The Response of Zimbabwean Sorghum and Maize Landraces to *Striga asiatica* Infestation

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Abstract

Sorghum and Maize are important cereals for food security in Zimbabwe. However maize and sorghum production in the smallholder farming sector is being threatened by witch weed, (*Striga asiatica*), which has the potential to reduce maize and sorghum yields by 100%. Studies on sorghum and maize resistance to *Striga asiatica* have mainly focused on new improved crop varieties but very few studies have been done on local non improved varieties commonly called 'landraces'. A controlled pot experiment was conducted at Henderson Research Station in Mazowe to test the hypothesis that early maturing sorghum landraces are more sensitive to *Striga* than late maturing landraces. We also tested the effect of *Striga* on two maize landraces. The results failed to support the hypothesis that early maturing sorghum landraces are more sensitive to *Striga* than late maturing landraces. Striga significantly reduced the vegetative growth rate as well as the above ground plant biomass of the late maturing landrace Khaki ($p<0.05$). The results also indicated that Striga increased the rate of growth in the other three sorghum landraces Nhongoro, Tsveta white and Musoswe but Striga had no significant effect on the above ground plant biomass ($p>0.05$). *Striga asiatica* caused a decline in the growth rate of the two maize landraces 2040 and 1714, but there was no significant effect on the above ground plant biomass ($p>0.05$),

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Dedication

To my Father

CHAPTER 1: INTRODUCTION

The parasitic weed *Striga asiatica* (L.) Kuntze which is commonly known as witch weed is one of the major biological constraints to cereal production in the smallholder farming sector in Sub Saharan Africa (Stroud 1993). Striga attacks the two main cereals grown by smallholder farmers that are important for food security which are maize and sorghum (Oswald and Ransom 2004). Striga can reduce crop yields to as much as 100% and therefore poses a serious threat to food security (Mabasa 1993). Maize and Sorghum are complementary food cereals in Zimbabwe; maize is a staple crop while sorghum is becoming increasingly important especially in low maize growing potential areas that are the semi-arid areas in Regions III, IV and V (Mukarumbwa and Mushunje 2010). Recommended control and management practices in Zimbabwe such as use of trap/catch crops, herbicides, high fertilizer rates and early planting, have not been widely adopted by smallholder farmers because of various technological and socioeconomic factors (Chivinge et al. 1995). *Striga asiatica* resistant landraces offer an economically feasible and culturally sustainable technology for small holder farmers since they do not require additional inputs (Mabasa 1996).

Although a lot of efforts have been put towards development of *Striga* resistant sorghum and maize varieties, very few *Striga* resistant varieties have been developed. This is due primarily to the high genetic diversity among *Striga* populations occurring in nature that always render newly developed landraces susceptible (Musimwa 2005). In sorghum, resistance results from one or a combination of several recognized mechanisms that influence parasitism (Ejeta *et al*. 1993). One such mechanism is low *Striga* germination stimulant production. Sorghum varieties that are resistant to striga have the genetic characteristic of producing low striga germination stimulants such that very few striga plants are able to germinate (Hess *et al*. 1992). However sorghum landraces vary in as much as a billion fold in germination

stimulant production and additionally it has been found that there are a number of several compounds that are also responsible for stimulating striga germination (Mutengwa 1999). In maize, striga resistant or tolerant landraces are those that have a short growth cycle which is known as the escape mechanism that is, less roots in the upper soil layer, early growth and vigor and physiological resistance to the phototoxic effects caused by Striga parasitism (Ransom *et al*. 1996, Oswald *et al*. 2001).

