* emergence and enhanced sorghum growth and yield and that the suppressive effects on the parasite could be as pointed out by Musyoka (2014) due to enhancement of soil fertility.

At 45 DAS all treatments comprising of intercropping plus inoculation with *B. megatherium*, *R.leguminosarum* and their combinations increased the length of the first sorghum internode (Table 4.15). However, only intercropping with cowpea B301inoculated with the combination of *B. megatherium* and *R. leguminosarum* resulted in a significant increase (50%). At 90 DAS only intercropping with cowpea, irrespective of genotype, inoculated with the bacterial combination yielded a significant increase in

length of the first internode. However, sorghum height was not significantly affected by any of the treatments (Table 4.15).

All treatments increased head length, significantly, in comparison to sole sorghum (Table 4.16). However, despite the lack of significant differences between the individual treatments, intercropping with cowpea inoculated with the bacterial combination achieved the highest increment.

All treatments increased head size in comparison to the sole sorghum control (Table4.16). Among all the treatments only intercropping with cowpea B301 inoculated with *B. megatherium* resulted in insignificant increment (33.6%). The highest increment in head size (122.4%) was attained by intercropping with cowpea B301inoculated with the combination *B. megatherium* and *R. leguminosarum* followed by intercropping with cowpea T100K-901-6 inoculated by the bacterial combination where the increment was 94.5%..

All treatments increased the 100 seed weight in comparison to sole sorghum (Table4.16). However, except intercropping with cowpea B 301 inoculated with *B. megatherium* and cowpea T100k-901-6 inoculated with *R. leguminosarum* all the other treatments resulted in significant increments. Of all treatments intercropping with cowpea B301 inoculated with the combination *B. megatherium* and *R.leguminosarum*gave achieved the highest increment in the 100 seed weight (66.7%) followed by intercropping with cowpea T100K-901-6, when similarly inoculated, where the increment was 50%.

Suppression of *Striga* emergence and dry weight and the increase in sorghum dry weight, head length, head size and the 100 seed weight and the association of the maximum increments with the inoculation with the combination of *R. leguminosarum* and *B. megatherium* is consistent with

reports by Ledgard and Steele (1992) and Mausyoka (2014) who observed over 2-3-fold increase in sorghum and grasses growth attributes on intercropping of sorghum with cowpea inoculated with a commercial *Rhizobium* strain together with further supplementation with inorganic phosphorus. Ledgard and Steele (1992) and Mausyoka (2014) attributed the improvement of cowpea intercropped sorghum and grasses in legume/grass pastures to increased availability of nitrogen through biological nitrogen fixation. Ledgard and Steele (1992) estimated the amount of nitrogen transferred below ground to the associated grasses, predominantly through decomposition of legumes roots and nodules, to be 3-102 kg $ha^{-1}yr^{-1}$. The amount of nitrogen fixed from atmospheric nitrogen in legume/grass pastures throughout the world was estimated to be 682 kg ha^{-1} yr^{-1}.

Nitrogen and phosphorus are the principle elements limiting land productivity in sub-Saharan Africa (Mausyoka, 2014). Furthermore, *Striga* infestation and damaging effects are also linked with low soil fertility and that nitrogen and phosphorus play key roles in the parasitic syndrome (Babiker, 2007). The use of legumes together with inoculation with *Rhizobium* as revealed by Ledgard and Steele (1992) and Mausyoka (2004) and phosphorus releasing bacteria as revealed by this study (Table 4.13-4.16) may provide the cheapest viable option to the resource- constrained sub-Saharan African farmers to improve soil fertility and consequently improve crop performance and *Striga* management.

Conclusions and recommendations:

Conclusions:

- Roots, stems and leaves powder as well as the root exudates induced germination of *S. hermonthica* sorghum and millet strains. High amount of powder reduced germination and radicle length of both strains.The root exudates of the genotypes tested was more effective on the millet strain where germination and radicle extension increased with concentration in contrast to the sorghum strain where both germination and radicle extension decreased with concentration.
- The cowpea genotypes B301 and T100K-906-2 have a prostrate growth habit and are an ideal choice for intercropping with sorghum. The latter genotype appears to be less competitive than the former.
- Intercropping with cowpea dressed with the combination *R. leguminosarum*TAL1399 and *B. megaterium* suppressed *Striga* emergence and growth and increased sorghum, head length, head size and 100 seed weight.

Recommendations:

- The technical and economic feasibilities of integrating mulching, trap cropping and intercropping with cowpea genotypes B301 and T100K-901-6, the seeds of which are to be dressed with *R.leguminosarum* TAL1399and the phosphorus releasing bacterium *B. Megatherium var phosphaticum* with existing measures of *Striga* management should be considered and evaluated under farmer's field conditions adopting a participatory approach.
- The greenhouse and field experiments should be repeated with millet.

- Further laboratory experiments are to be undertaken to delineate the nature of the germination stimulants in root exudates of the cowpea genotypes B301 and T100k-902-6 with special emphasis on the differential response of the *Striga* strains.

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Appendices

Appendix1. List and sources of cowpea genotypes used in the study.

Entry	(Accession No or name)	Source	Entry	(Accession No or name)	Source
1	Aloka	IITA	**13**	T183D-442	IITA
2	T198k-503-1	IITA	**14**	T185F-867-5	IITA
3	T199K-214-2	IITA	**15**	T186D-1010	IITA
4	T199K-377-1	IITA	**16**	T186F-2014-1	IITA
5	B301	IITA	**17**	T193K-93-10	IITA
6	T198K-409-4	IITA	**18**	T195M-190	IITA
7	T197K-499-35	IITA	**19**	T195M-309	IITA
8	T199K-573-2-1	IITA	**20**	T197K-207-15	IITA
9	T100K-1263	IITA	**21**	T197K-207-21	IITA
10	IFE Brown	IITA	**22**	IT97K-499-39	IITA
11	T100K-901-6	IITA	**23**	T197K-556-6	IITA
12	T182E-18	IITA	**24**	T198K-317-2	IITA

Appendix 2. Effects of cowpea root powder on germination of S. *hermonthica* (sorghum strain).

