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Screening finger millet (*Eleusine coracana* L. Gaertn) genotypes for pre and post-attachment resistance to witchweed (*Striga asiatica* L. Kuntze) infection under controlled environments

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ABSTRACT

Witchweed (*Striga asiatica* L. Kuntze) is an obligate hemi-parasitic weed that causes cereal yield loss of 20-100% depending on its seed bank size and susceptibility of host cereal. Climate change linked reduction of maize (*Zea maize* L.) productivity has created the need to identify small grains genotypes that can withstand the adverse effects of climate change in *S. asiatica* endemic areas. Hence, this study aimed to determine the resistance of finger millet genotypes to *S. asiatica* infection. Three genotypes that were bred at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were evaluated under laboratory and glasshouse conditions at the University of Zimbabwe during the 2018/2019 summer cropping season. In the laboratory assay, three finger millet genotypes (KNE624, KNE814 and SDMF1702) were screened for pre-attachment resistance using the Agar-gel technique. The experiment was laid out as a Completely Randomized Design (CRD) with ten replications. The measured parameters were *S. asiatica* germination percentage and furthest germination distance. In the pot study, a 3 x 2 factorial experiment was set up and arranged in a Randomised Complete Block Design (RCBD) with six replications. The measured parameters included plant height, Striga emergence, haustorial attachments, chlorophyll content, plant tissue biomass and grain yield of finger millet. The genotype SDMF1702 had significantly ($p<0.05$) lower Striga germination percentage and furthest germination distance than the other genotypes. There was a significant ($p<0.05$) genotype x Striga interaction on the plant height, chlorophyll content, stem biomass, root: shoot ratio and total above ground biomass where SDMF1702 showed tolerance. Striga infection did not significantly ($p>0.05$) reduce the final plant height of the genotype SDMF1702. For *S. asiatica* count, there were significant ($p<0.05$) crop genotype effects, where SDMF1702 supported the least number of infected *S. asiatica* plants. Infected finger millet plants had significantly ($p<0.05$) lower grain yield than non-infected plants across all genotypes. In conclusion, the genotypes that were screened showed varying degrees of tolerance and susceptibility to Striga infection, with finger millet genotype SDMF1702 appearing to be tolerant.

Key words: *Eleusine corocana*, parasitic weeds, pre-attachment resistance, post-attachment resistance, *Striga asiatica*

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RÉSUMÉ

L'herbe-sorcière (*Striga asiatica* L. Kuntze) est une mauvaise herbe hémi parasitaire obligatoire qui entraîne une perte de rendement céréalier de 20 à 100% en fonction de la taille de sa banque de graines et de la sensibilité de la céréale hôte. La réduction de la productivité du maïs (*Zea maïs* L.) liée au changement climatique a créé le besoin d'identifier les génotypes de petites céréales capables de résister aux effets néfastes du changement climatique dans les zones d'endémisme de *S. asiatica*. Ainsi, la présente étude vise à déterminer la résistance des génotypes d'éleusine à l'infection à *S. asiatica*. Trois génotypes d'eleusine développés à l'Institut International de Recherche sur les Cultures pour les zones Tropicales Semi-Arides (ICRISAT) ont été évalués dans des conditions de laboratoire et de serre à l'Université du Zimbabwe pendant la saison des cultures d'été 2018/2019. Dans le test de laboratoire, trois génotypes d'eleusine (KNE624, KNE814 et SDMF1702) ont été criblés pour la résistance pré-attachement en utilisant la technique Agar-gel. L'essai a été installé dans un dispositif complètement aléatoire (BCA) avec dix répétitions. Les paramètres mesurés étaient le pourcentage de germination de *S. asiatica* et la distance de germination la plus éloignée. L'expérimentation en pots a été installée dans un dispositif factoriel 3x2, organisée en blocs aléatoires complets (BAC) avec six répétitions. Les paramètres mesurés étaiaient la hauteur de la plante, l'émergence du striga, les haustoria, la teneur en chlorophylle, la biomasse des tissus végétaux et le rendement en grains du millet. Le génotype SDMF1702 avait un pourcentage de germination de Striga significativement plus faible ($p < 0,05$) et la distance de germination la plus éloignée que les autres génotypes. Il y avait une interaction génotype x Striga significative ($p < 0,05$) sur la hauteur de la plante, la teneur en chlorophylle, la biomasse de la tige, le rapport racine/pousse et la biomasse totale au-dessus du sol, où le génotype SDMF1702 a exhibé une tolérance. L'infection par Striga n'a pas réduit de manière significative ($p > 0,05$) la hauteur finale de la plante du génotype SDMF1702. Pour le dénombrement de *S. asiatica*, des effets significatifs ont observés sur les génotypes ($p < 0,05$). Le génotype SDMF1702 avait le nombre minimum de plantes infectées par *S. asiatica*. Les plants de millet contaminés avaient un rendement en grains significativement ($p < 0,05$) inférieur à celui des plants non infectés pour tous les génotypes. En conclusion, les génotypes qui ont été criblés ont montré des degrés variables de tolérance et de sensibilité à l'infection par Striga, le génotype d'éleusine SDMF1702 semble être le plus tolérant.

Mots clés: *Eleusine corocana*, mauvaises herbes parasites, résistance pré-attachement, résistance post-attachement, *Striga asiatica*

INTRODUCTION

Finger millet (*Eleusine coracana* L. Gaertn) is a primary food grain crop for millions of people located in the tropical and sub-tropical areas of Africa and India (Roden *et al*., 2007). By the year 2014, the area under finger millet was estimated to be 24.2 million hectares worldwide (FAO, 2014). Mason *et al*. (2015) reported that finger millet was ranked as the sixth most important cereal crop in the world after wheat (*Triticum aestivum* L.), maize (*Zea may*s L.), rice (*Oryza sativum* L.), barley (*Hordeum vulgare* L.) and sorghum (*Sorghum bicolour* L.).

Production of finger millet is affected by parasitic weeds in the Striga genus which is commonly known as witchweed and belongs to the family Orobanchaceae (Atera *et al*., 2013). There are many Striga species, but the major species in agriculture are *S*. *hermonthica* and *S*. *asiatica* which infect cereals such as upland

rice, maize, millets and sorghum (Parker, 2009). Striga is identified as the greatest biological constraint to cereal food production and has been estimated to infect around 64% of the total area that is under cereal production in West Africa (Gressel *et al*., 2004; Parker, 2012). Striga causes tremendous damage to the host plants before it emerges from the soil (Bouwmeester *et al*., 2003). Several germination stimulants have been identified in the root exudates of maize, sorghum, millets and these are collectively known as strigolactones (Parker, 2009). The Striga seeds will only germinate after induction of chemical signals has been exuded from the roots of the host plant (Mabasa, 1994). The exudates that are produced by the host plant activate the responsible genes for the initiation of the germination process.

