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Original article

Morphological and biochemical evaluation of salinity tolerance of barley cultivars in central regions of Iran

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Extended abstract

Introduction

One of the biggest challenges of agriculture in the present era is environmental stresses, especially drought and salinity stress and its destructive effect on food security. In this regard, this experiment was conducted with the aim of selecting of tolerant cultivar of barley to salinity stress and identifying tolerance mechanisms in new and old barley cultivars.

Material and method

This experiment was carried out during the two years of 2016-17 in the Milshbar Ardakan region located in Yazd province-Iran. Experimental treatments included 9 six-rowed barley cultivars including Nik, Mehr, Khatam, Reyhan, Goharan, Nosrat, Morocco, Afzal and Fajr 30 cultivars in three levels of irrigation water salinity including 4, 10 and 14 dS.m-1 were evaluated as a split plot experimental design so that water salinity as the main plots and cultivars as a sub-plots were randomly placed. The studied traits included yield and yield components as well as sodium and potassium levels, oxidizing enzymes and photosynthetic pigments.

Results and discussion

The results showed that salinity treatment had a significant effect on day to emergence, day to tillering and grain yield. Salinity stress reduced grain yield components but this reduction was not significant. The effect of cultivar on plant phenology and day to emergence, tillering and ripening was significant, but on yield and yield components became insignificant. However, among the studied cultivars, Nik, Mehr, Khatam and Reyhan cultivars had higher yields and yield components. Among the salinity treatments, the highest grain yield was obtained at salinity of 4 dS m^{-1} with 5770.64 kg ha^{-1}. With increasing salinity of irrigation water to 10 and 14 dS m^{-1}, grain yield decreased by 18.04 and 27.55%, respectively, and reached 4729.29 and 4180.87 kg ha^{-1}. The results of interaction showed that the interaction effect of year × salinity on grain yield components was significant and also the interaction of year × cultivar on 1000-Kernel weight and grain yield and year × salinity × cultivar on grain yield was significant. With increasing salinity stress, the amount of sodium ions in the shoots increased and

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potassium decreased, so the ratio of K/Na decreased. This mechanism was more effective in tolerant cultivars and in salinities of 4 and 10 dS m^{-1}. With increasing salinity stress, the amount of oxidizing enzymes increased, so that with increasing salinity from 4 to 10 and 14 dS m^{-1}, the amount of peroxidase enzyme was increased 1.59 and 2.23 times, catalase 1.52 and 1.95 times, and guaiacol peroxidase 1.47 and 2.89 times, respectively. With increasing salinity stress, all photosynthetic pigments increased. Among the cultivars, the amount of chlorophyll a and b in Morocco, Nik and Mehr was higher than other cultivars.

Conclusion

Based on the results of this experiment, it seems that tolerant cultivars, in addition to having high production potential, should have high potassium uptake mechanisms and high gene expression to produce enzymes that protect against oxidative stress in order to tolerate low to medium salinity stress.

