IJBPAS, February, 2016, 5(2), Special Issue: 45-56

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

REPRESENTATIVE ENVIRONMENT SELECTION IN COLD CLIMATE BARLEY (*HORDEUMVULGARE* L.) ADAPTABILITY TRIALS

[1]AMIR ABBAS TAGHIZADEH

[1]Horticulture Research Department

ABSTRACT

This research was conducted to evaluate and select barley cultivation representative environment among cold climate research stations in Iran. To achieve this objective, 20 barley promising lines were evaluated in Arak, Ardabil, Hamadan, Karaj, Mashhad, Miandoab, JolgeRokh and Tabriz research stations for two cropping seasons 2009-10 and 2010-11.To test stability of each environment, after harvesting, data were collected and stability analyses were applied using various methods including GGEBiplot and nonparametric, including methods Nsar& Han and Tnaratho as well as parametric methods such as Rick, environmental variance Roemer, coefficient of genotypic variation, Shukla stability variance, the slope of the regression line, deviation from the mean squares regression, R-squared value. The maximum record of stations' performance i.e. a yield of 6.986 ton per hectare was assigned to the Hamadan station. GGEBiplot analysis revealed that Arak (E1), Tabriz (E8) and JolgeRokh (E5) had the minimum deviations from the ideal environment. The same results were also obtained using the non-parametric methods. Using parametric methods, the research stations Arak (E1) and Tabriz (E8) as compared to the others showed a greater yield stability .Moreover, the lowest level of stability was observed in Miandoab (E7).

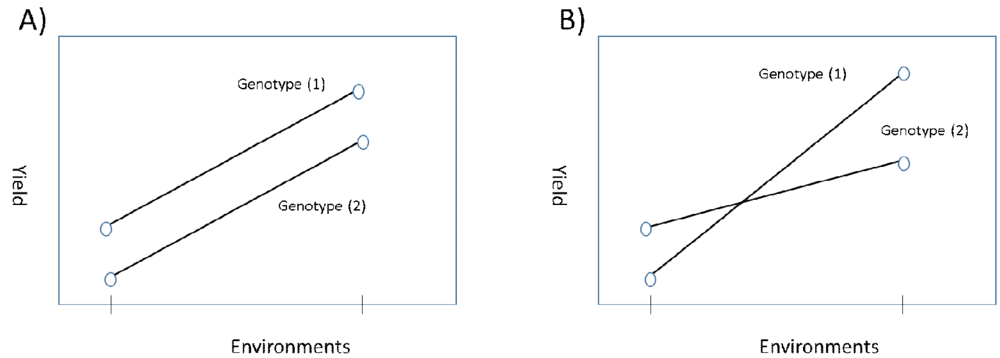
Keywords: Barley, representative environment, stability, multivariate analysis.

INTRODUCTION

After using breeding methods to produce and release new varieties, the most important issue that should be analyzed is conducting a series of trailson the new breeds to identify their adaptability to various uniform environmental conditions (8).

According to definition, environment is a combination of geographical, climate and living factors that impact a living organism, or in other words, biotic and abiotic factors that are in interaction with growing creature. Considering this definition environment in agriculture includes all conditions that plants grow in and mayinclude location, date,management operations and a combination of these factors. In this case each year and place is considered a separate environment.

When different genotypes in different environments, show different representation we witness the interactive genotype × environment effect. This interaction causes the phenotypic values unable to match genotypic values and a genotype that had a good representation in an environment, unable to do so in other environments (1).



Description of significant interaction in twofold environments with mutual levels of major tension reported frequently by researchers as "appropriate" when the tension is at lowestand yield is high and as "inappropriate" when tension is at maximum intensity and yield is minimum (4). In addition, significant mutual interaction may occur in twounfavorable environments and or two rather favorable environments that have similar mean yieldbut have a different major tension pattern (3). For example an environmental factor e.g soil structure might have similar yield, however the mutual genotype × soil structure effect, have considerableeffect (13). Adaptability level and compatibility of genetic factors of plant phenology determinant (like photoperiod and verbalization requirement) with environment characteristics related togrowth season (for example day length and temperature pattern) is one of other main mutual interaction factors determinants especially in extensive areas(24). Among mutual interactions to show patterns adaptability generallyonly the mutual genotype interaction × location is useful. Since only this mutual interaction could be selectedforspecific and general adaptability (16). When theenvironmental changes are predictable, mutual interaction of genotype and environment could be reduced by assigning different genotypes to different environments (9).

