**STABILITY ANALYSIS OF RICE RECOMBINANT INBRED LINE USING GGE BIPLOT METHOD**

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**ABSTRACT**

This study was done in order to assess the genetic differences among 87 rice recombinant inbred lines (RILs), identify the productive environments and measure the impacts of genotype environment interaction (GEI) on yield and yield related traits across four locations of the Khyber Pakhtunkhwa Province-Pakistan during 2020 and 2021. The pooled ANOVA showed significant differences among the environments, genotypes and GEI for the studied traits. Across eight environments, RIL AUP-3 displayed the least number of days to maturity (139). The maximum number of grains (226) panicle-1 were produced by AUP-30. AUP-30 revealed maximum grain yield at E-3 (5.4 t ha-1) and E-7 (4.9 t ha-1) whereas AUP-3 at E-1 (4.8 t ha-1)was particularly adaptable in the respective environmental conditions. A graphical method for analyzing experimental data from several environments is to consider genotype as main effect and genotype x environment interaction (GGE) biplot, which is used to assess the total number of genotypes visually. The first two primary components cumulatively explained 63.2%, 53.4% and 50.9% i.e., GEI is responsible for, respectively, more than half of the overall variation in days to maturity, grains panicle-1, and grain yield. Genotypes AUP-3 and AUP-40 can be successfully being adapted for days to maturity at Peshawar and Charsadda. Similarly, AUP-3 and AUP-30 can be can be successfully adapted for grains panicle-1 and grain yield at Swat and Mansehra, respectively. Peshawar and Charsadda constituted one mega environment while Swat and Mansehra comprised other mega environment for grain panicle-1 and grain yield. In the current study, RILs AUP-3 and AUP-30 were observed as the highest yielding, stable and ideal genotypes across environments for maturity and yield related traits.

**Key words:** Genotype × environment interaction, GGE Biplot, Rice, Stability analysis, Eight Environment

**1. INTRODUCTION**

About 20 wild species and two domesticated species, *O. sativa* (an Asian species) and *O. glaberrima* (an African species), make up the genus Oryza (Wanbugu et al., 2013). *O. sativa* is grown all over the world whereas *O. glaberrima* cultivation is limited to West Africa. The two main biotypes or subspecies of O. sativa, indica and japonica, exhibit evolutionary adaptation to environmental factors (Maclean et al., 2002). Since ancient times, rice (*Oryza sativa* L.), one of the world's most important cereal crops, has been a significant source of sustenance. The creation of novel cultivars with high yield and steady performance across a variety of settings is necessary to increase global rice production (Akter et al., 2014). Development of high yielding rice cultivars is needed to ensure food security of the rapidly increasing population not only in Pakistan but in the world as well.

A complex quantitative characteristic, yield is heavily impacted by the environment. As it is ineffective to choose superior genotypes at a single site and during a single year based solely on yield, therefore evaluation of genotypes for stability performance under varied environmental conditions and over multiple years for yield has become an essential component of crop improvement programs. Information on the interaction between genotype and environment enables the identification of stable genotypes, which could be used for commercial cultivation (Shrestha et al., 2012). Several advancements have been made in the recent past to analyze the varietal performance over diverse environments. The genotype main effects and genotype x environment interaction effects (GGE) model is one of the most popular techniques (Gauch Jr. 2006). The genotype by environment data analysis is made simple and complete by GGE biplot analysis. This method offers insights on long-term, fundamental issues in addition to short-term, practical questions (Yan and Tinker, 2006). A statistical technique called GGE biplot analysis employs a multivariate approach to the investigation. In separating GE components into distinct interactions between genes and environmental factors, it is superior to a univariate method (Flores et al. 1998). Compared to AMMI analysis, GGE could provide a more detailed explanation of the sources of variation in G (genotype) and GE (genotype environment), according to Yan et al. (2007). GGE biplot can display genotype average performance and stability, the best genotype and optimal location to maximise yield, the best genotype with the highest yield in a quadran comprising identical locations (Mega-E), and a specific location. Jambormias and Riry (2008) and Farshadfar and sadeghi (2014). Given the significance of GGE biplot analysis, the current study's objectives were to: (i) use GGE biplot to discover generally stable genotypes across settings; (ii) identify large habitats; and (iii) investigate genotypes that perform better at certain sites for the desired attributes.

