# Screening Maize (*Zea mays*) Genotypes for Tolerance to Witchweed (*Striga asiatica* L. Kuntze) Infection

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## Abstract

*Striga asiatica* (witchweed) is a parasitic weed that is a serious threat to maize (*Zea mays* L.) production in semi-arid environments in Africa. A pot experiment was conducted under glasshouse conditions to screen nine maize cultivars for their tolerance / tolerance to *Striga* infection at the University of Zimbabwe in the 2012 / 2013 rainfall season. *Striga* did not significantly (P > 0.05) reduce the final maize height of the maize cultivars, with the exception of three maize cultivars, namely, PHB3253, PHB30G19 and PHB30B50. Furthermore *Striga* did not significantly (P > 0.05) reduce the stem biomass, leaf biomass and cob biomass of all the maize cultivars evaluated. Generally the maize cultivars had significantly (P < 0.05) higher root / shoot ratios in the *Striga* infected plants compared to the uninfected plants. It was concluded that all the maize genotypes used in this study could possibly be tolerant to *S. asiatica*.

**Keywords:** *Striga asiatica*, tolerance, maize genotypes

## 1. Introduction

Maize (*Zea mays* L.) is the third largest grain crop in the world after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) (Chantereau & Nicou, 1994). It is the staple food of the 12.5 million inhabitants of Zimbabwe and is grown throughout the country including dry marginal areas of Natural Regions IV and V that receive between 450 mm to 650 mm rainfall annually. Apart from rainfall unreliability, maize production especially in the smallholder sector is affected by other biotic factors that include pests, diseases and weeds. Amongst the economically important weeds of maize is *Striga asiatica* (L.) Kuntze, an obligate root parasitic weed of cereals that belongs to the Orobanchaceae family. *S. asiatica* is the only economically important species of the *Striga* genus that is common in Zimbabwe (Mabasa, 2003). *Striga* is also a major weed of important cereal crops like sorghum (*Sorghum bicolour* L.) and millets (*Pennisetum americanum* L. and *Eleusine corocana* L. (Gaertn)), the major cereals grown in the savannah and Sahel regions of Africa (Lendzemo, 2004). Mabasa (1991) reported that maize is more susceptible to *S. asiatica* compared to pearl millet and sorghum. Yield reductions of between 10 and 80 % have been reported but can sometimes reach 100 % in susceptible maize cultivars under severe infestation resulting in field abandonments (Haussamann et al., 2000; M'boob, 1994; Odhiambo & Ransom, 1994). Technologies for the control of *Striga* developed so far have not been widely adopted, because there is a mismatch between technologies and the farmers' socio-economic conditions (Debrah, 1994). These range from cultural methods, chemical and genetic transformation of hosts. There has been little impact of the *Striga* control methods because farmers continue to grow crops which are very sensitive to *Striga*. It has to be noted that a small amount of *Striga* biomass could result in high grain yield losses in *Striga* sensitive cereals (Gurney et al., 1999). As a result smallholder farmers abandon these methods or simply do not invest time and money in adoption, because effective *Striga* control cannot be guaranteed in the current season with concomitant pay-offs in yield (Hearne, 2009).

The use of resistant / tolerant varieties appears to be the most promising and economically feasible means of combating *Striga* in resource poor farming systems. *Striga* tolerance in maize refers to the reaction of varieties that are parasitized to the same extent as susceptible ones but suffer less damage whereas resistance refers to crop varieties showing less attack, usually in terms of numbers of parasite attached or emerged (Mabasa, 2003). Although genes that confer resistance to *Striga* in maize have been identified in maize line ZD05, such genes have not yet been incorporated in commercial varieties (Kling et al., 2000). It has been reported that inbred ZD05 was able to demonstrate a great degree of resistance through three mechanisms; avoidance through a less branched root

architecture, some ability to resist attachments of nearby germinated *Striga* and a kind of incompatibility that does not support normal growth of attached parasites (Rich & Ejeta, 2008). The possibility of transferring such strong resistance into cultivated maize through breeding programs to build durable resistance appears likely. In the evaluations which took into account the presence and absence of *Striga,* the sorghum cultivar Ochuti tolerated *Striga* in Kenya (Gurney et al., 1995). Similar findings were obtained in the maize cultivar Staha in Tanzania (Gurney et al., 2002), maize genotypes CG4141 and R201 (Musambasi, 1997; Mabasa, 2003) in Zimbabwe, a land race sorghum cultivar, Tiemaringfing in Mali (Ast et al., 2000), the following sorghum varieties KSV-4, NR71150 and NR71182 when 50 to 250 kg / ha Nitrogen (N) was added.

