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Seasonal performance of cowpea (Vigna unguiculata) in humid tropics using GGE biplot analysis

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Summary

Season and location variations affect crop performance in the humid tropics where rainfall is characterized by bimodal pattern. Specific genotype selection based on seasonal performance relies on a thorough understanding of both stability of performance and yield capability in multi-environment trials (MET).This study presents a Genotype effect and a genotype by environment interaction effect using GGE biplot approach that facilitates visual analysis of genotype by season environment data. The high magnitude of 93% total variation in the Genotype (G) and genotype x environment interaction (GE), made the GGE biplot most appropriate in identifying discriminating genotypes. The biplot revealed the two late seasons of Ogbomoso and Abeokuta as most discriminating therefore removing one of the late seasons would not lead to any loss of information. The early season of Abeokuta was non-discriminating and cannot provide information on the genotypes. Owode and IT95k-1090-12 both from South Western Nigeria performed similarly and considered the best in the early season of Ogbomoso. Danilla,TVx-3236, IT90k-277-2 and AGIBVI gave average performance in the early and late seasons of Ogbomoso and Abeokuta environments. IT97k-499-2 was the winner genotype in early and late seasons of Ogbomoso as Owode and IT90k-1090-12 were found winners in the early season of Abeokuta

Key words: *Cowpea, early and late seasons, GxE interaction, GGE biplot, humidSavanna agro-ecology*

Introduction

Genotype evaluation and recommendation is an important aspect in plant breeding research. Accurate evaluation of both stability and high yield performance of crop genotypes across environments require multi-environment trials. The traditional analysis of genotype- environment interaction has focused on stability analysis rather than plasticity in genotypes. Numerous models for analyzing cultivar performance based on their consistency in response to environments have been developed (Lin and Binns 1994; Kang and Gauch 1996; Van Eeuwijk 1996). One of these models involves regressing genotype by environment matrix against environmental factors, genotypic traits or a combination of both (Cooper et al., 1997). A second model involves use of additive main effect and multiplicative model (AMMI). This model displays a structural variability that relates the genotypic and environmental scores derived from a principal component analysis of the genotype by environment interaction (GEI) matrix to genotypic and environmental covariates (Gauch 1996).

A recently released windows friendly soft ware package GGE Biplot,can be used to perform multi-environment trials (METS) and graphically display tester-entry relationship in target environment (Yan and Falk 2002). GGE biplot have been advanced to graphically address cultivar stability questions (Yan et al., 2000; Yan 2001). These questions include the which-one-where pattern, mega-environment investigation, mean performance and stability of genotypes, discriminating ability representativeness of environment,etc. GGE biplot is superior to AMMI model in that it removes the noise caused by the environment (E) and focuses on the genotype (G) and genotype by environment interaction. (GEI) components relevant in cultivar evaluation (Blanche et al., 2006). High yield in cowpea is obtainable in dryer agro-ecology than wet ecology as cowpea disease incidence is more traceable to hum id environment. However, varietal performance and stability even in the midst of such disease incidence differ from one genotype to the other and from one location to the other.

Given a two-way data genotypes tested in x environments, the yield response (y) of ith genotype in the jth environment can be explained as follows:

$$Yij = \mu + \alpha i + \beta j + \Phi ij + \Sigma jj \quad ....(1) \qquad (\varnothing\ \eta\eta\zeta\xi)$$

Where:

μ = grand mean
αi = genotype row main effect
βj = environment (column main effect
Φij = individual genotype by environment interaction
Σjj = error.

This two-way data model cannot be sufficiently approximated into graphical representation without decomposing the nth genotype and the xth environment two-way table (P). This table decomposition is achieved via singular value decomposition (SVD). Where P is decomposed into:

$$Pij = \sum_{i=1}^{r} \zeta ij\, \lambda\, \eta\, ij \quad ....(2)$$

And:

r = number of Principal Components (PC) representing the two-way table (P)
ζij = genotype vector
η ij = environmental vector.
λ = singular value.

Where data centering focus on cultivar evaluation in multi-environment trials (METs), the two-way table decomposed in equation 2 above merges with the yield response Y and equations 1 and 2 eventually translates into:

$$Pij = Yij - \mu - \beta j = \alpha i + \Phi ij \quad .... (3)$$

This equation contains both the genotype main effects and genotype- by environment (GE) interaction and called GGE biplot (Yan et al., 2000).It should be noted that all centering methods including genotype, environment and genotype-genotype or genotype- environment centered methods are built in GGE biplots. Where standardization (data scalling) and transformation options are inclusive, the GGE biplot is finally written as:

$$Pij = (Yij - \mu - \beta j)/sj = (\alpha i + \Phi ij/sj \quad .... (4)$$

Where Sj is a scaling factor and can be equal to 1. The other variables are as defined in the previous equations. Standardizations can be such that all columns are given equal weight (Yan, 2005).

A number of workers have demonstrated the effectiveness and convenience of GGE biplot as graphically addressing problems relevant to genotype evaluation in multi-environment trials (MET) (Yan 2001; Yan and Falk 2002; Yan and Kang 2003; Yan and Tinker 2005b).

