Genetic Gains from Selection for High Grain Yield and *Striga* Resistance in Early Maturing Maize Cultivars of Three Breeding Eras under *Striga* Infested and *Striga*-free Environments

IITA Research to Nourish Africa

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Introduction

The Savannas of West and Central Africa (WCA) have the potential to produce substantial market surpluses of maize for use in other agro-ecological zones and for export. However, maize production and productivity in the savannas is severly constrained by *Striga hemonthica* parasitism, drought and poor soil fertility, especially low soil nitrogen. *Striga* infestation can cause total crop loss and many maize farmers have been compelled to abandon their farmlands due to *Striga* which has defied control measures including hand pulling, crop rotation, trap and catch cropping, high rate of fertilizer application, fallow and seed treatment. Use of host plant resistance is the most economically feasible and sustainable approach for reducing the effects of the parasitic weed (Badu-Apraku and Akinwale, 2011). In recognition of the enormous potential of maize as a food and industrial crop, IITA established research programs to improve its productivity. Using inbreeding, hybridization and recurrent selection methods, a number of drought and low soil nitrogen tolerant and/or *Striga* resistant/tolerant early maturing cultivars have been developed for WCA during three breeding eras, 1988-2000, 2001–2006 and 2007–2010. Available maize varieties have contributed significantly to increased maize production and improved food security in the sub region. Despite the significant progress made, no studies have been conducted to document the genetic gains from selection for grain yield and *Striga* resistance in early maturing cultivars over the years. The objective of the present study was to assess the gains in improvement in grain yield of the cultivars developed in the IITA maize breeding program during the last three decades under *Striga*-infested and non-infested environments.

Materials and Methods

Fifty early-maturing cultivars were evaluated in 2010 and 2011 for grain yield and tolerance or resistance to *Striga* under artificial infestation with *S. hermonthica* at two locations each in the Republic of Benin and Nigeria. The evaluations in Nigeria were carried out at Mokwa and Abuja while Ina and Angaradebou were used in the Republic of Benin. Two rows of each entry were infested with seeds of *S. hermonthica* while the other two rows were *Striga*-free. A 10 x 5 lattice with three replications was used in all evaluations. The *Striga* infestation method developed by IITA Maize Program was used (Kim 1991). Data were recorded on both *Striga*-infested and *Striga*-free plots for grain yield and other important agronomic traits. In addition, host plant damage syndrome rating and number of emerged *Striga* plants were made at 8 and 10 weeks after planting (WAP) in the *Striga*-infested plots. *Striga* damage syndrome was scored per plot on a scale of 1–9 where 1= no damage, indicating normal plant growth and high resistance, and 9=complete collapse or death of the maize plant, i.e. highly susceptible (Kim 1991).

Analysis of variance was conducted for grain yield and other traits separately for the *Striga*-infested and *Striga*-free environments followed by a combined analysis across the two research environments. The yield data were also subjected to genotype main effect plus genotype × environment interaction (GGE) biplot analysis to obtain information on the superior cultivars under stress and non-stress environments and to investigate the stability of cultivars. The relationship between measured traits of maize cultivars and year of breeding (expressed as number of years since 1988) under *Striga*-infested and *Striga*-free conditions were determined using regression analysis.