It has been reported that increasing N supply to maize results in improved host performance under *Striga* infection. Previous studies carried out to screen maize genotypes for tolerance to *S. asiatica* in Zimbabwe were carried out under high N (Chivinge et al., 1995). Such high N applications rates are out of the reach of the majority of farmers and *Striga* management practices that involve an increase in the amount of N applied are likely not to receive widespread adoption among resource poor farmers. Mabasa (2003) reported that the majority of farmers in communal areas apply 30 kg or less N. Therefore varieties that perform better under low N conditions are likely to receive wide spread uptake by farmers. Currently the research focus of maize breeding in Zimbabwe has been to develop varieties that do well under low moisture and low nitrogen conditions. It has been reported that there are similarities between the physiological effects, specifically changes in ABA levels in plants caused by drought on cereals and those caused by *Striga*. Varieties with tolerance to drought and low N conditions are likely to suffer less damage from *Striga* infection than varieties susceptible to drought. Such varieties have been demonstrated to produce good yields especially under the basin planting. Planting basins are permanent holes (15cm x 15 cm x 15 cm) in which crop seeds are dry planted for the purposes of moisture conservation to ensure that the crop germinates with the early rains. Apart from increased moisture conservation, there are reduced chances of Nitrogen loss because all the fertilisers are spot applied in the planting basin where the risks of fertiliser losses due to sheet erosion are low. The drought and low nitrogen tolerant varieties developed so far have shown potential to produce good yields in marginal areas but their tolerance to *Striga* has not been studied. Such vital information would be very useful in enabling farmers to select varieties that can withstand both abiotic stress and *Striga* infection. Therefore there could be merit in screening land races and recently developed maize genotypes with the hope of identifying some that are tolerant to *Striga* infection. The objective of the study was to screen maize genotypes for tolerance / resistance to *S. asiatica* infection under N levels that mimic typical smallholder farmer conditions in Zimbabwe.

## 2. Materials and Methods

### 2.1 Study Site

A greenhouse pot experiment was conducted at the University of Zimbabwe (17.78 °S, 31.05 °E, and 1523 meters above sea level), Crop Science department during the 2012 / 2013 rainy season. The experiment was laid out as a Randomised Complete Block Design (RCBD) with three blocks. Blocking was done according to the position of the pots from the window. The treatment structure was a 9 x 2 factorial. The first factor was maize genotypes (nine maize genotypes) and the second factor was the *Striga* level (infested and uninfested maize genotypes). Maize genotypes that were used are shown in Table 1.

Table 1. Characteristics of maize genotypes under study

| Maize | Description |
|---|---|
| PHB 30D79 | Medium maturity, Grey Leaf spot resistance (GLS) and Maize streak virus (MSV) resistance. |
| PHB 30G19 | Medium maturity, MSV and GLS resistance. |
| PHB 30B50 | Medium maturity. |
| P 2859W | Short season. |
| PHB 3253 | Early maturing, Susceptible to MSV. |
| Sirda Maize | Medium maturity, drought tolerant, resistant to MSV and GSV. |
| AG541 | Short season |
| Landrace 1 | Broad base |
| R201 | Early maturity, heat stress tolerance moderate resistance to cob rot and Late blight. |

