CHAPTER 1. GENERAL INTRODUCTION

Striga asiatica (L.) Kuntze and the other *Striga species* are commonly referred to as witchweed which parasitise crops of the gramineae family and some wild indigenous grasses, where it forms intimate association with the host crop`s root system. The genus *Striga* has about 35 species, but at least 11 are known to attack crops (Parker and Riches 1993). *Striga asiatica, Striga hermonthica* (Del.) Benth*, Striga forbesii* Benth and *Striga gesneroides* (Willd.) Vatke are of economic importance in Africa and some parts of the world (Parker and Riches 1993). In Zimbabwe, *S. asiatica* is of importance and has been found causing damage in cultivated cereal fields at Matopos, Chiredzi, Buhera, Mutare, Darwendale and Masvingo (Kasembe, 1999) as well as in Makoni, Mutoko, Chiwundura and Tsholotsho farming areas (Musimwa *et al*., 2001).

Striga asiatica is a root parasite to the following cereal crops; maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], pearl millet [*Pennisetum glaucum* L. R.Br.], finger millet [*Eleusine coracana* (L.) Gaertn], upland rice (*Oryza sativa* L.) and sugarcane (*Saccharum officinale* L.). Maize and sorghum are the most widely damaged crops especially in Southern, Central and East Africa (Olivier, 1995, Parker and Riches*,* 1993). In Zimbabwe it has been found to infest maize, sorghum and pearl millet in all the eight provinces (Chivinge, 1988). *Striga gesneroides* is a root parasite of legumes, especially cowpea (*Vigna unguiculata* L. Walp) and bambaranut (*Vigna subterranea* L. Verdc).

1.1. Physiology of *Striga* seeds

Striga seeds need an after-ripening period before they can germinate an adaptation to the semi-arid tropics (Parker and Riches, 1993). This is a period of time the *Striga* seeds require before they can germinate, probably to complete the physiological processes and attain full maturity. This ensures that seeds are unable to germinate at the end of the rainy season in which they have been produced. The minimum after-ripening period is thought to be about 6 months following seed shed before germination would occur (Parker and Riches, 1993). Fresh seeds have been shown to germinate up to a germination level of 5 %, but it is important to note that the length of the after ripening period varies with different *Striga species* and geographical regions (Parker, 1984).

After ripening, *Striga* seeds may fail to germinate even in the presence of host stimulants, until a period of conditioning is received (Parker and Riches, 1993). During conditioning seeds have to imbibe water for a period of 10-21 days before exposure to germination stimulant. Conditioning is believed to leach out some chemical inhibitors from the seed, thus increasing the permeability of the aleurone layer (Worsham and Egley, 1990).

Parker *et al*., (1993) confirmed on the involvement of inhibitors that have to be leached out or degraded during conditioning and also the possibility of synthesis of some stimulant co-factors. Temperatures for conditioning range between 20 and 40^0C (Parker *et al*. , 1993). It is believed that the first rains of a wet season ensure that this requirement is met. Excessive conditioning in wet environment induces the *Striga* seeds into secondary dormancy known as wet dormancy, in which the seeds fail to germinate even if the other physiological requirements are fulfilled. Biochemical processes that are involved in conditioning and germination of *Striga species* have not yet been fully resolved (Parker *et al*., 1993).

Striga seeds are very small and as such the seed food reserves are very limited, implying that without a host, a seedling will die after only a few days (Parker and Riches, 1993). Because of this, seeds have to germinate within a few millimeters of a suitable host root, which produces germination stimulant. *Striga* seeds germinate when they are less than 2 cm away from the host`s root surface. Parker and Riches (1993) found germination stimulants to be synthesized by roots and exuded in a region 3-6 mm from the root apex.

The first natural germination stimulant to be identified was Strigol (Parker and Riches, 1993). Other synthesized related compounds include GR-7 and GR-24, which researchers nowadays use as reference germination stimulant, while natural and synthesized ethylene is also in use.

1.2. Morphology of *Striga asiatica* plants

Striga asiatica plants are erect herbs, which can attain height of between 15-30 centimeters (Parker *et al*., 1993). The calyx-lobes are subulate, and the calyx are distinctly 10-ribbed, about 10 millimeters in diameter and usually hispid. The collora tube is up 10 millimeters long, glandular pubescent while the bracts are linear-lanceolate and about 5 millimeters long (Parker *et al*., 1993).

Leaves are narrow and green but without conspicuous teeth. Flowers are red, white or yellow, with up to 6 open at a time (Parker *et al*., 1993). Populations can form distinct ecotypes, differing in their morphology, especially vigour, leaf size and flower colour.

This variation may be due to different growing conditions and host species (Parker *et al*., 1993).

1.3. Objectives

The main objectives of this study were to

1. evaluate the effect of cowpea, soyabean and bambaranut genotypes on *S. asiatica* emergence, growth and development,

2. evaluate a maize/legume intercrop ideal for *S. asiatica* management,

3. evaluate the appropriate cowpea genotype and optimum cowpea population for *S. asiatica* management in the smallholder farming sector of Zimbabwe and

4. evaluate the effect of *S. asiatica* density on maize grain yield, cob weight and maize plant height.

1.4. Hypotheses

1. Cowpea, soyabean and bambaranut genotypes under investigation have no effect on *S. asiatica* emergence, growth and development.

2. Cowpea populations under evaluation have no effect on *S. asiatica* emergence, growth and development.

3. Different *S. asiatica* emergence does not have similar effect on maize grain yield, cob weight and maize plant height.

CHAPTER 2. LITERATURE REVIEW

2.1. Occurrence

Witchweed (*Striga spp)* causes considerable yield losses in maize, sorghum and pearl millet in Africa, which forms most of the staple foods (Olivier, 1995). In a weed survey conducted by Chivinge (1988), it was observed that *S. asiatica* causes infestations on maize, sorghum, pearl millet and finger millet in all the eight provinces of Zimbabwe. The parasite was the second most aggressive weed in Mashonaland Central and third most aggressive in the Midlands and Masvingo provinces (Chivinge, 1988). Field observations revealed severe infestations and damage to late plant and poorly fertilized cereal crops especially in areas with erratic rainfall.

2.2. Yield Losses due to *S. asiatica*

Musselman (1987), Abayo, English, Kanampiu, Ransom and Gressel (1998) put the yield losses which occur in maize due to *S. asiatica* infection under conditions of low soil fertility and erratic rainfall at 25-100%. Mabasa (1989) observed a 100% maize grain yield loss in smallholder (SH) farming areas of Zimbabwe as a result of *Striga* infection. This is so because about 91% of communal areas in Zimbabwe are located in marginal areas with erratic rainfall and low soil fertility (Whitlow 1979). However, Parker and Riches, (1993) reported a 5% crop yield loss for every *S. asiatica*

plant m^{-2}. Shank (1995), reported a grain yield loss of 3-4 kg per 100 *Striga* plants ha^{-1} for sorghum and 5-6 kg per 100 *Striga* plants ha^{-1} for maize, showing that maize is more susceptible to the parasitic damage. Yield may be severely reduced even to zero levels if the infestation problem is allowed to get out of hand (Parker and Riches, 1993).

2.3. Influence of *S. asiatica* on cropping system

Farmers in the areas infested with *S. asiatica* have been forced to change their cropping systems by growing non-host crops and trap crops in order for them to maintain farm viability (Musambasi, 1997) while others have been forced to put their fields under long fallow period. However, as a result of increased population pressure on land, such long fallows have become less common. A survey done in Chihota, Nharira and Tsholotsho communal areas of Zimbabwe by Mabasa, Rambakudzibga, Mandiringana, Ndebele and Bwakaya (1995), showed that some SH farmers were using cowpea and pearl millet as trap crops for *S. asiatica*. However, the farmers could not establish the extent of their effectiveness.

Heavy infestations have led to some farms being abandoned and in some cases migration of farming communities have been reported (Hess and Lenne, 1999). Obilana and Ramaiah (1992) reported about 30-40% land abandonment in Western and Southern Africa as a result of *Striga* infestation, while in Zimbabwe; the Agronomy Institute (1989) reported about 10% land abandonment by smallholder farmers on whose farms *S. asiatica* is a problem. Land abandonment impact adversely on household and national food security as well as income generation (Kasembe, 1999).

In Chinyika Resettlement Area (CRA) of Zimbabwe, each household has a limited arable land with 5-6 ha household $^{-1}$ (Munguri, 1996) while in the communal areas the land sizes may even be smaller. Further subdivision of arable land experienced in CRA and many other SH farming sectors as family members establish their own homesteads, reduce the sizes of arable land which maybe under heavy *S. asiatica* infestation. This together with continued maize monocropping exacerbates the problem of *S. asiatica* infestations to levels the farmer cannot tolerate.

2.4. Weed Control

About 60% of the labour used in crop production is spent on weed control (Akobundu, 1980). Most crops have to be weeded three times that is at 2, 4 and 6-8 weeks after crop emergence in Zimbabwe (Mabasa and Rambakudzibga, 1994). This shows that hand hoeing is time consuming and uncomfortable. Unfortunately *S. asiatica* escape such high frequency of weeding, because it emerges late in the season. There is thus need to use alternative methods of *Striga* control in order to reduce the weeding burden and maximize crop yields.

2.5. Distribution

Striga has been reported to extend to new areas where it was not known previously (Fasil and Parker, 1994; Orodho and Kiriro, 1994, Frost, 1994). Parker (1991) reported that the areas infested by *Striga* as well as its intensity are on the increase in some parts of Africa, although there are few definitive studies that document these observations. Retained crop seeds have been reported to contain some *Striga* seeds especially with small grains and these have helped spread of the parasite as farmers exchange grain. Other transfer means include wind, storm water, domesticated animals and agricultural machinery

(Musselman, 1987). Human aided movement of *Striga* seeds is the most likely cause of new infestations (Ransom, Odhiambo and Oswald, 1997). Berner, Kling and Shingh (1995) found significant quantities of *Striga* seeds amongst crop seeds sold in the local Nigerian markets, indicating crop seed as a source of *Striga* seed transfer. Musselman (1987), highlighted that there was an increase in *Striga* infestation in the fields a season after the fields were stocked with cattle that had come from infested fields. Bebawi and Elhag (1983) have shown that up to 80 % of witchweed seed may pass through the intestinal tract of sheep with no loss in the ability to germinate. This may be the same with cattle, goats and other domesticated in Zimbabwe.

2.6. Difficulties in *S. asiatica* control

Witchweeds are amongst some of the biggest biological hindrance to cereal crop production in Africa, according to Eplee (1981) and Anonymous (1994). This means that for effective control strategies and techniques, a thorough understanding of its seed biology, haustoria attachment, and parasite emergence, growth and development characteristics is required. The parasitic weed entirely depends on the host for survival and compatibility of the seedling and its host ensures successful completion of its life cycle (Chanyowedza, Chivinge and Chiduza, 1997).

Striga asiatica is difficult to control because damage is inflicted before it emerges above the ground (Parker and Riches, 1993). It grows parasitically under the ground for a period of 6-8 weeks prior to emergence (Babiker, 2000) and it is during this period of subterranean growth when the parasite is most damaging (Pieterse and Persch, 1983).

This is so because at this stage *Striga* plants are non-photosynthetic. However, most control strategies are effective in the subsequent years than during the year in which they are implemented.

2.7. Seed Production

Much of the *Striga* infested areas of Africa have ultra-high levels of *Striga* seeds in the soil due to years of neglect and the plant`s ability to produce many thousands of seeds. *Striga* plants can produce a large number of seeds. The number of seeds produced per capsule for *S. asiatica* averages up to 800, while *S. hermonthica* produces up to 700 seeds, where as both *S. asiatica* and *S. hermonthica* produces about 60-70 capsules plant $^{-1}$ (Parker and Riches*,* 1993). A single mature and well-developed *S. asiatica* plant produces between 40 000 and 500 000 seeds (Doggett, 1984; Mabasa, 1996; Parker and Riches, 1993; Anonymous, 1994), a major reason why *Striga spp* are difficult to eradicate. This shows that *Striga* is very prolific in terms of seed production, which is continuously added to the already existing soil seed bank in the SH farming sector. Only portion/fraction of the seeds break dormancy when stimulated by a receptible host or non-host crop growing in their vicinity (Ariga, Ransom, Odhiambo, Abayo and Ndungu, 1997).

2.8. Seed Longevity

The seeds have longevity of between 14 and 20 years (Bebawi, 1987; Mabasa, 1996; Pieterse and Pesch, 1983). Bebawi, Eplee, Harris and Norris, (1984), observed that *S. asiatica* seeds remain viable for 6 years under open laboratory conditions and for 14 years when buried under field conditions. This shows why *S. asiatica* infection has been a problem for time immemorial because of its long life span. However, rapid decline in seed viability was found in fields in Mali, Benin and Kenya (Parker and Riches 1993), which may be a result of microbial degradation activities and germination stimulation by non-host plants.

2.9. *Striga* Management and Control Practices

Hand weeding of *Striga* towards flowering prevents seed shed, and removal of the weed at the early vegetative stage is likely to be more beneficial in terms of crop yield than removing it later (Bebawi and Farah, 1981). However, it could be more economic to interfere with haustorial attachment to the host cereal than an attached seedling.

Strategies for *Striga* control require expensive resource investment in the form of labour, chemicals and equipment which most of the SH farmers cannot afford (Chivinge, Mashingaidze and Mujuru 1995; Kasembe, 1999). Such control strategies have to be tailored to the degree of infestation and specific socio-economic conditions of the farmer with regard to access to resources like capital and labour so that they can be easily adopted and implemented. The young men and women migrate from these resettlement and communal areas into urban areas in search of formal employment and tertiary education, a case that appears to be common in CRA. The migration deprives the farmers of the required labour force, as a result hand weeding becomes less practical, however research on hand weeding in Western Kenya has shown that in soils which are not '*Striga* suppressive`, up to 4 years of continuous hand weeding is required before *Striga* seed numbers are reduced (but not eliminated) to the level at which yield losses are significantly reduced (Ransom, Odhiambo, Abayo and Oswald, 1997). Doggett (1965) reported that mechanical weeding might reduce yield loss caused by *Striga* infestation by about 15 % in the first year alone and this can be even more with continuous mechanical weeding.

