Original article

Evaluation of late season heat in barley genotypes using some susceptibility and tolerance indices

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Extended abstract

Introduction
Barley is one of the most important crops in the world and ranks fourth in terms of nutritional importance and area under cultivation among cereals after wheat, corn and rice, but it has ranks first in terms of the extent of cultivation in a variety of climates. The world's food production is severely limited by environmental stresses. One way to sustain production for the world's growing population is to minimize the reduction in production caused by these tensions. Given that heat stress, in particular late season heat is the most widespread type of heat stress in the world, especially in the subtropical regions, and as a major constraint in the production of sustainable crop yields, including barley. Therefore, identifying heat-tolerant genotypes can be a valuable solution to this problem. The present experiment was undertaken to understand the impact of high temperature on yield and its attributing traits and to select heat stress tolerant parents and cross combinations for future breeding program.

Materials and methods
To fulfill the requirement of this objective, the experiment was conducted in two environments i.e. normal and heat stress. Infact This study was performed to evaluate the heat tolerance at the end of the season and to identify barley tolerant genotypes using stress tolerance indices on experimental farm of the Gonbad Kavous University during the growing season of 2015-2016. The experimental plant materials were 120 barley genotypes which were evaluated in a randomized complete block design with two replications under two conditions without stress and heat stress. In addition, seeds of each genotype were grown in two meter rows with 20cm distance between the rows and the plant density was 270 plants per m^2.

Results and discussion
The results of this experiment showed that the highest yield mean in non-stress conditions was related to genotype Torsh and in stress conditions was related to genotype Line143-2. The results of analysis of

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variance for yield trait showed that the differences between genotypes and the interactions of genotype and environment were significant at the level of one percent for the trait, which indicates high diversity and different reactions of cultivars and lines in different environments. Comparison of indices also showed that YI, STI, GMP and MP indices had the highest significant correlation with yield under non-stress and stress conditions and the superior indices of this experiment were for screening heat tolerant genotypes. Cluster analysis based on indices and yield under stress and non-stress conditions divided the studied genotypes into three groups.

Conclusion

Overall, the results of cluster analysis and principal component analysis showed that genotypes Torsh, Zarjo and 4Shori had the highest tolerance and genotypes Line105, Nosrat, Line98-2 and Fajr30 had the lowest tolerance to heat stress. Obviously, it is necessary to repeat the experiment in other places to be surer of these results and to obtain definitive results. On the other hand, to obtain heat-tolerant cultivars, it is recommended to cross the Torsh, Zarjo and 4Shori genotypes, and to locate heat-tolerant control genes, tolerant genotypes (Torsh and Zarjo) cross with sensitive genotypes (Line105 and Nosrat) can be used as two parents.