## 2.2 Experimental Procedure

Fifty four black polythene bags, each measuring 180 x 140 x 320 mm were filled with sandy soil up to three quarters. The top five centimetres of soil in 27 of the polythene bags was thoroughly mixed with 0.04 g (approximately 9800 seeds) of *S. asiatica* seeds and the other 27 polythene bags remained uninfested and were used as the control. The *Striga* seed used had been collected from *Striga* plants associated with maize in Rushinga smallholder farming area in May 2012 in Zimbabwe. The *Striga* seed was not allowed to precondition prior to the introduction of the maize seed (Parkinson, 1985). Three seeds of maize were planted in each polythene bag at the depth of 5 centimetres on the 14th of November 2012 and the plants emerged on the 20th of November 2012. At planting, 8 g of compound D (7 % N: 14 % $P_2O_5$: 7 % $K_2O$) was banded below the maize seed in order to promote early root development. Thinning of maize seedlings was done one week after crop emergence (WACE) to leave one plant per polythene bag. Weeds other than *S. asiatica* that had emerged were hand pulled after every three days and the maize plants were irrigated using a watering can fitted with a fine rose every other day. Top dressing of maize plants was done using Ammonium Nitrate (AN) (34.5 % N) at 6 WACE at the rate of 30 kg per hectare (one gram of AN was added applied per polythene bag). Harvesting was done on the 20th of February 2013 by cutting maize stems at ground level using a pair of secateurs and the roots were carefully washed with water to remove the soil. The leaves, stems, cobs and roots from each polythene were placed in separate envelopes.

The number of *Striga* plants that had emerged was recorded at weekly intervals starting from 7 WACE up to harvesting of maize. The roots of maize were carefully washed and the number of *Striga* attachments was determined by physically counting the *Striga* attachments on the maize roots at harvesting. Maize leaf, stem, cob and root biomass was determined at physiological maturity by oven drying all the leaves, stems, cobs and roots separately at 80°C for 72 hours. The maize height measurements were taken from the ground level to the growing tip using a 30 centimeter ruler weekly starting at 40 days after planting (DAP).

## 2.3 Data Analysis

*Striga* and maize data were subjected to Analysis of Variance (ANOVA) using Genstat version 14, Minitab version 16. A repeated measure ANOVA was performed to test the effects on maize cultivar, *Striga* infection, maize height measuring time (40, 54, 61, 68, 78 and 82 days after planting) and their interactions on maize heights. Mean separation was done using Fischer's protected Least Significance Difference (LSD) at 5 % probability level.

## 3. Results

### 3.1 Striga Data

#### 3.1.1 Striga Emergence

*Striga* emergence was observed at 7 WACE in one pot of LANDRACE 1, one pot of R201 and in all the pots for AG541 only but did not emerge in the other polythene bags.
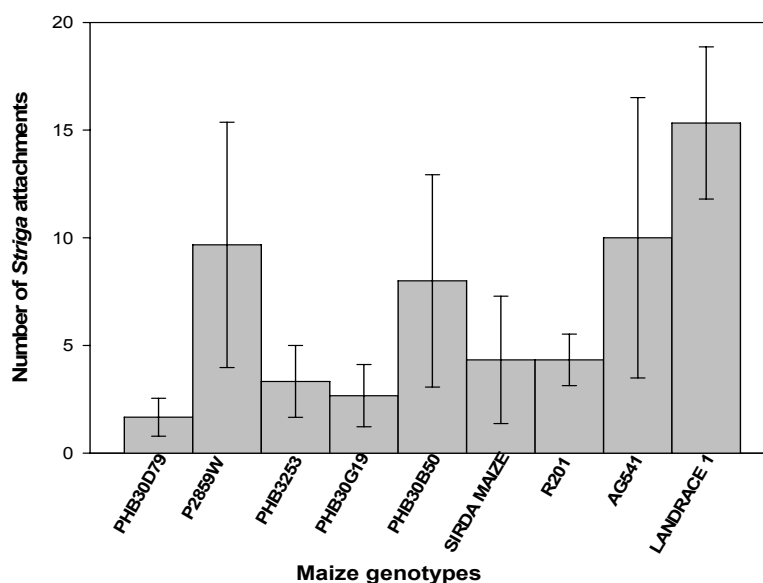


Figure 1. Number of *Striga* attachments in a pot experiment carried out at the University of Zimbabwe

### 3.1.2 Striga Attachments on Maize Roots

The number of *Striga* attachments (Figure 1) on maize plants was not affected by maize genotype (P > 0.05).

