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Stability Analysis for Seed Yield and Yield Components in Sesamum (*Sesamum indicum* L.)

P Jhansi Rani, P V Rama Kumar, J S V Samba Murthy and K V M Krishna Murthy
Department of Genetics and Plant Breeding, Agricultural College, Bapatla 522 101, Andhra Pradesh

ABSTRACT

Stability analysis for seed yield and yield components was studied using regression analysis and AMMI analysis for nine traits in ten sesamum genotypes over six environments sowing with three different dates of sowing each during *kharif* 2010 and *rabi* 2010-2011. The variance for genotypes and environments was significant indicating differences among the genotypes over environments. Both linear and non-linear components of GXE interaction were significant suggesting that genotypes interacted significantly with the environments. None of the genotypes was stable for all the characters, however the genotypes YLM 17 and YLM 78 were stable for seed yield per plant. The analysis of variance exhibited that all the three sources *i.e.*, genotype main effect, environmental additive effect, GXE interaction (non-additive effects) and IPCA 1 have significant effects for days to 50% flowering, number of seeds per capsule, 1000 seed weight and seed yield per plant. In AMMI 1 biplot, the genotype YLM 66 for days to 50% flowering, VZM 5 and YLM 66 for number of seeds per capsule, YLM 80 for 1000 seed weight and YLM 66 for seed yield per plant, were stable. In AMMI 2 biplot, the genotype YLM 66 for days to 50% flowering and number of seeds per capsule, YLM 17 for 1000 seed weight and seed yield per plant exhibited stable performance over environments.

Key words : AMMI, GXE interaction, Seed yield, Sesamum, Stability.

Sesame is one of the important oil seed crop. There has been large fluctuations in yield of this crop. One of the reasons seems to be the sensitive behaviour of varieties to different growing seasons/ conditions. Breeding varieties for different regions of predictable environmental conditions or identifying stable varieties over environments are the solutions to exploit the GXE interaction (Verma and Jay Lal Mahto, 1994). The ordinary analysis of variance is useful for identifying and testing sources of variability, it provides no insight into the particular pattern of the underlying interaction. The ordinary ANOVA model is additive and effectively describes the main (additive) effects, while the interaction (residual from the additive model) is non-additive and requires other techniques such as Principal Component Analysis (PCA) to identify interaction patterns. Thus ANOVA and PCA models combined to constitute the Additive Main effects and Multiplicative Interaction (AMMI) model (Gauch and Zobel, 1988). The differential response of genotypes to environmental changes for seed yield was evaluated in the present study by using both regression and AMMI models.

MATERIAL AND METHODS

The experimental material comprised of ten sesamum genotypes which were grown in a randomized block design with three replications during *kharif* 2010 and *rabi* 2010-2011 at Agricultural College Farm, Bapatla. Each plot consisted of 3 rows, of 3 m long with a crop geometry of 30 x 10 cm. Ten genotypes of sesamum were sown on 6 sowing dates 3 each in *kharif* and *rabi* thus providing 6 environments. Data were recorded on 9 characters *viz*., plant height, days to 50% flowering, number of primaries, number of secondaries, number of capsules per plant, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant. Stability parameters were analysed using regression model (Eberhart and Russell,1966) and AMMI model (Gauch, 1988). According to Eberhart and Russell (1966), the genotype with high mean, unit regression coefficient and non-significant deviation from regression were considered to be stable over environments. According to AMMI model, when one interaction PCA axis accounts for most of GXE, a feature of AMMI model is the biplot procedure in which genotypes and environments taking mean values on abscissa and IPCA scores on ordinate are plotted on the same diagram, facilitating inference about specific interactions as indicated by the sign and magnitude of IPCA values of individual genotypes and environments (Sharma *et al.*, 1988). The biplot of the first two IPCA axis demonstrates the relative magnitude of the G X E interaction for specific genotypes and environments. Since the G X E interaction effect is determined by the product of the correct PCA scores and be close to the center of the axis *i.e.*, they are stable across environments (Bahman Shafi *et al.*, 1992)

RESULTS AND DISCUSSION

The analysis of variance of pooled data (Table 1) showed highly significant mean sum of squares for genotypes and environments for most of the traits under study indicating the presence of substantial variation among the genotypes over environments. Significant G X E interaction indicated that genotypes under different environments behaved differently for the expression of characters of interest. It means a particular variety may not exhibit the same phenotypic performance under different environments or different varieties may respond differently to a specific environment (Sharathbabu *et al.*, 2008)

