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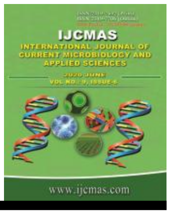

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Stability Analysis of Two-line Rice Hybrids (*Oryza sativa*) in Diverse Environments Utilizing AMMI Model

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ABSTRACT

Keywords

Stability Analysis, Two-line Rice Hybrids, *Oryza sativa*

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Genotype-environment interaction and stability analysis has been important for plant breeders and plays a vital role in identifying genotypes that are stable or unstable in each environment. Varieties that show low G x E interaction and high yield are desirable for crop breeders. The study was conducted in 2018 at six locations in India to (i) determine the presence of G x E of 171 single cross maize genotypes and (ii) To use the GGE biplot methodology to determine grain yield performance and stability of the genotypes evaluated across six environments. The effects of genotype and environment were significant ($P < 0.01$) for grain yield. Pooled ANOVA analysis of 171 genotypes in six environments (E1-E6) showed highly significant differences for environments, significance of variance due to G x E in pooled analysis also indicated the presence of significant genotype x environment interaction. Genotypes G4, G74, G72, G6, G5 and G107 were high yielders with high interaction with environment. Genotypes G73, G159, G97 have highest positive IPCV values and G91, G32, G75 and G132 have highest negative IPCV values indicating that these are highly unstable genotypes. The two-line system has been widely applied for rice breeding since it has many advantages such as, two-line system has more extensive germplasm resources that is beneficial to the development of heterosis, better hybrid seed production yields, absence of negative effects associated with sterility-inducing cytoplasm especially on grain quality.

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple foods worldwide, providing almost one-quarter of the global dietary energy supply for humans. The demand for food continues to rise as the population rapidly grows; necessitating the significant increase in production rice and arable land is limited together with environmental degradation. Rice is one of the most important food crops for half of the world's population. Worldwide, around 3.5 billion people depend upon rice for more than 20% of their calories requirement (Khush, 2013). India stands first in rice area with 44 million hectares and second in production with 105 million tonnes after China (IRRI, 2016). Rice production has increased tremendously from 34.5 million tonnes in 1960–61 to 112.91 million tonnes 2017–18 by developing high yielding semi-dwarf varieties, through crop management, adoption of hybrid varieties and plant protection practices.

The concept of two-line breeding emerged as an alternative to the three-line approach in China (Yuan, 1997). The main advantages of two-line heterosis breeding include the ability to use a wide range of genotypes as male parents, absence of negative effects associated with sterility-inducing cytoplasm and no need for maintainer lines. Male sterility in temperature sensitive genic male sterile (TGMS) lines is heritable. International Rice Research Institute has shown that two-line hybrids derived from TGMS lines had higher frequency of heterotic combinations than three-line hybrids derived from CMS lines (Lopez and Virmani, 2000).

Genotype-environment interaction and stability analysis has been important for plant breeders and plays a vital role in identifying genotypes that are stable or unstable in each environment. Varieties that show low G x E interaction and high yield are desirable for crop breeders and farmers, because it indicates that the environments have less effect on the performance of genotypes and their yield is largely due to the genetic composition (Linnemann 1995).

Among multivariate methods, the additive main effect and multiplicative interaction analysis (AMMI) has been extensively applied in the statistical analysis of multi-environment cultivar trials. A strong G×E interaction slows down selection and identification of genotypes and makes recommendations difficult. To analyze G×E interaction and phenotypic stability, several methods have been proposed, specifically univariate and multivariate stability statistics methods. A combined analysis of variance can quantify the interactions and describe the main effects (Genotype and Environment) reported by (Lin *et al.,* 1986). The effectiveness of AMMI procedure has been clearly demonstrated by various authors and more specifically by Zobel *et al*. (1988) in soybean, Crossa *et al*. (1990) in maize and Mahalingam *et al*. (2018) in greengram using multilocation trial data. Ponnuswamy *et al.*, 2017 reported in a study that AMMI and GGE biplots analyses were successful in assessing genotype by environment interaction in hybrid rice trials and aided in the identification of stable and adaptable rice hybrids with higher mean and stable yields. Jain *et al.,* (2018) reported that estimates of genotype x environment interaction and additive main effect were significant for all the traits viz., grain yield, tiller/plant, plant height and panicle weight. Shams Shaila Islam *et al.*, 2020 reported that highly significant differences were shown from the combined analysis for environments with grain yields, revealing that environments were different and indicated change ability between the genotypes and their interactions.