Cowpea genotypes	*Striga hermonthica* germination (%)			
	Powder (mg/well)			
	5	10	15	Mean
Aloka	60.3 (± 3.1) [1]	64.3 (± 1.7)	54.4 (± 0.8)	**59.7efghi**
T198K-503-1	69.0 (± 4.5)	81.2 (± 2.7)	54.9 (± 1.1)	**68.4bcdef**
T199K-214-2	62.0 (± 2.8)	67.1 (± 4.6)	48.6 (± 4.8)	**59.2efghi**
T199K-377-1	65.1 (± 6.8)	86.1 (± 2.1)	65.3 (± 4.6)	**72.2abcd**
B301	63.8 (± 1.6)	**74.2 (± 1.6)**	61.6 (± 7.2)	**66.6cdefgh**
T198K-409-4	41.0 (± 3.1)	51.4 (± 0.9)	60.1 (± 8.4)	**50.9ij**
T197K-499-35	67.7 (± 4.9)	**76.9 (± 1.6)**	50.5 (± 1.5)	**65.0cdefgh**
T199K-573-2-1	67.4 (± 1.7)	**77.7 (± 4.4)**	56.6 (± 2.6)	**67.2cdefg**
T100K-1263	67.4 (± 4.5)	**70.2 (± 8.5)**	61.7 (± 6.0)	**66.4cdefg**
IFE brown	**73.4 (± 3.7)**	86.0 (± 1.4)	**75.4 (± 1.8)**	**78.3ab**
T100K-901-6	63.2 (± 4.9)	**78.8 (± 3.4)**	52.8 (± 0.4)	**64.9cdefgh**
T182E-18	32.8 (± 7.9)	53.5 (± 0.6)	26.0 (± 3.5)	**37.4j**
T183D-442	65.7 (± 1.5)	67.2 (± 5.6)	61.2 (± 2.3)	**64.7cdefgh**
T185F-867-5	67.7 (± 2.8)	**75.3 (± 1.6)**	65.9 (± 3.1)	**69.6bcdef**
T186D-1010	50.0 (± 2.5)	66.4 (± 3.9)	49.9 (± 1.3)	**55.4ghi**
T186F-2014-1	**72.1 (± 1.7)**	81.7 (± 2.1)	58.0 (± 5.4)	**70.6bcde**
T193KK-93-10	62.6 (± 4.1)	**72.3 (± 2.3)**	66.9 (± 3.6)	**67.3cdefg**
T195M-190	62.7 (± 2.5)	68.5 (± 1.8)	40.9 (± 1.3)	**57.4fghi**
T195M-309	60.6 (± 2.3)	**72.4 (± 1.2)**	55.8 (± 1.6)	**62.9cdefghi**
T197K-207-15	55.8 (± 1.7)	57.0 (± 3.4)	50.9 (± 3.7)	**54.6ghi**
T197K-207-21	**70.3 (± 1.4)**	67.2 (± 2.6)	55.6 (± 1.3)	**64.4cdefgh**
IT97K-499-39	**74.0 (± 3.3)**	85.2 (± 3.6)	61.0 (± 2.6)	**73.4abc**
T197K-556-6	59.9 (± 2.7)	**72.9 (± 5.3)**	54.3 (± 5.4)	**62.4defghi**
T198K-317-2	85.5 (± 3.7)	80.7 (± 1.4)	**77.7 (± 5.5)**	**81.3a**
Mean	**63.3b**	**72.3a**	**56.9**	
Two- Way ANOVA				
Cowpea genotypes, CG	**16.0*** **			
Powder levels, PL	**95.9*** **			
CG*PL	**2.2****			
CV%	**14.7**			

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix 3. Influence of cowpea root powder on *S. hermonthica* radicle extension (Sorghum strain)

	Radicle length (10^{-2}×µm) Powder (mg/well)			
Genotypes	**5**	**10**	**15**	**Mean**
Aloka	10.8 (±0.5)	9.0 (±0.3)	7.3 (±0.1)	**9.1 bc**
T198k-503-1	13.7 (±1.3)	10.0 (±0.3)	8.2 (±0.2)	**10.6 abc**
T199K-214-2	13.1 (±0.6)	9.3 (±0.7)	6.8 (±0.3)	**9.7 bc**
T199K-377-1	13.7 (±1.1)	10.7 (±0.6)	7.5 (±0.3)	**10.6 abc**
B301	15.6 (±0.6)	10.8 (±0.7)	5.7 (±0.8)	**10.7 abc**
T198K-409-4	9.5 (±0.5)	7.9 (±0.4)	5.3 (±0.2)	**7.6 c**
T197K-499-35	15.5 (±0.4)	12.4 (±0.1)	10.3 (±0.1)	**12.7 abc**
T199K-573-2-1	11.4 (±0.1)	9.7 (±0.3)	7.2 (±0.1)	**9.4 bc**
T100K-1263	19.3 (±1.0)	14.9 (±1.7)	12.4 (1.1)	**15.5 ab**
Ife Brown	11.3 (±0.3)	9.1 (±0.5)	6.7 (±0.2)	**9.0 bc**
T100K-901-6	13.2 (±0.8)	11.1 (±0.5)	8.5 (±0.2)	**10.9 abc**
T182E-18	12. (±0.3)	10.7 (±0.3)	8.9 (±0.4)	**10.5 bc**
T183D-442	11.9 (±0.2)	9.5 (±0.3)	7.8 (±0.1)	**9.7 bc**
T185F-867-5	11.2 (±0.3)	9.4 (±0.1)	8.0 (±0.3)	**9.5 bc**
T186D-1010	16.3 (±0.6)	10.5 (±0.4)	7.9 (±0.3)	**11.6 abc**
T186F-2014-1	12.0 (±0.2)	9.5 (±0.2)	7.4 (±0.2)	**9.6 bc**
T193K-93-10	13.2 (±0.6)	10.9 (±0.2)	9.0 (±0.1)	**11.0 abc**
T195M-190	13.2 (±0.9)	10.2 (±0.2)	9.3 (±0.3)	**10.9 abc**
T195M-309	15.3 (±0.8)	12.2 (±0.2)	10.5 (±0.2)	**12.7 abc**
T197K-207-15	15.1 (±0.4)	10.3 (±0.5)	7.0 (±0.3)	**10.8 abc**
T197K-207-21	13.8 (±0.4)	12.1 (±0.2)	10.9 (±0.2)	**12.3 abc**
IT97K-499-39	11.6 (±0.3)	9.6 (±0.3)	6.8 (±0.3)	**9.3 bc**
T197K-556-6	34.9 (±23.6)	9.4 (±0.1)	7.6 (±0.2)	**17.3 a**
T198K-317-2	13.4 (±0.7)	11.1 (±0.4)	10.2 (±0.2)	**11.6 abc**
Mean	**14.2 a**	**10.4 b**	**8.2 c**	
Two- Way ANOVA				
Cowpea genotypes, CG	**1.6***			
Powder levels, PL	**27.6****			
CG*PL	**0.9 ns**			
CV%				

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix .4.Effects of cowpea stem powder on germination of *Striga hermonthica* (sorghum strain)

