AMMI ANALYSIS IN RICE (*Oryza sativa* L.) GERMPLASM

ABSTRACT

Seventy genotypes of rice were evaluated under three seasons. Additive main effects and multiplicative interaction (AMMI) model was applied to ascertain extent of genotype × into season interaction (GSI) and also the stability of rice genotypes over three seasons. Significant difference was observed by AMMI analysis among the 70 genotypes as well as seasons. The sum of the first principal component accounted to 87.04% of the GSI. In the present inquiry, the genotypes *viz.,* G_{26} (484.45 mg), G_{17} (474.78 mg) and G_{31} (377.87 mg) registered with high mean per day productivity and coupled with higher PCA scores. The aforementioned genotypes are exclusively suitable for favourable seasons. The genotypes G_7 and G_{11}, were nearer to the center point axes. They were influenced with the seasons. These genotypes had maximum per day productivity as well as stability and hence suitable for different seasons.

Keywords: *Oryza sativa,* AMMI biplot, AMMI stability value.

INTRODUCTION

Rice is life for many of the Asians. Therefore, stability in per day productivity remains the prime factor for sustainable agriculture. The mean production is 172580 thousand tones in 2019-2020 and average yield of 3878 kg ha^{-1} in India (GOI, 2020).

The manifestation of any trait is the result of joint action of genotypes (G), Seasons and G×s interaction. Hence, it is imperative to inquire G×S interaction as well as stability and to evaluate the persistence of performance of the genotypes of interest. When the response of two genotypes of varying seasons are not consistent, then the play of G×S interaction is evident. A through understanding of G×S interactions and consistency in performance in rice crop gains paramount importance in rice breeding programme. G×E interactions are unveiled using univariate and multivariate analyses. Eberhart and Russel's (1966) univariate method, in which the *per se* performance of genotypes are seasonal index. It is extensively used because of its implicit nature. But, this statistics are associated with stability and show little or no correlation with yield. Multivariate analysis of G×E interaction is an important method for evaluating the consistency in performance (Crossa, 1990). Gauch's (1992) AMMI model is a popular modification of ANOVA for deciphering of G×E interaction.

The AMMI model combines ANOVA from main effects of the genotype and season with the principal components analysis of G×S interactions (Zobel *et al.,* 1988, Gauch and Zobel, 1996). AMMI model considers both yield and stability parameters simultaneously (Alwala *et al.,* 2010). Several AMMI parameters are being used for studying the consistency in performance of the genotypes over seasons. Purchase (2000) developed AMMI stability value (ASV) to quantity the genotypes based on their consistency.

MATERIALS AND METHODS

During 2020 and 2021, seventy rice genotypes were evaluated for three seasons the same location *viz.*, Navarai, *Kharif* and Navarai (Table 1). The trail was planted in Randomized Block Design (RBD) in two row plots of 3 m length, with a spacing of 20 cm between rows and 15 cm with the row. Each plot consisted of forty plants. Trials were conducted at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India (Latitude 11°23'31.4" N; longitude 79°42'53.09" E; MSL: 5 M). Observations were recorded on per day productivity by dividing seed yield per plant with days to maturity.

For genotypic per day productivity across seasons, prediction assessment was conducted using the AMMI method (Gabriel, 1978). AMMI stability value (ASV) was calculated for each genotype by the contribution of principal component axis scores (IPCA 1 and IPCA 2) to the interaction sum of squares. The AMMI stability value (ASV) was described by Purchase *et al.* (2000) as follows.

$$\text{ASV} = \sqrt{\left[\frac{\text{IPCA 1 sum of square}}{\text{IPCA 2 sum of square}}(\text{IPCA 1 score})\right]^2 + (\text{IPCA score})^2}$$

RESULTS AND DISCUSSION

Genotype, season, and GSI interactions were estimated by AMMI model and presented in Table 2. In the present inquiry, the ANOVA for rice per day productivity was significant for season, genotypes and genotype × environment interaction. G×S interaction was inferred by changes in the relative performance of genotypes over three seasons. The effects of season followed by genotype and G×S interaction

effects were responsible for the variation. The results of ANOVA for seventy genotypes indicated that the MS of the IPCA 1 was highly significant (P<0.001). The second IPCAs also resulted in significant variation. The differences could be highly benefaction by 87.04% and seasonal effects (9.36%), whereas the effects of genotype and seasonal interaction was very less (3.60) for the per day productivity in rice. When the IPCA 1 score was negligible it was pretended that rice was having a small and stable interaction.