Environmental linear (Table 2) for plant height, days to 50% flowering, number of primaries, number of secondaries, number of capsules per plant, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant indicated the suitability of genotypes to these 9 characters in 6 different environments. The three parameters X, bi and S^2d together gave the idea of suitability of genotypes across environments (Eberhart and Russell, 1966). The genotypes were classified into three groups based on the stability parameters for all the traits at a time (Table 3). Considering the overall performance, the genotypes YLM 17 and YLM 66 showed superiority for maximum number of traits and ranked first and second, respectively, in seed yield per plant.

The combined analysis of variance (ANOVA) of ten genotypes in 6 environments pertaining to AMMI model is shown in Table 4. The IPCA scores of a genotype in the analysis are an indication of the stability of a genotype over environments.

AMMI analysis for days to 50% flowering showed that genotypes and environments were significant. The genotype, environment and genotype x environment interaction accounted for 30.72%, 47.22% and 22.06% of the total variation respectively indicating the G x E proportion is low in total sum of squares. The ANOVA table indicated that G x E interaction was partitioned into four interaction principal component axes (IPCAs). Only the IPCA 1 axis was significant and explained 46.91% of the total G x E interaction sum of squares percentage. The IPCA 2, IPCA 3 and IPCA 4 were explained 25.11%, 14.68% and 10.43% of the total G x E interaction sum of squares percentage and were non-significant. According to AMMI 1 biplot (Fig.1), genotypes 5 (YLM 66), 6 (YLM 82) and 4 (YLM 17) were identified as stable genotypes. In AMMI 2 biplot (Fig.2), the genotypes 5 (YLM 66) and 8 (VZM 5) were nearer to IPCA origin, hence these genotypes were stable over environments.

AMMI analysis for number of seeds per capsule showed that genotypes and environments were significant. The genotype, environment and genotype x environment interaction accounted for 16.95%, 65.84% and 17.21% of the total variation, respectively. The ANOVA table indicated that IPCA 1 and IPCA 2 were significant and were explained about 57.51% and 26.57% of the total G x E interaction sum of squares. The IPCA 3 and IPCA 4 explained 10.06% and 4.41% of the total G x E interaction and were non-significant. According to AMMI 1 biplot (Fig.3), genotypes 8 (VZM 5), 5 (YLM 66) and 7 (YLM 106) were identified as stable genotypes. In AMMI 2 biplot (Fig.4), the genotypes 5(YLM 66) and 3 (YLM-11) were nearer to IPCA origin, hence these genotypes were stable over environments. Among the environments, environment VI is most suitable as indicated by high mean value of IPCA 1 and low value of IPCA 2.

AMMI analysis for 1000- seed weight showed that genotypes and environments were significant. The genotype, environment and genotype x environment interaction accounted for 31.2%, 21.41% and 47.4% of the total variation respectively. The ANOVA table indicated that only the IPCA 1 was significant and explained 52.47% of total G x E interaction. The IPCA 2, IPCA 3 and IPCA 4 were explained 21.58%, 18.96% and 5.22% of the total G x E interaction and were non-significant. According to AMMI 1 biplot (Fig.5), genotype 10 (YLM 80) was identified as stable genotype. In AMMI 2 biplot (Fig.6), the genotypes 4 (YLM 17) and 9 (YLM 78)

Table 1. Analysis of variance (as per Eberhart and Russell, 1966) for stability performance of nine characters in sesamum

Source of variation	d.f.	Plant height	Days to 50% flowering	Number of primaries	Number of secondaries	Number of capsules per plant	Number of seeds per capsule	1000 seed weight	Oil content	Seed yield per plant
					Mean squares					
Genotype	9	227.589^{**+}	19.305**+	0.460^{**+}	0.699^{**+}	88.961**	159.446^{**+}	0.143**	19.158^{**+}	7.443**
Environment	5	520.849^{**+}	53.411^{**+}	0.925**	0.637^{**+}	798.758^{**+}	1114.581^{**+}	0.176**	37.380^{**+}	82.726^{**+}
Genotype × environment	45	40.59*	2.772*	0.197*	0.127*	32.528*	32.376*	0.043*	2.654*	2.072*
Environment (linear)	1	2604.244^{**+}	267.056^{**+}	4.626^{**+}	3.184^{**+}	3993.788^{**+}	5572.905^{**+}	0.881**	186.899^{**+}	413.631^{**+}
Genotype × environment (linear)	9	17.721*	4.283*	0.146*	0.213*	42.308*	37.508*	0.031*	3.931*	2.113*
Pooled deviation	40	41.682^{**+}	2.155^{**+}	0.189^{**+}	0.095^{**+}	27.075**	27.983^{**+}	0.042^{**+}	2.101**	1.855^{**+}
Pooled error	108	10.69	0.867	0.025	0.025	2.986	4.132	0.002	0.596	0.153