Materials and Methods

161 rice hybrids developed using 161 varieties crossed with one a TGMS line, PLIR75589TGMS at Hyderabad during November 2017 to May, 2018 seed production season. 161 hybrids along with 8 hybrid checks Viz., 25P35, 27P22, 27P31, 28P67, 27P37, PHB71, Arize 6444 Gold, US312 and 2 varietal checks Viz., MTU1010 and NDR-359 were evaluated at six locations *viz.*, Patna (E1), Purnea (E2) in Bihar, Lucknow(E3), Gosaiganj (E4), Barabanki (E5) and Prayagraj (E6) in Uttar Pradesh during 2018 rainy season of 2018 from, June to October period. The evaluation sites are in

the north central part of India (Figure1). A standard hybrid rice cultivation of practice as recommended by IIRR was adopted at each site during crop growth period. Evaluations were done under irrigated conditions. The genotypes were planted in a randomized complete block design with two replications. Each plot consisted 2-rows of 3.5-meter-long with 0.5 meter allay, with 20 cm space between rows and 15 cm between plants, accommodating 40 plants per entry per replication. Seedlings were raised in 5 meter by 1 meter raised nursery beds and transplanted into main field after puddling with 21-25 days old seedlings. Yield was calculated as kg/ha after extrapolating yield per 40 plants to 330000 plants/ha (15 x 20cm spacing) at standard 14 % moisture for standardisation across entries as follows

Yield (T/ha) = {(Yield/40 plants)*330000*(100-Moisture)/86}/1000000

Analysis of variance was computed for the individual environment as well as for across environments. The significance of all effects was tested against the mean square of error.

The AMMI method was applied with additive effects to 171 genotypes in six environments, and multiplicative was used for G×E interaction. According to Sabaghnia *et al*. (2008), the AMMI method at first adjusts additive effects for host genotypes and environments through the normal additive analysis of variance (ANOVA) technique and fits multiplicative effects for G×E by PCA. It affords a symbolic view of the transformed G×E interaction for any interpretation (Kempton, 1984). The statistical analysis computed using R programme.

Results and Discussion

Understanding of G x E interaction in plant species is of importance because it has implications for economic yield. In view of influence of environmental factors on crop growth, it is necessary to explore variation among genotypes (Anandan, 2011). From Table1, The ANOVA showed that mean squares due to genotypes were highly significant for grain yield in all (E1 to E6) environments, indicating differential performances of genotypes across environments, whereas ANOVA for replications showed no significant differences indicating the within non-significant location variation. Combined ANOVA analysis (Table 2) of 171 genotypes in six environments (Patna, Purnia, Lucknow, Gosaiganj, Barabanki, Prayagraj) showed highly significant differences for environments, significance of variance due to G x E, indicated the presence of significant genotype x environment interaction. The significance of genotypes mean squares indicated that genotypes differed among themselves and there existed a considerable variability irrespective of the effect of environments on the characters under study. The mean squares due to G × E interaction when tested against pooled error were significant for grain yield, hence the data was subjected to AMMI analysis.

In this study, the analysis of variance showed significance for PCA1 PCA2, PCA3,PCA4 and PCA5 (Table3). Among these, PCA 1, PCA2 and PCA3 together recorded 70.9 percent of total sum of squares. Hence, IPCA1, IPCA2, IPCA3may be used for explaining the G x E interaction within study.

Table 5 shows IPCA1 and IPCA2 scores that characterize the interaction of a genotype across environments as well as relationships between genotypes and environments. According to Yan and Hunt (2001) and Mohammadi *et al*. (2007), a genotype with a positive IPCA score in several environments must neutralize negative interactions in other environments. Hence, these scores exhibit an unequal genotype reaction to the environment. Nevertheless, both positive and negative signs, as well as genotypes and environments using large IPCA scores, have strong large interactions and are stable. For grain yield the genotypes G72 (9.954 T/Ha),G74 (9.798 T/Ha),G58 (9.672 T/Ha),G107 (9.621 T/Ha),G4 (9.591 T/Ha),G6 (9.521 T/Ha),G5 (9.318 T/Ha),G83 (9.284 T/Ha),G16 (9.282 T/Ha) were the top mean yielders across the location (Table 4).