Mosavyon and Ehdaii reviewed theadaptability state of 12 wheat genotypes in four regions and during cropping seasons using Eberhard and Russell stability analysis trail. They reported that for understanding general adaptation, conducting analysis in several location different regions is necessaryand at the same time not neglect the possibility of achieving genotypes with specific adaptability to use their potential in the special environments. They concluded that adaptability is under control of genetic agents and with selection of right parents and right management of breeding population, control the traits and provide better production (14).

Aghaiiet al (2010) usingEberhard and Russell stability analysis trail reported 20 advanced barley line and two witness figures in rain fed conditions during three cropping yearsin Kermanshah's Saravard research center that 6 genotypes are superior to others from perspective of crop yield(2).

In another test 30 other barley along six witness figures studiedin three environment regarding yield stability study. Based on the results genotype × environment is significant and four genotypes with high yield, bi =1 and lowS^2didentified as the most stable genotypes for all of the environments (5).

Rodrigues et al in a research on different germplasms of barley in order to study the mutual effect of genotype × environment, they concluded that specific adaptation for some genotypes to special environments is due tocrop traits such aslow bush height for wet environments, earliness for environments that face with tension drought at the end of the season or low number of seedsinwheatear, low number of tillers and weight of thousand grainsfor adaptability to dry environments (18).

The objectives of this study can be stated as follows: 1-examining the investigating environments in terms of stability value; 2- Selectingsuitable environments for isolationof stable genotypes; 3- Study the interaction of the genotypes and environment; 4- Specify the expressionenvironment forspecific genotypes isolation 5- Identify most stable and unstableenvironmentsby identifying the representative environment(s) and eliminating the inefficient ones. Inadaptability trails, that due to their large extent, can be very expensive, we can somewhat save. The results of these trails can be used in human resources and specialist management and making final decisions.

MATERIALS AND METHODS

The data used in this study obtained from two cropping seasons yield in 2010-2009 on twenty genotypes (table 2). The tests has been conducted in eight locations (table 1). The selection of the stations is done in scattered geographical cold regions in the country to find the most appropriate one in terms of high cultivation area and stable yield.

In the combined analysis trails, the typeconsidered as fixed factor and date and location are considered as random factors. The length of each trail plot is 6 m and its width is1.2 m and as a result, the area of each plot was 7.2 square meters, during the harvest 05 meters on both sides of each plot removed as a result of marginal iodine and from the harvest done over the remaining 6 meters.

The frequency of watering performed according to the customs of each region and environmental conditions. Finally, the harvest yield was calculated for each variety in the environment, and determined as Kg yield per plot (6 square meters) and converted to tons per ha. Finally, conventional analysis of variance was performed for each environment, then test mistakes homogeneity was tested usingBartlett test, after confirmation ofhomogeneity of variances, the compound trail analysis of genotype × environment and location × genotype × year were performed on the data. In order to evaluate the sustainability and adaptabilityof the genotypes and the examined environments and determining the mega environments and best environments different methods used that are as follows:

Multivariate GGEbiplot method which is common and new widespread methods to identify desired genotypes and environments, in adaptabilitytrails (26). The base of the method is given below:

$$Y_{ij} - \mu - \bar{Y}_j = \lambda_1 \xi_{i1} \eta_{1j} + \lambda_2 \xi_{i2} \eta_{2j} + \varepsilon_{ij}$$

Y_{ij} is the mean yield of i genotypes in the environment j), μ (overall average), $\bar{Y}_j$ (the mean yield of all genotypes in the environment j), λ_1 and λ_2 are Eigen values for PC1 and PC2), ξ_{i2} and ξ_{i1} (scores of PC1 and PC2 for the genotypes i), η_{1j} and η_{2j} (scores of PC1 and PC2 for the environment j), ε_{ij} (the remaining of models of genotypes I in the environment j).