Results and Discussion

Results revealed that E, Genotype (Era), Era, E × Genotype (Era), and E × Era interactions mean squares were significant for grain yield under both *Striga*-infested and *Striga*-free environments except E × Genotype (Era) and E × Era interactions when *Striga*-free (Table not presented). This suggested that there were large differences in environmental factors such as soil type, temperature, amount of rainfall and disease pressure at both test sites in Nigeria and Benin (Badu-Apraku et al., 2008). Under *Striga* infestation, grain yield ranged from 2537 kg ha^{-1} for cultivars bred during 1988–2000 to 3122 kg ha^{-1} for those developed during 2007–2010 (Table 1) with a corresponding genetic gain of 1.93% per year (Table 2). When *Striga*-free, grain yield ranged from 3646 kg ha^{-1} for cultivars bred during 1988–2000 to 4227 kg ha^{-1} for those developed during 2007–2010 (Table 1) with annual genetic gain of 1.0% (Table 2). The average rate of increase in grain yield was 41 kg ha^{-1} per year when *Striga*-infested and 34 kg ha^{-1} per year when *Striga*-free (Table 2). The increase in grain yield under *Striga* infestation was associated with significant decrease in the *Striga* damage rating and the number of emerged *Striga* plants at 8 and 10 WAP, improvement in ear aspect and increase in the number of ears per plant from old to modern era cultivars (Table 1). The *Striga* damage rating decreased from 3.3 to 2.9 for the old to modern era cultivars (Tables 1) with a genetic gain of -0.85% at 8WAP (Table 2). At 10WAP, the damage rating decreased from 4.6 to 4.1 for the old and modern era cultivars with genetic gain of -0.80%. For the number of emerged *Striga* plants, annual genetic gain of -0.63% for 8 WAP and -0.57% for 10 WAP were obtained for cultivars of the three breeding eras. The increase in annual genetic gains for the cultivars was 0.70% for EPP and -0.65% for ear aspect.

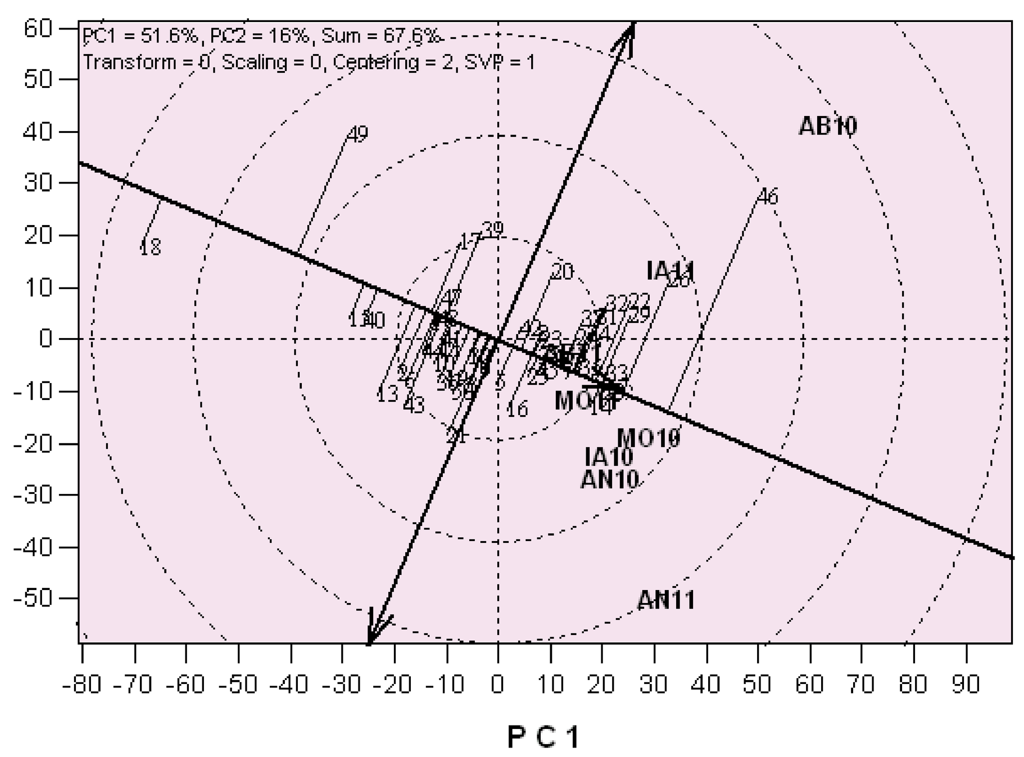
The GGE biplot analysis demonstrated that cultivars DTE-Y STR Syn C_1, EV DT-Y 2000 STR, and 2009 DTE-Y STR Syn were the highest yielding and the most stable across *Striga*-infested environments (Fig.1).

Table 1. Grain yield and other agronomic traits of maize cultivars of three breeding eras under *Striga*-infested and *Striga*-free conditions in Nigeria and Benin, 2010 and 2011.