BiPlot

The AMMI biplot with the genotype and environment main effects for grain yield on the x-axis and the IPCA1 scores on the y-axis is presented in Fig. 2. There are two basic AMMI biplots, the AMMI1 biplot where the main effects (genotype mean and environment mean) and IPCA1 scores for both genotypes and environments are plotted against each other and the AMMI 2 biplot where scores for IPCA1 and IPCA2 are plotted.

Genotypes close to the horizontal line have small interactions and are more stable than those farther from it. The biplot (Figure: 2) revealed large variability among the six test environments and variability among the 171 genotypes tested. The genotypes which are on or close to the horizontal line indicate the IPCA scores for these genotypes are nearer to zero and therefore had small interaction with the environments.G16 was right on the horizontal line with high mean value indicating that G16 is consistent high yielder across the environments tested. G169, G82, G68 G122 & G151 were average to high yielders and were on the horizontal line indicating that they are average to high yielders with stability across environments. Genotypes G4, G74, G72, G6, G5 and G107 were high yielders with high interaction with environment. The genotypes G-99, G-85, G-60 and G-103 are poor yielders across environments and are not suitable across growing environments. Genotypes G73, G159, G97 have highest positive IPCV values and G91, G32, G75 and G132 have highest negative IPCV values indicating that these are highly unstable genotypes. Mary Ann *et al.*, 2019 in their study on high zinc breeding material of IRRI indicated that the AMMI and GGE analyses showed significant genotype, environment, and G X E effects for Zn and YLD across seasons. Many earlier studies have also reported significant genotypic and G XE effects for yield, yield components, and grain micronutrients in rice (Chandel *et al*. 2010; Rerkasem *et al*. 2015; Nasrullah 2011; Ajmera *et al*. 2017).

In AMMI 2 biplot (Figure: 3) the environmental scores are joined to the origin by side lines. Environments with short vectors do not exert strong interactive forces. Those with longer vectors exerts strong interaction. In this study Barabanki (E5) had shorter vector and do not exert strong interactions with genotypes whereas environment Prayagraj (E6) has the longest vector indicating strong GxE interaction at this location. Environments like, Patna (E1), Purnia (E2), Lucknow(E3) and Gosaiganj (E4) had longer vectors and had good interaction with genotypes. The genotypes occurring close together on the plot will tend to have similar yields in all environments, while genotypes far apart may either differ in mean yield or show a different pattern of response over the environments. Hence, the genotypes near the origin are not sensitive to environmental interaction and those distant from the origins are sensitive and have large interaction.

The quadrants proposed by Olivoto, Lúcio, Da silva, Marchioro, *et al.* (2019) in the following biplot (Figure 3.) represent four classifications regarding the joint interpretation of mean performance and stability. The genotypes or environments included in quadrant I can be considered unstable genotypes or environments with high discrimination ability, and with productivity below the grand mean. Genotypes like G138, G97, G48, G84, G94, G86, G43, G31 and checks like G9 (MTU-1010) are unstable genotypes. Environments like Purnia (E2) and Prayagraj (E6) have high discrimination ability. In quadrant II are included unstable genotypes, although with yield higher than the grand mean. The environments included in this quadrant deserve special attention since, in addition to providing high magnitudes of the response variable, they present a good discrimination ability. Environments line Patna (E1), Lucknow (E3) and Barabanki (E5) represent such environments in the study. Genotypes like G72, G107, G46, G157, G58, G46, G57 and check hybrid like Arize6444 Gold registered high yield above mean but unstable. Gosiaganj location was right on the vertical line and can be effectively used to select genotypes which represent the overall trend across six locations. Genotypes within quadrant III have low productivity but can be considered stable due to the lower values of WAASB. The lower this value, the more stable the genotype can be considered. The environments included in this quadrant can be considered as poorly productive and with low discrimination ability. Genotypes like, G81, G100, G19, G125, G106, G14, G121, G108, G14, G64,, G67 etc are considered stable genotypes with average to poor yields.

