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Full Length Research Paper

Yield stability of promising lines of winter and facultative wheat in different climate of Iran

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Fourteen genotypes were studied for grain yield and its stability in different climate of Ardebil, Eqlid, Arak, Zanjan, Tabriz, Mashhad, Jolgerokh, Miandoab, Hamedan and Karadj using randomized complete block design with three replications in two years; results of combined analysis of variance showed that the interaction effects of year × location and genotype × year × location were significant at 1% probability level. For determination of genotypes with high yield and stability, parametric and non-parametric statistics were used among the methods which were used, AMMI model was found more effective than the others. Based on AMMI (AMMI1, AMMI2 and AMMI3) results, genotypes number 2, 5, 6, 7, 8 and 9 were determined as stable in most of the locations, genotypes number 9, 10 and 13 for Karadj, number 2 for Zanjan, number 4 for Jolgerokh and Ardebil, and number 7 for Mashhad showed specific adaptability.

Key words: Yield stability, promising lines, additive main effects and multiplicative interaction (AMMI) analysis.

INTRODUCTION

The best way to get the type of genotypes which are able to produce optimal yield in diverse climatic conditions is selecting high-yield genotypes which has a broad compatibility feature in diverse climatic conditions (Bigonah et al., 2005). Different methods are presented for statistical analysis, including parametric and nonparametric to estimate the nature of genotype interaction effects at environment and their control, but a method that was approved by everyone has not still been introduced (Kaya et al., 2006). The linear-bilinear models were helpful for data analysis of regional experiments and for explaining genotype interaction effects at environment and meanwhile the Aadditive Main effects and Multiplicative Interaction (AMMI) model are very important. AMMI method was performed by many researchers working on wheat, meanwhile we can refer to the researches of Bigonah Haml Abad on stability and drought tolerance of wheat (Bigonah et al., 2005), Akcura researches on the effects of genotype and environment on phenotypic characteristics and grain yield stability in different cultivars of durum wheat in Central Anatolia regions (Akcura et al., 2005), Tarakanovas studies on multiplicative incremental main effects in grain yield of wheat varieties in Lithuania and finally Sohail researches in the field of rotation and intercropping effects on wheat interactions (Tarakanovas and Ruzgus, 2006; Sohail and Riaz, 2004).

The AMMI analysis method had been tested on other crops, as well as wheat, that in this case Zobel and Crossa worked on analysis of multiplicative main effects on soybean interactions and on maize using data from multi-regional experiments, respectively (Zobel and Gauch, 1988; Crossa et al., 1990). Vijay Kumar used AMMI steps in the study of rice hybrids (Komar and Ramesha, 2001). Machiavelli studied AMMI analysis steps and genotype interactions on the environment which he called as fixed and mixing effects (Machiavelli and Balarini, 2002). In AMMI analysis steps, while drawing By-plots, the cultivars which their amount are about zero (IPCA) have general compatibility with experiment areas and their interaction is slight, in the bi-plots resulting from the AMMI analysis, locations or genotypes which have large interactions recognizes the private compatibility. In AMMI analysis, amounts of principal components may be positive or negative, the cultivars which possess the same values of IPCA for sign have had particularly positive interactions with each other while this interaction is as large as relevant amounts, and in contrast IPCA with contrary amounts represents negative interactions.

Table 1. Genotypes of winter and facultative bread wheat.

Row	Genotypes (ERWYT)	Pedigree	Type
1	C-81-1	Shahreyar(C-73-20)	Winter
2	C-81-2	C-75-5	Winter
3	C-81-3	1-61-12 /Tjn	Spring
4	C-81-4	Ald"s"/6/T.aest/5/Ti/4/La/3/Fr/Kad/Gb	Spring
5	C-81-5	Ures81//HD2206/hork"s"/1-67-78	Facultative
6	C-81-6	Fln/Acc//Ana/3/Pew"s"/4/F12.71/Coo//Cno97	Spring
7	C-81-7	Prl"s"/Pew"s"//Shi#4414/Crow"s"	Spring
8	C-81-8	BOW"s"/Crow"s"//GRU90-204781	Facultative
9	C-81-9	1-27-6275/Cf1770/5/Ghods/4/Anza/3/…	Winter
10	C-81-10	1-27-6275/Cf1770/5/Ghods/4/Anza/3/…	Winter
11	C-81-11	K2340/Sx//Mt/Gb/K340/Fr/Pi/…	Winter
12	C-81-12	Vee"s"/Tsi/5/wal/3/1154/45//Wal/Su92/4/Sol	Winter
13	C-81-13	Torik-15	Winter
	C-81-14	Vorona/Kauz	Winter