Table 1. The studied barley genotypes in this research

Code	Genotype	Pedigree
1	Zahak	POA/HJO//QJINA
2	Yousef	Lignee527/Chn-01//Gustoe/4/Rhn-08/3 /Deir Alla 106 //Dl71/Strain
3	Sahra	L.B.LRAN/UnaQL//Glorias"s"Com
4	Nosrat	Karon/Kavir
5	Fajr 30	Lignee131/Gerbel//Alger-Ceres
6	Badia	Local variety
7	Valfajr	CI-108985
8	Line 71-2	Ashar/Victoria//Cwb117-5-9-6/5/Lignee 527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla 106//Dl71/Strain 205/2-2
9	Line 72-2	Karoon/Kavir//Rhodes'S'//Tb/Chzo/3/Gloria'S'/6/ Bls-3(Sadik-10=(3896/1-3/4/1246/1-3/3/3887/28//3892/1-3/5/Grivita))-2
10	Nimroz	Trompillo
11	Peyghambari	Local variety
12	Lokht 5	Local variety
13	Line 79-2	Karoon/Kavir //Rhodes'S'//Tb/Chzo/3/Gloria'S'/6/ Bls-3(Sadik-10=(3896/1-3/4/1246/1-3/3/3887/28//3892/1-3/5/Grivita))/-3
14	Line 80-2	Zarza'S'/Agave'S'//Cardo/3/79W40762/Puebleda/5/ D5(Lignee 527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla 106//Dl71/Strain 205)
15	Line 81-2	Bgs/Dajia//L.1242/3/(L.B.Iran/Una8271//Gloria'S'/3/Alm/Una80//....)/4/Salt-4(LB.Iran/Una 8271//Gloria"S"/Come"s"-11M/3/Kavir)
16	Line 82-2	Bgs/Dajia//L.1242/3/(L.B.Iran/Una8271//Gloria'S'/3/Alm/Una80//....)/4/ Lignee 527/Nk1272//Jlb 70-63
17	Line 83-2	Dasht//Ebc(a)/Badia/3/Sahra
18	Line 84-2	Dasht//Ebc(a)/Badia/3/Lignee 527/Nk1272//Jlb 70-63
19	Line 85-2	(10th-Ebyt,Wb-88-16) Rojo/3/L.B.Iran/Una8271//Gloria"S"/Com"S"
20	Line 86-2	Dasht//Ebc(a)/Badia/3/Lignee 527/Nk1272//Jlb 70-63-1
21	Sina	Local variety
22	Fayezeh	Local variety
23	Line 89-2	Dasht//Ebc(a)/Badia/3/Lignee 527/Nk1272//Jlb 70-63-4
24	Line 90-2	Productive/Rihane-03//Nosrat-1
25	Line 91-2	Dasht//Ebc(a)/Badia/3/Lignee 527/Nk1272//Jlb 70-63-2
26	Line 92-2	Dasht//Ebc(a)/Badia/3/Lignee 527/Nk1272//Jlb 70-63-3
27	Line 93-2	Productive/Rihane-03//Nosrat-2
28	Line 94-2	Productive/Rihane-04/6/Bls-3(Sadik-10=(3896/1-3/4/1246/1-3/3/3887/28//3892/1-3/5/Grivita))-1
29	Lokht 7	Local variety
30	Lokht 17	Local variety
31	Harmal	Local variety
32	Line 98-2	Productive/Rihane-04/6/Bls-3(Sadik-10=(3896/1-3/4/1246/1-3/3/3887/28//3892/1-3/5/Grivita))-2
33	Line 99-2	Productive/Rihane-04/6/Bls-3(Sadik-10=(3896/1-3/4/1246/1-3/3/3887/28//3892/1-3/5/Grivita))-3
34	Line 100-2	Trompilu/4/Rhodes'S'//Tb/Chzo/3/Gloria'S' /5/ Sahra
35	Line 101-2	Cm67/Ipa265//Gustoe/Ipa7/3/D-10(Rhn-03//L.527/Nk1272)
36	Line 102-2	Ashar/Victoria//Cwb117-5-9-6/5/Lignee 527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla 106//Dl71/Strain 205
37	Line 103-2	Bereke-54/4/Legia/3/L.B.Iran/Una82 71//Gloria
38	Line 104-2	Trompilo/L.Moghan//Yousef-1
39	Line 105-2	Trompilo/L.Moghan//Yousef-2
40	Line 106-2	LB.Iran/Una 8271//Gloria"S"/Come"s"-11M/3/Kavir/4/Rhn-03//L.527/NK1272-1
41	Eizeh	Local variety
42	Afzal	Local variety
43	Line 109-2	LB.Iran/Una 8271//Gloria"S"/Come"s"-11M/3/Kavir/4/Rhn-03//L.527/Nk1272-2
44	Beicher	Local variety
45	Alcher	Local variety
46	Line 112-2	LB.Iran/Una 8271//Gloria"S"/Come"s"-11M/3/Kavir/4/Rhn-03//L.527/Nk1272-3
47	Zarjo	1-28-9926

