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AMMI-BIPLOT ANALYSIS OF YIELD PERFORMANCES OF BREAD WHEAT CULTIVARS GROWN AT DIFFERENT LOCATIONS

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ABSTRACT

The purpose of the study was to determine the stability and yield performances of 20 bread wheat cultivars grown in nine different environments. The trials were arranged in a Randomized Complete Block Design with four replications. Additive main effects and multiplicative interactions analysis (AMMI-biplot) indicated that the yield performances of bread wheat cultivars were highly affected by the major environmental factors. The first two principal component axes (PCA 1 and PCA 2) were significant and they explained 60.9 % of the total genotype x environment interaction. A biplot generated using genotypic and environmental scores of the first two AMMI components demonstrated that cultivars with larger PCA 1 and lower PCA 2 scores were high yielding and stable cultivars and cultivars with lower PCA 1 and larger PCA 2 scores were low yielding and unstable cultivars in tested locations. It could be concluded that the Basribey 95 had the highest yield performance and also the stable genotype in the test locations. İzmir 85 and Ziyabey 98 were poorly stable although they showed high yield performances in some of test environments. Momtchill had the lowest yield performance in all test locations. It was detected that Menemen location could be the most representative among the tested locations to determine the stability of bread wheat cultivars to recommend the farmers in the Western Coastal Zones in the Aegean Region under Mediterranean climatical conditions of Turkey.

Key Words: Bread wheat, AMMI-biplot analysis, genotype-environment, yield.

INTRODUCTION

Multi-location trials play an important role for plant breeders due to the high Genotype x Environment Interaction (GEI). The GEI complicate the process of selecting genotypes with superior performance and stability Therefore the GEI is an important in the plant breeding programs because it reduces the success of selection in any environment (Yau, 1995; Alberts, 2004). The genotype x environment interactions are mostly interpreted by using parametric and non-parametric methods. Promising lines are tested at different locations and years in order to determine the best genotypes for target areas. At this point, the GEI due to different responses of genotypes in diverse environments causes difficulties in choosing the superior genotypes in the plant breeding programs. Besides the GEI could not fully be explained with parametric methods and especially with conventional analysis of variance. Since the error variances over environments are heterogeneous. For example, the analysis of variance technique fails to demonstrate the mode of responses of genotypes and environments. However nonparametric approaches may provide more reliable estimates of genotype performance than considering the mean yield across environments also biplot technique helps to visualize relationships among genotypes and environments.

One of the non-parametric methods recommended by Gauch and Zobel (1996) is the Additive Main Effects and Multiplicative Interaction (AMMI). The model includes analysis of variance for additive main effects and Principal Component Analysis (PCA) for interaction effects (Yildirim et al., 1999; Akcura et al., 2009; Ilker et al., 2009; Akcura et al., 2011). The AMMI statistical model has been widely used to explain complicate GEI, to enhance selection efficiency and to ensure genetic gain from selection. The method is based on singular value decomposition (SVD) or principal component analysis (PCA) and is also considered to be an effective tool to diagnose the GEI patterns graphically.

Kaya et al. (2002) stated that expressing high PCA1 and low PCA2 genotypes are high yielding and stabile on the other hand genotypes with low PCA1 and high PCA2 are low yielding and not stable. Solomon et al. (2008) using the AMMI-biplot method for 15 maize genotypes in 9 environments in Ethiopia, reported that genotypes gathered in 4 groups and environments in three groups.

Nachit et al. (1992) evaluated durum wheat genotypes in a Mediterranean climate conditions with AMMI and linear regression models and they pointed out that sum of square in the AMMI method was 6 times higher than that of the regression model and they concluded that predictive assessment is a useful statistical tool in estimating precise yield to make accurate and successful selection in the durum wheat breeding programs. Furthermore Annicchiarico (1997) stated that AMMI analysis appears particularly useful for depicting adaptive responses of small grains tested over Italy. At the same time, the researcher explained that the joint regression and the AMMI analysis were more likely similar for small grains over coastal and southern areas of Italy, where cold stress is the limiting factor.

The aim of this study was to evaluate the GEI in order to determine superior and stabile bread wheat cultivars and also to discriminate environments by using the AMMI-biplot method in the Mediterranean coastal zone of Turkey.