MATERIALS AND METHODS

For the evaluation of Additive Main effects and Multiplicative Interaction (AMMI) model based on agriculture experiments design grain yield of 12 winter and facultative bread wheat advanced genotypes with shahriar cultivar and C-73-2 line as testamental (Table 1) were evaluated in the form of randomized complete blocks statistical design with three replications in 10 different locations of Iran, including Karaj, Miandoab, Hamadan, Arak, Ardabil, Tabriz, Mashhad, jolgerokh and Eghlid in 2011. The consumption fertilizer was based on soil test with formula (50-90-120) nitrogen-potassium-phosphor, the irrigation is as flooding method in which there was one-time fall irrigation and four times spring irrigations. Indices and statistical parameters were used to evaluate stability by using under formula:

$$\delta^2 = \frac{\sum_i^q (Xij - Xoi)^2}{q-1}$$

Rick ecovalence with formula:

$$Wi^2 = \sum_{j=1}^q (Xij - \overline{X}io - \overline{X}oj + \overline{X}oo)^2$$

Finley Wilkinson method with formula:

$$bi = \frac{\sum_{j=1}^q (Xij - \overline{Xio})(\overline{Xoj} - \overline{X}oo)}{\sum_{j=1}^q (\overline{Xo}j - \overline{X}oo)^2}$$

Coefficient of variations with formula:

$$CVi = \frac{Si}{\overline{\overline{X}}i} \times 100$$

Eberhart Russell regression deviation variance with formula:

$$Yij = \mu i + BiIj + \delta ij \text{ , } \delta^2 di = (\sum \delta i^2 j/(N-2) - \delta^2 e/r$$

and detection index with formula:

$$R = [\frac{COV(x,y)}{\sqrt{V(x).V(y)}}]^2$$

and finally AMMI method with formula:

$$Y = \mu + gi + ej + geij + \varepsilon ijk$$

Obtained data from environmental variance parameter, Rick covalence, coefficient of variations, Finley Wilkinson, Eberhart Russell, intra-local variance of Line and Binz using statistical software of EXCEL, and statistical data related to cluster analysis with SPSS software using *UPGAMA* method and square coefficients with a distance 3.47 for genotypes and 3.16 for locations had been used, IRRISTAT software was used in order to estimate incremental effects related to AMMI analysis and to draw by-plots.

RESULTS

Combined variance analysis was conducted given fixed effects of genotypes and random effects of year and location (Table 2). The interaction between year and location was meaningful, indicating the difference of years in different places. The genotype effect was not meaningful which represents there was no difference in yield between genotypes and this can be in the same level for advancement of genotypes. Bilateral interactions of genotype × place and genotype × year was also non meaningful. Three-way interaction of genotype × local × year were highly significant, thus application of yield averages of genotypes was not efficient to select superior genotype and stability analysis should be used to estimate interactions. Results from stability analysis methods are presented in Table 3, according to results

Table 2. Analysis of combined variance in grain yield genotypes.

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Local	9	1483314606	164812734^{ns}
Year	1	62901189	62901189 ^{ns}
Year × local	9	980069511	108896612**
Block (Year × local)	40	114083240	2852081**
Genotype	13	26066180	2005091**
Genotype × local	117	14550246	1261113^{ns}
Genotype × year	13	7304906	561916^{ns}
Genotype × year × local	117	171788843	1468281**
Error	520	317451869	610484

** Significant respectively at 0.01 and ns non significant.

Table 3. Estimated yield stability parameters in testing.