Carson (1989) reported that hand pulling benefits the crop, although much of the damage from *Striga* is caused before the weed emerges. Doggett (1965) reported that hand pulling of *Striga* plants under rain fed conditions every 2 weeks resulted in greater yields of sorghum than pulling weeds every 6 weeks. This shows that the frequency of hand pulling is important if appreciable yield levels are to be obtained. However, hand pulling is cumbersome especially in *Striga* heavily infected fields. . Weeding of *S. asiatica* plants before they flower is effective in reducing the soil seed bank (Eplee, 1991; Musambasi, 1997), but it is labour intensive and for the SH farmers, large weed volume that has to be cleared out at regular intervals makes the task difficult and beyond the farmers` resources (Chivinge, Musambasi, Mariga, 1999). *S. asiatica* emerges late in the season particularly in late January and February (Parker and Riches, 1993), while emergence may continue up to early March depending on the season in Zimbabwe. This is often after the main weeding has been done and it is difficult to convince the farmer to spend extra effort needed to hand-pull *Striga* and prevent seeding (Musambasi, 1997) although this is one of the most important ways of preventing further intensification and spread of the infestation.

Decades have passed by while researchers are trying to develop *Striga* control methods. However, African farmers have hardly benefited from these efforts (Kroschell, Sauerborn, Kachelriess, Hoffmann and Mercer-Quarshie, 1996); Chivinge and Mariga, (2003), because most of the control packages evaluated are not compatible with the farming system and situation practised. Another problem is that the extension personals are not knowledgeable on the control methods developed; however, they may become resource persons through training and demonstrating on the usefulness of the technologies.

Deep ploughing is reported to reduce infestation if the topsoil layer is properly turned to the bottom. This is associated with deep burial of *Striga* seeds, which require some exposure to light for successful germination. Deep burial of the seeds only enhances some form of dormancy, but does not eliminate the seed bank.

2.10. Improved soil fertility as a control measure

Nitrogen application has been shown to reduce sorghum yield loss due to *Striga* in areas of reliable rainfall (Last, 1960). Parker (1984) reported that at high nitrogen levels the development of *S. asiatica* was delayed and damage to the host was considerably minimal. This is referred to as the nitrogen effect, a situation whereby there is reduction of stimulant production by host plant caused by high nitrogenous fertilizers in the soil. Esilaba and Ransom (1997) reported both increased yield of the host and general reduction in emerging parasites following nitrogen applications of about 60-100 kg Nha^{-1}. Mumera (1983) recorded a 64% reduction in *S. hermonthica* emergence in maize after applying 39 kg N ha^{-1}. Increased supply of nitrogen is thought to enhance reproductive sinks in cereals and under non-parasitized conditions, the ear becomes the predominant sink after flowering which limits the amount of photosynthates partitioned to other parts of the plant. In the presence of *Striga* most of the photosynthates are diverted to the parasite, which is a stronger sink than the ear. Furthermore, the parasite can have as many roots as the number of roots the host has, thus become a major sink for nutrients and photosynthates produced by the host. This results in reduced ear formation; however, Egley (1971) suggested that high nitrogen supply increased the osmotic concentration of the host cell sap, thus significantly reducing mass flow of materials from the host plants to the parasite, thereby inhibiting *S. asiatica* parasitism.

Mabasa (1991) reported that improved fertility delayed emergence of *S. asiatica* and reduced its infestation. Musambasi (1997) went further to observe that 69 kg N ha^{-1} resulted in the least number of *S. asiatica* plants that emerged in CRA of Zimbabwe. Ognulela (1982) suggested that applied fertilizer might cause a change in host roots growth behaviour; rendering the crop less susceptible or it interfered with normal germination of the *Striga* seed. This raising of soil fertility would allow the host crop to compete more favourable with emerged *Striga* plants. However, Jasi (2002) observed that an application of 45kg ha^{-1} N resulted in higher *S. asiatica* counts, a variation from other findings.

2.11. Use of tolerant crops

The use of tolerant cereal crop cultivars is one of the most practical approach for the resource-constrained SH farmers to control and manage *Striga*. Several CIMMYT maize varieties in field trials have performed better to weed tolerance than the released hybrids used by farmers (CIMMYT, Zimbabwe 1993). Maize varieties tolerant to *Striga* are yet to be developed in Zimbabwe, thus breeding and selection for such traits should be promoted and funded. However, maize tolerance to *Striga* is quantitatively inherited, with additive gene action playing the major role for host plant damage, and grain yield, where as non-additive gene action predominantly controls *Striga* emergence (Kim, 1991). The reaction of host crop to *Striga spp* is a product of complex interactions between the host, pathogen and the environment. Furthermore, erratic distribution of *Striga* seeds in the soil makes results for yield loss assessment and breeding trials conducted under natural infestation not reproducible (Emechebe, Menkir, Ahonsi and Ikie, 2001). This problem has contributed to the slow progress of host plant resistance breeding for *Striga spp.* control, although there are some tolerant and susceptible maize varieties. Parker and Reid (1979) observed some *Striga* resistant cultivars that lost resistance when introduced in different geographical environment. This may be a result of different *S. asiatica* strains being endemic in different geographical areas, where resistance is expressed for one strain, but the host crop becomes susceptible to other strains. Some sorghum varieties have shown tolerance to *Striga* infection and farmers have managed to live with the level of damage that it does to those crops. Use of these varieties such as sorghum SAR cultivar would be ideal in *S. asiatica* endemic areas, although the SAR lines have a problem of low yielding (Mabasa, 1996).

Musimwa *et al*., (2001), managed to distinguish genetically between some *S. asiatica* strains from different geographical areas, although no strain effects on crop yield were observed.

Some work has been done and technologies developed with high potential for adoption. These include work by Kasembe (1997) on maize*cowpea intercrops which all resulted in lower *S. asiatica* plants that emerged. He also showed that ridging was effective in reducing *S. asiatica* emergence. Herbicide research work done in Zimbabwe by Musambasi (1997), showed that the use of 2,4-D and Dicamba suppressed *S. asiatica* emergence, however this technology is beyond the reach of many SH farmers because of high costs associated with herbicides. Researches by Chanyowedza, Chivinge and Chidhuza (1997), reported reduced *S. asiatica* emergence with mulches especially from *Acacia nilotica* (L.) Del, *Acacia karroo* Hayne *and Acacia anguistissima* (P.Mill.) Kuntze, and *Collophospermum mopane* (J. Kirk ex.Benth) mulches resulted in higher sorghum yield. This shows the amount of research done in Zimbabwe with the aim of controlling *S. asiatica* but adoption of all these technologies has been hampered by the lack of awareness on the part of the extension personnel and farmers.

2.12. Non-host Crops

Another means of reducing density of *Striga* plants is the use of non-host crops that stimulate *Striga* seed germination. Non-host crops can be grown in sole stands or intercropped with the staple cereals. Maize is intercropped with crops such as cowpeas, pumpkins (*Curcubita maxima*), field beans (*Phaseolus vulgaris* L.), squash (*Curcubita pepo*) and sparsely with groundnuts (*Arachis hypogea* L.) in Zimbabwe, with about 42% of the farmers in CRA practise intercropping (Munguri, 1996). Jasi (2002) researched on green manure legumes that included *Tephrosia vogelii* Hook, *Mucuna pruriens* (L.) DC, *Crotalaria juncea* (L.) and *Lablab purpureus* (L.) and found that these reduced *S. asiatica* when the legumes were intercropped at the same time with maize.

Crops that are intercropped with maize may benefit the farmer since they are nutritionally rich and would also generate extra income. Costs of inputs can be reduced in an intercrop compared to sole cropping where for instance legumes fix nitrogen in a maize/legume intercrop. Work by Musambasi (1997), Kasembe (1999) and Chitokomere (2000 *unpublished*) have shown promising potential of some cowpea, bambaranut and soyabean varieties to reduce/control *S. asiatica* infestation. However, there is considerable variability within the legume species, among varieties and accessions in their ability to stimulate *Striga* seed germination (Berner *et al* 1995).

Research in West Africa (Berner *et al*., 1995) found large differences among genotypes within a crop species for their ability to stimulate *Striga* seed germination, thus this trait can be used for trap cropping. From researches done at International Institute of Tropical Agriculture (IITA), Ibadan Nigeria, cotton (*Gossypium hirsutum* L.), cowpea and soyabean were reported to have the capacity to reduce parasitism of *S. hermonthica* when grown in rotation with maize (Ariga *et al.,* 1995). Abayo *et al*., (1997) also reported that cowpea and sweet potato (*Ipomea batatas* L.) intercropped with maize reduced *Striga* plant counts by 50 – 70 % while soyabean decreased the counts by 30 - 40 %. Incorporation of some crop residues in the parasite-infested soils prior to planting susceptible maize cultivars delayed the parasite emergence, reduced its parasitism and increased maize yields (Ariga *et al*., 1997). Other grain legumes such as bambaranut is much more efficient at fixing atmospheric nitrogen into the soil than groundnut and cowpea (Mukurumbira, 1985), hence its great potential in suppressing *Striga* growth as a result of the nitrogen effect. Besides, it has been shown to yield as much as 3500 kg ha^{-1} under good management practices in Zimbabwe (FAO, 1988), however the crop is adapted to poor soils and hot climates within which *Striga* has endemic levels.

Rambakudzibga and Mabasa (1995) identified the brown white eyed and red bambaranut varieties to induce the lowest germination of *S. asiatica*.

Some soyabean varieties especially those promiscuous such as Magoye, Hernon 147 and Hurungwe special, have the ability to fix soil nitrogen without inoculation and these may have a smothering and nitrogen effect on the *Striga* plants. In 1996, a task force was formed to facilitate extension of promiscuous soyabean varieties among SH farmers in Zimbabwe (Mpepereki, Makonese and Giller, 1996) and this programme has been active in about 10 districts within SH sectors. Adoption rates of the promiscuous soyabean varieties have been encouraging (Mpepereki, Javaheri, Davis and Giller, 1999). Umba (2000), screened soyabean cultivars for *S. hermonthica* germination and observed that genetic variability exists among soyabean lines in their capacity to germinate *Striga* seeds. This indicates their potential as trap crops that can be used to reduce infestation of the parasitic weed and their integration possibility into SH farming`s cropping systems. However, previous soyabean/maize intercropping experiments have shown that soyabean shaded by the cereal canopy result in low yields of intercropped soyabean (Kumwenda and Nyirenda, 1987), but this can be outweighed by the intercrop ability to suppress *Striga* through canopy shading and nitrogen effect. Intercropping of cowpea or soyabean with maize reduced *Striga* emergence significantly in comparison with monocropping of maize (IITA, 1991). According to Parkinson, Efron, Bello and Dashiell (1987), three years of consecutive soyabean cultivation reduced the population of *S. hermonthica* to the extent that maize cultivation was possible.

In a research carried out in CRA in 1996/97 and 1997/98 rainy seasons on comparing the effectiveness of six cowpea cultivars to suppressing *S. asiatica* in a maize/cowpea intercropping system, it was found that IT90K-76 and IT82D-849 were effective cultivars which significantly reduced the number of emerged *S. asiatica* plants, but the effects were only apparent in the first rainy season (Kasembe, 1999). This shows that cowpeas have a role in SH farming sector in the management of *Striga asiatica* besides other values; however, farmers are limited by seed source.

Rambakudzibga and Mabasa (1995) and Berner *et al*., (1995) reported that the germination of the parasitic weed was dependent on the quantities of the germination stimulant exuded by the host or non-host roots. Moreover, high cowpea population cause more roots per unit volume of soil, and thus has a tendency to increase the amount of stimulant for *Striga* germination. Effective germination stimulation of *Striga* in the field is also said to depend on root volume and distribution of each host and non-host genotypes. Genotypes with higher lateral root volume per unit area and well distributed within the topsoil, where *Striga* seeds are abundant would be more effective trap crops (Ariga *et al*., 1997) than those with deeper roots. Manipulation of crop spacing would also help attain a desired root distribution although this may have an adverse effect on crop yield. Kasembe (1999) suggested that farmers could raise density of trap crops and then hand weed any emerging *S. asiatica* plant before they flower. Kasembe (1999) reported that high population densities of 74 074-cowpea plants ha^{-1} supported the lowest number of emerged *S. asiatica* plants. Host and trap crop density and spatial arrangements have the potential to influence *Striga* seed germination, hence exhaust soil seed bank. Last (1960) reported more *Striga* emergence at narrower sorghum spacing than wider ones. This could be related to increased stimulant production as more roots ramify within a limited soil fraction. Ibikumle *et al*., (2000) noted that increasing plant density of grain sorghum from 57 100 to 114 300 plants ha^{-1} significantly increased the shoot yields of *Striga* by 49%, and subsequently its capsule numbers and dry matter, which could be the same case with maize. Other attributes such as shading due to high cowpea population may smoother the weed, but this effect may be apparent with spreading genotypes like Kavara.

CHAPTER 3. MATERIALS AND METHODS

3.1. Location of study

Two on-farm experiments were conducted in Chinyika Resettlement Area (18^0 02” and 18^0 17” S and 32^0 09” and 32^0 24” E) of Eastern Zimbabwe during 2002/2003 rainy seasons. The study was done in two agro-ecological zones (natural farming regions 11b and 111) which receive about 800-1000 mm and 600-750 mm (Vincent and Thomas, 1965) annual rainfall in normal seasons, respectively. The altitude of the area falls between 700-1200 m above sea level and the eastern part of the area is generally higher compared to the western part. The CRA lies about 50 km to the north of the nearest town of Rusape and is about 150 km to the east of Harare.

3.2. Site Selection

Fields with natural *S. asiatica* infestation were used as the experimental sites. Selection of the infested sites was done with the assistance of Department of Agricultural Research and Extension (AREX) personnel, and the farmers who identified the *Striga* infested field parts. During the 2001/2002 rainy season two sites were used per experiment but were increased to four sites in the 2002/2003 rainy season.