Studies on maize and sorghum resistance to *Striga asiatica* have mainly focused on new improved landraces but very few studies have been done on local non improved landraces commonly called 'landraces'. Landraces also known as farmers' "traditional" or primitive" varieties are defined as "geographically or ecologically distinct populations which are diverse in their genetic composition both between populations and within them" (Brown 1978). Landraces remain highly unexplored and underused and might contain very valuable additional sources of resistance or traits that could be used by farmers or introgressed in the improved varieties to achieve better resistance to parasitic weeds and diseases (Rubiales 2003). This is because landraces have evolved an assortment of alleles needed for resistance and tolerance hence have become adapted to the diseases, pests, and harsh environments found in their natural habitats (Hoisington *et al*. 1999). Many of these landraces have been collected and stored under *ex-situ* conservation in gene banks around the world. In Zimbabwe a collection of 1793 sorghum and 29 maize accessions of these landraces are available at the National Genebank housed at the Department of Research and Specialist Services (Ministry of Agriculture Mechanization and Irrigation Development 2009). These genetic resources therefore have the fundamental role towards crop development and improving agricultural productivity. It is therefore envisaged that these genetic resources could have resistant or tolerant traits to *Striga* and many other biological constraints due to their wide genetic diversity. The aim of this study is therefore to screen selected maize and sorghum landraces for *Striga*

resistance through a controlled pot experiment in order to test whether *Striga* has an effect on maize and sorghum landraces found in Zimbabwe. The controlled experiment will also be used to test the hypothesis that early maturing landraces are more sensitive to *Striga*.

Objectives

1. To test the hypothesis that early maturing sorghum landraces are more sensitive to *Striga asiatica* than late maturing landraces
2. To investigate the response of two maize landraces to *Striga asiatica* infestation

CHAPTER 2: MATERIALS AND METHOD

2.1 Study Site

The pot experiment was established on 1 March 2013 at the Henderson Research Station in Mazowe (25 km from Harare) and lies in agro-ecological region 2 of Zimbabwe. It receives an average rainfall of 864 mm per *annum* and experiences a mean annual temperature of about 21 degrees Celsius (Mujere and Mazvimavi 2012). The soil type at Henderson Research Station is red clay loam (Wulff et al. 2002).

2.2 Sorghum and maize landraces

The sorghum (*Sorghum bicolor*) and maize (*Zea mays*) landraces seed used in the experiment included four sorghum landraces identified by local names Tsveta white, Khaki, Nhongoro and Musoswe, and two maize landraces identified by accession numbers 2040 and 1714 (Table.1). The sorghum and maize landraces seed was obtained from the National Genebank seed collection at the Department of Research and Specialist Services in Harare. Table 1 below contains the list of the sorghum and maize landraces used in the experiment and the associated characterization data for each landrace.

Table 1. Sorghum and maize landraces used in the experiment (Preliminary crop evaluation data obtained from the Genetic Resources and Biotechnology Institute, 2009).

Local Name	Accession Number	1000 seed weight	Days to 50% flowering	Days to 50% Tasseling	Height (cm)	No of Tillers	Cob diameter	Head width (cm)	Ear Length (cm)
Tsveta White	1522	30.1	78		250	3		7	
Nhongoro	1343	17.2	89		310	3		4	
Musoswe	1356	18.9	95		335	4		6	
Khaki	1517	34.4	97		260	6		7	
*Unknown	2040			76			2.3		19
*Unknown	1714			76			2.9		14

*__Note__: Were the local name is unknown; the accession number is used instead to identify the landrace.

2.3 Experimental Design

We used a completely randomized design with two treatments *Striga* infestation and the control which had no *Striga*. The experimental units included four sorghum landraces and two maize landraces. We randomly assigned each experimental unit to the treatments and repeated the experiment 6 times. Therefore each of the sorghum and maize landraces was randomly assigned to a plastic pot that was filled with either striga infested soil or the control that had striga-free soil so that at the end we had 6 pots for each of the landraces under Striga infestation and 6 with no Striga infestation. Figure 1 illustrates the assigning of treatments to the experimental units. The plastic pots were then randomly arranged in space as indicated by Figure 2