MATERIALS AND METHODS

Twenty bread wheat varieties were tested in the following 9 environments [Menemen 00-01(E1), Bandırma 00-01(E2), Salihli 00-01(E3), Menemen 01-02(E4), Menemen 02-03(E5), Dalaman 02-03(E6), Menemen 03-04(E7), Dalaman 03-04(E8) and Bandırma 03-04(E9)] between 2001 and 2004. The Randomized Complete Block Design with four replications was used. One plot consisted of 8 rows, 5 m long and of 20 cm apart. 80 kg ha^{-1} pure phosphor (P_2O_5) and one half of 160 kg ha^{-1} pure nitrogen (N) were applied at sowing time and the rest of other nitrogen was applied at the stem elongation time for each trial. Grain harvest was performed in June for the all environments. Initially, grain yield was measured in grams per plot over 6 m^2 and then converted into kilogram per hectare (kg ha^{-1}).

Cultivars tested in this study were developed by the different research institutes and registered in Turkey (Table 1). Some combinations of years between 2001 and 2004 and four locations were treated as nine environments (E1-E9). The mean yields of cultivars over environments were presented at Table 2. The data were analyzed by the AMMI analysis to determine the effects of GEI on yields and GEI was partitioned into nine interaction principal components axes (IPCA), using XLSTAT developed by Addinsoft (2010) for MS Excel.

Table 1. Bread wheat cultivars used in the experiments

Code	Cultivar	Year of Registration	Owner
G1	Adana 99	1999	Çukurova Agricultural Researches Institute
G2	Bandırma 97	1997	Sakarya Agricultural Researches Institute
G3	Basribey 95	1995	Aegean Agricultural Researches Institute
G4	Ceyhan 99	1999	Çukurova Agricultural Researches Institute
G5	Cumhuriyet 75	1976	Aegean Agricultural Researches Institute
G6	Golia	1999	General Directorate of Agricultural Enterprises
G7	Gönen 98	1998	Aegean Agricultural Researches Institute
G8	İzmir 85	1985	Aegean Agricultural Researches Institute
G9	Karacabey 97	1997	Sakarya Agricultural Researches Institute
G10	Karacadağ 98	1998	South-Eastern Anatolian Agricultural Research Institute
G11	Kaşifbey 95	1995	Aegean Agricultural Researches Institute
G12	Momtchil	2000	Sakarya Agricultural Researches Institute
G13	Nurkent	2001	South-Eastern Anatolian Agricultural Research Institute
G14	Pamukova 97	1997	Sakarya Agricultural Researches Institute
G15	Panda	2001	Çukurova Agricultural Researches Institute
G16	Seri 82	1991	Çukurova Agricultural Researches Institute
G17	Seyhan 95	1995	Çukurova Agricultural Researches Institute
G18	Tahirova 2000	2000	Sakarya Agricultural Researches Institute
G19	Yüreğir 89	2002	Çukurova Agricultural Researches Institute
G20	Ziyabey 98	1998	Aegean Agricultural Researches Institute

RESULTS AND DISCUSSION

The results of the AMMI partition of GEI for grain yield of 20 wheat varieties tested in 9 environments in the western coastal areas of Turkey are shown in Table 3. The effect of environment, genotype and GEI was accounted for 55%, 17% and 28% of treatment combination sum squares, respectively (Table 3). The significant GEI indicated the possibility of further analysis. The high level of environmental effects indicated the significant differences were found among the environments for grain yield. Also, the effects of GEI were approximately twice than the genotype effects. This result of the AMMI analysis was partially in agreement with the results of Kaya et al. (2002) and Solomon et al. (2008).

Based on the mean grain yields of the cultivars over 9 environments are given (Table 2). The highest grain yield was obtained from Basribey 95 (7034 kg ha^{-1}) and the lowest grain yield from Momtchil (5093 kg ha^{-1}). The varieties registered by the Aegean Agricultural Research Institute had higher grain yield than other varieties in the western coastal areas of Turkey (Table 1 and 2).