**2. MATERIALS AND METHODS**

This research was conducted at four locations of the Khyber Pakhtunkhwa province namely, The University of Agriculture (UoA)-Peshawar, Agriculture Research Institute (ARI) Mingora-Swat, Agriculture Research Station (ARS) Bafa-Mansehra and Bacha Khan University (BKU)-Charsadda during the rice growing seasons 2020 and 2021. In summarized form the overall the eight environments (four locations across two years) were Peshawar-2020 (E-1), Mingora-2020 (E-2), Manshera-2020 (E-3), Charsadda-2020 (E-4), Peshawar-2021 (E-5), Mingora-2021 (E-6), Manshera-2021 (E-7) and Charsadda-2021 (E-8). Recombinant inbred lines (RILs) of rice produced from the F5 gene as well as the common check cultivars Pakhal, Kashmir-Basmati (K-Bas), and Fakhr-e-Malakand (F-MLD) made up the genetic material. The Department of Plant Breeding and Genetics at The University of Agriculture Peshawar's Rice Breeding Programme created the rice RILs. A programme of rice hybridization was started in 2010 by crossing several elite Pakistani rice cultivars. The segregating populations have grown substantially up to F4. On the basis of superior yield and attributes relevant to yield, single plants from the bulk populations of various cross combinations were chosen for F5. In F6, the seeds of each selected plant were grown in two-row plots. The lines showing uniformity were selected and undesirable lines were discarded. Using an alpha lattice design with three replications, the chosen lines were evaluated over the 2020 and 2021 rice growing seasons in four different locales. Each replication had six blocks, each of which contained 15 RILs. Each genotype was planted in four-row plots with a gap between rows of 30 cm and a row length of 3 metres.

**GGE biplot analysis**

Using the computer programme GEA-R, data on days to maturity, grains panicle-1, and grain yield were subjected to GGE biplot analysis. (Pacheco et al., 2015). The principal components (PCs) used in the singular value decomposition (SVD) of the GGE biplot model can be represented as;

*Yij*−μ − βj = λ1 ξi1 ηj1 + λ2 ξ­i2 ηj2 +εij

**3 RESULTS**

**3.1 Mean performance**

**3.1.1 Days to maturity**

For days to maturity utilising pooled analysis, significant differences (P0.01) were found between the genotypes, environments, and genotype environment interactions (Table 3.1). settings varied significantly from one another, and there were strong GEI effects that showed how genotype rankings and mean performance were affected by settings. Over eight habitats, the mean days to maturity ranged from 139 to 147 days, with a mean value of 144 days (Table 3.2). Early maturation was noted in E-5 (123 days), E-1 (124 days), E-8 (125 days), and E-7 (128 days), whereas delayed maturation was noted in E-2, E-4, and E-6 (162 days each), as well as E-3 (155 days) (Table 3.3). Minimum number of days to maturity was recorded for genotypes AUP-3 (139), AUP-62, AUP-29, AUP-61 and AUP-63 (141 days each), whereas maximum days to maturity (147 days) were observed for genotypes AUP-19, AUP-38, AUP-75 and AUP-51 (Table 3.2).

**3.1.2 Grains panicle-1**

For grains panicle-1, the genotypes, habitats, and GEI showed highly significant differences (P 0.01) (Table 3.1). The grains panicle-1 mean over eight environments ranged from 140 to 226 grains, with a mean value of 158 grains. The genotype AUP-30 had the most grains spike-1 (226), followed by AUP-3 (214), and AUP-29 (203.4), while the genotype AUP-53 had the fewest grains panicle-1 (140 grains) (Table 3.2). Environments E-01, E-02, E-03 and E-04 have grains ranged between 129-253, 119-264, 128-251 and 100 – 197, respectively. Whereas number of grains per panicle ranged between 119 – 264, 116 – 263, 125 - 255 and 85 - 202 for environment E-05, E-06, E-07 and E-08, respectively. (Table 3.3).

**3.1.3 Grain yield**

Highly significant (P≤0.01) differences among the genotypes, environment and GEI were observed for grain yield (Table 3.1). Across environments, grain yield ranged from 2.8 to 4.1 t ha-1 with a mean value of 3.6 t ha-1. Maximum grain yield was observed for AUP-3 and AUP-30 (4.1t ha-1), followed by genotype AUP-90 and AUP-29 (4.0t ha-1), while minimum grain yield was noticed for AUP-64 (2.8 t ha-1) (Table 3.2). Within environments, grain yield ranged from 2.6 to 4.8 t ha-1 in E-01; 3.0 to 4.6 t ha-1in E-02; 3.1 to 5.4 t ha-1 in E-03; 2.1 to 3.9 t ha-1 in E-04; 2.5 to 4.7 t ha-1 in E-05; 3.2 to 4.2 t ha-1 in E-06; 2.7 to 4.9 t ha-1 in E-07 and 1.9 to 3.8 t ha-1 in E-08 (Table 3.3).