Phenotypic stability under static concept measured by Roemer and the variance of a genotype in different environments and a genotype is stable that its environmental variance is lower (19).

$$S_i^2 = \frac{\sum_i (\bar{Y}_{ij} - \bar{Y}_{i.})^2}{q-1}$$

According to Rick's ecovalance of genotype effects in the environment used as a parameter for each genotype stability parameter such that this effectsquared for any genotype and collected in all environments. Genotypes with a Rick ecovalance of zero have the highest stability value, in other words, smaller values of ecovalance, have higher stability (25) that calculated as following:

$$W_i^2 = \sum_{j=1}^{q} (X_{ij} - \bar{X}_{i.} - \bar{X}_{.j} + \bar{X}_{..})^2$$

Shukla's stability variance is based on variance estimates of the genotypes in different environments based on the remaining of two-way classification of genotype in environment. Genotypes with minimum stability variance has the highest stability (22) that is calculated as:

$$\sigma_i^2 = \frac{P}{(p-2)(q-1)} \sum_{j=1}^{q} (X_{ij} - \bar{X}_{i.} - \bar{X}_{.j} + \bar{X}_{..})^2 - \frac{SS(G \times E)}{(p-1)(p-2)(q-1)}$$

Coefficient of genotypic changes actually measures the ithgenotype share in trail in the interaction between genotype and environment.Coefficient of variationis actually measures the deviation from the mean of a genotypes in all environments. According to this criterion a genotype is stable that has a lower CV (17). The Coefficient of variationcalculated as follows:

$$CV_i = \frac{S_i}{\bar{X}_{i.}} \times 100$$

Stability parameter in regression models shown with b_i. It is linear regression of genotype yield i in environment j on the mean yield of all genotypes j. Therefore, the mean yield on the environment j is an indicator of the overall capacity of the environment (7). Its calculation is as follows:

$$b_i = \frac{\sum_{j=1}^{q}(X_{ij} - \bar{X}_{..})(\bar{X}_{.j} - \bar{X}_{..})}{\sum_{j=1}^{q}(\bar{X}_{.j} - \bar{X}_{..})^2}$$

Han (1979), and Nassar and Han (1987), introduced two non-parametric statistics that combined the mean yield stability and sustainability (15). The two parameters based on ratings of genotypes yield in any environment are as follows:

$$S_i^{(1)} = [2\sum_{j}^{n-1}\sum_{j'=j+1}^{n} | r_{ij}^* - r_{ij'}^* |] / [n(n-1)]$$

$$S_i^{(2)} = [\sum_{j=1}^{n}(r_{ij}^* - r_{i.}^*)^2] / (n-1)$$

r_{ij}.,is genotype ith rank in jth environment, l is the number of genotypes and m is the number of regions, $\bar{r}_{i.}$ mean rank of all environments for the ith genotype

For genotype i with the maximum stability we know $S_i^{(1)} = S_i^{(2)} = 0$. The environmental effects have no impact on defined $S_i^{(1)}$ and $S_i^{(2)}$ stabilities. But the differences between genotypes impact measures of stabilityandthis may result in difference in stability between genotypes, while it is possible that in fact, no interaction be present between genotype and environment. To avoid this problem x_{ij} can be corrected for the effects of genotypes. To test the null hypothesis (all varieties have the same stability), statistical tests for significance based on the normal distribution can be used that are proposed by Nassar and Han (1987) as well as Han and Nassar (1989) as below. (10 and 15):

$$E\left(S_i^{(1)}\right) = \left(L^2 - 1\right) / 3L$$

$$\text{var}\left(S_i^{(1)}\right) = \left(L^2 - 1\right)\left[\left(L^2 - 4\right)\left(m+3\right) + 30\right] / 45L^2 m\left(m-1\right)$$

$$Z_i^{(1)} = \left[S_i^{(1)} - E\left(S_i^{(1)}\right)\right]^2 / \text{var}\left(S_i^{(1)}\right)$$

$$E\left(S_i^{(2)}\right) = \left(L^2 - 1\right) / 12$$

$$\text{var}\left(S_i^{(2)}\right) = \frac{\left(L^2 - 1\right)}{36m}\left[\frac{L^2 - 4}{5} + \frac{L^2 - 1}{2\left(m-1\right)}\right]$$

$$Z_i^{(2)} = \left[S_i^{(2)} - E\left(S_i^{(2)}\right)\right]^2 / \text{var}\left(S_i^{(2)}\right)$$

Z_i Value in the above equations is an approximate for χ^2 statistic that its degrees of freedom is equal to the number of genotypes and if in comparing with the chart, If not significant, shows the same stability for all genotypes.

