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Evaluation Yield Stability of Advanced Barley Genotypes in Terminal Drought Stress Condition

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ABSTRACT: In order to achieve genotypes with yield stability, 18 selected barley lines with two controls (EC82-6 and EDBYT82-9 for ABYT-DC1). Experiments were conducted for one year, using Randomized Complete Block Design with three replications in five stations of cold region including: Karaj, Mashhad, Miandoab, Tabriz and Hamedan during the cropping season 2014-2015. Simple and combined analyses of variance and multivariate analyses of data for all the traits and index parameters were performed. The results showed that there were significant differences among locations, genotypes and genotype × location interactions in both experiments under different irrigation regimes except for the effect of genotypes in the second experiment. Using all aspects of the analyses, the lines numbers: 13,9,18 and 7 showed the highest yield, and stability for ABYT-DC1 respectively. In overall, based on mean of grain yield, stability parameters and important traits such as early maturity, resistance to diseases, loading and cold tolerance, 7 genotypes were selected in both experiments and advanced to the elite barley lines yield trial of cold zone in 2014-2015.

Keywords: Advanced lines, Terminal drought, Yield Stability, cold region.

INTRODUCTION

Studying the tolerance to drought of the crops has fundamentally and applicably been made in Iran and other countries while considering the targets determined for them. In the studies made in international centers (CIMMYT and ICARDA) on the cereals such as wheat, barley and corn under the dry stress conditions, the yield was mostly depend on the number of seeds than to weight of it. Hence, studies for genetically improving of such crops under the dry stress conditions has mostly been concentrated on the events that happen during the flowering period (when the number of seeds is formed (Blum, 1996). Early ripening gives the crop the ability to yield before drought. According to Astin (1987) in many semi-dry environments, the relative humidity at the beginning of the growing season is in its highest amount which decreases progressively. Therefore, the varieties which push ahead the primary growing and maturity, increase water efficiency. (Derara *et al*., 1969) found that there is a negative correlation between the seed yield and number of days up to spike emergence in drought stress condition.

Fischer and Mourer (1978) found a higher yield in genotypes which have sooner entered the stage of flowering in the humidity stress condition. In conditions in which drought stress occurs at the beginning of growing season and ends before flowering, the late varieties will have a higher yield as compared to earlier varieties (Ehdaei *et al*., 1988). Difference in the date of emerging spike s is mainly a reaction toward photoperiod (Poehlman, 1987). However some environmental factors are affecting to some extent. In crops like wheat and barley, the time for emerging spike is determined by genes which are controllers of sensitivity to photoperiod and Verbalization as well as environmental factors likes day length and temperature. As Haji Christodoulou (1982) believes that there are complex and unpredictable interactions between maturity and rainfall distribution and their impact on the yield and the optimum domain of maturity for each region has to be determined after long term experiments with a large number of desired genotypes. In breeding materials for early maturity the above-said items have to be kept in mind.

The number of spike s per unit area is one of the yield component and in case other elements of the yield are constant, genetic increase in the number of spike will cause increase in the yield (Innes *et al*., 1981). The ratio of tillers that die or do not produce spike increases by emerging drought. Beggand Turner (1976) reported that the number of tillers that produce spike decrease with emerging water shortage in interval between the stages of flower discrimination and spike emergence. Tillering is genetically controlled and there are genotypes in most crops with evident differences in the number of tillers.(Innes *et al*., 1981). Plant height at the time of the crop maturity is known as a factor in the crop's reaction toward drought. However, it is believed that crop height by itself does not have any specific effect on water relations in the crop and determining an appropriate height for dry stress tension is done by taking other cultivation considerations(Blum, 1985).In an experiment made by Austin(1987) using semi-dwarf lines or long stems as control, on the impact of different irrigation and drought treatments on the seed yield, he found that in complete irrigation conditions, semi-dwarf lines have a yield ranging between 13 to 15 percent more than control and even in the conditions that they were exposed to early drought and season termination, the yield of semi-dwarf lines were estimated as 11 percent more than control. In similar studies made by Inez *et al*. (1981) different findings were gained in a way that in controlled environments and in perfect irrigation conditions, no evidence was found indicating the difference in yield in the groups with different height. In early drought conditions, dwarf genotypes showed a better yield compared to long stems genotypes. While in terminal drought conditions, high leg genotypes had significantly a higher seed yield as compared to dwarf genotypes. This can be related to the high leg lines higher capability to extract water from the soil. Eventually the duration for filling seeds in these genotypes ale less affected by drought (Innes *et al*., 1981). It may be possible that accumulation of more reserves of assimilates in stems and consuming them in the ending dry conditions played a role in this relationship (Nikkhah,1999).