The problem of *S. asiatica* has been in existence from as early as 1936 in the agricultural fields of farmers where it was causing huge losses (Khan *et al*., 2006). In Africa, infection by Striga parasite results in an estimated loss of 4.1 million tonnes of the total cereal grain yield produced and as a result, the welfare of over 100 million people is affected (Jamil *et al*., 2012). These losses have been due to the large densities of Striga in the field, the genotype and the host species (Atera *et al*., 2012). Crops that are infected by Striga incur grain yield losses ranging from 20-80%, but under severe circumstances, the losses can reach up to 100% (Gurney *et al*., 2002). As a result, this has contributed to major food shortages in developing countries where finger millet is a major crop.

In Zimbabwe, finger millet is mainly grown by small scale farmers who are located in marginal areas (agro-ecological region IV and V) with low soil fertility and low rainfall which ranges between 450 and 650 mm (Moyo, 2000). The effect of Striga in the smallholder sector is exacerbated by the fact that the majority of farmers do not apply synthetic or organic fertilisers in small grain cereal crops production because they are generally regarded inferior to maize (Ejeta *et al*., 1993). Traditionally, control of Striga seed in the soil has been minimized by long fallow periods, but with increased food crop demand due to the increased world population, there is increased utilization of the land hence long fallow periods are no longer practical and feasible (Mason *et al*., 2015).

It is important to find other methods of controlling Striga that will reduce further losses due to the root parasite (Berner and Singh, 1995). Several methods have been practiced to control Striga infection including crop rotations (Oswald and Ransom, 2001). Crop rotations are not viable in the case where land is limiting, hence the continued cereal mono-cropping that is currently practised in the smallholder sector increases Striga infestation (Gurney *et al*., 2003). There has also been an increase in human population that has led to continuous cropping systems being undertaken, avoiding crop rotations at the expense of soil fertility (Sikwese *et al*., 2003). In addition, legumes are no longer effective for rotations because Striga and Alectra (which are parasitic weeds of legumes) are now co-occurring in the same fields (Kabambe *et al*., 2008). Amongst the smallholder farmers, hand hoeing is the most common practice for controlling the weed although it is not effective because Striga causes damage well before it emerges above the ground (Nyakurwa *et al*., 2018). At the same time smallholder farmers have not been able to adopt management practices such as the use of trap crops or catch crops due to financial constraints (Sun *et al*., 2007).

Recurrence of droughts due to climate change in Southern Africa has created the need for identifying alternative cereals that can be grown in areas where maize productivity is dwindling. One such crop with resilience to adverse environmental conditions is finger millet

(*Eleusine coracana* (L.) Gaertn). However, the success of finger millet as a replacement for maize is dependent on the availability of genotypes that can withstand the debilitating effects of Striga since maize monoculture commonly practised by resource limited farmers has already caused a build-up of Striga seed reserves in the soil. Hence, the search for an economically benign and effective Striga management strategy is indispensable in the quest to ensure widespread and sustained production of finger millet.

MATERIALS AND METHODS

Experimental site and genetic stock. Laboratory and glasshouse experiments were carried out in the Department of Crop Science, at the University of Zimbabwe (17.78^0S, 31.05^0E and altitude of 1523m) during the 2018/2019 season to determine the effect of finger millet genotype on *S*. *asiatica* seed germination and growth. The temperature within the glasshouse ranged from 27 ^{o}C to 32 ^{o}C and was not controlled whilst the temperature in the laboratory ranged between 20 ^{o}C and 25 ^{o}C. The finger millet experimental lines (SDMF1702, KNE624 and KNE814) that were used in this study were bred and obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). *Striga asiatica* seed was obtained from Henderson Research Station in the 2017/2018 growing season.

Experiment one: Evaluating pre - attachment resistance of Striga to finger millet. The experiment was laid out in a Completely Randomised Design (CRD) with three treatments replicated ten times. Each variety represented a treatment. The study was carried out using the standard procedure that was developed at IITA (Hess *et al*., 1992).

Pre-conditioning of *S. asiatica* seeds and pre-germination of finger millet seeds. *Striga asiatica* seeds were preconditioned for 14 days in the glass house to break dormancy using the method described by Nyakurwa *et al*. (2018). Sterilisation of *S*. *asiatica* seeds was done by immersing them in 1% sodium hypochlorite (NaCIO) for five minutes. A total of 0.04g of *S*. *asiatica* seed was placed in 50 ml conical flasks and then rinsed three times with distilled water before being evenly placed into 90 mm diameter Petri dishes lined with one sheet of Whatman No.2 filter paper. Similarly, finger millet seeds were sterilised by immersing in 1% sodium hypochlorite (NaCIO) for five minutes and then rinsed three times using distilled water. Finger millet seeds were then placed in 90 mm diameter Petri dishes lined with one layer of Whatman No.2 filter paper. Twenty millimetres of distilled water were poured into the Petri dishes to moisten the filter paper and the Petri dishes were sealed using parafilm. Thereafter, the Petri dishes were covered with black plastic to avoid light penetration and were placed in the glasshouse where day and night temperatures ranged from 25 ^{o}C-32 ^{o}C. Pre-germination of finger millet seed was done two days prior to the agar gel assay. Only healthy-looking germinated seed were selected for the Agar-gel assay.

Agar gel preparation. Agar-gel was prepared using a ratio of 1 g bacto agar: 100 millitres distilled water (Nyakurwa *et al*., 2018). The agar-gel media was then autoclaved at a pressure of 15 psi and temperature of 121^{o}C for 20 minutes using an automatic graduated autoclave.

Agar gel assay technique. Two hundred micro-litres (approximately 600 seeds) of preconditioned *S*. *asiatica* seeds were pipetted into 90 mm diameter Petri dishes. Cooling agar gel was then poured into the Petri dishes before it solidified (Nyakurwa *et al*., 2018). The Petri dishes were gently shaken to ensure even distribution of *S*. *asiatica* seeds throughout the

media. One pre-germinated healthy finger millet seed was then placed on the solidifying media near the edge of the Petri dish with the tip of the root pointing across the Petri dish as described by Reda *et al*. (1994). Petri dishes were then incubated in a Mains Scientific incubator at 30 ^{o}C for 72 hours before data were collected.