	***Striga hermonthica* germination (%)**			
	powder (mg/well)			
Cowpea genotype	**5**	**10**	**15**	**Mean**
Aloka	53.8 (± 1.3) [1]	66.4 (± 4.0)	41.4 (± 2.6)	**53.9efghi**
T198K-503-1	45.7 (± 2.2)	69.5 (± 6.1)	44.4 (± 3.1)	**53.2efghi**
T199K-214-2	29.0 (± 5.8)	57.0 (± 2.9)	36.7 (± 3.7)	**40.9i**
T199K-377-1	56.0 (± 3.2)	**73.8 (± 2.8)**	52.3 (± 3.1)	**60.7abcdef**
B301	41.0 (± 4.0)	56.0 (±1.6)	40.2 (± 2.9)	**45.7hi**
T198K-409-4	45.7 (± 4.4)	60.0 (± 2.7)	35.5 (± 1.3)	**47.1ghi**
T197K-499-35	41.7 (± 4.2)	57.8 (± 1.4)	39.5 (± 1.8)	**46.3hi**
T199K-573-2-1	68.3 (± 3.3)	**71.2 (± 5.6)**	55.8 (± 4.9)	**65.1abcde**
T100K-1263	57.2 (± 5.3)	61.2 (± 6.7)	62.1 (± 8.0)	**60.2abcdef**
IFE brown	65.2 (± 1.6)	**77.4 (± 3.7)**	60.1 (± 7.7)	**67.6abc**
T100K-901-6	60.0 (± 3.1)	**70.5 (± 5.3)**	49.4 (± 10.3)	**61.9abcde**
T182E-18	38.3 (± 5.1)	50.9 (± 1.7)	36.8 (± 1.7)	**42.0i**
T183D-442	55.0 (± 0.7)	67.4 (± 5.3)	49.1 (± 1.5)	**57.1cdefgh**
T185F-867-5	**71.0 (± 2.7)**	**74.9 (± 2.4)**	61.1 (± 3.1)	**69.0ab**
T186D-1010	47.4 (± 4.3)	57.9 (± 1.0)	41.9 (± 1.5)	**49.1fghi**
T186F-2014-1	66.4 (± 3.0)	**78.9 (± 1.0)**	65.4 (± 6.5)	**70.2a**
T193KK-93-10	57.3 (± 1.7)	**70.2 (± 4.6)**	54.9 (± 1.2)	**60.8abcdef**
T195M-190	43.5 (± 2.6)	57.5 (± 3.2)	39.6 (± 2.9)	**46.8ghi**
T195M-309	69.1 (± 0.9)	**75.1 (± 0.6)**	55.1 (± 2.1)	**66.4abcd**
T197K-207-15	52.3 (± 1.0)	62.3 (± 1.1)	53.6 (± 3.1)	**56.0defgh**
T197K-207-21	56.2 (± 1.6)	63.1 (± 2.9)	47.4 (± 2.7)	**55.6defgh**
T97K-499-39	66.9 (± 1.4)	**72.9 (± 1.8)**	54.7 (± 1.5)	**64.8abcde**
T197K-556-6	60.0 (± 2.7)	**74.0 (± 1.4)**	41.7 (± 1.3)	**58.6bcdefg**
T198K-317-2	**74.6 (± 2.9)**	53.3 (± 1.7)	68.2 (± 6.0)	**65.4abcd**
Mean	**55.3b**	**65.8a**	**49.5c**	
Two- Way ANOVA				
Cowpea genotypes, CG	**14.7*** **			
Powder levels, PL	**103.7*** **			
CG*PL	**2.2*** **			
CV%	**16.1**			

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix .5. Influence of cowpea stem powder on *S. hermonthica* (sorghum strain) radicle extension

	Radicle extension (10^{-2}× µm)			
	Cowpea genotypes stems powder levels (mg)			
Genotypes	**5**	**10**	**15**	**Mean**
Aloka	6.5 (±0.6)	6.2 (±0.5)	6.5 (±0.2)	**6.4 def**
T198k-503-1	6.7 (±0.3)	5.3 (±0.2)	4.4 (±0.2)	**5.5 ef**
T199K-214-2	9.3 (±0.2)	6.5 (±0.5)	4.9 (±0.2)	**6.9 cdef**
T199K-377-1	5.5 (±0.2)	5.0. (±0.3)	4.6 (±0.2)	**5.0 ef**
B301	6.2 (±0.6)	4.4 (±0.3)	3.3 (±0.4)	**4.6 f**
T198K-409-4	8.9 (±0.3)	6.3 (±0.3)	4.6 (±0.2)	**6.6 cdef**
T197K-499-35	10.0 (±0.3)	6.3 (±0.2(	4.0 (±0.3)	**6.8 csef**
T199K-573-2-1	7.4 (±0.1)	5.3 (±0.1)	3.9 (±0.1)	**5.5 ef**
T100K-1263	12.3 (±1.8)	11.4 (±1.7)	7.9 (±0.9)	**10.5 ab**
Ife Brown	9.2 (±0.4)	8.8 (±0.3)	7.7 (±0.2)	**8.6 bcd**
T100K-901-6	9.8 (±0.3)	7.7 (±0.2)	5.7 (±0.3)	**7.7 bcde**
T182E-18	7.1 (±0.3)	5.9 (±0.2)	4.3 (±0.2)	**5.8 def**
T183D-442	9.9 (±0.1)	8.0 (±0.4)	4.7 (±0.3)	**7.3 cdef**
T185F-867-5	14.6 (±0.3)	11.9 (±0.3)	9.9 (±0.2)	**12.1 a**
T186D-1010	6.0 (±0.2)	5.0 (±0.2)	3.8 (±0.1)	**4.9 ef**
T186F-2014-1	11.0 (±0.1)	10.1 (±0.2)	7.4 (±0.2)	**9.5 abc**
T193K-93-10	8.2 (±0.3)	6.5 (±0.2)	5.0 (±0.2)	**6.6 cdef**
T195M-190	7.8 (±0.2)	7.1 (±0.2)	6.4 (±0.3)	**7.1 cdef**
T195M-309	8.8 (±0.2)	7.5 (±0.2)	7.3 (±0.2)	**7.9 bcde**
T197K-207-15	9.1 (±0.4)	6.1 (±0.6)	3.9 (±0.2)	**6.4 def**
T197K-207-21	9.9 (±0.3)	8.8 (±0.2)	7.3 (±0.1)	**8.7 bcd**
IT97K-499-39	9.3 (±0.4)	7. (±0.4)	4.8 (±0.4)	**7.0 cdef**
T197K-556-6	10.9 (±0.2)	9.9 (±0.3)	7.4 (±0.1)	**9.4 abc**
T198K-317-2	8.5 (±0.3)	6.8 (±0.3)	5.1 (±0.2)	**6.8 cdef**
Mean	**8.9 a**	**7.2 b**	**5.6 c**	
Two- Way ANOVA				
Cowpeagenotypes,G	**57.9*** **			
Powder levels, PL	**376.5*** **			
CG*PL	**3.7*** **			
CV%				

*=P<0.05;**= P<0.01; ***=P<0.001 and ^{ns}= Non significant

Appendix.6. Effects of cowpea leaves powder on germination of *Striga hermonthica* (sorghum strain)