**3.2 GGE Biplot Analysis**

**3.2.1 Days to maturity**

**Mean performance of genotypes and environments**

Days to maturity GGE biplot analysis revealed that, altogether, the first two main components accounted for 50.9% of the variation brought on by GEI (Fig. 3.1A). The most environment-responsive genotypes were found to be AUP-3, AUP-39, AUP-51, and AUP-72, which can be seen in their greater distances from their original locations. Due of their longer vectors, environments E-3 and E-5 forced genotypes to show their differences in days to maturity. E-1, E-2, E-6, and E-8, on the other hand, were generally stable environments that led to variance across genotypes of a smaller magnitude, as evidenced by their shorter vectors. The genotypes AUP-26, AUP-64, AUP-76, and AUP-83 were shown to be more stable and well-adapted for this trait when they were observed closer to the origin. Additionally, genotype AUP-76 was strongly related with E-1, E-2, and E-6, indicating that it has evolved specifically for these conditions. Analysis revealed reduced angles between the vectors of environments E-1, E-2, and E-6, suggesting similar growing conditions for genotype. On the other hand, bigger angles between E-3 and E-5 and E-7 were found, demonstrating that the genotypes' environments varied. E-5's position demonstrated its uniqueness among environments. (Fig. 3.1 A).

**Which-won-where pattern**

The which-won-where pattern of GGE biplot for days to maturity was displayed as polygon view in Figure 3.1 B. Seven of the eight genotype-observed areas on the biplot that got diverse environments were. In terms of genotypic response to various contexts, the number of sectors demonstrated the complexity of the data. Genotypes on the polygon's vertices were quite responsive to certain environments. Genotypes AUP-12, AUP-39, AUP-40, and AUP-55 interacted with E-5 in a substantial way. Similar interactions occurred between the genotypes AUP-44 and E-1, E-2, and E-06; AUP-3 and E-4 and E-7; and AUP-48 and AUP-51 with E-3 and E-8, indicating particular adaptation of these genotypes to their individual environments. AUP-72's poor performance in all of the test conditions is further shown by its position at the centre of an environment-free sector. AUP-3 and AUP-40 genotypes won the sectors with the best genotypes. With E-4, AUP-3 took first place in the category of genotypes with average performance, whereas AUP-48 was placed in the category of genotypes with low performance for days to maturity. (Fig. 3.1 B).

**Discriminating ability vs. representativeness of environments**

The image clearly shows that environments E-3 and E-8 were regarded as representative environments since they had lesser angles with the average environment axis (AEA). According to their larger angles with AEA, environments E-1, E-2, E-6, and E-8 were the least representative and the most discerning settings. As evidenced by their closer proximity to the origin and greater AEA angle, environments E-3, on the other hand, were the least discriminating and less representative (Fig. 3.1C). Figure 3.5A shows the location where the optimal genotype and environment would exist. As can be observed, the genotype AUP-16 and environment E-3 are close to the optimal location and can be thought of as the ideal genotype and environment for the number of days till maturity.

**Relationship among testing environments**

Figure 3.1C shows the relationship between days and maturity in testing environments. Since the angles between environments E-1, E-2, E-3, E-5, and E-6 were all 90 degrees, they were all virtually equally capable of differentiating genotypes. Environments E-1 and E-8 were at an angle of around 90 degrees, which showed that there was no connection between them. The angle between environment E-1 and environment E-7 is greater than 90 degrees, indicating a negative relationship between both environments and offering distinct conditions to differentiate genotypes. The angles between E-1 and E-04 were very close to 180o, showing that these environments were radically different from one another from days through maturity. Mansehra (E-3 and E-7) and Peshawar (E-5) conditions had longer vectors and provided an excellent opportunity to choose genotypes for days to maturity. (Fig. 3.3C).

**Mean vs. stability of genotypes**

Mean vs. stability biplot for days to maturity is presented in figure 3.1D. As can be observed, AUP-64 was an early maturing genotype with moderate stability because it required the fewest days for maturing with intermediate projection on the ordinate. AUP-3 and AUP-72 were found to be less stable than AUP-64 but to mature significantly later.

**3.2.2 Grains panicle-1**

**Mean performance of genotypes and environments**

Using the environment-centered scaling method, data for grains panicle-1 of 90 genotypes in eight habitats were subjected to GGE biplot analysis. In all, the first two principal components (PC1=39.3% and PC2=15.0%) accounted 54.3% of the variation caused by GEI. The larger distances from the origin of the genotypes AUP-30, AUP-3, AUP-29, and AUP-90 showed that these genotypes were more adaptable to a variety of situations. As can be seen from their larger vector lengths, E-1, E-2, E-5, and E-6 imposed more pressure to result in significant difference in the performance of genotypes. As seen by its shorter vector length, E-8 was the environment that was the most stable and exerted the least effect on genotype variation. As a result of their proximity to the origin, genotypes AUP-26, AUP-33, AUP-44, and AUP-48 were shown to be stable and widely adapted for grains panicle-1. Additionally, AUP-30 and E-6 interacted successfully, demonstrating their site-specific performance. The environments were closely related to two groups. According to smaller angles between their vectors, the first group included environments E-1, E-3, and E-7, while the second group included E4, E6, and E8 (Fig. 3.2A).

