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Evaluation of some genotypes of maize (*Zea mays* L.) for tolerance to *Striga hermonthica* (Del.) Benth in Northern Ghana

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A study was conducted in Nyankpala, northern Ghana, to screen twenty five genotypes of maize for tolerance to *Striga hermonthica* during the 2012 and 2013 cropping seasons. The genotypes were evaluated under pot and field conditions to determine the effects of *Striga* infestation on yield as well as agronomic characteristics of maize. For the pot experiment, seeds of the maize genotypes were planted in green house pots that were arranged in rows on a platform with a distance of 1 m between the rows using complete randomized design. The pots were infested with *Striga* two weeks before planting maize. In the field, maize and *Striga* seeds were both planted at stake on the prepared plots using 1% germinable *Striga* seed-sand mixture based on a pre-determined 70% purity and 65% germination of the *Striga* seed. There were non-striga infested maize plants and these were considered as control or 'normal' plants. Results showed that the following three maize genotypes: TAIS03, DT-STR-W-C2 and IWD-C3-SYN-F2 were highly tolerant, whilst the following six genotypes: TAANO4, NYAZ03-Y, KOBN03-OB, SISF03-OB, NYIA03 and CHFB04-OB were moderately tolerant. The remaining genotypes showed moderate to high levels of susceptibility to *Striga* infestation. *Striga* count, *Striga* plant rating and anthesis-silking interval were significantly reduced ($P < 0.05$) in the control treatments as compared to the infested genotypes. Grain yield, plant and ear height, days to anthesis, days to silking, leaf area, chlorophyll content, fresh and dry shoot weight and root length also increased significantly ($P < 0.05$) in the control as compared to the infested plants. This study has revealed that maize genotypes such as TAIS03, DT-STR-W-C2 and IWD-C3-SYN-F2, or their crosses may be used in *Striga*-infested fields for increased growth and grain yield.

Keywords: Maize; *Striga* tolerance; savanna; Ghana

Striga hermonthica (Del.) Benth (*Striga*) is considered to be one of the major biological constraints to food production in sub-Saharan Africa, probably a more agricultural problem than insects, birds or plant diseases (Ejeta and Butler, 1993). Over the years, the problem of *Striga* infestation has intensified across regions in Sub-Saharan Africa for a number of reasons, including: deteriorating soil fertility, shortening of the fallow period, expansion of production into marginal lands with little nutrient input and an increasing

trend towards continuous cultivation of one crop in place of the traditional rotation and inter-cropping systems. *Striga* severely affects an estimated 40 million hectares of land devoted to cereal production in West Africa alone, with additional 70 million hectares having moderate levels of infestation (Lagoke *et al*., 1991).

The annual yield losses due to *Striga* in the savanna regions alone are estimated to be worth US$7 billion and detrimental to the lives of over 100 million people in Africa (Mboob, 1986). The effects are likely to be long lasting as *Striga* plants produce millions of tiny seeds that can stay viable in the soil for many years. In Ghana, *Striga* is a serious problem in areas north of latitude 9°30'N, which represents about 57 percent of the total land area (Nyarko, 1986). The estimated yield losses amount to 4.1 million mega grams of grain in a year. The farm household systems in the northern parts of Ghana rank first in the production of the four major cereals across the country; namely: maize, rice, sorghum and millet (PPMED, 1993). But the production of the cereals is menaced by the threat of low productivity as a result of the parasitic weed, *Striga hermonthica* (Sauerborn, 199; Sprich, 1994). According to Sauerborn (1991), records of yield losses caused by *Striga hermonthica* in northern Ghana in 1988 amount to 16% for maize, 31% for millet and 29% for sorghum, representing a total economic loss of US$25 million for the three crops. Under heavy infestation, maize is more vulnerable to *Striga* parasitism than upland rice, sorghum and millet, with high losses in excess of 90% (Efron *et al*., 1989). *Striga* infestation can cause yield losses of 20-100 percent in maize, driving some farmers to give up cultivation of the crop entirely. Almost all the farm fields of every district in the northern parts of Ghana are infested with *Striga*. However, Runge-Metzger *et al*. (1997) stated that the state of knowledge with respect to the severity of *Striga* infestation, its geographical distribution in northern Ghana and its current trend is still extremely unsatisfactory.

In spite of the problem of *Striga* infestation, the cultivation of maize cannot be halted, since the crop is a major source of food for the people of Ghana and Africa in general. Maize is a staple food that constitutes the main diet of many people in the tropical and subtropical Africa (Oyekan *et al*., 1990). Its importance has increased as it has replaced other food staples, particularly sorghum and millet (Smith *et al*., 1994), and it has also become a major source of cash for smallholder farmers (Smith *et al*., 1997). Maize is also the widely consumed staple food with increasing production in Ghana since 1965 (FAO, 2008; Morris *et al*., 1999). It is an important cereal produced in all the five agro-ecological zones of Ghana (Obeng-Bio *et al*., 2011). Analysis based on 1987 maize consumption data in Ghana showed that maize and maize based foods accounted for 10.8% of food expenditure by the poor and 10.3% of food expenditure by all income groups (SARI, 1996). Breeding for *Striga* tolerance in maize may improve the performance of the crop even under *Striga* infested conditions and hence, increase the yield of maize. The objective of this study was to screen some genotypes of maize for tolerance to *Striga hermonthica* in the Northern Region of Ghana.

Materials and Methods

Land preparation, planting and experimental design

The experiments were conducted at the experimental field of the Savanna Agricultural Research Institute (SARI), and in the plant house of the Faculty of Agriculture, University for Development Studies, Nyankpala in the Northern Region of Ghana. The land was prepared by ploughing, after which all debris were removed. Land demarcation was done using lining and pegs. The prepared land was leveled using a hoe before seeds of the genotypes were planted.