Cowpea genotypes	*Striga hermonthica* germination (%) Powder (mg/well) 5	10	15	Mean
Aloka	34.4 (± 3.5) [1]	55.1 (± 1.9)	37.0 (± 5.3)	**42.2fgh**
T198K-503-1	38.4 (± 5.5)	63.8 (± 3.4)	36.0 (± 0.8)	**46.0efg**
T199K-214-2	37.1 (± 2.5)	47.9 (± 3.1)	31.9 (± 3.9)	**39.0ghi**
T199K-377-1	36.0 (± 1.8)	55.5 (± 2.6)	37.1 (± 2.8)	**42.9fgh**
B301	21.1 (± 3.3)	47.6 (± 1.6)	30.0 (± 4.2)	**32.9hi**
T198K-409-4	38.6 (± 2.9)	62.5 (± 9.7)	38.7 (± 1.1)	**46.6cdefg**
T197K-499-35	29.4 (± 2.9)	45.4 (± 3.2)	29.2 (± 2.0)	**34.7hi**
T199K-573-2-1	39.3 (± 0.9)	58.2 (± 5.4)	46.1 (± 3.7)	**47.9cdefg**
T100K-1263	64.3 (± 5.3)	38.2 (± 0.7)	37.7 (± 2.4)	**46.7defg**
IFE brown	66.4 (± 7.0)	**77.6 (± 0.9)**	66.5 (± 3.1)	**70.2a**
T100K-901-6	42.6 (± 4.5)	65.7 (± 2.7)	44.9 (± 1.2)	**51.1bcdef**
T182E-18	26.0 (± 2.0)	49.1 (± 1.3)	23.4 (± 5.7)	**32.9hi**
T183D-442	49.1 (± 2.8)	65.7 (± 5.8)	46.7 (± 2.4)	**53.8bcde**
T185F-867-5	53.7 (± 1.3)	**70.7 (± 2.5)**	53.3 (± 1.2)	**59.2b**
T186D-1010	40.1 (± 3.1)	54.2 (± 2.1)	37.0 (± 0.9)	**43.8efgh**
T186F-2014-1	55.3 (± 3.1)	66.8 (± 0.5)	52.8 (± 1.0)	**58.3bc**
T193KK-93-10	48.7 (± 1.9)	59.4 (± 1.3)	37.8 (± 1.7)	**48.6cdefg**
T195M-190	34.6 (± 7.7)	53.3 (± 5.2)	23.4 (± 1.8)	**37.1ghi**
T195M-309	40.8 (± 3.7)	45.7 (± 2.9)	17.9 (± 3.1)	**34.8hi**
T197K-207-15	49.6 (± 1.4)	58.2 (± 4.0)	44.0 (± 2.1)	**50.6bcdef**
T197K-207-21	48.0 (± 1.7)	56.3 (± 2.0)	41.4 (± 1.7)	**48.6cdefg**
T97K-499-39	67.0 (± 1.8)	66.0 (± 2.6)	38.0 (± 4.3)	**57.0bcd**
T197K-556-6	23.2 (± 2.8)	50.3 (± 1.1)	17.6 (± 1.8)	**30.4i**
T198K-317-2	47.0 (± 5.2)	18.7 (± 5.4)	22.4 (± 5.5)	**29.4i**
Mean [2]	**43.0b**	**55.5a**	**37.1c**	
Two- Way ANOVA				
Cowpea genotypes, CG	***24.1***			
Powder levels, PL	**163.0***			
CG*PL	**4.6****			
CV%	**17.5**			

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix.7. Influence of cowpea leaves powder on *S. hermonthica* (sorghum strain) radicle extension

	Radicle extension (10^{-2} ×µm) Powder (mg/well			
Cowpea genotypes	**5**	**10**	**15**	**Mean**
Aloka	6.1 (±0.5)	4.8 (±0.3)	3.0 (±0.1)	**4.6 cdef**
T198k-503-1	6.3 (±0.3)	4.6 (±0.2)	3.0 (±0.3)	**4.6 cdef**
T199K-214-2	6.5 (±0.7)	4.4 (±0.2)	2.3 (±0.2)	**4.4 cdef**
T199K-377-1	4.8 (±0.4)	3.2 (±0.2)	1.7 (±0.1)	**3.2 ef**
B301	4.5 (±0.1)	3.4 (±0.2)	2.6 (±0.3)	**3.5 def**
T198K-409-4	7.2 (±0.4)	5.4 (±0.2)	4.0 (±0.3)	**5.5 bcde**
T197K-499-35	7.6 (±0.1)	5.7 (±0.3)	3.2 (±0.6)	**5.5 bcde**
T199K-573-2-1	10.1 (±0.5)	8.1 (±0.2)	7.9 (±0.1)	**8.7 a**
T100K-1263	9.9 (±0.3)	7.8 (±0.3)	6.0 (±0.4)	**7.9 ab**
Ife Brown	10.4 (±0.6)	8.3 (±0.3)	6.5 (±0.3)	**8.4 a**
T100K-901-6	7.6 (±0.1)	6.7 (±0.2)	4.0 (±0.2)	**6.1 abcd**
T182E-18	3.9 (±0.2)	3.0 (±0.4)	1.9 (±0.2)	**2.9 ef**
T183D-442	8.6 (±0.2)	7.2 (±0.3)	4.0 (±0.1)	**6.6 abc**
T185F-867-5	9.9 (±0.3)	7.8 (±0.3)	5.4 (±0.3)	**7.7 ab**
T186D-1010	7.6 (±0.3)	4.8 (±0.5)	2.5 (±0.3)	**5.0 cdef**
T186F-2014-1	8.7 (±0.1)	7.6 (±0.2)	5.0 (±0.4)	**7.1 abc**
T193K-93-10	3.8 (±0.1)	3.2 (±0.3)	2.0 (±0.2)	**3.0 ef**
T195M-190	4.4 (±0.3)	3.9 (±0.2)	2.3 (±0.2)	**3.5 bef**
T195M-309	5.5 (±0.3)	3.9 (±0.1)	2.3 (±0.1)	**3.6 def**
T197K-207-15	3.9 (±0.5)	3.2 (±0.2)	2.6 (±0.3)	**3.2 ef**
T197K-207-21	6.3 (±0.3)	5.3 (±0.2)	4.5 (±0.2)	**5.4 bcde**
IT97K-499-39	9.8 (±0.4)	8.2 (±0.4)	7.1 (±0.3)	**8.4 a**
T197K-556-6	5.2 (±0.1)	3.4 (±0.1)	2.0 (±0.1	**3.5 def**
T198K-317-2	3.4 (±0.5)	2.5 (±0.1)	2.0 (±0.2	**2.6 f**
Mean	**6.7 a**	**5.2 b**	**3.7 c**	
Two- Way ANOVA				
Cowpea genotypes, CG		**126.1*** **		
Powder levels, PL		**627.4*** **		
CG*PL		**3.8*** **		
CV%				

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix 8. Effects of cowpea root powder on germination of *Striga hermonthica* (millet strain)