**Which-won-where pattern**

Figure 3.2B shows a polygonal perspective of the which-won-where pattern of the GGE biplot for grains panicle-1. Ten sectors with only four sector environments each included different genotypes. The placement of genotypes in the environment(s) suggested that those with unique genotypes performed differently depending on the environment. The majority of the genotypes were found in areas with no environmental influences, indicating that they were insensitive to all of the investigated settings. Particularly, RILs AUP-3 and AUP-30 shown improved performance for grains panicle-1 in E-1, E-5, and E-6, demonstrating their adapted to the local environment. As evidenced by their placement on vertices in environment-free sectors, the genotypes AUP-60, AUP-66, and AUP-85 were not responsive to their environments. In the category of top genotypes for the trait, genotypes AUP-3 and AUP-30 took first place (Fig. 3.2B). In sectors with seven conditions, AUP-3 and AUP-30 had the best results for grains panicle-1, proving the environmental stability of these genotypes.

**Discriminating ability vs. representativeness of environments**

Figure 3.2C displays the discriminating vs. representative biplot for grains panicle-1. The decreased angle with AEA and the average distances from origin of environments E-4, E-6, and E-8 indicate that they were representative settings with strong genotype discrimination. Due of its greater distance from the origin, Environment E-1 was the most discriminating. However, as is shown from its wider angle with AEA, it was regarded as being less representative. The fact that E-8 was so close to the source showed that it was the least discriminating environment. Environment E-02 exhibited adequate discriminating power but was less representative, as shown by the long vector and bigger angles with AEA (Fig. 3.2C). Figure 3.5B shows the concentric circles that represent the location of the perfect genotype and environment. It can be shown that the genotypes AUP-3 and AUP-30, as well as environment E-6, are close to the optimal place and may therefore be ideal for grains panicle-1.

**Relationship among the test environments**

Environments E-1, E-3 and E-4, E-5, E-6, E-7 and E-8 were highly correlated (angle 90o) and essentially equal in their ability to discriminate genotypes, according to research on the relationship between the test environments for grains panicle-1. The angle between environments E-1 and E-2 is roughly 90 degrees, which suggests that there was no connection between them. Environments E-01 and E-2 had longer vectors from origin based on vector length, allowing for the possibility to choose genotypes for these environments (Fig. 3.2C). For the other environments with steady performance, the genotypes with the best performance in one of these environments might be suggested.

**Mean vs. stability of genotypes**

**3.2.3 Grain yield**

Based on the genotypes' mean values for grain panicle-1 across environments, the biplot GGE approach ranks genotypes. The 'ordinate' line, which is perpendicular to the AEA and green, displays the level of genetic instability. The genotype would be more unstable the higher the projection on ordinate. According to its reduced projection on coordinate, which is depicted in figure 3.2D, AUP-30 was the genotype for grains panicle-1 that was consistently the most prolific and dependable in all conditions. The enormous projection of genotype AUP-3's coordinates suggests that it had the least stability, although producing an adequate number of grains panicle-1. However, as evidenced by its bigger projection on coordinate, AUP-29, the third highest grain production, remained rather constant. Contrarily, AUP-53 was the genotype for grain panicle-1 that performed poorly and was least stable, as seen by its longer projection on coordinate (Fig. 3.2C).

**Mean performance of genotypes and environments**

GGE biplot analysis was used to examine grain yield data from 90 rice genotypes grown in eight different settings. The variance brought on by GE interaction was reflected by the first two main components in total by 63.2% (Fig. 3.3A). The most variable genotypes in various contexts were AUP-3, AUP-30, AUP-90, and AUP-64, as seen by their greater distances from the origin. Because all environments had smaller vectors, they had the greatest potential to significantly alter how genotypes performed. AUP-3, AUP-30, and AUP-90 genotypes were found to be stable and widely adapted for grain yield, which is consistent with being close to the origin.

**Which-won-where pattern**

Figure 3.3B shows a polygonal perspective of the which-won-where GGE biplot for grain yield. Only four of the seven sectors of the biplot received environments, dividing the genotypes among them. Genotypes located at the center of ecosystems that contain sectors provided evidence of their site-specific performance. The adaptability of genotype AUP-30 in these conditions is suggested by its positive responses to E-3 and E-7. The better grain production of genotype AUP-3 in environments E-1 and E-5 indicated the trait's site-specific performance for the genotype. The only environments that AUP-29 interacted with were E-2 and E-6. In sectors where no environment was provided, genotypes AUP-58, AUP-64, and AUP-74 won, demonstrating their variable performance across all conditions. In general, genotype AUP-30 won the sector with the best genotypes, while genotype AUP-64 showed up in the sector with the worst genotypes for grain yield.