Data collection. Each Petri dish was divided into four equal sections. Within the demarcated boxes, the total number of *S*. *asiatica* seeds was counted as well as the total number of germinated seeds as viewed under the microscope. The germination data collected from four different areas of the Petri dish were averaged and germination percentage was calculated from these averages. The formula below was used for calculating germination percentage.

$$\text{Germination (\%)} = \frac{\text{Number of germinated } S.\,asitaica \text{ seeds in the demarcated box}}{\text{Total number of } S.\,asiatica \text{ seeds in the demarcated box}} * 100$$

The furthest germination distance of *S*. *asiatica* seeds from the finger millet root was measured using a microscope micrometre at x40 magnification. The furthest germination distance was measured as the distance from the furthest germinating Striga seed to the root.

Experiment two: Evaluating the effect of finger millet genotypes for post attachment resistance to *S. asiatica* under glasshouse conditions

Experimental design. A pot experiment was carried out in the glasshouse at the University of Zimbabwe. The experiment was laid down in a 3x2 factorial in a Randomised Complete Block Design (RCBD) with six replications. The factors were finger millet genotypes (KNE624, KNE814, and SDMF1702) and Striga infestation (infected and un-infected).

Planting and establishment. The experiment was done in pots with a top diameter of 23 cm, bottom diameter of 16 cm and height of 24 cm. Pots were filled up to three quarters with sandy soil that was collected from Henderson Research Station, so as to mimic the edaphic factors in which the parasite exerts its dominance. The inoculation with *S*. *asiatica* to the soil was done 14 days prior to planting where 0.02g (approximately 1000 seeds) of seed was thoroughly mixed within the top 5 to 8 cm of 50% of the pots. Basal fertilizer compound D (8% N: 14% P_2O5: 7% K_2O) was applied at the rate of 2 g per pot so as to match the fertilizer quantities that the small-scale farmers apply (Chitagu *et al*., 2014). The pots were irrigated to field capacity. After 14 days, finger millet seeds were planted within the top 2 cm of the soil in all the pots. Thinning was then done two weeks after planting leaving two plants per pot and further thinning was done a week later leaving one healthy plant per pot. Top dressing was done using ammonium nitrate (34.5% N) at a rate of 2g per pot six weeks after crop emergence (WACE). Weeds other than *S*. *asiatica* were hand pulled as soon as they emerged to allow interaction of finger millet and the parasitic weed only. Watering was done at a rate of 800 ml per pot after every seven days.

Data collection.Plant height of finger millet was measured from the soil level to the ligule of the last fully expanded leaf from week 7 up to week 15 using a metre rule. Chlorophyll content was measured using a chlorophyll meter SPAD-502 Plus (Minolta Corporation, Ltd., Osaka, Japan) from 8 up to 15 Weeks After Crop Emergence (WACE). Chlorophyll content readings were taken on young fully developed leaves between 12pm and 1pm. Number of days to first Striga emergence was recorded for each genotype and the total number of Striga plants was counted at harvest. Haustorial attachments were physically counted at harvesting in plants that were grown in Striga infested soil.

At harvest, the plants were cut at the base of the stem and leaves and the head (grain) were separated from the stem and each plant part was separately placed in a different khaki envelop.

Soil was washed off the roots using running tap water and placed in khaki envelops. All plant parts were oven dried at 80 °C for 36 hours. The leaf, stem, root, total plant and grain yield biomass were recorded using a sensitive balance. The root: shoot biomass ratio was calculated for all finger millet genotypes.

Data analysis. Analysis of variance (ANOVA) was done on measured parameters using Genstat 14th edition and means were separated using Fisher's Protected Least Significant Difference (LSD) at 5% significance level. Repeated measures ANOVA was carried out for plant height and chlorophyll content.

RESULTS

Agar gel assay. Striga germination percentages and furthest germination distances varied significantly ($p<0.05$) among finger millet genotypes (Table 1). Genotype SDMF1702 had significantly lower germination percentage and shorter furthest germination than for the other genotypes.

Plant height. There was no significant interaction ($p>0.05$) between *S. asiatic*a infestations x genotype x time, time x *S. asiatica* and *S. asiatica* x genotype on the height of finger millet genotypes. However, significant interactions ($p< 0.01$) were recorded between

Table 1. Effect of finger millet genotypes on germination percentage and furthest germination distance of *S. asiatica* in the laboratory

Finger millet Genotypes	Striga germination %	Furthest germination distance (mm)
KNE624	8.15[b]	1.420[b]
KNE814	8.34[b]	1.567[b]
SDMF1702	5.37[a]	0.985[a]
p-value	0.028	<0.01
LSD	0.47	0.2419

Means followed by the different letters in the same column are significantly different at $p<0.05$

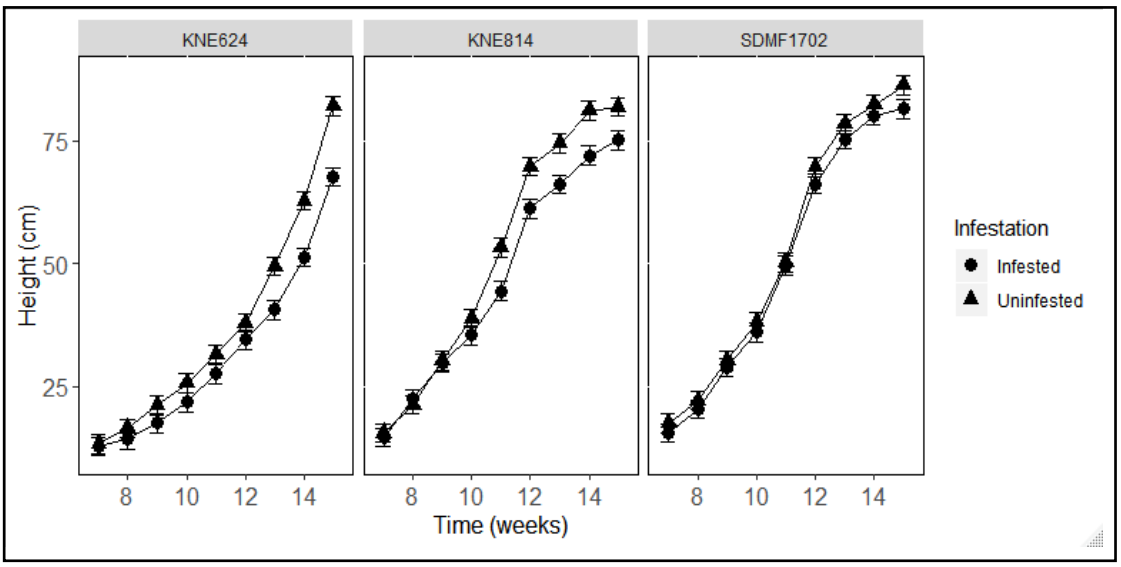

Figure 1. Effect of Striga infection on plant height (cm) of three finger millet varieties grown in pots under glasshouse conditions at the University of Zimbabwe in the 2018-2019 growing season. Error bars represent LSD at $p<0.05$

time x genotype. *Striga asiatica* infection significantly ($p<0.05$) reduced the height of KNE624 and KNE 814 but not SDMF1702 (Figure 1).