Twenty five maize genotypes developed by the International Institute for Tropical Agriculture (IITA) were obtained from the Savannah Agricultural Research Institute (SARI), Nyankpala of the Council for Scientific and Industrial Research (CSIR), and screened for tolerance to *Striga hermonthica* during the 2012 and 2013 cropping seasons under pot and field experimental conditions respectively.

The genotypes used were CHFB04-OB, KPAS04, OKOMASA , KOBN03-OB, NYAZ03-Y, NYAZ04-W, GUMA03-OB, GBRM04-BA, TZE-Y-DT-STR-C4, DORKE SR, NYAN03, TZE-W-DT-STR-C4, NYIA03, NYLA04, TAAN04, NYSW03-Y, DT-STR-W-C2, SISF03-0B, KOBN04-R, TAIS03, CHMA04, IWD-C3-SYN-F2, NYFA04, GH120 DYF/D POP and NYFA03. For the pot study, the maize seeds were planted in green house pots that were arranged in rows on a platform with a distance of 1 m between the rows using the completely randomized design. For *Striga* infested plants, pots were infested with *Striga* two weeks prior to the planting of maize. In the field experiment, maize and *Striga* seeds were both planted at stake on the prepared plots using 1% germinable *Striga* seed-sand mixture based on pre-determined 70% purity and 65% germination of the *Striga* seed according to the procedure of (IITA, 1991). In both the pot and field studies, there were non-striga inoculated plants which served as the control plants. Treatments were replicated three times in each case in the chosen designs. Fine sand, sieved through a 250 μm sieve was used to formulate the 1% germinable *Striga* seed-sand mixture. The sand-*Striga* mixture was applied at approximately 2,500 germinable *Striga* seeds to each maize hole.

Cultural practices

In both experiments, basal fertilizer was applied at 2 weeks after planting at the rate of 30 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. Plants were also top-dressed with additional N at 30 kg N ha^{-1} at 4 weeks after planting. In the case of the field study, pre-emergence chemical weed control was used. An application of a combination of Pendimethalin [N- (1-ethylpropyl) - 3, 4 – dimethyl –2, 6 – dinitrobenzenamine] and Gesaprim [2- chloro –4 – (ethylamino) –6- (isopropylamino) –5-triazine] at a rate of 1.5 l ha^{-1} and 1.0 l ha^{-1} were used at planting. Where there was heavy weed growth prior to planting, Paraquat (1, 1- dimethyl –4, 4 – bipyridinium ion) was also applied at 1.0 l ha^{-1} in addition to Pendimethalin and Gesaprim. Hand weeding was also carried out to keep the plots free of weeds at 4 weeks after planting in both the pot and field experiments.

Data collection and analysis

Measurements of crop growth parameters were taken from the vegetative stage through destructive harvesting at 6 weeks after plant establishment from the pot experiment during the 2012 cropping season. The parameters recorded include leaf number, shoot length, Chlorophyll Content, leaf area, stem girth, fresh shoot weight, dry shoot weight, fresh root weight, dry root weight and root length. Measurements were also made of growing crop parameters between flowering and physiological maturity for the field studies during the 2013 cropping season. These parameters include: plant height, days to 50% anthesis, days to 50% pollen shed, days to 50% silking, anthesis – silking interval (ASI), ear height, *Striga* count at 10 weeks and *Striga* plant rating at 10 weeks after plant establishment. Grain yield and yield components including hundred - grain weight and number of ears harvested were also measured. The data collected were subjected to Analysis of Variance (ANOVA) using Genstat statistical package and means separated using the Duncan's multiple range test at 5% level of probability.

Results and Discussion

Pot screening of genotypes for tolerance to *Striga*

There were significant ($P < 0.05$) variations in root biomass, produced by the genotypes (Table 1). For the *Striga*-infested treatments, SISF03-OB recorded the highest dry root biomass of 2.67 g, while NYSW03-Y recorded the lowest dry root biomass of 0.09 g. The wide variation in root biomass observed in this study, among other factors is due to differences in resistant mechanisms of the host plants. In general, the mean dry root biomass weight was lower in the 'normal' plants than in the *Striga* infested plants. The normal treatments recorded the lowest mean dry root biomass of 0.70 g, whilst the *Striga*-infested genotypes recorded the highest mean dry root biomass of 0.90 g (Table 1), indicating a probable enhancement of host root growth by *Striga*. This observation is in alignment with that of Parker and Riches (1993), who observed that by altering the host hormonal balance, *Striga* may affect host biomass allocation which could result in the root systems of infected plants being greatly stimulated, while the shoot is stunted and reduced. There was a significant ($P < 0.05$) variation in root length among genotypes especially within the infested treatments (Table 1). Within the control treatments genotype KPAS04 recorded the highest fresh root length of 24.05 cm, whilst NYFA03 recorded the lowest of 11.87 cm. For the *Striga*-infested treatments, SISF03-OB recorded the highest fresh root length of 17.79 cm, whilst GBRM04 recorded the lowest fresh root length of 7.26 cm. Root lengths produced by plants from *Striga*-infested plots were generally lower than those from the control. The normal treatments recorded the highest mean fresh root length of 16.48 cm, whilst the *Striga*-infested treatments recorded the lowest mean fresh root length of 12.78 cm. The relative reduction in root length among the striga-infested treatments was possibly caused by the *Striga* plants that competed with the maize plants for nutrients, moisture and space for growth and productivity. Variation also existed among leaf chlorophyll content of maize (Figure 1). The normal treatments recorded the highest mean chlorophyll content of 36.01, whilst the *Striga*-infested trial recorded the lowest mean chlorophyll content of 31.83. Chlorophyll content was reduced by 6.19% among the infested plants as compared to that of the control. This means that *Striga hermonthica* impacted negatively on leaf development. A number of authors (Gebremedhin *et al*., 2000, Gurney *et al*., 1995, Fros *et al*., 1997, Taylor *et al*., 1996) have reported that leaf number and area were reduced by 10% and 34%, respectively, as a result of S*triga* infestation.

