EVALUATION OF PROMISING RICE GENOTYPES FOR STABILITY BY AMMI ANALYSIS

ABSTRACT

Seventy genotypes of rice were evaluated under three seasons. Additive main effects and multiplicative interaction (AMMI) model was applied to ascertain extend of genotyping into environment interaction (GEI) and also the stability of rice genotypes across the seasons. Significant difference was observe by AMMI analysis among the tested genotypes and seasons. The sum of the first principal component conferred to 87.04 per cent of the total GEI. In the present inquiry, the genotypes *viz.*, G_{26} (484.45), G_{17} (474.78) and G_{31} (377.87) registered with high mean per day productivity and higher principal component analysis (PCA scores). Hence, these genotypes are specifically suitable for favourable seasons. Since, the genotypes G_7 and G_{11}, were nearer to the center point axes and hence were influenced by the seasons. The genotypes recorded higher per day productivity as well as stability and hence suitable for different seasons. The AMMI model made it easy for visual comparison and identification of elite genotypes for every set of season.

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

INTRODUCTION

Rice is life for many of the Asians. About 90% of the world’s rice is produced in Asia. Rice is the most important food crop for South Indians. Therefore, stability in flowering and per day productivity is very important for sustainable agriculture and food security of resource poor farmers. India is the second producer of rice in the world, with an average production of 172580 thousand tones in 2019-2020 and average yield of 3878 kg ha^{-1} (GOI, 2020).

The manifestation any trait is a combined result of the genotypes (G), the environment (E) and the interaction of genotype with the environment (GE). It is necessary to inquire on G×E interaction and stability, to evaluate the consistency of rice per day productivity and develop genotypes that respond positively and consistently across seasons. When the response of two genotypes to varying seasons are not consistent, then the play of G×E interaction is evident. Hill (1975) opined that a good and efficient genotype must be acceptable in different years and environmental conditions. A through understanding of G×E interactions and stability in rice crop is being used as a decision food for the suggestions of released varieties as well as germplasm for the crop improvement programme through crop breeding. G×E interactions are unveiled using univariate and multivariate analyses. Eberhart and Russel's (1966) univariate method, in which the mean value of each genotype is regressed on the environmental 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 alternative but complementary method for evaluating stability (Crossa, 1990). Gauch's (1992) AMMI model (Additive main effects and multiplicative interaction) is a popular modification of ANOVA for deciphering of G×E interaction. This method brings out genotype and environment main effects and utilizes interaction principal components (IPCs) to define patterns in the G×E interaction or residual matrix which explains a multiplicative model (Romagosa and Fox, 1993).

The AMMI model combines ANOVA from main effects of the genotype and environment with the principal components analysis of G×E 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 stability of genotype across seasons. Purchase (2000) developed the AMMI stability value (ASV) to quantity the genotypes based on their stability. It is established upon the first and second IPC scores for each genotype. This method comparable with Eberhart and Russell's (1966) method. Samonte *et al.* (2005) used AMMI parameters to assess stability of rice grain yield. Bose *et al.* (2014b) analysed AMMI parameters and stability of 17 early maturing rice genotypes over four seasons, and found that the first two IPC's cumulatively explained 93.76% of the total interaction effects. Tarang *et al.* (2013) evaluated ten rice genotypes for three years using AMMI methods and characterized two stable lines based on the smallest distance from the offset of coordinates in AMMI vectors. Bose *et al.* (2014a) used AMMI analysis for evaluating 12 rice genotypes and determined stable ones from three years tests. Tariku *et al.* (2013) evaluated 16 rainfed lowland rice genotypes at three locations of eight environments and indicated the G×E interaction is partitioned among the first four IPC's which cumulately captured 91.13% of the total interactions. Payman Shavifi (2017) stated that interactions were an important source of rice yield variation, and its AMMI biplots were forceful for visualizing the response of genotypes of environments.

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 150 cm with the row. Each plot consisted of 40 plans. 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). The AMMI model was applied to estimate the adaptability and phenotypic stability. According to Farshadfar *et al.* (2011), the AMMI model can be written as

$$Yij = \mu + gi + ej + n \Sigma K=1 > \lambda k \ \alpha \ i \ k \ y \ j \ k + eij$$

Where Yij = the yield of the i^{th} genotype in the j^{th} environment, gi is the mean of the i^{th} genotype minus the grand mean; λK is the square root of the Eigen value of the PCA axis K; αik and Yjk are the principal component scores for PCA axis K of the i^{th} genotype and j^{th} environment, respectively, eij is the residual value. The environment and genotypic PCA scores and expressed as unit vector times the square root of λK; *i.e.,* environment PCA score = λK YiK; genotype PCA score = >kαik.