Table 1: Environments Specifications which are participating in experiments

Rainfall	Height	Long	Lat	Station
328.46	1708	$49^0 46' E$	$34^0 06' N$	Arak
296.47	1350	$48^0 17' E$	$38^0 15' N$	Ardabil
255.55	1680	$48^0 41' E$	$35^0 12' N$	Hamadan
338.02	1314	$50^0 54' E$	$35^0 56' N$	Karaj
149.54	1650	$58^0 13' E$	$35^0 50' N$	Jolge Rokh
243.02	990	$59^0 38 E$	$36^0 16' N$	Mashhad
296.98	1300	$43^0 03' E$	$36^0 58' N$	Miandoab
247.01	1361	$46^0 17' E$	$38^0 05' N$	Tabriz

Table 2: Specifications genotype participating in trails

Genotype	Genotype Code	Genotype	Genotype Code	Genotype	Genotype Code	Genotype	Genotype Code
G1	Bahman	G6	EC88-06	G11	EC88-11	G16	EC88-16
G2	EC88-02	G7	EC88-07	G12	EC88-12	G17	EC88-17
G3	EC88-03	G8	EC88-08	G13	EC88-13	G18	EC88-18
G4	EC88-04	G9	EC88-09	G14	EC88-14	G19	EC86-10
G5	EC88-05	G10	EC88-10	G15	EC88-15	G20	EC86-14

*Genotype in bold letters are witnesses.

RESULTS AND DISCUSSION

According to the present genotypes yield in each of stations it was determined that Hamadan station (e3) with the mean performance of 6 tons and 986 kg per hectare, achieved the highest production and Miandoab (e 7) and Karaj (e 4) stations ranked next respectively.

Figure 3 identifies the hypothetical ideal environment specified using the GGEbipl method. Identification of the hypothetical ideal environment was based on the concepts of stability and grain yields. In other words, in the studied environments, a desired environment is defined thathave the highest performance and stability. The environment closest to the hypothetical environment is a superior environment (25). On these basis JolgeRokh (E5),Tabriz (E8) and Arak(E1)have the shortest distance from the hypothetical ideal environment and have demonstrated the highest levels of stability. One of the important applications of GGEbiplotis polygon chart that can produce different interpretation. Thepolygonchart in two years formean barley genotypes and environments in figure 2, this procedure has also been used by other researchers. (20).

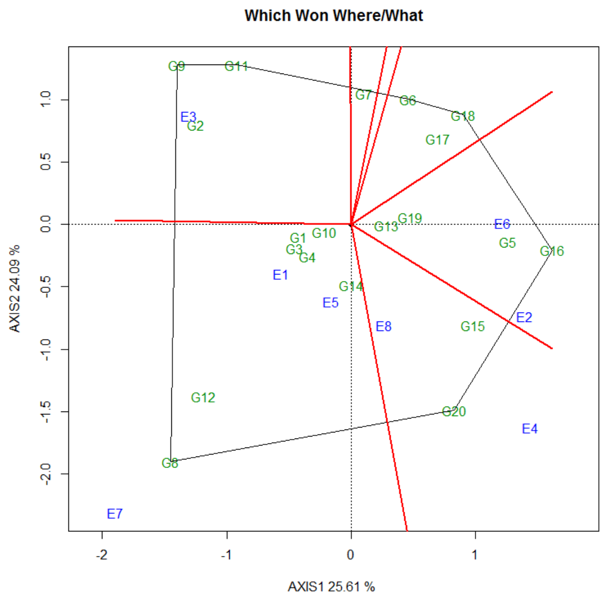


Figure 1: calculated polygon for genotypes and environments participating in the experiment; Arak (E1), Ardabil (E2), Hamadan (e3), Karaj (E4), JolgeRokh (E5), Mashhad (E6), Miandoab(E7), Tabriz (E8)