	***Striga hermonthica* germination (%)**			
	Powder (mg/well)			
Cowpea genotypes	**5**	**10**	**15**	**Mean**
Aloka	64.0 (± 3.5)	68.1 (± 2.0)	56.3 (± 3.5)	**62.8bcdef**
T198K-503-1	61.9 (± 2.8)	81.1 (± 4.4)	59.0 (± 3.1)	**67.3bcde**
T199K-214-2	**71.1 (± 5.3)**	68.8 (± 2.4)	49.9 (± 2.4)	**63.3bcdef**
T199K-377-1	59.9 (± 1.8)	**72.5 (± 4.1)**	55.1 (± 4.7)	**62.5bcdef**
B301	45.6 (± 0.7)	61.3 (± 4.1)	33.4 (± 5.5)	**46.8g**
T198K-409-4	53.1 (± 2.5)	59.7 (± 1.5)	42.2 (± 4.2)	**51.7fg**
T197K-499-35	54.3 (± 11.5)	64.2 (± 8.5)	49.1 (± 5.0)	**55.8efg**
T199K-573-2-1	**75.8 (± 1.4)**	80.4 (± 3.1)	56.9 (± 2.1)	**71.0bc**
T100K-1263	94.7 (± 2.4)	95.1 (± 1.9)	94.7 (± 1.0)	**94.8a**
IFE brown	**75.8 (± 2.5)**	**78.6 (± 1.9)**	56.2 (± 2.0)	**70.2bcd**
T100K-901-6	**79.0 (± 3.5)**	**74.5 (± 1.9)**	59.0 (± 3.8)	**70.8bc**
T182E-18	58.8 (± 3.2)	67.0 (± 0.3)	45.7 (± 4.1)	**57.2efg**
T183D-442	68.3 (± 6.6)	60.7 (± 5..8)	62.9 (± 1.9)	**63.9bcdef**
T185F-867-5	**78.4 (± 2.4)**	**76.1 (± 3.4)**	63.3 (± 4.1)	**72.6b**
T186D-1010	62.3 (± 5.3)	62.6 (± 1.6)	47.2 (± 1.7)	**57.4efg**
T186F-2014-1	52.4 (± 4.5)	**70.1 (± 1.8)**	55.9 (± 0.8)	**59.5defg**
T193KK-93-10	64.9 (± 1.4)	82.4 (± 1.2)	55.1 (± 1.8)	**67.5bcde**
T195M-190	62.1 (± 2.8)	67.2 (± 5.5)	41.3 (± 2.4)	**56.9efg**
T195M-309	**72.0 (± 4.6)**	**78.4 (± 4.2)**	58.9 (± 4.0)	**69.8bcd**
T197K-207-15	65.7 (± 2.6)	**75.4 (± 1.0)**	65.5 (± 3.1)	**68.9bcde**
T197K-207-21	60.4 (± 2.3)	65.2 (± 2.6)	55.0 (± 0.7)	**60.2cdefg**
T97K-499-39	68.7 (± 2.4)	84.9 (± 2.0)	64.2 (± 2.2)	**72.6b**
T197K-556-6	59.7 (± 4.8)	**75.1 (± 2.5)**	63.4 (± 5.8)	**66.1bcde**
T198K-317-2	68.5 (± 2.3)	**78.1 (± 2.6)**	**72.2 (± 3.3)**	**72.9b**
Mean[2]	**65.7b**	**72.8a**	**56.8c**	
Two- Way ANOVA				
Cowpea genotypes, CG	***25.0*****			
Powder levels, PL	**104.0*****			
CG*PL	**2.0****			
CV%	**14.2**			

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix9. Influence of cowpea root powder on *S. hermonthica*, radicle extension (millet strain)

Radicle extension (10^{-2} ×µm)

Powder (mg/well)

Cowpea genotypes	5	10	15	Mean
Aloka	9.9 (±0.2)	9.4 (±0.1)	7.4 (±0.3)	**8.9 bcdef**
T198k-503-1	10.9 (±0.3)	8.6 (±0.2)	7.3 (±0.2)	**8.9 bcdef**
T199K-214-2	10.3 (±0.3)	8.0 (±0.3)	6.5 (±0.3)	**8.3 def**
T199K-377-1	11.6 (±0.3)	8.3 (±0.5)	8.2 (±0.3)	**9.4 bcdef**
B301	10.4 (±0.2)	7.7 (±0.3)	5.5 (±0.3)	**7.9 ef**
T198K-409-4	9.3 (±0.4)	7.4 (±0.1)	6.1 (±0.3)	**7.6 ef**
T197K-499-35	17.6 (±1.0)	11.3 (±0.3)	8.7 (±0.1)	**12.5 ab**
T199K-573-2-1	12.2 (±0.1)	8.5 (±0.4)	5.6 (±0.3)	**8.8 cdef**
T100K-1263	15.9 (±0.7)	13.0 (±0.2)	11.6(±0.3)	**13.5 a**
Ife Brown	10.1 (±0.1)	9.4 (±0.2)	7.9 (±0.4)	**9.1 bcdef**
T100K-901-6	15.2 (±0.8)	11.2 (±0.3)	10.6 (±1.1)	**12.3 abc**
T182E-18	12.0 (±0.3)	10.8 (±0.1)	9.5 (±0.2)	**10.8 abcde**
T183D-442	7.8 (±0.4)	5.4 (±0.1)	3.9 (±0.1)	**5.7 f**
T185F-867-5	10.0 (±0.2)	8.3 (±0.2)	7.5 (±0.2)	**8.6 cdef**
T186D-1010	14.7 (±0.3)	9.9 (±0.4)	6.4 (±0.7)	**10.3 abcde**
T186F-2014-1	9.0 (±0.3)	7.3 (±0.1)	5.3 (±0.1)	**7.2 ef**
T193K-93-10	9.9 (±0.3)	7.8 (±0.3)	7.1 (±0.2)	**8.3 def**
T195M-190	10.7 (±0.3)	9.5 (±0.2)	8.6 (±0.2)	**9.6 bcde**
T195M-309	11.4 (±0.2)	10.0 (±0.3)	9.0 (±0.2)	**10.1 abcde**
T197K-207-15	15.8 (±0.3)	11.7 (±0.1)	8.5 (±0.4)	**12.0 abcd**
T197K-207-21	11.3 (±0.6)	8.9 (±0.2)	8.0 (±0.1)	**9.4 bcdef**
IT97K-499-39	11.2 (±0.3)	9.6 (±0.2)	6.2 (±0.5)	**9.0 bcdef**
T197K-556-6	10.0 (±0.7)	9.4 (±0.4)	7.1 (±0.3)	**8.8 bcdef**
T198K-317-2	10.8 (±0.2)	8.6 (±0.5)	7.6 (±0.2)	**9.0 bcdef**
Mean	**11.6 a**	**9.2 b**	**7.5 c**	

Two- Way ANOVA	
Cowpea genotypes, CG	**72.1*** **
Powder levels, PL	**751.2*** **
CG*PL	**8.1*** **
CV%	

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix 10. Effects of cowpea stem powder on germination of *Striga hermonthica* (millet strain)

