Journal of Sugar Beet
http://jsb.sbsi.ir/
Journal of Sugar Beet 2012, 28(1)

Study of genotype ×environment interaction for sugar beet monogerm cultivars using AMMI method

F. Moradi[(1)]*, H. Safari[(2)] and A. Jalilian[(3)]

[(1)] *M.Sc. of Plant Breeding, Payame Noor University, Kermanshah, Iran.*
[(2)] *Instructor of Agricultural and Natural Resources Research Center of Kermanshah, Kermanshah, Iran.*
[(3)] *Assistant professor of Agricultural and Natural Resources Research Center of Kermanshah, Kermanshah, Iran*

Moradi F, Safari H, Jalilian A. Study of genotype ×environment interaction for sugar beet monogerm cultivars using AMMI method. J. Sugar Beet. 2012; 28(1): 29-35.

Received February 9, 2010; Accepted December 27, 2012

ABSTRACT

In order to study the effect of genotype × environment interaction and stability of sugar beet varieties, four cultivars, including Shirine, Zarghan, Laetitia and 7112 hybrid were planted in five major areas near to sugar beet factory of Biseton as Kangavar, Sahneh, Chamchamal, Dinavar and Ravansar for three years (2006-2008) using a randomized complete block designs, with three replications. Analysis of variance for root yield, sugar yield and sugar content showed that the environment and genotype main effects and genotype × environment interaction were significant. AMMI model with the first two principal components explained most of the genotype × environment interaction (99.9%, 99.3 % and 99.4 %) for root yield, sugar yield and sugar content, respectively. Laetitia was the best genotype based on the biplots, but had the least general adaptation to the environments and showed specific adaptation to Sahneh location. Zarghan had the most highest general adaptation to the locations, but had the average value for the traits studied. 7112 hybrid had the specific adaptation to Kangavar location. Among the locations, Sahneh was the best location, and was more similar to Chamchamal. Based on means and the first two interaction components, Dinavar was the poorest location. Therefore, Sahneh and Ravansar are recommended as suitable places for planting of sugar beet and Laetitia is suggested as the best genotype for these locations.

Keywords: AMMI, genotype × environment interaction, stability, sugar Beet

INTRODUCTION

Sugar beet cultivation area in Iran in year 2007 was 54000 ha with average yield of 34 t/ha. The province of Kermanshah, with average yield of 34.2 t/haand the third rank for its cultivation area, is one of the most important provinces in sugar beet production (Binaam 2007). Therefore, this crop deserves special attention.

The natural effects of environment and genotype cause the considerable expressions of genotypes in different environments, which decrease the correlation between phenotypic expressions and genotypic quantities (Delacy et al. 1990) from the agronomists view point. If these interactions do not cause changes in the genotypes ranks, it could be ignored, but if it would be great to such an extent to cause changes among ranks of genotypes in different environments, it could be considered and must be evaluated and interpreted (Raiger and Prabhakaran, 2007). Since analysis of the ordinary methods such as using combined variance analysis tables gives just information about the presence or absence of interactions between genotype and environment, researchers have evaluated different methods of stability and each one has suggested a method (Roostayee et al. 2003).

Various studies have been done in evaluating the stability of various sugar beet varieties in different areas through using the methods of parametric uni-variate (Ebrahimian et al. 2008, Keshavarz et al. 1999, Ggyllenspetz 1998) and also using multi-variate methods and AMMI model (Ranji et al. 2005, Paul et al. 1993). The method of

*Corresponding author's email: moradi_farzad@yahoo.com

AMMI (Additive main Effect and Multiplicative Interaction) is one of the most capable methods of stability analysis in regional trials (Crossa 1990). In this method the existence of the first 2 significant components is the best state for the evaluation of interaction of genotype and environment (Akura et al. 2005).

The reason for the extensive use of AMMI is that the model could justify a major part of the total deviation of interaction and differentiate the main and interactions from each other (Ebdon and Gauch 2002).

