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World Journal of Biological Research
Revue Mondiale de la Recherche Biologique

World Journal of Biological Research 001: 1

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

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Received 04 august 2007 /Accepted 20 September 2007/ published 27 February 2008

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:

$Yij = \mu + \alpha i + \beta j + \Phi ij + \Sigma jj$ ....(1) (Ø ηηζξ)

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:

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

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:

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

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

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

$Pij = (Yij - \mu - \beta j = \alpha i + \Phi ij$: 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

When the cosine of the angle between the vectors of two environments is in the same direction, it approximates a positive correlation between the environments. Where as, when the cosine of the angle runs in opposite direction or Further away, the environments are negatively correlated. If two environments are closely correlated, removing one of such would not lead to any loss of information. Contrarily, negative correlations among test environments are indications of strong crossover GE. Test environments that are consistently non-discriminating provide no information on the genotypes and therefore should not be used as test environments.

In Genotype-centered GGE biplot, the position of the average environment axis (AEA) determines the stability of the genotype. Genotypes located near the AEA are similar and have average performance across environments. Genotypes farther away from the AEA are said to be unstable with indications of GE interaction. Where genotypes are close to the single arrow line of the AEA, such are said to produce above average yield. Genotypes farthest away AEA arrow line, produce below average yield.

Genotypes at the vertex of a polygon explain the "which- one-where" of the GGE biplot and such genotypes are said to be winners in such environments (Yan 2002).

All biplots presented in this work generated using the GGE biplot software package developed and released by Weikai Yan (2006) during the GGE biplot analysis and Genotype by Environment Interaction Workshop at IITA Ibadan, Nigeria May 2006.

All data were column (genotype) centered.

Results

The magnitudes of Environment (E), Genotypes (G) and Genotype x Environment interaction (GE) variance components across the locations and seasons are used as indicators of the total variation due to each environment and season (Table 3). Variation due to G or GE is a measure of how the 18 genotypes respond across the four season environments. The environment component (E) measures how the cultivar means are different among the seasons. The high magnitude of GE interaction relative to G justifies the dominance of genotype x environment interaction in the genotypes response to specific location and season environments. In the four-season environments, GE accounted for the highest total variation in the early season of Ogbomoso. This is an indication that the response of the genotypes to early planting season is largely due to the interaction between the genotype and the environment. The GGE biplot explained 93% of the total yield variation due to G and GE (fig 1) this magnitude in the biplot variation guarantees the suitability of the GGE biplot in explaining the discriminating environment. Fig 2 shows relationship among testers. This relationship is based on environment centered (centering = 2) interaction table without scaling (scaling =0) and environment metric preserving (SVP=2) and explains 78% of the two-way table. This outcome can be understood from the peculiarities in seasonal interaction pattern with late seasons of Ogbomoso and Abeokuta (E2 and E4) being most discriminating.

Fig. 3 is the same GGE biplot except that it is Genotype metric preserving (SVP=1). The lines connecting the genotypes to the biplot origin measure genotype differences from the grand mean and genotypes with long vectors are either best or poorest performers in the environment. Genotypes near the biplot origin are said to show average performance.IT97k-499-39 (G2) IT95k-508-2 (G13) both from south western part of Oyo, Nigeria and Owode (G9) from Ogun, all in Nigeria, have long vectors and far away from the biplot origin. Danilla, TVx-3236, IT90k-277-2 and AGIBVI (G1, G5, G11and G15) are closely found near the biplot origin.IT97k-499-39 (G2) and Medino1 (G17)are distantly located on the biplot whereas, IT90k-76 (G2) and IT93k-686-2 (G6) are quite similar. Genotype evaluation based on average performance and stability across the season environments is detailed in Fig 4. The single-arrowed line known as average environment axis (AEA) points to higher average yield. Owode (G9) recorded the highest average yield followed by IT97k-499-39 (G2), IT95k-1090-12 (G10) both from South Western Nigeria and LDPD (G8) from North Western Nigeria. IT90k-277-2 (G11) and IT97k-1034-94 (G16) both from Southern zone of Nigeria had a mean yield similar to the grand mean while Medino1 (G17) had the least mean yield.