Table 1. Continued

Code	Genotype	Pedigree
48	Aras	Star
49	Line 115-2	Fajr30/3/Rhn-03//L.527/Nk1272-3
50	Line 116-2	Lignee 527/Nk1272//Jlb 70-63/5/Arbayan/Nk1272/4/Arar/3/Mari/Aths*2//M-Att-73-337-1
51	Line 117-2	L.527/Nk1272//Alanda/3/Alanda-01*2/4/Lignee 527/Nk1272//Jlb 70-63
52	Line 118-2	Ashar/Victoria//Cwb117-5-9-5/3/Kavir-1
53	Line 119-2	Ashar/Victoria//Cwb117-5-9-5/3/Kavir-2
54	Triton	Local variety
55	Line 125-2	Karoon/Kavir //Rhodes'S'//Tb/Chzo/3/Gloria'S' /4/Sahra-1
56	Line 126-2	Karoon/Kavir //Rhodes'S'//Tb/Chzo/3/Gloria'S' /4/Sahra-2
57	Khoram	Sfa-02/3/RM1508/Pro//W12269/4/Hml ArabiAbiad//ER/ApmICB92-0926-0AP-2AP-0AP
58	Mahor	Wi2291/Wi2269//Er/Apm
59	Line 129-2	Karoon/Kavir //Rhodes'S'//Tb/Chzo/3/Gloria'S' /4/Sahra-3
60	Line 130-2	Karoon/Kavir //Rhodes'S'//Tb/Chzo/3/Gloria'S' /4/Sahra-4
61	Line 131-2	Comp.Cr229//As46/Pro/3/Srs/4/Express/5/Yousef
62	Line 132-2	Kmk//Rbr/Wa2196-68/3/Ebc(A)/4/Icnb93-369-2
63	Line 133-2	WI2219//Mza/DL71/3/WI2198/Emir/4/Icnb93-328-1
64	Line 135-2	73M4-30/Rihane-03-1
65	Line 136-2	Rihane-03/3/Rihane//Aths/Bc
66	Line 138-2	Johoob/4/Post//Copal"s"/Gloria"s"/3/Kavir-1
67	Line 140-2	L.527/1-Bc-80100
68	Line 143-2	Kavir/Badia//1-Bc-80073
69	Line 144-2	Teran 78/1-Bc-80411
70	Line 149-2	Ashar/5/L.527/Chn-01//Gostoe/4/Rhn-08/3/Deir Alla106//Dl71/Strain205
71	Line 178-2	LB.Iran/Una 8271//Gloria"S"/3/Kavir/4/Arigashar-1
72	Line 181-2	73M4-30/Rihane-03-2
73	Line 184-2	Johoob/4/Post//Copal"s"/Gloria"s"/3/Kavir-2
74	Line 186-2	Johoob/4/LB.Iran/una8271//Gloria"s"/3/L.Moghan-1
75	Line 187-2	Johoob/4/LB.Iran/una8271//Gloria"s"/3/L.Moghan-2
76	Hml/Bichy	Hml/Bichy
77	Line 195-2	Shuyler/3/M.RNB86.80/NB 2905//L.527/4/ICNB93-328
78	Line AB-2-10	LB.Iran/UNA 8271//Gloria"S"/3/Kavir/4/Arigashar-2
79	Ciru/M111	Ciru/M111
80	Ebyt-W-90-15	Gob/Aleli//Canela/3/Arupo*2/Jet/4/Arupo/K8755//Mora
81	Line AB-2-14	Kmk//Rbr/Wa2196-68/3/Ebc(A)/4/Icnb93-369-1
82	Line AB-2-15	D5(Lignee 527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla 106//Dl71/Strain 205)/5/(Cabuya/Mja//Petunia 1)-1
83	Line AB-2-19	Rhn-03/3/Mr25-84/Att//Mari/Aths*3-02/4/Sahra-1
84	Line AB-2-5	Wa2138-68/Ill62-19/3/G.L./72Ab58/…/4/Granado
85	Line AB-2-9	Rihane//Aths/BC/3/Dictoo"s"/Wa 1094.76//Aloe/Rue
86	Line EB-91-12-2	Cin/80.5138//Gloria/Copal"s"/3/Icnb93-328
87	Line EB-91-13	WI2219//Mza/Dl71/3/WI2198/Emir/4/Icnb93-328-2
88	Productive	Local variety
89	Eram	Local variety
90	D 10	Local variety
91	Line EB-92-1	L.527/1-Bc-80100-4
92	Line EB-92-11	Kavir*2/Zdm938//Icnb93-369-1
93	Line EB-92-13	Kavir*2/Zdm938//Icnb93-369-2
94	Line EB-92-16	P.sto/3/Lbiran/Una80//Lignee640/4/Bllu/5/Petunia 1/6/Zigzig/4/Egypt4/Teran78/P.sto/3/Quina
95	Line EB-92-17	P.sto/3/Lbiran/Una80//Lignee640/4/Bllu/5/Petunia 1/6/Zigzig//Cucapah/Puebla
96	Line EB-92-3	Arupo/K8755//Mora/3/Msel