The AMMI results also showed that IPCA 1 as well as IPCA 2 accounted that the interaction SS of 100 per cent. It implied that the first two IPCA were sufficient to explain genotype and environment interaction for per day productivity of rice genotypes. The IPCA 1 and IPCA 2 accounted for 77.8% and 22.2%, respectively and together benefaction of 100 per cent of the variability in rice per day productivity of the seventy genotypes tested at three seasons. Average per day productivity recorded 265.88 mg and 197.82 mg for season 2 and season 1, respectively (Table 3).

Amid the 70 genotypes, 31 genotypes were showed on the right side of the mid point of the perpendicular line and exhibited higher per day productivity. The mean per day productivity 227.21 mg. The per day productivity in their order to maximum were G_{11} (232.23 mg), G_{69} (230.07 mg), G_{23} (272.97 mg), G_{14} (345.43 mg), G_{17} (474.78 mg), G_{24} (270.83 mg), G_{20} (328.86 mg), G_{18} (280.51 mg), G_{4} (325.26 mg), G_{3} (260.65 mg), G_{2} (256.43 mg), G_{21} (266.89 mg), G_{60} (247.60 mg), G_{30} (321.10 mg), G_{26} (484.45 mg), G_{70} (354.10 mg), G_{19} (231.70 mg), G_{32} (280.35 mg), G_{58} (276.26 mg), G_{61} (318.64 mg), G_{49} (247.75 mg), G_{48} (268.69 mg), G_{22} (230.98 mg), G_{34} (285.43 mg), G_{15} (325.35 mg),

G_{16} (290.79 mg), G_{27} (303.28 mg), G_{64} (347.16 mg), G_1 (322.42 mg), G_{66} (347.48 mg) and G_{31} (377.87 mg).

Higher per day productivity was recorded as 484.45 mg (G_{26}) and the minimum as 108.46 mg (G_{56}) per day productivity. The seasons mean per day productivity ranged from 265.88 mg (Season 2) to 197.82 mg (Season 1) and the grand mean per day productivity was 227.21mg (Table 3).

The measuring of stability value quantitatively is called AMMI stability value (ASV), which was developed by Purcahse *et al.* (2000). The ranking of genotypes to rank genotypes through the AMMI model was considered to be the most appropriate single method of describing the stability genotypes. In Table 3 scores of IPCA 1 and IPCA 2 for each genotypes per day productivity and the corresponding AMMI stability value (ASV) which was calculated, and their ranks were presented.

The variety with the highest mean yield coupled with lowest ASV score is found to be the most stable (Rea *et al.*, 2017) and the breeder will find this method valuable in rice improvement programme. Acceding to this, the least ASV has higher per day productivity than the grand mean such as 0.75 (G_{67}), 0.77 (G_{14}), 1.56 (G_{33}) and 1.81 (G_{11}) were considered as the stale genotypes across all seasons, whereas the genotypes with ASV, 2.36 (G_6), 2.64 (G_{32}), 3.38 (G_{68}), 4.61 (G_{50}) and 5.00 (G_{46}) were suitable for the specific season even though they had higher per day productivity than the grand mean. The other genotypes were deemed unfit for any season because of their lower average yield, regardless of ASV rank, as a result, the most stable genotypes do not always provide the best yield, both in terms of daily output and ASV. Rice breeding programmes should take these factors into account at the same time.

Biplot analysis is the most powerful interpretative tool for the AMMI model. Biplots are plotted graphs that show the intercorrelations between genotypes and seasons. There are two basic AMMI biplots on the same axes (Vargas and Crossa, 2000), which plots main effects of per day productivity (genotype mean and season mean) and IPCA 1 scores for both genotypes and seasons against each other; the second, on the other hand, is AMMI which plots IPCA 1 and IPCA 2 scores. Many genotypes did not have consistent per day productivity performance during three seasons. The IPCA and the mean (Fig. 1) and IPCA 2, IPCA 1 (Fig. 2) biplots demonstrate the effect of each genotype and season. The X-coordinate indicated the consequence of the interaction (IPCA 1). IPCA 1 values were found closer to the axis center point suggested a lower level of interaction than those found further away.