Striga infestation reduced leaf area, fresh shoot weight and dry shoot weight (Table 2). Among the control, the genotype KPAS04 recorded the highest leaf area of 150.69 cm², while OKOMASA recorded the lowest leaf area of 87.19 cm². However, SISFO3-OB recorded the highest leaf area of 97.57 cm², while NYSW03-Y recorded the lowest leaf area of 33.09 cm² among the *Striga*-infested treatments. Because the soils and prevailing environmental parameters were same, the differences in leaf area among various genotypes could be due to variability in genetic factors. The normal treatment recorded the highest mean leaf area of 107.15 cm², whilst the *Striga*-infested treatments recorded the lowest mean of 71.13 cm². Leaf area of the infested treatments was therefore, reduced by 33.62% relative to that of the 'normal' plants. Biomass accumulation of the shoot was rather higher in the 'normal' treatment than the infested plants. The normal genotypes recorded the highest mean fresh shoot biomass of 46.46 g, whilst the *Striga*-infested trial recorded the lowest mean fresh shoot biomass of 33.42 g (Table 2). The observation made here is in support of the

findings of Adetimirin *et al*. (2000) that *Striga* reduces the height, dry matter and grain yield of maize, and the reductions were dependent on host genotypes.

Table 1: Variation in root biomass and root length of different maize genotypes as affected by *Striga* infestation under pot conditions

Genotype	Dry root biomass (g)		Root length (cm)		Fresh root biomass (g)	
	Striga-infested	Normal	Striga-infested	Normal	Striga-infested	Normal
CHFB04-OB	1.06^{bcdef}	1.25^{a}	17.62^{ab}	21.35^{ab}	4.56^{bcde}	4.90a
KPAS04	0.60^{def}	0.85^{abc}	12.30^{defghi}	24.05^{a}	3.60^{bcdefg}	4.25^{abc}
OKOMASA	0.38^{ef}	0.73^{abc}	8.92^{ij}	13.07^{efg}	1.68^{efg}	2.93^{abc}
KOBN03-OB	0.80^{cdef}	0.43^{bc}	13.02^{cdefgh}	14.73^{cdefg}	3.78^{bcdefg}	2.40^{abc}
NYAZ03-Y	0.36^{ef}	0.47^{abc}	13.48^{cdefg}	15.93^{bcdefg}	2.10^{cdefg}	2.13^{abc}
NYAZ04-W	0.45^{def}	0.53^{abc}	12.72^{cdefghi}	21.30^{ab}	2.31^{cdefg}	2.40^{abc}
GUMA03-OB	0.83^{cdef}	0.40^{c}	14.28^{abcdefg}	16.33^{bcdefg}	4.38^{bcdef}	2.00^{bc}
GBRM04-BA	0.18^{ef}	0.53^{abc}	7.26 ^{j}	14.33^{cdefg}	1.29^{g}	1.87^{c}
TZE-Y-DT-STR-C4	1.17^{bcdef}	0.43^{bc}	11.31^{fghi}	16.37^{bcdefg}	4.83^{abc}	2.27^{abc}
DORKE SR	0.74^{cdef}	1.00^{abc}	15.4^{abcde}	16.75^{bcdef}	3.38^{bcdefg}	4.35^{abc}
NYAN03	0.42^{ef}	0.67^{abc}	12.26^{defghi}	20.13^{abc}	2.40^{cdefg}	3.80^{abc}
TZE-W-DT-STR-C4	0.23^{ef}	0.80^{abc}	10.79^{ghij}	13.65^{defg}	1.62^{fg}	3.35^{abc}
NYIA03	1.11^{bcdef}	0.50^{abc}	16.62^{abc}	18.03^{bcde}	4.38^{bcdef}	2.17^{abc}
NYLA04	0.90^{cdef}	1.20^{ab}	10.77^{ghij}	16.70^{bcdef}	4.41^{cdef}	4.83^{ab}
TAAN04	0.51^{def}	0.33^{c}	11.31^{fghi}	12.60^{efg}	2.22^{cdefg}	1.77^{c}
NYSW03-Y	0.09^{f}	0.53^{abc}	9.00^{ij}	13.13^{efg}	1.02^{g}	2.77^{abc}
DT-STR-W-C2	0.36^{ef}	0.83^{abc}	11.67^{efghi}	20.03^{abc}	1.59^{fg}	3.57^{abc}
SISF03-0B	2.67^{a}	0.43^{bc}	17.79^{a}	15.57^{bcdefg}	7.53^{a}	2.03^{abc}
KOBN04-R	0.35^{ef}	0.63^{abc}	9.36^{hij}	17.73^{bcdef}	1.83^{defg}	2.83^{abc}
TAIS03	1.86^{abc}	0.97^{abc}	15.15^{abcdef}	14.43^{cdefg}	5.73^{ab}	3.30^{abc}
CHMA04	1.57^{abcd}	0.87^{abc}	13.72^{bcdefg}	19.47^{abcd}	4.76^{abc}	2.70^{abc}
IWD-C3-SYN-F2	1.78^{abc}	0.65^{abc}	16.20^{abcd}	10.50^{g}	5.76^{ab}	3.90^{abc}
NYFA04	0.84^{cdef}	0.67^{abc}	14.64^{abcdefg}	15.47^{bcdefg}	2.06^{cdefg}	3.43^{abc}
GH120 DYF/D POP	2.09^{ab}	1.10^{abc}	12.06^{efghi}	18.40^{abcde}	4.62^{bcd}	4.45^{abc}
NYFA03	1.25^{bcde}	0.67^{abc}	11.82^{efghi}	11.87^{fg}	2.74^{cdefg}	2.57^{abc}
Mean	0.90	0.70	12.78	16.48	3.22	3.08
SEM	0.06	0.05	0.52	0.51	0.20	0.20