The harvest index decreases under undesired environmental factors specially drought or water deficit. The harvest index percentage depends on various factors including the relative weight of dry matter before and after flowering and the ability to transfer the reserves in stem to the seed after flowering. Specially if the cultivation environment is semidry with no sufficient water available for the crop. Under such environmental conditions, if a considerable percentage of the water stored in the soil is consumed by the crop for vegetative organs before flowering and grain filling, there won't be enough water for formation and seed filling. As a result, the number and weight of the seeds reduce and the grain yield and harvest index percentage will show a sharp fall as well. Determinate tillering and an appropriate time of flowering can help the matter balance before and after flowering and the water stored for crucial periods (Ehdaei, 1993). Also, In a study made on a number of indigenous and advanced figures of spring wheat in under stress environments they found that the correlation between (SSI) with yield stress(Ys),harvest index(HI),TKW and the number of grains per panicle was significant and negative. This shows that selection for each of these traits in stress conditions cause reduction in sensitivity to stress. Nikkhah (1999) showed that GMP and STI are appropriate indicators that can be considered as an appropriate index for recognizing desired genotypes in dry stress conditions. Generally, genotypes with high yield, had a high biomass and straw. Considering the significance and the role of improved seeds in increasing yield and recognizing special genotypes to be used in breeding programs, implementing this crop is of special importance.

Generally, in optimal use of crop production, biotic and abiotic stresses are among the most crucial obstacles in providing food for human and feeding livestock and poultry. Meanwhile, with the aim of studying the impacts of drought and choosing drought tolerant lines, today stress tension has devoted a wide range of breeding program to itself (Ehdaei, 1993). Among abiotic stresses, drought and coldness are considered as the most significant risks for successful production including barley. Since barley holds an extensive ecological adaptation and has a more tolerance to drought, salinity and alkalinity of soil and considering the increase in population and demand for meat and animal protein, producing barley which contains high protein and high amount of essential amino acids and currently is used as the most major material in the diet in animal farms, is of great significance. Since barley has diverse varieties with different tolerances against water stress, for more efficient use of existing water, it is required that in each region, the varieties which have a higher yield with minimum irrigation while preserving the quality of the seed and have a better adaptation are determined. Thus, doing researches for preparing the varieties tolerant to terminal water stress in barley irrigated agriculture seems essential. This study was made for the first time for the goal of evaluating and gaining high yielding lines and tolerant to terminal drought stress in cold regions of Iran is suggested and performed.

MATERIAL AND METHODS

In the present study, selected 18 advanced barley lines from the drought tests of the last year were compared over two potential conditions (complete irrigation and irrigation termination after 50 percentage flowering in five stations i.e. Karaj, Mashhad, Uremia, Tabriz and Hamedan) for the period of one year, with two controls (EC82-6 and EDBYT82-9). The experiment was laid out in a complete randomized block design with three replications and in each genotype was cultivated in six rows and 5 meters. Preparing land and cultivating operations was done based on the conventional practices for crops tests. In spring, after the frost was over, irrigation was made depending on the crop's requirement and weather conditions and it was terminated after emerging 50% of the spikes. However, in normal conditions, irrigation was made depending on the crop's requirement up to end of the season. During the growing season, required note-takings of experimental plots were made and sensitivity indicators or drought tolerance were estimated of the equations suggested by Fischer and Maurer (1987). Preparing land and cultivating operations was done based on the custom of crops experiment.