The evaluation of the rank correlation coefficients among stability parameters, calculated for root yield and sugar content in sugar beet varieties, showed that the information derived from analysis of AMMI, in most cases, were more stable than other methods of stability analysis and also the new information are obtained through this method, which otherwise cannot be identified by other methods (Ranji et al. 2005). Considering the fact that in sugar beet, varieties with high yield, in comparison to the varieties with average yield have less stability (Ggyllenspetz 1998), evaluation of field stability of sugar beet varieties in different areas in order to find the high-yielding and stable varieties, is one of the important issues in the sugar beet breeding programs. The purpose of this research is the identification of the interaction of genotype × environment and the study of general and specific adaptation of sugar beet monogerm varieties in the cultivating areas of Bisotoon Sugar Factory on the basis of AMMI model.

MATERIALS OF METHODS

Foursugar beet monogerm varieties, including Shirin, Zarghan, Laetitiaand hybrid 7112, were studied in an experiment based on a randomized complete block design with 3 replications in 5 areas and 3 continuous years (2006-2008) in the sugar beet cultivation areas of Bisotoon Sugar Factory in Kermanshah province, including Kangavar, Sahne, Dinvar, Chamchamal andRavansar. Shirin is diploid and type Z, hybrid 7112 is triploid and type N-E, Zarghan is diploid, type N-Z and rhizomania resistant and Laeticia is diploid and type N and rhizomania– rhizoctonia resistant.

Each year, the experiment was done in different areas and the cultural practices, in the previous autumn, were accomplished, including deep plowing (40 cm) and distributing the phosphate fertilizer (200-300 kg/ha). In spring, the supplementary operation of field preparation including shallow plowing, disking and leveling were done.

After leveling, Urea fertilizer (100-200 kg/ha) was used (the quantity was determined, through the soil testing, by Bisotoon Sugar Factory Soil Lab.). Each plot included 4 sowing rows with 50 cm distance and 10 m length. The distances between the plots and the replications were one meter. For pests and weeds control, the chemical pesticides and herbicides and the mechanical methods were applied. In the harvesting process, after removing the border rows, from beginnings and ends of the middle rows, all the plants of the plots were harvested and weighed, so the total harvested area of each plot was 8 m^2.25 roots from each plot, as samples, were randomly selected and from each the root pulps were made and kept frozen in freezer, then transferred to the laboratory of Bisotoon Sugar Factory in order to determine their sugar content.

For analysis of interaction of genotype × environment, the AMMI model was used according to the following equation:

$$Y_{ger} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \alpha_{gn} \gamma_{en} + \rho_{ge} + \varepsilon_{ger}$$

where the genotype performance (g) in the environment (e) and replication (r) , the total mean (μ), the main effect of genotype ($\propto g$) (the subtraction sum of a genotype from the genotypes mean), the main effect of environment (β_e) (the subtraction sum of one environment mean from environments mean), a special quantity for the main component axis (λ_n), the number of the remained PCA axis in AMMI model (n), the special vector of genotype from n main components of interaction ($\propto_{gn}$) (IPCA), the specific vector of special environment from the main component of interaction (γ_{en}), the remnant effect of genotype × environment (ρ_{ge}) and error (ε_{ger}) (Cornelius 1993, Farshadfar and Sutka 2003). In order to determine the genotypes stability, the first and second main components were used and in order to relate the different genotypes to the different environments the bi-plot diagrams were utilized (Gabriel 1971). For statistical analysis and drawing the diagrams, the statistical software of SPSS and Excel were used and for AMMI analysis, the IRISTAT software was utilized.

RESULTS & DISCUSSION

Considering that the influence of years, the interactions of year × genotype and year × location × genotype for the studied characteristics in the combin edvariance analysis of the varieties in the different areas were not significant (Table 1), the

Table 1. Mean of squares of combined variance analysis of some measured characteristics in tested varieties during 2006-2008

Source of variation	Degrees of freedom	Root yield	Sugar content	Sugar yield
year	2	34.10 ns	2.07 ns	2.47 ns
Location	4	365.44 **	8.80 **	13.87 **
Year × Location	8	23.33 ns	0.28 ns	2.24 *
Error 1	30	21.06	1.20	0.875
Variety	3	1415.68 **	6.76 **	53.67 **
Variety × Year	6	25.06 ns	0.28 ns	1.46 ns
Variety × Location	12	100.81 **	1.38 *	3.53 **
Variety × Location × Year	24	22.13 ns	0.86 ns	1.05 ns
Error 2	90	19.35	0.72	0.967