* Significant at 0.05 level }
** Significant at 0.01 level } When tested against pooled error

+ Significant at 0.01 level when tested against pooled deviation

Table 2 . Environment index values (I_j) of six environments for different characters (as per Eberhart and Russell, 1966) in sesamum

Character	Environmental index					
	E I	E II	E III	E IV	E V	E VI
1 .Plant height	-10.311	4.379	7.293	2.065	4.271	-7.697
2. Days to 50% flowering	-3.56	-1.272	3.380	0.123	0.880	0.447
3 .Number of primaries	-0.47	0.172	0.246	0.236	0.106	-0.291
4 .Number of secondaries	-0.073	-0.237	0.465	-0.07	0.083	-0.169
5. Number of capsules plant^{-1}	-11.993	-5.561	4.973	2.122	13.616	-3.157
6. Number of seeds capsule^{-1}	-13.198	-12.077	8.614	3.224	12.304	1.134
7.1000- seed weight	-0.183	-0.098	0.035	0.195	-0.021	0.072
8. Oil content	1.479	1.332	-0.866	2.158	-2.724	-1.379
9. Seed yield/plant	-3.543	-2.769	1.884	0.978	4.036	-0.586

Table 3. Sesamum genotypes classified into different adaptability groups to environmental conditions as per Eberhart and Russell (1966).

Character	Group I	Group II	Group III
Plant height	YLM 17, YLM 66	YLM 106	YLM 11
Days to 50% flowering	YLM 78	VZM 5, YLM 80	-
Number of primaries	-	Gouri	YLM 82
Number of secondaries	-	Gouri, VZM 5	-
Number of capsules per plant	-	Gouri,YLM 80	-
Number of seeds per capsule	YLM 11	YLM 82	YLM 66
1000- seed weight	-	Madhavi	YLM 82
Oil content	YLM 66	YLM 11	YLM 78
Seed yield per plant	YLM 17	-	Madhavi

Group I : Stable genotypes for average environmental conditions. Genotypes with high mean, regression coefficient near to unity and least deviation from regression

Group II : Stable genotypes for favourable conditions. Genotypes with high mean, regression coefficient significant and higher than unity and least deviation from regression

Group III : Stable genotypes for poor environmental conditions. Genotypes with high mean, less than unity regression and least deviation from regression.

Table 4. Analysis of variance of the AMMI model in sesamum.

Source	Days to 50% flowering			number of seeds capsule^{-1}			1000- seed weight			Seed yield plant^{-1}		
	df	MSS	% explained	df	MSS	% explained	df	MSS	% explained	df	MSS	% explained
Trials	59	9.58**	30.72	59	143.47**	16.95	59	0.069*	31.20	59	9.73**	
Genotypes	9	19.3**	47.22	9	159.44**	65.84	9	0.142**	21.41	9	7.44**	12.02
Environments	5	53.41**	22.06	5	1114.58**	17.21	5	0.176**	47.40	5	82.73**	72.08
G X E interaction	45	2.77	46.91	45	32.37	57.51	45	0.043	52.47	45	2.07	16.25
PCA I	13	4.5*	25.11	13	64.65**	26.57	13	0.078*	21.58	13	3.8*	53.06
PCA II	11	2.84	14.68	11	35.18*	10.06	11	0.038	18.96	11	2.02	23.90
PCA III	9	2.035	10.43	9	16.29	4.41	9	0.041	5.22	9	1.62	15.66
PCA IV	7	1.85	2.87	7	9.19	1.45	7	0.014	1.77	7	0.53	3.96
RESIDUAL	5	0.716		5	4.22		5	0.006		5	0.64	3.42
POOLED RESIDUAL	32	2.06		5	4.22		32	0.028		5	0.64	

* Significant at 0.05 level
** Significant at 0.01 level

MSS = Mean Sum of Squares
df = Degree of freedom

were nearer to IPCA origin, hence these genotypes were stable over environments. Among the environments, environment IV is most suitable as indicated by high mean value of IPCA 1 and low value of IPCA 2.