In this diagram, the genotypes with maximum distance from origin coordinates are connected to form one polygon, then from the origin, lines drawn on the sides of the polygon, and the mega environmentsdetermined. In this figuremega environments and genotypes that are adaptable with them have been assigned. Arak(E1),Jolge Rokh (E5) and Miandoab (e 7) region have formed a mega environment as well as Mashhad(E6) and Ardebil (E2)too formed a mega environment together and Tabriz and (E8),Karaj (e 4) environment too have created a mega environment. It is worth mentioning that the Hamadan station (e3) was alone in a mega environment. Stations located in any mega environment were evaluated as same environmental conditions. The GGE bi plot method to determine the stability of farm products, such as soybeans (27), rapeseed (12), barley (6), lentils (21), and pea (23).

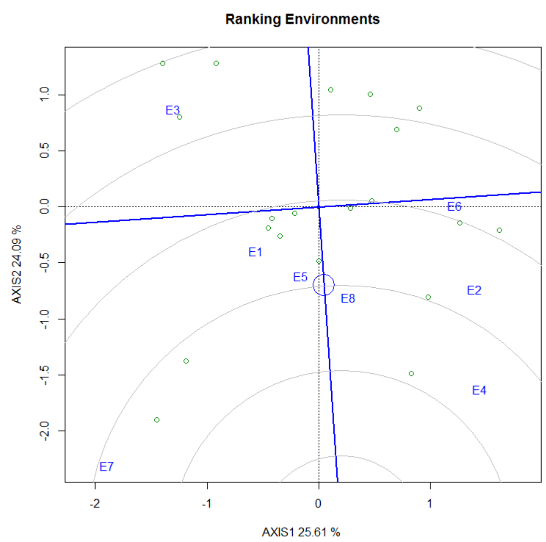


Figure 2 hypothetical ideal environment based on two factors: stability and higher yield. Arak (E1), Ardabil (E2), Hamadan (e3), Karaj (E4), JolgeRokh (E5), Mashhad (E6), Miandoab(E7), Tabriz (E8)

In most methods of calculating the adaptability parameter, it was found that the Arak(E1) and Tabriz (E8) environments are the most stable environments, for example Arak station (E1) with Rick ecovalance of 2.138 and Tabrizstation (E8) with Rick ecovalance of 2.227 had better stability than other environments. Shukla's stability variance as well as were0.103 and 0.109 respectively and Roemer's environmental variance were0.122 and 0.184 respectively that confirms the result. Respectively. The coefficient of variation for the Arak(E1) and Tabriz (E8) environment are 5.71 and 7.56 percent that is an evidence for the sustainability of the two environment, but the coefficients of detection, points to Hamadan (e3) and Mashhad (E6) environments as a stable environment. Also, due to the small difference between the regression coefficient wiki (E2) and plain occurred (E5) a, the two environments have shown high stability.