Experimental Units	**Treatments**											
	Replicate 1		**Replicate 2**		**Replicate 3**		**Replicate 4**		**Replicate 5**		**Replicate 6**	
Tsveta White (Sorghum)	1	2	3	4	5	6	7	8	9	10	11	12
Khakhi (Sorghum)	13	14	15	16	17	18	19	20	21	22	23	24
NPGRC 2040 (Maize)	25	26	27	28	29	30	31	32	33	34	35	36
Nhongoro Sorghum	37	38	39	40	41	42	43	44	45	46	47	48
Musoswe Sorghum	49	50	51	52	53	54	55	56	57	58	59	60
NPGRC 1714 (Maize)	61	62	63	64	65	66	67	68	69	70	71	72

NB Striga infestation is denoted by △ and the Control (No *Striga* infestation) is denoted by □

Figure 1. Assigning Experimental Units to the treatments and replicating the procedure 6 times

Plastic pots with a volume of 5 liters were used for planting and filled with sandy soil obtained from Henderson Research Station (Figure 3). We then mixed 5 cm depth of the soil in the pots with 0.09 grams of *Striga* seed. Twenty seeds were planted for the sorghum landraces and 3 seeds for maize and after the plants emerged we thinned them to leave one plant per pot.

We applied fertilizer at the rate of 2 grams in each pot for Compund D (8% Nitrogen, 14% Phosphate and 7% Potassium) as the basal dressing at the planting stage. We then applied top dressing fertilizer at the rate of 2 grams of Ammonium Nitrate (34.5% Nitrogen) at 3 weeks from planting and repeated the application at 5 weeks from planting. We carried out the fertilizer application following recommended application rates for Striga experiments as indicated in the Striga Research Methods Manual (International Institute of Tropical Agriculture 1997).

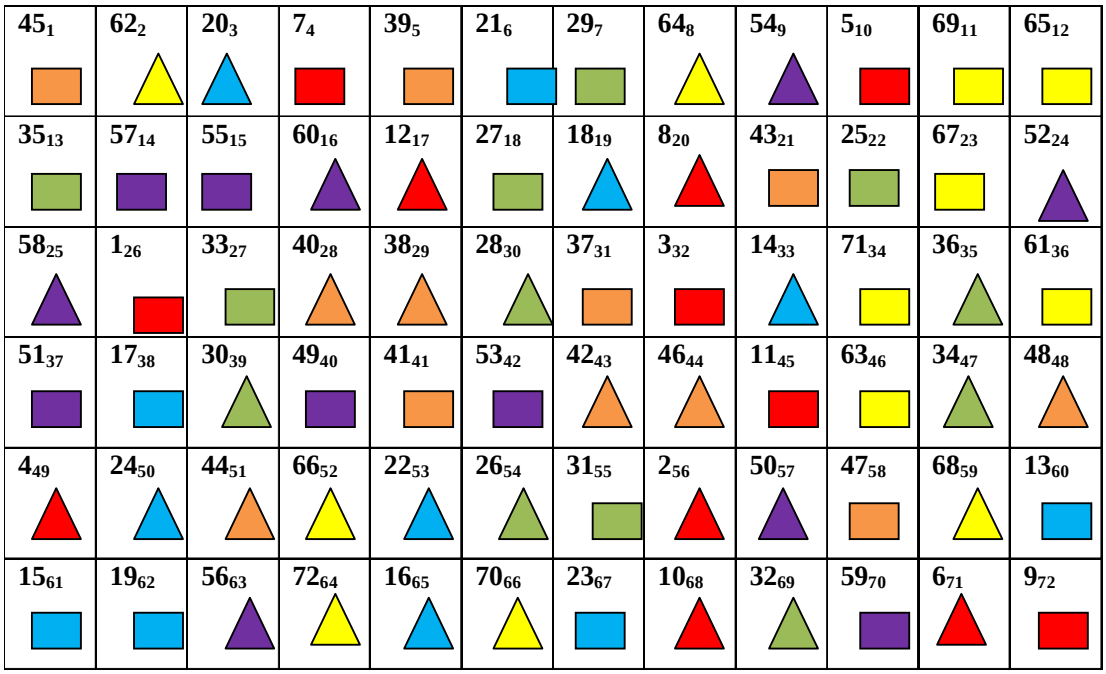

Figure 2 Completely randomized design in space, with the treatment at two levels Striga infestation and Control with No striga infestation, replicated six times.

