University of Birjand

تنشهای محیطی در علوم زراعی
Environmental Stresses In Crop Sciences
Vol. 14, No. 2, pp. 475-485
Summer 2021
http://dx.doi.org/10.22077/escs.2020.2926.1753

Original article

Evaluation of quinoa (*Chenopodium quinoa* Wild.) cultivars in saline conditions using germination indices in controlled environment

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Received 5 November 2019; Accepted 19 October 2020

Extended abstract

Introduction

About 6.8 million hectares of agricultural lands in the country have different degrees of salinity, of which 4.3 million hectares have only salinity limits. The response of plants to salt stress is complex and depends on various factors such as concentration and type of solutes, plant species, plant growth stage and environmental factors. The use of salinity tolerant cultivars is currently one of the most effective ways to exploit and increase yield in saline and low saline soils. *Chenopodium quinoa* Willd. is a native plant of the Andean region of South America that was cultivated there from 5,000 to 7,000 years ago. The Food and Agriculture Organization (FAO 2002) designated Quinoa as one of the most important crops for food security of the world's population in the last century. Most Quinoa cultivars are capable of growing in salinity at concentrations of 40 (dSm^{-1}) and even higher. This salinity is too high for most crops. Increasing the concentration of NaCl in the nutrient solution, followed by increasing the osmotic potential, adsorption of Na^+ and Cl^- ions during seed germination causes cell damage and ultimately inhibits or reduces germination. Therefore, the purpose of this study was to evaluate the effect of salinity caused by the use of poor quality water on yield and yield components of Quinoa as well as germination components of different Quinoa cultivars.

Materials and methods

This study was carried out in cultivation in controlled environment (germination apparatus) at the Faculty of Agriculture, Shahid Chamran University, Ahvaz, Iran, in order to evaluate the reaction of cultivars and genotypes to salt stress conditions. In the experiment conducted under controlled conditions, the experimental treatments included salinity (NaCl) at six levels (0, 10, 20, 30, 40 and 50 dSm^{-1}) and three genotypes and genotypes of Quinoa (Giz, Titicaca, Q26) was performed as factorial experiment in a completely randomized design with three replications. To find plant respanses and chose the best one using seed number and germination rate, percentage and germination rate, seed Vigor index, mean germination time, time to 10% germination, time to 50% germination and time to 90% germination were calculated according to the equations.

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Results

The results of analysis of variance showed that salinity stress had a significant effect on germination percentage and rate, and other measured germination indices ($P<0.01$). Interaction of cultivar and salinity stress on root length, stem length, root dry weight and shoot dry weight, seed vigor index, germination uniformity, D10, D50 at 1% and germination percentage at 5% were significant. With increasing salinity levels from the control treatment to the highest salinity level (50 dSm^{-1}), the decreasing trend of root and shoot length as well as root and shoot dry weight was observed. Titicaca showed the highest germination percentage and the highest seed vigor index in control treatment. In the salinity-free treatment, Titicaca showed the best and worst yield in Q26 at 50 (dSm^{-1}) for 10% germination. Among other cultivars, Titicaca showed the highest root and shoot length and the lowest root and shoot length at 50 (dSm^{-1}) under non-salinity stress conditions. Titicaca cultivar had the highest and Giz cultivar had the lowest germination and root dry weight. Titicaca cultivar in control treatment showed the highest root and shoot length with an average of 5.53 and 5.57 cm, respectively, while in salinity treatment of 50 dS/m^{-1} with an average of 0.4 and 0.3 cm minimum root and shoot length. Also, the best uniformity in germination with 20.2 hours was observed in Titicaca cultivar in control treatment.