The double-arrowed line is the Average environment co-ordinates (AEC) and points to genotype variability. The greater the variability, the smaller the stability. The longer the AEC, the more the variability. IT90k-59 (G14) gave high AEC line thus very unstable. IT90k-277-2, Ife-brown, IT97k-508-2 and IAR48B (G11, G12, G13 and G7) are very stable with highly reduced or no AEA line, this indicates no variation. The best genotype for which environment is explained the in Fig 5. Winning genotypes for each environment are located on the vertex of the polygon. IT97k-499-39 (G2) from South Western Nigeria is the winner genotype in the early and late seasons of Ogbomoso and late season of Abeokuta (E1, E2 and E4). While Owode and IT95k-1090-12 are winner genotypes for early planting season of Abeokuta.

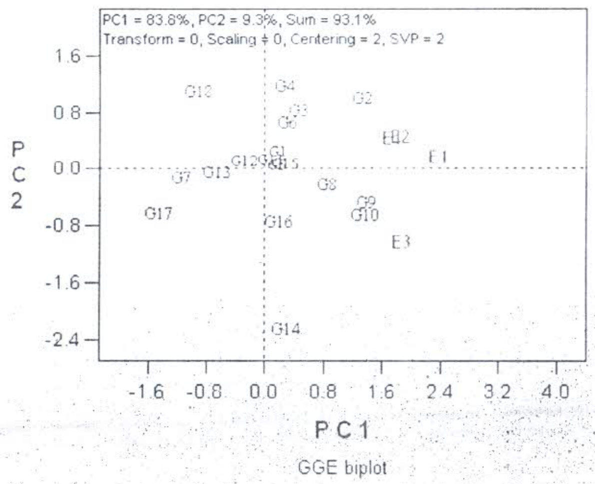

Figure 1:GGE biplot

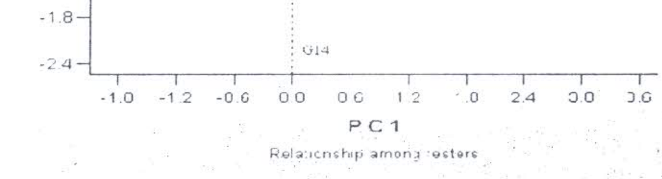

Figure 2: Showing relationship among testers

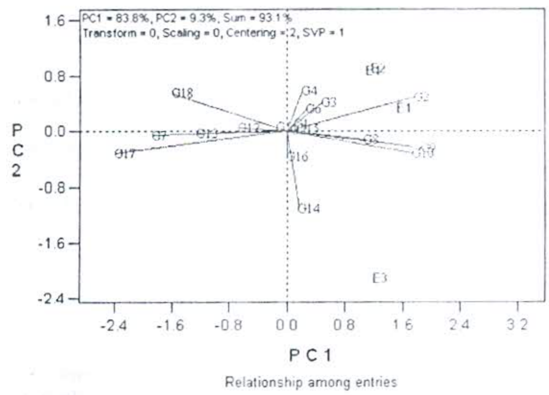

Figure 3. Showing relationship among entries

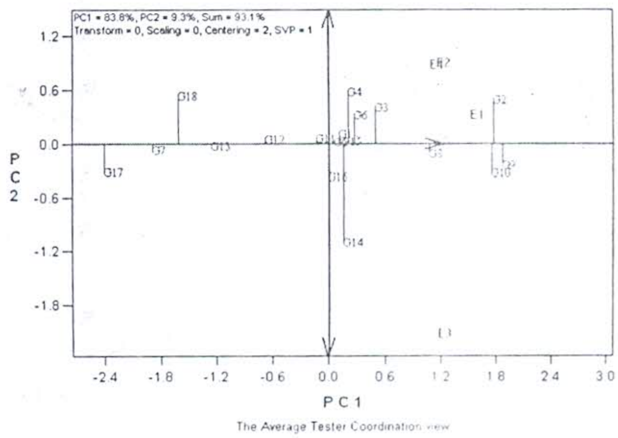

Fig. 4. Showing Average tester Coordination view

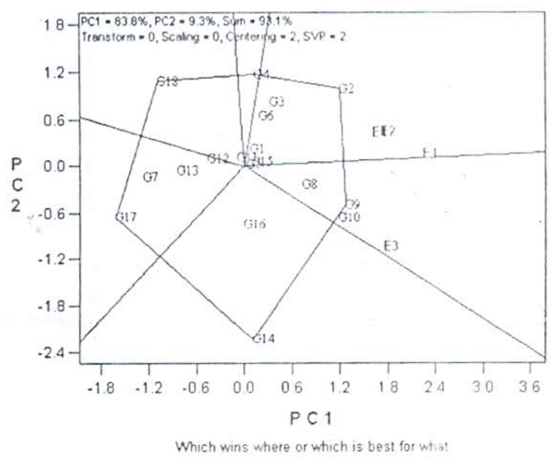

Fig. 5. Showing which genotype wins which environment

Discussion

The GGE concept is based on the understanding that genotypes main effect (G) and genotype by environment interaction (GEI) are the two sources of variation that are relevant to genotype evaluation and that they must be considered simultaneously, for appropriate genotype evaluation (Yan, 2005). Results of this study indicate that GE interactions are more likely to occur for some genotypes. Moreover, the GGE biplot explained very high percentage of the total yield variation in the environments and therefore the justification for the use of GGE biplot to identify discriminating genotype performance. That the two late seasons of Ogbomoso (E2) and Abeokuta (E4) are strongly correlated and most discriminating, imply that removing one of the late seasons would not lead to any loss of information. Yan (2005), reported positive correlation between two growing environments of wheat in Ontario. This outcome can be understood from the peculiarities of late seasons known for minimal rainfall distribution. Early season growing of cowpea in humid transition ecology of Abeokuta would not provide information on the genotypes especially for cowpea research purpose and therefore should not be used as test environments. Yan and Tinker (2005a) reported that test environments that are none discriminating provide no information on the genotypes and therefore should not be used as test environments.