2.4 Data collection

Plant heights were recorded in weekly intervals starting from the two weeks after planting to 12 weeks. Also some of the data that was collected includes the above ground biomass of the plants, the days to emergence of the Striga, the number of Striga plants per pot, the days to flowering of sorghum and days to tasseling for and the final total above ground plant biomass. The total above ground dry matter was obtained by harvesting whole plants and drying them in an oven drier for 48 hours.

2.5 Data analysis

Data for plant heights was analyzed using Repeated measures analysis of variance to test the effect of Striga on the vegetative growth of sorghum and maize using the software STATISTICA release 7.

The data for plant biomass was analyzed using the Statistical Package for the Social Sciences (SPSS) and a *t* test to test the differences in means between the treatment and control at 95% level of significance was performed.

CHAPTER 3: RESULTS AND DISCUSSION

3.1. Effect of *Striga* on the rate of vegetative growth of Sorghum landraces

Figures 3 and 4 illustrate the change in vegetative growth of sorghum landraces Tsveta white an early maturing landrace, Nhongoro a late maturing landrace, Khaki an early maturing landrace and Musoswe a late maturing landrace and plant height over time in weeks under *Striga* infestation. Figures 3 and 4 indicate all *Striga* infested sorghum landraces growing slower than the control during the first 6 weeks from planting then the growth rate starts to increase after 6 weeks for the sorghum landraces Tsveta white, Nhongoro and Musoswe while the growth for the landrace Khaki continues to decrease.

(i) Early Maturing Sorghum Landraces

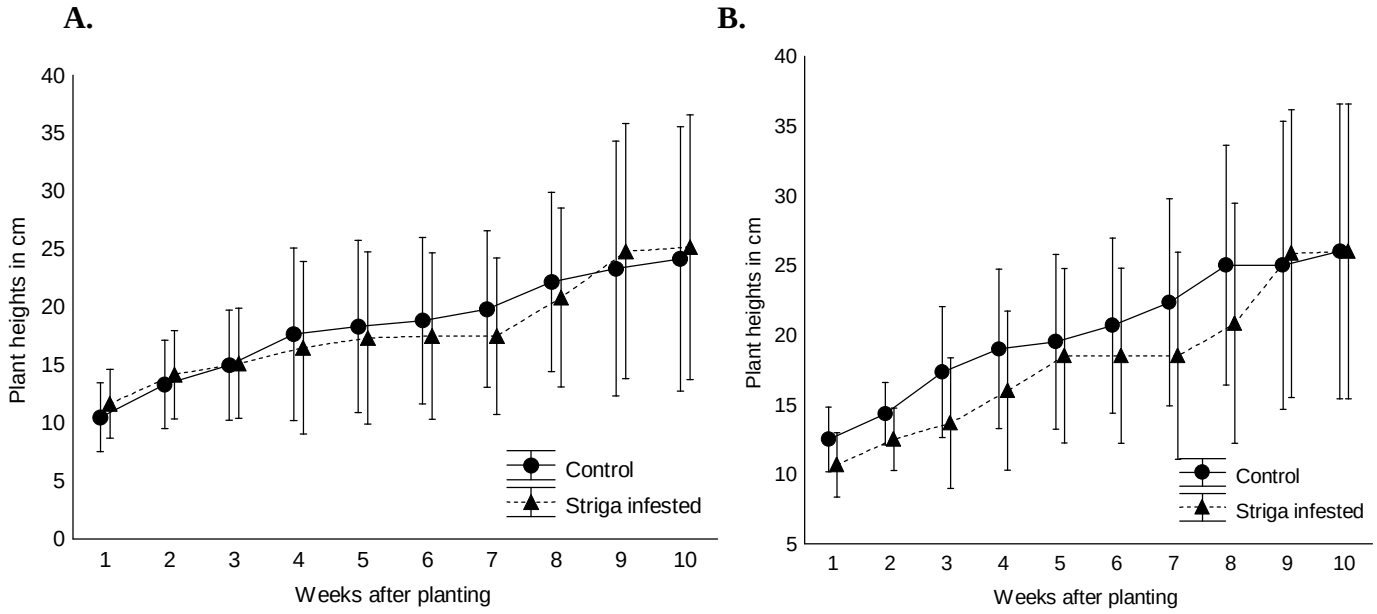

Figure 3: Effect of Striga on the rate of vegetative growth of early maturing Sorghum landraces, **(A)** Nhongoro and **(B)** Tsveta white over 10 weeks.