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. IPCA 1 represent the response of the genotypes that are proportional to the environments associated with the GEI and the second principal component (IPCA 2) provides information about cultivation locations that are accountable to G×E cross over interaction. The AMMI stability value (ASV) was described by Purchase *et al.* (2000) as follows.

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

Where, SSIPCA 1/SSIPCA 2 is that the weight of the IPCA 1 value. This is calculated by dividing the sum of squares IPCA 1 by the sum of squares IPCA 2. It is interpreted that the larger IPCA score irrespective of its sign (positive or negative value), the genotype is more adapted to a particular environment only whereas the genotype is more stable across all environments it the score of ASV is smaller.

RESULTS AND DISCUSSION

Genotype, environment, and GEI interactions were estimated by the additive main effect and multiplicative interaction (AMMI) model and presented in Table 2. In this study, the ANOVA for rice per day productivity was significant for environment, genotypes and genotype and environment interaction. Genotype and environment interaction was interred by changes in the relative performance of genotypes across various seasons. The effects of environment followed by genotype and genotype by seasons interaction effects were responsible for the variation. In the present study, the results of ANOVA for the seventy genotypes revealed that the mean square of the first interaction principal component axis (IPCA 1) was found to be highly significant (P<0.001), while also the second IPCAs captured in significant variation. In the study, the variation could be highly benefaction by the (87.04%) and environmental effects (9.36%), whereas the effects of genotype and environmental interaction was very less (3.60) for the per day productivity in rice. When the IPCA 1 score was almost zero or equal, it was pretended that the rice was having a small and stable interaction.

The AMMI results also showed that IPCA 1 and IPCA 2 explained that interaction sum squares of 100 per cent, indicating 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 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).

Among 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 average 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).

Based on the mean per day productivity of genotypes over the seasons the maximum 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 over seasons and genotypes is 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.

It is concluded that the variety with a high mean yield and least ASV score is the most stable (Rea *et al.*, 2017) and for the breeder, this strategy will be useful in the rice breeding programme. Based on this, the lowest ASV having higher per day productivity over 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 considered to be suitable for the specific environment even though they recorded higher per day productivity than the grand mean. The remaining genotypes were considered unsuitable to any season since they had less average yield whatever may be ASV rank. Therefore, the most stable genotypes do not necessarily offer the best yield, both high per day productivity and less ASV should be considered concurrently in rice breeding programmes.

The most powerful interpretive tool for the AMMI model is biplot analysis biplots are graphs to identify the inter-relationships between genotypes and seasons which are plotted.

On the same axes (Vargas and Crossa, 2000) there are two basic AMMI biplot, the AMMI 1 biplot, where the main effect of per day productivity (genotype mean and season mean) and IPCA 1 scores for both genotypes and seasons are plotted against each other. On the contrast, the second is AMMI where scores for IPCA 1 and IPCA 2 are plotted. There was no consistent per day productivity performance over the three seasons by many of the genotypes. The effect of each genotype and season IPCA 1 *vs* the means (Fig. 1) and IPCA 2 *vs* IPCA 1 (Fig. 2) biplots are shown in Fig. 1. The main effect of the interaction (IPCA 1) were indicated by X-coordinate, the effects of the interaction (IPCA 1) were indicated by the Y-coordinate. IPCA 1 values positioned nearer to the center point of the axis indicated a lesser interaction than those found far from the axes.

The genotypes G_{11}, G_{69}, G_{23} and G_{14} had a low positive interaction with a higher main effect and made them the most preferable for selection. The genotypes G_{68}, G_{46} and G_{29} had a low negative interaction as evident from their low IPCA 1 score. These genotypes may be used as having high adaptability to different seasons because these genotypes were less influenced by seasons.

Thus, it was clear from Fig. 1 the genotypes plotted at the right-handed side of the grand mean level and near to PCA 1=0 line were found 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 resulted in specific adaptation to the favourable season. The genotypes stationed near the origin of the biplot showed greater stability over the environment while those genotypes were distant from the biplot origin indicates their instability and specific adaptability over the season (Kumar *et al.*, 2016).

The stability of the genotypes as well as extent of interactions effect of each genotype and season, AMMI biplot were drawn using IPCA 1 and IPCA 2 scores (Fig. 2). The higher interaction effect was interpreted by those genotypes positioned far from the center point and was found to be sensitive while the genotypes positioned near the origin are not sensitive to environmental interaction. The genotypes G_7 and G_{11} were found to be close the origin and therefore unaffected by environment. These genotypes were identified as stable genotypes with high per day productivity and thus making them suitable for cultivation in a variety of 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. Multi-location evaluation over the years and seasons will provide the information for the selection of genotypes in terms of productivity and fitness. Those genotypes which exhibited higher productivity and wider adaptation would be recommended for commercial cultivation and/or could be utilized as donors in the further breeding programme.