Genotype	Detection index	Regression deviation (Sdi)	Finley Wilkinson method	Rick covalence	Shokula	Coefficient of variations	Environmental variance	Amplitude changes	Intra-local variance
1	0/90	288637	0/09*	2645418	325513	24	2577212	4906	5841712
2	0/08*	2411769	1/07*	878385*	96505*	22/79	2324743	4298	5715724
3	0/92	263711	1/14	3165436	392907	25/04	2804506	4745	6631332
4	0/95	171095*	1/21	2176561	264749	26/06	3038686	4847	5655961
5	0/94	147976*	1/03*	1206973	139090	22/24	2213154	4130*	3711348*
6	0/94	113253*	0/97	426660*	37962*	20/95*	1963878	3378*	2545155*
7	0/96	95433*	0/99	735326*	77965*	21/34	2038273	3301*	2950322*
8	0/94	119463*	0/94	1242608	143708	20/38*	1857547	3168*	3366517*
9	0/95	127282*	1/02*	1121250	127980	21/94	2153114	4009*	3533659*
10	0/88	182045*	0/94	1957404	136346	20/68*	1913308	4261	4293386*
11	0/88	236859	0/91	1256838	145552	20/27*	1838893	4160	3482325*
12	0/82*	337830	0/83	3202487	397709	19/20*	1648926	4291	5591264
13	0/89	269367	0/98	2539814	311826	21/88*	2141065	4197	5266293
14	0/90	188919	0/88*	1781238	213515	19/42*	1688019	3322*	3875035*

*Stability line.

from evaluation of methods determining the stability of genotypes, it was concluded that genotypes 2, 5, 6, 7, 8, 9 had stable form in evaluation of most parameters, while genotypes 1, 4, 11, 12, 13 showed a relatively stable form in a few of under-study methods present in this table. Genotype of 3 had unstable form in all studied methods determining stability in this part, including coefficient of explanation, mean

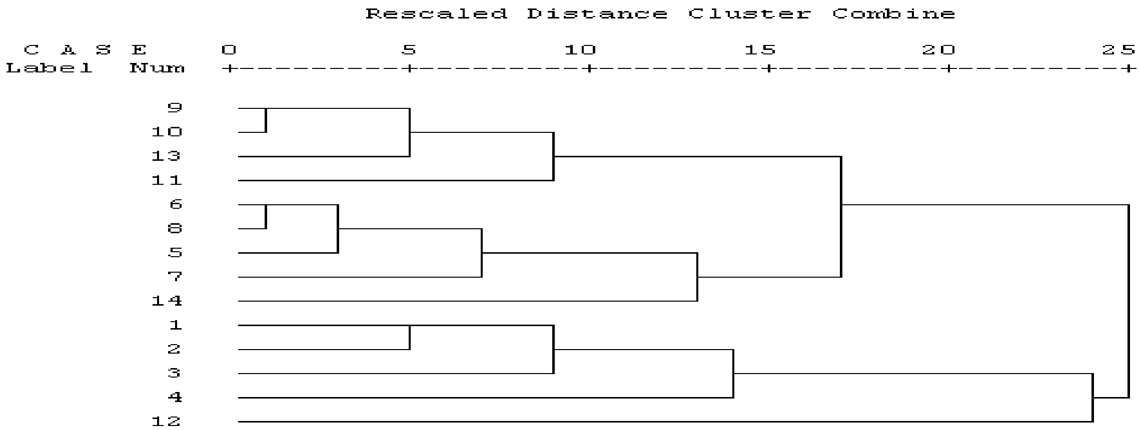

Figure 1. Cluster analysis of wheat cultivars and lines.

Table 4. Results of a variance analysis AMMI model.