**Discriminating ability vs. representativeness of environments**

Figure 3.3C shows a discriminating vs. representativeness biplot for grain yield. The longer distances from the genesis of the environments E-2, E-4, E-6, and E-8 suggest that they were substantially more discriminating settings. However, because of their greater angle with the AEA (Average-Environment Axis), these environments were not regarded as representative environments. Because of their greater distances from the origin, environments E-1, E-3, E-5, and E-7 were also the discriminating environments. Due to the reduced AEA angle, these habitats were considered to be relatively representative environments. Due to its shortest angle with AEA and adequate representative power for genotypes, Environment E-1, however, seemed to be the most representative one (Fig. 3.3 C). Figure 5.4 C shows the location of the optimal genotype and environment for grain yield. The optimal genotypes and environment for grain yield were represented by RILs AUP-3 and AUP-30 and environment E-1, which were all placed close to the ideal site.

**Relationship among environments**

Figure 3.3 C shows the relationship between test environments. By their smaller angles with one another, environments E-1, E-3, and E-7 can be demonstrated to have close associations. The environments E-2 and E-6 were similar in that they were connected. The angle of environment E-04 with environments E-2 and E-6 is greater than 90 degrees, indicating a negative relationship between these environments and providing contrasting conditions to distinguish genotypes. Environment E-7 had longer vectors based on vector length, allowing for the possibility of genotype selection based on grain yield. (Fig. 3.3C).

**Mean vs. stability of genotypes**

Figure 3.3 D shows a biplot of mean vs. stability for grain yield. As can be observed, AUP--30 was a high yielding genotype with moderate stability since it produced a higher mean grain yield with an intermediate projection on the ordinate. AUP-90 was discovered to be less stable than AUP-30 but comparatively low yielding in comparison. In a similar vein, AUP-64 had mediocre yields and average stability. (Fig. 3.3 D).

**Table 3.1. Pooled mean squares for various traits of 90 genotypes across eight environments during 2020 and 2021 rice growing seasons.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SoV** | **Df** | **Days to maturity (days)** | **Grains panicle-1** | **Grain yield (t hac-1)** |
| **Environments** | 7 | 35310.8\*\* | 104338.2\*\* | 72.5\*\* |
| **Replications (E)** | 16 | 113.3 | 350.9 | 0.5 |
| **S-Block (Rep (E))** | 120 | 24.2 | 905.8 | 0.1 |
| **Genotypes** | 89 | 59.8\*\* | 4753.9\*\* | 0.7\*\* |
| **G × E** | 623 | 41.6\*\* | 1160.0\*\* | 0.1\* |
| **Error** | 1304 | 24.5 | 778.0 | 0.1 |

**Table 3.3. Means of 90 rice genotypes for various parameters across eight environments during 2020and 2021 rice growing seasons.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Parameters** | | | |
| **Environments** |  | **Days to maturity** | **Grains panicle-1** | **Grain yield (t ha-1)** |
| **E-1**  **(Peshawar, 2020)** | Minimum | 124.3(AUP-55) | 129(AUP-86) | 2.6 (AUP- 64) |
| Maximum | 144.0(AUP-72) | 253(AUP-3) | 4.8 (AUP- 3) |
| Mean | 128.7 | 167.5 | 3.7 |
| **E-2**  **(Swat, 2020)** | Minimum | 132.7(AUP-29) | 118.7(AUP-60) | 3.0 (AUP- 64) |
| Maximum | 161(AUP-75) | 264(AUP-29) | 4.6 (AUP- 29) |
| Mean | 156.6 | 169.9 | 3.7 |
| **E-3**  **(Mansehra, 2020)** | Minimum | 132(AUP-72) | 128.3(AUP-11) | 3.1 (AUP- 59) |
| Maximum | 155(AUP-48) | 251(AUP-30) | 5.4 (AUP- 30) |
| Mean | 141 | 167.1 | 4.1 |
| **E-4**  **(Charsadda, 2020)** | Minimum | 151(AUP-6) | 99.7(AUP-4) | 2.1 (AUP- 7) |
| Maximum | 161.7(AUP-56) | 197.3(AUP-40) | 3.9 (AUP- 40) |
| Mean | 157.1 | 124.2 | 2.9 |
| **E-5**  **(Peshawar, 2021)** | Minimum | 123(AUP-3) | 118.7(AUP-63) | 2.5 (AUP- 64) |
| Maximum | 149.3(AUP-39) | 264(AUP-3) | 4.7 (AUP- 3) |
| Mean | 136.1 | 168 | 3.7 |
| **E-6**  **(Swat, 2021)** | Minimum | 151.3(AUP-3) | 116(AUP-51) | 3.2 (AUP- 40) |
| Maximum | 161.7(AUP-57) | 262.7(AUP-29) | 4.4 (AUP- 29) |
| Mean | 157.5 | 172.2 | 3.8 |
| **E-7**  **(Mansehra, 2021)** | Minimum | 128.3(AUP-62) | 125(AUP-72) | 2.7 (AUP- 64) |
| Maximum | 149.7(AUP-74) | 255(AUP-30) | 4.9 (AUP- 30) |
| Mean | 138 | 166.6 | 3.8 |
| **E-8**  **(Charsadda, 2021)** | Minimum | 125(AUP-40) | 85(AUP-28) | 1.9(AUP- 64) |
| Maximum | 146(AUP-9) | 202(AUP-40) | 3.8 (AUP- 40) |
| Mean | 135.9 | 128.4 | 2.8 |
| **Mean across all** | Minimum | 138.5(AUP-3) | 137.9(AUP-53) | 2.8 (AUP- 64) |
| **Environment** | Maximum | 147.4(AUP-19) | 226.0(AUP-30) | 4.1 (AUP- 3) |
|  | Mean | 143.9 | 158.0 | 3.6 |