Chlorophyll content. There was no significant ($p>0.05$) interaction among time x Striga infection x genotype, time x genotype and Striga x genotype. However, there was a significant interaction ($p<0.05$) between time x Striga infection on finger millet chlorophyll content. Striga infection significantly ($p<0.05$) reduced chlorophyll content of the finger millet genotypes. There were no significant differences in final chlorophyll content between infected and non-infected KNE 814 and SDMF1702 (Figure 2). However, genotype KNE 624 had lower chlorophyll content under different Striga infection levels.

Striga counts and attachments. There was a significant difference ($p<0.01$) between finger millet genotypes on the Striga haustorial attachments where KNE 814 recorded the highest haustorial attachments followed by KNE 624 with SDFM 1702 having the least haustorial attachment (Table 2). There were no significant ($p>0.05$) difference among the finger millet genotypes on Striga counts (Table 2).

Leaf biomass. Effect of Striga x genotype interaction was not significant ($p>0.05$) on leaf biomass. There were no significant ($p>0.05$) differences in leaf biomass among the finger millet genotypes (Figure 3). On the other hand, Striga infection significantly ($p<0.05$) reduced leaf biomass of the finger millet genotypes (Figure 4).

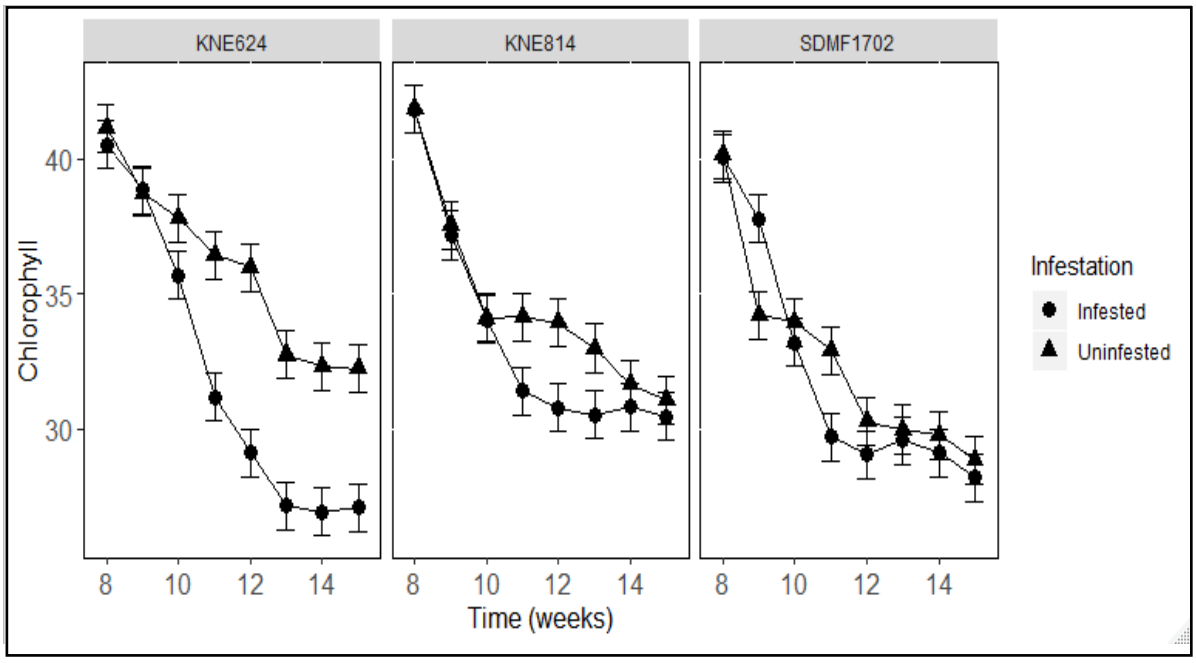

Figure 2. Effect of *S. asiatica* infection on chlorophyll content of three finger millet genotypes in pots under glasshouse conditions at the University of Zimbabwe in the 2018-2019 season. Error bars represent LSD at $p<0.05$.

Table 2. Effect of Striga infection on number of haustorial attachments and Striga counts on three finger millet genotypes

Genotype	Number of haustorial attachments	Striga counts
KNE 624	5.26[b]	2.00
KNE 814	14.01[c]	5.00
SDFM 1702	1.00a	1.00
p-value	<0.01	0.222
LSD (0.05)	2.413	NS

Means followed by the different letters in the same column are significantly different at p<0.05.
NS – not significant