Keywords: K/Na, Salinity stress, Six-rowed barley

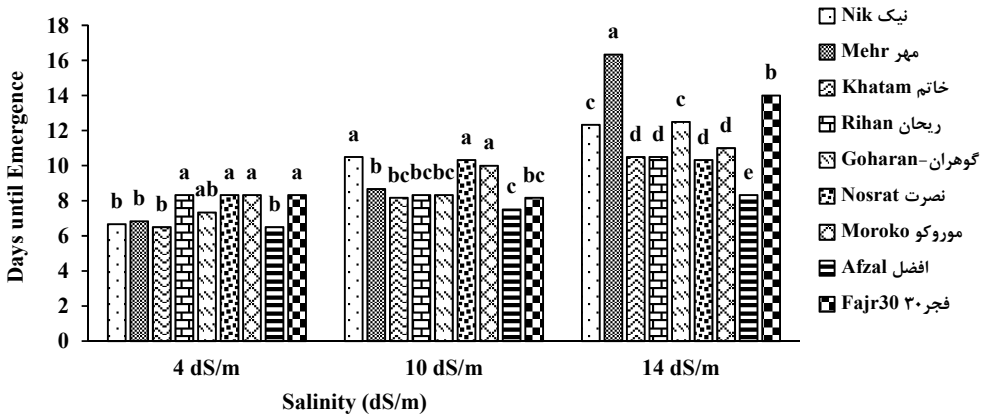

Fig. 1. Interaction effect of Salinity×Variety in days until emergence. Comparison of means is based on slicing of interaction.

Table 1. Analysis of variance of studied traits in barley cultivars under salinity stress and non-stress conditions in Milshbar region of Yazd province during 2016-2017.

S.O.V	df	Days to Emergence	Days to Tillering	Days to Maturity	Fertile Tiller Num.
Year	1	16.59 ^{ns}	430.22 ^{ns}	17194.8 ^{ns}	0.77 ^{ns}
Rep×Year	4	1.66 **	66.12 **	36.80 *	0.06 ^{ns}
Salinity	2	258.57 **	10417.4 *	3923.19 ^{ns}	2.93 ^{ns}
Year×Salinity	2	2.12 **	953.68 **	3050.38 **	3.76 **
Rep×Year×Salinity	8	0.27 ^{ns}	35.27 **	22.31 *	0.15 ^{ns}
Variety	8	16.68 **	50.88 *	476.85 **	0.37 ^{ns}
Salinity×Variety	16	14.09 **	22.18 ^{ns}	90.84 ^{ns}	0.17 ^{ns}
Year×Variety	8	0.87 **	11.75 ^{ns}	30.19 **	0.27 ^{ns}
Year×Salinity×Variety	16	0.78 **	11.42 ^{ns}	100.11 **	0.25 ^{ns}
Error	96	0.19	10.65	11.06	0.15
CV (%)		*4.69*	*7.18*	*2.08*	*17.94*

Table 1. Continued

S.O.V	df	Grains.Spike^{-1}	Spike.m^{-2}	TKW	Grain Yield
Year	1	4119.80 ^{ns}	30752.0 ^{ns}	37.49 ^{ns}	2824020.1 ^{ns}
Rep×Year	4	2.65 ^{ns}	2616.5 ^{ns}	1.08 ^{ns}	61243.65 ^{ns}
Salinity	2	2933.66 ^{ns}	117082.2 ^{ns}	405.10 ^{ns}	35212999 **
Year×Salinity	2	748.97 **	150414.2 **	105.66 **	297560.2 ^{ns}
Rep×Year×Salinity	8	14.40 ^{ns}	5952.8 ^{ns}	1.53 ^{ns}	259226.4^{ns}
Variety	8	58.58 ^{ns}	15856.4 ^{ns}	75.96 *	2052967.4^{ns}
Salinity×Variety	16	19.15 ^{ns}	6875.4 ^{ns}	20.24 *	427481.9^{ns}
Year×Variety	8	40.32 ^{ns}	10794.7 ^{ns}	14.25 *	1560993.8**
Year×Salinity×Variety	16	28.06 ^{ns}	10016.9 ^{ns}	8.31 ^{ns}	849509.09 **
Error	96	29.14	6176.7	5.27	317585.5
CV (%)		*14.46*	*17.94*	*6.54*	*11.52*

**, * and ns: significant at 5%, 1% probability levels and non significant, respectively.

Table 2. Means of irrigation salinity treatment in evaluated traits base on Duncan multiple test and probability level of 5 percent.