Table.1 Mean squares of analysis of variance (ANOVA) for grain yield across 6 locations

Source of Variation	**DF**	**Mean Sum of squares for grain Yield**					
		E1	**E2**	**E3**	**E4**	**E5**	**E6**
Genotype	**170**	3.752***	4.455***	2.824***	2.3133***	3.225***	3.519***
Rep	**1**	0	0.001	0.0057	0.0014	0.007	0.001
Error	**170**	0.012	0.013	0.0133	0.0125	0.013	0.014

Table.2 Mean squares of analysis of variance (ANOVA) for grain yield across 6 locations

Source of Variation	**DF**	**Mean squares for Grain Yield**
Hybrid	**170**	16.74***
Rep	**1**	0.01
Location	**5**	97.3***
GE*Location	**850**	0.67***
Residuals	**1025**	0.01

Table.3 AMMI analysis for grain yield (T/Ha) of rice Hybrids across 6 locations

Source of Variation	**Df**	**SS**	**Explained TSS (%)**	**MS**	**F**	**p -value**	**Explained (%)**
Environment (E)	5	486.52	10.85	97.305	34884.5	2.6712E-13***	
Replicate/Environment	6	0.02	0.00	0.003	0.21	0.9726	
Genotype (G)	170	2845.4	63.45	16.737	1281.0	<0.001***	
Interaction (GE)	850	569.6	12.70	0.670	51.29	<0.001***	
IPCA1	174	157.9	3.52	0.908	69.48	<0.0001***	27.7
IPCA2	172	133.5	2.98	0.777	59.41	<0.0001***	23.4
IPCA3	170	112.8	2.51	0.663	50.77	<0.0001***	19.8
IPCA4	168	91.3	2.04	0.544	41.59	<0.0001***	16
IPCA5	166	74.09	1.65	0.447	34.16	<0.0001***	13
Residual	1020	13.33	0.30	0.0131	NA	NA	
Total	2901	4484.4	100.00	1.546	NA	NA	<NA>

Table.4 High Yielding rice hybrids and their IPCA score for grain yield (T/Ha)

Genotype Code	**Genotype**	**Grain Yield (T/ha)**	**IPCA1**	**IPCA2**	**IPCA3**	**IPCA4**	**IPCA5**
G4	27P37	9.591	0.09102	-0.258	-0.074	0.2643	-0.3369
G5	28P67	9.318	-0.0640	0.178	-0.050	0.2936	0.1082
G6	BSBArize6444 Gold	9.521	0.1994	0.311	-0.390	0.0268	0.4713
G16	PLIR75589TGMS/IR07A250	9.282	0.00790	0.206	0.4502	-0.146	0.1168
G58	PLIR75589TGMS/PL1823315	9.672	-0.1355	-0.304	-0.128	0.2659	0.2398
G72	PLIR75589TGMS/PLADT44	9.954	0.4226	0.228	0.0804	-0.1724	-0.5531
G74	PLIR75589TGMS/PLASD20	9.798	0.2819	0.1112	0.1104	-0.2761	0.01249
G83	PLIR75589TGMS/PLChampa	9.284	-0.0651	0.1951	0.1835	-0.2428	-0.1721
G107	PLIR75589TGMS/PLIR547452231983	9.621	0.2017	0.5319	0.2832	0.1302	0.1709

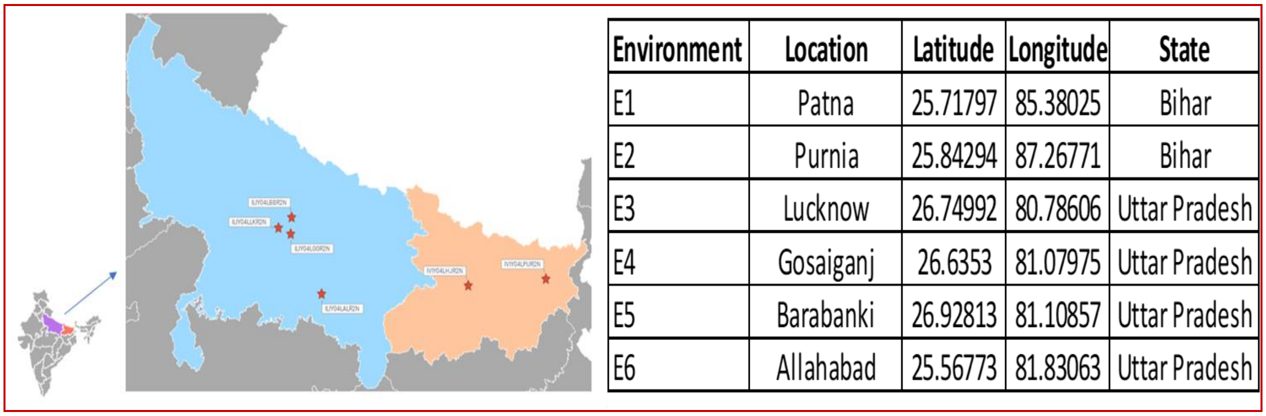
Table.5 Performance of genotypes and their IPCA1 score for yield (mt/ha)