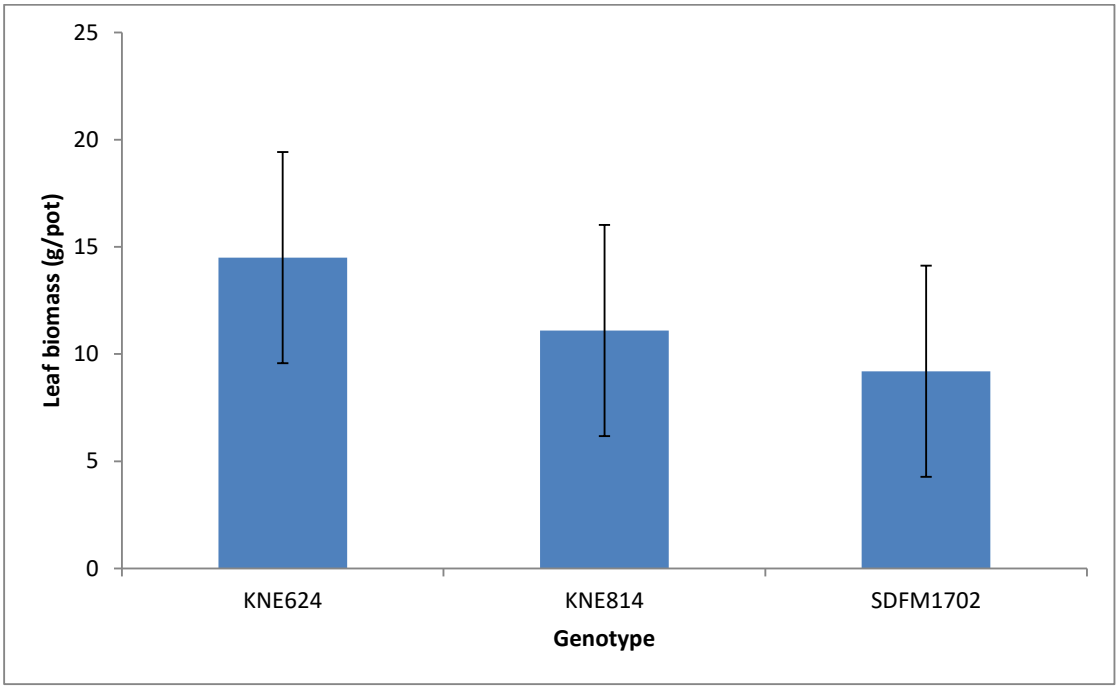

Figure 3. Effect of *S. asiatica* infestation on leaf biomass (g/pot) of three finger millet genotypes grown in pots in the glasshouse at the University of Zimbabwe in the 2018/19 season. Error bars represent LSD at p<0.05.

Stem biomass. The Striga x genotype interaction had a significant (p<0.05) effect on stem biomass. Finger millet genotypes were significantly different on stem biomass. Striga infection significantly reduced stem biomass of all finger millet genotypes (Figure 5).

Root biomass. The effect of *S. asiatica* genotype was significant (p<0.05) on *S. asiatica* infection (Figure 6). Overall, Striga infection significantly reduced the root biomass of the finger millet genotypes with significant (p<0.05) differences amongst the test genotypes. Striga infection significantly reduced the root biomass of the genotypes KNE624 and KNE 814. In contrast Striga infection did not affect root biomass of SDMF1702.

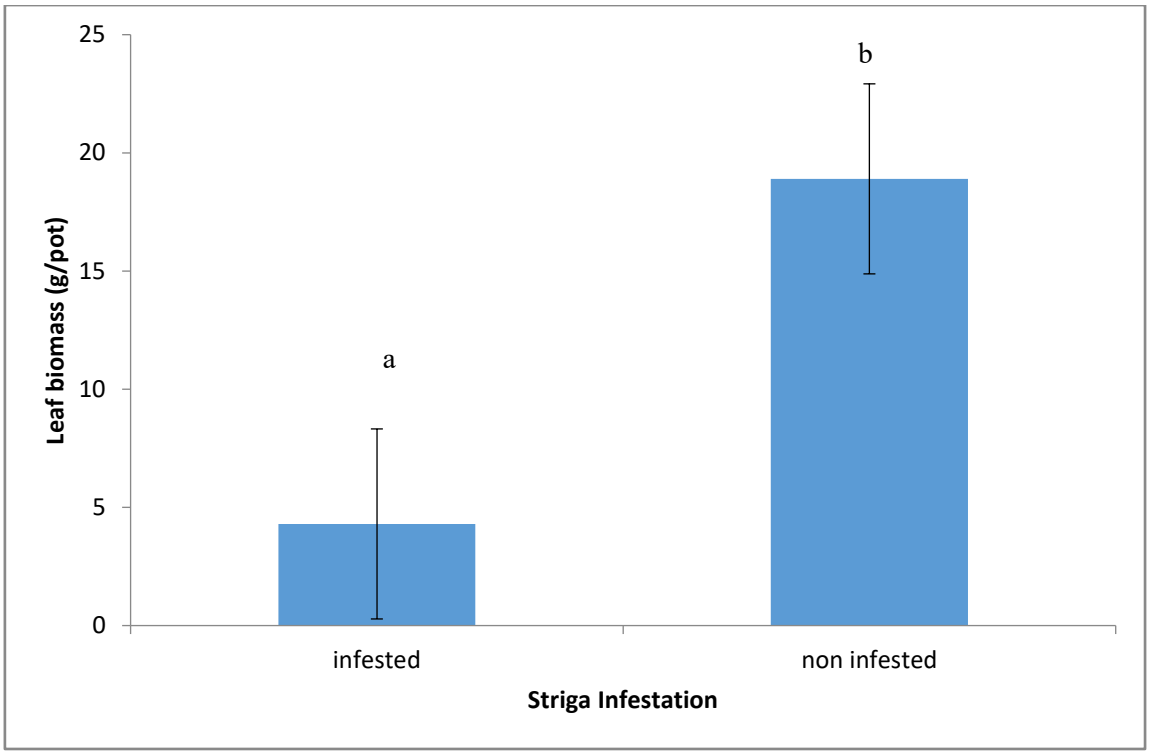

Figure 4. Response of finger millet biomass (g/pot) to *S. asiatica* infection. Error bars represent LSD at p<0.05