**, * and ns are significant at levels of 5%, 1% and insignificant, respectively.

average of 3 years, for the evaluated varieties in the regions under study, was analyzed through AMMI. On the other hand, the environment included the regions and the effect of years was not considered. The results of variance analysis of the characteristics showed that the main effects of environment and genotype were significant at the of 5% and 1% probability levels, respectively (Table 2). The existence of significant difference among the varieties was the representation of the difference of genetic potentiality of the varieties for the evaluated characteristics; also, the existence of significant difference among the studied regions represents the significant variety effect in the additive structure of data for the evaluated characteristics among the regions. Similar results were reported by Ebrahimian et al. (2008) and Ranji et al. (2005).

The interaction of genotype × environment was significant for the evaluated characteristics at 1%probability level. The genotype contribution to total sum of squares for root yield, sugar content and sugar yield were 61%, 30% and 62% and the environment contribution were estimated to be 21%, 45%, 21%, respectively, and for the interaction of genotype × environment, these quantities were 17.5%, 23.8%, 16.4%, respectively. The existence of high genotype and environment share of the total sum of squares percentages is representative of the difference in the genetic potential of varieties and also the difference in the productivity potential of various environments (Aghayee Sarbarzeh et al. 2007).

The interaction of genotype × environment was separated into 2 main components ($p<0.05$). The first main component share of the interaction for root yield, sugar content, sugar content, sugar yield, from the variance of interaction of genotype × environment were 93.1 %, 62.19 %, 74.8 % and for the second main component were 6.8%, 32.9%, 24.6%, respectively (Table 2). The explanation of high percentage of variance of interaction of genotype × environment with the first 2 components of the interaction represents this fact that these 2 components well described the significant interaction of genotype × environment, caused by the multiplicative structure of the data. Farshadfar et al. (2010) stated that the AMMI method is suitable for the stability analysis, paying attention to the fact that it justifies 89.30 % of genotype × environment interaction changes with the first two main components. The first and second Interaction Principal Components Score (IPCS) for genotypes and environments has been represented in Tables 3 and 4. The comparison of means, through Duncan method, for the main effects and interac-

Table 2. Analysis of AMMI for the evaluated characteristics in sugar beet varieties (2006-2008)

Source of variation	df	Root yield			Sugar content			Sugar yield		
		Sum of squares	Sum of squares percentage	Mean of squares	Sum of squares	Sum of squares percentage	Mean of squares	Sum of squares	Sum of squares percentage	Mean of squares
Genotype	3	471.89	61.38 a	157.20 **	2.486	30.17 a	0.828 *	17.89	62.18 a	5.96 **
Environment	4	162.42	21.12 a	40.60 *	3.785	45.94 a	0.946 *	6.16	21.42 a	1.54 *
Genotype × Environment	12	134.41	17.50 a	11.20 **	1.968	23.88 a	0.164 **	4.72	16.40 a	0.29 **
$IPCA_1$	6	125.15	93.10 b	20.86 **	1.224	62.19 b	0.204 *	3.53	74.80 b	0.59 *
$IPCA_2$	4	9.15	6.80 b	2.29 *	0.648	32.92 b	0.162 *	1.16	24.60 b	0.29 *
Residual	2	0.11	0.10 b	0.06	0.094	4.77 b	0.047	0.03	0.60 b	0.02
Total	19		768.73			8.239			28.77	

** and * are significant at levels of 1% and 5%, respectively.
a and b are the percentage of sum of squares and the sum of squares of treatment × environment interaction, respectively.