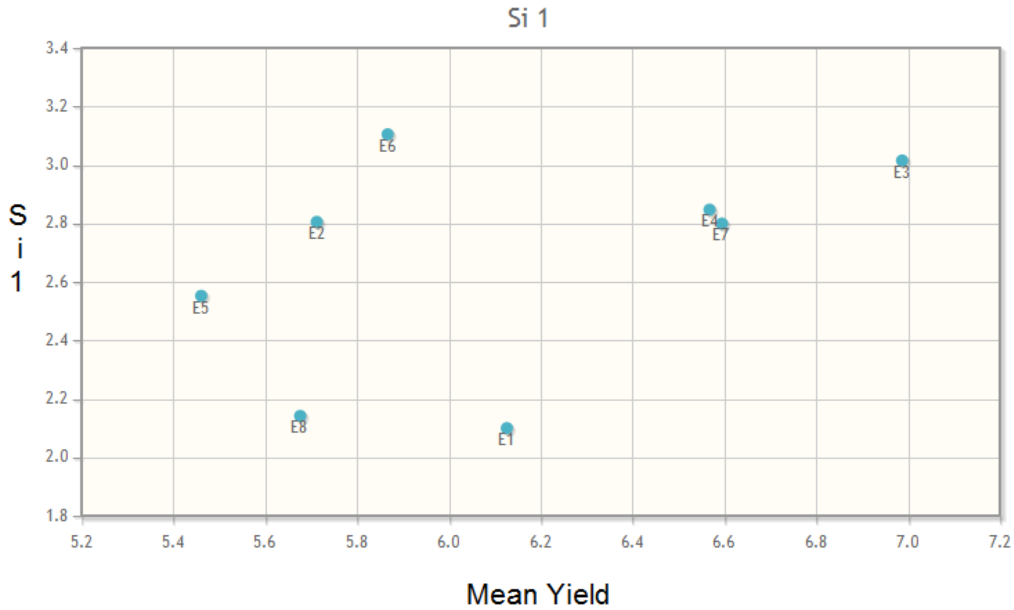


Figure 3: Rating and yield mean difference of each environment; Arak (E1), Ardabil (E2), Hamadan (e3), Karaj (E4), plain there (E5), Mashhad (E6), Miandoab (E7), Tabriz (E8)

Table 3: parametric statistics calculated for each station in crop years 2010-2011

Station	Abbreviation	Mean production	Regression slope difference	Coefficient of determination	Squared regression deviation	Regression slope	Shukla's stability variance	Rick's ecovalance	Coefficient of variation	Roemer's environmental variance
Arak	E1	0.123	5.715	2.138	0.103	0.623	0.113	0.129	0	6.126
Ardebil	E2	0.275	9.188	4.565	0.273	0.931	0.253	0.128	0	5.712
Hamadan	E3	0.317	8.060	6.599	0.416	0.130	0.334	0.002	0	6.987
Karaj	E4	0.385	9.446	5.234	0.320	1.840	0.260	0.359	0.840	6.568
JolgeRokh	E5	0.272	9.551	4.106	0.241	1.184	0.227	0.210	0.184	5.460
Mashhad	E6	0.223	8.042	4.581	0.274	0.273	0.232	0.014	0	5.866
Miandoab	E7	0.521	10.944	8.041	0.517	1.696	0.426	0.225	0.696	6.594
Tabriz	E8	0.184	7.566	2.228	0.109	1.323	0.119	0.387	0.323	5.676

Table 4: non-parametric statistics were calculated for each crop year 90-1389 station

np(2)	np(1)	Z(2)	S(2)	Z(1)	S(1)	Abbreviation	Station
0.29	1.45	3.14	3.31	3.40	2.10	E1	Arak
0.68	2.05	0.20	5.73	0.40	2.81	E2	Ardebil
0.31	2.35	2.20	6.87	1.88	3.02	E3	Hamadan
0.32	2.05	0.51	6.03	0.61	2.85	E4	Karaj
1.85	1.85	0.20	4.77	0.07	2.55	E5	JolgeRokh
0.69	2.40	3.43	7.27	2.84	3.11	E6	Mashhad
0.33	2.00	0.30	5.85	0.38	2.80	E7	Miandoab
0.48	1.45	2.49	3.52	2.87	2.14	E-8	Tabriz

SUM.Z1= 12.4432 SUM.Z2= 12.4625
E (s1) =2.6250E (S2) =5.2500Var (S1) =0.0812Var (S2) =1.1951

S (1), S (2), Z (1), Z (2) Nassarand Han stability statistics, np (1), np (2) Tnarazov Stability statistics.

The E(s1) = 2.625 and E(s2) =5.25, accordingly, Nassar and Han non-parametric method found that Arak(E1),Tabriz (E8) stations JolgeRokh (E5) are stable environments, Tnarazov confirmed the same assessment.