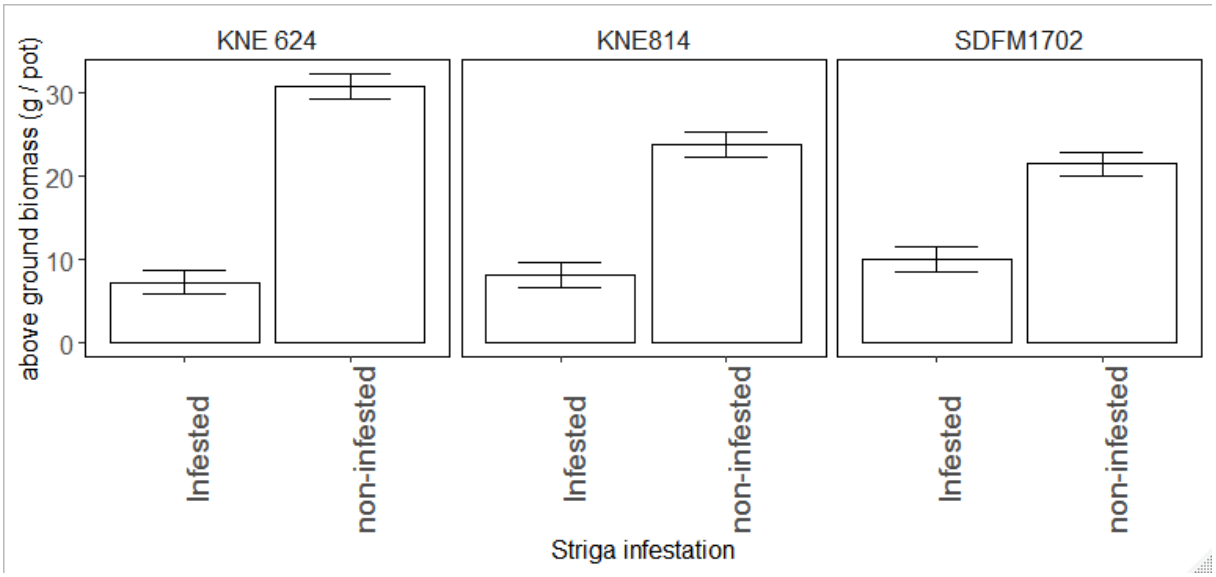

Figure 5. Effect of *S. asiatica* infestation on stem biomass of three finger millet genotypes grown in pots in the glasshouse at the University of Zimbabwe in the 2018/19 season. Error bars represent least significant differences (LSD) at p<0.05.

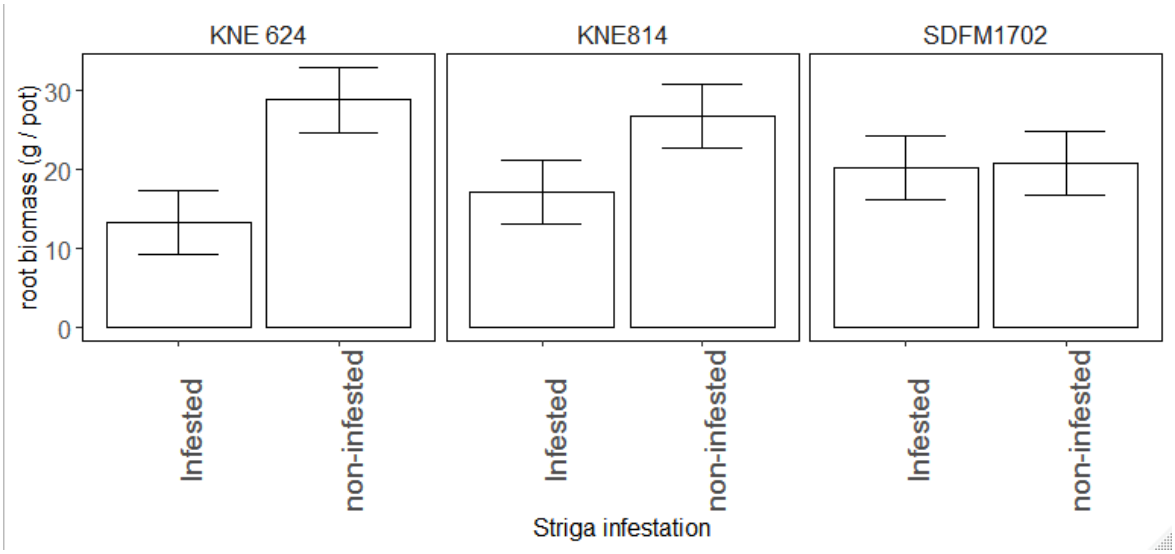

Figure 6. Effect of *S. asiatica* infestation on root biomass (g/pot) of three finger millet genotypes. Error bars represent LSD at p<0.05

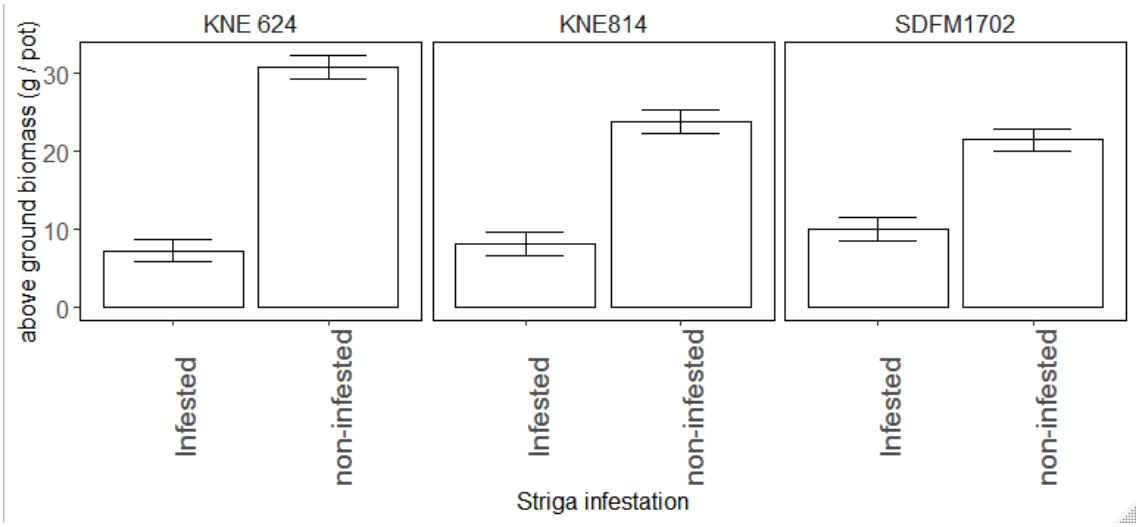

Figure 7. Effect of *S. asiatica* infestation on the above ground biomass of three finger millet genotypes grown in pots in the glasshouse at the University of Zimbabwe in the 2018/19 season. Error bars represent least significant difference at p<0.05.

Total above ground biomass. There was a significant interaction ($p<0.001$) between *S. asiatica* infection and genotype on total above ground biomass. Striga infection significantly reduced total above ground biomass of all the genotypes (Figure 7). *Striga asiatica* infection significantly ($p<0.001$) reduced the total above ground biomass of all the three finger millet genotypes.

Root to shoot ratio. There was no significant interaction between *S. asiatica* infection and genotype ($p>0.05$) on root to shoot ratio of finger millet genotypes. Finger millet genotypes did not significantly ($p>0.05$) differ on root to shoot biomass (Figure 8). However, *S. asiatica* infection significantly ($p<0.05$) reduced the root to shoot ratio of the finger millet genotypes (Figure 9).