The genotypes G_{11}, G_{69}, G_{23} and G_{14} exhibited the lowest positive interaction and the highest main effect, making them the most preferable for selection. As evidenced by their lower IPCA 1 score, the genotypes G_{68}, G_{46} and G_{29} showed a minimal negative interaction. Because these genotypes were less influenced by seasons, they considered to have high adaptability to different seasons.

As evidenced from Fig. 1 the genotypes plotted on the right-handed side of the grand mean level and close to PCA 1=0 line were identified as G_{11} and G_{23} and adapted to all seasons. Those genotypes G_{70}, G_{30} and G_6 with high mean yield and large IPCA 1 scores adapted specifically to the favourable season. Those genotypes stationed near the biplot origin showed more seasonal stability, whereas those genotypes stationed farther away showed greater instability and specific adaptability during the season (Kumar *et al.,* 2016).

Using IPCA 1 and IPCA 2 scores, AMMI biplots were constructed to show genotype stability as well as the amount of interactions between each genotype and season (Fig. 2). The genotype located far from the center point perceived the larger interaction effect and were found to be sensitive, but genotypes located near the origin were not sensitive to seasonal interaction. G_7 and G_{11} genotypes were discovered close the origin and so unaffected by season. These genotypes were stable genotypes with excellent per day productivity, making them suitable for cultivation throughout the seasons.

Per day productivity is a measurable trait which is likely to be influenced by environment. The aim of the rice breeder is to evolve new lines with high per day productivity and stable over seasons. To minimize the effect G and E interaction, both per day productivity and stability of genotypes should be considered simultaneously. The results of multi-location study across several years and seasons will be used to the genotypes for productivity and fitness. Those genotypes with higher productivity and a wider range of adaptation would be suggested for commercial cultivation and/or used as donors in further crop improvement programme.

CONCLUSION

Crop yield is a complicated attribute that is influenced directly or indirectly by a number of component traits as well as the environment. We could provide rice growers that most diverse stable heterotic hybrids it we could generate high yielding stable rice for a diverse conditions. The AMMI statistical model could be useful tool for the identifying the most suited and stable high yielding for distinct and diverse situations. The AMMI model revealed that environments accounted for the majority of the total variation in per day productivity in the present study. The majority of

genotypes showed seasonal specificity. The mean per day productivity values of genotypes *viz.*, G_{26}, G_{17} and G_{31} had the highest mean value of per day productivity. However, it is registered that the genotypes *viz.*, G_7 and G_{11} were endowed with higher per day productivity than all other genotypes as well as stable over the seasons.

REFERENCES

Alwala, S., K.T. Kwole, M. McPherson, J. Pellow and D. Meyer. 2010. A comprehensive comparison between Eberhart and Russell regression and GGE biplot analyses to identify stable and high yielding maize hybrids. *Field Crop Res.,* **119:** 225-230.

Crossa, J. 1990. Statistical analysis of multi-location trials. *Adv. Agron.,* **44:** 55-85.

Eberhart, S.A. and W.A. Russell. 1966. Stability parameters for comparing varieties. *Crop Sci.,* **6:** 36-40.

Gabriel, K.R. 1978. Analysis of morphological data by means of canonical decomposition and biplots. *J. Appl. Meterol.,* **12:** 1072-1077.

Gauch, H.G. 1992. Statistical analysis of regional yield trials: AMMI analysis of factorial designs. Elsevier, Amsterdam, The Netherlands. (Chinese ed., China National Rice Research Inst., Hangzhou, China, 2001.

Gauch, H.G. and R.W. Zobel. 1996. AMMI analyses of yield trials. M.S. Kang, H.G. Gauch (Eds.) Genotype by environment Interaction, CRC, Boca, Raton, Florida, pp. 85-122.

Kumar, V., A.S. Kharub, R.P.S. Verma and A. Verma. 2016. AMMI, GGE biplots and regression analysis to comprehensive the G×E interaction in multienvironment barley trials. *Indian J. Genet.,* **76:** 202-214.

Purchase, J.L., H. Hatting and C.S. Vanderenter. 2000. Genotype and environment interaction of winter wheat (*Triticum aestivum* L.) in South Africa: II stability analysis of yield performance. *South Africa J. Plant Soil,* **17:** 101-107.

Rea, R., S.V. Orlando, D. Alida, R. Miguel, R. Brileno, J. George and M. Nino. 2014. Variety environment interaction in sugarcane by AMMI and site regression models in Venezuela. *Rev. Fac. Agron.,* **31:** 326-376.