Table 2. Grain yield (kg ha^{-1}) of 20 bread wheat cultivars at 9 environments

Cultivar*	E1	E2	E3	E4	E5	E6	E7	E8	E9	Mean
G1	6356	3845	9546	6437	5261	4658	7515	6458	6188	6251
G2	6650	4761	6887	6438	7022	5961	7400	6106	6471	6410
G3	7789	5724	8338	7410	6649	5884	8564	6397	6551	7034
G4	6801	4243	9263	6401	5688	5409	7689	7048	6913	6606
G5	7124	4732	5929	6116	5621	3392	7753	4893	6327	5765
G6	6825	5633	8048	6488	5352	5458	7806	7353	6592	6617
G7	6897	4755	6960	6783	6417	4635	7068	6093	6309	6213
G8	6929	6092	7169	6496	6524	5650	8735	6254	7431	6809
G9	6751	4838	7985	5967	6399	5384	7713	4673	6697	6267
G10	6251	3660	5532	6267	6241	5584	6483	5031	5525	5619
G11	7837	5284	5003	4793	5458	5464	7870	6629	6892	6137
G12	5442	4128	6213	3687	3983	4298	6213	5724	6151	5093
G13	6279	3898	8747	6490	6131	5757	7422	5896	7052	6408
G14	6280	4436	7329	5322	5527	4902	7134	4827	5522	5698
G15	5785	3630	7686	5419	5987	5223	5920	5934	6237	5758
G16	7050	4823	6349	4379	5937	4653	6981	5900	6599	5852
G17	6838	5247	8633	6304	6377	6656	7175	6195	6473	6655
G18	5613	4628	6371	5181	4789	5110	7705	7123	6807	5925
G19	5814	3232	7916	6357	5384	5599	7139	6161	6447	6005
G20	7379	4948	8694	6614	6800	6758	8373	6656	6512	6970
Mean	6634	4627	7430	5967	5877	5322	7433	6067	6485	6205

*: G1: Adana 99, G2: Bandırma 97, G3: Basribey 95, G4: Ceyhan 99, G5: Cumhuriyet 75, G6: Golia, G7: Gönen 98, G8: İzmir 85, G9: Karacabey 97, G10: Karacadağ 98, G11: Kaşifbey 95, G12: Momtchil, G13: Nurkent, G14: Pamukova 97, G15: Panda, G16: Seri 82 G17: Seyhan 95, G18: Tahirova 2000, G19: Yüreğir 89, G20: Ziyabey 98
Menemen 00-01(E1), Bandırma 00-01(E2), Salihli 00-01(E3), Menemen 01-02(E4), Menemen 02-03(E5), Dalaman 02-03(E6), Menemen 03-04(E7), Dalaman 03-04(E8) and Bandırma 03-04(E9). Codes (00-01, 01-02, 02-03 and 03-04) of the environments are the abbrevation of the years

The results of AMMI analysis given in Table 3 showed that the first interaction principal component axis (IPCA1) covered 42.62% of the GEI sum of squares while the second and third interaction principal component axis (IPCA2 and IPCA3) explained a further 18.30% and 15.95% of sum of squares of this interaction. The first five interaction principal component axes (IPCA 1-5) accounted for 90.08% of total GEI. Besides, sum of the squares of first three interaction principal component axes (IPCA 1, IPCA 2 and IPCA 3) were higher than the sum of squares of the cultivars. Although some researchers applied the AMMI model consist of more than two principal component axes in their AMMI analysis (Nachit et al. 1992), evaluation of the AMMI analysis depending on two principal component axes were commonly used. Since disturbance and complication mostly increase in the analysis based on more than two principal component axes (Kaya et al. 2002). For that reason, the first two interaction principal component axes (IPCA 1 and IPCA 2), which explained 60.92% of total GEI, were used in the AMMI analysis and in constructing the biplot to evaluate cultivars for adaptation of environments.

The AMMI biplot constructed by plotting the first two interaction principal component axes consists of four groups (Figure 1). The environments divided into two groups and E3, E4, E5 and E6 fall into the one group while E1, E2, E7, E8, E9 fall into another group. It could be seen that Basribey 95 (G3) and Ziyabey 98 (G20) were the best varieties for the environments in group one and G8 (İzmir 85) and G11 (Kaşifbey 95) for the environments in group two.

The cultivars placed the origin of plot were less responsive to the environments. Gönen 98 (G7) and Karacabey 97 (G9) had low grain yield due to their low IPCA 1 and IPCA 2 values.