Table 3. Quantities of the first and second components of interaction and means of characteristics for the evaluated locations (2006-2008)

Environment	Root yield (t/ha)			Sugar content (%)			Sugar yield (t/ha)		
	Mean	$IPCs_1$	$IPCs_2$	Mean	$IPCs_1$	$IPCs_2$	Mean	$IPCs_1$	$IPCs_2$
Kangavar	29.83 c	-0.675	0.119	17.49 a	0.539	0.284	5.24 cd	-0.295	0.257
Sahne	37.25 a	2.089	0.370	17.17 ab	-0.781	-0.214	6.40 a	0.849	-0.185
Dinvar	30.23 c	-2.377	-0.515	16.43 b	0.186	-0.289	4.97 d	-1.065	-0.269
Chamchamal	32.81 bc	0.869	-0.577	17.41 a	-0.264	0.577	5.73 bc	0.419	-0.221
Ravansar	35.19 ab	0.095	1.343	17.67 a	0.320	-0.358	6.25 ab	0.092	0.418

The same letters in each column, on the basis of Duncan test have no significant differences at 5% level.

tion of environment × genotype were shown in the same Table. It was found that among the studied areas, Sahne and Ravansar had the favorite quantities for each 3 characteristics, in comparison to other areas, whereas Dinvar showed the weakest quantities for the characteristics. Among the varieties, Laetitia had the highest quantities, for all 3 characteristics and in this case Shirin was the most unfavorable genotype.

The study of root yield bi-plot (Figure 1) shows that the genotypes of Laetitia and Shirin had the highest and lowest root yield (41.08 and 28.06 t/ha) and the other 2 varieties were in the middle range. On the other hand, considering the first component, the variety Zarghan and, to some degree hybrid 7112, had the general adaptability. Among the areas, Sahne and Ravansar had the highest root yield, but the quantity of first component for Ravansar was less.

In bi-plots, it is favorable to use the 2 components having the highest variance explained (Zali et al. 2007).The interpretation of structure of genotype × environment interaction by using the bi-plot resulting from the first and second components of the interaction (using the $AMMI_2$model) was reported in various studies (Danyaie et al. 2011;Farshadfar and Sutka 2003;Kaya et al. 2002).

The bi-plot of root yield, in the Figure 2, was the representative of the close relationships with the environment for 2 areas of Sahneand Chamchamal and also the specific adaptation of variety Laetitiatothe area of Sahne and the specific adaptation of hybrid 7112 to thearea of Kangavar. Concerning this bi-plot, hybrid 7112 had the highest general adaptation with the areas. On the basis of sugar content bi-plot (Figure 2), 2 areas of Ravansar and Dinvar had the close environmental relationship and the varieties hybrid 7112, Shirin and Laetitia had the specific adaptation to the areas of Kangavar, Sahne and Chamchamal, respectively. The bi-plot of sugar content also showed that the area of Sahne with Chamchamal and the area of Ravansar with Kangavar had the highest environmental closeness and the variety Shirin the specific adaptation with area of Dinvar. Hybrid 7112 with areas of Ravansar and Kangavar, and Latitia with the area of Sahne had the specific adaptation. The highest adaptation also belonged to Shirin.

Considering the relative correspondence of distribution of varieties and the area vectors in the bi-plots resulted from root yield and sugar yield, it can be described that the trend of the rank differences of the varieties in the studied areas for the two traits are the same. In other words, in this research, sugar yield was more influenced by root yield than by sugar content.

Totally, considering the main effect of additivity for the varieties (mean comparison), and also evaluation of the multiplicative interaction of varieties × areas, the variety Laetitia had a high genetic potential for the studied characteristics, but it had a less general adaptability in the areas and because of its specific adaptability with the areas of Sahne and Chamchamal, it is capable of being introduced to these areas. The variety Shirin was

Table 4. Quantities of the first and second components of interactions and comparison of means of characteristics for the evaluated genotypes (2006-2008)

Genotype	Root yield (t/ha)			Sugar content (%)			Sugar yield (t/ha)		
	Mean	IPCs1	IPCs2	Mean	IPCs1	IPCs2	Mean	IPCs1	IPCs2
Laetitia	41.08 a	2.788	0.375	17.50 a	-0.222	0.614	7.24 a	1.212	0.132
7112	32.05 b	-1.031	0.316	17.58 a	0.853	0.037	5.63 b	-0.566	0.391
Shirin	28.06 c	-1.530	0.673	16.69 b	-0.571	-0.127	4.67 c	-0.579	-0.050
Zarghan	31.06 b	-0.227	-1.363	17.16ab	-0.061	-0.524	5.34 b	0.067	-0.473

The same letters in each column, on the basis of Duncan test, have no significant differences at 5% level.

