Archive of SID.ir

Original Article

Journal of Drought and Climate change Research (JDCR)

Summer 2023, Vol. 1, No. 2, pp 41-52

10.22077/JDCR.2023.5977.1007

Performance of Different Genotypes of Barley (*Hordeum Vulgare* L.) Under Normal and Saline Environments

Seyyed Hamid Raza Ramazani[1*], Mohammad Hossein Saberi[2]

1. Department of Plant Production and Genetics, College of Agriculture, University of Birjand, Birjand, Iran.
2. Department of Cereal Research, Agricultural and Natural Resources Researches Center of South Khorasan, Agricultural Research, Education and Extension Organization (AREEO), Birjand, Iran.

***Corresponding Author: hrramazani@Birjand.ac.ir**

Keywords:
Barley, Correlation, Grain yield, Path analysis, Salt stress.

Received:
Jan/03/2023

Revised:
Mar/2022/2023

Accepted:
May/29/2023

Abstract

In this study, two experiments were conducted to compare the performance of eight different genotypes, their correlations, path analysis, and select the best genotype/ genotypes of barley in two environments including normal (Birjand) and saline (Amirabad) environments in South Khorasan province of Iran in 2015-2016 growing season. Results of combined analysis of variance for combined data of both studied environments showed significant effects for the genotype treatment on most of the studied traits. Means comparison data indicated that the highest and the lowest means of majority of investigated characteristics of barley genotypes were related to Salt4 and MBS-90-10 genotypes, respectively. Number of days to maturity and plant height had the highest simple correlation with grain yield in investigated genotypes of barley but these correlations were not significant. In forward regression analysis for grain yield as independent variable, five traits including one-thousand grain weight, number of days to maturity, mean grain weight, canopy temperature, and plant height entered to regression model in five steps with R-square=0.99. The path coefficient analysis based on grain yield, as a dependent variable implicated that number of days to maturity had the highest positive direct effect on grain yield of investigated genotypes of barley. The highest positive indirect effect on the grain yield was related to the mean grain weight trough the number of days to maturity; therefore, these two traits were the most important phenological and morphological characteristics that affect grain yield of barley under two studied environments and can used as selection criteria in investigated genotypes of barley.

How to cite this article:
Ramazani, S.H.R., & Saberi, M.H. (2023).Performance of Different Genotypes of Barley (*Hordeum Vulgare* L.) Under Normal and Saline Environments. *Journal of Drought and Climate change Research* (JDCR), 1(2), 41-52. 10.22077/JDCR.2023.5977.1007

Copyright: © 2022 by the authors. Licensee Journal of *Drought and Climate change Research* (JDCR). This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Archive of SID.ir

Archive of SID.ir

Introduction

Plants are frequently subjected to a variety of both biotic and abiotic stresses worldwide and their maximum genetic potentials undergo significant reductions (Gupta et al., 2018; Piasecka et al., 2019; Godoy et al., 2021). Among these, salinity is one of the most important abiotic stresses affecting more than 50% of agricultural irrigated lands, which subsequently limits different germination, growth, development, and production processes of plants (Cheng et al., 2016; Liang et al., 2018; Arif et al., 2020; Rajabi Dehnavi et al., 2020). Some studies have also defined salinity as high concentrations of solute salts of K^+, Na^+, Cl^-, Ca^{2+}, and Mg^{2+} in soils (Saneoka et al., 1999; Rogel et al., 2000; Zhaoyong et al., 2014; Gondek et al., 2020; Mohammadi et al., 2022), which can be resulted in metabolic changes, membrane structure changes, oxidative and/or osmotic stresses, ionic stress, and other disorders in plants and plant cells (Parida and Das, 2005; Rahneshan et al., 2018; Shahmoradi and Naderi, 2018). In a general definition, soils with electrical conductivity more than 4 dS. mL^{-1} or 40Mm NaCL are considered as saline soils that affect normal growth of crops (Munns and Tester, 2008). Accordingly, although there is still a long way to go, it was stated that understanding the response of crops, different mechanisms of plants' tolerance to soil salinity and mining the salt-tolerance-associated genetic resource can eventually help to increase plant/crop yields under saline conditions (Chinnusamy et al., 2005; Zhao et al., 2020; Alkharabsheh et al., 2021; Gul et al., 2022). Acosta-Motos et al. (2017) reported that there are numerous strategies to reduce the adverse effects of salt stress. Another study suggested that the selection and breeding of plants are the most economical and effective ways to overcome soil salinity problems and decrease the adverse effects of salinity stress (Sadat Noori, 2005). On the other hand, one of the main influential challenges for plant breeders is enhancing salinity tolerance in desirable crops (Nguyen et al., 2013). In this regard, advanced screening methods, appropriate germplasm, and a combination of conventional and molecular breeding approaches are reported as requirements for improving a crop's salinity tolerance (Flowers, 2004).