Table 1. Continued

Code	Genotype	Pedigree
97	Line EB-92-4	Sumbard400/Bermejo//Sen/3/Tocte/4/Sumbard400/Bermejo//Sen/3/Sumbard400/5/Alanda
98	Line EB-92-7	L.527/1-Bc-80100-4
99	Line EB-92-8	Zabol-F6-2761
100	Line EB-92-9	Ebyt-W-91-17 (Rhn-03/Anodium//Icnb 93-328)
101	Line EB-YT-90-5-2	D5(Lignee 527/Chn-01//Gustoe/4/Rhn-08/3/Deir Alla 106//Dl71/Strain 205)/5/(Cabuya/Mja//Petunia 1)-2
102	Dasht	Probestdwarf
103	Makohy	Star
104	5 Shori	Rodasht1
105	4 Shori	Rodasht
106	12 Shori	Rodasht2
107	Reyhan	Rihane
108	Mb 8212	Behrokh
109	Gorgan 4	Herta
110	Kavir	Arivat
111	Jonob	Gloria s / copal s
112	Shirin	Local variety
113	Torsh	Local variety
114	Bahman	CWB111-5-905
115	Eb 88-16	Rojo/3/LB.IRAN/Una8271//Gloria"S"/Com"S"
116	Komino	Local variety
117	KhoshkI2	Local variety
118	Cm67/Ipa265	Cm67/Ipa265
119	Karon	Strain 205
120	Karaj	Local variety

Table 2. Physical and chemical properties of the experimental soil

EC	Organic carbon	Total nitrogen	Phosphorus	Potassium	Sand	Clay	Silt
ds m^{-1}	----------------%----------------		------------mg kg^{-1} --------------		------------%-------------		
1.44	0.15	0.14	14.12	321	10.41	40.4	49.19

Table 3. Result of grain yield combined analysis of variance of studied genotypes in non-stress and stress conditions

Sources of Variations	df	Yield
Stress	1	50113.12**
Error1	2	3019.31
Genotype	119	2311.64**
Genotype×Stress	119	2018.32**
Error 2	238	1132.405
C.V %		*30.41*

ns, * and **: Not-significant and significant at 5% and 1% probability levels, respectively

Table 4. Comparison of grain yield mean of genotypes in non-stress and stress conditions using PLSD test