Conclusions

At low salinity levels, acceptable yield was observed but in sever salinity condition most of the crops could not grow during the phenological stages. According to the results of this study and the study of quinoa behavior and high tolerance of the plant in the germination stage in the face of salinity stress, to improve salinity resistance in crops through breeding programs, and further study of salinity defense mechanisms in susceptible cultivars It is recommended. It seems that despite the significant effectiveness of all three cultivars and significant reduction in germination indices at high salinity levels Titicaca cultivar had a higher tolerance threshold than the other two cultivars, indicating the diversity of cultivars in response to physiological processes to salinity stress. It is also possible to use this cultivar with further research into breeding and breeding programs of other sensitive quinoa cultivars.

***Keywords*:** Germination uniformity, Grain yield, Seed vigor, Seedling establishment

Table1. Analysis of variance for germination traits of Quinoa.

S.O.V	df	Root length	Shoot length	Root dry weight	Shoot dry weight	Seed vigor index	Mean germination time
Repeat	2	0.042^{ns}	0.044^{ns}	9.62^{ns}	4.01^{ns}	0.05^{ns}	0.06^{ns}
Cultivar(C)	2	0.88^{**}	0.59^{**}	2.56^{**}	1.8^{**}	6.34^{**}	0.72^{**}
Salinity (S)	5	41.01^{**}	49.3^{**}	3.51^{**}	9.12^{**}	153.13^{**}	58^{**}
S × C	10	0.31^{**}	0.1^{**}	1.32^{**}	4.6^{**}	1.3^{**}	0.15^{ns}
Error	53	0.026	0.016	4.21	2.7	0.04	0.1
Cv%		*6.4*	*5.11*	*5.6*	*3.66*	*5.6*	*6.9*

Table 1. Continued

S.O.V	df	Germination percentage	Germination rate (R_{50})	Germination uniformity	D_{10}	D_{50}	D_{90}
Repeat	2	9.4^{ns}	0.00005^{ns}	72.6^{ns}	16.7^{ns}	67.6^{ns}	22.2^{ns}
Cultivar(C)	2	420^{**}	0.00008^{*}	84^{ns}	228.4^{**}	471.7^{**}	362.2^{*}
Salinity (S)	5	9838.5^{**}	0.007^{**}	5780.7^{**}	33426^{**}	35189.8^{**}	36977.8^{**}
S × C	10	24.6^{*}	0.00003^{ns}	299^{**}	101.2^{**}	139.2^{*}	167.6^{ns}
Error	53	9.9	0.00002	90.5	26.8	65	110.5
Cv%		*6.5*	*13.2*	*14.75*	*11.23*	*11.5*	*9.5*

ns and **: Non – significant and significant at 1% level of probability, respectively

Table 2. Interaction effects of variete and salinity on measured traits in quinoa.

Treatment					
Salinity (ds.m^{-1})	**Cultivar**	**Root length**	**Shoot length**	**Root dry weight**	**Shoot dry weight**
		---------- cm ----------		---------- gr.seeding^{-1} ----------	
	Titicaca	5.53^{a}	5.73^{a}	0.00067^{a}	0.00086^{b}
0	**Giz**	4.8^{b}	5.13^{bc}	0.00064^{a}	0.0009^{a}
	Q$_{26}$	4.8^{b}	5.26^{b}	0.00057^{b}	0.00078^{d}
	Titicaca	5.5^{a}	5.67^{a}	0.00058^{b}	0.00075^{d}
10	**Giz**	4.7^{b}	5.1^{bc}	0.00056^{b}	0.00082^{c}
	Q$_{26}$	4.1^{c}	4.93^{c}	0.00055^{b}	0.00075^{d}
	Titicaca	3.27^{e}	3.13^{d}	0.0004^{c}	0.00053^{e}
20	**Giz**	2.93^{f}	2.67^{e}	0.0004^{c}	0.00054^{e}
	Q$_{26}$	3.57^{d}	2.23^{f}	0.00041^{c}	0.00039^{f}
	Titicaca	1.93^{g}	1.4^{g}	0.00024^{d}	0.00041^{f}
30	**Giz**	1.5^{h}	1.4^{g}	0.00023^{de}	0.00036^{g}
	Q$_{26}$	1.43^{h}	1.3^{g}	0.00025^{d}	0.00034^{g}
	Titicaca	0.37^{i}	0.27^{h}	0.00023^{de}	0.00012^{h}
40	**Giz**	0.37^{i}	0.27^{h}	0.00023^{de}	0.00012^{h}
	Q$_{26}$	0.4^{i}	0.3^{h}	0.0002^{e}	0.000013^{h}
	Titicaca	0.23^{i}	0.13^{h}	0.00014^{f}	0.00008^{i}
50	**Giz**	0.2^{i}	0.2^{h}	0.00013^{f}	0.00008^{i}