Trait	Era	Number of cultivar	*Striga* infested	*Striga* free
Grain yield, kg ha^{-1}	1988-2000	15	2537 ± 74.6	3646 ± 98.3
	2001-2006	16	2697 ± 73.9	3770 ± 93.2
	2007-2010	19	3122 ± 65.1	4227 ± 87.5
Days to silking	1988-2000	15	56 ± 0.2	55 ± 0.1
	2001-2006	16	56 ± 0.1	55 ± 0.1
	2007-2010	19	56 ± 0.1	55 ± 0.1
Days to anthesis	1988-2000	15	54 ± 0.2	54 ± 0.1
	2001-2006	16	54 ± 0.1	54 ± 0.1
	2007-2010	19	54 ± 0.1	54 ± 0.1
Anthesis-silking interval	1988-2000	15	2.5 ± 0.09	1.9 ± 0.06
	2001-2006	16	2.6 ± 0.08	1.9 ± 0.05
	2007-2010	19	2.4 ± 0.06	1.8 ± 0.05
Plant height, cm	1988-2000	15	144 ± 1.0	159 ± 1.0
	2001-2006	16	148 ± 0.9	164 ± 0.9
	2007-2010	19	149 ± 0.9	165 ± 0.8
Striga rating at 8WAP	1988-2000	15	3.3 ± 0.08	-
	2001-2006	16	3.2 ± 0.07	-
	2007-2010	19	2.9 ± 0.06	-
Striga rating at 10WAP	1988-2000	15	4.6 ± 0.08	-
	2001-2006	16	4.5 ± 0.07	-
	2007-2010	19	4.1 ± 0.06	-
Striga count at 8WAP	1988-2000	15	19 ± 1.2	-
	2001-2006	16	20 ± 1.2	-
	2007-2010	19	20 ± 1.2	-
Striga count at 10WAP	1988-2000	15	27 ± 1.2	-
	2001-2006	16	29 ± 1.3	-
	2007-2010	19	27 ± 1.3	-
Plant aspect	1988-2000	15	-	3.0 ± 0.08
	2001-2006	16	-	2.8 ± 0.07
	2007-2010	19	-	2.8 ± 0.10
Stalk lodging, %	1988-2000	15	9 ± 0.8	2 ± 0.2
	2001-2006	16	9 ± 0.8	3 ± 0.3
	2007-2010	19	8 ± 0.7	2 ± 0.2
Ear aspect	1988-2000	15	4.2 ± 0.1	3.4 ± 0.07
	2001-2006	16	4.1 ± 0.1	3.2 ± 0.07
	2007-2010	19	3.8 ± 0.1	3.0 ± 0.06
Ears per plant	1988-2000	15	0.8 ± 0.01	0.9 ± 0.01
	2001-2006	16	0.8 ± 0.01	0.9 ± 0.01
	2007-2010	19	0.9 ± 0.01	0.9 ± 0.01

Table 2. Genetic gain and regression coefficients (b) of grain yield and other agronomic traits of maize cultivars under *Striga*-infested and *Striga*-free conditions.

Trait	Relative genetic gain (% per year)	R^2	a	b
Striga-infested environments				
Grain yield, kg ha^{-1}	1.93	0.262	2145.40	41.389
Days to anthesis	0.04	0.037	53.26	0.022
Days to silking	0.01	0.001	56.11	0.004
ASI	-0.64	0.066	2.85	-0.018
Plant height, cm				
Ear height, cm	0.21	0.098	140.49	0.289
Striga rating (8WAP)	-0.85	0.284	3.75	-0.032
Striga rating (10 WAP)	-0.80	0.336	5.07	-0.040
Striga count (8 WAP)	-0.63	0.032	22.28	-0.141
Striga count (10 WAP)	-0.57	0.035	30.83	-0.176
Ear aspect	-0.65	0.229	4.64	-0.030
Stalk lodging, %	-155.62	0.069	0.07	-0.108
EPP	0.78	0.334	0.73	0.006
Striga-free environments				
Grain yield, kg ha^{-1}	1.00	0.216	3373.50	33.901
Days to anthesis	0.06	0.106	52.99	0.034
Days to silking	0.05	0.053	54.98	0.025
ASI	-0.44	0.044	1.99	-0.009
Plant height, cm	0.20	0.123	157.84	0.316
Ear height, cm	0.24	0.082	72.03	0.170
Plant aspect	-0.17	0.009	3.10	-0.005
Husk cover	-0.28	0.104	2.91	-0.008
Ear aspect	-0.67	0.326	3.76	-0.025
Stalk lodging, %	-0.64	0.006	2.81	-0.018
EPP	0.22	0.132	0.90	0.002