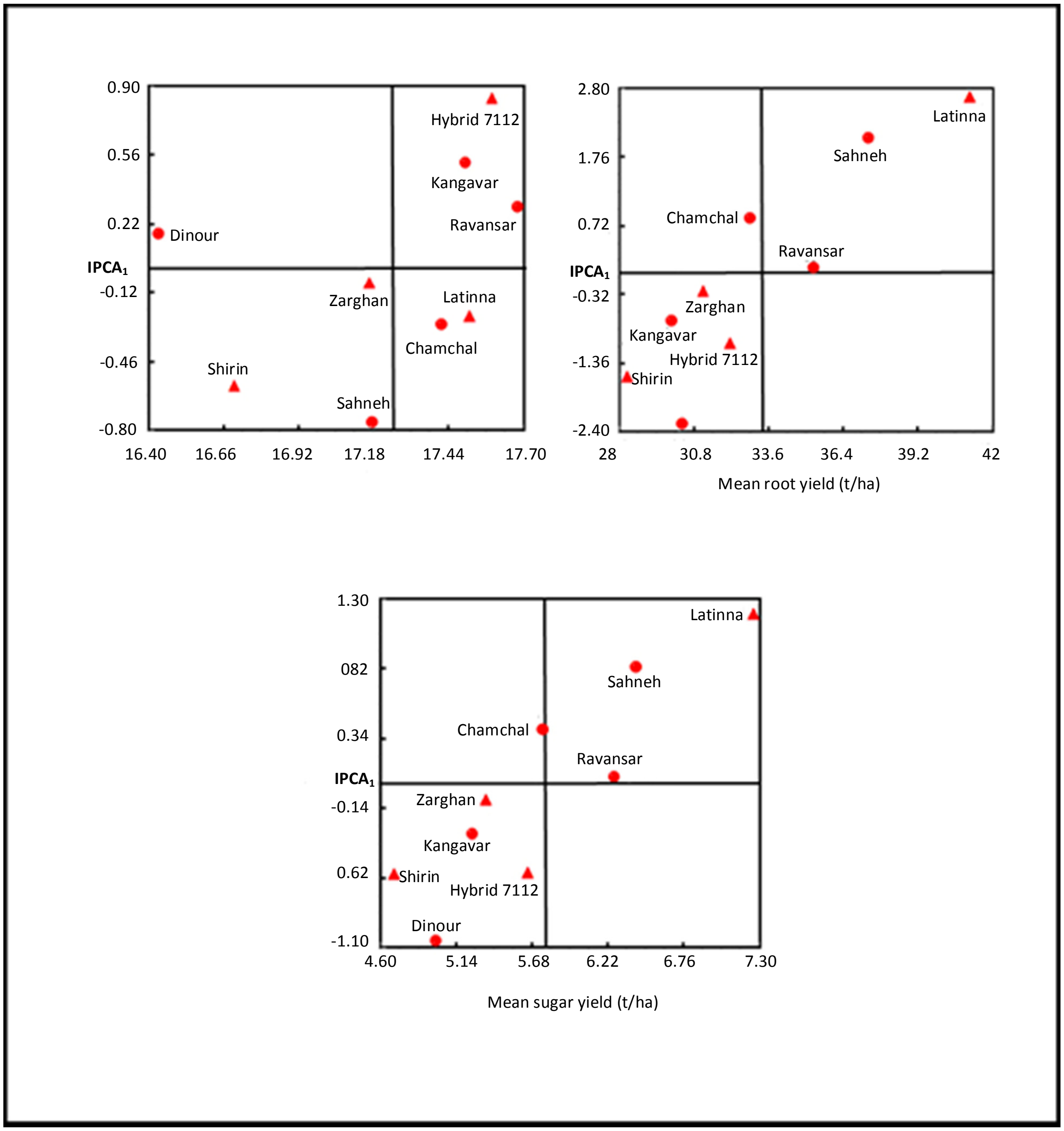
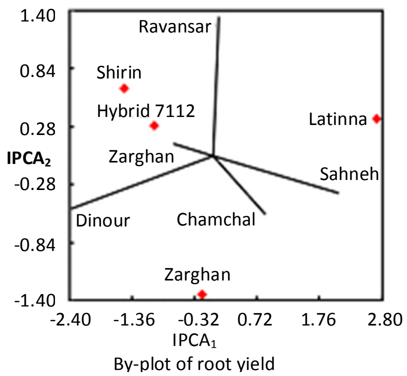
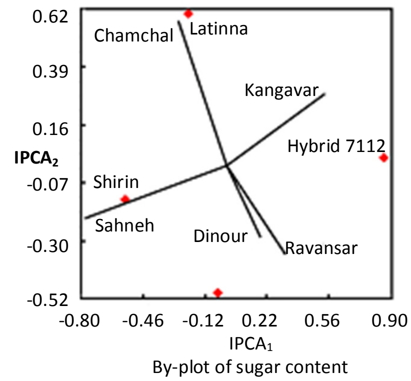