Salinity	Days to emergence	Days to Tillering	Days to Maturity	Fertile Tiller Num.	Grain.Spike^{-1}	Spike.m^{-2}	TKW	Grain Yield
dS.m^{-1}							gr	kg.ha^{-1}
4	7.46^{c}	29.96^{b}	166.48^{a}	2.45^{a}	45.74^{a}	490.81^{a}	38.25^{a}	5770.64^{a}
10	8.89^{b}	49.50^{ab}	162.91^{a}	2.01^{a}	32.02^{a}	402.37^{a}	33.23^{a}	4729.29^{b}
14	11.76^{a}	56.83^{a}	150.26^{a}	2.11^{a}	34.23^{a}	421.33^{a}	33.84^{a}	4180.87^{c}

Means with similar letter in each columns have no significant difference.

Table 3. Means of Variety treatment in evaluated traits base on Duncan multiple test and probability level of 5 percent

Variety	Days to emergence	Days to Tillering	Days to Maturity	Fertile Tiller Num.	Grains.Spike^{-1}	Spike.m^{-2}	TKW	Grain yield
							gr	kg.ha^{-1}
Nik	9.83 ^{bc}	43.94 ^{cd}	152.44 ^{d}	2.44 ^{a}	39.68 ^{a}	488.44 ^{a}	33.96 ^{bcd}	5317.7 ^{a}
Mehr	10.61 ^{a}	44.89 ^{bcd}	165.44 ^{a}	2.26 ^{a}	39.43 ^{a}	452.89 ^{a}	34.53 ^{bcd}	5249.0 ^{a}
Khatam	8.39 ^{e}	46.67 ^{abc}	165.72 ^{a}	2.28 ^{a}	38.50 ^{a}	456.89 ^{a}	35.40 ^{bc}	5193.5 ^{a}
Rihan	9.06 ^{de}	44.22 ^{cd}	165.89 ^{a}	2.07 ^{a}	37.56 ^{a}	414.67 ^{a}	34.38 ^{bcd}	4984.6 ^{a}
Goharan	9.39 ^{cd}	45.72^{abcd}	155.00 ^{cd}	2.00 ^{a}	37.14 ^{a}	400.44 ^{a}	39.02 a	4894.1 ^{a}
Nosrat	9.67 ^{bcd}	43.72 ^{d}	160.83 ^{b}	2.26 ^{a}	35.71 ^{a}	452.44 ^{a}	36.15 ^{abc}	4828.6 ^{a}
Moroko	9.78 ^{bcd}	47.50 ^{ab}	155.06 ^{cd}	2.14 ^{a}	37.56 ^{a}	428.00 ^{a}	31.97 ^{d}	4728.7 ^{a}
Afzal	7.44 ^{f}	44.00 ^{cd}	157.44 ^{bc}	2.02 ^{a}	36.40 ^{a}	404.00 ^{a}	36.88 ^{ab}	4552.9 ^{a}
Fajr 30	10.17 ^{ab}	48.22 ^{a}	161.11 ^{b}	2.23 ^{a}	34.00 ^{a}	445.78 ^{a}	33.66 ^{cd}	4293.2 ^{a}

Means with similar letter in each columns have no significant difference.

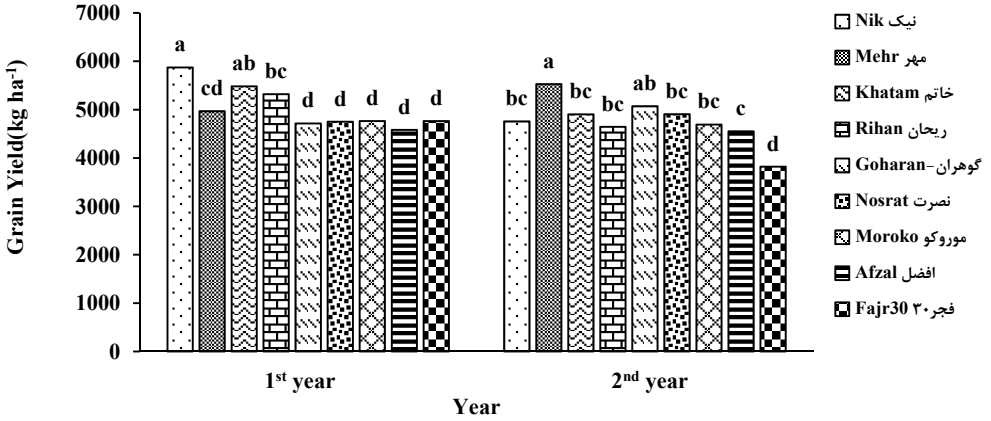

Fig. 2. Interaction effect of Year ×Variety in grain yield. Comparison of means is based on slicing of interaction.