Varges, M., J. Crossa, F.A. Van Eeuwijk, K.S. Sayre and M.P. Reynolds. 2001. inter-putting treatment × environment interaction in agronomy trials. *Agr. J.,* **93:** 949-960.

Zobel, R.W. M.J. Wright and H.G. Gauch. 1998. Statistical analysis of a yield trial. *Agron. J.,* **80(3):** 388-393.

Table 1. Genotypes used in the present inquiry

Genotype No.	Name	Genotype No.	Name
G_1	Annanda	G_{36}	IC-0142508
G_2	Durga	G_{37}	IC-0123083
G_3	CR 1014	G_{38}	IC-0135529
G_4	Satyabhama	G_{39}	IC-0134873
G_5	CR dhan 204	G_{40}	IC-0207992
G_6	Phalguni	G_{41}	IC-0207955
G_7	CR dhan 203	G_{42}	IC-206447
G_8	CR dhan 305	G_{43}	IC-125757
G_9	CR dhan 601	G_{44}	IC-0514489
G_{10}	Kalinga III	G_{45}	IC-114312
G_{11}	Jalamani	G_{46}	IC-0627835
G_{12}	CR dhan 501	G_{47}	IC-0623213
G_{13}	CR dhan 101	G_{48}	IC-214312
G_{14}	CR dhan 202	G_{49}	IC-135191
G_{15}	CR dhan 310	G_{50}	IC-377869
G_{16}	CR dhan 408	G_{51}	IC-379136
G_{17}	CR dhan 307	G_{52}	IC-611162
G_{18}	CR dhan 303	G_{53}	IC-386231
G_{19}	Sumit	G_{54}	IC-ARC-11203
G_{20}	Tapaswini	G_{55}	IC-67725
G_{21}	Pooja	G_{56}	IC-264987
G_{22}	Vandana	G_{57}	IC-518987
G_{23}	Pyari	G_{58}	IC-ARC-7432
G_{24}	Improved Lalat	G_{59}	IC-ARC-10595
G_{25}	Gayatri	G_{60}	ADT 36
G_{26}	Samalei	G_{61}	ADT 37
G_{27}	Naveen	G_{62}	ADT 42
G_{28}	Anjali	G_{63}	ADT 43
G_{29}	Savala	G_{64}	ADT 45
G_{30}	CR dhan 701	G_{65}	ADT 48
G_{31}	Swarna Sub 1	G_{66}	ASD 16
G_{32}	IC-0098989	G_{67}	ADT 39
G_{33}	IC-0124198	G_{68}	CR 1009 (Sub 1)
G_{34}	IC-0135769	G_{69}	IC-0203398
G_{35}	IC-0123756	G_{70}	IC-0124570

Table 2. Mean squares and per cent variation explained by genotype (G), season (S) and G×S interaction for per day productivity

Sources	df	Sum sq	Mean sq	'F' value	Pr (<F)	Explained percentage
Env.	2	489402	244701	615.6909	1.140e-07***	9.36
Rep. (Env)	6	2835	397	0.8022	0.5686	-
Genotype	69	4551675	65966	133.1475	<2.2e-16***	87.04
Env:Gen	138	188062	1363	2.7506	2.874e-15***	3.60
Residuals	414	205111	495			-
PC 1	70	146303.07	2090.0438	4.22	0.0000	77.8
PC 2	68	41759.25	614.1066	1.24	0.1084	22.2

Significant Codes: 0.01 = * ; 001 = ** ; 0 = *** ; 0.1 = 1 ; 0.05 = ′

Table 3. Mean, AMMI stability value and genotype selection index X_{18}) Per day productivity (mg)