Code	**Hybrid**	**Yield (T/ha)**	**IPCA1**	**Code**	**Hybrid**	**Yield (T/ha)**	**IPCA1**
G1	25P35	7.29	-0.216	G47	Hyb-73	9.08	0.246
G2	27P22	8.72	0.309	G48	Hyb-75	7.46	-0.160
G3	27P31	8.88	0.305	G49	Hyb-77	8.07	-0.249
G4	27P37	9.59	0.091	G50	Hyb-79	7.89	-0.107
G5	28P67	9.32	-0.064	G51	Hyb-81	7.77	0.275
G6	Arize6444 Gold	9.52	0.199	G52	Hyb-83	6.10	-0.313
G7	PHB71	8.30	-0.100	G53	Hyb-86	8.15	-0.035
G8	US312	7.88	0.233	G54	Hyb-87	7.87	0.187
G9	MTU1010	4.96	-0.361	G55	Hyb-89	7.21	-0.108
G10	NDR359	6.42	-0.187	G56	Hyb-91	7.36	0.286
G11	Hyb-02	7.64	0.234	G57	Hyb-93	8.07	0.075
G12	Hyb-04	7.54	0.316	G58	Hyb-95	9.67	-0.136
G13	Hyb-06	8.44	-0.078	G59	Hyb-97	7.70	0.113
G14	Hyb-08	7.30	-0.161	G60	Hyb-99	3.82	0.120
G15	Hyb-10	8.19	0.106	G61	Hyb-101	7.28	-0.010
G16	Hyb-12	9.28	0.008	G62	Hyb-103	7.11	-0.037
G17	Hyb-14	7.53	-0.099	G63	Hyb-105	8.89	0.092
G18	Hyb-16	8.26	0.024	G64	Hyb-107	7.42	0.049
G19	Hyb-18	7.14	-0.034	G65	Hyb-109	8.15	0.072
G20	Hyb-20	8.77	-0.198	G66	Hyb-111	7.81	0.126
G21	Hyb-22	8.97	-0.258	G67	Hyb-113	7.35	0.005
G22	Hyb-24	7.24	0.076	G68	Hyb-115	8.40	0.006
G23	Hyb-26	8.59	0.195	G69	Hyb-117	7.85	0.367
G24	Hyb-28	7.28	-0.069	G70	Hyb-120	7.77	-0.045
G25	Hyb-30	7.77	-0.311	G71	Hyb-121	7.84	-0.007
G26	Hyb-32	5.66	-0.495	G72	Hyb-123	9.95	0.423
G27	Hyb-34	8.12	0.242	G73	Hyb-125	8.44	0.189
G28	Hyb-36	7.96	0.281	G74	Hyb-127	9.80	0.282
G29	Hyb-38	7.63	0.264	G75	Hyb-129	6.38	-0.579
G30	Hyb-40	7.63	0.146	G76	Hyb-131	6.61	0.043
G31	Hyb-42	6.12	-0.538	G77	Hyb-133	6.70	-0.013
G32	Hyb-44	9.19	-0.367	G78	Hyb-136	7.86	0.054
G33	Hyb-46	7.05	-0.175	G79	Hyb-137	7.73	-0.101
G34	Hyb-48	8.79	0.428	G80	Hyb-139	6.96	-0.030
G35	Hyb-50	7.66	0.036	G81	Hyb-141	7.54	-0.130
G36	Hyb-52	7.87	0.296	G82	Hyb-144	8.56	0.005
G37	Hyb-54	7.86	-0.059	G83	Hyb-145	9.28	-0.065
G38	Hyb-55	7.83	0.015	G84	Hyb-147	6.93	-0.291