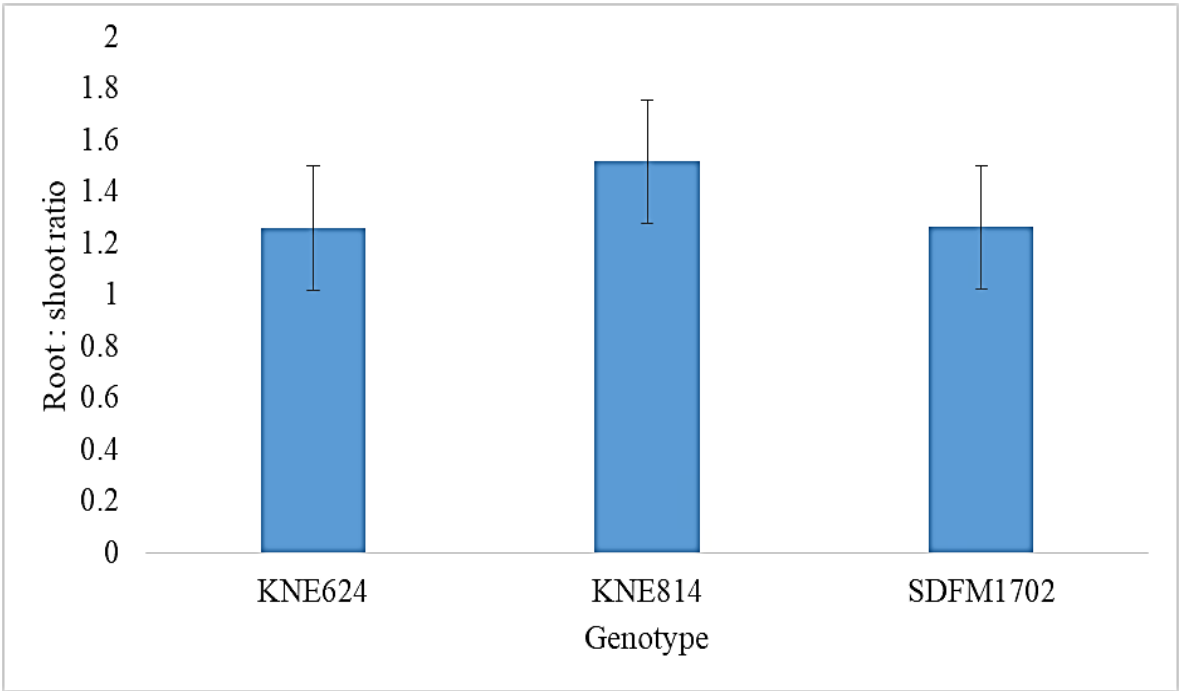

Figure 8. Effect of genotype on root to shoot ratio of three finger millet genotypes grown under greenhouse conditions at the University of Zimbabwe in the 2018/19 growing season. Error bars represent LSD at p<0.05

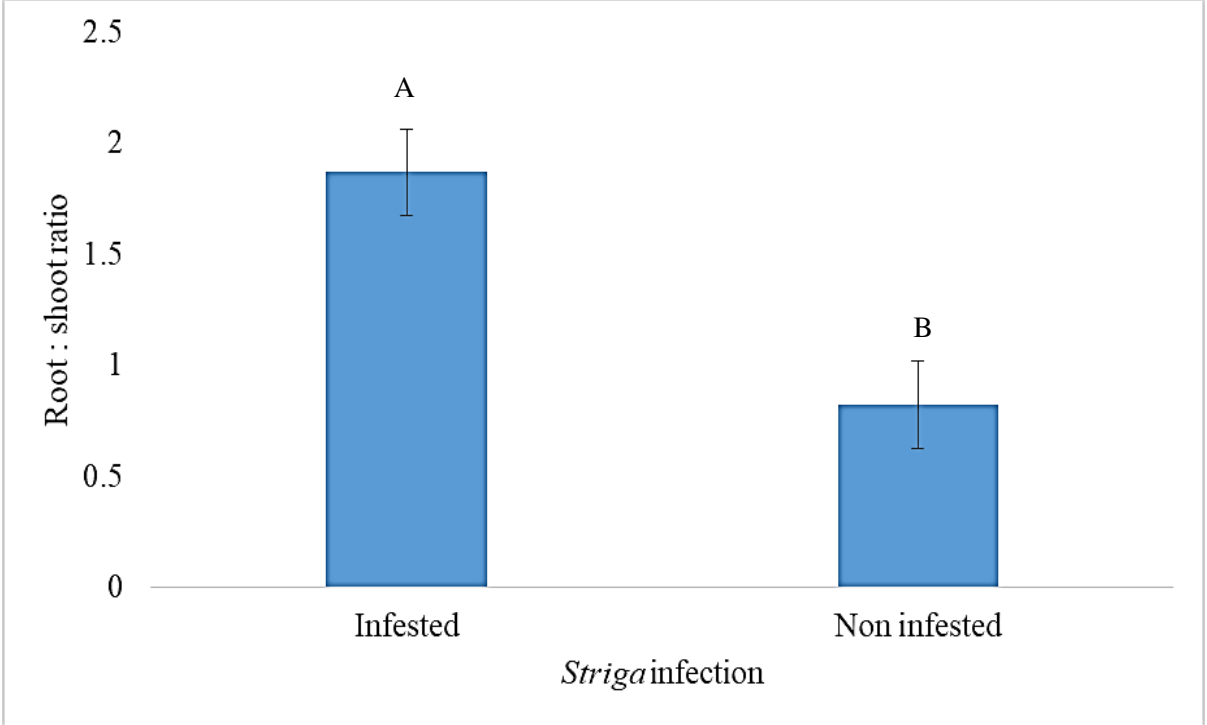

Figure 9. Effect of *S. asiatica* infection on root to shoot ratio of three finger millet genotypes grown under greenhouse conditions at the University of Zimbabwe in the 2018/19 growing season. Error bars represent LSD at p<0.05.