This study therefore describes tester-entry relationship in two locations and two seasons of humid and Savanna agro-ecology of Nigeria

Materials and methods

Data Source

The eighteen (18) cowpea (Vigna unguiculata (L) walp) genotypes used were sourced from various locations in Nigeria (Table 1).

Yield data were collected from the teaching and research farms of the University of Agriculture Abeokuta (UNAAB) and Ladoke Akintola University of Technology (LAUTECH) Ogbomoso both in Savanna and Humid agro-ecology respectively. At each location a randomized complete block design was used with five-row plots replicated three times. Plot size was 3m by 3m and spaced 1m apart. The between and within row spacing was 60cm and 45cm. Two seeds were sown per hole to give a total of 70 plants per plot

Models for genotype- environment biplots.

Depending on research emphasis GGE biplots can be of different models. One model takes into account a genotype-centerd data, another, environment-centered data with the following equations:

$$Pij = (Yij - \mu - \alpha i = \beta j + \Phi ij \quad : \text{Genotype-centered}..........(5)$$

$$Pij = (Yij - \mu - \beta j = \alpha i + \Phi ij \quad : \text{Environment-centered}..........(6)$$

All variables are as defined in the previous equations.

All variables in this study focus on environment-centered data model and the data subjected to singular value partitioning (SVP). The resultant Principal components 1and 2 from the SVP are used to construct a GGE biplot. Other smaller principal components are regarded as residues and not explained.

Data analysis and interpretation

The yield data from the 18 cowpea genotypes were subjected to a recently used software package known as GGE biplot of Yan 2006

In the GGE biplot analyses, comparisons of stability and mean performance of each genotype in a target environment are graphically displayed

Graph interpretations in Environment centered and genotype centered GGE biplot

Table 1. Origin and source of Cowpea genotypes used in the study

GENOTYPE	GENOTYPE SOURCE ORIGIN
DANILLA	KADUNA NORTH WEST NIGERIA
IT97k-499-39	OYO STATE SOUTH WEST NIGERIA
IT90K-76	OYO STATE SOUTH WEST NIGERIA
IT95K-1091-3	OYO STATE SOUTH WESTE NIGERIA
TVX-3236	OYO STATE SOUTH WEST NIGERIA
IT93K-686-2	OYO STATE SOUTH WEST NIGERIA
IAR-48B	KADUNA SOURTH WEST NIGERIA
LDPD	KADUNA NORTH WEST NIGERIA
OWODE	OGUN STATE SOUTH WEST NIGERIA
IT95K-1090-12	OYO STATE SOUTH WEST NIGERIA
IT90K-277-2	OYO STATE SOUTH WEST NIGERIA
IFE-BROWN	OYO STATE SOUTH WEST NIGERIA
IT97K-508-2	OYO STATE SOUTH WEST NIGERIA
IT90K-59	OYO STATE SOUTH WEST NIGERIA
AGIB VI	OYO STATE SOUTH WEST NIGERIA
IT97k-1034-94	OYO STATE SOUTH WEST NIGERIA
MEDINO I	CAMEROUN SOUTH WEST PROVINLE
MEDINO II	CAMEROUN NORTH PROVINCE

Table 2. Average weather record of experimental site during the study year 2005

Location /season	Mean yield (Kg/ha)	Rainfall (mm)	Mean temp (+c)	Relative humidity	Co-ordination Latitude	Longitude
Ogbomoso Early E1	792.80	1075.08	28.01	89	04010E	08 10N
Ogbomoso Late E2	610.22	949.02	34.71	71	04o 10E	080 10N
Abeokuta Early E3	674.40	981.71	31.24	65	03o 24o	07o 20N
Abeokuta Late E4	507.44	737.39	37.53	43	03o 24E	07o24N

Table 3. Variance components of environment main effect (E), genotype main effect (G) and genotype x environment (GE) effect in the 2005 yield trials.

No of plants	Year	Location	Season	E	G	GE	E	G	GE
35	2005	Ogbomoso	Early E1	0.22	0.033	0.040	37.24	16.53	45.8
35	2005	Ogbomoso	Late E2	0.015	0.039	0.051	14.01	36.04	49.51
35	2005	Abeokuta	Early E3	0.030	0.015	0.041	34.68	17.44	47.72
35	2005	Abeokuta	Late E4	0.049	0.043	0.030	20.45	46.23	32.60

Table 3. Variance components of environment main effect (E), genotype main effect (G) and genotype x environment (GE) effect in the 2005 yield trials.

			Variance components			% of total variance			
No of plants	Year	Location	Season	E	G	GE	E	G	GE
35	2005	Ogbomoso	Early E1	0.22	0.033	0.040	37.24	16.53	45.8
35	2005	Ogbomoso	Late E2	0.015	0.039	0.051	14.01	36.04	49.51
35	2005	Abeokuta	Early E3	0.030	0.015	0.041	34.68	17.44	47.72
35	2005	Abeokuta	Late E4	0.049	0.043	0.030	20.45	46.23	32.60