Barley (*Hordeum vulgare* L.) is a remarkably critical cereal crop to be used for food and medicinal purposes that ranks the fourth most important cereal crop in production quantity and cultivated area after wheat, rice, and maize (Bhuttaet al., 2005; Madakemogekar et al., 2018; El-Hashash and El-Absy, 2019; Yang et al., 2022). Barley can successfully cultivate in a wide range of different climates and has a significant potential for growth under drought and saline conditions (Zaefizadeh et al., 2011). This plant is a salt-tolerant crop, which is usually used as an excellent model crop for studies on the mechanisms and inheritance of salinity tolerance and for developing tools to improve salt tolerance in cereals (Walia et al., 2007; Witzel et al., 2010). Vegetative growing and flowering are two main growth stages of barley that can be significantly affected by salinity stress (Nguyen et al., 2013). Different characteristics of this plant is correlated to salinity tolerance at different growing and developing stages. Genotype × environment interaction is the main drawback for direct selection for yield under abiotic stress conditions and low heritability for the product, making the process very time-consuming (Blum, 1988).

Selection based on physiological traits is an alternative approach in which lines are selected based on the specific attributes determined to be beneficial under stressful conditions (Bidinger and Witcombe, 1989). Identifying morphological or physiological characteristics are closely linked to yield

Archive of SID.ir

Archive of SID.ir

in stressful environments that can facilitate breeding for challenging and complex traits such as drought and salinity tolerance (Ober et al. 2005). There are several methods for analyzing yield components according to the project objective that researchers can select between them. Techniques such as analysis of variance, simple correlation coefficient, multiple regression, and path analysis usually are used to analyze yield components (Fraser and Eaton, 1983). Many studies employed correlation coefficient and path analysis to find interrelationship and selection criteria for barley grain yield under different situations (Bhutta et al., 2005; Carpici and Celik, 2012; Jouyban et al., 2015; Markova Ruzdik et al., 2015; Mohammadi, 2015). Hence, the present study aimed to evaluate the performance of eight new varieties of barley under normal and saline environments of the South Khorasan province of Iran and to find the most fundamental selection criteria for improving/increasing grain yield of various barley genotypes in both studied conditions.

Materials and Methods

This research was conducted in two different environments of South Khorasan province of Iran including normal (Birjand) and saline (Amirabad) environments. Therefore, a randomized complete block design (RCBD) with three replications was employed to investigate the effect of location on eight genotypes of barley including Salt4, Nosrat, MBS-89-10, MBS-89-11, MBS-89-18, MBS-90-10, MBS-90-13, and MBS-90-18 genotypes (Table 1).

Table 1. The pedigree of barley cultivars investigated in the present study

Nosrat	Check-1
Salt4	Check-2 (Probably Khatam cultivar)
MBS-89-10	Bahtim 7DL/79-W40762//Yazd-5
MBS-89-11	Bahtim 7DL/79-W40762//Yazd-5
MBS-89-18	Assala'S'//Avt/Aths/3/Jonoob/4/Afzal
MBS-90-10	Ashar/1-BC-80320
MBS-90-13	Rihane -03/1-BC-80320
MBS-90-18	MBS-87-12 (Mehr cultivar)

In each experiment, two 60 cm back furrows of six meters in length (with three planting stripes on each back furrow) were prepared after the tillage operations, and planting processes were carried out on November 6, 2015. In addition, planting densities were considered equal to 400 and 450 grains per m^2 for normal and saline conditions, respectively. At the end of the experiments (early May 2016), data of grain yield (GY), canopy temperature (CT), SPAD (SP), relative water content (RWC), yield components traits such as spike length (SPL), peduncle length (PL), 1000-grain weight (TGW), number of grains per spike (NGS), mean grain weight (GW), plant height (PH), biomass yield (BY), along with phenological traits of the number of days to hardening (NDH), and the number of days to maturity (NDM), were recorded separately. Leaf chlorophyll content was measured using a SPAD meter (SPAD-502, MINOLTA, Japan). Also, the canopy temperature trait was estimated remotely by the infrared thermometer (IRT), and RWC was calculated based on the methods presented by Ritchie et al. (1990) by the following equation:

Equation (1) $$RWC = \frac{F_w - D_w}{T_w - D_w} \times 100$$

In which,

Fw, Dw, and Tw were represented fresh weight,

Archive of SID.ir

Archive of SID.ir

dry weight, and turgid weight of leaves, respectively.

The path analysis was also done for independent variables that were entered to forward regression analysis for grain yield. In this step, using a correlation between independent variables and also between independent and dependent variables, the direct and indirect effects of independent variables on dependent variables were calculated.

Statistical analysis

Overall, multivariate analyses (such as simple correlation coefficient, forward regression analysis, and path analysis) were employed to estimate the means of combined data using the mean matrix. In forward regression analysis, grain yield was considered a dependent variable, and other 12 traits were assumed as independent variables. Also, the correlation matrix between independent variables (RXX) and the correlation vector between independent variables and dependent variable (RXY) were utilized for path analysis. Eventually, the obtained data were analyzed using SAS statistical software (9.1), and the LSD test was used to compare means at $p<0.05$.

Results and discussion

Climate change is a concerning crisis for agriculture and crop products around the world (Arenas-Corraliza et al., 2022). Therefore, understanding the effects of climate change, which has led to the occurrence of various types of stress such as salinity, drought, and other stresses in agriculture and has significant effects on crop production, is extremely important (Jamshidi and Javanmard, 2018). Meanwhile, saline fields and salinity-related problems are distributed in developing regions, especially Iran (Qadir et al., 2008; Zurqani et al., 2018; Shokat and Großkinsky, 2019). Accordingly, finding suitable strategies to cope with crop plants (especially barley) against salinity stress can be helpful for more efficient uses of saline fields around the world.