The lowest amount of production in this cropping year occurred on the JolgeRokh (E5) that is about 5 tons and 460 kg yield per hectare and Tabriz (E8) that is 5 tons and 675 kg yield per hectare. The most unstable environments, based on the GGEbiplot method ideal environments calculation are Miandoab(E7),Hamadan (e3),Karaj(E4) and Mashhad(E6)stations respectivelyThat had the maximum distance from an ideal environment. Tnarazov non-parametric method concluded that the Mashhad (E6) and Hamadan (e3) environment had lowest stability during the cropping years. Nassar and Han Method give the same result for unstable environments.

Roemer parametric methods of environmental variance, coefficient of variation, ecovalance of Rick and stability variance of Shukla indicate that Miandoab station (E7) to be the most unstable. While the coefficient of determination, points to Tabriz station (E8) and the deviation of the slope of the regression line points to Karaj station (E4)for unstable environments.

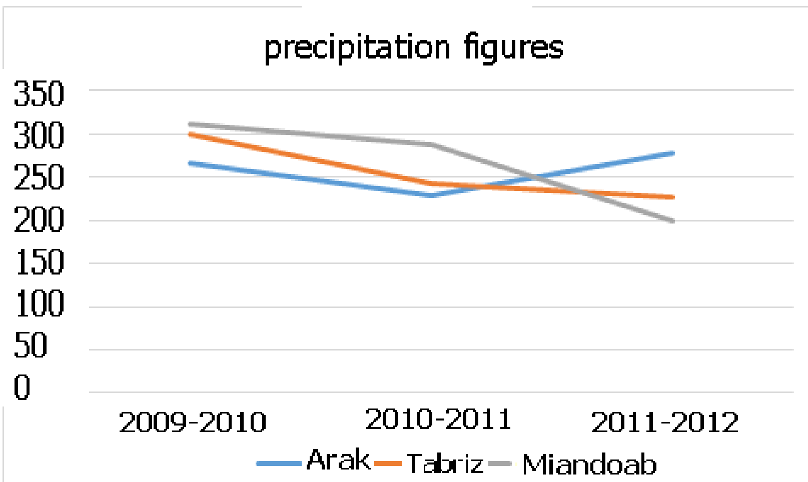


Figure 4: amount of precipitation in stable and unstable stations

As mentioned, to determine the representative environment the stability and yield factors required. One of the key factors in production, is the amount of rainfall and humidity in environment. Figure 5 shows the amount of rainfall in the study period (11). The two superior environment of Tabriz (E8) and Arak(E1) has a relatively uniform or rising precipitation while the unstable environment of Miandoab(E7)has a decrease in the amount of rainfall during the crop year.

Another contributing factor associated with the yield, is ambient temperature and thermal needs of plant, as cold resistance is one of the main objectives of the barley correction. Arak(E1) and Tabriz (E8) with mean temperatures of 14.9 and 13.8° c has higher temperature than the ambient mentioned of Miandoab(E7) with amean temperature of 12 degrees Celsius (11). According to the survey, it seems that temperature and amount of rainfall have a significant impact on the stable and unstable environments that have been studied. Overall,by taking into account the statistical methods which has used in the study, it was determined that the Arak station (E1)despite the lower yield, is more stable than other stations under investigation.

ACKNOWLEDGEMENTS

Hereby, I thank all the experts, specialists and technicians in various centers and stations which this study is the result of their efforts.

REFERENCES

1- Ahmadikhah, A. 2010. Advanced Plant Breeding. Gorgan University of Agricultural Sciences and Natural Resources, pp 460. (In Persian).

2- Aghaie-Sarbarzeh, M., R. Rajabi and D. Ansari. 2010. Evaluation of grain yield stability and two-steps screening for drought stress tolerance in barley genotypes. Iranian Journal of Crop Sciences. 12 (3) 305-317. (In Persian).

3- Annichiarico, P. 1997. Joint regression vs AMMI analysis of genotype environment interactions for cereals in italy. Euphytica 94: 53-62.

4- Ceccarelli, S. 1989. Wide adaptation: how wide? Euphytica 40: 197-205.

5- Chand, N., S.R. Vishvakarma, O.P. Verma and M. Kumar. 2008. Phenotypic stability of elite barley lines over hetrogeneous environments. Barley Genetics Newsletter 38: 14-17.