Fertilizer was consumed based on soil testing with equation (90N-90P-50K) in which potash fertilizer of the source of potassium sulphate and phosphorous fertilizer of ammonium phosphate as base and nitrogen fertilizer of urea. Nitrogen fertilizer was consumed at the beginning of stem lengthening. It was furrow irrigation. In spring, after the frost was over, irrigation was made depending on the crop's requirement and weather conditions and it was terminated after emerging 50% of the spike. However, in normal conditions, irrigation was made depending on the crop's requirement up to end of the season. The amount of consumed seed in each plot based on 350 seeds in each square meter was done considering the figures TKW. During the growing season, required note-takings of experimental plots were made including the most major ones were: the date of emerging spike, number of fertile tillers, date of maturity, grain filling period, spike length, peduncle length, plant height, percent of lodging, biological yield, grain number in spike, grain weight per spike, harvest index and TKW. Grain yield was harvested of the total plot area. To estimate the sensitivity or drought tolerance of the genotypes being studied the equations suggested by Fischer and Mourer (1987) and Fernandez (1992) were used. Studying the data and variance analysis of significant traits related to end of season drought and using drought tolerance indicators for choosing high yield and drought stress tolerant genotypes was done. The multi-variable statistical methods like AMMI analysis and GGE biplot were used to study the status of stability of genotypes.

$$SI = \left(\frac{Y\overline{S}}{Y\overline{\overline{P}}}\right)$$

$$SSI = \frac{1-(Ys/Yp)}{SI}$$

TOL = yp- ys

$$STI = \frac{Yp}{(Y\overline{\overline{p}})}\frac{Ys}{(Y\overline{\overline{s}})}\frac{(Y\overline{\overline{S}})}{(Y\overline{\overline{P}})} = \frac{(Yp)(Ys)}{(Y\overline{\overline{P}})2}$$

GMP = $\sqrt{(Ys)(Yp)}$

$$MP = \frac{Ys+Yp}{2}$$

RESULTS AND DISCUSSION

Table 1, shows the changes of several significant traits of the made experiments. The figures in the table indicate the average traits for all research stations that show diversity in the statistical community being studied. Also, Tables 2 and 3 the results of analyzing the data ranks of advanced lines of barley end season drought experiment in cold climate under normal irrigation condition. Here, the lines who had a higher yield and acceptable stability had the most YIR and the least R rank and related SD. The results of similar experiments done under the stress condition of end season irrigation termination are also shown in tables 4 and 5. The effects of environment and genotypes were significant in all cases except in the second experiment. Results related to multivariable statistical analysis of methods analyze through the stability of the AMMI and GGE biplot been studied, are presented. The related results are shown in figures 1 to 8, generally, the diagrams indicate the status of genotypes, environment and their interaction in relation with choosing the best line in the point of adaptability and stability, the most desired environment in the place of dividing the genotypes response to the average of years in the places being studied and choosing genotypes based on private and public adaptability.

Table 1: Advanced genotypes specifications trial terminal drought ABYT-DC1 contains pedigree and genotype code abbreviations.

Genotypes	pedigree	RT	N				S			
			DHE	PLH	DMA	TKW	DHE	PLH	DMA	TKW
G1	(EC82-6)TWWd85-37/kavir	6	112	80	165	39	110	85	149	30
G2	Zarjau/80-5151/Radical	6	108	85	153	36	109	95	150	34
G3	Avt/Atts/EBC(ay3Toji"s"	6	109	60	150	47	110	85	148	31
G4	W12291w12269/Stirling	2	102	55	144	50	100	70	140	37
G5	Lignee527/Lignee527/NK1272	6	109	80	156	43	107	85	147	39
G6	Manitou/Alanda/Zafraa	6	105	70	149	41	106	85	147	41
G7	Pamir-149Nictoria	2	105	65	147	52	105	85	144	40
G8	GK5813Kc/MulersHeydla/Sls	2	107	60	150	40	107	75	145	44
G9	Vixen/Pamir-147	2	102	60	142	41	101	70	141	44
G10	AcuarioT75/Azaf	2	103	70	153	46	102	80	143	41
G11	Pamir-146/YEA389-3/YEA475-4	2	108	70	152	45	108	85	148	34
G12	Alpha/Durral/Pamir-160	2	111	75	154	42	110	90	150	41
G13	Pamir-013/Sonata	2	111	70	165	46	110	80	151	35
G14	Xemus/Rhn-03	2	106	70	151	38	105	90	143	38
G15	Robur/WA2196-68/Wysor	2	106	65	147	49	109	85	149	37
G16	Bugar/DZ48-232	2	108	80	152	41	107	85	147	42
G17	Belt67-1608/Slr/3/Dicktoo/Cascade/Hip/4/	2	113	85	159	47	112	90	153	44
G18	Rhn-03/Lignee527/NK12725/Lignee527/C/	6	107	85	151	42	107	90	145	40
G19	Lingnee527/NK1272/7/Gustoe/6/M64-76/Bor	6	104	75	150	42	105	90	145	32
G20	(EDBYT82-9)Rhn-03/L.527/NK1272	6	107	80	152	51	107	95	147	32

Table 2: Results of compound variance was data lines, advanced tested terminal drought barley in the cold climate under normal conditions, irrigation.