In this regard, some researchers have been stated that salt-resistant cultivars have unique characteristics to overcome salinity and salinity-related problems (Gul et al., 2022; Raza et al., 2022). Zaefizadeh et al. (2011) also reported the significant differences among 22 hulless barley genotypes for yield and yield component traits in two diverse studied environments. Based on the results, our findings showed a significant effect of location on the number of days to hardening, number of days to maturity, spike length, peduncle length, plant height, the number of grains per spike, canopy temperature, SPAD, biomass yield, grain yield, and RWC at $p<0.01$ and on the mean grain weight at $p<0.05$ (Table1). According to the results, the location had no significant effect on the one-thousand grain weight trait (Table 2); hence, it can be concluded that the average of one-thousand grain weight was almost similar in both investigated regions.

In addition to the above, the combined analysis of variance results presented in Table 2 also indicated that the genotype treatment had significant effects on the number of days to hardening, number of days to maturity, plant height, one-thousand-grain weight, number of grains per spike, mean grain weight, canopy temperature, grain yield, and relative water content traits at $p<0.01$ and on SPAD at $p<0.05$. However, no significant effects were observed for spike length, peduncle length, and biomass yield traits under the application of study genotypes. Jamshidi and Javanmard (2018) examined the response of 26 barley genotypes under field saline conditions and showed different degrees of resistance/sensitivity, performance, and other plant responses of the studied cultivars under non-saline and saline conditions. The latter researchers also stated that plant height, leaf area index, yield, and yield components, which had the

Archive of SID.ir

Archive of SID.ir

highest rate of variation, could be properly employed for developing tolerate-barley genotypes under saline environments. Result of mean comparison of combined data (Table 3) demonstrated that the maximum mean of the number of days to hardening trait (114.33 days) was related to Salt4 genotype, whereas the lowest mean was obtained for the MBS-89-10 genotype (109.66 days). Also, the highest means of the number of days to maturity (148 days), number of grains per spike (58.03 grains), and grain weight (2.48 $g.m^{-2}$) traits were also recorded for the Salt4 genotype, whereas the lowest mean of number of days to maturity (equal to 142.16 days) was calculated jointly for MBS-90-10 and MBS-90-18 genotypes, and the lowest mean values of number of grains per spike and mean grain weight traits (42.46 grains and 1.83 $g.m^{-2}$, respectively) were related to MBS-89-10 genotype. Plus, the highest and lowest means of plant height were also obtained for the Nosrat and MBS-90-13 genotypes with mean values of 49.1 and 39.51 cm, respectively (Table 3). According to the statements of recent researchers, it can therefore be seen that the Salt4 genotype is the best genotype for the studied saline areas.

Table 2. Combined analysis of variance for investigated attributes in barley genotypes under normal and saline environments

S.O.V.	MS												
	df	NDH	NDM	SPL	PL	PH	TGW	NGS	GW	CT	SP	BY	GY	RWC
Location (L)	1	1408.3**	1938.0**	39045.0**	2112.05**	38635.0**	0.72^{ns}	302.00**	0.48*	4688.65**	24435.18**	30577.75**	51038.56**	23412.75**
Block (L)	4	5.16^{ns}	9.41^{ns}	12.41^{ns}	0.22^{ns}	78.04^{ns}	39.37^{ns}	26.38^{ns}	0.10^{ns}	19.97^{ns}	24.68^{ns}	175.97^{ns}	58.90^{ns}	10.54^{ns}
Genotype (G)	7	11.95**	31.61**	14.97^{ns}	8.87^{ns}	73.63**	56.06**	124.62**	0.27**	2.73**	28.42*	145.44^{ns}	54.82**	35.51**
G × L	7	3.90^{ns}	12.44^{ns}	9.01^{ns}	6.00^{ns}	21.50^{ns}	7.33^{ns}	14.63^{ns}	0.07^{ns}	4.88^{ns}	28.16^{ns}	158.04^{ns}	51.99^{ns}	31.90^{ns}
Error	28	0.71	4.41	6.73	5.01	15.61	15.55	12.53	0.06	2.11	8.85	65.93	14.11	9.73
C.V. (%)		0.76	1.45	7.45	17.03	8.78	9.68	7.11	12.69	8.59	11.43	22.42	10.20	6.76

** , *: significant at 1% and 5% probability level, respectively; ns: not significant.
NDH: Number of days to hardening; NDM: number of days to maturity; SPL: Spike length; PL: Peduncle length; PH: Plant height; TGW: One-thousand grain weight; NGS: Number of grains per spike; GW: Grain weight; CT: Canopy temperature; SP: SPAD; BY: Biomass yield; GY: Grain yield; RWC: Relative water content.

Table 3. Mean comparison of combined data for investigated attributes in barley genotypes under normal and saline environments using the LSD test at p<0.05.