For seed yield per plant the analysis of variance exhibited that all the three sources *i.e.*, genotype main effect, environmental additive effect and G × E (non-additive) effects had significant effects and accounted for 12.02%, 72.08% and 16.25% of the total variance, respectively, indicating there by differential response of genotypes with the change of locations. The G × E interaction was significant and was further partitioned into AMMI components IPCA 1, IPCA 2, IPCA 3 and IPCA 4 with the contribution of 53.06%, 23.9%, 15.66% and 3.96%, respectively to the total G × E interaction variance. The first three AMMI components were significant and jointly contributed 92.62% of the interaction component.

In AMMI 1 biplot (Fig. 7), the genotypes, 5, 2, 10 and 4 (YLM 66, Madhavi, YLM 80 and YLM 17), were are stable because IPCA scores were near to zero with high mean. The genotype, 7 (YLM 106) and environment 6 had the same sign on IPCA axis, their interaction was positive i.e., this genotype was specifically adapted to this environment. In AMMI 2 biplot (Fig. 8), genotype 4 (YLM 17) is nearer to the IPCA origin hence genotypes is stable over environments for this trait. These results are in conformity with Manivannan and Ganesan (2001).

The results discussed in the present analysis confirm that AMMI analysis with its biplot is a very useful tool in analyzing data. AMMI partition the non linear interaction component of genotype with environment interaction and also helps in having deeper insight into study of environmental contribution to GXE interaction as reported by Zobel *et al*. (1988).

The genotypes YLM 17 and YLM 66 showed desirable performance for seed yield per plant using both regression and AMMI models.

Days to 50% flowering, number of seeds per capsule, 1000- seed weight and seed yield per plant expressed significant IPCA 1 score in AMMI analysis in interpreting stable genotypes compared to Eberhart and Russell (1966) model.

Fig.1. Biplot (AMMI 1) for days to 50% flowering

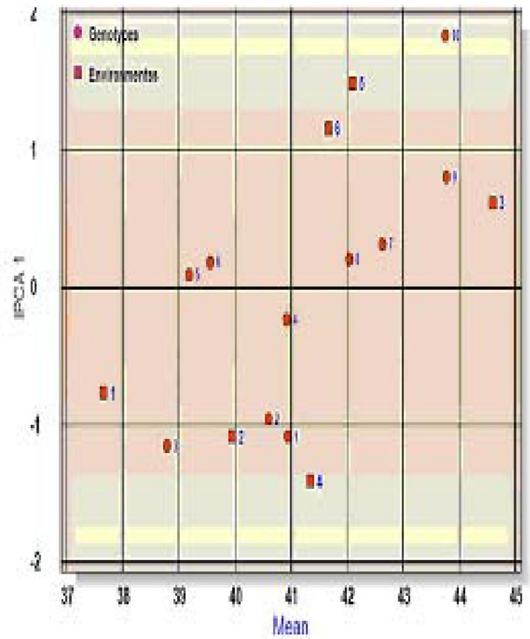
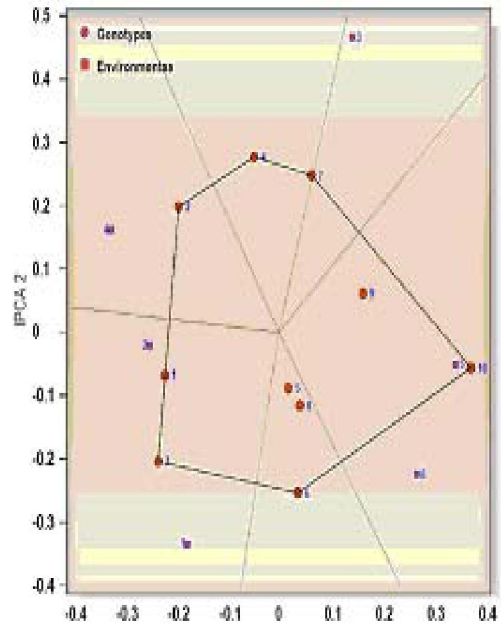