Table 2. Continued

Treatment						
Salinity (ds.m^{-1})	**Cultivar**	**Seed vigor index**	**Germination**	**Germination uniformity**	**D$_{10}$**	**D$_{90}$**
			%	---------- h ----------		
	Titicaca	10.74^{a}	95.33^{a}	20.2^{f}	2.52^{f}	12.62^{g}
0	**Giz**	8.34^{d}	84^{cd}	29.12^{ef}	2.77^{f}	13.75^{g}
	Q$_{26}$	9.09^{c}	90^{b}	24^{ef}	2.68^{f}	13.4^{g}
	Titicaca	9.82^{b}	88^{bc}	59.45^{d}	3.14^{f}	15.072^{g}
10	**Giz**	7.12^{e}	72.67^{e}	71.24^{bcd}	3.8^{f}	19^{g}
	Q$_{26}$	7.25^{e}	80^{d}	68.77^{cd}	3.16^{f}	15.83^{g}
	Titicaca	4.27^{f}	66.67^{f}	79.3^{abc}	4.67^{ef}	25.5^{fg}
20	**Giz**	3.1^{g}	55.33^{g}	81.19^{abc}	5.45^{ef}	34.43^{f}
	Q$_{26}$	3.17^{g}	54.67^{g}	86.13^{ab}	5.46^{ef}	32.8^{f}
	Titicaca	1.15^{h}	34.67^{h}	82.2^{abc}	20.8^{d}	63.06^{de}
30	**Giz**	0.82^{h}	28.67^{i}	93.67^{a}	12.93^{de}	59.67^{e}
	Q$_{26}$	0.97^{h}	35.33^{h}	90.4^{a}	21.2^{d}	76^{d}
	Titicaca	0.16^{i}	25.33^{ij}	69.27^{cd}	103.53^{c}	133.67^{c}
40	**Giz**	0.09^{i}	14.67^{k}	92.67^{a}	100.93^{c}	122^{c}
	Q$_{26}$	0.14^{i}	20.67^{j}	81.47^{abc}	119.6^{b}	151^{b}
	Titicaca	0.04^{i}	10^{kl}	63.06^{ef}	126.33^{b}	149.33^{b}
50	**Giz**	0.03^{i}	6.67^{l}	31.67^{d}	140.53^{a}	156.67^{ab}

Similar letters in each column indicate that there is no significant difference based on the Fisher at the 5% probability level

Table 3. Reaction of simple effects of cultivar and salinity on germination traits of Quinoa

Treatment		Mean germination time	R_{50} Germination rate (R_{50})	D_{90}
Salinity (ds/m^{-1})				
0	۰	2.12^{f}	0.075^{a}	27.10^{e}
10	۱۰	2.60^{e}	0.060^{b}	69.85^{d}
20	۲۰	3.20^{d}	0.034^{c}	87.40^{c}
30	۳۰	4.14^{c}	0.015^{d}	107.10^{b}
40	۴۰	7.45^{b}	0.007^{e}	189.16^{a}
50	۵۰	8.00^{a}	0.006^{e}	182.60^{a}
Cultivar				
Titicaca		4.82^{a}	0.036^{a}	114.80^{a}
Giz		4.50^{b}	0.032^{b}	110.95^{ab}
Q_{26}		4.45^{b}	0.032^{b}	105.84^{b}

Similar letters in each column indicate that there is no significant difference based on the Fisher at the 5% probability level.