G39	Hyb-58	7.96	0.086	G85	Hyb-149	4.48	0.186
G40	Hyb-60	5.48	-0.346	G86	Hyb-151	5.08	-0.475
G41	Hyb-62	6.53	-0.049	G87	Hyb-153	7.50	-0.084
G42	Hyb-63	7.04	0.133	G88	Hyb-155	7.26	0.215
G43	Hyb-65	7.53	0.277	G89	Hyb-157	6.94	0.031
G44	Hyb-67	9.26	-0.100	G90	Hyb-159	7.52	-0.055
G45	Hyb-69	8.18	0.208	G91	Hyb-161	5.81	-0.673
G46	Hyb-71	9.15	0.258	G92	Hyb-163	8.27	-0.134
Code	**Hybrid**	**Yield (T/ha)**	**IPCA1**	**Code**	**Hybrid**	**Yield (T/ha)**	**IPCA1**
G93	Hyb-165	7.42	-0.046	G137	Hyb-253	7.83	0.134
G94	Hyb-167	6.24	-0.376	G138	Hyb-255	5.49	-0.623
G95	Hyb-169	5.84	0.028	G139	Hyb-257	5.46	-0.285
G96	Hyb-171	7.61	0.040	G140	Hyb-259	8.52	0.199
G97	Hyb-173	6.56	0.644	G141	Hyb-261	8.15	-0.027
G98	Hyb-175	7.97	0.001	G142	Hyb-263	8.05	0.217
G99	Hyb-177	4.09	0.025	G143	Hyb-265	8.29	0.200
G100	Hyb-179	7.61	0.171	G144	Hyb-267	7.95	0.215
G101	Hyb-181	5.51	-0.325	G145	Hyb-269	7.98	0.306
G102	Hyb-183	6.87	-0.162	G146	Hyb-271	7.07	-0.331
G103	Hyb-185	3.21	-0.110	G147	Hyb-273	5.28	-0.412
G104	Hyb-187	7.58	0.127	G148	Hyb-275	7.93	0.124
G105	Hyb-189	6.41	-0.367	G149	Hyb-277	6.71	-0.278
G106	Hyb-191	7.24	0.019	G150	Hyb-279	8.16	-0.184
G107	Hyb-193	9.62	0.202	G151	Hyb-282	8.47	-0.004
G108	Hyb-195	7.28	-0.088	G152	Hyb-283	7.20	-0.291
G109	Hyb-197	8.20	0.142	G153	Hyb-285	6.41	0.086
G110	Hyb-199	5.94	-0.111	G154	Hyb-287	8.23	0.116
G111	Hyb-201	8.48	0.229	G155	Hyb-289	7.70	0.168
G112	Hyb-203	7.78	0.199	G156	Hyb-292	6.71	-0.363
G113	Hyb-205	7.80	0.329	G157	Hyb-293	9.27	0.137
G114	Hyb-207	7.89	-0.087	G158	Hyb-295	7.44	-0.169
G115	Hyb-209	8.05	-0.072	G159	Hyb-297	8.32	0.138
G116	Hyb-211	6.73	-0.069	G160	Hyb-299	8.54	-0.096
G117	Hyb-213	6.75	-0.110	G161	Hyb-301	8.00	0.304
G118	Hyb-215	6.79	-0.320	G162	Hyb-303	8.79	0.110
G119	Hyb-217	7.66	-0.318	G163	Hyb-306	6.97	-0.094
G120	Hyb-219	8.84	0.186	G164	Hyb-307	8.79	-0.150
G121	Hyb-221	7.35	-0.273	G165	Hyb-309	6.98	0.285
G122	Hyb-223	8.02	-0.023	G166	Hyb-311	8.03	0.306
G123	Hyb-225	6.83	0.206	G167	Hyb-313	9.24	0.448
G124	Hyb-227	7.46	0.038	G168	Hyb-315	7.20	-0.028
G125	Hyb-229	7.29	-0.142	G169	Hyb-317	8.39	0.042

G126	Hyb-231	6.04	-0.055	G170	Hyb-319	3.81	0.361
G127	Hyb-233	7.90	0.325	G171	Hyb-321	6.40	-0.142
G128	Hyb-235	8.97	0.084				
G129	Hyb-237	8.43	0.296	**Environments**			
G130	Hyb-239	8.08	-0.129	**Patna (E1)**		8.01	-0.39
G131	Hyb-241	8.44	-0.213	**Purnia (E2)**		6.975	1.645
G132	Hyb-243	7.50	0.086	**Lucknow (E3)**		8.04	-1.165
G133	Hyb-245	7.36	-0.051	**Gosaiganj (E4)**		7.512	-1.551
G134	Hyb-247	5.60	-0.313	**Barabanki (E5)**		7.913	-0.0444
G135	Hyb-249	7.70	-0.165	**Prayagraj (E6)**		6.837	1.505
G136	Hyb-251	6.97	0.019				