Rank	Genotypes	Yield	Duncan levels	
			5%	1%
1	G18	6.544	a	a
2	G14	6.519	a	a
3	G13	6.514	a	a
4	G16	6.438	ab	a
5	G20	6.413	ab	a
6	G10	6.387	ab	a
7	G1	6.218	ab	ab
8	G6	6.218	ab	ab
9	G19	6.137	ab	ab
10	G17	6.135	ab	ab
11	G11	6.030	abc	ab
12	G9	6.007	abc	ab
13	G2	5.937	abc	ab
14	G7	5.887	abc	ab
15	G12	5.795	abc	ab
16	G5	5.676	abc	ab
17	G4	5.584	abc	ab
18	G3	5.455	bc	ab
19	G15	5.449	bc	ab
20	G8	5.079	c	b

Source of variations	df	SS	MS	F
Location	3	198.51	66.17	**
Error l (Environment)	8	9.02	1.13	
G(Genotypes)	19	39.04	2.05	*
G*L (Genotype×location)	57	57.45	1.01	**
Error 2 (total error)	152	80.36	0.53	
Total	239	384.37		

Table 3: The results of analyzing the data ranks of advanced lines of barley end-season drought experiment in cold climate under normal irrigation condition.

Entry	parents	M (KRJ)	M (HMD)	M (MND)	M (MSH)	YLD (T/ha)	STD_Y	CV_Y	R	STD_R	Y.I.R
G1	(EC82-6)TWWd85-37/kavir	6.578	7.103	4.772	6.421	6.218	6.75	1.01	5.32	16.20	128
G2	Zarjau/80-5151/Radical	6.853	6.772	4.100	6.022	5.937	7.50	1.28	5.80	21.57	122
G3	Avt/Atts/EBC(ay3Toji"s"	5.442	6.614	3.300	6.464	5.455	10.25	1.53	6.70	28.01	112
G4	W12291w12269/Stirling	5.072	6.453	4.894	5.619	5.584	14.75	0.73	7.37	13.09	114
G5	Lignee527/Lignee527/NK1272	6.408	6.842	3.361	6.091	5.676	10.00	1.57	4.27	27.72	116
G6	Manitou/Alanda/Zafraa	6.742	6.411	4.822	6.897	6.218	9.00	0.95	5.35	15.32	127
G7	Pamir-149Nictoria	6.708	6.600	4.117	6.122	5.887	10.00	1.21	2.45	20.51	121
G8	GK5813Kc/MulersHeydla/Sls	5.908	5.847	3.028	5.533	5.079	16.00	1.38	5.66	27.12	104
G9	Vixen/Pamir-147	6.656	6.531	4.833	6.007	6.007	12.75	0.83	3.30	13.84	123
G10	AcuarioT75/Azaf	6.339	7.028	5.767	6.414	6.387	10.25	0.52	3.69	8.08	131
G11	Pamir-146/YEA389-3/YEA475-4	6.744	6.625	4.822	5.928	6.030	11.25	0.88	4.99	14.06	124
G12	Alpha/Durral/Pamir-160	6.814	6.203	4.194	5.970	5.795	13.00	1.12	5.94	19.41	119
G13	Pamir-013/Sonata	7.542	6.575	4.983	6.954	6.514	8.00	1.09	6.00	16.81	134
G14	Xemus/Rhn-03	6.708	5.542	6.183	6.644	6.519	10.75	0.23	3.77	3.59	134
G15	Robur/WA2196-68/Wysor	5.825	5.864	3.928	6.178	5.449	15.50	1.03	3.42	18.83	112
G16	Bugar/DZ48-232	6.678	7.186	4.700	7.190	6.438	7.50	1.18	6.86	18.38	132
G17	Belt67-1608/Slr/3/Dicktoo/Cascade/Hip/4/	5.363	7.042	5.828	6.035	6.135	13.50	0.63	5.92	10.20	126
G18	Rhn-03/Lignee527/NK12725/Lignee527/C/	7.431	7.861	3.728	7.157	6.544	5.75	1.90	8.18	29.03	134
G19	Lingnee527/NK1272/7/Gustoe/6/M64-76/Bor	7.408	6.928	3.150	7.061	6.137	8.25	2.00	7.37	32.61	126
G20	(EDBYT82-9)Rhn-03/L.527/NK1272	6.650	7.239	4.639	7.123	6.413	9.25	1.21	8.46	18.86	131