3.3. Experimental design

Experiment 1 was an investigation of the effect of cowpea genotypes and populations on *Striga asiatica* emergence growth and development and was a 2*3*3 factorial in a Randomised Complete Block Design (RCBD) replicated four times. The cowpea genotypes were Kavara and IT18 planted at spacing of 0.9m*0.2m, 0.9m*0.17m and 0.9m*0.15m giving populations of P_1 55 000, P_2 65 000 and P_3 75 000, respectively. The second factor was the cropping system that included sole cowpea, Maize SC513 cowpea intercrops and Maize Pan 6363cowpea intercrops.

Experiment 2 was an evaluation of the effect of grain legume species and genotypes on *Striga asiatica* emergence, growth and development and was a 3*3*2 factorial in a Randomised Complete Block Design, replicated four times. The factors were three legume species ie soyabean, cowpea and bambaranut. Each species had two genotypes, which were soyabean (Magoye, Hurungwe), cowpea (Kavara, IT18) and bambaranut (White, Brown). The legumes were grown as either sole crops or intercrops of maize genotypes SC513 and Pan6363.

Soyabean was planted at a spacing of 0.9m*0.05m, cowpea at 0.9m*0.17m and bambaranut at 0.9m*0.07m.

For both experiments, plots were 3m*3.6m with a gross plot area of

$10.8m^{-2}$, and each plot consisted of five crop rows spaced at 0.9m for maize between a row while an in-row spacing was used.

3.4. Land Preparation, Planting and Fertilization

The land was ploughed using ox-drawn ploughs in both experiments and seasons. Land preparation was done from November onwards after attainment of field capacity to 30 cm depth. Planting followed in mid December for both seasons, after opening up some planting furrows. Two maize kernels were planted at each station and thinned out to one plant per station at 2 WACE, while the grain legumes were planted within maize rows. Maize fert (7%N, 14%P, 7%K and 8%S) was banded at planting as basal dressing at 300 kg ha^{-1} during both seasons.

3.5. Data collection

3.5.1. *Striga asiatica* parameters

For both experiments natural *Striga* emergence $plot^{-1}$ at two-week interval, starting from 8 weeks after crop emergence (WACE) was recorded from the gross plot area. Other records included cumulative *Striga seed* capsules $plot^{-1}$, days from emergence to first *Striga* flowering (days) and cumulative *Striga* dry matter (g $plot^{-1}$). Flowered S*triga* plants were uprooted to determine seed capsule numbers and dry matter. *Striga* data was subjected to square root (x + 0.5) transformation before analysis.

3.5.2. Crop parameters

Maize height (m), cob weight (kg $plot^{-1}$), stover (kg $plot^{-1}$), and all grain yields (t ha^{-1}) and height of randomly sampled maize plants` plot were recorded. Maize height measurements were taken from the ground level to the growing tip. Maize grain yield, stover and cob weights were determined at physiological maturity from the net plot area ie inner 3- rows. Stover and cobs were dried before weights were determined. Maize grain yield was adjusted to 12.5% moisture content before statistical analysis. Pearson correlation analysis was carried out to study /evaluate the relationship between *Striga asiatica* counts and maize yield, cob weight and plant height. No correlation data was recorded during the 2001/2002 season, mainly because of the effects of drought. All the data were subjected to ANOVA using Minitab version 12.

Total Land Equivalent Ratio (TLER) was calculated to measure the productiivity efficiency of intercrops in comparison to the sole crops, and it was calculated by the following formula, where TLER= a/A+b/B. A and B represents the yields of two sole crops each $hectare^{-1}$, and a and b denotes their intercrop yields $hectare^{-1}$. Other records included rainfall, which were taken from all sites in 2002/2003 season only.

3.6. Weeding and Topdressing

During the 2001/2002 season weeding was done at 3 and 6 WACE only.

Hand weeding with hoes was done at 2, 6 and 8 WACE during the 2002/2003season. Weeding frequency was high owing to persistent rains that sustained and promoted weed emergence and growth during the 2002/2003 rainy season. During 2002/2003, weeds were removed by hand pulling, as hoe weeding was envisaged to potentially interfere with emerging *S. asiatica* plants.

Ammonium Nitrate (34.5%N)) was side dressed to maize at 6 WACE at the rate of 250 kg ha^{-1} during the 2002/2003 rainy season only. Control of insect pests such as a phids (*Aphis crassivora*) in cowpea and maize stalkborer (*Busseola fusca* Fuller) in maize was done using Dimethoate 40% EC and Carbaryl respectively in both seasons.

CHAPTER 4. RESULTS

4.1. *Striga asiatica* emergence.

Cropping system had a highly significant effect ($P<0.01$) on *Striga* emergence at 10 and 12 WACE at sites 1, 2, 3 and 4 in the 2002/2003 season (Table 4.1.1.).

Table 4.1.1.Effect of cropping system on *Striga* emergence at sites in Chinyika Resettlement Area in 2002/2003 season.

	Site 1		Site 2		Site 3		Site 4	
Cropping System	10WACE	12WACE	10WACE	12WACE	10WACE	12WACE	10WACE	12WACE
			(square root transformed m^{-2})					
Sole cowpea	0.71b	o.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b
SC513	2.50a	3.97a	1.95a	2.65a	1.68a	2.88a	1.80a	2.72a
Pan6363	2.02a	3.32a	1.73a	2.02a	1.58a	1.97a	1.73a	3.03a
Mean	1.74	2.72	1.46	1.79	1.32	1.85	1.41	2.15
$LSD_{(0.05)}$	1.07	1.66	0.54	0.74	0.51	0.78	0.45	0.81
SED	0.51	0.79	0.26	0.36	0.25	0.38	0.22	0.40
CV%	71. 57	54.1	60.5	56.4	62	46.6	55.8	
Pvalue	0.007	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

WACE. Weeks After Crop Emergence.

There was no *Striga* emergence in the sole cowpea treatment at 10 and 12 WACE for all sites (Table 4.1.1.). A significantly higher *Striga* emergence was recorded in the maize cowpea intercrops than in sole cowpeas for all sites at 10 and 12 WACE (Table 4.1.1). There was generally no significant difference in the number of *Striga* that emerged in the cowpea intercropped with maize SC513 and cowpea intercropped with maize Pan6363 variety. An exception to this was observed at site 3 during 12 WACE when maize SC513 cowpea intercrops recorded a significantly higher *Striga* emergence than maize Pan6363 cowpea intercrops (Table 4.1.1). There was no *Striga* emergence at 8 and 14 WACE throughout all the sites.

Cowpea genotype ($P>0.05$) and cowpea density did not significantly affect *Striga* emergence at 10 and 12 WACE for all four sites (A1-A8). A significant cowpea genotype effect was recorded at 10 WACE at site 4. An exception occurred at site 3 at 10 WACE, when cowpea genotype registered a significant effect on *Striga* emergence (Table 4.1.2).

Table 4.1.2. Effect of cowpea genotype on *Striga* emergence at 10 WACE at site 3

Cowpea genotype	*Striga asiatica* emergence (square root transformed) (m^{-2})
Kavara	1.54a
IT 18	1.11b
$LSD_{(0.05)}$	0.41
SED	0.20
CV%	56.4

Pvalue	0.042

Striga emergence was significantly lower ($P<0.05$) in the cowpea variety IT 18 than in local variety Kavara (Table 4.1.2).

There was no interaction between any of the two factors on cowpea emergence (Appendix A1-A8). A significant three-way interaction among cropping system, cowpea density and cowpea genotype was recorded at 10 WACE at site 4 (Appendix A7).

There was a significant ($P<0.05$) interaction between cropping system and cowpea genotype on *Striga* emergence at 12 WACE (Table 4.1.3). The interaction shows that effectiveness of the maize cowpea intercrop in suppressing *Striga* emergence differed according to the specific combination of maize and cowpea varieties (Table 4.1.3).

Table 4.1.3. Interaction between cropping system and cowpea genotype on *Striga asiatica* emergence (sq. rt. transformed) at 12 WACE at site 1.

	Cowpea genotype	
Cropping system	Kavara	IT18
Sole cowpea	0.71a	0.71a
SC513 cowpea	5.35b	2.60a
Pan6363 cowpea	2.50a	4.14b

Cropping system x cowpea genotype	0.04
Interaction SED	1.11
Interaction $LSD_{(0.05)}$	2.35

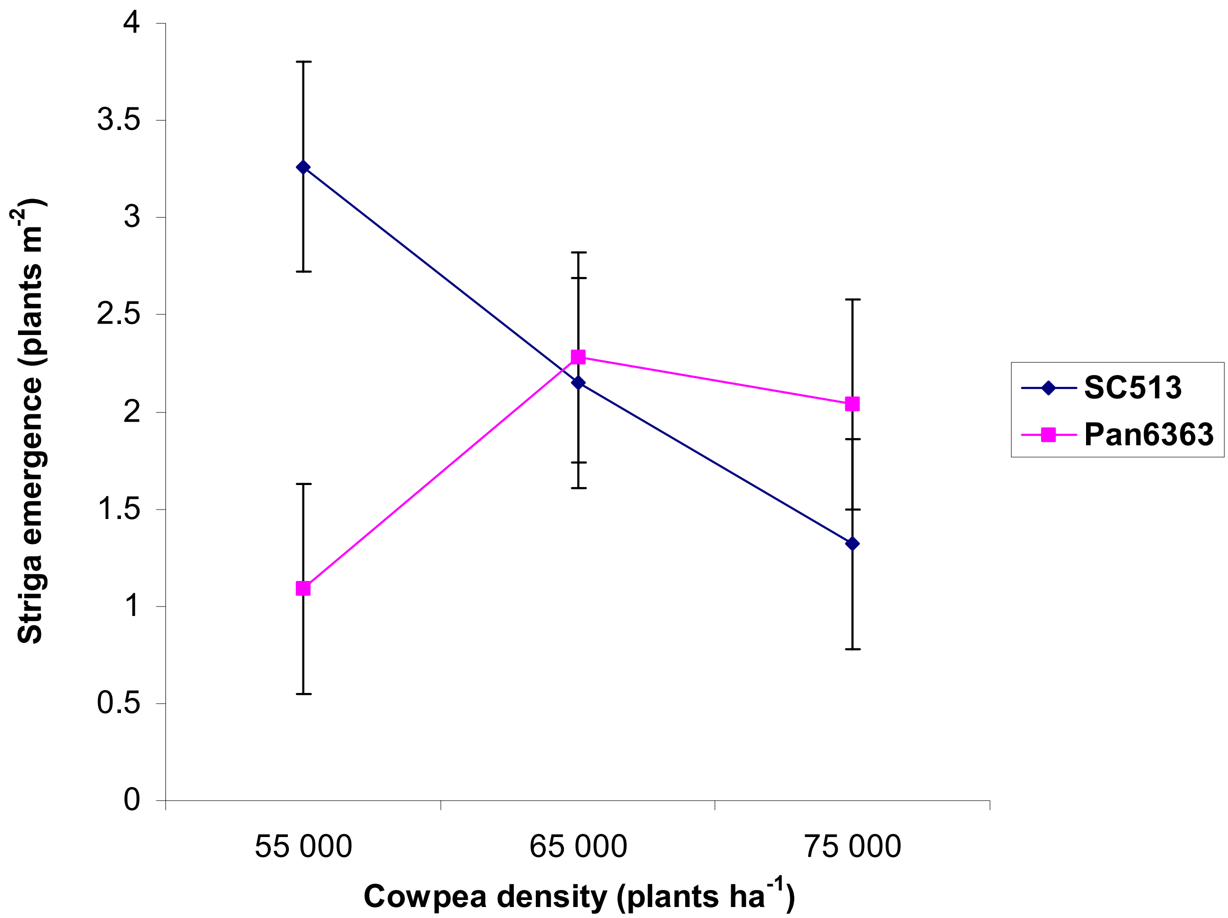

Fig.4.1. 1. Effect of cowpea density and maize genotype in maize cowpea intercrops on *Striga* emergence when intercropped with cowpea variety Kavara at site 4.

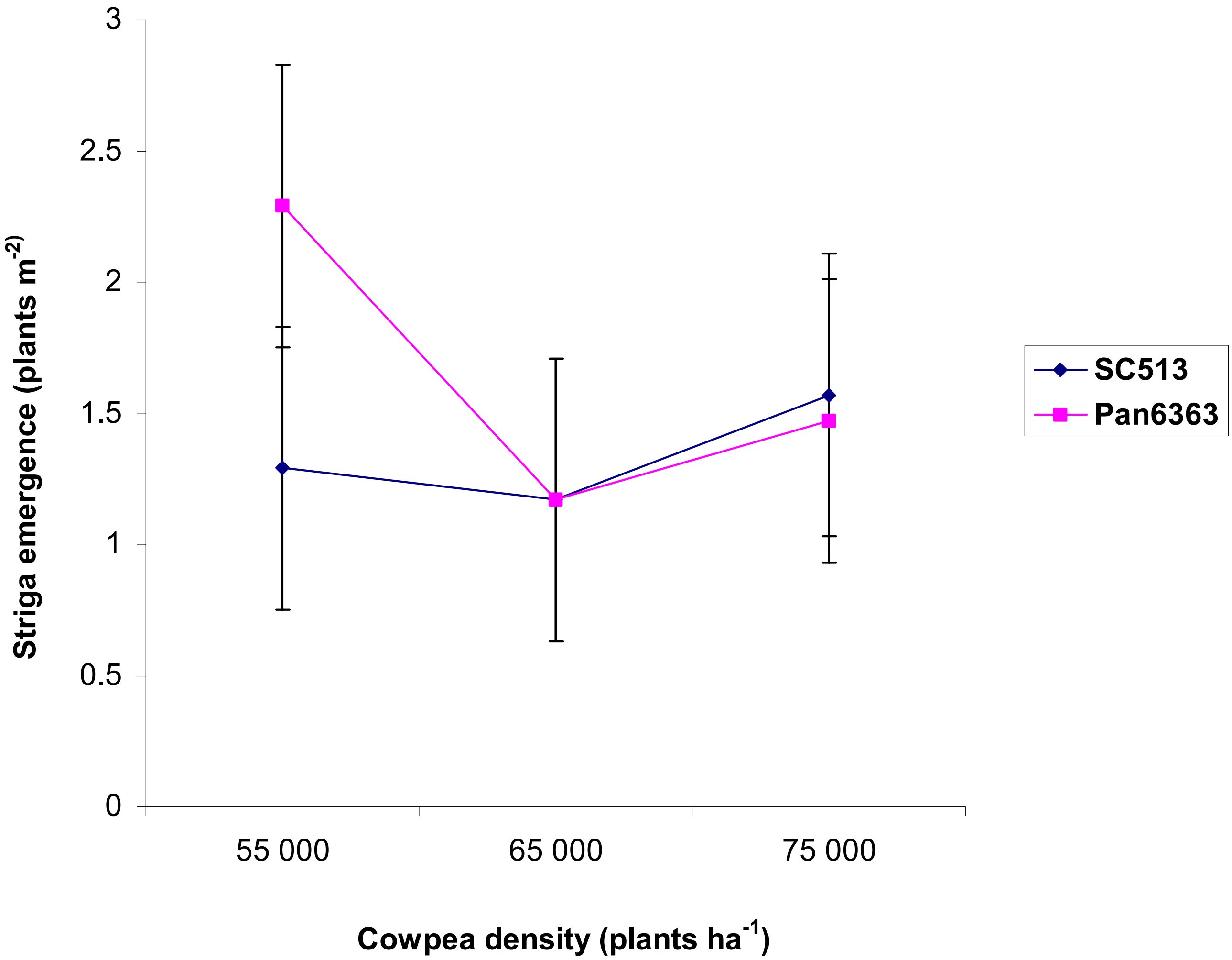

Fig.4.1.2. Effect of cowpea density and maize genotype in maize cowpea intercrops on *Striga* emergence when intercropped with cowpea variety IT18 at site 4