Figure.1 Locations details where yield trials were planted



Environment	Location	Latitude	Longitude	State
E1	Patna	25.71797	85.38025	Bihar
E2	Purnia	25.84294	87.26771	Bihar
E3	Lucknow	26.74992	80.78606	Uttar Pradesh
E4	Gosaiganj	26.6353	81.07975	Uttar Pradesh
E5	Barabanki	26.92813	81.10857	Uttar Pradesh
E6	Allahabad	25.56773	81.83063	Uttar Pradesh

Figure.2 AMMI BiPlot 1

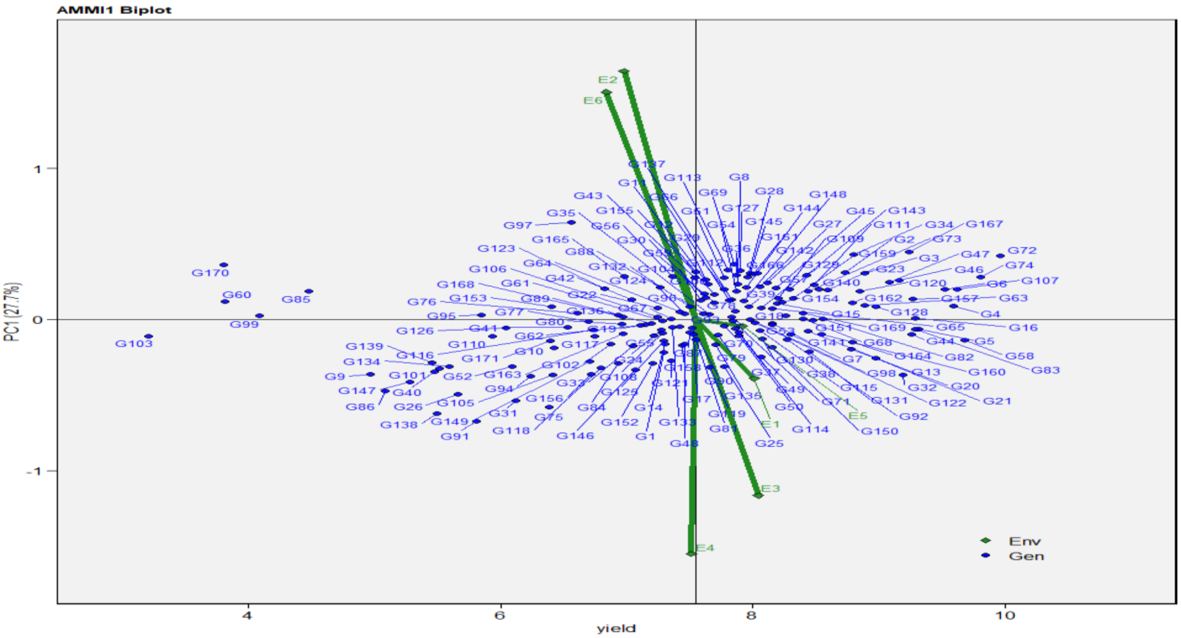


Figure.3 AMMI BiPlot 2

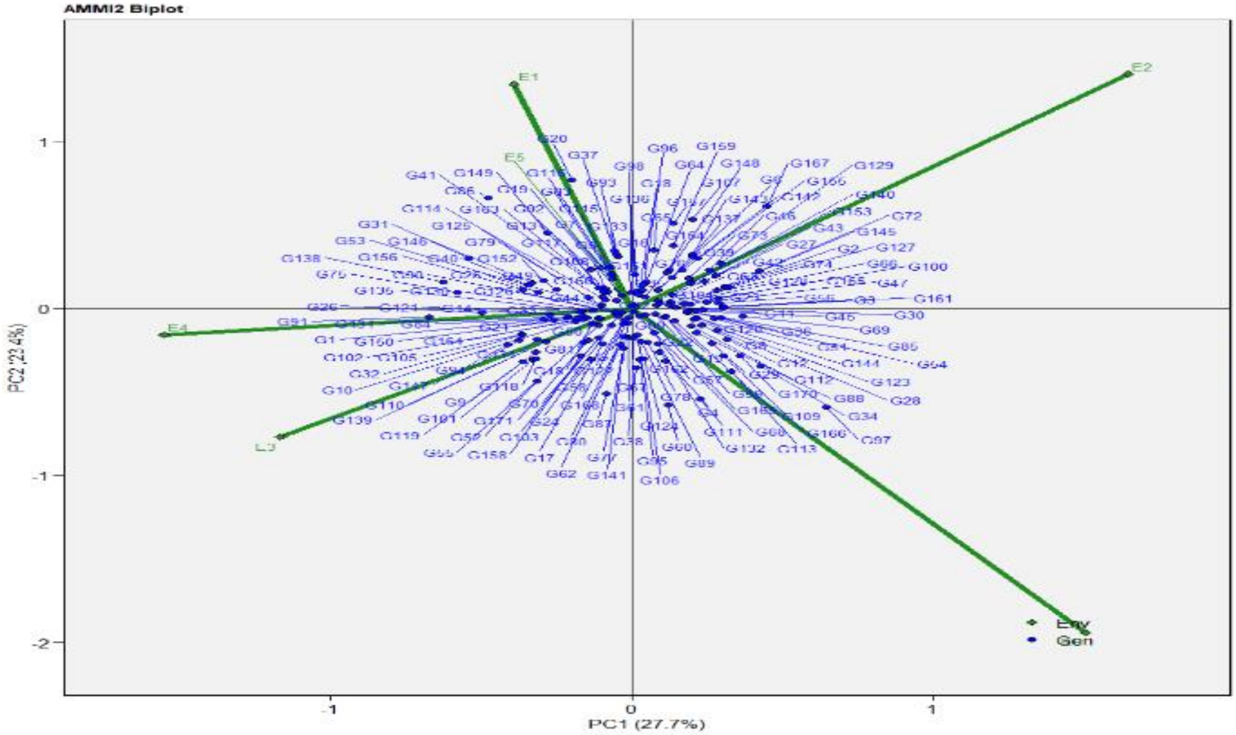
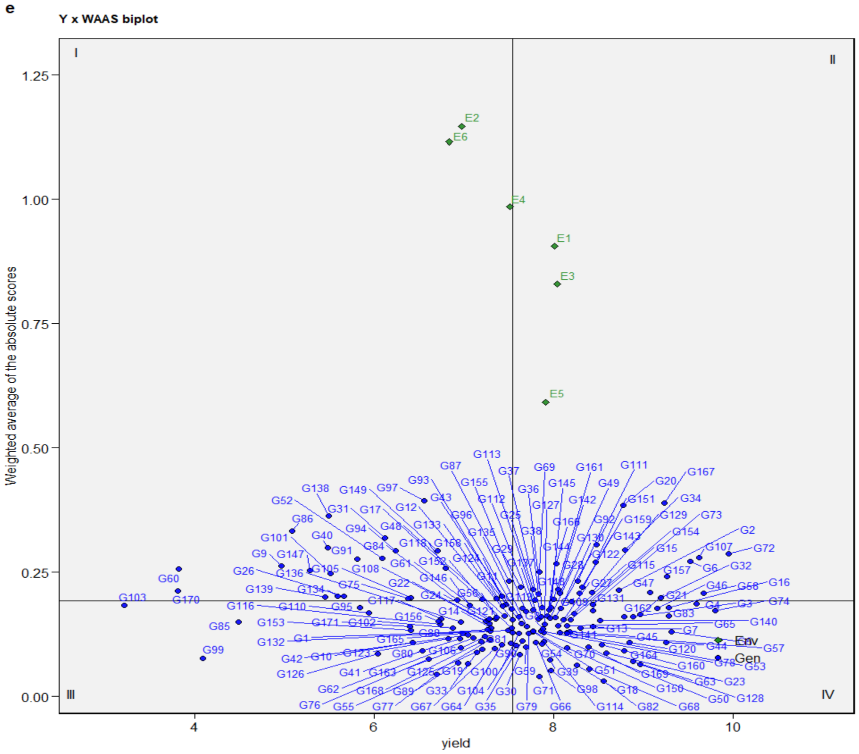


Figure.4 Y x WAAS BiPlot



The genotypes within the quadrant IV are highly productive and broadly adapted due to the high magnitude of the response variable and high stability performance (lower values of WAASB). Genotypes like, G4, G74.G3, G83, G16, G7, G78, G44, G120 & G46 are high yielding and fairly stable hybrids across tested environments.

This study indicated the presence of large GXE interaction across the tested environments. The genotype G16 (PLIR75589TGMS/IR07A250) is a consistent high yielder across the environments tested and is recommended for cultivation in the sampled environments. G169, G82, G68 G122 & G151 arethe second set of high yielding stable hybrids cross environments. Genotypes G4, G74, G72, G6, G5 and G107 were high yielders with high interaction with environment and therefore can be recommended to specific locations were they are performing well with lease environmental interaction.

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