There is evidence that Striga stimulated growth of Tsveta, Nhongoro and Musoswe at 6 weeks whilst it suppressed the growth of Khaki (RepANOVA: $F_{27,216}$ = 1.60; P=0.036). The results illustrate that the landrace Khaki is the most sensitive to *Striga* infestation because it has the greatest difference in magnitude of the gradient between the *Striga* infested and the control and also it was observed that growth of Khakhi decreased sharply after 6 weeks from planting.

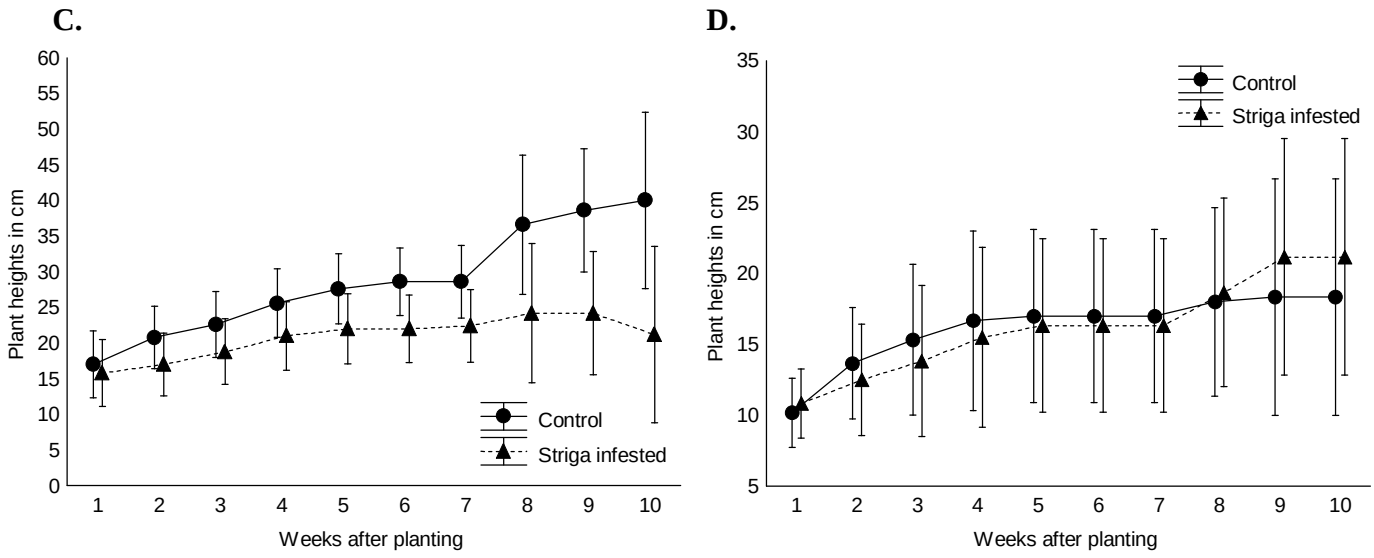

Figure 4: Effect of Striga on the rate of vegetative growth of late maturing Sorghum landraces, **(C)** Khakhi and **(D)** Musoswe over 10 weeks.