Genotypes	NDH	NDM	PH	TGW	NGS	GW	CT	SP	GY	RWC
Salt4	114.33 a	148.00 a	40.78 b	42.93 ab	58.03 a	2.48 a	16.31 b	26.43 ab	35.81 ab	47.30 ab
Nosrat	111.16 b	144.33 b	49.10 a	36.60 c	50.70 b	1.85 c	16.48 b	23.43 c	39.56 a	46.43 ab
MBS-89-10	109.66 c	143.00 b	45.88 a	43.43 a	42.46 d	1.83 c	16.70 ab	26.53 ab	36.65 ab	48.93 a
MBS-89-11	110.83 c	146.66 ab	46.71 a	37.55 bc	51.20 b	1.93 bc	17.28 ab	29.78 a	38.83 ab	44.26 b
MBS-89-18	110.50 c	146.83 ab	44.61 ab	38.40 c	51.10 b	1.96 bc	17.00 ab	27.93 ab	39.18 a	47.61 ab
MBS-90-10	110.50 c	142.16 b	39.51 b	44.18 a	45.56 cd	2.01 bc	16.60 ab	23.26 c	30.83 c	41.86 c
MBS-90-13	110.50 c	143.33b	44.08 ab	43.38 ab	50.46 b	2.18 b	18.38 a	25.41 b	39.01 ab	44.13 bc
MBS-90-18	110.50 c	142.16 b	49.06 a	39.43 ab	48.80 bc	1.93 bc	16.46 b	25.50 bc	34.56 b	48.20 ab
LSD	0.99	2.48	4.67	4.66	4.18	0.30	1.71	3.51	4.44	3.69

NDH: Number of days to hardening; NDM: number of days to maturity; PH: Plant height; TGW: One-thousand grain weight; NGS: Number of grains per spike; GW: Grain weight; CT: Canopy temperature; SP: SPAD; GY: Grain yield; RWC: Relative water content.

Archive of SID.ir

Archive of SID.ir

On the other hand, Jamshidi and Javanmard (2018) also pointed out that since indices of chlorophyll content rate, 1000 grain weight, and length of rootlets were less affected by salinity stress than other traits, it is not appropriate to select salinity-tolerant genotypes based on these traits. In the other research, with the increase of salinity stress, the morphological characteristics decreased (Saeidinia et al., 2023). Based on means comparison analysis, it was also observed that the highest and lowest means of one-thousand grain weight (equal to 44.18 and 36.6 g) were corresponded to MBS-90-10 and Nosrat genotypes of barley (Table 3); hence, since the mentioned genotypes had a less mean of the number of days to maturity compared to the Salt4 genotype, they may not be suitable for the salinity conditions investigated in the present study. For the canopy temperature trait, the highest and lowest mean values were estimated to be equal 18.38 and 16.31 °C for MBS-90-13 and Salt4 genotypes, respectively (Table 3). One of the non-destructive monitoring parameters of whole plant, which can be used to evaluate plant responses to environmental stresses, is canopy temperature (Royo et al., 2002; Roohi et al., 2015). Low values of CT can have used as selection tool for abiotic stress tolerance (Roohi et al., 2015). Cooler canopy can help to better osmotic adjustment during abiotic stress of drought and salinity (Mamnouie et al., 2006). Therefore, in present study Salt4 genotype can considered as salt tolerance genotype with lower value of CT and higher values of NDH, NDM, NGS, and GW characteristics.

The highest mean of SPAD, grain yield, and relative water content traits were related to MBS-89-11, Nosrat, and MBS-89-10 genotypes of barley, respectively. However, the lowest mean values were achieved for the MBS-90-10 genotype (Table 3). Overall, the highest means of the investigated characteristics of barley, including NDH, NDM, NGS, and GW, were related to the Salt4 genotype, whereas the lowest mean values for PH, SP, GY, and RWC traits were recorded for the MBS-90-10 genotype of barley (Table 3). Based on means comparison analysis, the MBS-89-10 genotype also had the lowest means for the number of days to hardening, number of grains per spike, and mean grain weight traits; therefore this genotype, along with MBS-90-10 genotype were considered as low-performance genotypes in both investigated sites.

Results of simple Pearson correlation analysis showed that the number of days to hardening had a positive and significant correlation with the number of grains per spike and mean grain weight traits at $p<0.01$ (Table 4), and the highest correlation was observed between the number of days to hardening and number of grains per spike ($r=0.86$; $p<0.01$). Based on simple correlation analysis, the number of days to maturity just had a positive and significant correlation with the number of grains per spike trait ($r=0.81$; $p<0.05$) (Table 4). The number of days to maturity also had a positive correlation with the mean grain weight, SPAD, and grain yield, but these correlations were not significant (Table 4). Based on simple correlation analysis, plant height had a negative and significant correlation with the one-thousand-grain weight trait ($r=-0.73$; $p<0.05$). Also, there was a negative correlation between plant height and the number of days to hardening, and a similar outcome was also reported in the study presented by Zaefizadeh et al. (2001). Another significant correlation between investigated characteristics of barley under two saline locations was observed between the number of grains per spike and the mean grain weight traits, and their correlation was positive and significant at $p<0.05$ ($r=0.73$; $p<0.05$) (Table 4).

Results of forward regression analysis for grain yield trait using combined means of

Archive of SID.ir

Archive of SID.ir

Table 4. Correlation coefficients for grain yield and other investigated characteristics in 8 genotypes of barley under control and saline environments.