### 3.2 Maize Response to Striga Infection

### 3.2.1 Maize Height

The repeated measures ANOVA showed that there was a significant (P < 0.01) interaction of maize cultivar, *Striga* infection and measuring times (40, 54, 61, 68, 78 and 82 days after planting) on maize heights. The maize heights generally increased with time from planting regardless of maize cultivar and *Striga* infection (Figure 2). *Striga* infection significantly reduced the final maize heights of maize genotypes PHB3253 and PHB30G19. However, the heights of the other maize genotypes were not affected by *Striga* infection.
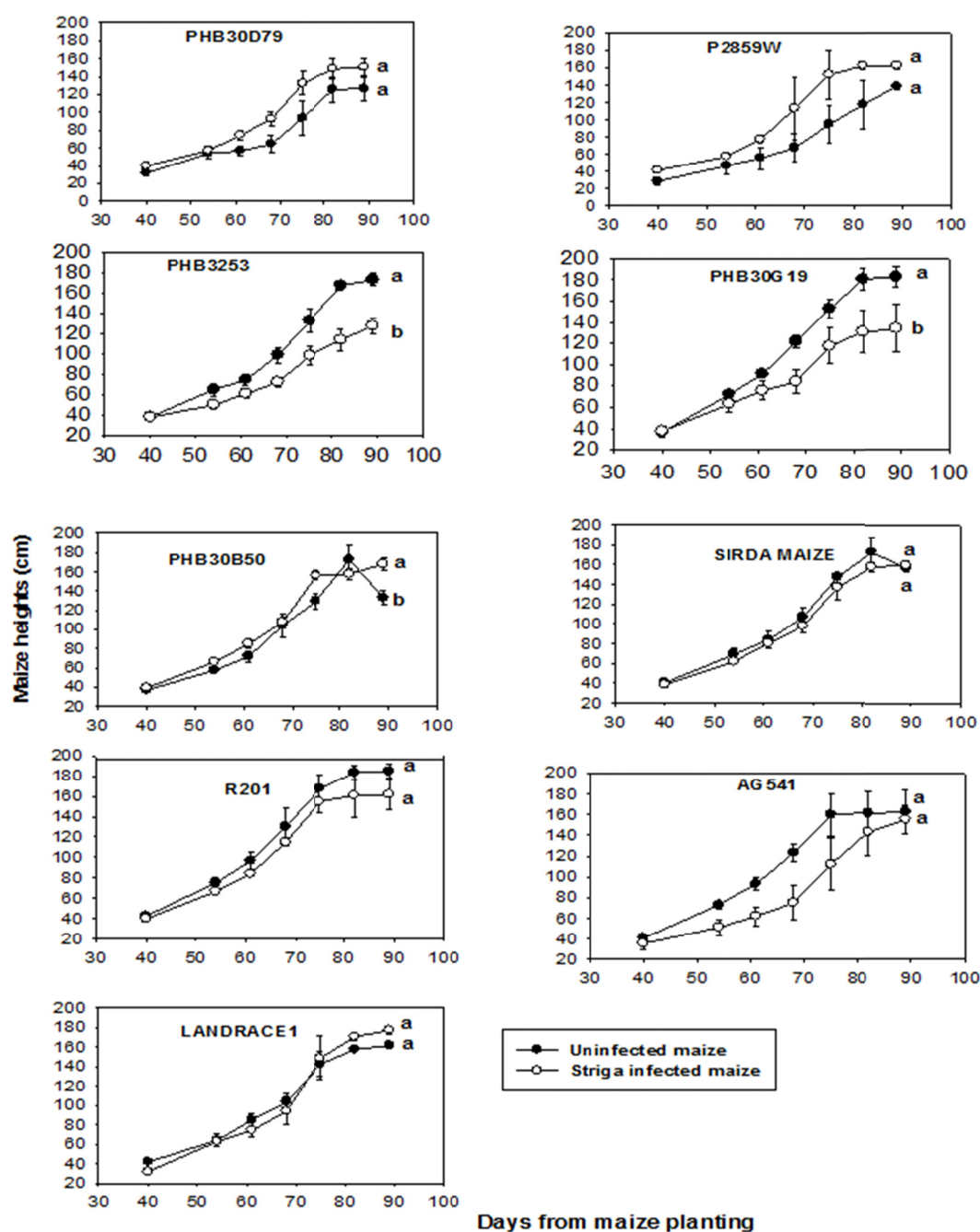