When cowpea variety Kavara was intercropped with maize, it resulted in significantly lower *Striga* emergence than when intercropped with Pan6363. In contrast, when cowpea variety IT18 was intercropped with SC513, it significantly suppressed *Striga* emergence by 37% more than when it was intercropped with Pan6363 (Table 4.1.3). A significant ($P<0.007$) three-way interaction among cowpea genotype, cowpea density and cropping system on *Striga* emergence was observed at site 4 (Fig.4.1/2). The interaction is shown by differences in effectiveness of increasing cowpea density in suppressing *Striga* emergence when the maize cowpea intercrop involved the maize genotype SC513 or Pan6363 in combination with cowpea genotype Kavara or IT18 (Fig.4.1/2). When Kavara was intercropped with SC513, an increase in cowpea density from 55 000 to75 000 plants ha^{-1} significantly reduced *Striga* emergence (Fig.4.1 1). In contrast, when IT18 was intercropped with SC513, an increase in cowpea density did not result in a significant decrease in *Striga* emergence (Fig 4.1.2). When Kavara was intercropped with Pan6363, and cowpea density was increased from 55 000 to 75 000 plant ha^{-1}, an increase in *Striga* density occurred, albeit statistically not significant (Fig 4.1.1). In contrast, when IT18 was intercropped with Pan6363, and cowpea density was increased from 55 000 to 65 000 plants ha^{-1}, *Striga* emergence significantly decreased (Fig 4.1.2). In addition, it is noticeable that at the lowest cowpea density (55 000 plant ha^{-1}), maize variety had a greater effect on *Striga* emergence when maize was intercropped with Kavara (Fig 4.1.1) than when intercropped with IT18 (Fig 4.1.2). The three-way interaction suggests that higher cowpea densities than 55 000 plants ha^{-1} should be used when the cowpea genotype Kavara is intercropped with maize SC513, to get maximum *Striga* suppression but when its intercropped with IT18, cowpea density from 55 000 to 75 000 plants ha^{-1} is not an issue (Fig 4.1.1). When IT18 is intercropped with maize Pan6363, cowpea density should be increased above 55 000 plants ha^{-1}, and when its intercropped with Pan6363, cowpea density between 55 000 to 75 000 is not important for suppression of *Striga.*

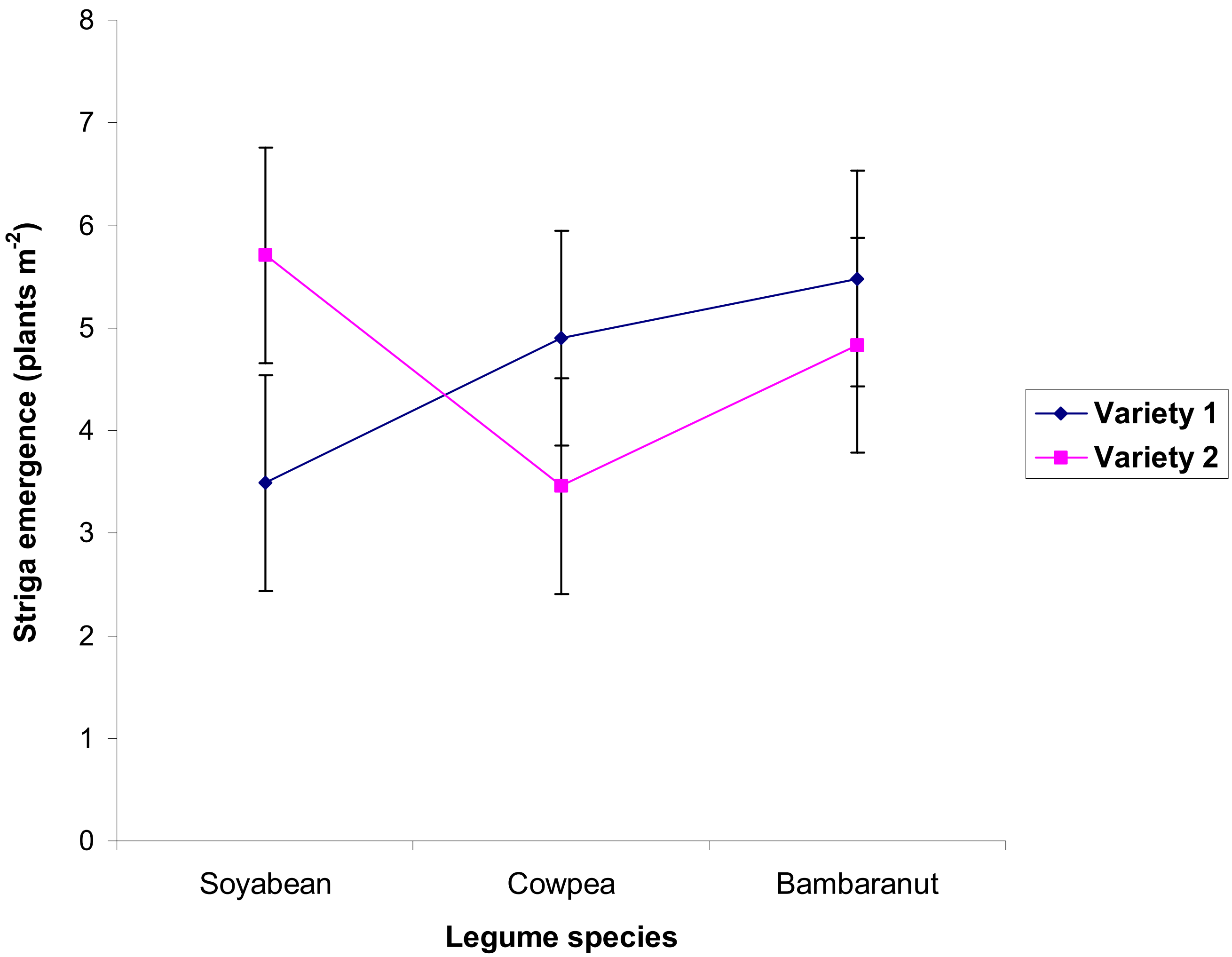

Fig.4.1.3. Interaction between crop species and variety on *Striga asiatica* emergence during 12 WACE at site 1.

Bambaranut caused the highest mean emergence, followed by soyabean (Fig 4.1.3) in maize legume intercrop, while cowpea varieties had the least mean *Striga* emergence . Soyabean varieties showed significant ($P<0.05$) difference in inducing *Striga* emergence, with variety Hurungwe having the highest emergence compared to variety Magoye, while the other legume species had no significant emergence differences (Fig 4.1.3) as shown above. .

4.2. *Striga asiatica* days to flowering

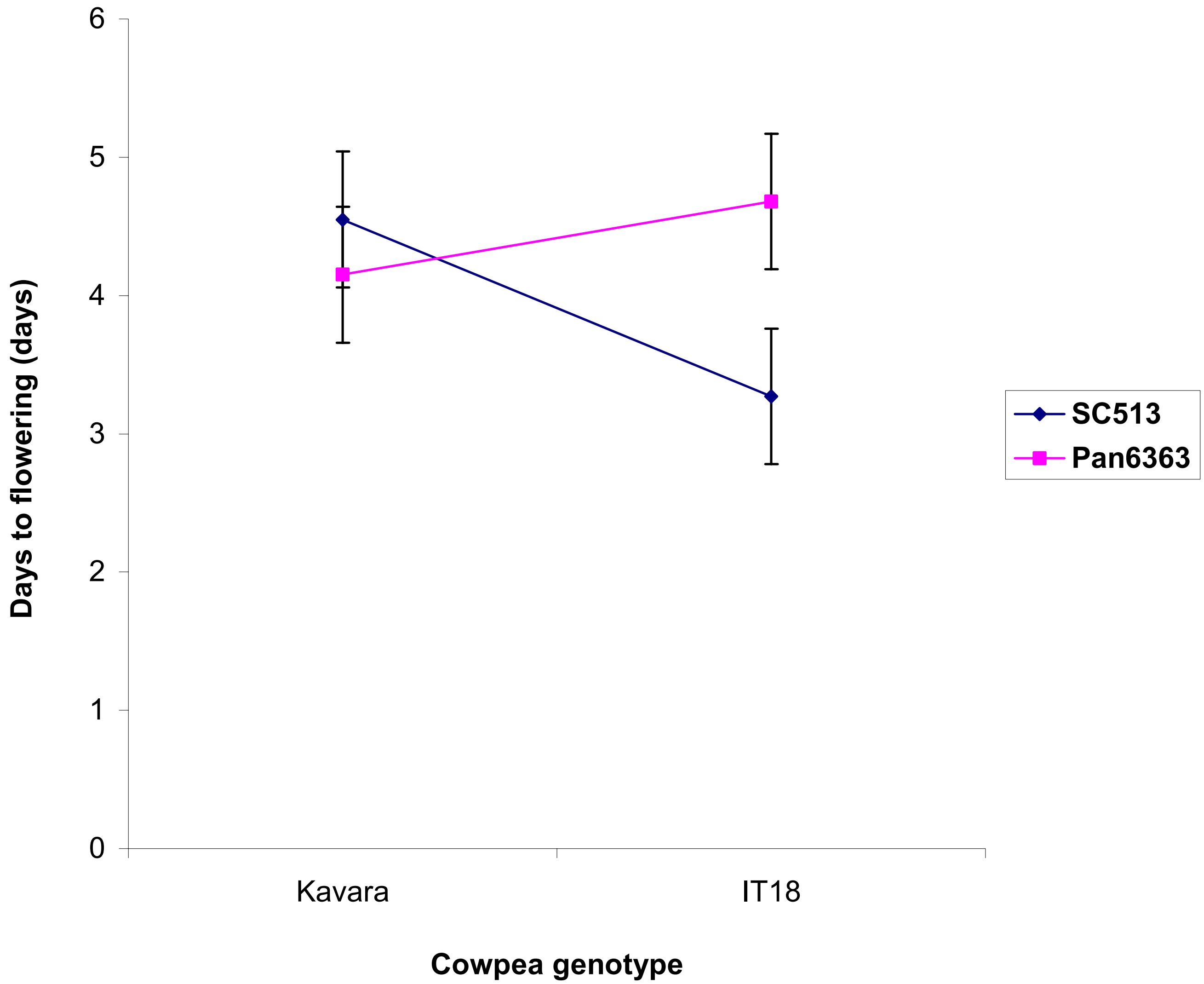

Fig. 4.2.1 Cropping system and cowpea genotype interaction effect on *Striga asiatica* days to flowering at site 4.

There was a significant (P<0.037) interaction effect between cropping system and cowpea genotypes on *Striga asiatica* days to flowering at site 4 as shown above. Maize SC513 and Pan6363 by cowpea genotype Kavara had similar non-significant (P>0.05) effect on *Striga asiatica* days to flowering. Maize Pan6363 by cowpea genotype IT18 interacted to cause significantly ($P<0.05$) more *Striga asiatica* days to flowering (Fig.4.2.1.). Maize SC513 by cowpea genotype IT18 had the least significant days to flowering.

For the maize cowpea intercrops, there was no significant (P. >0.05) effect on the number of *Striga asiatica* days to flowering between maize SC513 cowpea and maize Pan6363 cowpea intercrops across all the sites (Table 4.2.).

Generally maize Pan6363 cowpea intercrop had more *Striga asiatica* days to flowering compared to maize SC513 cowpea intercrop, although there was no significant ($P>0.05$) difference between them across sites (Table 4.2.).

Table 4.2. Effect of cropping system on *Striga asiatica* days to flowering across sites.