6- Dehghani, H., A. Ebadiand and A. Yousefi. 2006. Biplot Analysis of genotype by environment interaction for barley yield in iran. Agronomy Journal 98: 388-393.

7- Eberhart, S. and W.A Russell.1966. Stability parameters for vomparing varieties. Crop Science, 6:36-40.

8- Farshadfar, E. 1998. Application f Biometric Genetics in Plant Breeding. Taghe-Bostan Press, Razi University, pp 396. (In Persian).

9- Francis, T.R. and L.W Kanenberg. 1987. Yield stability studies in short season maize (I). A discriptive method for genotypes. Canadian Journal of Plant Science 58:429-434.

10- Huhn, M. and R. Nassar, 1989. On the tests of significance for non-parametric measures of phenotypic stability. Biometrics, 45: 997-1000.

11- Islamic Republic Of Iran Meteorological Organization (IRIMO)

12- Javidfar, F., B. Alizadeh, H. Amirioghan, and N. Sabbagnia. 2011. A study of genotype by environment interaction in oilseed rape genotypes, using GGE biplot method. Iranian Journal of Field Crop Science, 41: 771-779 (in Persian).

13- Koutsos, T., M. Koutsika-Sotiriou and A.C. Fasoulas. 1992. The impact of genotype x soil texture interaction on the efficiency of selection for yield in maize (*Zeamays* L.). Euphytica, 61: 61-65.

14- Musaviun, M. and B. Ehdaie. 1987. Specific and general adaptation and yield stability of wheat (*Triticumaestivum* L.) genotypes. Journal of Agronomy and Crop Science, 158: 317-323.

15- Nassar, R., and M. Hühn. 1987. Studies on estimation of phenotypic stability: tests of significance for nonparametric measures of phenotypic stability. Biometrics, 43: 45-53.

16- Piepho, H.P., J. B. Denis and F.A. Van Eeuwijk. 1998. Predicting cultivar differences using covariates. Journal of Agricultural Biological and Environmental Statistics. 3: 151-162.

17- Pinthus, J.M. 1973. Estimate of genotype value:a proposed method. Euphytica, 22(1): 121–123. ISSN 1573-5060.

18- Rodriguez, M., D. Rau, R. Papa and G. Attene. 2008. Genotype by environment interactions in barley (*Hordeumvulgare* L.): Different Responses of Landraces, Recombinant Inbred Lines and Varieties to mediterranean environment. Euphytica, 163: 231-247.

19- Roemer, T. 1917. Sind die ertragsreichensortenerteragssichers? Mitt.DLG 32: 87-89.

20- Sabaghnia, N., H. Dehghani, and S.H. Sabaghpour. 2006. Nonparametric methods for interpreting genotype × environment interaction of lentil genotypes. Crop Science, 46: 1100-1106.

21- Sabaghnia, N., H. Dehghani, and S.H. Sabaghpour. 2008. Graphic analysis of genotype × environment interaction for lentil (Lens culinarisMedik) yield in iran. Agronomy Journal, 100: 760–764.

22- Shukla, G.K. 1972. Some statistical aspects of partitioning genotype-environmental components of variability. Heredity, 29:383-390.

23- Suriharn, B., A. Patanothai, K. Pannangpetch, S. Jogloy, and G. Hoogenboom. 2008. Yield Performance and Stability Evaluation of Peanut Breeding Lines With the CSM-CROPGRO-peanut Model. Crop Science, 48: 1365-1372.

24- Wallace, D.H., R.W. Zobel and K.S. Yourstone. 1993. A whole-system reconsideration of paradigms about

photoperiod and temperature control of crop yield. Theor. Appl. Genet. 86:17-26.
25- Wricks, G. 1962. Ube Eien method zuterfussung der okologischenstreubreite in feldversuchen. z.pflanzenzuecht, 47: 92-96.
26- Yan, W., and M.S. Kang. 2003. GGE biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists. Boca Raton London New york Washington, DC.
27- Zhang, M., M.S. Kang, Jr. P.F. Reese and H.L. Bhardwaj. 2005. Soybean cultivar evaluation via GGE biplot analysis. Journal of New Seeds 7 (4): 37-50.