Figure 2. Effect of *Striga* infestation on the height (cm) of maize genotypes

### 3.2.2 Maize Leaf Biomass

The interaction of maize genotypes and *Striga* effects were not significant on leaf biomass (P > 0.05). *Striga* infestation had no impact on leaf biomass across the maize genotypes (Figure 3).
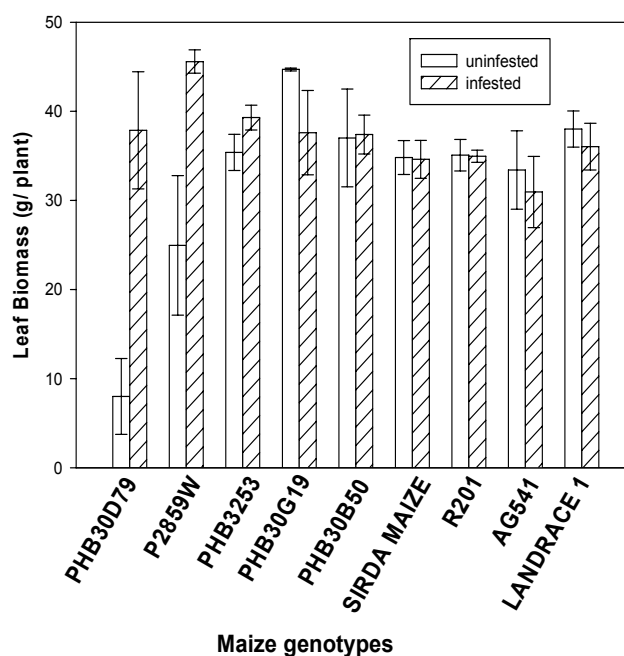


Figure 3. Effect of *Striga* infestation on leaf biomass of maize genotypes

### 3.2.3  Maize Stem Biomass

The interaction of maize genotype x *Striga* effects was not significant (P > 0.05) on stem biomass (Figure 4). However, there were significant (P < 0.05) differences in stem biomass amongst the nine maize genotypes. P2859W and AG 541 had significantly lower stem biomass than PHB 3253, R201 and Landrace 1, but their stem biomass was not significantly different from the other genotypes.
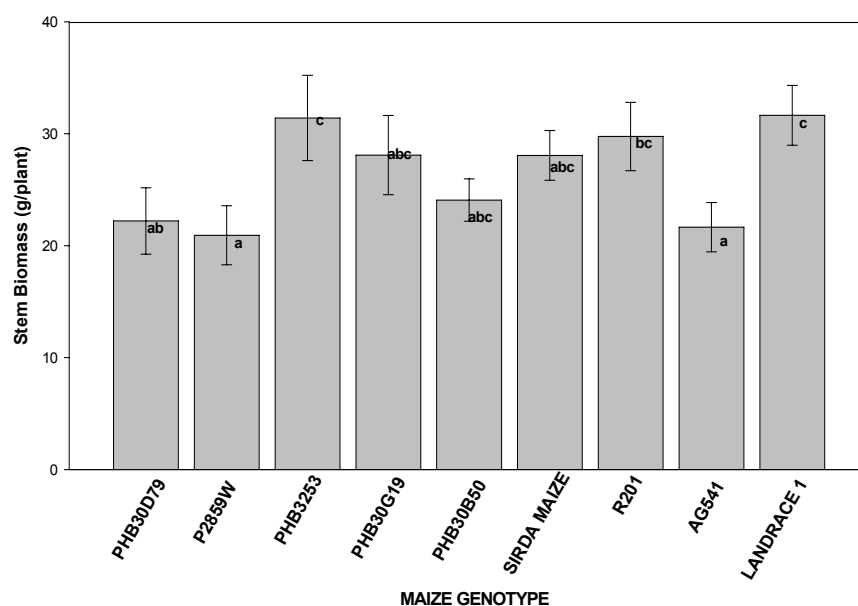