	NDH	NDM	PH	TGW	NGS	GW	CT	SP	GY	RWC
NDH	1									
NDM	0.65^{ns}	1								
PH	-0.38^{ns}	-0.19^{ns}	1							
TGW	0.07^{ns}	-0.27^{ns}	-0.73*	1						
NGS	0.86**	0.81*	-0.15^{ns}	-0.25^{ns}	1					
GW	0.83**	0.57^{ns}	-0.64^{ns}	0.46^{ns}	0.73*	1				
CT	-0.33^{ns}	0.29^{ns}	-0.01^{ns}	0.13^{ns}	-0.01^{ns}	0.07^{ns}	1			
SP	0.02^{ns}	0.62^{ns}	0.13^{ns}	-0.29^{ns}	0.24^{ns}	0.01^{ns}	0.24^{ns}	1		
Y	-0.03^{ns}	0.57^{ns}	0.53^{ns}	-0.58^{ns}	0.31^{ns}	-0.13^{ns}	0.45^{ns}	0.45^{ns}	1	
RWC	0.07^{ns}	0.11^{ns}	0.47^{ns}	-0.21^{ns}	0.04^{ns}	-0.11^{ns}	-0.39^{ns}	0.23^{ns}	0.29^{ns}	1

** , *: significant at 1% and 5% probability levels, respectively; ns: not significant.
NDH: Number of days to hardening; NDM: number of days to maturity; PH: Plant height; TGW: One-thousand grain weight; NGS: Number of grains per spike; GW: Grain weight; CT: Canopy temperature; SP: SPAD; GY: Grain yield; RWC: Relative water content.

two studied locations showed that one-thousand-grain weight, number of days to maturity, mean grain weight, canopy temperature, and plant height were the most influential characteristics of barley among all investigated traits affected its grain yield under two investigated environments with different salinity levels (Table 5). In the first step of the analysis, the one-thousand-grain weight was entered into the model with a negative regression coefficient significant at $p<0.05$ (Table 5). In second, third, fourth, and fifth steps of analysis, traits of the number of days to maturity, mean grain weight, canopy temperature, and plant height were entered, respectively (Table 5). The regression coefficient of GW and CT also demonstrated negative and significant relations at $p<0.05$ (Table 5). The regression coefficient of PH was positive, but showed no significant association (Table 5). The positive correlation of PH with the GY of barley was reported in two previous studies (Bhutta et al., 1991; Bhutta et al., 2005). Singh et al. (1987) also stated that plant height is the main trait that can affect the grain yield of barley. The maximum partial R-square of the model was related to TGW in the first step with 0.59 (Table 5).

Table 5. Stepwise Regression analysis for grain yield (dependent variable) in barley genotypes

Step	Entered Variable	Intercept	b_1	b_2	b_3	b_4	b_5	Model R-square	Partial R-square
1	TGW	67.78**	-0.77*					0.59	0.59
2	NDM	-9.36^{ns}	-0.66^{ns}	0.50^{ns}				0.73	0.14
3	GW	-94.56**	-0.28*	1.01**	-8.85*			0.85	0.12
4	CT	-115.21*	-0.04**	1.95^{ns}	-19.15**	-5.48^{ns}		0.97	0.11
5	PH	-158.94	0.18^{ns}	1.91^{ns}	-16.13*	-4.23^{ns}	0.29^{ns}	0.99	0.02

**,*: significant at 1% and 5% probability levels, respectively; ns: not significant.
TGW: One-thousand grain weight; NDM: number of days to maturity; GW: Grain weight; CT: Canopy temperature; PH: Plant height.

The results of path analysis showed that the maximum direct effect of independent variables was related to the number of days to maturity trait and this effect was positive (Table 6). As shown in Table 4, the number of days to maturity singly had a positive and significant correlation with the number of grains per spike trait, and here, NDM had the highest direct effect on the barley grain yield. So, these

Archive of SID.ir

Archive of SID.ir

Table 6. Path analysis for grain yield (dependent variable) in barley genotypes

Traits	TGW	NDM	GW	CT	PH	R_{XY}
TGW	**0.56**[*]	-0.31[+]	-0.23	0.01	-0.6	-0.58
NDM	-0.15	**1.15**	-0.29	0.02	-0.15	0.57
GW	0.25	0.65	**-0.52**	0.006	-0.52	-0.13
CT	0.07	0.33	-0.03	**0.08**	-0.008	0.45
PH	-0.40	-0.21	0.33	-0.00	**0.82**	0.53

[*]Values on the diagonal denote direct effect of yield components on grain yield of barley genotypes.
[+]Values on above and below diagonal denote indirect effect of yield components on grain yield of barley genotypes.
TGW: One-thousand grain weight; NDM: number of days to maturity; GW: Grain weight; CT: Canopy temperature; PH: Plant height.