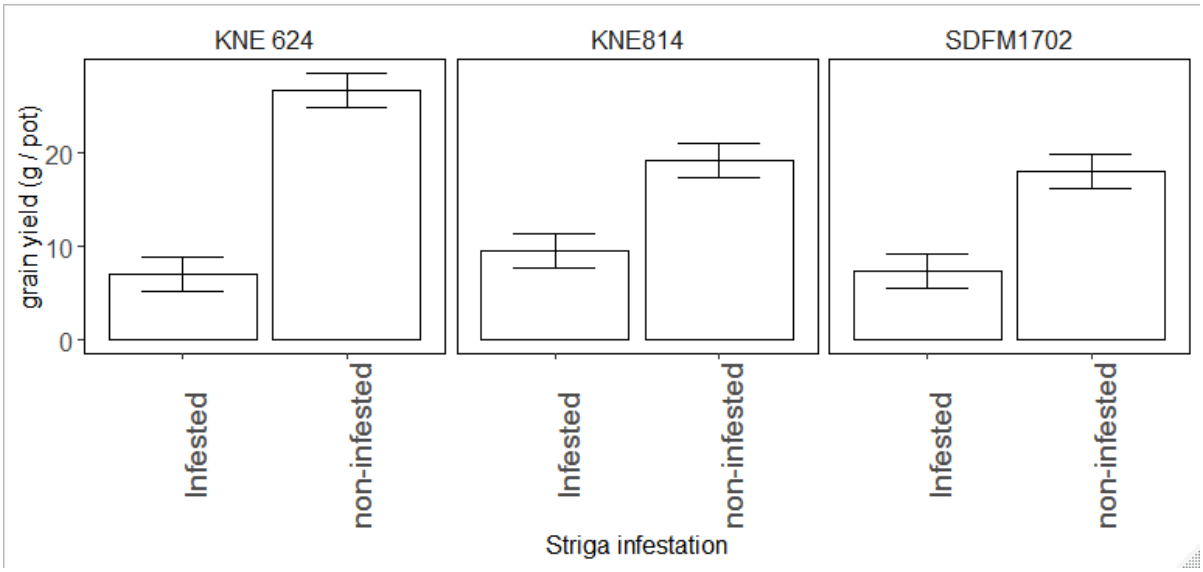

Figure 10. Effect of *S. asiatica* infestation on the total grain yield of three finger millet genotypes grown in pots in the glasshouse at the University of Zimbabwe in the 2018/19 season. Error bars represent LSD at p<0.05

DISCUSSION

The agar gel experiment revealed that there was a significant difference on Striga germination percentage and furthest germination distance. This result indicates that genotypes are genetically different in terms of germination stimulant production. All genotypes showed pre-attachment resistance with furthest germination distance being less than 10 mm. Hess *et al*. (1992) also reported that genotypes with furthest germination distances less than 10 mm have pre-attachment resistance and vice versa. Similarly the present results concur with the findings by Mandumbu *et al*. (2017) who reported that genotypes differed in strigolactone production levels. From our study, genotype SDFM 1702 had the least Striga haustorial attachments indicating low germination stimulant production. This correlates with the results of the agar gel assay where this genotype had the lowest Striga germination percentage and furthest germination distance.

From the glasshouse experiment, Striga infection significantly reduced the plant height of finger millet genotypes KNE 624 and KNE 814. This reduction in plant height can be attributed to stunted growth induced by Striga infection (Berner and Singh, 1995). It has been documented that plant height is one of the most sensitive parameter to S. *asiatica* infection (Mabasa, 1994). The finger millet genotype SDFM 1702 had low plant height reduction due to Striga infestation which might indicate some level of tolerance to *Striga asiatica* infection. These results corroborate the findings of Mandumbu *et al*. (2018) who reported differential response of different genotypes to Striga infection on plant height. Chlorophyll content is a very important parameter in plant growth as it is responsible for the plant's canopy and also carbon assimilation. Striga infection had a significant effect on the chlorophyll content of finger millet genotypes. Infected genotype KNE 624 recorded the least chlorophyll content, an indication of susceptibility compared to KNE 814 and SDFM 1702. The results suggest that susceptible genotypes may not be able to maintain

their chlorophyll concentration. Furthermore, this may contribute to stunting of finger millet genotypes as chlorophyll is a light harvesting component thereby affecting photo-assimilates production and partitioning. Moreover, for such affected genotypes there might be an accumulation of abscisic acid which causes closing of stoma resulting in photo inhibition (Frost *et al*., 1997). Thus the difference in height may be attributed to partitioning of assimilates where the Striga plant would act as the sink for the nutrients (Cechin and Press,1993; Smith *et al*., 1995; Gurney *et al*., 2002).

Striga parasitism had similar negative effects on stem biomass, root biomass, total above ground biomass and grain yield. Striga reduced stem root biomass and yield but not in KNE 624 and KNE 814. Stem biomass is documented as another sensitive parameter to Striga infestation (Mabasa, 1994). Our results concur with the findings of Mandumbu *et al*. (2017), who reported that Striga infection reduced sorghum stem biomass. Thus the present result indicates that the genotypes KNE 624 and KNE 814 were susceptible to Striga infection. In such genotypes, host proteins maybe exposed to the parasite causing weakening of the host defence mechanism thus susceptibility to parasitism (Nyakurwa *et al*., 2018). The low resistance of the genotypes could be caused by perturbation in host carbon assimilation that could also limit nitrogen assimilation and in turn lowers chlorophyll synthesis, plant height, portioning of assimilates thereby causing reduction in yield. Smith *et al*. (1995) reported yield reduction in maize to have been caused by the parasite being the sink of carbon, inorganic solutes and water thus lowering carbon gain on infected genotypes. In addition, the parasite may have a strong metabolic sink due to its strong xylem to xylem and or xylem to phloem connection to the host thereby reducing total above ground biomass and yield. Similar results were reported by Atera *et al*. (2012) in NERICA rice.

There was an imbalance in the distribution and partitioning of nutrients where infected genotypes (KNE 814 and SDFM 1702) had the highest root to shoot ratio compared to non- infected plants. According to Pierce *et al*. (2003) plants that are affected by Striga parasitism respond to infection by allocating dry matter to below ground parts rather than above ground parts hence leading to lower root to shoot ratio in infected plants.

Different finger millet genotypes still managed to produce grain yield even when they were under Striga infection. This might be due to the ability of the finger millet genotypes to maintain some levels of photosynthesis even when exposed to unfavourable conditions (Gurney *et al*., 2002). Low levels of post attachment resistance were observed in all the three genotypes that were evaluated. In our study, the results indicated that there were particular processes and parameters of finger millet genotype SDMF1702 which gave it relative pre attachment resistance based on the furthest germination distance as well as lack of Striga effect on stem height.

CONCLUSION

All the finger millet genotypes used in this study were not resistant to *Striga asiatica* infection because they supported Striga seed germination and attachment. They did not exhibit pre and post attachment resistance. Results showed that yield and yield components were significantly reduced by Striga infection. Genotype SDMF1702 which had the least Striga germination percentage and the lowest germination distance might have some tolerance which should be further evaluated under field conditions.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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