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Original article

Identify the effective traits for the selection of quinoa (*Chenopodium quinoa* Willd.) lines in spring cultivation under saline condition

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Extended abstract

Introduction

Quinoa is an allotraploid crop, C3 (2n = 4x = 36) from the Amaranthaceae family and is of great global interest due to its high nutritional value. Quinoa is native to South America and has been cultivated in these areas for 5,000 years. Quinoa has an average of 16% protein and free gluten. Climate change and salinity and drought stress have led farmers to turn to new plants to maintain production in these conditions. Quinoa has a high genetic diversity in terms of tolerance to salinity stress, maturity time and other agricultural traits. The project aims to select promising quinoa lines in saline conditions in spring cultivation.

Materials and methods

In order to select quinoa lines in spring cropping under saline conditions, 13 lines with different maturity periods in 3 lines with 5 meter lines at Sadough salinity research farm of Yazd based on complete randomized block design with three repetitions with 14 dS/m saline water in 2016. Initially, the seeds were planted in a seedling tray and after 21 days, transferred to the farm on March 9. Twice spraying was performed to control the spodoptera larvae during the floral initiation stage. The three stages of urea fertilizer were carried out at first, at the beginning of the floral initiation and anthesis stages. The phenological steps were recorded and the sodium percent, the potassium percent in the leaves and the ratio of potassium to sodium in the anthesis stage and finally the plant height, the thousand kernel weight (TKW), biomass and seed yield were measured. Data were analyzed with SAS software and cluster analysis, correlation analysis and principle component analysis were performed by Statographic software.

Results and discussion

The results of analysis of variance showed that in terms of all the measured traits the difference among the lines was significant. The mean comparison showed that Line 6 had the highest seed yield (1422 Kg ha-1) with a significant difference, and then Lines 7, 10 and 11 had high seed yield. TKW of lines 6 and 11 with a rate of 1.9 and 1.8 g had a significant difference with other lines. The correlation relationship between traits showed that seed yield had significant correlation with TKW and days to maturity. In the

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cluster analysis, lines 11 and 6 in the early group had the highest seed yield and TKW. The high temperature during the period of grain filling in spring cultivation reduced the seed yield and TKW and lines 15 and 16 because of high temperature and long day did not start flowering. The evaluation of temperature in the grain filling period showed that with increasing each degree of the average temperature and maximum temperature seed yield decreased by 118 and 184 Kg ha-1 and TKW decreased by 0.2 and 0.27 g, respectively. Principle component analysis showed that the three components had the largest share in variance, and in the first, second and third components, the TKW, the ratio of potassium to sodium and the percentage of potassium in the positive direction and day to maturity, day flowering and plant height with seed yield had the largest share in the negative direction, respectively. Lines 11, 6 and 10 had the highest share in the total of three components in the direction of yield.

Conclusions

Quinoa had a high ability to absorb potassium under salinity stress, and the heat of the end of the season reduced the yield and TKW in the late mature genotypes. The most important traits for selection in spring cropping under salinity stress were grain yield, early maturity, TKW and potassium-to-sodium discrimination trait, and finally lines 11 and 6 were selected for further study in spring cropping. Among the studied traits, TKW, day to maturity, and the percentage of sodium and potassium ions were effective in line selection.

***Keywords*:** Saline water, Selection, Yield, Yield components

Table1. Quinoa line names and numbers under saline condition

Line Number	Line Name	Line Number	Line Name	Line Number	Line Name	Line Number	Line Name
4	NSRCQ4	8	NSRCQ8	12	NSRCQ12	16	NSRCQ16
5	NSRCQ5	9	NSRCQ9	13	NSRCQ13		
6	NSRCQ6	10	NSRCQ10	14	NSRCQ14		
7	NSRCQ7	11	NSRCQ11	15	NSRCQ15		

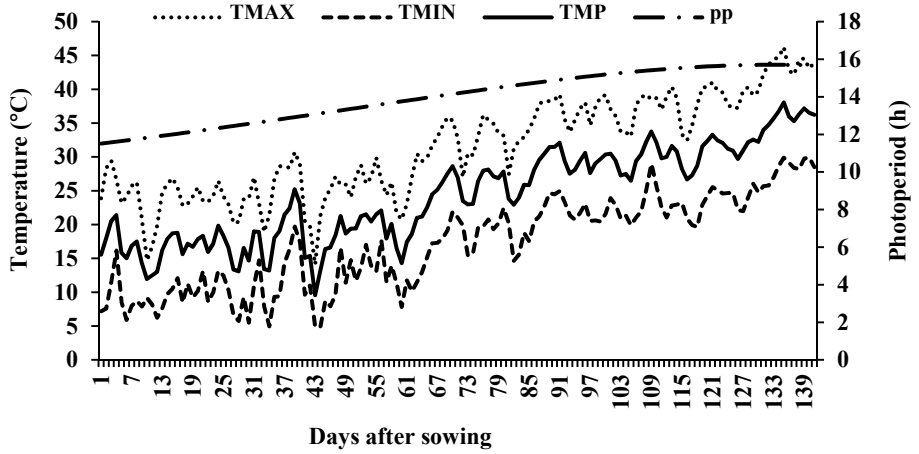

Fig. 1. Maximum temperature (TMAX), minimum temperature (TMIN), Mean temperature (TMP) and photoperiod (PP) during growing cycle of quinoa