**Table 3.2. Means of 90 rice genotypes for various parameters across eight environments during 2020and 2021 rice growing seasons.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Rice genotypes** | **Days to maturity** | **Grains panicle-1** | **Grain yield (t ha-1)** | **Rice genotypes** | **Days to maturity** | **Grains panicle-1** | **Grain yield (t ha-1)** |
| **AUP-1** | 142 | 147 | 3.4 | **AUP-47** | 143 | 165 | 3.4 |
| **AUP-2** | 143 | 156 | 3.4 | **AUP-48** | 139 | 159 | 3.5 |
| **AUP-3** | 139 | 214 | 4.2 | **AUP-49** | 143 | 165 | 3.5 |
| **AUP-4** | 143 | 141 | 3.5 | **AUP-50** | 143 | 158 | 3.4 |
| **AUP-5** | 143 | 157 | 3.5 | **AUP-51** | 145 | 142 | 3.5 |
| **AUP-6** | 145 | 163 | 3.4 | **AUP-52** | 144 | 159 | 3.4 |
| **AUP-7** | 144 | 154 | 3.4 | **AUP-53** | 144 | 138 | 3.4 |
| **AUP-8** | 144 | 158 | 3.4 | **AUP-54** | 144 | 148 | 3.4 |
| **AUP-9** | 144 | 171 | 3.5 | **AUP-55** | 143 | 145 | 3.6 |
| **AUP-10** | 143 | 155 | 3.6 | **AUP-56** | 143 | 150 | 3.4 |
| **AUP-11** | 143 | 144 | 3.2 | **AUP-57** | 142 | 165 | 3.3 |
| **AUP-12** | 142 | 151 | 3.4 | **AUP-58** | 143 | 167 | 3.2 |
| **AUP-13** | 143 | 144 | 3.4 | **AUP-59** | 144 | 145 | 3.3 |
| **AUP-14** | 144 | 147 | 3.3 | **AUP-60** | 144 | 149 | 3.5 |
| **AUP-15** | 144 | 149 | 3.3 | **AUP-61** | 145 | 158 | 3.3 |
| **AUP-16** | 145 | 158 | 3.5 | **AUP-62** | 145 | 142 | 3.4 |
| **AUP-17** | 145 | 149 | 3.4 | **AUP-63** | 144 | 155 | 3.3 |
| **AUP-18** | 144 | 155 | 3.4 | **AUP-64** | 147 | 154 | 2.8 |
| **AUP-19** | 147 | 154 | 3.4 | **AUP-65** | 144 | 149 | 3.4 |
| **AUP-20** | 144 | 166 | 3.5 | **AUP-66** | 145 | 157 | 3.5 |
| **AUP-21** | 145 | 160 | 3.4 | **AUP-67** | 146 | 153 | 3.6 |
| **AUP-22** | 146 | 148 | 3.5 | **AUP-68** | 145 | 153 | 3.5 |
| **AUP-23** | 145 | 158 | 3.5 | **AUP-69** | 146 | 155 | 3.4 |
| **AUP-24** | 146 | 172 | 3.2 | **AUP-70** | 142 | 152 | 3.4 |
| **AUP-25** | 142 | 165 | 3.5 | **AUP-71** | 144 | 152 | 3.4 |
| **AUP-26** | 144 | 151 | 3.4 | **AUP-72** | 144 | 146 | 3.5 |
| **AUP-27** | 144 | 170 | 3.5 | **AUP-73** | 142 | 148 | 3.6 |
| **AUP-28** | 142 | 149 | 3.4 | **AUP-74** | 141 | 159 | 3.3 |
| **AUP-29** | 141 | 204 | 4.1 | **AUP-75** | 142 | 149 | 3.6 |
| **AUP-30** | 142 | 226 | 4.2 | **AUP-76** | 145 | 144 | 3.2 |
| **AUP-31** | 145 | 161 | 3.5 | **AUP-77** | 145 | 157 | 3.5 |
| **AUP-32** | 145 | 153 | 3.3 | **AUP-78** | 145 | 155 | 3.5 |
| **AUP-33** | 145 | 157 | 3.6 | **AUP-79** | 146 | 148 | 3.4 |
| **AUP-34** | 146 | 158 | 3.5 | **AUP-80** | 145 | 148 | 3.4 |
| **AUP-35** | 145 | 162 | 3.4 | **AUP-81** | 145 | 148 | 3.4 |
| **AUP-36** | 145 | 166 | 3.4 | **AUP-82** | 145 | 156 | 3.4 |
| **AUP-37** | 145 | 165 | 3.4 | **AUP-83** | 147 | 156 | 3.5 |
| **AUP-38** | 147 | 156 | 3.3 | **AUP-84** | 146 | 158 | 3.5 |
| **AUP-39** | 146 | 166 | 3.3 | **AUP-85** | 142 | 157 | 3.5 |
| **AUP-40** | 142 | 178 | 3.5 | **AUP-86** | 146 | 151 | 3.4 |
| **AUP-41** | 146 | 172 | 3.3 | **AUP-87** | 145 | 158 | 3.5 |
| **AUP-42** | 145 | 155 | 3.3 | **Pakhal** | 142 | 168 | 3.5 |
| **AUP-43** | 142 | 162 | 3.5 | **K-Bas** | 144 | 166 | 3.4 |
| **AUP-44** | 144 | 154 | 3.4 | **F-MLD** | 146 | 201 | 3.8 |
| **AUP-45** | 146 | 149 | 3.5 | **Means** | **144** | 160 | 3.5 |
| **AUP-46** | 142 | 165 | 3.4 | **LSD (0.05)** | **2.81** | 15.8 | 0.19 |