SEM: Standard error of mean; genotypes having the same letters (vertical direction) are not significantly different at 5% level of probability

Field screening of the genotypes during the 2013 cropping season

A clear effect of *Striga hermonthica* infection was observed on plant height (Table 3). There were differences in plant heights among the infested genotypes. Genotype CHMA04 recorded the highest plant height of 160.03 cm, whilst GH120 DYF/D POP recorded the least of 117.87 cm among the striga-infested treatments (Table 3). The differences in plant height may not have been attributed only to differences in levels of soil fertility of the experimental field and variation of host plant resistant mechanisms but also germination or haustorial initiation of *Striga.* Most of the genotypes grown in the infested plots were shorter than their counterparts in the non-infested plots. The control recorded the highest mean plant height of 155.39 cm, whilst the *Striga*-infested treatments recorded the lowest mean plant height of 129.15 cm (Table 3). The observation made here is a clear manifestation that *Striga hermonthica* had caused reduction in the growth of the

host plants as a result of competition for growth parameters with the host plants. *Striga* might have also acted not only as an additional sink but probably also had a strong 'toxic' or 'pathological' effect on the host, and hence causing the reduction in growth and development of the host. Graves *et al*. (1989) stated that this parasitic plant induces reduction in host photosynthesis and this has been the most important mechanism of growth reduction. The authors also reported that about 80% of the decrease in host growth rate could be attributed to the impact *Striga* has on host photosynthesis.

Table 2: Variation in leaf area and shoot biomass of different maize genotypes as affected by *Striga* infestation under pot conditions

Genotype	Leaf Area (cm^2)		Fresh Shoot Weight (g)		Dry Shoot Weight (g)	
	Striga-infested	Normal	Striga-infested	Normal	Striga-infested	Normal
CHFB04-OB	87.47^{ab}	136.5^{ab}	41.32^{bcde}	85.90^{a}	5.32^{bcdef}	8.95^{ab}
KPAS04	82.32^{abc}	150.7^{a}	37.44^{cde}	88.45^{a}	5.34^{bcdef}	10.20^{a}
OKOMASA	68.04^{bcd}	87.2^{e}	14.88^{fgh}	38.93^{bcd}	2.88^{efg}	3.97^{d}
KOBN03-OB	74.40^{abcd}	113.4^{bcde}	38.10^{bcde}	33.27^{cd}	5.18^{bcdef}	3.77^{d}
NYAZ03-Y	59.91^{bcde}	95.6^{cde}	23.14^{efgh}	28.43^{cd}	3.16^{defg}	3.30^{d}
NYAZ04-W	76.83^{abcd}	106.2^{cde}	31.00^{cdef}	41.10^{bcd}	3.87^{cdefg}	4.50^{d}
GUMA03-OB	69.22^{abcd}	103.7^{cde}	30.99^{cdefg}	46.00^{bcd}	3.75^{cdefg}	4.37^{d}
GBRM04-BA	74.68^{abcd}	89.9^{de}	11.04^{gh}	38.77^{cd}	2.61^{fg}	4.03^{d}
TZE-Y-DT-STR-C4	63.07^{bcd}	99.6^{cde}	26.22^{defgh}	38.50^{cd}	3.69^{cdefg}	3.90^{d}
DORKE SR	73.03^{abcd}	107.5^{cde}	40.70^{bcde}	56.35^{bc}	5.70^{bcdef}	6.35^{bcd}
NYAN03	84.96^{abc}	118.47^{bc}	24.76^{efgh}	53.43^{bcd}	3.22^{defg}	5.53^{cd}
TZE-W-DT-STR-C4	67.61^{bcd}	109.0^{bcde}	33.12^{cdef}	68.20^{ab}	4.83^{bcdef}	7.95^{abc}
NYIA03	68.75^{bcd}	97.1^{cde}	47.16^{abc}	47.40^{bcd}	6.75^{abc}	4.63^{d}
NYLA04	86.09^{abc}	104.4^{cde}	33.36^{cdef}	43.47^{bcd}	5.31^{bcdef}	4.57^{d}
TAAN04	68.87^{bcd}	110.4^{bcde}	29.07^{cdefg}	25.67^{d}	4.08^{cdef}	3.40^{d}
NYSW03-Y	33.09^{e}	115.9^{bcd}	7.00^{h}	44.40^{bcd}	0.63^{g}	4.97^{cd}
DT-STR-W-C2	58.67^{cde}	100.8^{cde}	33.78^{cdef}	55.87^{bc}	4.11^{cdef}	6.07^{bcd}
SISF03-0B	97.57^{a}	100.1^{cde}	57.81^{ab}	45.60^{bcd}	9.12^{a}	4.60^{d}
KOBN04-R	83.14^{abc}	108.9^{bcde}	26.04^{defgh}	43.90^{bcd}	3.33^{defg}	4.03^{d}
TAIS03	72.56^{abcd}	108.4^{cde}	63.78^{a}	35.90^{cd}	7.83^{ab}	3.73^{d}
CHMA04	76.52^{abcd}	111.1^{bcde}	39.34^{bcde}	42.70^{bcd}	6.18^{abcde}	4.10^{d}
IWD-C3-SYN-F2	49.37^{de}	107.1^{cde}	40.05^{bcde}	29.00^{cd}	6.48^{abcd}	4.05^{d}
NYFA04	73.46^{abcd}	108.4^{cde}	27.68^{cdefg}	45.13^{bcd}	4.52^{bcdef}	3.90^{d}
GH120 DYF/D POP	48.93^{de}	92.0^{cde}	45.75^{abcd}	49.40^{bcd}	7.68^{ab}	4.75^{d}
NYFA03	79.58^{abc}	96.3^{cde}	32.00^{cdef}	35.80^{cd}	6.78^{abc}	4.93^{cd}
Mean	71.13	107.15	33.42	46.46	3.64	4.98
SEM	3.51	1.78	2.31	2.44	0.28	0.27