3.3 The Effect of *Striga* asiatica on the vegetative growth of Maize landraces

Figure 5 below illustrates that *Striga* infested maize was growing faster than the non-infested control at the first 8 weeks from planting. After 8 weeks from sowing the growth rate for the *Striga* infested maize began to decline. The decline in growth after 8 weeks was greater in the maize landrace 1714 (Figure 5 F) compared to the landrace 2040 (Figure 5 E). The difference in the magnitude of the gradient at 8 weeks between the *Striga* infested maize and the control indicates the degree of the sensitivity to *Striga* infestation of that maize landrace. Figure 5 indicates that the landrace 1714 was more sensitive to *Striga* infestation than 2040 because the difference in the gradient between the *Striga* infested maize landrace 1714 and its control was greater than the same difference observed for the landrace 2040.

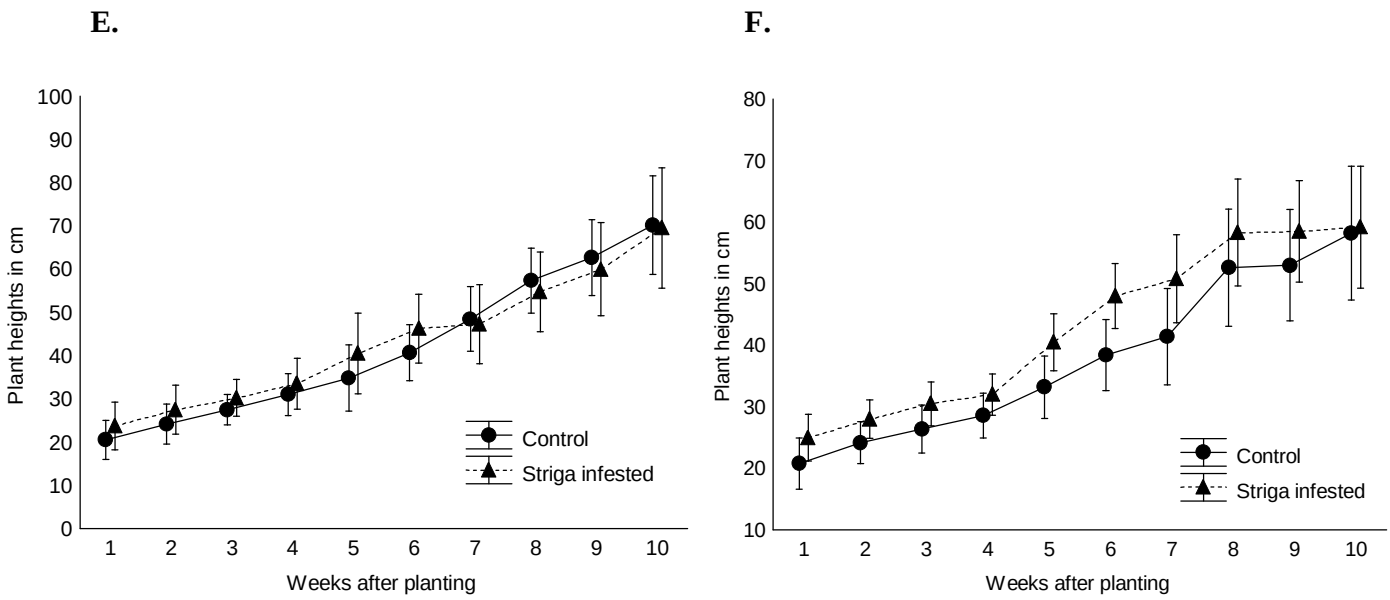

Figure 5: Effect of Striga on the vegetative growth of **(E)** Maize landrace 2040 and **(F)** Maize landrace 1714, measured in centimeters.