Figure 4. Effect of maize genotypes on maize stem biomass

3.2.4 Maize Cob Biomass

The maize genotype x *Striga* infestation interaction was not significant (P > 0.05). *Striga* effects on cob biomass were also not significant (P > 0.05). However, the maize cob biomass was significantly different (P = 0.006) amongst the maize genotypes (Figure 5). Cob biomass for P2859W, PHB 3253, SIRDA MAIZE and AG541 was significantly lower than PHB 30D79, PHB 30G19, PHB30B50, R201 and Landrace 1.
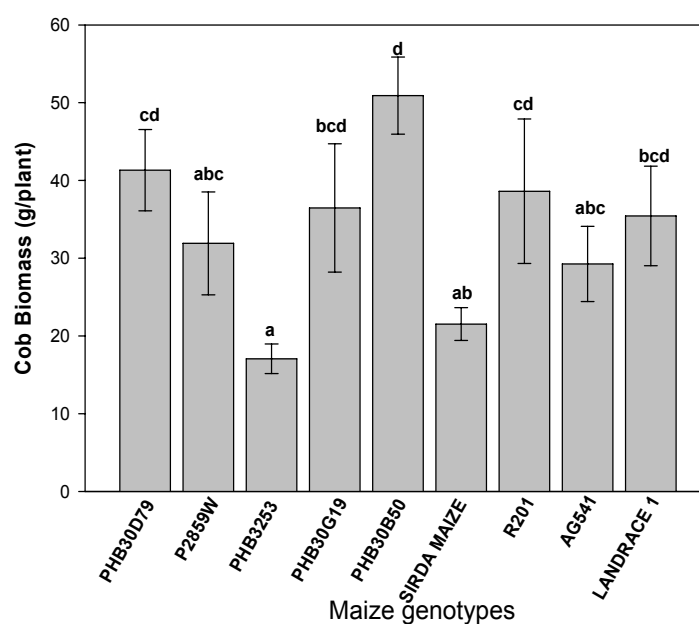
Figure 5. Effect of maize genotypes on maize cob biomass

3.2.5 Maize Root Biomass

The maize genotype x *Striga* infestation interaction was not significant (P > 0.05) on root biomass (Figure 6). Maize root biomass was not significantly different (P > 0.05) amongst the maize genotypes. *Striga* infestation significantly influenced root biomass (P = 0.006). The *Striga* infested maize had significantly higher root biomass as compared to the uninfested maize.
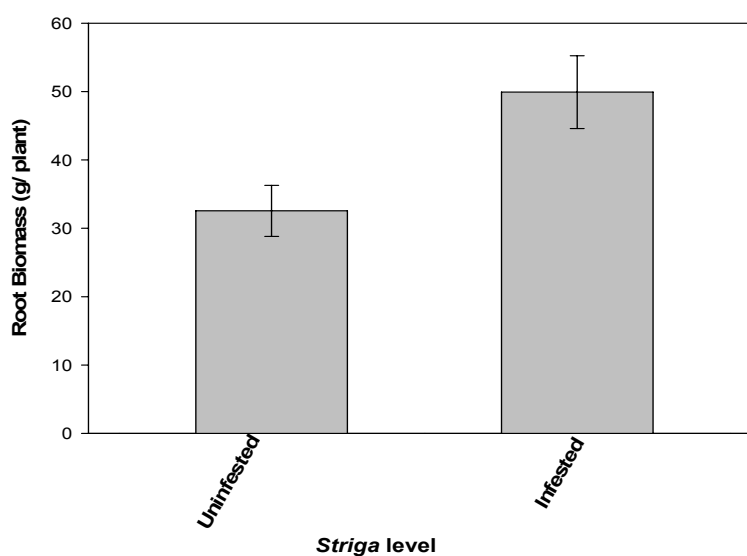
Figure 6. Effect of *Striga* infestation on maize root biomass