SEM: Standard error of mean; genotypes having the same letters (vertical direction) are not significantly different at 5% level of probability

The infested genotypes generally took lower number of days to reach anthesis than non-infested genotypes (Table 3). The control plots recorded the highest mean number of 59 days to anthesis, whilst the *Striga*-infested plot recorded the lowest mean number of 58 days to anthesis. There were in fact differences among infested genotypes with respect to number of days to anthesis. The genotype GBRM04-BA recorded the highest number of 67 days to anthesis, whilst TZE-Y-DT-STR-C4 and TZE-W-DT-STR-C4 recorded the lowest number of 53 days to anthesis among the *Striga*-infested treatments. A

similar observation was made with number of days to pollen shed (Table 3). The observed trend in flowering could be attributed to differences in the levels of *Striga* tolerance among the infested genotypes.

Table 3: Variation in plant height, days to anthesis and days to pollen shed of different maize genotypes as affected by *Striga* infestation during field screening in the 2013 cropping season

Genotype	Plant height		Days to 50% anthesis		Days to 50% pollen shed	
	Striga-infested	Normal	Striga-infested	Normal	Striga-infested	Normal
CHFB04-OB	149.13^{abcd}	159.27^{abcde}	58.33^{cde}	59.67^{cdefgh}	66.67^{bcd}	68.00^{abcd}
KPAS04	132.77^{bcdef}	145.87^{defgh}	58.00^{de}	60.00^{bcdefgh}	66.33^{cde}	68.33^{abc}
OKOMASA	131.10^{cdef}	135.33^{efghi}	61.67^{b}	64.00^{a}	66.67^{bcd}	70.67^{a}
KOBN03-OB	138.53^{abcdef}	153.57^{cdefg}	57.67^{def}	62.00^{abcde}	65.00^{defgh}	68.67^{abc}
NYAZ03-Y	147.83^{abcd}	162.37^{abcd}	57.67^{def}	60.33^{abcdefg}	65.00^{defgh}	69.00^{ab}
NYAZ04-W	149.73^{abc}	168.23^{abcd}	55.00^{fg}	57.00^{ghij}	66.00^{cdef}	63.00^{efgh}
GUMA03-OB	142.67^{abcde}	174.35^{abc}	59.67^{bcd}	61.67^{abcdef}	67.67^{bc}	70.00^{ab}
GBRM04-BA	152.53^{abc}	172.97^{abc}	67.00^{a}	62.33^{abcd}	71.67^{a}	69.67^{ab}
TZE-Y-DT-STR-C4	118.83^{f}	127.07^{hi}	53.00^{g}	55.00^{ijk}	61.67^{j}	59.33^{hi}
DORKE SR	138.40^{abcdef}	134.80^{fghi}	58.33^{cde}	59.00^{defgh}	66.00^{cdef}	69.00^{ab}
NYAN03	149.83^{abc}	168.93^{abcd}	58.33^{cde}	58.67^{defghi}	65.33^{cdefg}	67.67^{abcd}
TZE-W-DT-STR-C4	119.33^{f}	121.00^{i}	53.00^{g}	51.33^{k}	58.00^{k}	59.00^{i}
NYIA03	144.33^{abcde}	183.10^{a}	57.67^{def}	57.00^{ghij}	65.33^{g}	61.67^{fghi}
NYLA04	156.03^{ab}	165.10^{abcd}	61.00^{bc}	59.00^{defgh}	69.00^{b}	66.33^{bcde}
TAAN04	150.53^{abc}	181.37^{ab}	58.67^{cde}	58.00^{fghi}	65.33^{cdefg}	66.33^{bcde}
NYSW03-Y	131.43^{cdef}	169.23^{abcd}	53.00^{g}	54.00^{jk}	58.67^{k}	61.00^{ghi}
DT-STR-W-C2	129.53^{cdef}	129.67^{ghi}	57.00^{def}	63.67^{ab}	64.00^{efghij}	70.00^{ab}
SISF03-0B	130.63^{cdef}	157.90^{bcdef}	57.67^{def}	56.33^{hij}	65.00^{defgh}	63.00^{efgh}
KOBN04-R	132.10^{cdef}	165.50^{abcd}	56.67^{ef}	55.00^{jk}	63.67^{fghij}	64.33^{g}
TAIS03	150.03^{abc}	148.70^{defgh}	57.00^{def}	60.33^{abcdefg}	63.33^{ghij}	67.00^{abcd}
CHMA04	160.03^{a}	169.63^{abcd}	59.00^{bcde}	63.00^{abc}	67.00^{bcd}	69.67^{ab}
IWD-C3-SYN-F2	125.90^{def}	131.00^{ghi}	56.67^{ef}	58.33^{fghi}	62.33^{ij}	65.00^{cdef}
NYFA04	144.27^{abcde}	167.00^{abcd}	58.00^{de}	60.33^{abcdefg}	64.67^{defghi}	68.00^{abcd}
GH120 DYF/D POP	117.87^{f}	161.33^{abcd}	57.33^{def}	61.33^{abcdef}	62.67^{hij}	70.33^{a}
NYFA03	122.77^{f}	131.53^{ghi}	57.33^{def}	63.00^{abc}	65.33^{cdefg}	70.67^{a}
Mean	129.15	155.39	57.79	59.21	63.11	66.63
SEM	2.96	2.50	0.34	0.43	0.49	0.46