Code	Environment
AB10	Abuja, *Striga*-infested 2010
AB11	Abuja, *Striga*-infested 2011
MO10	Mokwa, *Striga*-infested 2010
MO11	Mokwa, *Striga*-infested 2011
IA10	Ina, *Striga*-infested 2010
IA11	Ina, *Striga*-infested 2011
AN10	Angaredebou, *Striga*-infested 2010
AN11	Angaredebou, *Striga*-infested 2011

Code	Cultivars	Year of breeding
1	KAMB 88 Pool 16 DT	1988
2	EV DT 94 C2	1994
3	EV DT 97 STR C1	1997
4	EV DT-W 99 STR QPM	1999
5	EV DT-W 99 STR C0	1999
6	AC 94 Pool 16 DT STR	1994
7	TZE-W DT STR C4	2004
8	TZE-Y DT STR C4	2004
9	TZE Comp 3 DT C2 F2	2006
10	TZE COMP 3 x 4 F2	2000
11	TZE Comp3 DT C1F2	2004
12	TZE Comp 3 DT C3	2001
13	90 Pool 16 DT	1990
14	EV DT-Y 2000 STR	2000
15	EV DT-W 2000 STR C0	2000
16	TZE-W DT STR QPM C0	2004
17	TZE-W Pop x 1368 STR	2000
18	TZE-W Pop x 1368 STR QPM	2004
19	TZE-Y DT STR QPM C0	2004
20	EV DT-Y 2000 STR QPM	2004
21	EV DT-Y 2008 STR	2008
22	EV DT-W 2008 STR	2008
23	2008 DTMA-W STR	2008
24	2008 DTMA-Y STR	2008
25	2009 TZE-W Pop DT STR	2009
26	2009 TZE-Y Pop DT STR	2009
27	2009 DTE-W STR Syn	2009
28	2009 DTE-Y STR Syn	2009
29	TZE-W DT C2 STR	2010
30	TZE-Y DT C2 STR	2010
31	TZE-W DT C1 STR	2010
32	TZE-Y DT C1 STR	2010
33	DTE-Y STR Syn C1	2010
34	DTE-W STR Syn C1	2010
35	Syn DTE STR-Y	2010
36	Syn DTE STR-W	2010
37	DT-Y STR Synthetic	2010
38	DT-W STR Synthetic	2010
39	98 Syn WEC STR C0	1998
40	2000 Syn WEC	2000
41	BG 97 TZE COMP3 x 4	1997
42	TZE-Y Pop DT STR C2	2002
43	TZE-W Pop DT STR C0	2001
44	TZE-Y Pop DT STR C0	2001
45	2004 TZE-W Pop DT STR C4	2004
46	2004 TZE-Y Pop DT STR C4	2004
47	TZE-W Pop DT STR C3	2003
48	TZE-Y Pop DT STR C3	2003
49	99 Syn WEC	1999
50	Tillering Early DT	2007

Figure 1. The ‘mean vs. stability’ view of the GGE biplot based on a genotype x environment yield data for 50 early-maturing maize cultivars under *Striga* infestation at eight environments, 2010 and 2011.

Conclusions

Substantial progress has been made in breeding for high yielding, *Striga* resistant / tolerant cultivars during the past three decades. The outstanding *Striga* resistant cultivars, DTE-Y STR Syn C_1, EV DT-Y 2000 STR, and 2009 DTE-Y STR Syn should be extensively tested in WCA and promoted for adoption by farmers to contribute to food security in the sub region.

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