	Striga hermonthica germination (%)			
	powder (mg/microplate)			
Cowpea genotypes	**5**	**10**	**15**	**Mean**
Aloka	52.1 (± 3.1) [1]	57.9 (± 1.7)	38.8 (± 3.9)	**49.6fghij**
T198K-503-1	52.5 (± 4.8)	58.9 (± 5.9)	42.3 (± 2.3)	**51.3efghi**
T199K-214-2	28.1(± 2.3)	50.6 (± 1.9)	40.6 (± 5.7)	**39.7jk**
T199K-377-1	55.5 (± 1.2)	60.3 (2.3)	50.8 (± 5.5)	**55.5defgh**
B301	36.8 (± 5.0)	61.0 (± 2.7)	39.0 (± 2.7)	**45.6hijk**
T198K-409-4	27.5 (± 3.1)	50.4 (± 1.7)	32.7 (±3.2)	**36.9k**
T197K-499-35	38.1 (± 5.3)	47.8 (± 1.5)	39.6 (± 3.2)	**41.8jik**
T199K-573-2-1	66.6 (± 4.1)	**76.8 (± 4.0)**	42.3 (± 1.9)	**61.9bcd**
T100K-1263	82.8 (± 2.3)	89.3 (± 1.9)	92.4 (± 1.5)	**88.2a**
IFE brown	60.1 (± 4.6)	**75.0 (± 1.9)**	61.0 (± 1.5)	**65.3bcd**
T100K-901-6	**70.3 (± 4.1)**	**74.5 (± 1.1)**	55.0 (± 0.7)	**66.6bc**
T182E-18	45.7 (± 1.2)	56.6(± 2.0)	44.7 (± 1.6)	**49.0fghij**
T183D-442	58.4 (± 0.9)	69.4 (± 1.9)	54.1 (± 0.9)	**60.6cde**
T185F-867-5	67.1 (± 2.3)	**79.8 (± 4.4)**	65.0 (± 3.4)	**70.6b**
T186D-1010	51.7 (± 7.7)	57.9 (± 2.4)	42.1 (± 0.8)	**50.6efghij**
T186F-2014-1	66.2 (± 3.6)	**73.6 (± 3.4)**	55.3 (± 3.3)	**65.1bcd**
T193KK-93-10	57.3 (± 2.6)	64.5 (± 2.7)	54.7 (± 2.1)	**58.8cdefg**
T195M-190	37.7 (± 0.8)	56.3 (± 1.6)	41.4 (± 2.2)	**45.1hijk**
T195M-309	60.1 (± 2.0)	**70.2 (± 2.3)**	59.3 (± 1.5)	**63.2bcd**
T197K-207-15	68.7 (± 6.6)	64.1 (± 4.5)	66.3 (± 1.5)	**66.4bc**
T197K-207-21	42.2 (± 1.7)	64.6 (±1.7)	37.4 (± 4.2)	**48.1ghijk**
T97K-499-39	65.4 (± 0.5)	**72.7 (± 6.0)**	57.3 (± 3.1)	**65.1bcd**
T197K-556-6	56.4 (± 2.1)	**74.0 (± 0.6)**	47.2 (± 2.0)	**59.2cdef**
T198K-317-2	66.9 (± 7.8)	**76.4 (± 3.5)**	66.7 (± 5.1)	**70.0b**
Mean [2]	**54.8**	**65.9**	**51.1**	

Two- Way ANOVA	
Cowpea genotypes, CG	**39.6*** **
Powder levels, PL	**118.1*** **
CG*PL	**2.6*** **
CV%	**13.8**

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix. 11. Influence of cowpea stem powder on *S. hermonthica* radicle extension (millet strain)

	Radicle extension (10^{-2} ×µm) Powder (mg/well)			
Cowpea genotypes	**5**	**10**	**15**	Mean
Aloka	5.9 (±0.3)	4.8 (±0.2)	3.6 (±0.2)	**4.8 gh**
T198K-503-1	7.8 (±0.2)	6.6 (±0.1)	4.8 (±0.2)	**6.4 cdefgh**
T199K-214-2	5.4 (±0.2)	4.0 (±0.2)	4.0 (±0.3)	**4.5 h**
T199K-377-1	6.8 (±0.5)	4.8 (±0.3)	3.9 (±0.2)	**5.2 fgh**
B301	8.1 (±0.5)	8.4 (±0.3)	5.3 (±0.3)	**7.3 abcdef**
T198K-409-4	7.4 (±0.4)	5.5 (±0.4)	4.4 (±0.3)	**5.8 defgh**
T197K-499-35	9.6 (±0.3)	7.9 (±0.1)	7.1 (±0.4)	**8.2 abc**
T199K-573-2-1	8.1 (±0.3)	5.3 (±0.1)	3.2 (±0.1)	**5.5 efgh**
T100K-1263	9.8 (±0.3)	8.9 (±0.2)	8.1 (±0.2)	**8.9 ab**
IFE brown	8.8 (±0.3)	7.6 (±0.3)	6.0 (±0.5)	**7.5 abcdef**
T100K-901-6	9.7 (±0.4)	8.2 (±0.4)	7.6 (±0.2)	**8.5abc**
T182E-18	7.7 (±0.3)	7.3 (±0.2)	6.2 (±0.3)	**7.1 abcdef**
T183D-442	7.2 (±0.4)	4.6 (±0.4)	2.9 (±0.2)	**4.9gh**
T185F-867-5	7.8 (±0.3)	6.5 (±0.3)	5.2 (±0.1)	**6.5 cdefgh**
T186D-1010	6.9 (±0.2)	7.8 (±0.3)	5.1 (±0.2)	**6.6 bcdefgh**
T186F-2014-1	8.3 (±0.2)	7.3 (±0.2)	5.2 (±0.1)	**6.9 abcdefg**
T193KK-93-10	6.4 (±0.3)	5.5 (±0.2)	4.4 (±0.3)	**5.4 fgh**
T195M-190	9.1 (±0.3)	7.4 (±0.2)	7.4 (±0.2)	**8.0 abcd**
T195M-309	7.4 (±0.2)	6.5 (±0.2)	5.8 (±0.2)	**6.6 cdefgh**
T197K-207-15	8.3 (0.3)	6.9 (±0.2)	5.3 (±0.3)	**6.8 abcdefg**
T197K-207-21	6.5 (±0.3)	5.2 (±0.3)	3.8 (±0.1)	**5.2 fgh**
T97K-499-39	9.5 (±0.3)	8.3 (±0.3)	5.7 (±0.4)	**7.8 abcde**
T197K-556-6	10.6 (±0.2)	9.0 (±0.2)	7.5 (±0.3)	**9.0 a**
T198K-317-2	6.7 (±0.2)	5.4 (±0.2)	4.6 (±0.1)	**5.5 afgh**
Mean[2]	**7.9 a**	**6.7 b**	**5.3 c**	
Two- Way ANOVA				
Cowpea genotypes, CG	**72.7*** **			
Powder levels, PL	**549.2*** **			
CG*PL	**4.4*** **			
CV%				

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix.12. Effects of cowpea leaves powder levels on germination of *Striga hermonthica* (millet strain)