	Number of days to flowering (days) (square root transformed)				
Cropping system	Site 1	Site 2	Site 3	Site 4	Mean
Sole cowpea	0.710^{b}	0.710^{b}	0.710^{b}	0.710^{b}	0.710
SC513 cowpea intercrop	3.830^{a}	3.680^{a}	3.830^{a}	3.910^{a}	3.810
Pan6363 cowpea intercrop	4.120^{a}	3.440^{a}	3.950^{a}	4.410^{a}	3.980…
Mean	2.886	2.610	2.830	3.010	
LSD $_{(0.05)}$	1.109	0.910	0.744	0.703	
SED	0.526	0.448	0.366	0. 346	
CV%	44.6	51.5	38.8	34.5	
P value	<0.001	<0.001	<0.001	<0.001	

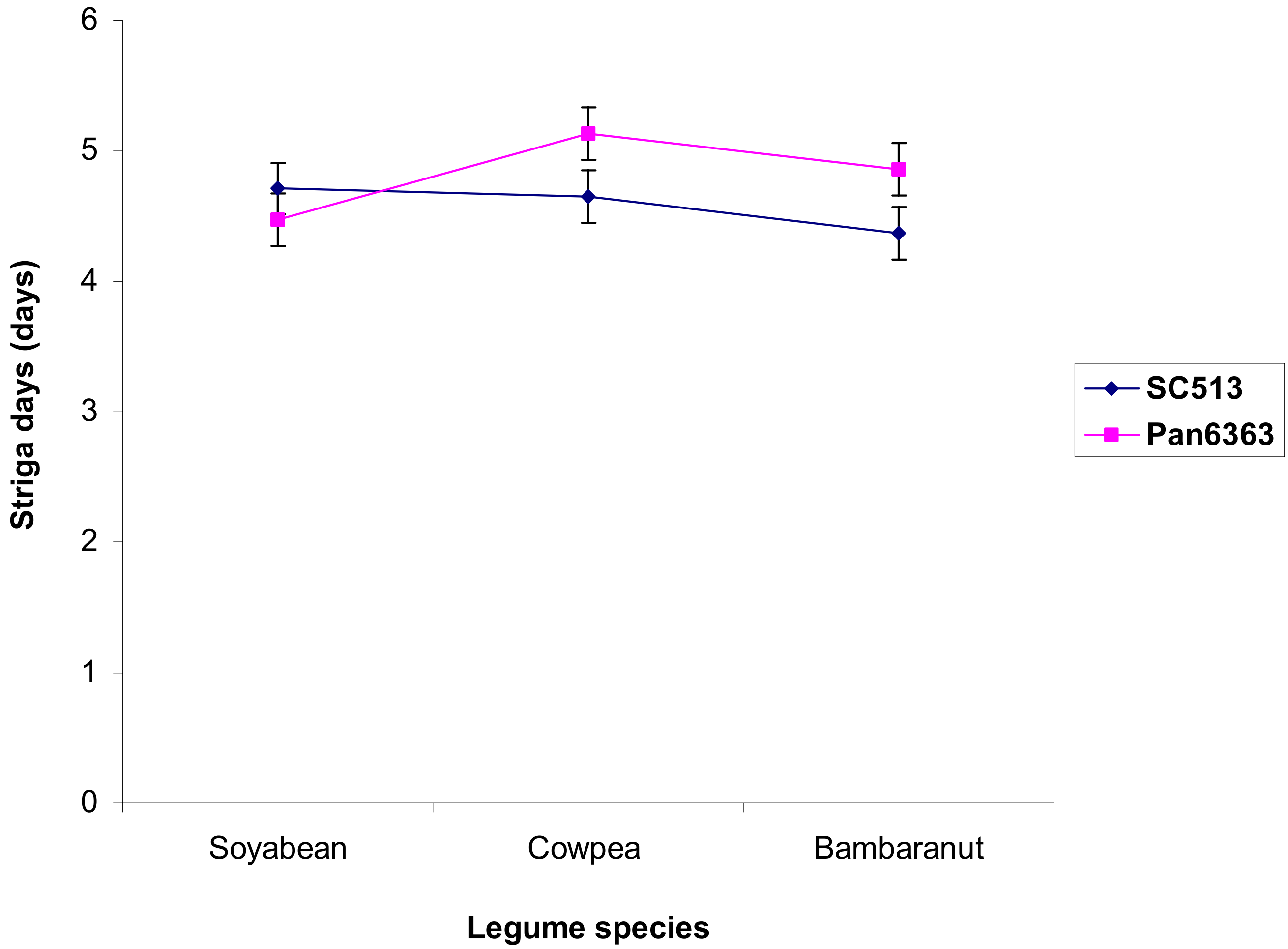

Fig. 4.2.2. Interaction between cropping system and crop species on *Striga* days to flowering at site 1.

Cropping system and crop species interacted to cause a significant (P<0.045) effect on *Striga* days to flowering at site 1, particularly cowpea and bambaranut in maize intercrop. Maize Pan6363 by cowpea intercrop had the highest number of *Striga* days to flowering compared to maize SC513 intercrops (Fig.4.2.2). Maize SC513 and Pan6363 when intercropped with soyabean caused similar *Striga* days to flowering (Fig. 4.2.2).

4.3. *Striga asiatica* dry matter accumulation

Across sites the cropping systems caused significant ($P<0.05$) effect on *Striga asiatica* dry matter accumulation (Table 4.3.). Across sites, maize SC513 cowpea intercrop had the highest dry matter that accumulated followed by maize Pan6363 cowpea intercrop, but the accumulated dry matter did not differ significantly ($P>0.05$). Generally low *Striga asiatica* dry matter accumulated in the maize cowpea intercrops (Table 4.3.).

Table 4.3. Effect of cropping system on *Striga asiatica* dry matter accumulation across sites.

	Striga asiatica dry matter (g m^{-2}) (square root transformed)				
Cropping system	Site 1	Site 2	Site 3	Site 4	Mean
Sole cowpea	0.710^{b}	0.710^{b}	0.710^{b}	0.710^{b}	0.710
SC513 cowpea intercrop	1.334^{a}	1.046^{a}	1.073^{a}	0.877^{a}	1.083
Pan6363 cowpea intercrop..	0.995^{ab}	0.826^{b}	0.871^{ab}	0.916^{a}	0.902
Mean	1.013	0.860	0.885	0.834	0.898
$LSD_{(0.05)}$	0.339	0.209	0.215	0.080	
SED	0.161	0.103	0.106	0.039	
CV%	38.8	35.9	35.9	14.1	
P value	0.004	0.009	0.006	<0.001	

4.4. *Striga asiatica* seed production

Significant ($P<0.001$) cropping systems effect on *Striga asiatica* seed capsule formation was evident across sites (Table 4.4). At site 1, and 4, no significant ($P>0.05$) number of *Striga asiatica* seed capsule was observed between maize SC513 cowpea and maize Pan6363 cowpea intercrops, while at site 2 and 3, a significant ($P<0.001$) effect on the number of *Striga asiatica* seed capsule formed was observed between maize SC513 cowpea and maize Pan6363 cowpea intercrops (Table 4.4.). Across the cropping systems, maize SC513 cowpea intercrop caused formation of more seed capsules numbers compared to maize Pan6363 cowpea intercrop.

Table 4.4. Effect of cropping system on *Striga asiatica* seed production across sites.

	Striga asiatica seed capsules/m^{-2} (square root transformed)				
Cropping system	Site 1	.Site 2.	Site 3	..Site 4	.Mean
Sole cowpea	0.710^{b}	0.710^{c}	0.710^{c}	0.710^{b}	0.710
SC513 cowpea intercrop	9.520^{a}	7.410^{a}	7.960^{a}	5.700^{a}	7.468
Pan6363 cowpea intercrop	6.210^{a}	3.610^{b}	4.410^{b}	6.500^{a}	5.183
Mean	5.480	3.910	4.360	4.303	4.513
LSD $_{(0.05)}$	3.783	3.032	2.879	1.777	
SED	1.793	1.492	1.417	0.874	
CV%	80.2	114.5	97.5	61	
P value	<0.001	<0.001	<0.001	<0.001	

WACE .Weeks After Crop Emergence

4.5. Maize plant height

Generally, maize plant height increased gradually from 6 to 14 WACE. There was no significant (P>0.05) maize height difference across sites, except during 14 WACE at site 4.

4.6. Correlations between *Striga* emergence and maize parameters

At site 1, the crop parameters showed positive correlation coefficients against *Striga asiatica* emergence, with maize plant height showing significance (r=0.438, P=0.04).

All correlation coefficients at site 2 were negative and non-significant, except *Striga asiatica* emergence against maize cob weight (r=0.425, P=0.005). At site 3, maize grain yield and maize cob weights gave negative insignificant (P>0.05) correlation coefficients respectively (Table 4.6.).

Table 4.6. Correlations between *Striga asiatica* emergence, maize yield and growth parameters during 2002/2003 season.

	Cumulative *Striga* emergence			
	Site 1	**Site 2**	**Site 3**	**Site 4**
	r p	**r p**	**r p**	**r p**
Maize grain yield	0.304(0.05)	-0.164(0.295)	-0.151(0.339)	0.278(0.074)
Maize cob weight	0.210(0.172)	-0.425(0.005)	0.090(0.570)	-0.178(0.260)
Maize plant height	0.438(0.004)	-0.139(0.382)	0.247(0.116)	0.302(0.052)

r = correlation coefficients, p = significance levels of correlation

4.7. Discussion

4.7.1. *Striga asiatica* emergence

Striga asiatica emergence generally started at 10 WACE and increased to 12 WACE, thereafter started to decline as maize plant roots become dry plant senesce and dry out, thus would no longer support the parasite with resources. Peak *Striga asiatica* emergence across sites was observed during 12 WACE. Kasembe (1997) made similar observations and suggested synchronization of the parasite to the crop host`s growth and development, which was evident.

No emergence was observed before and during 8 WACE, probably the parasite was still responding to dormancy breaking mechanisms and experiencing its underground growth phase, during which it develops haustoria to attach to the host crop. Delayed *S.asiatica* emergence could also be a result of inadequate seed conditioning at the beginning of the season.

Sole cowpea stands had no *Striga* emergence and this may be attributed to biologically fixed nitrogen which suppress parasitism and also the non-host nature of the crop. Between the maize cowpea intercrops, maize SC513 cowpea intercrop induced higher *S. asiatica* emergence across all the sites.

Maize SC513 intercropped with cowpea genotype Kavara at 55 000 and 65 000 plants ha^{-1} caused higher *S. asiatica* emergence. Maize SC513 and cowpea genotype Kavara could have interacted positively at both populations to cause significantly ($P<0.05$) higher emergence. Both host and non-host plants might have cumulatively produced higher amounts of stimulants that resulted in more stimulation, germination and emergence. It is suggested that the differences in germination of *Striga* induced by different crops is a result of different amounts and type of germination stimulant produced (Olupot *et al*., 2001). It can be inferred that at 55 000 and 65 000 plants ha^{-1}, Kavara did not have as much shading effect as at 75 000 plants per hectare to cause reduced *Striga* emergence.

Maize SC513 intercropped with cowpea genotype IT18 at 75 000 plants ha $^{-1}$ and maize Pan6363 intercropped with cowpea genotype IT18 at 65 000 and 75 000 plants ha $^{-1}$ suppressed *S.asiatica* emergence. Cowpea genotype IT18 at 65 000 and 75 000 plants ha $^{-1}$ might have fixed biologically reasonable amount of nitrogen into the soil, which resulted in reduced *Striga asiatica* emergence, thus as cowpea genotype IT18`s population increases, a reduction in *Striga asiatica* emergence occurs. Pieterse and Verkleij (1991) suggested that nitrogen fixed by legumes might interact with *Striga* growth, since the amount of available nitrogen apparently affect the number of *Striga asiatica* emerged plants. Maize Pan6363 can be associated with low stimulant production, which together with attributes from cowpea genotype IT18 interacted to suppress *S. asiatica* emergence. It can also be suggested that maize Pan6363 has a slightly deep root system, which means interacting with very few parasitic seeds in the soil, as most of the seeds are within the top most soil. Cereal hosts whose root system ramifies immediately below the soil surface promote host root-parasite seed interaction; hence increase the chances of attachment and emergence. Ransom *et al*., (1997) identified genetic variability for *Striga* resistance in maize, which can also explain the trend.

Another cause could be attributed to lower stimulant production by cowpea genotype IT18 at 65 000 and 75 000 plants ha^{-1}, resulting in suppressed emergence. Cowpea genotype IT18 has a determinant growth habit and quickly attains maturity and senesce in a reasonable short period, implying no more *S. asiatica* stimulation thereafter.

Between the cowpea genotypes, IT18 at 65 000 and 75 000 plants ha $^{-1}$ suppressed more *S. asiatica* emergence than Kavara. In any case the trap crop should be well managed to ensure good root growth and development to optimise their effectiveness (Ransom and Odhiambo, 1997). Cowpea genotype Kavara at 65 000 and 75 000 plants ha $^{-1}$ developed a dense ground cover, such that some etiolated and diseased S. *asiatica* plants were observed during wet part of the season.

The dense ground cover formed could have affected *S. asiatica* emergence, and the young emerging seedlings may have died before being accounted for, and thus had an effect on *S. asiatica* growth and development. Musambasi *et al*., (2002) observed prevalence of fungal diseases associated with wet conditions. Cowpea genotype Kavara has an indeterminant growth habit and with the dense canopy it forms one would expect it to be effective in suppressing *S. asiatica* emergence.

4.7.2. *Striga asiatica* days to flowering

Longer *S. asiatica* vegetative growth phase implies a longer parasitism period associated with high depletion of host resources. It also means the parasite is able to develop to full maturity and can shed a lot of its fully developed minute seeds.

Maize Pan6363 intercropped with cowpea genotype IT18 and maize SC513 intercropped with cowpea genotype Kavara caused longer *S. asiatica* vegetative growth period. A significant cropping system and cowpea genotype effect was observed at site 4. Maize Pan6363 and cowpea interacted to give longer *S. asiatica* vegetative growth phase followed by maize SC513 cowpea intercrop. A short vegetative growth phase of the parasite would imply reduced extraction of the host plant resources, however much of the damage is inflicted onto the host crop before emergence.

4.7.3. *Striga asiatica* seed production

Maize cowpea intercrops induced the highest number of seed capsules that formed across sites. Higher numbers of *S. asiatica* seed capsules that were formed imply increased parasitic infestation into the already infested soil, if allowed to mature and rain back into the soil, while treatments with low seed capsule numbers would reduce infestation levels. Formation of higher number of *S. asiatica* seed capsules means a lot of host plant resources have been utilized. The parasitic weed has survival strategy of producing a lot of seed capsules, thus ensure continued presence of the parasite in the soil seed bank.

4.7.4. *Striga asiatica* dry matter accumulation

More *Striga asiatica* dry matter accumulated in maize SC513 cowpea intercrop, although it did not differ significantly ($P<0.05$) with maize Pan6363 cowpea intercrop. Treatments that had more *Striga asiatica* emergence consequently accumulated higher amounts of dry matter. However, low dry matter accumulation would mean reduced extraction of host plant resources by the parasite and a general low infection level throughout the sites. The parasitic plant has a reduced morphology, hence low dry matter accumulation.