Table 4: The results of compound variance was data lines, advanced tested terminal drought barley in the cold climate under stress conditions and irrigation.

Rank	Genotypes	Yield	Duncan levels	
1	G18	5.858	5%	1%
2	G14	5.518	a	a
3	G13	5.760	a	a
4	G16	5.745	ab	ab
5	G20	5.682	ab	ab
6	G10	5.585	ab	ab
7	G1	5.532	abc	ab
8	G6	5.435	abcd	ab
9	G19	5.382	abcd	ab
10	G17	5.315	abcd	ab
11	G11	5.256	abcd	ab
12	G9	5.233	abcd	ab
13	G2	5.218	abcd	ab
14	G7	5.205	abcd	ab
15	G12	5.089	abcd	ab
16	G5	4.947	bcd	ab
17	G4	4.932	bcd	ab
18	G3	4.790	cd	ab
19	G15	4.774	cd	ab
20	G8	4.702	d	b

Source of variations	df	SS	MS	F
Location	3	21.60	7.20	*
Error l (Environment)	8	10.09	1.26	
G(Genotypes)	19	20.11	1.58	*
G*L (Genotype×location)	57	41.14	0.72	**
Error 2 (total error)	152	58.93	0.39	
Total	239	161.18		

Enjoying the information of stress indicators can also help us in finding the most efficient methods and criteria of selection, while making it possible to simultaneously select high potential, with desired stability and stress-tolerant lines. The findings showed that the relations between indicators and recognizing the lines with the above-said qualifications were well done by the used methods.

Table 5: The results of analyzing the data ranks of advanced lines of barley end-season drought experiment in cold climate under stress irrigation condition.

Entry	parents	M (KRJ)	M (HMD)	M (MND)	M (MSH)	YLD (T/ha)	STD_Y	CV_ Y	R	STD_R	Y.I.R
G1	(EC82-6)TWWd85-37/kavir	5.097	4.800	4.500	4.764	4.790	16.25	0.24	2.36	5.10	98
G2	Zarjau/80-5151/Radical	4.900	5.453	5.050	5.528	5.233	11.23	0.31	5.62	5.84	107
G3	Avt/Atts/EBC(ay3Toji"s"	4.739	4.494	4.989	4.586	4.702	17.50	0.22	4.36	4.60	96
G4	W12291w12269/Stirling	4.097	5.511	4.006	5.482	4.774	14.50	0.84	7.14	17.50	98
G5	Lignee527/Lignee527/NK1272	4.961	5.208	4.706	4.853	4.932	15.75	0.21	1.26	4.30	101
G6	Manitou/Alanda/Zafraa	5.000	6.542	4.817	5.382	5.435	9.50	0.77	5.51	14.25	111
G7	Pamir-149Nictoria	6.317	5.961	4.461	5.602	5.585	8.00	0.80	6.63	14.40	115
G8	GK5813Kc/MulersHeydla/Sls	5.097	5.636	4.461	5.162	5.089	14.25	0.48	2.63	9.48	104
G9	Vixen/Pamir-147	5.881	6.344	5.428	5.606	5.815	3.50	0.40	1.29	6.87	119
G10	AcuarioT75/Azaf	5.158	6.383	6.050	5.447	5.760	5.75	0.56	4.65	9.68	118
G11	Pamir-146/YEA389-3/YEA475-4	5.228	6.217	4.656	4.926	5.256	12.00	0.68	4.24	12.97	108
G12	Alpha/Durral/Pamir-160	5.417	5.364	5.306	5.175	5.315	9.50	0.10	4.65	1.96	109
G13	Pamir-013/Sonata	6.744	5.700	5.100	5.184	5.682	7.50	0.76	4.51	13.31	117
G14	Xemus/Rhn-03	5.442	4.986	4.233	5.127	4.947	14.00	0.51	5.72	10.36	101
G15	Robur/WA2196-68/Wysor	5.183	6.085	5.211	5.647	5.532	6.50	0.43	4.20	7.70	113
G16	Bugar/DZ48-232	5.408	6.606	4.822	4.692	5.382	10.50	0.87	7.05	16.23	110
G17	Belt67-1608/Slr/3/Dicktoo/Cascade/Hip/4/	4.761	5.817	5.128	5.166	5.218	11.75	0.44	4.65	8.41	107
G18	Rhn-03/Lignee527/NK12725/Lignee527/C/	5.428	7.194	5.083	5.274	5.745	6.50	0.98	3.79	17.00	118
G19	Lingnee527/NK1272/7/Gustoe/6/M64-76/Bor	5.581	4.667	5.278	5.296	5.205	9.25	0.38	6.65	7.39	107
G20	(EDBYT82-9)Rhn-03/L.527/NK1272	6.586	6.336	5.483	5.27	5.858	6.25	0.73	6.13	12.43	120

