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Principal Component Analysis of Striga-Tolerant Maize Varieties

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Abstract: Ten Striga-tolerant maize (*Zea mays* L.) inbreds were evaluated in striga-endemic area of Temidire in 2001, 2002 and 2003. The evaluation was done under artificial and natural striga infestation conditions with the objective of identifying parameters that contribute to striga tolerance and grain yield via principal component analysis, correlation coefficients and character mean performance. Grain yields of the infested maize plots were slightly lower than those of non-infested maize plots, but not significantly different. Similarly, pairs of maize characters, such as ear harvest and ear aspect; striga syndrome rating and ear aspect; striga syndrome rating and plant height; and, grain yield and plant stand were highly and significantly correlated (r varied between 0.70 and 0.82). For the infested maize plants, the first 4 components (plant stand, plant height, plant harvest and ear harvest) accounted for 96.06% of the total variation, whereas these 4 components jointly contributed 95.34% under non-striga infestation. Selecting for these 4 important traits in breeding for striga tolerance and grain yield would be better than breeding for striga-resistant varieties *per se* because they return higher eigen values than the other parameters.

Key words: Breeding, principal component analysis, striga tolerant maize, correlation coefficient

INTRODUCTION

Principal Component Analysis (PCA) is one of the multivariate methods of analyzing relationships among several quantitative variables measured on many objects (Bailey, 1974). It involves mathematically transforming or reducing a number of correlated variables into a smaller number of uncorrelated variables. These uncorrelated variables are called principal components. The principal component analysis is concerned with explaining the variance-covariance structure through a few linear combinations of the original variables (Richard and Dean, 1998; Gomez and Gomez, 1981). It reveals relationships that were not previously suspected and thus allows interpretations that would not have been ordinarily made. Allan (1999) described principal component analysis as the earliest best-known descriptive technique. It explores the magnitudes of eigen values (which is analogous to variances) in explaining the correlations among various quantities (Sokal and Rohlf, 1969).

The objective of the Striga-Tolerant Maize (STM) varieties program is to develop maize varieties with resistance to striga infestation. Tolerance level of these STM varieties can be assessed via a number of parameters of emerging maize plants. Thus, the need to determine the parameters that are principally affected by the treatments cannot be over-emphasized. It is therefore, desirable to determine correlated maize agronomic parameters that contribute significantly to the overall variance for striga tolerance/resistance without losing vital information. The general objectives of this study were: To reduce the large number of agronomic parameters usually involved in selecting for STM varieties, To compare artificially infested and non-infested maize varieties and To identify underlying variables that contribute significantly to striga-resistant genotypes and higher grain yield in maize.

MATERIALS AND METHODS

Ten Striga-tolerant maize inbreds (0107-15, 0107-17, 0108-15, 0108-17, 0108-20, 0108-21, 0108-22, 5051, 5057 and 9450 as check) were collected from International Institute of Tropical Agriculture (IITA), Ibadan in 2000. They were evaluated in 2001, 2002 and 2003 cropping seasons at Temidire, Eruwa (a hot spot for *Striga lutea*; longitude 3°21'E and latitude 7°25'N). It is a Striga-endemic location in Southern Guinea savanna of Nigeria. The land used was a farmer's abandoned field due to Striga menace. The field was prepared by ploughing twice, harrowing and ridging. Fourteen days before planting, hills were inoculated with about 40,000 germinable seeds of previous year's striga inoculum. This was to allow the Striga inoculum to re-condition itself to the new

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environment. Striga seed extraction, inoculum preparation and application were according to the methods described by Berner *et al.* (1997). Planting was done on 4 -row plots (3×5m) by placing 2 seeds hill^{-1} at a spacing of 75×50 cm to obtain a population density of 55.333 ha^{-1}. The corresponding un-infested plots were planted directly opposite to the infested plots with an alley of about 1 m between them. Infested plots were those inoculated with Striga seeds artificially, whereas un-infested plots were not inoculated but could be naturally infested by Striga due to its presence in the soil.