Table 4. Comparison of Means of Year× Variety× Salinity interaction in grain yield. Comparison of means are on base of slicing of year.

	1st year			2nd year		
Variety	**4 dS.m-1**	**10 dS.m-1**	**14 dS.m-1**	**4 dS.m-1**	**10 dS.m-1**	**14 dS.m-1**
Nik	5958.33 ab	5709.73 abc	5960.43 ab	6470.68 a	4229.17 f-i	3578.12 ij
Mehr	5403.83 bcd	4895.47 c-h	4605.67 d-h	6413.62 a	5419.14 bcd	4756.25 c-g
Khatam	6470.68 a	5038.80 c-g	4943.46 c-g	5958.33 ab	4520.83 e-h	4229.17 f-i
Rihan	6550.08 a	5363.22 b-f	4053.19 hi	5266.67 b-e	4561.46 d-h	4112.82 f-j
Goharan	6049.85 ab	4520.83 e-h	3578.12 i	5395.83 b-e	5593.75 abc	4226.04 f-i
Nosrat	6413.62 a	4229.17 ghi	3608.33 i	5955.50 ab	4933.47 c-f	3831.77 hij
Moroko	5307.29 b-f	4705.47 d-h	4285.58 ghi	6106.39 ab	4226.04 f-i	3741.67 hij
Afzal	5036.07 c-g	4495.48 fgh	4217.82 ghi	5388.05 b-e	4243.90 f-i	3935.91 g-j
Fajr 30	5378.77 b-e	4607.85 d-h	4354.83 ghi	4347.92 f-i	3833.33 hij	3286.46 j

Means with similar letter in each columns have no significant difference.
Note: Comparison of means is done separately by year.

Table 5. Correlation coefficient of studied traits with grain yield under non-saline conditions

	Studied traits	1	2	3	4	5	6	7	8
1	**Days to Emergence**	1	0.58**	-0.25**	-0.09ns	-0.20**	-0.09ns	-0.32**	-0.43**
2	**Days to Tillering**	0.14ns	1	-0.47**	-0.27**	-0.49**	-0.27**	-0.40**	-0.65**
3	**Days to Maturity**	0.13ns	0.65**	1	-0.04ns	0.46**	-0.04ns	0.14ns	0.37**
4	**Fertile Tiller Num.**	0.33*	0.35*	0.22ns	1	0.50**	0.99**	0.50**	0.50**
5	**Grains per Spike**	0.28*	0.59**	0.67**	0.64**	1	0.50**	0.58**	0.61**
6	**Spike per m²**	0.33*	0.35*	0.22ns	0.99**	0.63**	1	0.50**	0.50**
7	**1000 Kernel weight**	-0.04ns	0.31*	0.33*	0.50**	0.54**	0.50**	1	0.45**
8	**Grain Yield**	-0.08ns	-0.13ns	0.11ns	0.48**	0.35**	0.48**	0.24ns	1

**, * and ns: significant at 5%, 1% probability levels and non significant, respectively.
Note: The upper half corresponds to the all of salinity treatments and the lower half corresponds to the salinity of 4 dS m-1.