In figure 1 and 4, AMMI analysis biplot in which, the first component in normal condition and first component in stress condition against the average genotypes yield. The genotypes approximate to horizontal axis in the middle of the axis or the values approximate to zero of the first component IPC1 hold the highest degree of stability and the lines holding more main effects had more adaptability with environments being studied. In figures 2,3,5,7 and8 the best genotypes and the more favored environments being studied are shown.

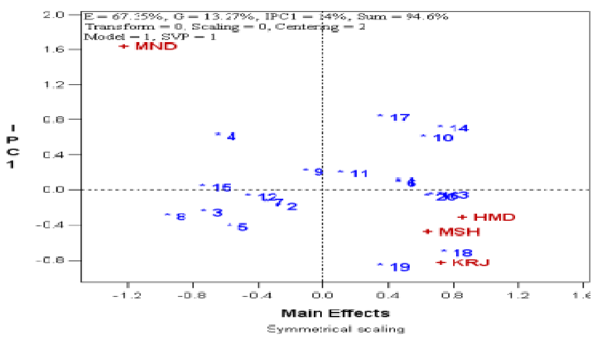

Fig. 1. Diagram biplot of the first component, versus average yield of genotypes using a AMMI model under normal irrigation.

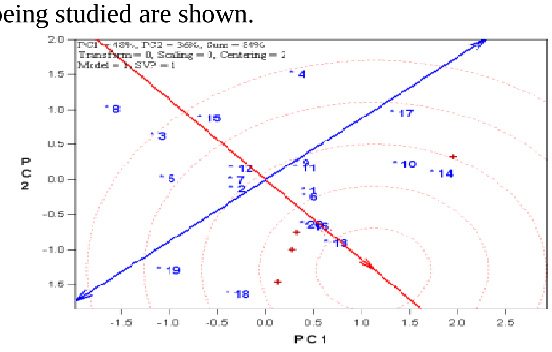

Fig. 2. Diagram of studied genotype the ideal barley using the GGE biplot method under conditions of normal irrigation.

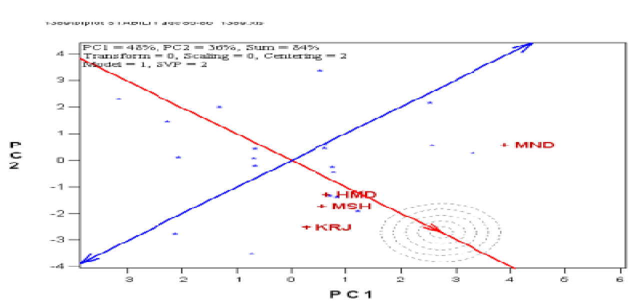

Fig. 3. Diagram ideal environment studied using barley GGE biplot under conditions of normal irrigation