3.2.6 Root / Shoot Ratio

The maize genotype x *Striga* infestation interaction was significant (P = 0.018) on root to shoot ratio (Figure 7). Root to shoot ratio was significantly higher in infested than uninfested maize in PHB 30G19, PHB 30B50, SIRDA MAIZE, R201, AG 541 and Landrace 1. However, *Striga* infestation did not cause a significant effect on root to shoot ratio in PHB30D79, PHB 2859W and PHB 3253.
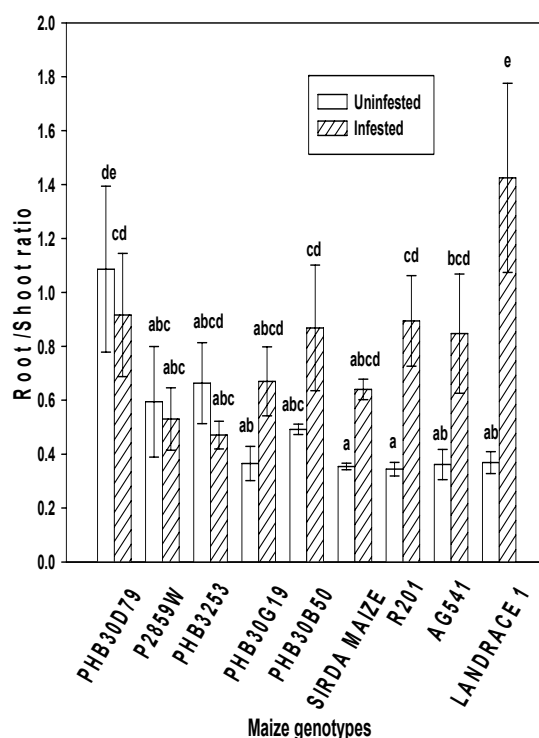


Figure 7. Effect of *Striga* infestation x maize genotype on root/shoot ratio of *Striga* infested and uninfested maize

## 4. Discussion

Only few *Striga* plants emerged at 35 days after planting (seven weeks after crop emergence (WACE)) but they did not produce flowers. The parasite did not emerge in most of the *Striga* infested pots although it managed to attach to the roots of all the maize genotypes used in this study. The delay in emergence can be explained by a delay in the onset of attachment (Ast, 2006) due to the fact that the seed of *Striga* was not preconditioned when maize seeds were planted in infested polythene bags. These findings imply that host avoidance of the parasite is likely to be an important *Striga* management strategy, especially in the arid parts of Zimbabwe where some farmers practice early planting in planting basins. Maize planted in planting basins germinates early and is likely to grow for a few weeks before the *Striga* seed is preconditioned resulting in delayed onset of parasite attachment to the host.

This study also showed that all the genotypes used equally supported few attachments of the parasite to the host. This can be partly explained by the delay in the onset of attachments but the low numbers of attachments observed could be an indication of similarly low stimulant production capacity of the genotypes. It is now known that the production of strigolactones, a group of *Striga* germination stimulants produced by the host plants are responsible for causing germination of *Striga* seeds. It is also well documented that the production of strigolactones among host genotypes could account for differences in numbers of *Striga* attachments among genotypes (Jamil et al., 2011). The capacity of these genotypes to produce stimulants has not yet been studied. There is therefore need for further research to find out whether the lack of differences in attachments on the genotypes was due to similarities in their onset and capacity of stimulant production.

The maize height data over time showed that the maize genotypes differed in their sensitivity to *Striga* infection. The most sensitive genotypes to *Striga* infection were PHB3253 and PHB30G19. In these genotypes *Striga* significantly reduced maize heights compared to uninfested maize. This suggests that these genotypes are