	***Striga hermonthica* germination (%)**			
	Powder (mg/well)			
Cowpea genotypes	**5**	**10**	**15**	**Mean**
Aloka	40.3 (± 3.6) [1]	58.2 (± 6.6)	35.2 (± 2.1)	**44.5fgh**
T198K-503-1	48.6 (± 2.2)	59.4 (± 2.7)	42.9 (± 1.0)	**50.3defg**
T199K-214-2	34.2 (± 5.8)	49.0 (± 7.8)	25.7 (± 1.9)	**36.3hij**
T199K-377-1	41.3 (± 5.7)	66.4 (± 4.9)	42.5 (± 1.4)	**50.0cdefg**
B301	17.5 (± 6.0)	43.7 (± 1.5)	17.2 (± 3.6)	**26.1jkl**
T198K-409-4	24.4 (± 3.9)	46.3 (± 2.4)	29.4 (± 3.7)	**33.4hjik**
T197K-499-35	32.2 (± 2.2)	45.4 (± 6.6)	40.3 (± 2.7)	**39.3ghi**
T199K-573-2-1	24.2 (± 4.6)	43.6 (± 2.5)	25.9 (± 5.1)	**31.2jik**
T100K-1263	86.7 (± 6.1)	93.4 (± 0.9)	84.5 (± 2.1)	**88.2a**
IFE brown	67.2 (± 5.7)	63.0 (± 0.8)	53.4 (± 5.3)	**61.2bc**
T100K-901-6	72.6 (± 3.3)	70.9 (± 3.7)	56.8 (± 3.6)	**66.8b**
T182E-18	20.4 (± 4.3)	42.1 (± 4.6)	22.6 (± 3.5)	**28.4jikl**
T183D-442	46.4 (± 4.0)	51.5 (± 0.5)	38.3 (± 0.8)	**45.4fgh**
T185F-867-5	52.9 (± 1.3)	64.9 (± 2.9)	52.7 (± 1.1)	**56.8bcde**
T186D-1010	35.4 (± 3.0)	50.4 (± 1.9)	34.2 (± 3.4)	**40.0fghi**
T186F-2014-1	57.8 (±2.2)	65.4 (± 1.2)	51.3 (± 0.8)	**58.2bcd**
T193KK-93-10	31.8 (± 3.2)	58.6 (± 1.6)	42.5 (± 2.2)	**44.3fgh**
T195M-190	36.2 (± 1.4)	55.6 (± 2.3)	28.8 (± 2.6)	**40.2fghi**
T195M-309	8.0 (± 1.5)	12.5 (± 1.2)	26.3 (± 8.3)	**15.6l**
T197K-207-15	48.7 (± 2.5)	65.7 (± 4.1)	38.4 (± 2.9)	**50.9cdef**
T197K-207-21	40.5 (±3.3)	55.6 (± 0.9)	40.5 (± 2.3)	**45.5efgh**
T97K-499-39	46.4 (± 3.5)	56.6 (± 2.1)	48.8 (± 0.8)	**50.6defg**
T197K-556-6	20.9 (± 2.2)	31.0 (± 2.4)	10.6 (± 1.9)	**20.9kl**
T198K-317-2	60.6 (± 8.2)	24.0 (± 3.5)	17.1 (± 2.6)	**33.9hji**
Mean[2]	**41.5b**	**53.0a**	**37.7c**	
Two- Way ANOVA				
Cowpea genotypes, CG	**[3]59.1*** **			
Powder levels, PL	**106.3*** **			
CG*PL	**4.2****			
CV%	**18.7**			

*=P<0.05;**= P<0.01; ***=P<0.001

Appendix13. **Influence of cowpea leaves powder on *S. hermonthica* radicle extension (millet strain)**

	Radicle extension (10^{-2} ×µm) Powder (mg/well)			
Cowpea genotypes	**5**	**10**	**15**	**Mean**
Aloka	4.8 (±0.2)	3.0 (±0.2)	2.3 (±0.1)	**3.4 efghi**
T198K-503-1	7.6 (±0.5)	5.4 (±0.4)	3.3 (±0.4)	**5.4 abcdefg**
T199K-214-2	4.0 (±0.3)	3.2 (±0.2)	2.1 (±0.3)	**3.1 ghi**
T199K-377-1	4.6 (±0.3)	2.7 (±0.3)	2.0 (±0.2)	**3.1 ghi**
B301	3.0 (±0.9)	3.5 (±0.6)	2.3 (±0.3)	**2.9 ghi**
T198K-409-4	7.9 (±0.4)	6.3 (±0.2)	4.6 (±0.4)	**6.3 abcd**
T197K-499-35	8.3 (±0.3)	7.6 (±0.3)	3.4 (±0.5)	**6.4 abc**
T199K-573-2-1	7.5 (±0.3)	5.1 (±0.3)	3.7 (±0.2)	**5.3 abcdefh**
T100K-1263	8.8 (±0.2)	7.9 (±0.1)	6.4 (±0.2)	**7.7 ab**
IFE brown	9.5 (±0.2)	8.0 (±0.2)	6.0 (±0.5)	**7.8 a**
T100K-901-6	7.8 (±0.1)	5.8 (±0.4)	3.9 (±0.2)	**5.8 abcdef**
T182E-18	4.1 (±0.9)	3.7 (±0.2)	1.9 (±0.2)	**3.2 fghi**
T183D-442	7.1 (±0.3)	5.0 (±0.3)	3.3 (±0.2)	**5.1 bcdefgh**
T185F-867-5	7.8 (±0.3)	5.9 (±0.5)	4.1 (±0.2)	**5.9 abcde**
T186D-1010	7.2 (±0.3)	5.2 (±0.3)	3.6 (±0.3)	**5.3 abcdefg**
T186F-2014-1	8.0 (±0.4)	5.4 (±0.2)	3.9 (±0.1)	**5.8 abcdef**
T193KK-93-10	3.7 (±0.2)	2.4 (±0.1)	1.8 (±0.2)	**2.6 hi**
T195M-190	5.8 (±0.3)	3.7 (±0.4)	2.0 (±0.2)	**3.8 cdefghi**
T195M-309	3.3 (±0.7)	2.5 (±0.3)	1.5 (±0.4)	**2.4 i**
T197K-207-15	4.4 (±0.3)	3.6 (±0.2)	2.3 (±0.4)	**3.4 efghi**
T197K-207-21	3.4 (±0.1)	2.6 (±0.1)	2.0 (±0.4)	**2.7 ghi**
T97K-499-39	9.7 (±0.2)	8.1 (±0.4)	5.8 (±0.3)	**7.9 a**
T197K-556-6	5.6 (±0.5)	3.3 (±0.1)	2.1 (±0.3)	**3.7 defghi**
T198K-317-2	3.5 (±0.2)	2.3 (±0.1)	1.6 (±0.2)	**2.5 i**
Mean[2]	**6.1 a**	**4.7 b**	**3.2 c**	
Two- Way ANOVA				
Cowpea genotypes, CG	**84.7*** **			
Powder levels, PL	**466.9*** **			
CG*PL	**3.4*** **			
CV%				

*=P<0.05;**= P<0.01; ***=P<0.00

Appendix 14. Host-Parasite relationship as influenced by selected growth attributes {Sole sorghum}

Correlation coefficients

L 30	1											
L 60	2	0.824***										
L 90	3	0.846***	0.926***									
P 30	4	0.211	0.040	0.113								
P 60	5	0.306	0.181	0.167	0.871***							
P 90	6	0.456*	0.359*	0.373*	0.780***	0.894***						
S 30	7	-0.632***	-0.521**	-0.605***	-0.492**	-0.528**	-0.654***					
S 60	8	-0.680***	-0.463*	-0.553**	-0.452**	-0.492**	-0.606***	0.828***				
S 90	9	-0.634***	-0.439*	-0.522**	-0.434*	-0.445*	-0.566**	0.805***	0.961***			
S dr	10	-0.661***	-0.493**	-0.592***	-0.486**	-0.550**	-0.710***	0.797***	0.847***	0.828***		
S odr	11	0.511**	0.255	0.418*	0.372*	0.367*	0.440*	-0.699***	-0.727***	-0.703***	-0.693***	
		1	2	3	4	5	6	7	8	9	10	11

*,** and ***= Significantly differenct from zero at 0.05, 0.01 and 0.001 probability level, L=leafarea, P= plant heght, S= *Striga* emergence, SDW= *Striga* dry weightand SODW= Sorghum dry weight