Source of variation	Degrees of freedom	Sum of square	Mean square
Genotype	13	4343210	334093
Local	9	247218000	27468700
Genotype × local	117	24593800	21203
AMMI1	21	9475310	451205**
AMMI2	19	5508430	289917**
AMMI3	17	4258280	2504878**
AMMI4	15	2477560	165170**
Residual (E×G)	45	2874210	-
Total	139	276155000	-

** Significant at 0.01.

deviation of regression square, regression slope of Finley Wilkinson, Rick ecovalence, Shokla, coefficient of variation, environmental variance, variations slope and intra-spatial variance. In cluster analysis between cultivars and lines in ten different places, Arak, Ardabil, Eghlid,Hamedan, Jolgerokh, Karaj, Mashhad, Miandoab, Tabriz, Zanjan, of 14 under-study lines, in cutting place at a distance of 3.74 in terms of square, the number of lines were examined using UPGAMA method, and in this study, according to Dendrogram (Figure 1) based related to genotypes, lines 9 and 10 were placed in one cluster and lines 5, 6, 8 were placed in other cluster and other lines individually were placed in an independent cluster.

In the 2nd dendrogram related to cluster analysis of different places which was evaluated at a distance of 3.16 from cutting place using the squares of number of locations by UPGAMA method, experiment locations No.1 and 3 means Arak and Eghlid were placed in one group, experiment locations No. 9 and 10 means Tabriz and Zanjan were placed in one group, and locations No. 7 and 8 means Mashhad and Miandoab were place in other independent group and all of locations 2, 4, 5 and 6 means Ardabil, Hamedan, jolgerokh and Karaj were placed in other independent group. The results from AMMI analysis showed that all four principal components AMMI 1, AMMI 2, AMMI 3 and AMMI 4 were meaningful in probability level of 0.01% (Table 4). Based on software estimation in IRRISTAT program, Models of AMMI 1, AMMI 2 and AMMI 3 have justified 94.5, 60.9 and 78.2% of the total variations related to genotypes interactions in the environments respectively. All three first principal components (AMMI 1, AMMI 2 and AMMI 3) which were meaningful in probability level of less than 0.01 and have the highest percent of total variations related to genotypes interaction in the environments were used in decision making about stability of genotypes and drawing of by-plots. In by-plot No.1 (Figure 3), circular black spots represent experiment locations and low color triangle spots are represented genotypes, whatever these spots are near zero or origin of coordinates, so they have little interactions and if their yield is high, then they would be more stable and spots which are farther from the origin of coordinates are unstable, accordingly, genotypes, 2, 5, 6, 7 and 8 were near zero or origin of coordinates, so that they placed on group of genotypes which are high-yield and have good stability, in this study based on by-plot

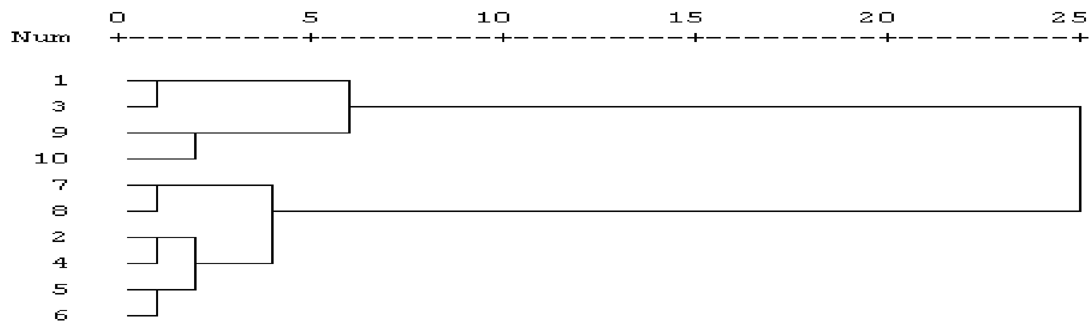

Figure 2. Cluster analysis places of experiment (1-Arak-2 Ardabil -3 Eqlid -4 Hamadan -5 Jolgerokh -6 karaj -7 Mashhad -8 Miandoab -9 Tabriz -10 Zanjan).