susceptible to *Striga* infection. *Striga* infection did not affect the height and stem biomass of the genotypes AG541, R201, SIRDA MAIZE, LANDRACE 1, PHB30D79 and P2859W implying that these genotypes are tolerant to *S. asiatica* infection. Maize stem biomass and height are the most sensitive parameters to *Striga* infection (Gurney et al., 2003; Mabasa, 2003). Therefore, genotypes whose stem biomass and height were not affected by *striga* infection could be tolerant to *Striga* infection (Gurney et al., 1999; Cechin & Press, 1993). However, tolerance of the genotypes to *Striga* infestation can not only be determined by the low sensitivity of these genotypes to *Striga* infection in terms of stem biomass and heights. As mentioned earlier on, this sensitivity could be due to late attachment of the parasite to the roots of the host. *Striga* seeds could have germinated and attached at a later stage on roots developing superficially, when the host had already developed capacity to tolerate the effect of *Striga* infection (Gurney et al., 1999). These findings are supported by the work of Cechin and Press (1993) who observed that severe damage to host under controlled conditions can only be observed when *S. asiatica* attachment to host occurs early in the life cycle of the host. However, the reduced effect of *Striga* on the host cannot be wholly attributed to avoidance due to late attachment but could also indicate the presence of a certain level of tolerance especially given that the height of some of the genotype were reduced by the late *Striga* attachments. The low sensitivity of the maize genotypes evaluated in this study to *Striga* infection in terms of stem biomass and stem heights could also be explained by the fact that most of the genotypes used in this study are drought tolerant. The maize genotypes did not express the characteristic wilting symptoms which are associated with the presence of *Striga* infection. *Striga* infection is known to cause accumulation of abscisic acid (ABA) in maize genotypes (Taylor et al., 1996) leading to reduced rates of photosynthesis in some maize genotypes. High ABA levels in the plants are responsible for causing stomatal closure and this will limit the entry of carbon dioxide into the leaf resulting in a reduction in the photosynthetic rate of the plant. Maize genotypes which are drought tolerant are known to accumulate less ABA in their leaves after receiving the signal from the roots (Taylor et al., 1996) and their photosynthetic rate is therefore not reduced.

The root biomass of *Striga* infested maize genotypes was significantly higher than the uninfested maize genotypes and hence resulted in higher root / shoot ratio. The response of root / shoot ratio in two cultivars, R201 and LANDRACE 1 was greater than in the other genotypes, which means that *Striga* elicited a greater shift in favour of root growth in these two cultivars. It is well documented that *Striga* infection affects the host in many ways. Firstly there is an increase in host root biomass at the expense of shoot biomass due to competition for photoassimilates, amino acids and water because the parasite will be acting as an additional sink. Secondly, it is reported that *Striga* infection also causes hormonal imbalances in *Striga* infected hosts characterised by increased levels of abscisic acid and decreased levels of cytokinins and gibberellins (Ast, 2006). Parker and Riches (1993) reported that these changes in hormonal balance result in the stimulation of root growth and reduced shoot growth in *Striga* infected hosts. Thirdly the increase in root to shoot ratio in infected hosts could be explained by the fact that most of the *Striga* remained below the ground and a few managed to emerge above ground and this could have imposed a heavy burden on the maize plants in terms of carbohydrate requirements since *Striga* plants have high respiration rates (Cechin & Press, 1993). On the contrary emerged *Striga* plants contain chlorophyll and are able to process part of their carbon through photosynthesis. The impact of *Striga* on the maize genotypes was not significant in terms of dry matter production. This probably confirms the fact that these maize genotypes are indeed *Striga* tolerant.

## 5. Conclusion and Recommendations

It was observed in this study that the maize genotypes LANDRACE 1, SIRDA MAIZE and R201 are tolerant to *S. asiatica* infection and have a potential to be grown in *Striga* endemic areas where most of the resource poor farmers are located. The data on stem heights showed that all the maize genotypes with the exception of PHB3253, PHB30B50 and PHB30G19, were not sensitive to *Striga* infection. This confirms the hypothesis that the maize genotypes have different sensitivities to *Striga* infection. The maize genotypes which are not sensitive to *Striga* infection could be tolerant to *Striga* and those that are sensitive are *Striga* susceptible. The genotypes, PHB30D79, P2859W and AG541can also be grown in *Striga* endemic areas since they indicated some level of tolerance. However, there is a need to evaluate these maize genotypes under field conditions in order to confirm their tolerance to *S. asiatica* infection. There could also be merit in studying the effects of different strains of *Striga asiatica* on these maize genotypes.

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