Genotype No.	Mean	IPCA 1	IPCA 2	ASI	RBSI	Rank
G_1	322.42	3.342	-1.731	30.58	72	67
G_2	256.43	-1.738	-0.698	15.68	70	46
G_3	260.65	-1.390	0.534	12.52	63	37
G_4	325.26	-1.225	0.081	10.81	45	35
G_5	144.24	-0.588	0.223	5.29	71	10
G_6	117.48	0.011	0.501	2.36	73	5
G_7	219.67	0.974	0.177	8.63	60	28
G_8	150.87	-0.229	1.679	8.17	87	24
G_9	203.37	2.138	-0.436	18.97	89	55
G_{10}	142.49	-1.442	-0.568	13.00	100	38
G_{11}	232.23	-0.199	0.094	1.81	35	4
G_{12}	143.31	-0.675	-0.139	5.99	74	15
G_{13}	196.86	1.846	0.725	16.64	88	50
G_{14}	345.43	-0.088	0.010	0.77	9	2
G_{15}	325.35	1.604	-3.225	20.76	61	57
G_{16}	290.79	2.516	-3.166	26.74	72	64
G_{17}	474.78	0.172	-1.749	8.38	26	25
G_{18}	280.51	-1.387	-1.003	13.12	58	39
G_{19}	231.70	0.378	-1.668	8.54	54	27
G_{20}	328.36	-0.918	-0.018	8.09	32	23
G_{21}	266.99	-1.712	-0.957	15.76	70	48
G_{22}	230.98	2.240	-0.756	20.07	81	56
G_{23}	272.97	-0.456	0.854	5.69	35	12
G_{24}	270.83	-0.923	-0.441	8.40	47	26
G_{25}	131.83	-1.753	-0.576	15.69	111	47
G_{26}	484.45	-1.626	-0.241	14.39	45	43
G_{27}	303.28	2.649	1.014	23.85	75	61
G_{28}	219.93	-5.996	-1.874	53.62	107	70
G_{29}	211.85	-1.582	-0.862	14.53	79	44
G_{30}	321.10	-1.926	-0.336	17.06	63	57
G_{31}	377.87	3.580	-0.503	31.66	71	68
G_{32}	280.35	0.292	-0.126	2.64	24	06
G_{33}	175.27	0.097	0.278	1.56	51	3
G_{34}	285.43	1.935	0.477	17.21	69	53
G_{35}	207.60	2.750	1.592	25.39	98	62
G_{36}	193.90	-1.046	-0.065	9.23	72	30
G_{37}	162.37	-1.851	-1.748	18.29	103	54

Table Contd…

Genotype No.	Mean	IPCA 1	IPCA 2	ASI	RBSI	Rank
G_{38}	164.85	-0.804	0.799	8.03	77	22
G_{39}	177.41	0.859	-0.327	7.73	65	21
G_{40}	140.57	2.368	1.735	22.43	119	59
G_{41}	168.36	-0.468	0.980	6.19	69	17
G_{42}	181.03	-2.856	-1.481	26.14	110	63
G_{43}	152.56	1.103	-0.816	10.46	84	34
G_{44}	150.49	2.387	1.802	22.70	117	60
G_{45}	141.58	-0.514	2.802	13.96	108	41
G_{46}	199.41	-0.541	-0.320	5.00	49	09
G_{47}	126.25	-1.070	-0.482	9.71	97	31
G_{48}	268.89	1.561	-1.757	16.07	66	49
G_{49}	247.75	1.410	1.376	14.02	70	42
G_{50}	180.89	0.520	0.107	4.61	53	08
G_{51}	154.41	-0.655	-0.683	6.61	71	18
G_{52}	138.28	1.120	0.138	9.90	90	32
G_{53}	179.53	1.270	-1.146	12.44	77	36
G_{54}	141.43	3.162	0.310	27.93	120	66
G_{55}	153.16	-0.825	-0.353	7.46	76	20
G_{56}	108.46	-0.668	-0.345	6.11	86	16
G_{57}	192.04	-1.916	-0.577	17.12	95	52
G_{58}	276.26	0.644	-0.078	5.69	33	12
G_{59}	154.70	0.785	0.113	6.95	70	19
G_{60}	247.60	0.605	1.573	9.13	58	29
G_{61}	318.64	0.592	0.526	5.78	25	14
G_{62}	206.18	-0.679	3.054	15.59	91	45
G_{63}	141.48	-1.470	0.938	13.70	105	40
G_{64}	347.16	2.398	1.162	21.85	64	58
G_{65}	216.37	1.177	0.252	10.45	66	33
G_{66}	347.48	-1.878	4.706	27.68	80	65
G_{67}	108.85	0.058	0.116	0.75	70	01
G_{68}	199.56	-0.327	-0.374	3.38	46	07
G_{69}	230.07	-0.133	-1.100	5.32	41	11
G_{70}	354.10	-4.989	1.996	45.00	82	69