The trial was a randomized complete block design with three replications. Herbicides were not used to allow good Striga survival. Weeds were carefully removed by hoeing. A low level of nitrogen fertilizer was applied (50 kg ha^{-1} of NPK 20-10-10) to minimize nitrogen suppression of Striga seedlings. The following data were collected from the two middle rows of each plot: Striga emergence count m^{-2} at 10 weeks after planting, Striga syndrome rating (using a scale 1-9) where 1 = normal growth, no visible symptoms, 2 = small and vague, purplish-brown leaf blotch, 3 = mild leaf blotching, with some purplish-brown necrotic spot, 4 = extensive blotching and mild wilting, slight but noticeable stunting and reduced ear and tassel size, 5 = extensive leaf blotching, wilting and some scorching, moderate stunting, ear and tassel reduction, 6 = extensive leaf scorching with mostly gray necrotic spots, some stunting and reduction in stem diameter, ear size and tassel size, 7 = definite leaf scorching, with gray necrotic spots and leaf wilting and rolling, severe stunting and reduction in stem diameter, ear size and tassel size, often causing stalk lodging, brittleness and husk opening late in the plant growth, 8 = definite leaf scorching with extensive gray necrotic spots, conspicuous stunting, leaf wilting, rolling, severe stalk, lodging and brittleness, reduction in stem diameter, ear size and tassel size, 9 = complete scorching of all leaves causing premature death or collapse of host plant and no ear formation (Kim, 1994). Data on plant establishment, stand, plant and ear heights (cm), ear harvest, ear a spect (using rating of 1-5, where 1 = excellent, 3 = fair and 5 = poor) and grain yield (t ha^{-1}) were recorded.

Data analysis: Data sets on plant stand, plant height, plant harvest, ear aspect, striga syndrome ating, striga plant count and grain yield were subjected to variance and correlation analysis. The correlation matrix was converted into principal components with the eigen vectors calculated from the correlation coefficient matrix. Also determined were the differences of each eigen value (D), which represented differences of each component from the subsequent component.

$$D = x_j - x_{j+k}$$

Where D = Difference of a component from the subsequent component x_j = position of the eigen values at point j and x_{j+1} = position of the eigen values at point j+1.

The proportion of total population variance was measured via the following relationship

$$= \frac{\lambda_k}{\lambda_1 + \lambda_2 + \lambda_3 \ldots\ldots \lambda_p}$$

$$k = 1,2\ldots,p,$$

Where λ_k = each eigen value and $\lambda_1+\lambda_2+\lambda_p$ = summation of all the selected eigen values.

RESULTS

Character mean performance: Character means for the parameters measured from the striga-infested/non-infested maize plants are presented in Table 1. Mean grain yield recorded was 287.45 per hactare. For the non-infested maize, mean yield was 381.44 per hectare. Plant stand, striga count and striga syndrome rating were higher for the infested plants compared with non-infested plants (Table 1). The analysis of variance for both striga and maize agronomic parameters are presented in Table 2. Years were highly significant ($p<0.01$) for all parameters except grain yield. Maize varieties were significantly different at $p<0.01$ for plant height, plant harvest and ear aspect. This variability should provide sources of desirable genes for plant breeders working to develop striga-tolerant maize. Striga treatments (infestation condition) were only significant for ear harvest, striga rating, striga count and grain yield. Variety by treatment interaction was only significant for ear aspect at $p<0.01$, (Table 2).

Correlation studies: Correlation coefficients (r) under the control (non-striga) treatment (Table 3) showed a positive and significantly close relationship between the following pairs of maize characters; plant stand vs. ear harvest; plant stand vs. plant harvest; plant harvest vs. ear harvest; as well as plant height vs. ear harvest. A moderate correlation existed between ear harvest and

Table 1: Descriptive statistics for both striga-infested and non-infested maize plants