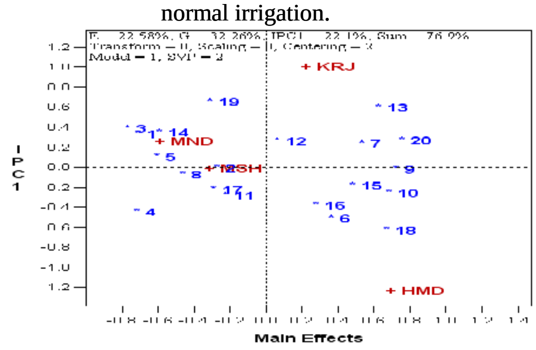

Fig. 4. Diagram biplot of the first component, versus average yield of genotypes using a AMMI model under stress

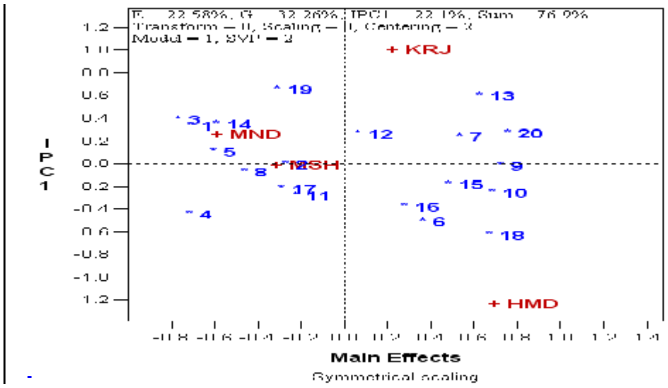

Fig. 5. Diagram studied genotype the ideal barley using the GGE biplot method under stress.

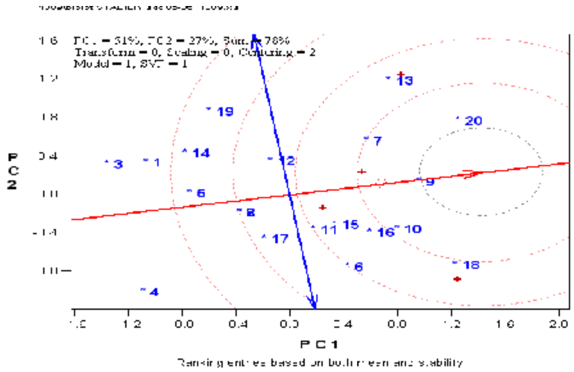

Fig. 6. Diagram the ideal environment studied barley using the GGE biplot method under stress.

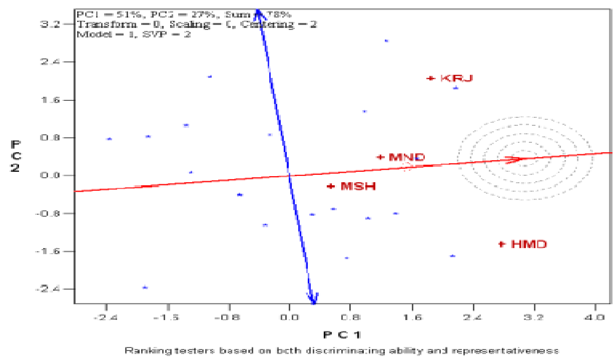

Fig.7. Diagram biplot studied genotypes and indexes stress tolerance.

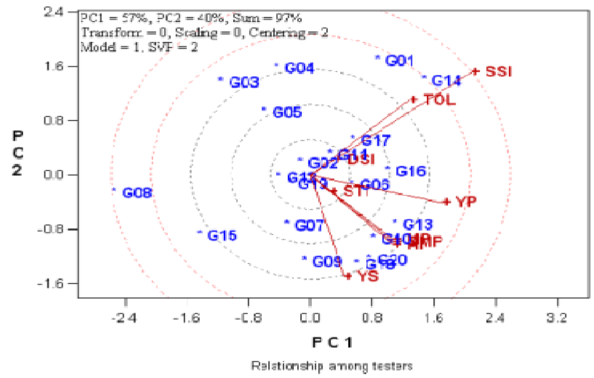

Fig. 8. Biplot superior genotypes with respect to indexes stress tolerance.

Totally, the findings of experiments introduced lines 7, 9, 13 and 18 from as the most adaptable or most stable genotypes being studied. Hamedan environment also showed a high favorability for screening stable genotypes. After final data analysis of all stations, 7 superior lines were selected to participate in end season, drought tolerant promising lines adaptability experiment for choosing end season high yield, drought tolerant genotypes.

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