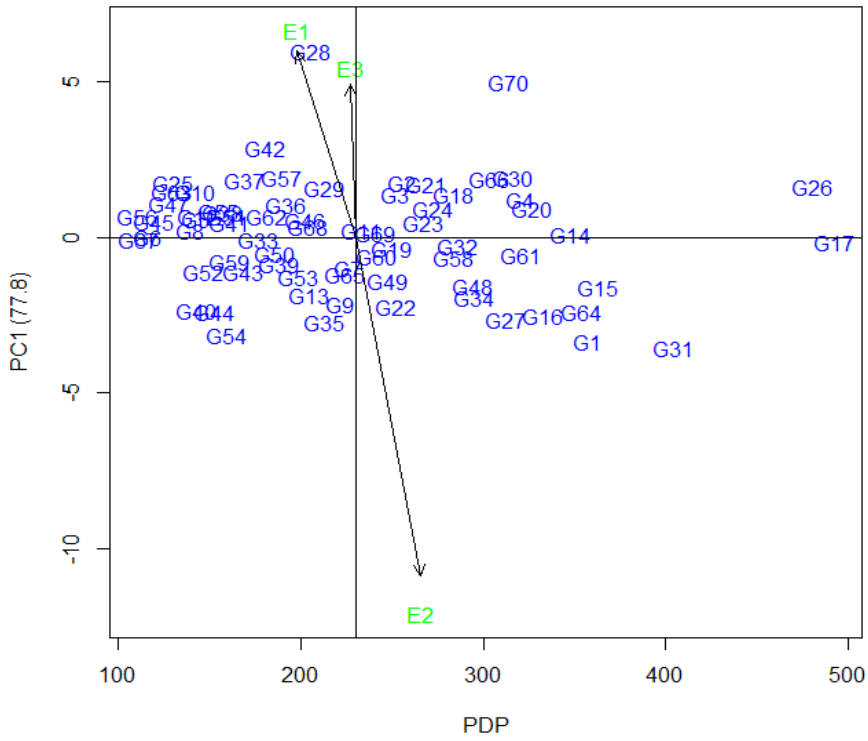

Fig. 1. AMMI I biplot showing main effects and ICAP1 interaction effects of 70 rice genotypes and three seasons on Per day productivity

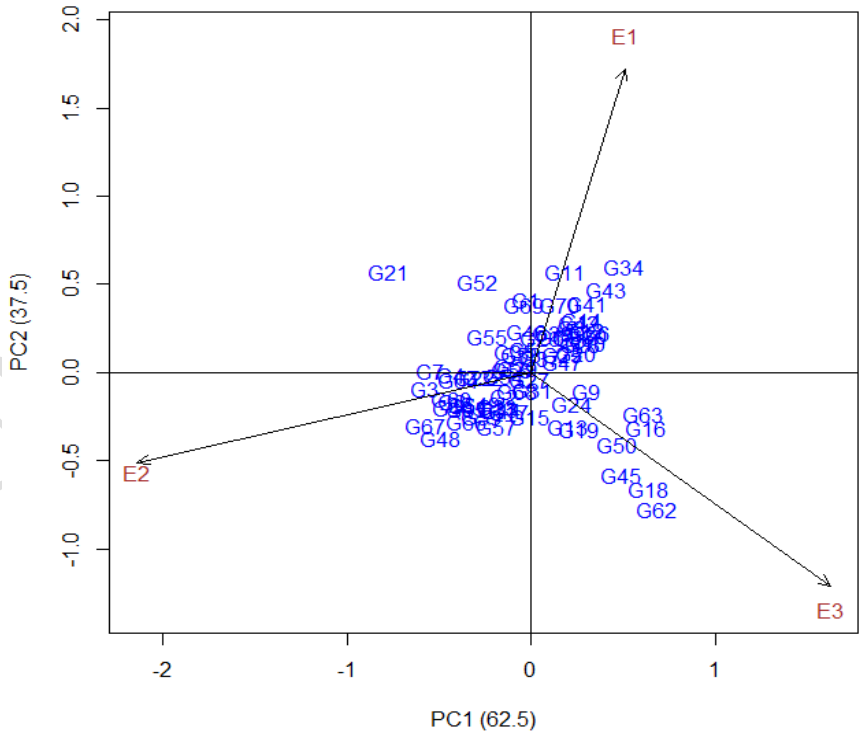

Fig. 2. AMMI II biplot of first two principal components (IPCA 1 *vs* IPCA 2) of interaction effects Per day productivity