Cultivars, with low PCA1 scores below zero and placed on the left side of the AMMI-biplot, had lower yield values than the mean yields across environments (Gauch and Zobel, 1996). Therefore cultivars Adana 99 (G1), Cumhuriyett 75

(G5), Karacadağ 98 (G10), Momtchil (G12), Panda (G15), Seri 82 (G16) and Yüreğir (G19) were unstable and low yielding for all the environments tested in the study. On the other hand, cultivars with PCA1 scores nearly zero were stable for all the environments but they had average grain yield across environments. However low and average yielding genotypes had stable yield that does not benefit from the favorable environments (Hill et al., 1998).

Table 3. Additive main effects and multiplicative interactions analysis of variance for grain yield (kg ha^{-1}) of the bread wheat cultivars across environments.

Source	Degrees of freedom	Sume of square.	Mean square	F values	(%) GxE Explained
Environments (E)	8	5379608.450	672451.056	214.819**	55
Genotypes (G)	19	1705520.014	89764.211	28.676**	17
GxE	152	2750837.399	18097.614	5.781**	28
IPCA 1	26	1172269.358	45087.283	14.403**	42.615
IPCA 2	24	503293.211	20970.550	6.699**	18.296
IPCA 3	22	438758.565	19943.571	6.371**	15.950
IPCA 4	20	214812.892	10740.645	3.431**	7.809
IPCA 5	18	148600.236	8255.596	2.637**	5.402
IPCA 6	16	103981.654	6498.853	2.076	3.780
IPCA 7	14	84698.284	6049.877	1.933	3.079
IPCA 8	12	64177.037	5348.086	1.708	2.333
IPCA 9	10	20246.163	2024.616	0.647	0.736
Eror	513	1605848.636	3130.309		

**: Significant at the 0.01 probability level.

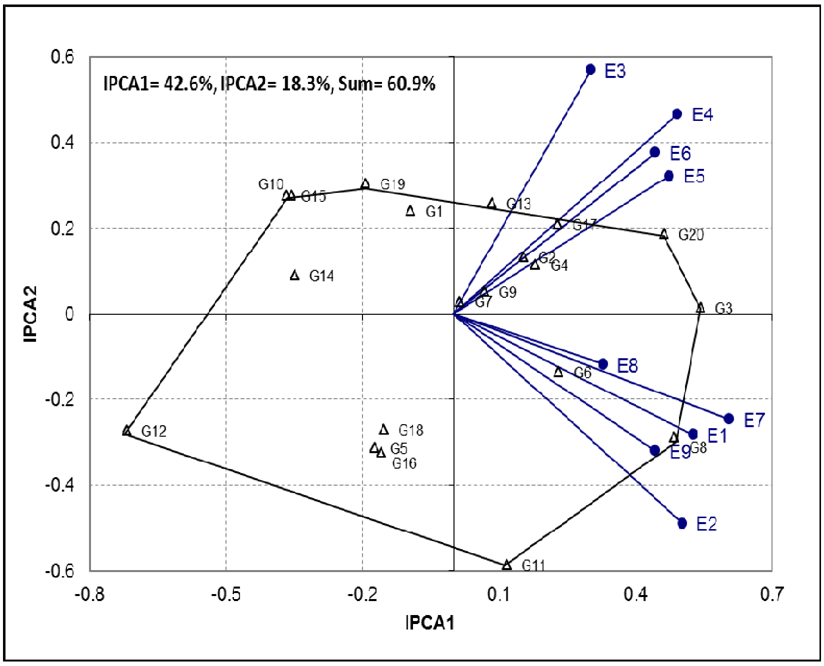

Figure 1. Based on genotype and environment scores, AMMI-biplot for 20 bread wheat cultivars using the mean grain yield obtained from 9 environments.

The Basribey 95 (G3) was the high yielding genotype with considerably high stability. This result was in agreement with Bayram and Demir (2009). Menemen (E7) between the years 03-04 was the furthest environment from the origin with low PCA2 scores and it was the best ideal location for determining differences among genotypes. Although Dalaman 03-04 (E8) had lower PCA2 scores, it was the closest environment to the origin thus it could possibly be the most unfavorable location for evaluation of differences among cultivars.

In conclusion, based on the AMMI-biplot analysis Menemen location could be the best representative area among tested locations to determine the bread wheat cultivars and lines to be recommended for the farmers. But this conclusion should be tested by studying the correlation between this location and others in the target area. Also the AMMI results showed that Basribey 95 and Ziyabey 98 are suitable cultivars for Western Coastal Zones in Aegean Region, where climate dominated by the Mediterranean climatical condition.

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