	Infested			Non-infested		
	Mean	Std. dev.	Range	Mean	Std. dev.	Range
Plant stand	11.789	±4.11	7.78-16.00	11.76	±4.27	7.49-16.03
Plant height(cm)	128.167	±21.87	118.13-161.87	133.61	±22.96	110.65-156.57
Plant harvest	9.450	±5.18	3.71-14.07	9.722	±4.21	5.06-13.48
Ear aspect(1-5)	2.440	±1.12	0.88-3.12	2.778	±1.21	1.57-3.99
Ears harvested	5.350	±3.54	1.46-8.54	6.567	±3.89	2.68-10.46
Striga syndrome rating(1-5)	3.687	±1.375	1.18-3.93	3.006	±1.42	1.586-4.426
Striga count	14.00	±9.10	-1.77-16.43	0.94	±1.72	-0.78-2.66
Grain yield (kg^{-1}ha)	287.45	±232.74	33.93-499.41	381.44	±307.13	74.31-688.57

Table 2: Analysis of variance for the different parameter of striga tolerant maize

		F statistics							
Sources of variation	Degrees of freedom	Plant stand	Plant height	Plant harvest	Ear aspect	Ear harvest	Striga plant rating	Striga count	Grain yield
Years	2	4.85**	6.090**	21.30**	11.990**	22.940**	19.05**	19.610**	1.840
Reps	2	0.41	3.110*	0.610	2.460	6.110**	5.11**	0.360	3.450*
Variety (V)	9	1.230	2.630**	2.620**	2.660**	1.270	2.340*	1.870	0.580
Striga treatment (T)	1	0.000	2.540	0.220	1.160	5.900*	9.210**	69.42**	4.67*
Year*variety	18	1.250	1.820*	1.030	1.310	1.520	1.343	0.820	0.610
Year*treatment	2	0.444	0.160	1.020	0.11	0.260	7.880**	20.320**	0.030
Variety*treatment	9	0.740	0.210	1.260	3.580**	0.430	0.790	1.920*	0.280
Year*variety*treatment	18	0.22	0.160	0.49	0.560	0.490	1.340	0.850	0.333
Error	118								
Total	179								

Table 3: Correlation matrix for the different parameters for the striga infested and non infested maize plants

	Plant stand	Plant height	Plant harvest	Ear aspect	Ear harvest	Striga syndrome rating	Striga count	Grain yield
Plant stand	1							
Plant height	-0.33	1						
	(0.28)							
Plant harvest	0.59	-0.57*	1					
	(0.88**)	(0.31)						
Ear aspect	-0.08	0.53*	0.24	1				
	(0.21)	(0.51*)	(-0.20)					
Ear harvest	-0.32	0.20	0.29	0.82**	1			
	(0.86**)	(0.62**)	(0.76**)	(-0.17)				
Striga syndrome rating	-0.18	0.71**	-0.22	0.18**	0.64**	1		
	(0.17)	(-0.18)	(0.19)	(0.55*)	(0.00)			
String count	-0.22	0.30	-0.29	-0.10	-0.07	0.13	1	
	(0.25)	(-0.50*)	(0.18)	(-0.27)	(-0.45)	(-0.12)		
Grain yield	-0.03	0.28	0.21	0.50*	0.41	0.43	0.69*	1
	(0.34)	(0.37)	(0.19)	(-0.31)	(0.55*)	(-0.53*)	(0.32)	

*, ** Significant at $p<0.05$ and 0.01, respectively. Values in parenthesis are for the non infested maize plants

grain yield. However, striga count and certain other parameters were inversely related. Plant stand and ear harvest were the most prominent parameters in the correlation matrix.

As for the infested maize plants (Table 3), relatively high and positive correlations were detected for the following: Ear harvest vs. ear aspect (r = 0.82**); striga syndrome rating vs. ear aspect (r = 0.81**); striga syndrome rating vs. plant height (r = 0.71**); and grain yield vs. striga count (r = 0.70**). A moderate correlation coefficient (r = 0.59*) was obtained for plant stand vs. plant harvest (Table 3). Unlike the trend for the non-infested maize plants, inverse relationships were obtained between plant stand and all other parameters. Ear aspect and striga syndrome rating were however, the most important among closely related parameters under artificial striga infestation.