SEM: Standard error of mean; genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

The *Striga* infested genotypes generally recorded significantly ($P \leq 0.05$) higher anthesis-silking intervals than the non-infested genotypes (Table 4). The *Striga*-infested plot recorded the highest mean anthesis-silking interval of 8.83 days, whilst the normal trial recorded the least mean of 6.97 days (Table 4). The *Striga*-infested genotypes also significantly ($P \leq 0.05$) varied with respect to the trait. Among the *Striga*-infested treatments, NYAZ04-W recorded the highest anthesis-silking interval of 12.67 days, whilst NYSW03-Y recorded the least anthesis-silking interval of 6.00 days (Table 4). The variation of the anthesis-silking interval among various genotypes within the infested plot could be attributed to varied *Striga* tolerance levels among genotypes. Lu *et al*. (2010) stated that anthesis-silking interval is a trait used mostly in screening

genotypes for tolerance to stresses especially for drought and *Striga* resistance and that the lesser the gap between tasseling to silking in a genotype, the greater will be the probability of grain setting and grain yield. Kim *et al*. (2002) also recommended the use of *Striga* rating in assessing crop genotypes for tolerance to *Striga* infestation. The mean striga plant rating of the infested genotypes (Table 4) indicates that the genotypes TAIS03, IWD-C3-SYN-F2, TAAN04, TZE-W-DT-STR-C4, NYAN03, DORKE SR, GBRM04-BA and NYAZ04-W were rated 2 and therefore, have similar abilities to tolerate *Striga*. The rating of other genotypes ranged from 3 to 5. All genotypes that were rated lower are more tolerant to *Striga* than those with higher ratings. The high tolerance to *Striga* of some of the genotypes could be due to the development of necrotic areas at the *Striga* attachment sites on the maize roots. This is in consonance with the observation made by Ejeta *et al*. (2000) that the development of necrotic lesions on the root of maize causes poor development leading to the death of attached *Striga* on the host. The high tolerance to *Striga* of some of the genotypes may also be due to the low production of host plant root exudates and compounds that are essential for *Striga* seed germination.

Table 4: Variation in silking, anthesis-silking interval and striga plant rate of different maize genotypes as affected by *Striga* infestation during field screening in the 2013 cropping season

Genotype	Days to 50% silking		Anthesis-silking interval		Striga plant rating
	Striga-infested	Normal	Striga-infested	Normal	
CHFB04-OB	67.67^{de}	66.00^{cdefgh}	9.33^{cde}	6.33^{bcd}	2.67^{bcd}
KPAS04	67.67^{de}	67.00^{abcdef}	9.67^{bcd}	7.00^{bcd}	2.67^{bcd}
OKOMASA	72.00^{bc}	72.00^{a}	10.33^{abc}	8.00^{abc}	3.67^{a}
KOBN03-OB	67.00^{ef}	67.67^{abcdef}	9.33^{cde}	5.67^{bcd}	3.33^{ab}
NYAZ03-Y	66.33^{ef}	68.33^{abcde}	8.67^{cdef}	8.00^{abc}	3.67^{a}
NYAZ04-W	67.67^{de}	62.67^{fghij}	12.67^{a}	5.67^{bcd}	2.33^{cde}
GUMA03-OB	70.00^{cd}	70.00^{abc}	10.33^{abc}	8.33^{abc}	2.67^{bcd}
GBRM04-BA	75.00^{a}	70.00^{abc}	8.00^{cdef}	7.67^{abcd}	2.33^{cde}
TZE-Y-DT-STR-C4	61.67^{g}	58.33^{j}	8.67^{cdef}	4.00^{d}	2.67^{bcd}
DORKE SR	67.00^{ef}	70.00^{abc}	8.67^{cdef}	11.00^{a}	2.33^{cde}
NYAN03	67.00^{ef}	67.00^{abcdef}	8.67^{cdef}	8.33^{abc}	2.33^{cde}
TZE-W-DT-STR-C4	59.67^{g}	58.00^{j}	6.67^{ef}	6.67^{bcd}	2.33^{cde}
NYIA03	66.67^{ef}	61.00^{ij}	9.00^{cde}	6.00^{dbc}	3.33^{abcd}
NYLA04	73.33^{ab}	66.67^{bcdefg}	12.33^{ab}	7.67^{abcd}	2.67^{bcd}
TAAN04	67.33^{def}	66.67^{bcdefg}	8.67^{cdef}	8.67^{ab}	2.33^{cde}
NYSW03-Y	59.00^{g}	58.67^{ij}	6.00^{f}	4.67^{cd}	3.00^{abc}
DT-STR-W-C2	66.00^{ef}	71.67^{ab}	9.00^{cde}	8.00^{abc}	3.00^{abc}
SISF03-0B	66.67^{ef}	61.67^{ghij}	9.00^{cde}	5.33^{bcd}	3.33^{ab}
KOBN04-R	66.67^{ef}	63.67^{efghi}	10.00^{abcd}	8.67^{ab}	3.67^{a}
TAIS03	66.00^{ef}	67.33^{abcdef}	9.00^{cde}	7.00^{bcd}	2.00^{de}
CHMA04	68.33^{de}	70.00^{abc}	9.33^{cde}	7.00^{dbc}	3.00^{abc}
IWD-C3-SYN-F2	64.67^{ef}	64.00^{defgh}	8.00^{cdef}	5.67^{dbc}	1.67^{e}
NYFA04	67.00^{ef}	66.67^{bcdefg}	9.00^{cde}	6.33^{bcd}	3.00^{abc}
GH120 DYF/D POP	64.67^{f}	69.00^{abcd}	7.33^{def}	7.67^{abcd}	3.67^{a}
NYFA03	68.00^{de}	68.00^{abcde}	10.67^{abc}	5.00^{bcd}	3.33^{ab}
Mean	65.75	66.08	8.83	6.97	2.84
SEM	0.51	0.56	0.35	0.29	0.60