Fig.2 . Interaction Biplot (AMMI 2) for days to 50% flowering



.3 . Biplot (AMMI 1) for seeds per capsule

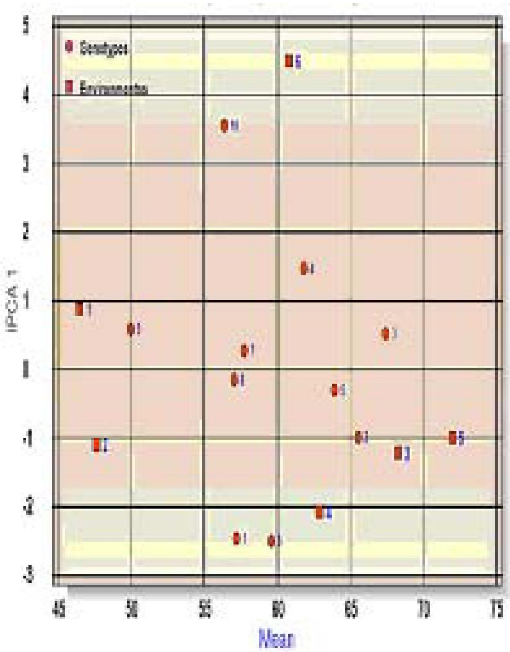
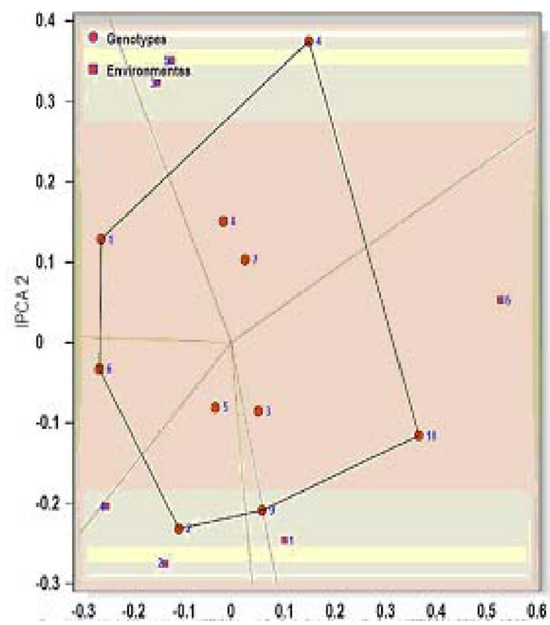


Fig.4. Interaction Biplot (AMMI 2) for seeds per capsule



GENOTYPES

1.Gouri	2.Madhavi	3. YLM 11	4. YLM 17	5. YLM 66
6 . YLM 82	7. YLM 106	8. VZM 5	9. YLM 78	10. YLM 80

Environments

Kharif	1. 17.07.2010	2. 2.08.2010	3. 17.09.2010
Rabi	4. 2.12.2010	5. 17.12.2010	6. 3.01.2011