results showed that NDM is a critical trait for investigated genotypes of barley that can affect their performance in direct and indirect ways. All independent variables had a positive direct effect on grain yield except the GW trait, which had a negative direct effect on grain yield of investigated genotypes of barley under two studied environments. The second positive direct effect of independent variables was related to plant height. Zaefizadeh et al. (2011) reported that genotypes with higher plant height have better performance in terms of stress than other genotypes. According to the results, although the highest negative indirect impact on grain yield was made by one-thousand-grain weight through plant height, the highest positive indirect effect was completed by the grain weight through the number of days to maturity trait (Table 6). Zaefizadeh et al. (2011) used path analysis to find the most influential attributes that affected the performance of 22 hulless barley genotypes under two different environments and reported that the maximum positive direct effect on yield was related to the number of grains per spike; But, the maximum negative direct impact on the grain yield was related to days to heading. They also reported a positive direct effect of plant height and days to maturity on the grain yield of barley. Markova Ruzdik et al. (2015) employed both correlation coefficient and path coefficient analyses to find the most important characteristics that affected grain yield of two-row winter barley varieties in two different environments and reported that the highest direct effect on grain yield was obtained by the number of spikes per m^2 in both localities and this trait can have used as the criterion to improve the yield of barley varieties.

Conclusion

According to combined analysis results, genotype had significant effects on all investigated traits except spike length, peduncle length, and biomass yield. On the other hand, location treatment significantly affected all attributes except the one-thousand-grain weight trait. Mean comparison analysis for combined data revealed that the highest mean for grain yield was related Nosrat genotype, whereas the lowest mean value for this trait was related to the MBS-90-10 genotype. Correlation coefficients analysis indicated that NDM, PH, GW, and CP had positive correlations with grain yield of investigated genotypes of barley. In forward regression analysis for grain yield as an independent variable, five traits (including TGW, NDM, GW, CT, and PH) were entered into the regression model in five steps with R-square=0.99. The regression coefficients for TGW, GW, and CT were negative, and the regression coefficients of NDM and PH were positive and significant. Path coefficient analysis based on grain yield, as a dependent variable, implicated that GW had the highest negative direct effect on grain yield of investigated barley genotypes under two environments with

Archive of SID.ir

Archive of SID.ir

different soil salinity levels. The highest negative indirect effect on grain yield was related to TGW through the PH trait.

Abbreviations: BY, Biomass yield; CT, Canopy temperature; GY, Grain yield; LSD, least significant difference; NDH, Number of days to hardening; NDM, number of days to maturity; NGS, Number of grains per spike; PH, Plant height; PL, Peduncle length; RWC, Relative water content; SP, SPAD; SPL, Spike length; GW, Grain weight; TGW, One-thousand grain weight.

References

Acosta-Motos, J. R., Ortuño, M. F., Bernal-Vicente, A., Diaz-Vivancos, P., Sanchez-Blanco, M. J. & Hernandez, J. A. (2017). Plant responses to salt stress: adaptive mechanisms. Agronomy, 7(1), 18. https://doi.org/10.3390/agronomy7010018

Alkharabsheh, H. M., Seleiman, M. F., Hewedy, O. A., Battaglia, M. L., Jalal, R. S., Alhammad, B. A. & Al-Doss, A. (2021). Field crop responses and management strategies to mitigate soil salinity in modern agriculture: A review. Agronomy, 11(11), 2299. https://doi.org/10.3390/agronomy11112299

Al-Tabbal, J.A. & Al-Fraihat, A.H. (2011). Genetic variation, heritability, phenotypic and genotypic correlation studies for yield and yield components in promising barley genotypes. Journal of Agricultural Science 4(3), 193-205.

Arenas-Corraliza, M. G., López-Díaz, M. L., Rolo, V., Cáceres, Y. & Moreno, G. (2022). Phenological, morphological and physiological drivers of cereal grain yield in Mediterranean agroforestry systems. Agriculture, Ecosystems & Environment, 340, 108158. https://doi.org/10.1016/j.agee.2022.108158

Arif, Y., Singh, P., Siddiqui, H., Bajguz, A. & Hayat, S. (2020). Salinity induced physiological and biochemical changes in plants: An omic approach towards salt stress tolerance. Plant Physiology and Biochemistry, 156, 64-77.

Bhutta, M.A., Iqbal, J., Khaliq, I. & Sadaqat, H.A. (1991). Correlation and path coefficient analysis of some economic traits in six-rowed barley. Journal of Animal and Plant Sciences, 1, 171-173.

Bhutta, W.M., Barley, T. & Ibrahim, M. (2005). Path-coefficient analysis of some quantitative characters in husked barley. Caderno de PesquisaSér. Bio., Santa Cruz do Sul, 17(1), 65-70.

Bidinger, F. R. & Witcombe J. R. (1989). Evaluation of specific drought avoidance traits as selection criteria for improvement of drought resistance. In: Baker, F.W.G. (Ed.), Drought Resistance in Cereals, CAB International, Oxon, UK, pp. 51–63.

Blum A. (1988): Plant Breeding for Stress Environments, CRC Press, London.

Carpici, E.B. & Celik, N. (2012). Correlation and path coefficient analyses of grain yield and yield components in two-rowed of barley (Hordeum vulgare convar. distichon) varieties. Notulae Scientia Biologicae, 4(2), 128-135.

Cary N. C. (2004). SAS Institute. The SAS system for windows. Release 9.1. SAS Inst, 654 p.

Cheng, X., Deng, G., Su, Y., Liu, J.J., Yang, Y., Du, G.H., Chen, Z.Y. & Liu, F.H. (2016). Protein mechanisms in response to NaCl-stress of salt-tolerant and salt-sensitive industrial hemp based on iTRAQ technology. Industrial Crops and Products 83, 444-452.