Fig 3.1. GGE Biplot for days to maturity including A= GGE biplot, B= which won where/what C= discriminating vs. representativeness and D= Mean vs. Stability

|  |  |
| --- | --- |
| **A** | **B** |
| Days To Maturity  **C** | **D** |

Fig 3.2. GGE Biplots for grains panicle-1 including A= GGE biplot, B= which won where/what C= discriminating vs. representativeness and D= Mean vs. Stability

|  |  |
| --- | --- |
| **A**  E:\Data analysis and report\aziz material\for AMMI\AMMI analysis\GGE BIPLOT\AZIZGGE GRP\GGE1.jpg | **B**  E:\Data analysis and report\aziz material\for AMMI\AMMI analysis\GGE BIPLOT\AZIZGGE GRP\GGE3.jpg |
| E:\Data analysis and report\aziz material\for AMMI\AMMI analysis\GGE BIPLOT\AZIZGGE GRP\GGE4.jpg  **C**  Grains Panicle-1 | E:\Data analysis and report\aziz material\for AMMI\AMMI analysis\GGE BIPLOT\AZIZGGE GRP\GGE5.jpg  **D** |

Fig 3.3. GGE Biplots for grains yield including A= GGE biplot, B= which won where/what C= discriminating vs. representativeness and D= Mean vs. Stability

|  |  |
| --- | --- |
| **A** | **B** |
| Grain yield  **C** | **D** |

Fig 3.4. GGE Biplots for ranking genotypes including A= days to maturity, B= grains panicle-1, C= grain yield = point of ideal genotype

|  |  |
| --- | --- |
| **A**    Days to maturity | **B**  ­­­­­­­­E:\Data analysis and report\aziz material\for AMMI\AMMI analysis\GGE BIPLOT\GRP\GGE7.jpg  Grains panicle-1 |
| **C**  Grain yield |

**4. DISCUSSION**

Traits like early maturity enable the breeders to develop high yielding and short duration varieties through getting optimum duration for grain developments (Akter et al., 2014). Rice genotypes were tested in a variety of habitats, and results showed significant differences between genotypes, environments, and genotype by environment interactions for days to maturity (Haradari et al., 2017). In their study, rice genotypes 23-5-108 showed early maturity (116 days). Ogunbayo et al., 2014 examined 48 rice genotypes over 12 sites, and substantial differences were found for habitats, genotypes, and the interaction between genotype and environment. They observed a mean value of 119 days for maturity parameter in their tested genotypes. In addition, selection conducted for high values of the yield components, revealed that the number of grains panicle-1 could be used as selection criteria in rice breeding Surek and Beser (2015). The findings of this study agree with those of Luguterh et al. (2016) and Dewi et al. (2014). 15 rice genotypes were examined by Luguterh et al. (2016) using a complete randomised block design with three replications in four different sites. For factors related to yield, the combined analysis of variance revealed substantial genotype and environment interaction. Similar to this, Dewi et al. (2014) assessed the yield and qualities associated with yield in six environments using ten advanced rice lines and two control varieties. They found that the genotypes for grains panicle-1 responded differently across diverse conditions. The quantity of seeds in panicle-1, a quantitative feature of rice, directly affects the crop's production. Selecting the best genotypes with the highest stable yields by exposing the potential lines to a number of various environmental conditions is one of the most difficult jobs involved in developing high yielding genotypes. Loffler et al., 2005 and Kaya et al., 2002. The findings of Akter et al. (2015) and Staso et al. (2016) are consistent with the findings of the current investigation. Akter et al. (2015) used a randomized complete block design with three replications and four locations to assess 12 rice genotypes. Differences between genotypes, habitats, and GEI were extremely significant (P 0.01) in terms of grain yield, according to the analysis of variance. Similar to this, Staso et al. (2016) evaluated 20 rice genotypes utilizing six settings for yield and attributes associated to yield and found that the genotypes responded differently for grain yield depending on the environment. The highest grain yield was found to be produced by the rice genotype IR79156A/PK88 (6.11 t ha-1). The development of high yielding genotype, which affects the future of the crop, its growers, and the nations, is a crucial component of every plant breeding programme.