Principal component analysis: For the infested maize plants, the first four principal components (plant stand, plant height, plant harvest and ear harvest) accounted for 96.06% of the variation as compared with 95.34% of the variation for non-infested plants (Table 4). However, the fifth principal component for the infested varieties contributed slightly less (2.64%) to the variation as compared with non-infested maize plants (3.40%).

Table 4: Eigen value of the correlation matrix, the proportion and the total variance explained by the principal components for the infested maize plants

	Infested maize						Non infested maize					
Principal components	Eigen value	Percentage contribution to variance	Cumulative (%)	Difference	Proportion	Cumulative	Eigen value	Percentage contribution to variance	Cumulative (%)	Difference	Proportion	Cumulative
1	3.358	41.981	41.981	1.3	0.162	0.162	3.337	41.71	41.714	1.31	0.4171	0.4171
2	2.058	25.72	67.701	0.641	0.257	0.419	2.027	25.34	67.057	0.627	0.2534	0.6705
3	1.417	17.71	85.408	0.565	0.177	0.595	1.400	17.50	84.560	0.538	0.175	0.8455
4	0.852	10.66	96.063	0.635	0.106	0.701	0.862	10.78	95.335	0.59	0.108	0.9535
5	0.217	2.64	98.707	0.125	0.027	0.728	0.272	3.40	98.731	0.174	0.034	0.9875
6	0.092	1.15	99.857	0.0817	0.0115	0.7395	0.098	1.22	99.952	0.0942	0.0123	0.9998
7	0.0103	0.128	99.985	0.0091	0.0013	0.7408	0.0038	0.047	99.999	0.00369	0.0005	1.0003
8	0.0012	0.015	100.000	-	0.00015	0.74095	0.0001	0.0013	100.000	-	0.000014	1.000314

DISCUSSION

The results established that there existed an unequal relationship between the plant parameters (plant stand, plant height, plant harvest, ear harvest, ear aspect and grain yield). Different plant parameters are controlled by different genes for growth and development. While some of the parameters were positively correlated, others were inversely related. The inverse relationship obtained for the infested maize plants confirmed the adverse effects of striga infestation. Olakojo (2004) reported significant correlation coefficients of 0.86 and 0.88 for plant stand vs. striga rating at 10 weeks after planting and ear harvest vs. grain yield, respectively. Some pairs of traits showed a relationship even under artificial striga infestation. The first four components of the infested STM varieties confirmed their importance in breeding to develop striga-tolerant varieties. Maize parameters, such as plant stand, plant height, plant harvest and ear aspect, are important. These characters contributed equally to maize yield potential under infestation just as they did under non-infestation by striga. Also, the relatively high proportion of the first four components confirmed that selecting for these four plant characters was more important than breeding for striga tolerance *per se*. Selecting for all other maize parameters may not contribute significantly to yield and striga tolerance.

Farm areas that had been infested and devastated by Striga could be regarded as new environments for maize production. For such endemic ecology to be fully utilized, crossing of cultivars of maize from different provenances, such as adaptation, disease resistance, high yield and better utilization potential, were recommended by Brandolini and Brandolini (2004) to develop adaptable and striga-resistant maize populations. Assuming the measured dimensional variables is $\{X_i\}$ i = 1.8 while the principal components $\{Z_k\}$ k = 1.8. This can, therefore, be expressed as the linear combination as follows:

$$Z_k = a_1kX_1+a_2kX_2+....+a_8kX_8$$

Where a_i = principal components; X_i = the correlation matrix. This implies that if relationships between the emerging plant parameters are desirable, the variables that are suspected to give a stronger relationship are as mentioned earlier.

From this present study, eigen values of 0.75 and above are similar to those recommended by Jolliffe (1986). Invariably four important maize agronomic characters (plant stand, plant height, ear harvest and ear aspect) contributed significantly to the observed variations under artificial Striga infestation. In an earlier investigation, the use of principal component analysis revealed geographical diversification of the native maize landraces of Mexico (Yoshihiro *et al*., 2002). It is therefore recommended that selecting for characters with high eigen values especially for adaptation and grain yield could probably enhance striga tolerance and grain yield in maize more than selecting for striga-tolerant genotypes *per se*.

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