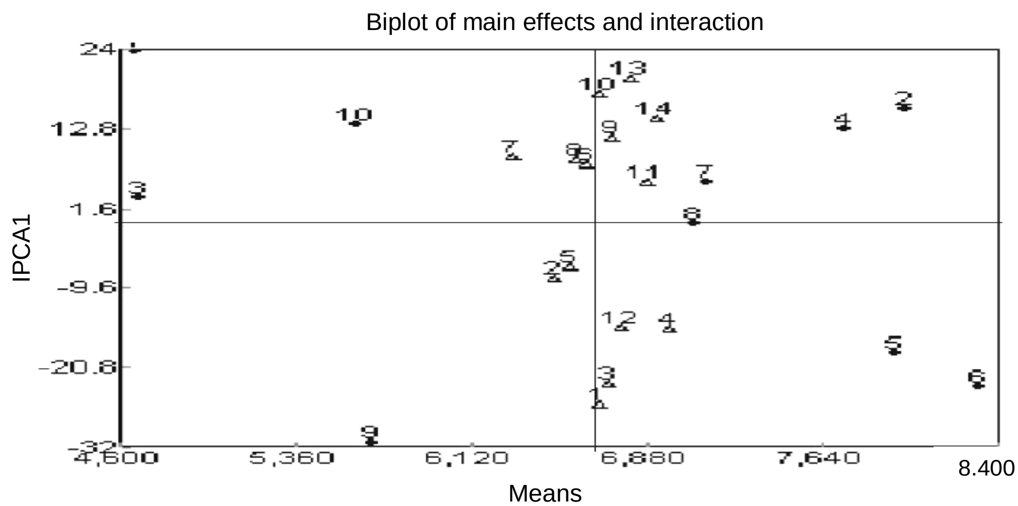

Figure 3. Main and interaction effect for AMMI1 method for 14 genotype in 10 locals of 1-karaj 2-miandoab 3-hamadan 4-mashhad 5-jolgerokh 6-ardabil 7-arak 8-tabriz 9-zanjan 10-eqlid.

No.1 (Figure 3) in contrary, genotypes 1, 3, 10 and 13 are farther from the origin of coordinates and they are unstable.

In this model, locals of 7 and 8 means Tabriz and Arak are near to each other and accordingly these locations placed in one group, locals 2 and 4 means Miandoab and Mashhad and local 5 and 6 means Ardabil and Jolgerokh were placed in one group due to being close to each other. In by-plot No.2 (Figure 4) related to model AMMI 2 in which locations and genotypes are displayed as linear and points respectively, genotypes 1, 3, 11, 12 and 14 were more far away from the origin of coordinates and based on this model they are recognized as unstable genotypes, accordingly genotypes 2, 4, 6, 7, 8 and 9 are near to origin of coordinates and they have general compatibility relation to the most regions. Based on Figure 2 related to by-plot of AMMI 2 model, genotypes9, 10 and 13 have exclusive compatibility to place of Karaj, because of being close to the line related to location No.1 means Karaj, likewise genotype 2 compared to location No. 9 means Zanjan and genotype 4 compared to locations 5 and 6 means Ardabil and Jolgerokh have exclusive compatibility, in this case genotype 7 has had exclusive compatibility as compare with location 4 means Mashhad. According to the by-plot resulting from the interaction analysis of genotype in the environment of AMMI 2 model, locations 2 and 10 means Miandoab and Eghlid are close to each other and have the angle less than 90° to one another and are placed in one group (Figure 4), therefore in the obtained by-plot, locations 3, 7 and 8 means Hamedan, Arak and Tabriz were also placed in one group, consequently locations 5 and 6 means Jolgrokh and Ardabil are replaced in one group, in this study locations 1 and 9 means Karaj and Zanjan are placed on independent group individually. Considering by-plot 3 (Figure 5) related to the genotype share (IPCA1 × IPCA2) AMMI3 model, genotypes 2, 5, 6, 7, 8 and 9 are near to origin and have lower interactions, and they are more stable than other genotypes, genotypes 1, 3, 10, 11, 12, 13, 14 are farther from the origin and have more