Table 6. Correlation coefficient of studied traits with grain yield under saline conditions

	Studied traits	1	2	3	4	5	6	7	8
1	Days to Emergence	1	0.02^{ns}	0.12^{ns}	0.02^{ns}	0.16^{ns}	0.02^{ns}	-0.17^{ns}	0.16^{ns}
2	Days to Tillering	-0.36^{**}	1	-0.37^{**}	0.15^{ns}	-0.40^{**}	0.15^{ns}	0.16^{ns}	-0.24^{ns}
3	Days to Maturity	0.19^{ns}	-0.70^{**}	1	-0.40^{**}	0.62^{**}	-0.40^{**}	-0.08^{ns}	0.22^{ns}
4	Fertile Tiller Num.	0.16^{ns}	-0.24^{ns}	0.27^{*}	1	-0.06^{ns}	0.92^{**}	0.41^{**}	0.35^{**}
5	Grains per Spike	0.09^{ns}	-0.06^{ns}	0.16^{ns}	0.67^{**}	1	-0.06^{ns}	0.08^{ns}	0.44^{**}
6	Spike per m^2	0.16^{ns}	-0.24^{ns}	0.27^{*}	0.99^{**}	0.67^{**}	1	0.41^{**}	0.35^{**}
7	1000 Kernel weight	-0.07^{ns}	-0.009^{ns}	-0.06^{ns}	0.22^{ns}	0.38^{**}	0.21^{ns}	1	0.21^{ns}
8	Grain Yield	0.02^{ns}	-0.05^{ns}	0.15^{ns}	0.45^{**}	0.56^{**}	0.45^{**}	0.15^{ns}	1

**, * and ns: significant at 5%, 1% probability levels and non significant, respectively.
The upper half corresponds to a salinity of 14 dS m^{-1} and the lower half corresponds to a salinity of 10 dS m^{-1}.

Table 7. Means of irrigation salinity treatment in evaluated traits base on Duncan multiple test and probability level of 5 percent.

Salinity	Peroxidase	Catalase	Gayacol Peroxidase	Superoxide dismutase	Ascorbate peroxidase	Prolin	K/Na Ratio
$dS.m^{-1}$	----------µm.min^{-1}/g----------					mg/g	
4	8.38 ^{c}	21.33 ^{c}	3.49 ^{b}	0.299 ^{c}	84.086 ^{b}	1.02 ^{a}	7.20 ^{a}
10	13.38 ^{b}	32.47 ^{b}	5.15 ^{b}	0.034^{b}	86.894 ^{b}	1.03 ^{a}	2.63 ^{b}
14	18.67 ^{a}	41.71 ^{a}	10.09 ^{a}	0.039^{a}	96.871 ^{a}	1.11 ^{a}	0.74 ^{c}

Table 7. Continued

Salinity	Chlorophyll a	Chlorophyll b	Total Chlorophyll	Carotenoid	Anthocyanin	Flavonoid
$dS.m^{-1}$	----------mg/g----------					
4	3.597 ^{c}	1.170 ^{c}	4.767 ^{c}	0.292 ^{a}	0.110 ^{a}	1.568 ^{c}
10	3.746 ^{b}	1.323 ^{b}	5.069 ^{b}	0.308 ^{a}	0.109 ^{a}	1.697 ^{b}
14	3.901 ^{a}	1.689 ^{a}	5.590 ^{a}	0.318 ^{a}	0.113 ^{a}	2.005 ^{a}

Means with similar letter in each columns have no significant difference.