The differential response of 90 rice genotypes across eight settings for grain yield and other production parameters was confirmed by the GGE biplot. Days to maturity, grains panicle-1, and grain yield changes owing to GEI were each explained by the first two primary components to a cumulative extent of 63.2%, 53.4%, and 50.9%, respectively. The current experiment's findings concur with earlier research by Lakew et al., 2014 and Khatun et al., 2015. Using GGE biplot analysis to divide GE interaction, Khatun et al. (2015) found that PC1 and PC2 were responsible for 86.5% and 86.7% of the GGE sum of squares, respectively. In their study of rice, Lakew et al. (2014) found that the first two main components together explained 79.9% of the variance. In the current biplot, the genotypes were distributed inside the polygon that was produced by connecting the vertex genotypes with straight lines. Because they were the furthest from the biplot origin, the placements indicated that these genotypes were either the best or the worst performers in all or some of the tested environments Yan and Kang, 2003. AUP-3 and AUP-40 genotypes won the sectors with the best genotypes. It can be concluded that a superior genotype can be successfully adapted for days to heading in Peshawar (E-1) and Charsadda (E-4), whereas genotypes AUP-3 and AUP-30 can be successfully adapted for grain panicle-1 and grain yield in Peshawar (E-1 and E-5) and Mansehra (E-3 and E-7). The standard deviation of cultivar means present in the environment, considered to be a measure of the environment's discriminating capacity, is directly proportional to the environment vector length. Test settings that regularly lack discrimination (are non-informative), which means they don't reveal enough about the genotypes. The same biplot for representativeness of test environments is shown, with the addition of a "Average-Environment Axis" by Yan and Hunt (2001). It should be observed that the AEA line passes through both the biplot origin and the typical environment. The little circle with the average coordinates of all test environments has been used to represent the average environment. If a test environment has a smaller angle with the AEA, it is more likely to be representative of other test conditions (Khatun et al. 2015). Although the "ideal" genotype may not exist in reality, it can nevertheless be used as a guide when assessing genotypes. 2012 Mitrovia et al. Any genotype that is placed nearer to the "ideal" genotype will be regarded favourably. Mitrovia et al. (2012) and Kaya et al., 2002. On the graph, the genotype ranking is represented by the so-called genotype "ideal" genotype. A genotype is considered to be excellent if it consistently performs at the highest level across all test settings and has the best yield. Farshadfar et al. (2012) and Yan and Kang (2003). E-4 (Charsadda) was the optimal habitat for days to maturity because it was close to the ideal location. The settings in Peshawar and Swat were good for grains panicle-1 and grain yield. The cosine of the angle between the vectors, which are actually lines connecting the environments to the biplot origin, defines the relationship between testers in the "relationship among testers". Greater relationship between surroundings and the angle is indicated by Yan and Kang's (2003) and Yan and Tinker's (2006) findings. The close link between the environments E-1, E-3, and E-7 in this instance is indicated by their smaller angles with one another. The environments E-2 and E-6 were similar in this regard. A negative link between these environments, which provide opposing circumstances to separate genotypes, is suggested by the angle of environment E-04 with environments E-2 and E-6 being >90o. Longer vectors in environments E-4, E-7, and E-8 made it possible to choose between different genotypes for grain yield.

The current study discovered conditions that can be used to effectively select people based on attributes in the appropriate places. Testing genotypes in various situations is important, but identifying the best and optimum genotype is even more important. It is important to note that while identifying the optimum genotype may not be entirely accurate, it can be used as a guide. A genotype with high yield and consistent performance across a range of conditions is preferable. In 2003, Yan and Kang. It implies that a high steady yield may be obtained in test conditions with a certain genotype. Yan et al., 2007.

**5. CONCLUSION**

In the current study, AUP-3 and AUP-30 stand out as not only among the highest yielding lines for all the studied traits but was also highly stable ones across the environments. These genotypes were identified as desirable genotype for all the studied traits.

**Abbreviation:**

**Author Contributions:** Aziz Ur Rehman; Main author, perform research, data collection, data analysis and writeup.

Faiz Ur Rehman; Help in data collection, data analysis, writeup and presentation.

Syed Mehr Ali Shah; Design research, proof reading of manuscript.

Muhammad Ali Shah and Abdul Waheed; Help in data collection and data organizing.

Roohul Amin; Help in research management.

Syed Majid Rasheed; Corresponding author.

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