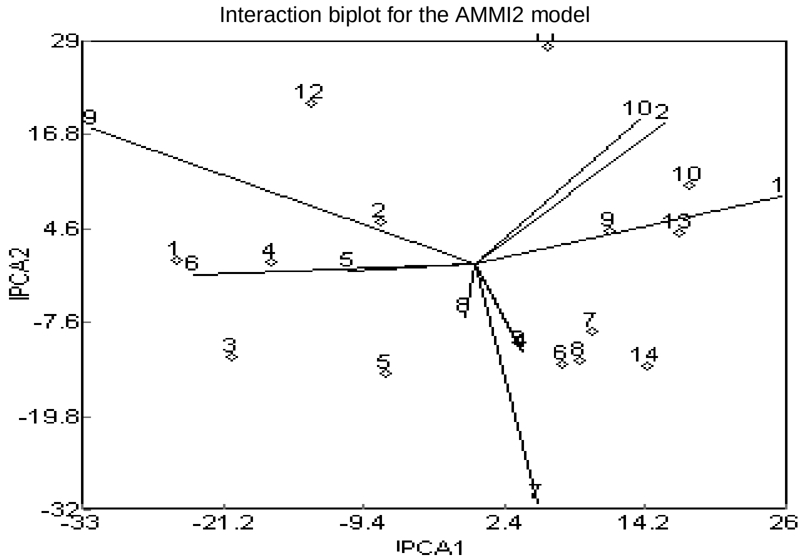

Figure 4. Main and interaction effect for AMMI2 method for 14 genotype in 10 locals of 1-karaj 2-miandoab 3-hamadan 4-mashhad 5-jolgerokh 6-ardabil 7-arak 8-tabriz 9-zanjan 10-eqlid.

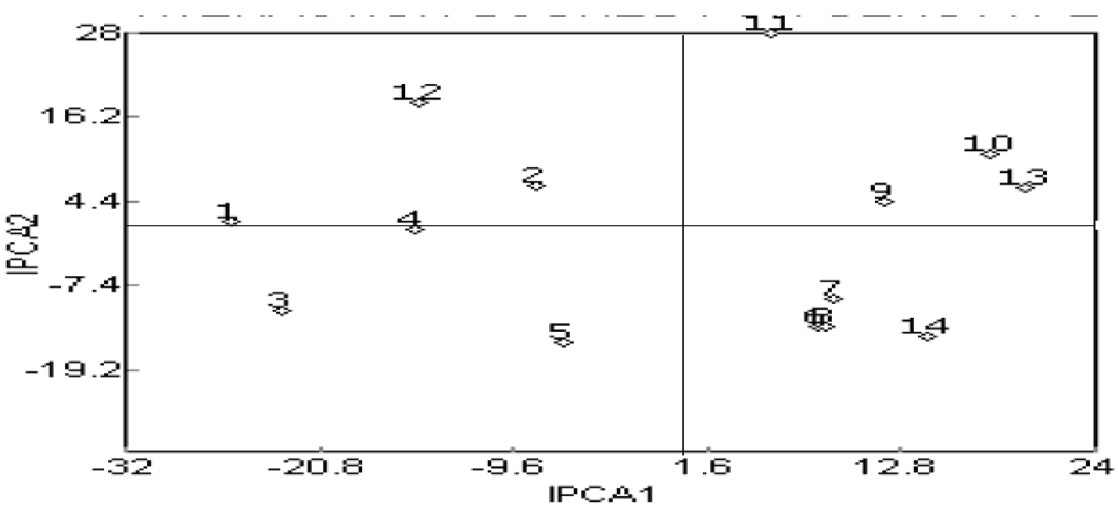

Figure 5. Main and interaction effect for AMMI3 method for 14 genotype in 10 locals of 1-karaj 2-miandoab 3-hamadan 4-mashhad 5-jolgerokh 6-ardabil 7-arak 8-tabriz 9-zanjan 10-eqlid.

severe interactions they are unstable based on this model.According to four by-plots related to share (IPCA1 × IPCA3) model AMMI3, genotypes number, 2, 5, 6, 7, 8, 9, 11, near to origin of coordinates has little interaction effects thus they are stable, genotypes number 1, 3, 10, 13, 14 farther from the origin of coordinates and have more severe interaction effects they are unstable based on this model. According to the by-plot No.5 (Figure 7) related to interactions share (IPCA2 × IPCA3) of AMMI 3 model, genotypes 4, 11, 12, 14 farther from the origin coordinates and have more severe interaction effects they are unstable based on this model, so on the other genotypes, genotypes 1, 2, 3, 7, 9, 13 in this model are near to the origin of coordinates and they have less interactions and have general compatibility with the environment.