Having a genotype metric preserving (SVP=1) biplot made the data most appropriate for genotype evaluation. Owode, (G9) IT95K-1090-12 (G10) and IT97k-499-39 (G2) all from south western Nigeria performed similarly and considered the best in the early season of Ogbomoso (E1) by recording the highest mean yield performance. It could imply that these genotypes require highly sufficient rainfall for optimum yield growth performance which of course was made available in the early season growth. Medino 1 (G17) and Medino II (G18) from southern and Eastern Province of Cameroon were the poorest performers and gave contrasting relationship with G9 and G10. According to Yan et al., (2005) the wider the distance between two genotypes the more the dissimilarity. The origin of a genotype affects the performance of such genotype in another test environment (Aremu, 2005). Therefore, the similarity between G9 and G10 from Southern West Nigeria confirms origin relationship. Better still, G9 and G18 from Nigeria and Cameroon respectively further explain variation in performance as a result of origin and location differences. This could be attributed to differences in weather and climatic conditions of the genotype origin Table1. For optimum yield performance, Danilla, Tvx3236, IT90k-277-2 and AGIBVI (G1, G5, G11andG15) located near the biplot origin are environment insensitive, and therefore, can be grown in any of the two seasons tested; location notwithstanding. According to Yan et al. (2000), the greater the variability in genotype performance, the smaller the stability. The double arrowed line revealed IT90k-59 (G14) to be most unstable where as LDPD (G8) was most stable in the test location season environments. This indicates that IT90k-59 can grow and produce high yield only in a specific environment whereas, LDPD can be adaptable to all seasons. However, the polygon identified most stable genotype for specific environment adaptation. Therefore, IT97k-499-39 (G2) which is chosen to specifically adapt to the late seasons of Ogbomoso and Abeokuta does not require high rainfall to produce high yield. This is because this specific season is characterized by low rainfall regime. Where as, Owode (G9) and IT95k-1090-12 (G10) are winners in the early season of Abeokuta and does not confirm any of the two as most adaptable.