Genotype number	Yield at non-stress conditions	Yield at stress conditions	Yield difference	Genotype number	Yield at non-stress conditions	Yield at stress conditions	Yield difference
	-------------------- g m^{-2} --------------------				-------------------- g m^{-2} --------------------		
1	97.92	113.23	-15.31*	42	135.72	127.33	8.39*
2	121.27	108.48	12.79*	43	170.90	76.80	94.1**
3	95.78	108.75	-12.97*	44	169.63	122.23	47.4**
4	60.10	92.45	-32.35**	45	136.75	71.60	65.15**
5	69.77	90.27	-20.5**	46	130.19	116.95	13.24*
6	125.40	107.07	18.33**	47	261.50	106.77	154.73**
7	109.48	126.30	-16.82**	48	216.36	107.47	108.89**
8	111.02	137.03	-26.01**	49	170.30	141.17	29.13**
9	85.83	135.13	-49.3**	50	85.72	102.93	-17.21**
10	127.70	107.72	19.98**	51	168.95	104.64	64.31**
11	78.65	106.82	-28.17**	52	141.08	129.05	12.03*
12	120.27	108.12	12.15*	53	95.17	89.42	5.75 ns
13	74.37	106.67	-32.3**	54	124.00	115.48	8.52*
14	107.05	59.53	47.52**	55	133.42	103.13	30.29**
15	127.00	68.68	58.32**	56	193.68	107.87	85.81**
16	86.05	113.08	-27.03**	57	110.67	127.78	-17.11**
17	109.08	78.22	30.86**	58	89.67	74.50	15.17*
18	178.10	97.92	80.18**	59	163.87	121.15	42.72**
19	128.12	73.09	55.03**	60	105.03	103.40	1.63 ns
20	136.80	80.65	56.15**	61	82.53	126.03	-43.5**
21	131.20	14.27	116.93**	62	159.05	124.63	34.42**
22	87.38	139.65	-52.27**	63	163.98	72.33	91.65**
23	143.42	147.45	-4.03**	64	177.13	107.22	69.91**
24	107.65	93.27	14.38**	65	165.44	91.97	73.47**
25	182.92	106.01	76.91**	66	142.20	74.17	68.03**
26	87.63	117.05	-29.42**	67	96.43	90.55	5.88 ns
27	107.35	60.20	47.15**	68	122.92	191.12	-68.2**
28	95.80	115.00	-19.2**	69	115.87	95.97	19.9**
29	161.12	138.45	22.67**	70	113.02	132.45	-19.43**
30	168.85	90.35	78.5**	71	77.43	120.90	-43.47**
31	184.80	97.91	86.89**	72	140.42	68.15	72.27**
32	68.12	89.82	-21.7**	73	121.98	125.98	-4 ns
33	78.70	64.43	14.27**	74	195.17	136.11	59.06**
34	82.03	148.40	-66.37**	75	116.60	115.33	1.27 ns
35	107.40	97.75	9.65*	76	144.92	88.44	56.48**
36	97.00	132.00	-35**	77	153.33	92.25	61.08**
37	109.23	82.75	26.48**	78	106.35	79.02	27.33**
38	128.13	106.07	22.06**	79	130.83	116.70	14.13*
39	59.00	82.97	-23.97**	80	105.85	97.750	8.1*
40	123.88	111.25	12.63*	81	107.90	110.500	-2.6 ns
41	90.15	98.17	-8.02*	82	207.78	115.500	92.28**

Table 4. Continued

Genotype number	Yield at non-stress conditions	Yield at stress conditions	Yield difference	Genotype number	Yield at non-stress conditions	Yield at stress conditions	Yield difference
	-------------------- g m^{-2}--------------------				-------------------- g m^{-2}--------------------		
83	175.87	111.43	64.43**	**102**	123.80	75.70	48.1**
84	150.98	81.78	69.19**	**103**	207.55	122.11	85.437**
85	106.58	119.93	-13.35*	**104**	95.10	109.60	-14.5*
86	141.77	131.22	10.55*	**105**	246.50	105.49	141.00**
87	126.47	107.48	18.983**	**106**	275.33	116.99	158.33**
88	113.23	73.43	39.797**	**107**	100.75	131.54	-30.79**
89	70.52	120.70	-50.18**	**108**	206.76	66.88	139.88**
90	111.47	117.66	-6.197*	**109**	96.91	83.71	13.19*
91	135.17	119.08	16.087**	**110**	128.60	129.87	-1.27 ns
92	142.20	122.60	19.6**	**111**	142.49	110.49	31.99**
93	98.53	151.80	-53.27**	**112**	79.01	63.64	15.36*
94	106.80	68.61	38.183**	**113**	285.78	94.00	191.78**
95	102.02	114.80	-12.78*	**114**	173.72	78.26	95.45**
96	140.45	120.06	20.383**	**115**	144.00	78.61	65.38**
97	130.30	105.08	25.215**	**116**	175.83	142.81	33.01**
98	191.33	168.98	22.347**	**117**	191.32	87.39	103.93**
99	130.65	146.13	-15.483*	**118**	138.23	109.73	28.49**
100	149.27	94.23	55.037**	**119**	124.43	103.31	21.11**
101	143.38	94.58	48.797**	**120**	149.97	72.37	77.6**
PLSD$_{5\%}$	*59.08*	*81.63*		**PLSD$_{5\%}$**	*59.08*	*81.63*	

ns, * and **: Not-significant and significant at 5% and 1% probability levels, respectively

Table 5. Correlation coefficients between yield in stress and nonstress conditions with tolerance indices in barley genotypes