SEM: Standard error of mean; genotypes having the same letters (vertical direction) are not significantly different at the 5% level of probability

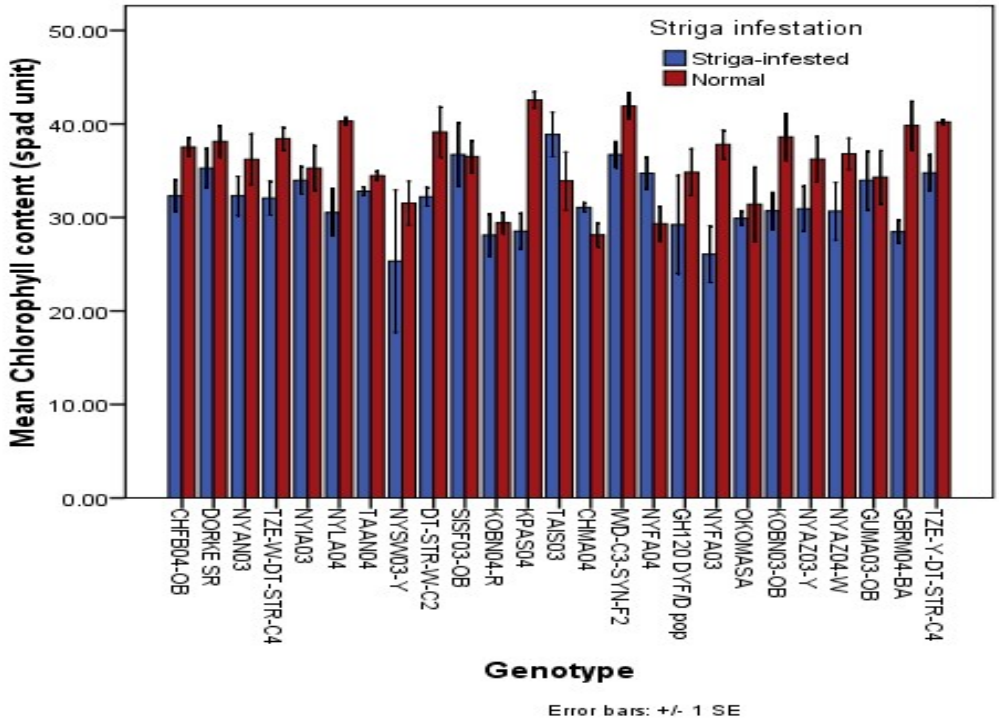

Figure 1: Changes in chlorophyll content of the genotypes during screening under greenhouse conditions in 2012

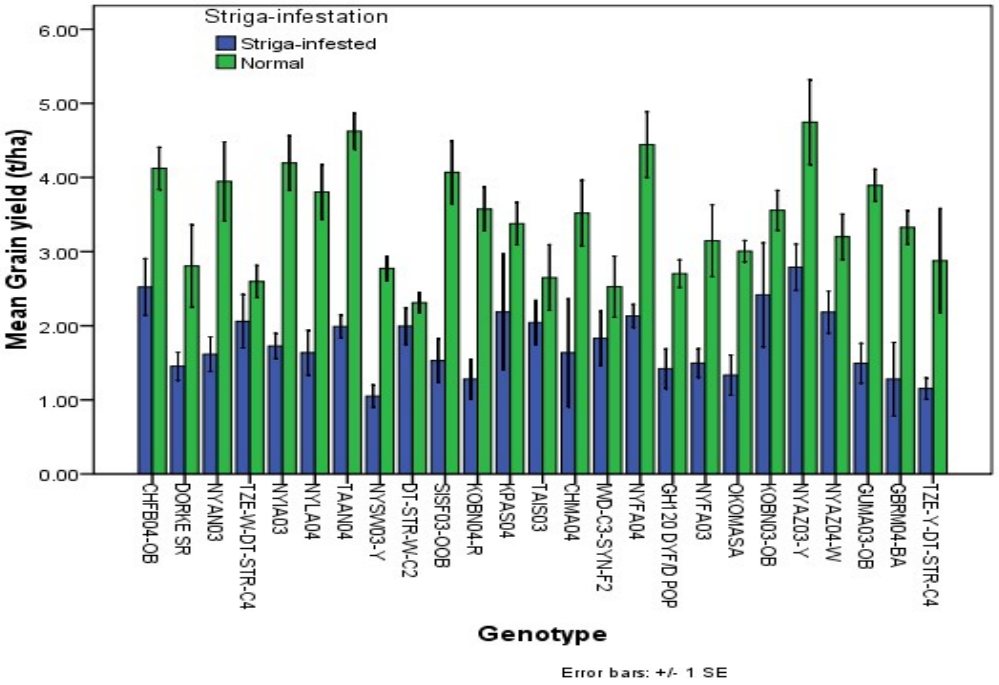

Figure 2: Changes in grain yield of the genotypes during screening in the 2013 cropping season