This biplot analysis has revealed that low yield in cowpea genotypes in the guinea savanna agro-ecology can be improved upon by selecting specific genotypes for specific planting seasons so as to have high or optimal yield performance depending on choice of location-season environment.

References

Aremu, C.O, 2005. Diversity, Selection and Genotype x Environment Interaction in Cowpea Vigna unguiculata (L) Walp. Ph D Thesis, University of Agriculture, Abeokuta Nigeria. 131pp

Blanche, B. S., G. O. Myers, J. Z. Zumba, D. Caldwell, Hayes, J., 2006. Stability Comparisons between Conventional and Near-isogenic Transgenic Cotton Cultivars. The Journal of cotton Science (10) 17-28.

Cooper, M. S., R.E, Delacy, I. H., Harch B.D., 1997. Wheat Breeding nurseries, target environments and indirect selection for grain yield. Crop Sci. 37: 1168-1176.

Gauch, H.G, Zobel, R.W., 1996. AMMI Analysis of yield trials. In : M.S. Kang and H. Gauch. Genotype-by-environment interaction. CRC Boca Raton, Florida.

Kang, M. S., Gauch H.G., 1996. Genotype- by- environment interaction. CRC Press, Boca Raton, FL.

Lin, C.S., Bins M.R, 1994 Concepts and methods for analyzing regional trial data for cultivar and location selection. Plant Breeding Rev. 12: 271-279.

Van Eeuwijk, F.A. 1996. Between and beyond additivity and non-additivity: The statistical modeling of genotype by environment interaction in plant breeding. Ph.D. thesis. Wageningen Agricultural University, Wageningen, the Netherlands.

Yan , W. 2001. GGEbiplot-a Windows application for graphical analysis of multienvironment trial data. Agron J 94: 1396-1401.

Yan, W. 2002. Singular value partitioning for biplot analysis of multi-environment trial data. Agron J 94: 990-996.

Yan, W. 2005. Use of biplot analysis in crop Breeding. Proceeding of the Eastern Wheat Workers and Southern small Grain Workers Conference May 9-12, 2005 Bowling Green, Ky. (7-29).

Yan, W, L.A. Hunt, Sheng, Q., Szlavnics Z., 2000. Cultiver evaluation and mega-environment investigation based on GGEbiplot. Crop Sci. 40 (3): 597-605.

Yan, W., Falk, D.E., 2002. Biplot analysis of host by pathogen data. J. Plant Disease 86: 12. 1396-1401.

Yan, W., Kang, M. S, 2003. GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticist and Agronomists. CRC Press. Boca Raton, FL.

Yan, W, Tinker, N.A., 2005a. An Integrated system of biplot analysis for displaying, interpreting and exploring genotype-environment integrations. Crop Science 45 (3) 47-50.

Yan, W., Tinker N. A., 2005b. A biplot approach to the investigation of QTL- by-environment patterns. Molecular Breeding 15: 31-43.

Yan, W, A. Tinker, Falk, D., 2005. QTL identification, mega-environment classification and strategy development for marker-based selection using biplots. J. Crop Improvement 14 (1/2) 210-215.

Yan, W., 2006. A workshop on "GGE biplot Analysis and Genotype- by-Environment Interaction" at International Institute of Tropical Agricultre (IITA) Ibadan, 17th-18th may 2006.