	YP	YS	STI	GMP	MP	YSI	YI	TOL	SSI
YP	0.43**	0.83**	0.83**	0.78**	0.29**	1**	-0.28**	-0.29**	
YS		0.73**	0.85**	0.9**	-0.57**	0.43**	0.73**	0.57**	
STI			0.92**	0.91**	-0.1 ns	0.83**	0.15*	0.13 ns	
GMP				1**	-0.21**	0.83**	0.28**	0.21**	
MP					-0.24**	0.78**	0.36**	0.24**	
YSI						0.29**	-0.83**	-1**	
YI							-0.28**	-0.29**	
TOL								0.83**	

ns, * and **: Not-significant and significant at 5% and 1% probability levels, respectively. YP: Yield in non-stress condition, YS: Yield in stress condition, SSI: stres susceptibility index, STI: stress tolerance index, GMP: geometric mean productivity, MP: mean productivity, YSI: yield stability index, TOL: tolerance, YI: yield index.

Table 6. Number, eigenvalues, the percentage of cumulative variance of principal components and tolerance indices and yield under non- stress and stress in barley genotypeS.

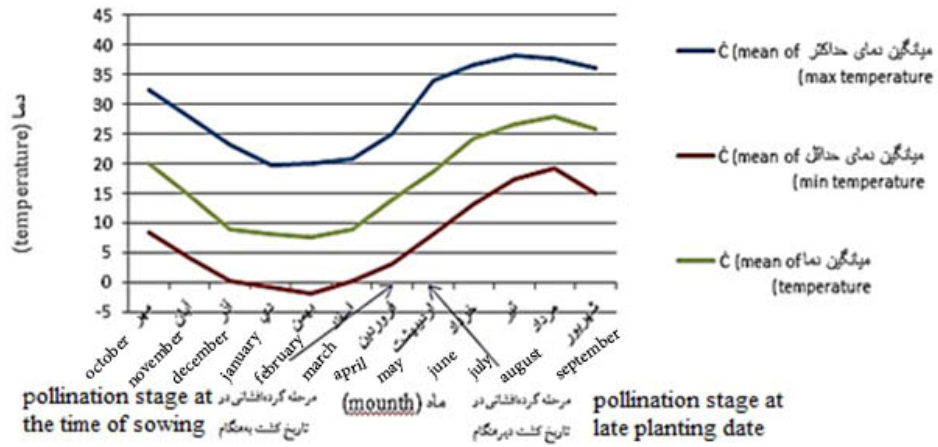| Principal component	Eigen value	Cumulative variance (%)	Yp	Ys	MP	GMP	STI	TOL	SSI
PCA-1	4.237	66.321	0.439	0.012	-0.967	-0.312	-0.281	0.102	0.528
PCA-2	1.924	99.213	0.631	0.788	0.851	0.921	0.946	0.012	0.04

Fig.1. Temperature change graph in different months of the growing season using the 20-year average meteorological statistics of Gonbad Agricultural Research Station
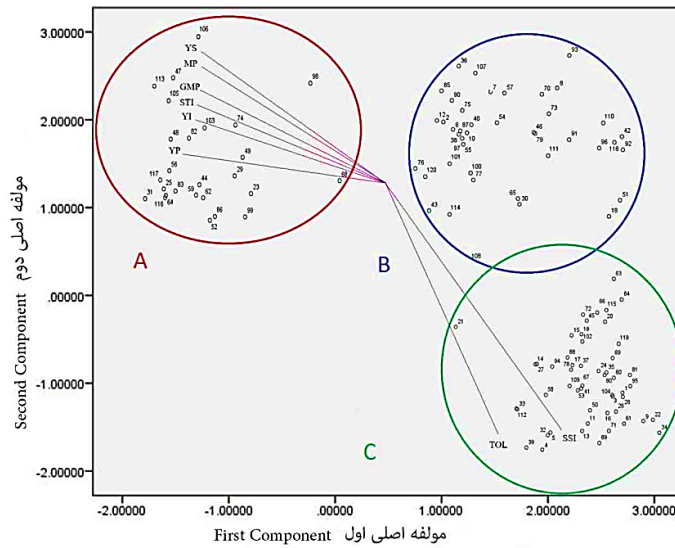