DISCUSSION

In combined variance analysis in the experiment was performed (Table 2) existence of meaningful interactions between genotype and location and year had identified that application of mean yield of genotypes was not

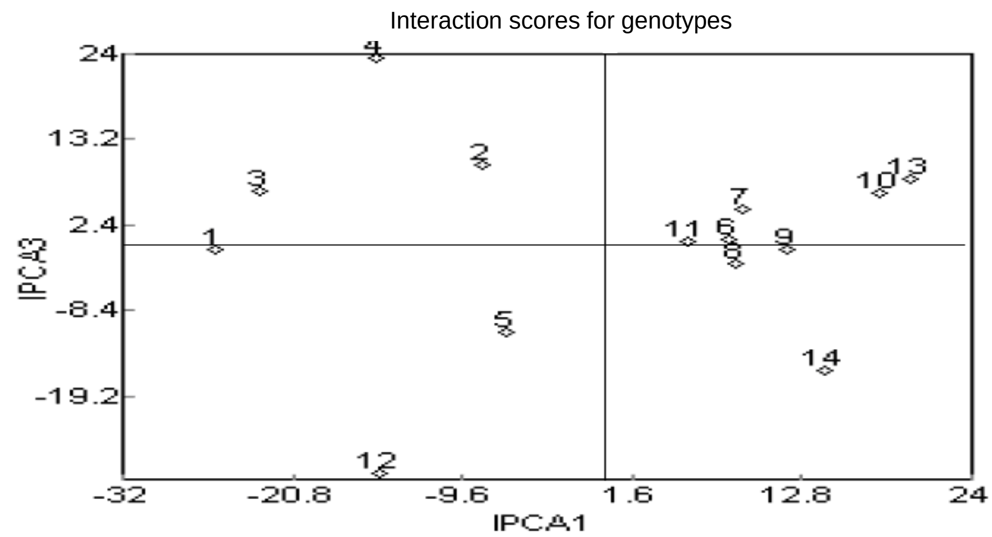

Figure 6. Main and interaction effect for AMMI3 method for 14 genotype in 10 locals of 1-karaj 2-miandoab 3-hamadan 4-mashhad 5-jolgerokh 6-ardabil 7-arak 8-tabriz 9-zanjan 10-eqlid.

effective to select the superior genotypes and we should use stability analysis to estimate interactions. Thus, in order to estimate interactions of different environments on different genotypes, in addition to different methods of stability analysis, to explain results Aadditive Main effects and Multiplicative Interaction AMMI model was used, in which all methods interpretation of interactions was effective and the results are similar with the results of AMMI and other performed studies (Vargas et al., 1999). According to Table 3, in the studies done in different parametric methods, genotypes 2, 5, 6, 7, 8, 9 are mostly stable and genotypes 1, 4, 11, 12, 13 are recognized as stable in a few methods. In estimation of nonparametric method of cluster analysis by UPGMA method for grain yield in genotypes, lines 9 and 10 were placed in one group and lines 5, 6, 8 were placed in another group and the rest of the lines were placed separately in separate groups finally (Figure 1). In evaluation of cluster analysis among 10 locations with the mentioned method for grain yield in hectare, locations Arak and Eghlid were placed in one group, Tabriz and Zanjan were also placed in one group, Mashhad and Miandoab were placed in one group and locations Ardabil, Hamedan, Jolgerokh and Karaj were placed in another group (Figure 2). Considering grain yield analysis by AMMI method, it was realized that all four principal components AMMI1, AMMI 2, AMMI3 and AMMI4 were meaningful in probability level of 0.01% (Table 4) and included the highest percentage of the total variations related to genotypes interactions in different places, and three first principals were used because of the highest percentage of variations in drawing of by-plots which its results in relevant by-plots (Figures 3, 4, 5, 6, 7) are compatible with Ackura and Sohail experiment (Ackura et al., 2005; Sohail et al., 2004).