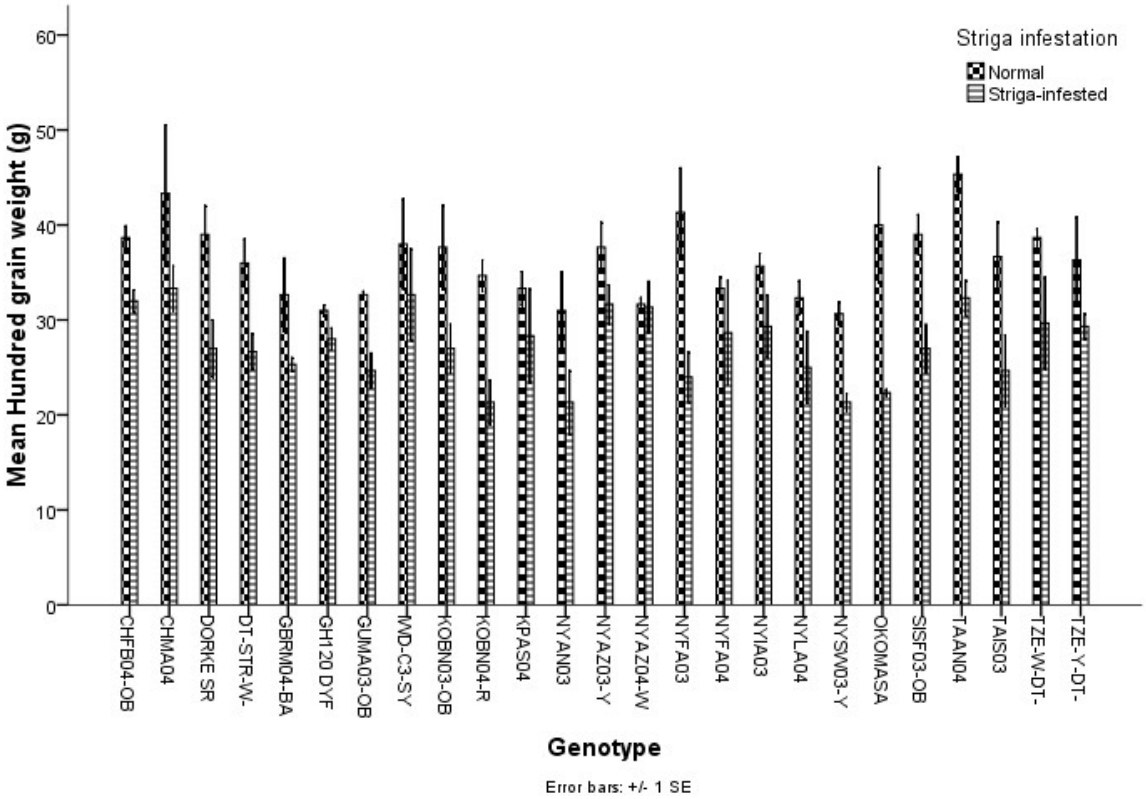

Figure 3: Change in hundred – grain weight of the genotypes during screening in 2013 cropping season

A clear impact of *Striga* infestation was observed on grain yield (Figure 2). There was a significant ($P < 0.05$) variation in grain yield between the control and striga infested treatments. The yields produced in the control trial (non-infested plots) were generally higher than those in the *Striga*-infested plots (Figure 2). The control plots recorded the highest mean grain yield of 3.41 tons/ha, whilst the *Striga*-infested plots recorded the lowest mean grain yield of 1.77 tons/ha. There was a statistical difference ($P < 0.05$) in grain yield among the *Striga*-infested genotypes. NYAZ03-Y recorded the highest grain yield of 2.80 tons/ha, whilst NYSW03-Y recorded the lowest of 1.04 tons/ha. In general, grain yield is determined by the levels of tolerance of the host genotype, by severity of infestation and/or by the levels of soil fertility. Kim *et al*. (2002) reported that tolerant varieties suffer lower yield reduction and often produce 2 - 2.5 times the yield of susceptible varieties, especially under high infestation. Okonkwo (1966) attributed grain yield losses due to *Striga* infestation to the diversion of photosynthates, mineral salts and water from the host to the parasite. Similarly, infested genotypes recorded lower values of 100 - grain weights than the non-infested genotypes (Figure 3). Ouattar *et al.* (1987) observed that *Striga* parasitism in maize plants decreased photosynthesis, and grain growth was more sensitive to infestation during endosperm cell division than during the period of starch deposition.

Conclusion

Genotypes TAIS03, IDW-C3-SYN-F2, SISF03-OB, NYIA03, CHFB04-OB and DT-STR-W-C2 produced the best results from the pot studies, with reference to number of leaves formed, shoot length, stem girth, leaf area,

chlorophyll content, fresh root biomass, dry root biomass, root length, fresh shoot biomass and dry shoot biomass. From the field studies, genotypes TAAN04, TAIS03, DT-STR-W-C2, NYAZ03-Y, IDW-C3-SYN-F2 and KOBN03-OB performed the best when screened using *Striga* plant rating, grain yield, number of ears harvested, hundred-grain weight, plant height, ear height, days to anthesis, days to pollen shed, days to silking and anthesis-silking interval. From the above results, therefore, the study has revealed that the cultivation of one or more of the following genotypes: TAIS03, DT-STR-W-C2 and IWD-C3-SYN-F2 or their crosses will give good yield on *Striga* infested land.

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