Appendix 15. Host-Parasite relationship as influenced by selected growth attributes { Greenhoue experiment sorghum intercropped with cowpea B301}

Correlation coefficient

L 30	1											
L 60	2	0.452*										
L 90	3	0.259	0.053									
P 30	4	0.282	0.259	0.261								
P 60	5	0.535**	0.470*	0.268	0.694***							
P 90	6	0.585**	0.323*	0.206	0.733***	0.882***						
S 30	7	-0.219	0.001	-0.263	-0.557**	-0.453*	-0.577**					
S 60	8	-0.411*	-0.579**	-0.101	-0.524**	-0.625***	-0.578**	0.651***				
S 90	9	-0.341*	-0.351*	-0.117	-0.515**	-0.582**	-0.538**	0.737***	0.936***			
S dr	10	-0.333*	-0.544**	-0.023	-0.622***	-0.587**	-0.616***	0.462*	0.671***	0.600***		
S odr	11	0.230	0.345*	0.167	0.653***	0.526**	0.547**	-0.681***	-0.647***	-0.635***	-0.708***	
		1	2	3	4	5	6	7	8	9	10	11

*,** and ***= Significantly differenct from zero at 0.05, 0.01 and 0.001 probability level, L=leafarea, P= plant heght, S= *Striga* emergence, SDW= *Striga* dry weightand SODW= Sorghum dry weight

Appendix 16. Host-Parasite relationship as influenced by selected growth attributes { Greenhoue experiment sorghum intercropped with cowpea T100K-901-6}

Correlation of coefficient

L 30	1											
L 60	2	0.577**										
L 90	3	0.392*	0.328*									
P 30	4	0.057	0.405*	0.212								
P 60	5	0.026	0.386*	0.305	0.954***							
P 90	6	0.181	0.556**	0.395*	0.849***	0.888***						
S 30	7	-0.370*	-0.463*	-0.450*	-0.529**	-0.517**	-0.652***					
S 60	8	-0.363*	-0.510**	-0.36*	-0.532**	-0.494**	-0.642***	0.935***				
S 90	9	-0.416*	-0.593***	-0.432*	-0.527**	-0.507**	-0.632***	0.896***	0.947***			
S dr	10	-0.319*	-0.3039	-0.428*	-0.498**	-0.526**	-0.611***	0.529**	0.624***	0.581**		
So dr	11	0.197	0.473*	0.578**	0.686***	0.752***	0.800***	-0.630***	-0.621***	-0.669***	-0.650***	
		1	2	3	4	5	6	7	8	9	10	11

*,** and ***= Significantly differenct from zero at 0.05, 0.01 and 0.001 probability level, L=leafarea, P= plant heght, S= *Striga* emergence, SDW= *Striga* dry weightand SODW= Sorghum dry weight

Appendix. 17. Host-Parasite relationship as influenced by selected growth attributes {Field experment}

Correlation of coefficient

100%se	1											
IN45	2	0.233										
IN90	3	0.317	0.185									
H-LEN	4	-0.126	-0.160	0.169								
H-SIZE	5	0.469*	0.526*	0.409*	-0.176							
PH90	6	-0.012	0.191	0.301	0.082	0.243						
PH30	7	0.088	-0.044	0.002	0.029	0.166	0.570**					
PH60	8	0.027	0.038	-0.273	0.089	0.178	-0.014	0.314				
SC35	9	-0.644**	-0.529*	-0.347	0.202	-0.426*	0.015	0.014	0.122			
SC50	10	-0.358	-0.431*	-0.139	0.598**	-0.508*	0.044	0.272	0.185	0.645**		
SC65	11	-0.554**	-0.455*	-0.172	0.471*	-0.574**	0.253	0.108	0.014	0.635**	0.778***	
SC80	12	-0.552**	-0.490*	-0.2455	0.423*	-0.517*	0.218	0.158	0.099	0.703***	0.794***	0.980***
		1	2	3	4	5	6	7	8	9	10	11	12

*,** and ***= Significantly differenct from zero at 0.05, 0.01 and 0.001 probability level, 100%se=100 seed weight,IN=intrnode, P= plant heght, SE= *Striga* emergence,

Appendix .18. *Striga* seeds germination as influenced by cowpea genotype, powder amount and *Striga* strain.

Sorghum	Powder amount (mg)	poor	M	SA	G	E
	5	8.3	12.5	58.3	16.7	4.2
Root	10	-	12.5	25.0	37.5	25.0
	15	16.7	41.7	33.3	8.3	-
	5	33.3	29.2	29.2	8.3	-
Stem	10	0	29.2	29.2	41.7	-
	15	54.2	25.0	20.8	0	-
	5	79.2	8.3	12.5	-	-
Leaves	10	29.2	37.5	25.0	8.3	-
	15	87.5	8.3	4.2	-	-
Millet						
	5	4.2	25.0	41.6	25.0	4.2
Root	10	-	4.2	37.5	41.6	16.7
	15	29.2	45.8	16.7	4.2	4.2
	5	29.2	29.2	33.3	4.2	4.2
Stem	10	4.2	29.2	25.0	37.5	4.2
	15	50.0	29.2	16.7	-	4.2
	5	75.0	8.3	8.3	4.2	4.2
Leaves	10	37.5	33.3	20.8	4.2	4.2
	15	79.2	16.7	-	-	4.2

P=poor, M=moderate, SA=satisfatry, G=good, E=excellent

Appendix**.19. *Striga* germilings radicle extension as influenced by cowpea genotype, powder amount and *Striga* strain**.

Sorghum	Powder amount (mg)	Very short	short	medium	long
	5	-	4.2	66.7	29.1
Root	10	-	41.7	58.3	-
	15	-	79.2	20.8	-
	5	-	79.2	20.8	-
Stem	10	4.2	-	83.3	12.5
	15	50.0	50.0	-	-
	5	29.1	62.5	8.3	-
Leaves	10	54.2	45.8	-	-
	15	75.0	25.0	-	-
Millet					
	5	-	20.8	62.5	16.7
Root	10	-	75.0	25.0	-
	15	4.2	87.5	8.3	-
	5	-	95.8	4.2	-
Stem	10	16.7	0	83.3	-
	15	41.7	58.3	-	-
	5	41.7	58.3	-	-
Leaves	10	50.0	50.0	-	-
	15	87.5	12.5	-	-

V=very short, S= short, M=medium, L= long

Appendix 20

Four-Way ANOVA (Striga germination %)

Source of variation	DF	Mean square (MS)	F. value
***Striga* Strains, SS**	1	4.4	415.7***
Powder levels, PL	3	14.1	1343.2***
Cowpea parts, CP	2	6.6	625.5***
Cowpea genotypes, CG	23	0.6	62.4***
SS*PL	3	5.1	482.4***
SS*CP	2	0.01	1.5^{ns}
SS*CG	23	0.2	23.1**
PL*CP	6	0.7	70.5***
PL*CG	69	0.2	12.3**
CP*CG	46	0.1	9.5**
SS*PL*CP*CG	397	0.1	2.3**
CV%		15.3	

*=P<0.05;**= P<0.01; ***=P<0.001 and ^{ns}= Non significant