Fig. 1. By-plot diagram of the first main components of interaction with mean genotypes and environments for the studied traits of sugar beet (2006-2008)

the weakest variety among the evaluated varieties and although it had a specific adaptability with the areas of Kangavar and Dinvar, it is better not to use it in the studied areas. The varieties Zarghan and hybrid 7112 had an average genetic potential for the studied characteristics, but the variety Zarghan, because of its high general adaptability, can be introduced for all areas. On the other hand, hybrid 7112, because of having high IPC, less general adaptability and good specific adaptability with the areas of Kangaver and Dinvar, is capable to be introduced to the areas. Therefore, the highest general adaptability belonged to the variety, which had average quantities for characteristics. Thepoint that in sugar beet the varieties with average yield have higher stability of yield in the areas hasbeen reported earlier (Ebrahimian et al. 2008; Ggyllenspetz 19980).

Among the areas, for Ravansar, less quantities of IPC were obtained on the basis of the first and second components; therefore, there was no limitation in introducing Zarghan and hybrid 7112. The areas Kangavar and Dinvar were the weakest for the characteristics, but there was no environmental similarity between the two areas and the grade differences of varieties for the evaluated characteristics in Kagavar were less than that in Dinvar. On the other hand, the area of Kangavar





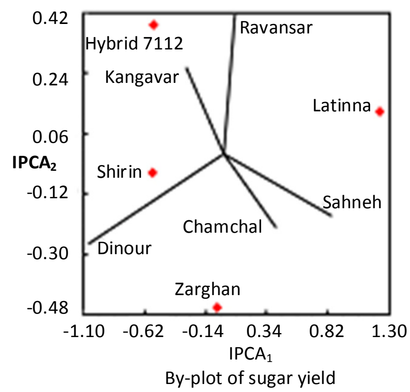


Fig. 2. By-plot diagram of the first and second main components for the studied traits (2006-2008)

had less quantity of the first and second components in comparison with that in Dinvar. Because of this reason, Dinvar was the weakest area for sugar beet cultivation. The areas of Sahne and Chamchamal had the environmental similarity, but the quantities for the characteristics in Shane were more than those in ChamChamal, on the basis of which the areas of Sahne and Ravansar were more suitable for cultivation and the genotype of Laetitia for the cultivation in Sahne and Chamchamal were the most suitable among the evaluated varieties.

ACKNOWLEDGMENTS

Herewith we express our ultimate thanks and appreciation to the staff of Sugar Department of Bisotoon Sugar Factory and Soil laboratory for their collaboration in this study.

REFERENCES

Aghaee-Sarbarzeh M, Safari H, Rostaei M, Nadermahmoodi K, Pour Siabidi MM, Hesami A, Solaimani K, Ahmadi MM, Mohammadi R. Study of general and specific adaptation in dryland advance wheat (Triticum aestivum L.) lines using GE biplot based on AMMI model. Pajouhesh and sazandegi. 2007; 77:41-48. (in Persian)

Akura M, Kaya Y, Taner S. Genotype-environment interaction and phenotypic stability analysis for grain yield of durum wheat in the central Anatolian region. J. Agric.2005; 29: 369-375.