3.4 Effect of *Striga asiatica* on the plant biomass of sorghum and maize landraces

Table 2. Table showing a comparison between control and treatment means of plant biomass for sorghum and maize landraces

Crop	Landrace	Treatment Means	Treatment 95% CI	Control Means	Control 95% CI	t-value	df	p-value
*Sorghum	Khakhi	1.40	0.69	8.66	5.08	2.46	7	0.04
Sorghum	Musoswe	4.84	3.68	4.32	3.75	0.19	10	0.85
Sorghum	Nhongoro	9.46	8.78	12.71	4.64	0.64	10	0.54
Sorghum	Tsveta	18.44	9.66	15.40	6.60	0.51	10	0.62
Maize	2040	32.23	4.12	40.03	6.19	1.82	8	0.11
Maize	1714	24.39	3.73	28.82	10.26	0.79	10	0.45

Table 2 above shows results from a *t* test for the differences in plant biomass means between the treatment and control of the sorghum and maize landraces. The results show that Striga had no significant effect on the plant biomass of both maize and sorghum landraces ($p>0.05$) except for the Sorghum landrace Khakhi. Striga significantly decreased the plant biomass of the sorghum landrace Khakhi ($p<0.05$) showing thus the landrace was sensitive to Striga parasitism. Growth suppression was also observed in landrace Nhongoro but however effects were not significant ($p>0.05$). There was evidence of induced growth in the landraces Musoswe and Tsveta because the mean biomass for the striga infested plants were greater than the control although however the differences were insignificant ($p>0.05$). The maize landraces all showed that their growth was suppressed although the effects were insignificant ($p>0.05$).

3.4 Discussion

Among the Sorghum landraces that were screened Khakhi is the most sensitive to *Striga*. The study showed that the vegetative growth of Khakhi was constantly slower for the treatment means compared to the control. Furthermore the final biomass for Khakhi was significantly lower in the treatment group compared to the control. The remaining sorghum landraces and the maize landraces were all tolerant to Striga. The study also showed that *Striga* caused an increase in vegetative growth in the other three sorghum landraces which are Tsveta white, Nhongoro and Musoswe and the maize landraces 2040 and 1714, indicating possible compensatory growth, during the vegetative growth phase, as a response to the phototoxic effects of *Striga*. Studies done by (Van Ast and Bastiaans 2006) showed that sorghum responds to *Striga* parasitism through changes in dry matter allocation, in particular sorghum that is infested with *Striga* has a reduced panicle and stem fraction while the leaf and root fraction is increased. This partly explains why these sorghum landraces were able to tolerate *Striga* infestation unlike Khaki. On the same note it is important to note the observation that the sorghum landraces Tsveta white and Musoswe all had higher plant biomass in the treatment group than the control although the differences were not statistically significant. It is not clearly understood why the landrace Khakhi was so susceptible to Striga but part of the explanation could be derived from the fact that Khakhi is a late maturing landrace unlike Tsveta and Nhongoro. There is scant literature on the relationship between the duration of maturity and striga infestation among sorghum landraces. However some studies have been done on maize varieties in Kenya and it was found out that early maturing maize landraces are more tolerant to Striga than late maturing landraces through a mechanism termed ‘the escape mechanism’ (Ransom and Odhiambo 1995). According to Ransom and Odhiambo, early maturing maize has the ability to escape the phytotoxic effects of Striga through vigorous early growth before the Striga can cause serious damage to the plants.

3.4 Conclusion

The study implies that the sorghum landrace Khakhi is not suitable for further development of Striga resistant sorghum because it is highly sensitive to Striga infestation. The sorghum landraces Tsveta white, Musoswe and Nhongoro and also the maize landraces 2040 and 1714 are suitable for variety development of striga resistant Sorghum and Maize since they are tolerant to Striga infestation. Although a lot of studies have been done on the response of maize and sorghum to Striga, much attention has been focused on improved varieties or hybrids. Very little attention has been put on the non-improved varieties, 'the landraces' which are found in National genebanks worldwide. This study showed that the crop landraces are quiet important in addressing crop production challenges and there is need to carry out much more such studies in the future.

The major limitation of this study is that the study was conducted as a pot experiment, hence the conditions are different from those in the field and there is a possibility that the findings may not be the same if the study was conducted in the field. It would be ideal if the experiment was conducted in the field and replicated at different sites. The other limitation was that the landraces that were used were quiet few and were only for two cereal crops maize and sorghum. There is need to increase the number of different landraces that have different days to maturity in order to enhance the quality of the findings.

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