4.8. Maize grain yield, cob and stover weights

Maize grain yield, cob and stover weights had similar non-significant results. Lack of cob weight differences could have resulted in non-significant difference in maize grain yield.

One reason for non-significant maize grain yield, cob and stover weights could be the effect of intercrop competition. Levels of *S. asiatica* infection were significantly different, and that should cause a direct grain yield, cob weight, and stover weight difference. The infection levels did not cause significant treatments effects. Emechebe *et al*., (2001), however made observations that maize cob yield decreased with increase in inoculum of artificially introduced *S. hermonthica*. Despite artificial introduction of inoculum, this view should be also true with natural inoculum, but the difference could result because of uneven inoculum distribution in the soil.

4.9. Correlations between *Striga asiatica* emergence and maize parameters

Negative correlation coefficients that characterized the relationship indicate that an increase in *Striga asiatica* emergence caused a reduction in maize grain yield, cob weight and plant height, which is a normal trend with infection versus yield component experiments. Mutengwa, Tongoona, Mabasa, Chivinge and Icishahayo (1999), made similar observations on *S. asiatica* counts against sorghum yield parameters. The correlation coefficients were very low, implying that the relationships were very weak and did not explain the parameters versus infection level very much. This may show that the infection levels were too low to influence maize height reduction, thus the crop had a normal growth. This positive relationship may be a result of uneven distribution of *Striga asiatica* inoculum in the soil.

Maize grain yield, cob weight and plant height showed negative correlation coefficients, when correlated to *S. asiatica* emergence across sites. This may be a result of significantly higher *S. asiatica* emergence at the site, which adversely influenced the host crop grain yield, cob weight and height. Such relationship was also evident at site 3 for *S. asiatica* against maize grain yield, and *S. asiatica* against cob weight at site 4. Again, it shows that the response is site dependent. Other parameters recorded positive coefficients, which could be explained by the parameters` reduced sensitivity to the infection level. Perhaps sensitivity could be expressed beyond a certain infection threshold level, and before that threshold level is reached, control is not worthwhile. This reduces input cost to the smallholder farmer who in most cases is resource constrained.

4.10. Grain yield and Total Land Equivalent Ratios

Cowpea grain yield was similar across sites, genotypes and populations. It is expected that moderate to higher populations especially of indeterminate genotype yield more compared to determinate at lower population. Yield similarity could also suggest that planting at higher cowpea population is expensive compared to planting at lower population because all treatments resulted in similar yields.

However, for the farmer, other benefits from cowpea such as source of tender nutritive leaves, green pods, green and dried seeds may out weigh yield benefits.

CHAPTER 5. GENERAL DISCUSSION

All the sole legume species and genotype stands completely suppressed *S. asiatica* emergence, consequently seed capsule formation and dry matter accumulation, showing that they are non-hosts.

These might have caused suicidal germination, were *S. asiatica* seeds are induced to germinate because of the stimulant they produce, but cannot be parasitised as they are non-host crops. Worsham (1987) suggested that suicidal germination of the parasite seeds in the absence of roots of a host cereal crop leads to death of parasite seedlings within 3-5 days, thus the parasitic seedling has to be close to the host crop roots.

Nitrogen fixed by the grain legumes might also have played a role in the suppression of the parasitic weed, especially in sole legume stands, as nitrogen has been reported to have detrimental effects on *S. asiatica*. However, in the intercrops, sole grain legumes and maize stands, varying levels of stimulants were produced; therefore different levels of *S. asiatica* were induced to emergence. Olupot *et al*., (1997) indicated that crops that stimulated more Striga seeds to germinate possibly produced more germination stimulant. Differences in host crop`s days to physiological maturity, to which *S. asiatica* growth pattern is synchronized, might have caused parasite emergence differences in intercrops and sole maize stands. Maize Pan6363 reached physiological maturity within 125-130 days, while maize SC513 took about 137 days. The difference could suggest more parasite emergence with maize SC513, which has a longer vegetative growth phase than maize Pan6363. Ransom *et al*., (1997) found more similar results, were early maturing maize genotypes supported less *Striga* than full season genotypes. Moreover, Ransom and Odhiambo (1995) found significant correlation between length of maturity of maize genotypes and *Striga* emergence.

Intercrop shading might have caused difference in *S. asiatica* emergence. Shading by the understorey in intercrops could cause reduced soil temperatures, which might have interfered with *Striga* emergence as suggested by Carsky *et al*., (1994). Similar effects were reported by Chanyowedza *et al*., (1997), who noted mulching to increase the number of days to *S. asiatica* emergence.

Generally, crop species and genotypes differ in their ability to induce *S. asiatica* emergence. Berner, Kling and Singh (1995) made similar observations by reporting large differences among genotypes within a crop species for their ability to stimulate *Striga* seed germination.

More *S. asiatica* seed capsules formation and cumulative dry matter were expected under longer vegetative growth phase compared to a shorter one, however, results did not suggest this. Days from emergence to first flowering of *S. asiatica* suggest the length of parasitism period, which is detrimental to the host crop. It also suggest the length of time during which the parasitic plant become fully mature, and have the chance to shed well developed seeds into an already existing seed bank.

Some witchweed plants emerged between 10-12 WACE and this may have been too late for them to reduce maize grain yield, cob weight, stover weight and maize plant height significantly. Wet dormancy, a phenomenon induced by excessive soil moisture content, might have played a role in causing delayed emergence as most sites where characterized by high rainfall in December and January, a period during which the parasite was suppose to germinate and emerge, thus delay and reduce cumulative *S. asiatica* emergence.

Generally, *Striga* pathogenecity depends upon a number of factors such as the biomass ratio of the parasite to the host, the number of parasites attached to an individual host plant, the length of time required for the parasite to complete its life cycle and the extent of co-evolutionary tuning that has occurred overtime between the two species (Nickrent, 2002) among other factors.

Further analysis by correlating *Striga asiatica* emergence against maize grain yield, cob weights and plant heights generally showed negative correlation coefficients. This suggests that *S. asiatica* infection caused reduction effect on maize grain yield, cob weight and plant height, however, the coefficients were non- significant ($P>0.05$).

Correlation coefficient values were very small showing very weak relationship, thus *S. asiatica* emergence had little impact, although adverse on maize grain yield, cob weight and plant height. Emechebe *et al.,* (2001) made observations that maize cob yield decreased with increase in inoculum of artificially introduced *S. hermonthica.* Despite artificial introduction of inoculum, this view should be true with natural inoculum, but differences could result because of uneven inoculum distribution in the soil.

A cause for low correlation coefficients could be late emergence of the parasite, which generally started during 10 WACE, as a result of high rainfall received during the pre-emergence period. After emergence, the parasite had limited vegetative growth phase within which to exert significant adverse effects on maize yield, cob weight and plant height. Inherent low inoculum levels and the unavoidable uneven distribution of the inoculum in the field could also have had an effect on the coefficient levels. However, few the infection level might have been, it still induced reduction effect on some host crop growth and yield parameters.

5.1. Conclusions

Conclusions that can be made from the work done are:

The soyabean, cowpea and bambaranut varieties in sole stands completely suppressed *S. asiatica* emergence, hence seed capsule formation and dry matter.

Maize Pan6363 intercropped with cowpea IT18 at 65 000 and 75 000 plants ha^{-1} suppressed *S. asiatica* emergence, seed capsule formation and dry matter, making them ideal intercrops for *S. asiatica* management in smallholder sectors.

Soya bean variety Magoye suppressed *Striga* emergence compared to variety Hurungwe.

Between the cowpea varieties, IT18 performed much better than Kavara in suppressing *S. asiatica* emergence, growth and development. For the cowpea populations, 65 000 and 75 000 plants ha^{-1} managed to suppress *S. asiatica* emergence, growth and development.

Maize SC513 intercropped with cowpea Kavara at 55 000 plants ha^{-1} and maize Pan6363 intercropped with cowpea IT18 at 65 000 plants ha^{-1} caused shorter *S. asiatica* vegetative growth phase and thus results in a shorter parasitism period.

Maize grain yield, cob weight and plant height were negatively affected by *Striga asiatica* infection.

5.2. Recommendations

Farmers can be advised to plant maize Pan6363 intercropped with cowpea IT18 at 65 000 and 75 000 plants ha^{-1} to reduce *S. asiatica* infection levels in the smallholder farming sector.

Farmers in *S. asiatica* endemic SH sectors can plant the sole grain legumes in rotation with cereals to keep infestation levels low.

Farmers can be advised to plant maize SC513 intercropped with cowpea variety Kavara at 55 000 plants ha^{-1} and maize Pan6363 intercropped with cowpea variety IT18 at 65 000 plants ha^{-1} to reduce the parasitic growth phase of *S. asiatica.*

Green house experiments should be done to confirm the findings

Laboratory analysis of the grain legumes and maize genotypes is necessary to bio-chemically differentiate them.

An infection threshold level for the Zimbabwean situation needs to be established, beyond which control measures need to be implemented.

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List of Appendices

Appendix A: Effect of cowpea genotypes and populations on *Striga asiatica* emergence, growth and development for 2002/2003 season.

A1. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	1	0.081	0.081	0.05	
Rep*Units*stratum					
Cropping system	2	20.586	10.293	6.62	0.007
Genotypes	1	0.112	0.112	0.07	0.791
Population	2	0.315	0.158	0.10	0.904
Cropping system*Genotype	2	1.424	0.712	0.46	0.630
Cropping system*Population	4	5.135	1.284	0.83	0.527
Genotype*Population	2	2.600	1.300	0.84	0.450
Cropping*Genotype*Population	4	4.152	1.038	0.67	0.623
Residual	17	26.421	1.554		
Total	35	60.827			

A2. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	1	4.410	4.410	1.19	
Rep*Units*stratum					
Cropping system	2	64.526	32.263	8.70	0.002
Genotypes	1	1.988	1.988	0.54	0.474
Population	2	0.297	0.149	0.04	0.961
Cropping system*Genotype	2	28.984	14.492	3.91	0.040
Cropping system*Population	4	21.146	5.286	1.43	0.268
Genotype*Population	2	6.667	3.333	0.90	0.425
Cropping*Genotype*Population	4	6.988	1.747	0.47	0.756
Residual	17	63.021	3.707		
Total	35	198.026			

A3. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	1	1.127	1.127	0.68	
Rep*Units*stratum					
Cropping system	2	85.797	42.899	25.88	<.001
Genotypes	1	0.460	0.460	0.28	0.605
Population	2	1.160	0.580	0.35	0.710
Cropping system*Genotype	2	3.703	1.852	1.12	0.350
Cropping system*Population	4	0.925	0.231	0.14	0.965
Genotype*Population	2	0.726	0.363	0.22	0.805
Cropping*Genotype*Population	4	2.345	0.586	0.35	0.838
Residual	17	28.185	1.658		
Total	35	124.428			

A4. Analysis of Variance for *Striga asiatica* seed capsules at site1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	1	5.09	5.09	0.26	
Rep*Units*stratum					
Cropping system	2	475.18	237.59	12.32	<.001
Genotypes	1	0.29	0.29	0.02	0.903
Population	2	6.88	3.44	0.18	0.838
Cropping system*Genotype	2	135.28	67.64	3.51	0.053
Cropping system*Population	4	62.11	15.53	0.81	0.539
Genotype*Population	2	12.04	6.02	0.31	0.736
Cropping*Genotype*Population	4	13.68	3.42	0.18	0.947
Residual	17	327.86	19.29		
Total	35	1038.42			

A5. Analysis of Variance for *Striga asiatica* dry matter at site1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	1	0.0831	0.0831	0.54	
Rep*Units*stratum					
Cropping system	2	2.3434	1.1717	7.57	0.004
Genotypes	1	0.0132	0.0132	0.09	0.774
Population	2	0.1552	0.0776	0.50	0.614
Cropping system*Genotype	2	0.6699	0.3350	2.16	0.145
Cropping system*Population	4	0.8124	0.2031	1.31	0.305
Genotype*Population	2	0.0742	0.0371	0.24	0.790
Cropping*Genotype*Population	4	0.1363	0.0341	0.22	0.923
Residual	17	2.6314	0.1548		
Total	35	6.9192			

A6. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	1.2547	0.6273	1.00	
Rep*Units*stratum					
Cropping system	2	15.7336	7.8668	12.57	<.001
Genotypes	1	0.0542	0.0542	0.09	0.770
Population	2	2.9816	1.4908	2.38	0.108
Cropping system*Genotype	2	0.1779	0.0889	0.14	0.868
Cropping system*Population	4	3.7096	0.9274	1.48	0.229
Genotype*Population	2	0.5852	0.2926	0.47	0.631
Cropping*Genotype*Population	4	4.7148	1.1787	1.88	0.136
Residual	34	21.2781	0.6258		
Total	53	50.4896			

A7. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	3.318	1.659	1.41	
Rep*Units*stratum					
Cropping system	2	35.247	17.624	14.96	<.001
Genotypes	1	1.779	1.779	1.51	0.228
Population	2	3.159	1.580	1.34	0.275
Cropping system*Genotype	2	3.230	1.615	1.37	0.268
Cropping system*Population	4	5.781	1.445	1.23	0.318
Genotype*Population	2	5.983	2.992	2.54	0.094
Cropping*Genotype*Population	4	7.013	1.753	1.49	0.228
Residual	34	40.057	1.178		
Total	53	105.567			

A8. Analysis of Variance for *Striga asiatica* days from flowering to emergence at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.896	0.448	0.25	
Rep*Units*stratum					
Cropping system	2	97.865	48.932	27.13	<.001
Genotypes	1	1.402	1.402	0.78	0.384
Population	2	2.278	1.139	0.63	0.538
Cropping system*Genotype	2	6.302	3.151	1.75	0.190
Cropping system*Population	4	12.974	3.244	1.80	0.152
Genotype*Population	2	0.928	0.464	0.26	0.775
Cropping*Genotype*Population	4	3.780	0.945	0.52	0.719
Residual	34	61.324	1.804		
Total	53	187.749			