Fig. 2. Barley genotypes cluster and biplot display in 6 heat tolerance indices with yield in non-stress and stress environments base on first and second components.
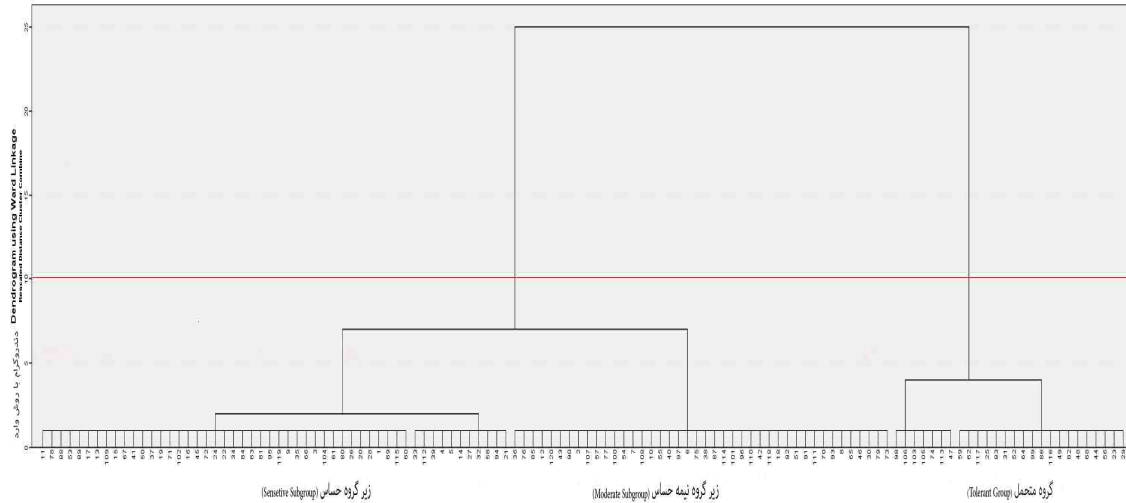
Fig. 3. Barley genotypes dendrogram of classification based on six indices MP, GMP, STI, SSI, TOL and YI and yield under non-stress (Yp) and stress (Ys) with ward method.

Table 8. Members and mean and percentage of deviation from total mean for the groups derived from cluster analysis for tolerance indices and yield under non-stress (Yp) and stress (Ys). a. The name and number of genotypes are shown in Table 1.

Groups	Genotype number[a]	Yp	Ys	YI	MP	GMP	STI	Indices
Tolerant	26 genotypes (23, 25, 29, 31, 44, 47, 48, 49, 52, 56, 59, 62, 64, 68, 74, 82, 83, 86, 98, 99, 103, 105, 106, 113, 116, 117)	178.77	123.37	1.13	155.39	149.76	22595.32	Mean
		46.94	18.21	0.17	36.71	34.13	8649.16	Deviation from total mean
Moderate	42 genotypes (2, 6, 7, 8, 10, 12, 14, 18, 21, 27, 30, 32, 33, 36, 38, 39, 40, 42, 43, 46, 51, 54, 55, 57, 58, 65, 70, 73, 75, 76, 77, 79, 85, 87, 90, 91, 92, 93, 94, 96, 97, 100, 101, 107, 108, 110, 111, 112, 114, 118, 120)	134.65	110.68	1.02	122.66	120.52	14559.97	Mean
		2.82	5.51	0.05	3.99	4.88	613.80	Deviation from total mean
Sensitive	52 genotypes (1, 3, 4, 5, 9, 11, 13, 14, 15, 16, 17, 19, 20, 21, 22, 24, 26, 27, 28, 32, 33, 34, 35, 37, 39, 41, 45, 50, 53, 58, 60, 61, 63, 66, 67, 69, 71, 72, 78, 80, 81, 84, 88, 89, 94, 95, 102, 104, 109, 112, 115, 119)	102.58	91.60	0.84	97.09	94.63	9125.82	Mean
		-29.25	-13.56	-0.1	-21.58	-21.01	-4820.34	Deviation from total mean