Chinnusamy, V., Jagendorf, A., & Zhu, J. K. (2005). Understanding and improving salt tolerance in plants. Crop science, 45(2), 437-448.

El-Hashash, E. F. & El-Absy, K. M. (2019). Barley (Hordeum vulgare L.) breeding. Advances in Plant Breeding Strategies: Cereals: Volume 5, 1-45. https://doi.org/10.1007/978-3-030-23108-8_1

Flowers, T.J. (2004): Improving crop salt tolerance. Journal of Experimental

Archive of SID.ir

Archive of SID.ir

botany, 55(396), 307-319.
Fraser, J. & Eaton, G.W. (1983). Application of yield component analysis to crop research. Field crop, 39, 787-797.
Godoy, F., Olivos-Hernández, K., Stange, C., & Handford, M. (2021). Abiotic stress in crop species: improving tolerance by applying plant metabolites. Plants, 10(2), 186. https://doi.org/10.3390/plants10020186
Gondek, M., Weindorf, D. C., Thiel, C., & Kleinheinz, G. (2020). Soluble salts in compost and their effects on soil and plants: A review. Compost science & utilization, 28(2), 59-75.
Gul, Z., Tang, Z. H., Arif, M., & Ye, Z. (2022). An insight into abiotic stress and influx tolerance mechanisms in plants to cope in saline environments. Biology, 11(4), 597. https://doi.org/10.3390/biology11040597
Gupta, B. K., Sahoo, K. K., Ghosh, A., Tripathi, A. K., Anwar, K., Das, P., & Singla-Pareek, S.L. (2018). Manipulation of glyoxalase pathway confers tolerance to multiple stresses in rice. Plant, Cell & Environment, 41(5), 1186-1200.
Jamshidi, A., & Javanmard, H. R. (2018). Evaluation of barley (Hordeum vulgare L.) genotypes for salinity tolerance under field conditions using the stress indices. Ain Shams Engineering Journal, 9(4), 2093-2099.
Jouyban, A. Sadeghi Give, H. & Noryan, M. (2015). Relationship between agronomic and morphological traits in barley varieties under drought stress condition. International Research Journal of Applied and Basic Sciences, 9(9), 1507-1511.
Liang, W., Ma, X., Wan, P., & Liu, L. (2018). Plant salt-tolerance mechanism: A review. Biochemical and biophysical research communications, 495(1), 286-291.
Madakemogekar, A. H., Talekar, N. S., Kamboj, A. D., & Thakur, G. (2018). Scope of hulless barley (Hordeum vulgare L.) as a nutritious and medicinal food: A review. Acta Scientific Agriculture, 2(12), 11-13.
Mamnouie, E., FotouhiGhazvini, R., Esfahani, M. & Nakhoda, B. (2006). The effects of water deficit on crop yield and the physiological characteristics of barley (Hordeum vulgare L.) varieties. Journal of Agricultural Science and Technology, 8, 211-219.
Mohammadi, H., Rahimpour, B., Pirasteh-Anosheh, H., & Race, M. (2022). Salicylic acid manipulates ion accumulation and distribution in favor of salinity tolerance in Chenopodium quinoa. International Journal of Environmental Research and Public Health, 19(3), 1576. https://doi.org/10.3390/ijerph19031576
Mohammadi, M. (2015). Character association and path analysis for selection criteria in barley breeding under rain fed conditions. Current Opinion in Agriculture, 4(1), 5-14.
Munns, R. & Tester, M. (2008). Mechanisms of salinity tolerance. Annu. Rev. Plant Biol., 59, 651-681.
Nguyen, V.L., Ribot, S.A., Dolstra, O., Niks, R.E., Visser, R.G. and van der Linden, C.G. (2013). Identification of quantitative trait loci for ion homeostasis and salt tolerance in barley (Hordeum vulgare L.). Molecular breeding, 31(1), 137-152.
Ober, E. S., Bloa, M. L., Clark, C. J. A., Royal, A., Jaggard, K. W. & Pidgeon, J. D. (2005). Evaluation of physiological traits as indirect selection criteria for drought tolerance in sugar beet. Field Crops Research, 91, 231–249.
Parida, A. K., & Das, A. B. (2005). Salt tolerance and salinity effects on plants: a review. Ecotoxicology and environmental safety, 60(3), 324-349.
Piasecka, A., Kachlicki, P. & Stobiecki, M. (2019). Analytical methods for detection of plant metabolomes changes in response to biotic and abiotic stresses. International journal of molecular sciences, 20(2), 379. https://doi.org/10.3390/ijms20020379
Qadir, M., Qureshi, A. S., & Cheraghi, S. A. M. (2008). Extent and characterization of salt-affected soils in Iran and strategies for

Archive of SID.ir

Archive of SID.ir

their amelioration and management. Land Degradation & Development, 19(2), 214-227.

Rahneshan, Z., Nasibi, F., & Moghadam, A.A. (2018). Effects of salinity stress on some growth, physiological, biochemical parameters and nutrients in two pistachio (Pistacia vera L.) rootstocks. Journal of plant interactions, 13(1), 73-82.