A9. Analysis of Variance for *Striga asiatica* seed capsules at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	62.76	31.38	1.57	
Rep*Units*stratum					
Cropping system	2	405.87	202.94	10.13	<0.001
Genotypes	1	7.09	7.09	0.35	0.556
Population	2	49.68	24.84	1.24	0.302
Cropping system*Genotype	2	3.55	1.77	0.09	0.916
Cropping system*Population	4	33.83	8.46	0.42	0.792
Genotype*Population	2	34.03	17.01	0.85	0.437
Cropping*Genotype*Population	4	137.73	34.43	1.72	0.169
Residual	34	681.33	20.04		
Total	53	1415.86			

A10. Analysis of Variance for *Striga asiatica* dry matter at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.39178	0.19589	2.06	
Rep*Units*stratum					
Cropping system	2	1.04610	0.52305	5.49	0.009
Genotypes	1	0.07859	0.07859	0.82	0.370
Population	2	0.14236	0.07118	0.75	0.481
Cropping system*Genotype	2	0.04064	0.02032	0.21	0.809
Cropping system*Population	4	0.19880	0.04970	0.52	0.720
Genotype*Population	2	0.26478	0.13239	1.39	0.263
Cropping*Genotype*Population	4	0.70526	0.17632	1.85	0.142
Residual	34	3.23989	0.09529		
Total	53	6.10819			

A11. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	1.4167	0.7084	1.27	
Rep*Units*stratum					
Cropping system	2	10.2177	5.1089	9.19	<.001
Genotypes	1	2.4704	2.4704	4.44	0.042
Population	2	0.7622	0.3811	0.69	0.511
Cropping system*Genotype	2	1.2399	0.6199	1.12	0.340
Cropping system*Population	4	1.5171	0.3793	0.68	0.609
Genotype*Population	2	1.1014	0.5507	0.99	0.382
Cropping*Genotype*Population	4	1.0235	0.2559	0.46	0.764
Residual	34	18.8995	0.5559		
Total	53	38.6485			

A12. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	1.820	0.910	0.69	
Rep*Units*stratum					
Cropping system	2	42.644	21.322	16.16	<.001
Genotypes	1	2.323	2.323	1.76	0.193
Population	2	0.039	0.020	0.01	0.985
Cropping system*Genotype	2	6.700	3.350	2.54	0.094
Cropping system*Population	4	2.123	0.531	0.40	0.806
Genotype*Population	2	2.628	1.314	1.00	0.380
Cropping*Genotype*Population	4	5.486	1.372	1.04	0.401
Residual	34	44.849	1.319		
Total	53	108.613			

A13. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.081	0.041	0.03	
Rep*Units*stratum					
Cropping system	2	121.489	60.745	50.29	<.001
Genotypes	1	1.760	1.760	1.46	0.236
Population	2	0.217	0.108	0.09	0.914
Cropping system*Genotype	2	4.007	2.004	1.66	0.205
Cropping system*Population	4	1.675	0.419	0.35	0.844
Genotype*Population	2	3.032	1.516	1.26	0.298
Cropping*Genotype*Population	4	3.463	0.866	0.72	0.586
Residual	34	41.066	1.208		
Total	53	176.790			

A14. Analysis of Variance for *Striga asiatica* seed capsules at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	53.27	26.64	1.47	
Rep*Units*stratum					
Cropping system	2	473.56	236.78	13.11	<.001
Genotypes	1	18.95	18.95	1.05	0.313
Population	2	30.32	15.16	0.84	0.441
Cropping system*Genotype	2	27.50	13.75	0.76	0.475
Cropping system*Population	4	57.02	14.25	0.79	0.540
Genotype*Population	2	59.98	29.99	1.66	0.205
Cropping*Genotype*Population	4	83.27	20.82	1.15	0.349
Residual	34	614.04	18.06		
Total	53	1417.91			

A15. Analysis of Variance for *Striga asiatica* dry matter at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.2131	0.1065	1.06	
Rep*Units*stratum					
Cropping system	2	1.1894	0.5947	5.90	0.006
Genotypes	1	0.1130	0.1130	1.12	0.297
Population	2	0.1396	0.0698	0.69	0.507
Cropping system*Genotype	2	0.0567	0.0284	0.28	0.757
Cropping system*Population	4	0.3696	0.0924	0.92	0.466
Genotype*Population	2	0.2879	0.1439	1.43	0.254
Cropping*Genotype*Population	4	0.4092	0.1023	1.01	0.414
Residual	34	3.4287	0.1008		
Total	53	6.2071			

A16. Analysis of Variance for *Striga asiatica* emergence during 10 WACE at site 4

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	4.6655	2.3327	5.41	
Rep*Units*stratum					
Cropping system	2	13.2930	6.6465	15.40	<.001
Genotypes	1	1.6960	1.6960	3.93	0.056
Population	2	0.6449	0.3224	0.75	0.481
Cropping system*Genotype	2	2.0617	1.0308	2.39	0.107
Cropping system*Population	4	1.5971	0.3993	0.93	0.461
Genotype*Population	2	0.8360	0.4180	0.97	0.390
Cropping*Genotype*Population	4	7.2548	1.8137	4.20	0.007
Residual	34	14.6721	0.4315		
Total	53	46.7211			

A17. Analysis of Variance for *Striga asiatica* emergence 12 WACE at site 4

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	19.456	9.728	6.73	
Rep*Units*stratum					
Cropping system	2	57.139	28.569	19.77	<.001
Genotypes	1	0.038	0.038	0.03	0.871
Population	2	1.843	0.921	0.64	0.535
Cropping system*Genotype	2	0.344	0.172	0.12	0.888
Cropping system*Population	4	1.799	0.450	0.31	0.868
Genotype*Population	2	3.959	1.979	1.37	0.268
Cropping*Genotype*Population	4	7.793	1.948	1.35	0.272
Residual	34	49.127	1.445		
Total	53	141.498			

A18. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 4

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	4.183	2.091	1.94	
Rep*Units*stratum					
Cropping system	2	145.168	72.584	67.44	<.001
Genotypes	1	0.854	0.854	0.79	0.379
Population	2	0.669	0.334	0.31	0.735
Cropping system*Genotype	2	7.798	3.899	3.62	0.037
Cropping system*Population	4	1.652	0.413	0.38	0.819
Genotype*Population	2	0.579	0.289	0.27	0.766
Cropping*Genotype*Population	4	0.599	0.150	0.14	0.967
Residual	34	36.591	1.076		
Total	53	198.093			

A19. Analysis of Variance for *Striga asiatica* seed capsules at site 4

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	85.797	42.898	6.23	
Rep*Units*stratum					
Cropping system	2	354.078	177.039	25.73	<.001
Genotypes	1	0.990	0.990	0.14	0.707
Population	2	23.839	11.920	1.73	0.192
Cropping system*Genotype	2	11.706	5.853	0.85	0.436
Cropping system*Population	4	12.600	3.150	0.46	0.766
Genotype*Population	2	13.293	6.647	0.97	0.391
Cropping*Genotype*Population	4	16.655	4.164	0.61	0.662
Residual	34	233.982	6.882		
Total	53	752.939			

A20. Analysis of Variance for *Striga asiatica* dry matter at site 4

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.03991	0.01996	1.43	
Rep*Units*stratum					
Cropping system	2	0.43011	0.21506	15.45	<.001
Genotypes	1	0.01467	0.01467	1.05	0.312
Population	2	0.03121	0.01561	1.12	0.338
Cropping system*Genotype	2	0.02934	0.01467	1.05	0.360
Cropping system*Population	4	0.04367	0.01092	0.78	0.543
Genotype*Population	2	0.07721	0.03861	2.77	0.077
Cropping*Genotype*Population	4	0.13330	0.03332	02.39	0.070
Residual	34	0.47329	0.01392		
Total	53	1.27272			

Appendix B. Effect of grain legume species and genotype on *Striga asiatica* emergence, growth and development during 2001/2002 season.

B1. Analysis of Variance for *Striga asiatica* emergence at 8 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.21982	0.10991	2.69	
Rep*Units*stratum					
Cropping system	1	10.76288	10.76288	263.53	<.001
Crop	2	0.09240	0.04620	1.13	0.341
Variety	1	0.09451	0.09451	2.31	0.142
Cropping system*Crop	2	0.09240	0.04620	1.13	0.341
Cropping system*Variety	1	0.09451	0.09451	2.31	0.142
Crop*Variety	2	0.07158	0.03579	0.88	0.430
Cropping*Crop*Variety	2	0.07158	0.03579	0.88	0.430
Residual	22	0.89852	0.04084		
Total	35	12.39819			

B2. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	1.4835	0.7418	2.86	
Rep*Units*stratum					
Cropping system	1	28.8808	28.8808	111.17	<.001
Crop	2	0.1463	0.0731	0.28	0.757
Variety	1	0.0459	0.0459	0.18	0.678
Cropping system*Crop	2	0.1463	0.0731	0.28	0.757
Cropping system*Variety	1	0.0459	0.0459	0.18	0.678
Crop*Variety	2	0.6174	0.3087	1.19	0.324
Cropping*Crop*Variety	2	0.6174	0.3087	1.19	0.324
Residual	22	5.7155	0.2598		
Total	35	37.6990			

B3. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	3.4622	1.7311	2.52	
Rep*Units*stratum					
Cropping system	1	46.7739	46.7739	68.16	<.001
Crop	2	0.2317	0.1159	0.17	0.846
Variety	1	0.0106	0.0106	0.02	0.902
Cropping system*Crop	2	0.2317	0.1159	0.17	0.846
Cropping system*Variety	1	0.0106	0.0106	0.02	0.902
Crop*Variety	2	0.0289	0.0144	0.02	0.979
Cropping*Crop*Variety	2	0.0289	0.0144	0.02	0.979
Residual	22	15.0961	0.6862		
Total	35	65.8747			

B4. Analysis of Variance for *Striga asiatica* emergence at 14 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	1.6291	0.8146	3.71	
Rep*Units*stratum					
Cropping system	1	25.1266	25.1266	114.35	<.001
Crop	2	1.1909	0.5955	2.71	0.089
Variety	1	0.0055	0.0055	0.03	0.875
Cropping system*Crop	2	1.1909	0.5955	2.71	0.089
Cropping system*Variety	1	0.0055	0.0055	0.03	0.875
Crop*Variety	2	0.2201	0.1100	0.50	0.613
Cropping*Crop*Variety	2	0.2201	0.1100	0.50	0.613
Residual	22	4.8342	0.2197		
Total	35	34.4230			

B5. Analysis of Variance for *Striga asiatica* seed capsules at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	127.70	63.85	3.62	
Rep*Units*stratum					
Cropping system	1	968.14	968.14	54.87	<.001
Crop	2	10.49	5.24	0.30	0.746
Variety	1	2.52	2.52	0.14	0.709
Cropping system*Crop	2	10.49	5.24	0.30	0.746
Cropping system*Variety	1	2.52	2.52	0.14	0.709
Crop*Variety	2	0.18	0.09	0.00	0.995
Cropping*Crop*Variety	2	0.18	0.09	0.00	0.995
Residual	22	388.17	17.64		
Total	35	1510.37			

B6. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.4367	0.2184	1.24	
Rep*Units*stratum					
Cropping system	1	116.5518	1165518	662.88	<.001
Crop	2	0.3269	0.1635	0.93	0.410
Variety	1	0.0001	0.0001	0.00	0.983
Cropping system*Crop	2	0.3269	0.1635	0.93	0.410
Cropping system*Variety	1	0.0001	0.0001	0.00	0.983
Crop*Variety	2	0.1674	0.0837	.048	0.627
Cropping*Crop*Variety	2	0.1674	0.0837	.048	0.627
Residual	22	3.8682	0.1758		
Total	35	121.8455			

B7. Analysis of Variance for *Striga asiatica* dry matter at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	2.5654	1.2827	4.05	
Rep*Units*stratum					
Cropping system	1	4.8270	4.8270	15.26	<.001
Crop	2	0.1342	0.0671	0.21	0.811
Variety	1	0.6316	0.6316	2.00	0.172
Cropping system*Crop	2	0.1342	0.0671	0.21	0.811
Cropping system*Variety	1	0.6316	0.6316	2.00	0.172
Crop*Variety	2	0.1734	0.0867	0.27	0.763
Cropping*Crop*Variety	2	0.1734	0.0867	0.27	0.763
Residual	22	6.9595	0.3163		
Total	35	16.2302			

B8. Analysis of Variance for *Striga asiatica* emergence 8 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.07264	0.03632	0.91	
Rep*Units*stratum					
Cropping system	1	10.54820	10.54820	265.05	<.001
Crop	2	0.4656	0.02328	0.58	0.566
Variety	1	0.12192	0.12192	3.06	0.094
Cropping system*Crop	2	0.4656	0.02328	0.58	0.566
Cropping system*Variety	1	0.12192	0.12192	3.06	0.094
Crop*Variety	2	0.02924	0.01462	0.37	0.697
Cropping*Crop*Variety	2	0.02924	0.01462	0.37	0.697
Residual	22	0.87554	0.03980		
Total	35	11.89181			

B9. Analysis of Variance for *Striga asiatica* emergence 10 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.3373	0.1687	1.41	
Rep*Units*stratum					
Cropping system	1	16.0889	16.0889	134.29	<.001
Crop	2	0.0226	0.0113	0.09	0.910
Variety	1	0.0189	0.0189	0.16	0.695
Cropping system*Crop	2	0.0226	0.0113	0.09	0.910
Cropping system*Variety	1	0.0189	0.0189	0.16	0.695
Crop*Variety	2	0.3649	0.1825	1.52	0.240
Cropping*Crop*Variety	2	0.3649	0.1825	1.52	0.240
Residual	22	2.6357	0.1198		
Total	35	19.8748			