Anonymous. Amarnameh Agriculture, Department of Planning and Budget, Office of Statistics and Information, Ministry of Agriculture., 2007; pp.135. (in Persian)

Campbell IG, Kern JJ. Cultivar × environmental interactions in sugar beet yield trials. Agron. Journal. 1982; 22: 932-935.

Cornelius PL. Statistical tests and retention of terms in the additive main effects and multiplicative interaction model for cultivar trials. Crop Sci. 1993; 33: 1186-1193.

Crossa J. Statistical analyses of multilocation trials. Advances in Agronomy. 1990; 44: 55-85.

Danyaie A, Tabaei-Aghdaei SR, Jafari AA, Matinizadeh M, Mousavi A. Additive main effect and multiplicative interaction analysis of flower yield in various *Rosa damascena* Mill. genotypes across * environments in Iran. Journal of Food, Agriculture & Environment. 2011. 9(2): 464-468. (in Persian)

Delacy IH, Eisemann RL, Cooper M. The importance of genotype by environment interaction in regional variety trials. Pp. 287-300 In: kang. M.S., (Eds). Genotype by Environment Interaction and plant Breeding Baton Rouge. Louisiana state university, USA.1990; pp. 333.

Ebdon JS, Gauch HG. Additive main effect and multiplicative interaction analysis of natural turf grass performance trials. Crop Scie. 2002; 42: 497-506.

Ebrahimian HR, Sadeghian SY, Jahadakbar MR, Abasi Z. Study of adaptability and stability of sugar beet monogerm cultivars in different locations of IRAN. Journal of Sugar Beet. 2008. 24(2): 1-13. (in Persian, abstract in English)

Farshadfar E, Sutka J. Locating QTL_S controlling adaptation in wheat using AMMI Model. Cereal Research Communication. 2003; 31: 3-4.

Farshadfar M, Moradi F, Mohebi A, Safari H. Investigation of yield stability of 18 agropyron elongatum genotypes in stress and non-stress environments, using AMMI model. Iranian Journal of Ranglands and Forests Plant Breeding and Genetic Research. 2010. 18(1):45-54. (in persian)

Gabriel KR. The biplot graphic display of matrices with application to principal component analysis. Biometrika. 1971; 58: 453-467

Ggyllenspetz U. Genotype × environment interaction and stability of diploid and triploid sugar beet (*Beta vulgaris* L.) varieties. Sveriges Lantbruksuniv, Uppsala (Sweden).1998; pp191.

Kaya Y, Palta C, Taner S. Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turk J. Agric.2002; 26: 275-279.

Keshavarz S, Mesbah M, Ranji Z, Amiri R. Study on stability parameters for determining the adaptation of sugar beet commercial varieties in different areas of IRAN. Journal of Sugar Beet. 2001. 17(1): 15-36. (in Persian, abstract in English)

Paul H, Van Eeuwijk, FA, Heijbroek, W. Multiplicative models for cultivar by location interaction in testing sugar beets for resistance to beet necrotiv yellow vein virus. Euphytica. 1993; 71: 63-74.

Raiger HL, Prabhakaran VT. A study on the performance of a few non-parametric stability measures using pearl-millet data. Indian Journal of Genetics. 2001; 61: 7-11.

Ranji Z, Mesbah M, Amiri R, Vahedi S. Study on the efficiency of AMMI method and pattern analysis for determination of stability in sugar beet varieties. Iranian Journal of crop sciences.2005. 7(1): 1-21. (in Persian, abstract in English)

Rostaee M, Sadeghzadeh Ahari D, Hesami A, Soleimani K, Pashahpoure H, Nader Mahmodi K, Porsiabidi MM. Ahmadi MM, Hasanpor Hasani M, Abedi Asel A. Study of adaptability and stability of grain yield of bread wheat in cold and moderate –cold dryland areas.2003.19(2):263-280. (in Persian)

Zali H, Sbaghpour SH, Pezeshkpor P, Safikhani M, Sarparast R, Hashembaigi A. Stability Analysis of Yield in Chickpea Genotypes using Additive Main effects and multiplicative interaction effects (AMMI). Journal of Sciences and Technology of Agriculture and Natural Resources. 2006.11(42):173-180. (in Persian, abstract in English)