In study of the resulting by-plots from different models of AMMI analysis genotypes 2, 4, 5, 6, 7, 8 and 9 have stable form in most environments which its results is consistent with assessments performed about stability analysis in different ways parametric methods contained in Table 3. Mean comparison experiments and especially stability of cultivars are mostly influenced by limitation factors like lack of time for experiments, lost plot and genotypes interactions in the environments which these factors results in making error in experiments, considering these experiments are expensive, so we should use suitable statistical method that modify these effects as possible. About which method is better for stability analysis, the general agreement among researchers has not been obtained (Bigonah et al., 2005) so far principles for evaluation of genotypes for stability in variable environmental conditions so far has not introduced any modification. Though according to their circumstances and tastes of one of the methods, set of methods for estimating the stability of use. Determine the best method to estimate interactions in the stability analysis, according to the AMMI model combines the analysis of variance and principal components analysis which separated the additive variance from the multiped variance and makes the main components on the effects of interaction with more details to describe this method for data analysis and interpretation of tests results in regional interaction genotype environment interactions is useful.

Similar stability test was conducted on winter wheat genotypes for private adaptation to the different environment by AMMI methods also (Tarakanovas and Ruzgas, 2006), the obtained results were similar to other experiments (Saeed and Moghaddam, 2003; Tarakanovas and Ruzgas, 2006; Nemati et al., 2001; Kaya et al., 2006). In the current study, the number of sites tested high and

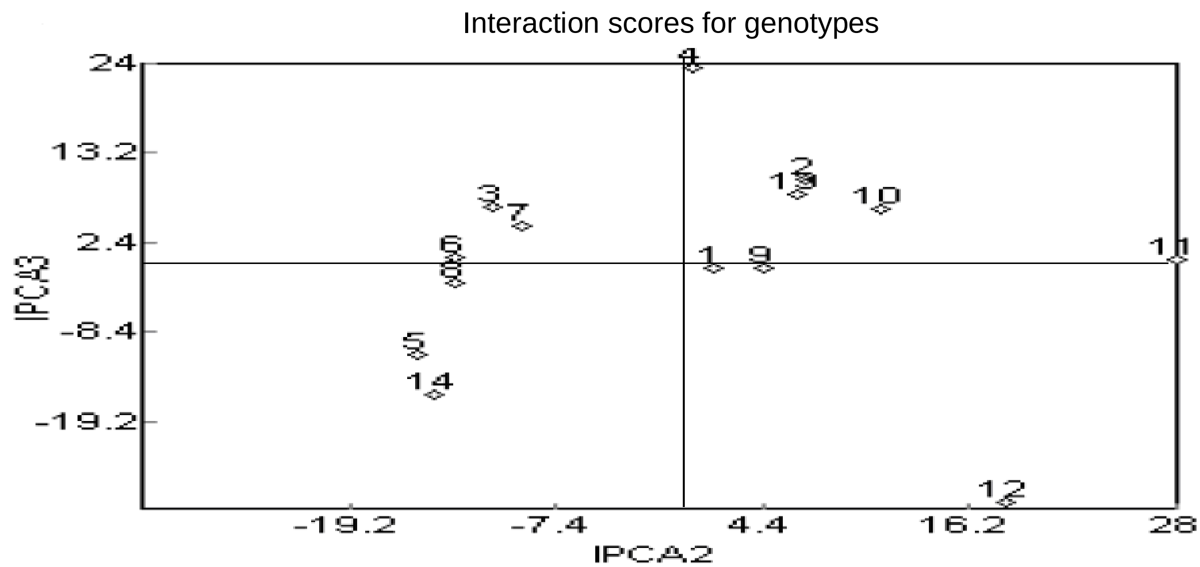

Figure 7. Main and interaction effect for AMMI3 method for 14 genotype in 10 locals of 1-karaj 2-miandoab 3-hamadan 4-mashhad 5-jolgerokh 6-ardabil 7-arak 8-tabriz 9-zanjan 10-eqlid.

addition in terms of climate for analysis recommended AMMI method in such circumstances, because it combined analysis of variance and principal components, this model depict additive and multiplication variance favorably, and shows principal component analysis in more detail, thus the AMMI model recommended as the best method to estimate the stability.

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