B10. Analysis of Variance for *Striga asiatica* emergence 12 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.0483	0.0242	0.20	
Rep*Units*stratum					
Cropping system	1	18.5616	185616	156.16	<.001
Crop	2	0.0389	0.0194	0.16	0.850
Variety	1	0.0477	0.0477	0.40	0.533
Cropping system*Crop	2	0.0389	0.0194	0.16	0.850
Cropping system*Variety	1	0.0477	0.0477	0.40	0.533
Crop*Variety	2	0.2400	0.1200	1.01	0.381
Cropping*Crop*Variety	2	0.2400	0.1200	1.01	0.381
Residual	22	2.6150	0.1189		
Total	35	21.8780			

B11. Analysis of Variance for *Striga asiatica* emergence 14 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.007057	0.003528	0.48	
Rep*Units*stratum					
Cropping system	1	6.266010	6.266010	849.34	<.001
Crop	2	0.007057	0.003528	0.48	0.626
Variety	1	0.014113	0.0141130	1.91	0.181
Cropping system*Crop	2	0.007057	0.003528	0.48	0.626
Cropping system*Variety	1	0.014113	0.0141130	1.91	0.181
Crop*Variety	2	0.007057	0.003528	0.48	0.626
Cropping*Crop*Variety	2	0.007057	0.003528	0.48	0.626
Residual	22	0.162305	0.007377		
Total	35	6.491825			

B12. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.09591	0.04796	1.80	
Rep*Units*stratum					
Cropping system	1	101.70319	101.70319	3812.65	<.001
Crop	2	0.08926	0.04463	1.67	0.211
Variety	1	0.06218	0.06218	2.33	0.141
Cropping system*Crop	2	0.08926	0.04463	1.67	0.211
Cropping system*Variety	1	0.06218	0.06218	2.33	0.141
Crop*Variety	2	0.01858	0.00929	0.35	0.710
Cropping*Crop*Variety	2	0.01858	0.00929	0.35	0.710
Residual	22	0.58685	0.02668		
Total	35	102.72599			

B13. Analysis of Variance for *Striga asiatica* seed capsules at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	7.192	3.596	0.99	
Rep*Units*stratum					
Cropping system	1	436.728	436.728	120.83	<.001
Crop	2	2.530	1.265	0.35	0.709
Variety	1	0.119	0.119	0.03	0.858
Cropping system*Crop	2	2.530	1.265	0.35	0.709
Cropping system*Variety	1	0.119	0.119	0.03	0.858
Crop*Variety	2	17.107	8.554	2.37	0.117
Cropping*Crop*Variety	2	17.107	8.554	2.37	0.117
Residual	22	79.517	3.614		
Total	35	562.949			

B14. Analysis of Variance for *Striga asiatica* dry matter at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.04250	0.02125	0.70	
Rep*Units*stratum					
Cropping system	1	0.84858	0.84858	27.99	<.001
Crop	2	0.01699	0.00849	0.28	0.758
Variety	1	0.00408	0.00408	0.13	0.717
Cropping system*Crop	2	0.01699	0.00849	0.28	0.758
Cropping system*Variety	1	0.00408	0.00408	0.13	0.717
Crop*Variety	2	0.08762	0.04381	1.45	0.257
Cropping*Crop*Variety	2	0.08762	0.04381	1.45	0.257
Residual	22	0.66692	0.03031		
Total	35	1.77538			

Appendix C. Effect of grain legume species and genotype on *Striga asiatica* emergence, growth and development during 2002/2003 season.

C1. Analysis of Variance for *Striga asiatica* emergence at 8 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.0791	0.0396	0.06	
Rep*Units*stratum					
Cropping system	2	8.3860	4.1930	6.76	0.003
Crop	2	0.0007	0.0004	0.00	0.999
Variety	1	0.0192	0.0192	0.03	0.861
Cropping system*Crop	4	1.7353	0.4338	0.70	0.598
Cropping system*Variety	2	0.3692	0.1846	0.30	0.745
Crop*Variety	2	0.9006	0.4503	0.73	0.491
Cropping*Crop*Variety	4	2.0159	0.5040	0.81	0.526
Residual	34	21.0994	0.6206		
Total	53	34.6055			

C2. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	6.756	3.378	0.47	
Rep*Units*stratum					
Cropping system	2	285.083	142.541	20.00	<.001
Crop	2	7.301	3.651	0.51	0.604
Variety	1	4.272	4.272	0.60	0.444
Cropping system*Crop	4	31.164	7.791	1.09	0.376
Cropping system*Variety	2	6.327	3.163	0.44	0.645
Crop*Variety	2	17.638	8.819	1.24	0.303
Cropping*Crop*Variety	4	34.268	8.567	1.20	0.328
Residual	34	242.323	7.127		
Total	53	635.132			

C3. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	10.850	5.425	1.10	
Rep*Units*stratum					
Cropping system	2	435.939	217.970	44.40	<.001
Crop	2	8.511	4.255	0.87	0.429
Variety	1	0.022	0.022	0.00	0.947
Cropping system*Crop	4	16.655	4.164	0.85	0.505
Cropping system*Variety	2	0.145	0.072	0.01	0.985
Crop*Variety	2	33.474	16.737	3.41	0.045
Cropping*Crop*Variety	4	36.518	9.129	1.86	0.140
Residual	34	166.929	4.910		
Total	53	709.043			

C4. Analysis of Variance for *Striga asiatica* days to flowering at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.3430	0.1715	1.47	
Rep*Units*stratum					
Cropping system	2	191.6460	95.8230	818.87	<.001
Crop	2	0.4407	0.2204	1.88	0.168
Variety	1	0.0229	0.0229	0.20	0.661
Cropping system*Crop	4	1.2752	0.3188	2.72	0.045
Cropping system*Variety	2	0.0546	0.0273	0.23	0.793
Crop*Variety	2	0.5079	0.2539	2.17	0.130
Cropping*Crop*Variety	4	1.3359	0.3340	2.85	0.038
Residual	34	3.9786	0.1170		
Total	53	199.6048			

C5. Analysis of Variance for *Striga asiatica* seed capsules at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	7.50	3.75	0.05	
Rep*Units*stratum					
Cropping system	2	5966.62	2983.31	37.08	<.001
Crop	2	35.21	17.61	0.22	0.805
Variety	1	30.93	30.93	0.38	0.539
Cropping system*Crop	4	397.66	99.41	1.24	0.314
Cropping system*Variety	2	26.60	13.30	0.17	0.848
Crop*Variety	2	263.14	131.57	1.64	0.210
Cropping*Crop*Variety	4	666.93	166.73	2.07	0.106
Residual	34	2735.40	80.45		
Total	53	10129.99			

C6. Analysis of Variance for *Striga asiatica* dry matter at site 1

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.5396	0.2698	0.37	
Rep*Units*stratum					
Cropping system	2	39.9615	19.9808	27.49	<.001
Crop	2	0.1447	0.0724	0.10	0.906
Variety	1	0.6168	0.6168	0.85	0.363
Cropping system*Crop	4	2.8584	0.7146	0.98	0.430
Cropping system*Variety	2	0.3788	0.1894	0.26	0.772
Crop*Variety	2	3.1557	1.5778	2.17	0.130
Cropping*Crop*Variety	4	5.0501	1.2625	1.74	0.165
Residual	34	24.7150	0.7269		
Total	53	77.4206			

C7. Analysis of Variance for *Striga asiatica* emergence at 8 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.7616	0.3808	3.22	
Rep*Units*stratum					
Cropping system	2	1.2669	0.6334	5.36	0.009
Crop	2	0.0558	0.0279	0.24	0.791
Variety	1	0.3392	0.3392	2.87	0.099
Cropping system*Crop	4	0.7606	0.1902	1.61	0.195
Cropping system*Variety	2	0.4034	0.2017	1.71	0.197
Crop*Variety	2	0.4304	0.2152	1.82	0.177
Cropping*Crop*Variety	4	0.3609	0.0902	0.76	0.557
Residual	34	4.0187	0.1182		
Total	53	8.3975			

C8. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	60.525	30.262	10.31	
Rep*Units*stratum					
Cropping system	2	155.332	77.666	26.46	<.001
Crop	2	1.058	0.529	0.18	0.836
Variety	1	0.744	0.744	0.25	0.618
Cropping system*Crop	4	7.376	1.844	0.63	0.646
Cropping system*Variety	2	1.285	0.642	0.22	0.805
Crop*Variety	2	0.455	0.228	0.08	0.926
Cropping*Crop*Variety	4	7.303	1.826	0.62	0.650
Residual	34	99.791	2.935		
Total	53	333.868			

C9. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	72.153	36.076	5.22	
Rep*Units*stratum					
Cropping system	2	462.829	231.414	33.45	<.001
Crop	2	0.700	0.350	0.05	0.951
Variety	1	1.262	1.262	0.18	0.672
Cropping system*Crop	4	6.360	1.590	0.23	0.920
Cropping system*Variety	2	0.675	0.337	0.05	0.952
Crop*Variety	2	16.509	8.255	1.19	0.316
Cropping*Crop*Variety	4	11.564	2.891	0.42	0.795
Residual	34	235.186	6.917		
Total	53	807.239			

C10. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.3131	0.1566	0.47	
Rep*Units*stratum					
Cropping system	2	153.9548	76.9774	228.99	<.001
Crop	2	1.1891	0.5945	1.77	0.186
Variety	1	0.4069	0.4069	1.21	0.279
Cropping system*Crop	4	0.6148	0.1537	0.46	0.766
Cropping system*Variety	2	0.3049	0.1524	0.45	0.639
Crop*Variety	2	1.5227	0.7614	2.26	0.119
Cropping*Crop*Variety	4	2.0106	0.5026	1.50	0.225
Residual	34	11.4295	0.3362		
Total	53	171.7464			

C11. Analysis of Variance for *Striga asiatica* dry matter at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	8.2359	4.1180	6.62	
Rep*Units*stratum					
Cropping system	2	30.4603	15.2301	24.48	<.001
Crop	2	0.0745	0.0373	0.06	0.942
Variety	1	0.4621	0.4621	0.74	0.395
Cropping system*Crop	4	0.7573	0.1893	0.30	0.873
Cropping system*Variety	2	0.2554	0.1277	0.21	0.815
Crop*Variety	2	0.0534	0.0267	0.04	0.958
Cropping*Crop*Variety	4	1.4832	0.3708	0.60	0.668
Residual	34	21.1550	0.6222		
Total	53	62.9372			

C12. Analysis of Variance for *Striga asiatica* dry matter at site 2

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	8.2359	4.1180	6.62	
Rep*Units*stratum					
Cropping system	2	30.4603	15.2301	24.48	<.001
Crop	2	0.0745	0.0373	0.06	0.942
Variety	1	0.4621	0.4621	0.74	0.395
Cropping system*Crop	4	0.7573	0.1893	0.30	0.873
Cropping system*Variety	2	0.2554	0.1277	0.21	0.815
Crop*Variety	2	0.0534	0.0267	0.04	0.958
Cropping*Crop*Variety	4	1.4832	0.3708	0.60	0.668
Residual	34	21.1550	0.6222		
Total	53	62.9372			

C13. Analysis of Variance for *Striga asiatica* emergence at 10 WACE at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	2.800	1.400	1.26	
Rep*Units*stratum					
Cropping system	2	38.716	19.358	17.36	<.001
Crop	2	2.116	1.058	0.95	0.397
Variety	1	1.293	1.293	1.16	0.289
Cropping system*Crop	4	1.320	0.330	0.30	0.878
Cropping system*Variety	2	0.663	0.332	0.30	0.745
Crop*Variety	2	1.786	0.893	0.80	0.457
Cropping*Crop*Variety	4	0.908	0.227	0.20	0.935
Residual	34	37.903	1.115		
Total	53	87.505			

C14. Analysis of Variance for *Striga asiatica* emergence at 12 WACE at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	7.987	3.993	2.37	
Rep*Units*stratum					
Cropping system	2	114.805	57.402	34.00	<.001
Crop	2	4.768	2.384	1.41	0.258
Variety	1	4.126	4.126	2.44	0.127
Cropping system*Crop	4	6.198	1.550	0.92	0.465
Cropping system*Variety	2	2.266	1.133	0.67	0.518
Crop*Variety	2	5.426	2.713	1.61	0.215
Cropping*Crop*Variety	4	3.257	0.814	0.48	0.749
Residual	34	57.410	1.689		
Total	53	206.242			

C15. Analysis of Variance for *Striga asiatica* days to flowering from emergence at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	3.888	1.944	1.66	
Rep*Units*stratum					
Cropping system	2	139.960	69.980	59.87	<.001
Crop	2	0.075	0.037	0.03	0.969
Variety	1	2.484	2.484	2.13	0.154
Cropping system*Crop	4	3.088	0.772	0.66	0.624
Cropping system*Variety	2	2.016	1.008	0.86	0.431
Crop*Variety	2	2.997	1.498	1.28	0.291
Cropping*Crop*Variety	4	1.992	0.498	0.43	0.789
Residual	34	39.741	1.169		
Total	53	196.241			

C16. Analysis of Variance for *Striga asiatica* seed capsules at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	118.14	59.07	2.45	
Rep*Units*stratum					
Cropping system	2	1511.23	755.61	31.31	<.001
Crop	2	41.48	20.74	0.86	0.432
Variety	1	12.78	12.78	0.53	0.472
Cropping system*Crop	4	59.87	14.97	0.62	0.651
Cropping system*Variety	2	21.81	10.91	0.45	0.640
Crop*Variety	2	60.44	30.22	1.25	0.299
Cropping*Crop*Variety	4	63.87	15.97	0.66	0.623
Residual	34	820.52	24.13		
Total	53	2710.14			

C17. Analysis of Variance for *Striga asiatica* dry matter at site 3

Source of variation	DF	SS	MS	VR	Fpr
Rep stratum	2	0.9950	0.4975	2.93	
Rep*Units*stratum					
Cropping system	2	8.4602	4.2301	24.90	<.001
Crop	2	0.2199	0.1100	0.65	0.530
Variety	1	0.0941	0.0941	0.55	0.462
Cropping system*Crop	4	0.4655	0.1164	0.69	0.607
Cropping system*Variety	2	0.1960	0.0980	0.58	0.567
Crop*Variety	2	0.4350	0.2175	1.28	0.291
Cropping*Crop*Variety	4	0.4969	0.1242	0.73	0.577
Residual	34	5.7762	0.1699		
Total	53	17.1389			