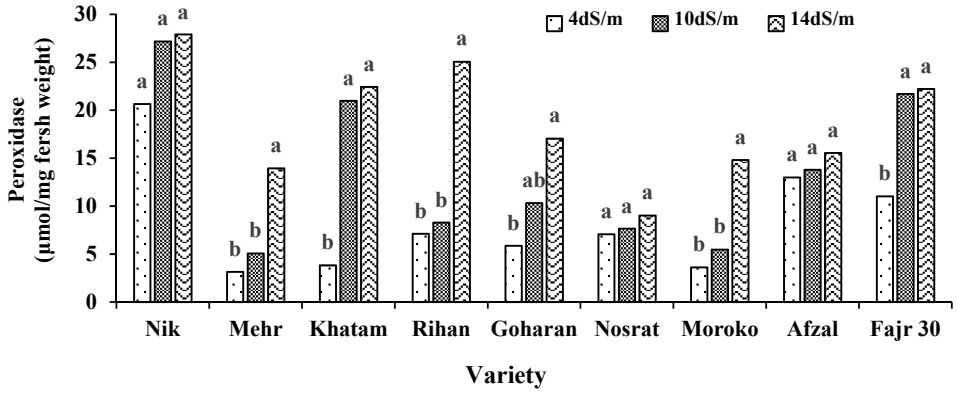

Fig. 3. Interaction effect of Salinity×Variety in peroxidase enzyme. Comparison of means is based -on slicing of interaction.

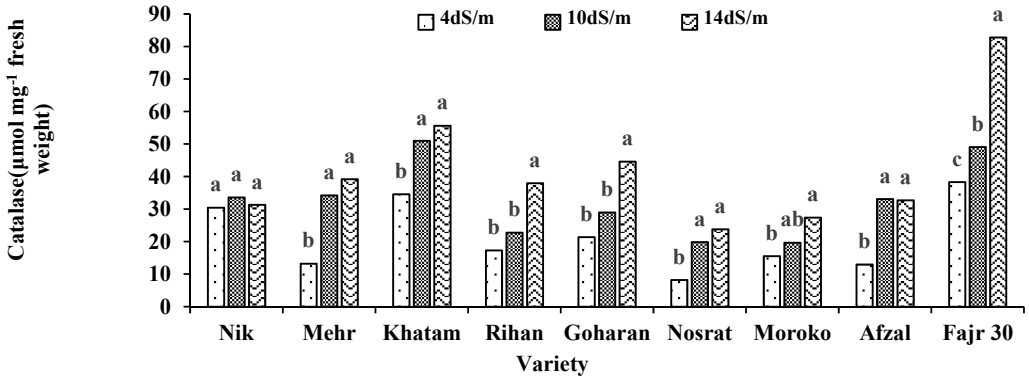

Fig. 4. Interaction effect of Salinity×Variety in catalase enzyme. Comparison of means is based on slicing of interaction.

Table 8. Means of Variety treatment in evaluated traits base on Duncan multiple test and probability level of 5 percent.

Variety	Peroxidase	Catalase	Gayacol Peroxidase	Superoxide dismutase	Ascorbate peroxidase	Prolin	K/Na Ratio
	----------µm.min^{-1}/g----------					mg/g	
Nik	25.25 ^{a}	31.79 ^{c}	7.91 ^{abc}	0.032 ^{ab}	89.04 ^{a}	1.03 ^{a}	3.47 ^{a}
Mehr	7.39 ^{d}	28.88 ^{c}	6.03 ^{bcd}	0.038 ^{a}	95.06 ^{a}	1.20 ^{a}	3.55 ^{a}
Khatam	15.75 ^{bc}	47.07 ^{b}	5.17 ^{bcd}	0.037 ^{ab}	86.14 ^{a}	1.01 ^{a}	3.42 ^{a}
Rihan	13.49 ^{bc}	26.02 ^{cd}	4.13 ^{d}	0.034 ^{ab}	78.56 ^{a}	0.89 ^{a}	3.39 ^{a}
Goharan	11.08 ^{cd}	31.64 ^{c}	5.24 ^{bcd}	0.035 ^{ab}	89.38 ^{a}	1.19 ^{a}	3.55 ^{a}
Nosrat	7.92 ^{d}	17.27 ^{e}	4.80 ^{cd}	0.028 ^{b}	98.82 ^{a}	1.17 ^{a}	3.60 ^{a}
Moroko	7.97 ^{d}	20.87 ^{de}	9.30 ^{a}	0.040 ^{a}	78.35 ^{a}	0.92 ^{a}	3.55 ^{a}
Afzal	14.11 ^{bc}	26.25 ^{cd}	8.26 ^{ab}	0.031 ^{ab}	96.16 ^{a}	1.00 ^{a}	3.60 ^{a}
Fajr 30	18.32 ^{b}	56.74 ^{a}	5.34 ^{bcd}	0.034 ^{ab}	92.04 ^{a}	1.09 ^{a}	3.58 ^{a}