Fig. 5 .Biplot (AMMI 1) for 1000- seed weight

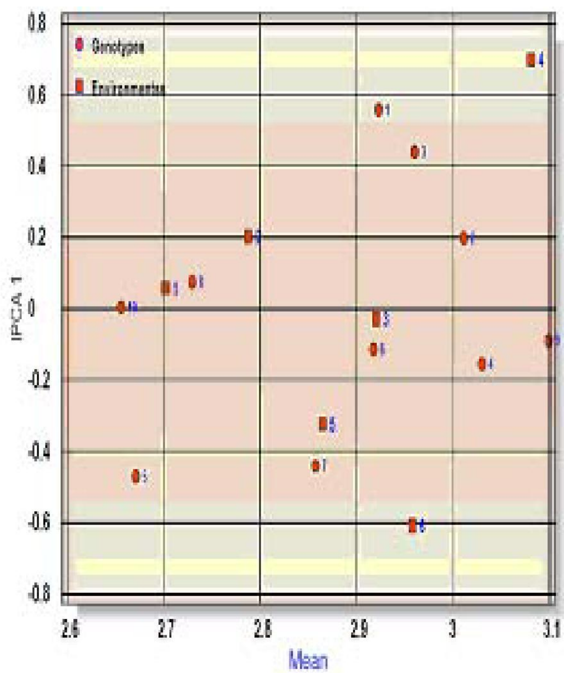


Fig.6 . Interaction Biplot (AMMI 2) for 1000 -seed weight

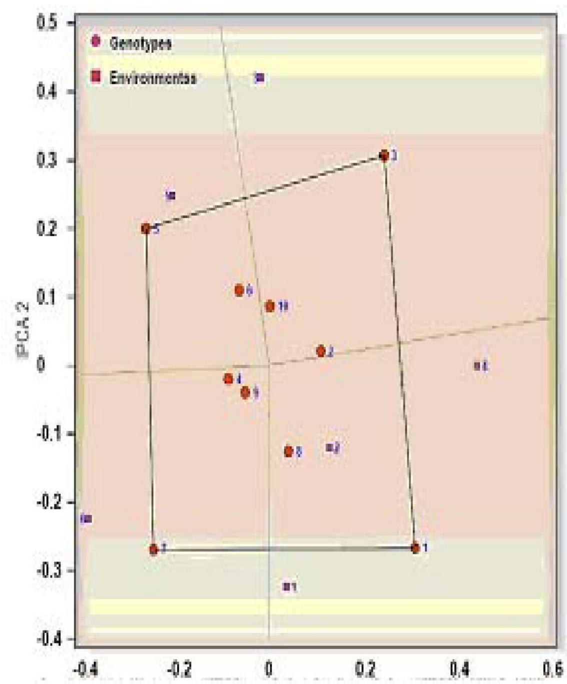


Fig. 7. Biplot (AMMI 1) for seed yield per plant

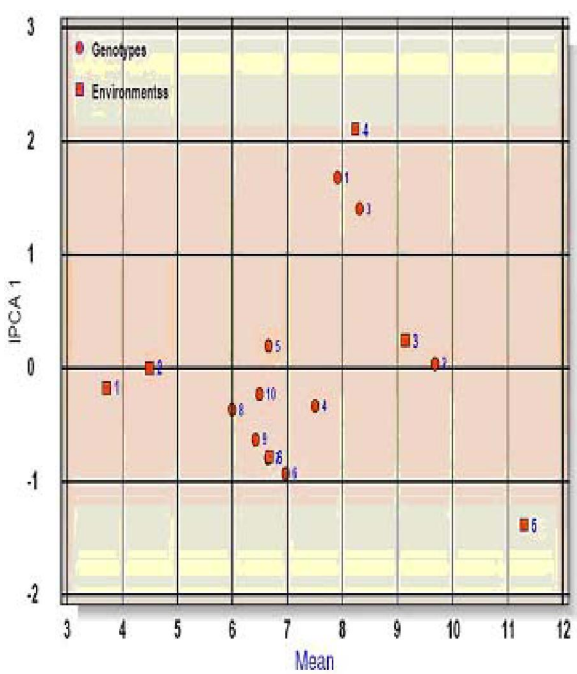
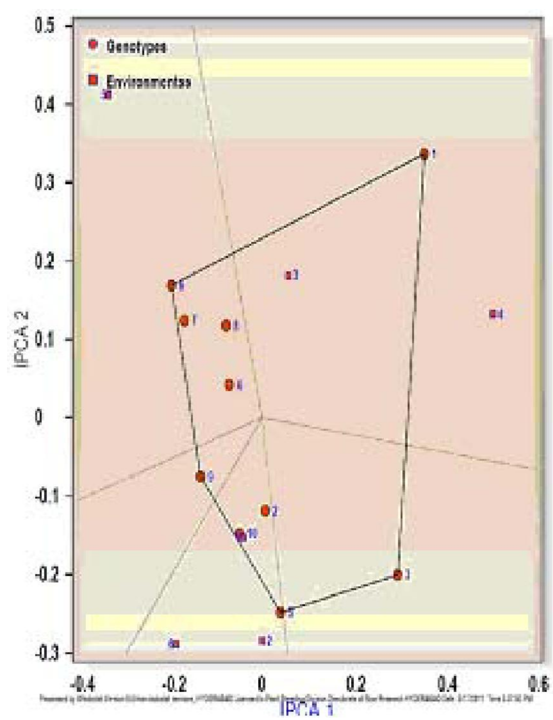


Fig.8 . Interaction Biplot (AMMI 2) for seed yield per plant



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