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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

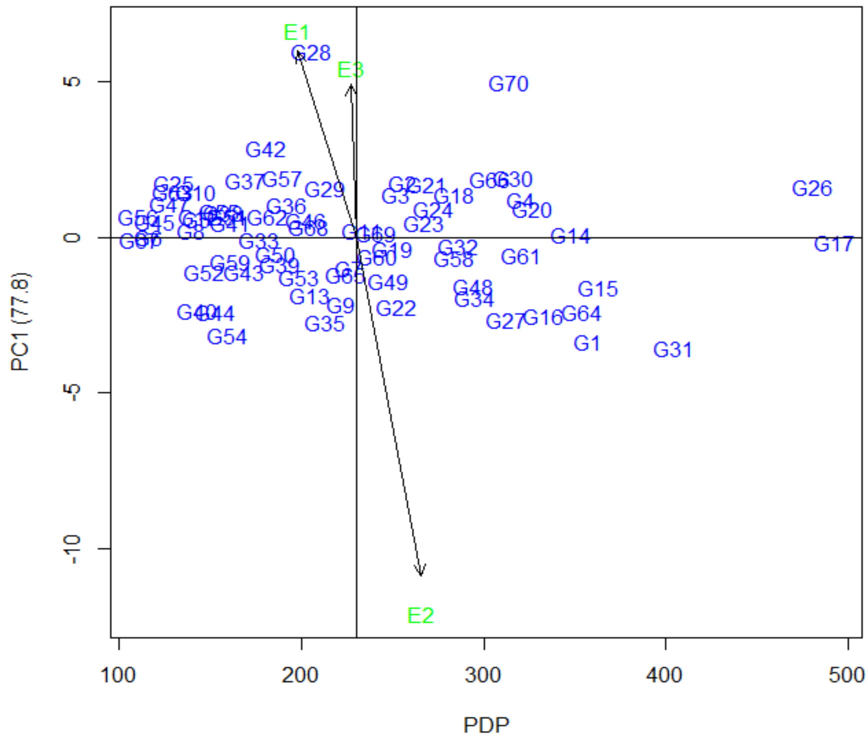

Fig. 1. AMMI I biplot showing main effects and ICAP1 interaction effects of 70 rice genotypes and three seasons on Per day productivity

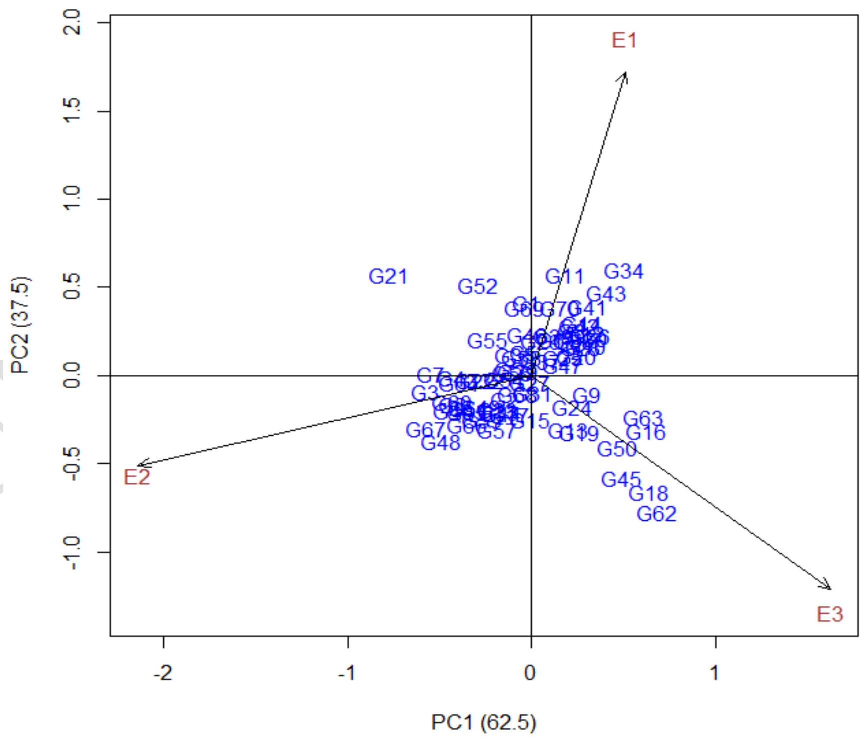

Fig. 2. AMMI II biplot of first two principal components (IPCA 1 *vs* IPCA 2) of interaction effects Per day productivity