Table 8. Continued

Variety	Chlorophyll a	Chlorophyll b	Total Chlorophyll	Carotenoid	Anthocyanin	Flavonoid
	----------mg/g----------					
Nik	4.159 ^{abc}	1.642 ^{a}	5.801 ^{ab}	0.285 ^{a}	0.099 ^{a}	1.866 ^{a}
Mehr	3.718 ^{cde}	1.422 ^{ab}	5.140 ^{bc}	0.324 ^{a}	0.122 ^{a}	1.832 ^{a}
Khatam	3.836 ^{bcd}	1.429 ^{ab}	5.264 ^{bc}	0.297 ^{a}	0.103 ^{a}	1.758 ^{a}
Rihan	4.217 ^{ab}	1.458 ^{ab}	5.674 ^{ab}	0.276 ^{a}	0.109 ^{a}	1.670 ^{a}
Goharan	3.027 ^{f}	1.079 ^{c}	4.106 ^{d}	0.344 ^{a}	0.123 ^{a}	1.802 ^{a}
Nosrat	3.350 ^{ef}	1.284 ^{bc}	4.634 ^{cd}	0.330 ^{a}	0.114 ^{a}	1.703 ^{a}
Moroko	4.386 ^{a}	1.632 ^{a}	6.018 a	0.265 ^{a}	0.109 ^{a}	1.778 ^{a}
Afzal	3.472 ^{def}	1.307 ^{bc}	4.799 ^{cd}	0.304 ^{a}	0.112 ^{a}	1.706 ^{a}
Fajr 30	3.568 ^{de}	1.293 ^{bc}	4.861 ^{c}	0.328 ^{a}	0.105 ^{a}	1.694 ^{a}

Means with similar letter in each columns have no significant difference.

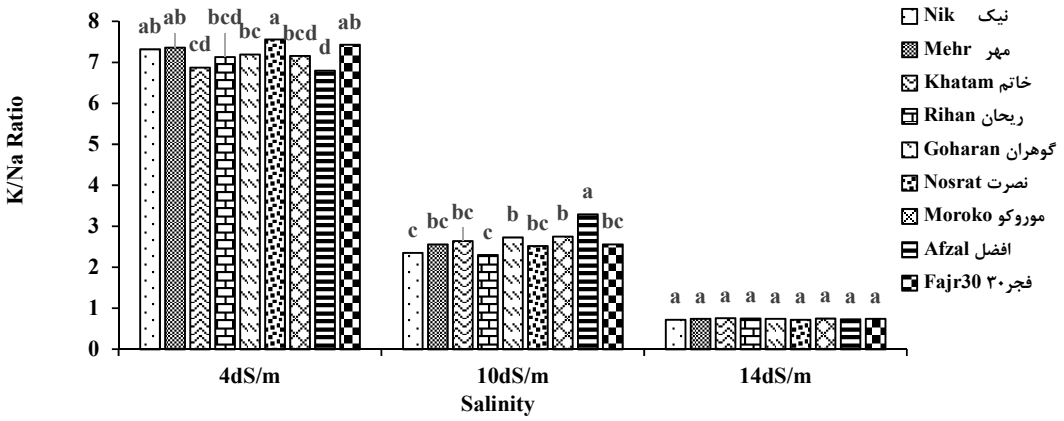

Fig. 5. Interaction effect of Salinity×Variety in K/Na. Comparison of means is based on slicing of interaction