Rajabi Dehnavi, A., Zahedi, M., Ludwiczak, A., Cardenas Perez, S., & Piernik, A. (2020). Effect of salinity on seed germination and seedling development of sorghum (Sorghum bicolor (L.) Moench) genotypes. Agronomy, 10(6), 859. https://doi.org/10.3390/agronomy10060859

Raza, A., Tabassum, J., Fakhar, A. Z., Sharif, R., Chen, H., Zhang, C. & Varshney, R. K. (2022). Smart reprograming of plants against salinity stress using modern biotechnological tools. Critical Reviews in Biotechnology, 1-28. https://doi.org/10.1080/07388551.2022.2093695

Ritchie, S.W., Nguyen, H.T., & Holaday, A.S. (1990). Leaf water content and gas-exchange parameters of two wheat genotypes differing in drought resistanceCrop science,30(1), 105-111.

Rogel, J.A., Ariza, F.A., & Silla, R.O. (2000). Soil salinity and moisture gradients and plant zonation in Mediterranean salt marshes of Southeast Spain. Wetlands, 20(2), 357-372.

Roohi, E., Tahmasebi-Sarvestani, Z., ModarresSanavy, S.A.M. & Siosemardeh, A. (2015). Association of some photosynthetic characteristics with canopy temperature in three cereal species under soil water deficit condition. Journal of Agricultural Science and Technology, 17(5), 1233-1244.

Royo, C., Villegas, D., Del Moral, L.G., Elhani, S., Aparicio, N., Rharrabti, Y. & Araus, J.L. (2002). Comparative performance of carbon isotope discrimination and canopy temperature depression as predictors of genotype differences in durum wheat yield in Spain. Crop and Pasture Science, 53(5), 561-569.

Sadat Noori, S.A. (2005). Assessment for salinity tolerance through intergeneric hybridization: Triticum durum × Aegilopsspeltoides. Euphytica, 146(1), 149-155.

Saeidinia, M., Beiranvand, F., Mumivand, H., & Mousavi, H.S. (2023). The effect of the salinity stress on the yield, morphological characteristics, essential oil and RWC of Satureja hortensis (case study: Khoramabad Iran). Journal of Drought and Climate change Research, 1(1), 97-108. 10.22077//JDCR.2023.6152.1017

Saneoka, H., Shiota, K., Kurban, H., Chaudhary, M. I., Premachandra, G.S., & Fujita, K. (1999). Effect of salinity on growth and solute accumulation in two wheat lines differing in salt tolerance. Soil science and plant nutrition, 45(4), 873-880.

Shahmoradi, H., & Naderi, D. (2018). Improving effects of salicylic acid on morphological, physiological and biochemical responses of salt-imposed winter jasmine. International Journal of Horticultural Science and Technology, 5(2), 219-230.

Shokat, S., & Großkinsky, D.K. (2019). Tackling salinity in sustainable agriculture-What developing countries may learn from approaches of the developed world. Sustainability, 11(17), 4558.

Singh, M.K., Pandey, R.L. and Singh, R.P. (1987). Correlation and path coefficient analysis in barley grown on saline soil. Current Agriculture, 11(1-2), 55-58.

Walia, H., Wilson, C., Condamine, P., Liu, X., Ismail, A.M. & Close, T.J. (2007). Large-scale expression profiling and physiological characterization of jasmonic acid-mediated adaptation of barley to salinity stress. Plant, Cell & Environment, 30(4), 410-421.

Witzel, K., Weidner, A., Surabhi, G.K., Varshney, R.K., Kunze, G., Buck-Sorlin, G.H., Boerner, A. & Mock, H.P. (2010). Comparative analysis of the grain

Archive of SID.ir

Archive of SID.ir

proteome fraction in barley genotypes with contrasting salinity tolerance during germination. Plant, cell & environment, 33(2), 211-222.

Yang, X., Chen, J., Ma, Y., Huang, M., Qiu, T., Bian, H. & Wang, J. (2022). Function, mechanism, and application of plant melatonin: An update with a focus on the cereal crop, barley (Hordeum vulgare L.). Antioxidants, 11(4), 634. https://doi.org/10.3390/antiox11040634

Zaefizadeh, M., Ghasemi, M., Azimi, J., Khayatnezhad, M. & Ahadzadeh, B. (2011). Correlation analysis and path analysis for yield and its components in hulless barley. Advances in Environmental Biology, 5(1), 123-126.

Zhao, C., Zhang, H., Song, C., Zhu, J. K., & Shabala, S. (2020). Mechanisms of plant responses and adaptation to soil salinity. The innovation, 1(1), 100017. https://doi.org/10.1016/j.xinn.2020.100017

Zhaoyong, Z., Abuduwaili, J., & Yimit, H. (2014). The occurrence, sources and spatial characteristics of soil salt and assessment of soil salinization risk in Yanqi Basin, Northwest China. PLoS One, 9(9), e106079. https://doi.org/10.1371/journal.pone.0106079

Zurqani, H., Mikhailova, E., Post, C., Schlautman, M., & Sharp, J. (2018). Predicting the classes and distribution of salt-affected soils in Northwest Libya. Communications in soil science and plant analysis, 49(6), 689-700.

Archive of SID.ir