Table 2. Irrigation Water quality

Irrigation water	EC	pH	SAR	Na	Ca	Mg	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}
	dS/m			meq l^{-1}						
Saline water	14.52	7.30	23.18	104.57	13.20	28.52	0	3.30	134.0	8.99

Table 3. Soil salinity of saturated paste extract (dS m^{-1}) during growing cycle and soil texture

Soil depth (cm)	40 days after sowing	67 Days after sowing	92 Days after sowing	Sand	Silt	Clay	Texture
	ECe (dS m^{-1})			%			
0-30	18.4	18.1	21.3	60	22	18	SL
30-60	13.6	13.2	13.2				

Table 4. Days to anthesis and maturity, GDD from anthesis up to maturity and minimum, maximum and mean temperature during seed filling period of different lines of quinoa at spring cropping under saline condition

Line	Days to anthesis	Days to maturity	GDD up to anthesis	GDD up to maturity	Mean of photoperiod during seed filling period	Temperature during seed filling period		
						Average	Minimum	Maximum
4	67	141	1161	1905	15.15	29.0	22.6	37.8
5	91	141	1524	1732	15.47	31.4	24.0	38.8
6	67	110	1161	1905	14.80	28.0	20.9	35.1
7	67	134	1161	1905	15.09	29.2	21.9	36.6
8	88	134	1504	1905	15.39	30.6	23.2	38.1
9	88	134	1504	1905	15.39	30.6	23.2	38.1
10	67	134	1161	1905	15.09	29.2	21.9	36.6
11	60	110	1025	1732	14.67	26.9	20.9	35.1
12	88	141	1504	1905	15.43	31.4	24.0	38.8
13	67	141	1161	1905	15.15	29.0	22.6	37.8
14	67	141	1161	1905	15.15	29.0	22.6	37.8
15					-			
16					-			

Table 5. Analysis of variance of measured traits of different lines of quinoa in spring cropping under saline condition

S.O.V	df	Seed yield	TKW	Biomass	Na content	K content	K/Na ratio	Plant height
Block	2	21343^{ns}	0.033^{ns}	1052306^{ns}	1.52^{ns}	0.34^{ns}	0.001^{ns}	15^{ns}
Treatment	12	470668^{**}	0.937^{**}	6026186^{**}	4.85^{**}	8.00^{**}	$^{**}0.005$	1140^{**}
Error	24	13569	0.025	369844	0.49	2.39	0.0005	88
CV%		*24.1*	*17.07*	*13.5*	*21.4*	*16.6*	*35.2*	*12.6*

**,* and ns: significant at 1 and 5 percent and non-significant, respectively

Table 6. Means comparison of measured traits of different lines of quinoa in spring cropping under saline condition

Line	Biomass	Seed yield	Thousands Kernel weight	Na content	K content	K/Na ratio	Plant height
	(Kg ha^{-1})	(Kg ha^{-1})	(g)	(%)	(%)		(cm)
4	3315.4 ^{de}	433.7 ^{c}	1.2 ^{b}	2.06 ^{e}	10.19 ^{abc}	5.46 ^{b}	96.4 ^{b}
5	3163.3 ^{de}	214.9 ^{d}	0.4 ^{e}	3.46 ^{cd}	10.22 ^{abc}	3.46 ^{b}	85.0 ^{bc}
6	5629.9 ^{abc}	1422.3 ^{a}	1.9 ^{a}	3.76 ^{bcd}	9.94 ^{abc}	2.68 ^{b}	65.5 ^{def}
7	5366.7 ^{abc}	804.7 ^{b}	0.7 ^{cd}	5.16 ^{a}	11.60 ^{a}	2.26 ^{b}	52.10 ^{f}
8	4664.2 ^{c}	273.6 ^{cd}	1.4 ^{bd}	4.00 ^{abc}	11.00 ^{ab}	2.90 ^{b}	56.8 ^{ef}
9	4704.2 ^{c}	367.7 ^{cd}	1.3 ^{b}	4.08 ^{abc}	8.63 ^{bcde}	2.20 ^{b}	56.8 ^{ef}
10	2059.3 ^{f}	906.3 ^{b}	1.2 ^{b}	4.69 ^{ab}	6.03 ^{e}	1.28 ^{b}	62.0 ^{def}
11	2493.7 ^{ef}	751.9 ^{b}	1.8 ^{a}	2.13 ^{e}	10.35 ^{abc}	4.99 ^{b}	55.9 ^{f}
12	6038.1 ^{ab}	298.7 ^{cd}	0.8 ^{c}	3.08 ^{cde}	9.09 ^{abcd}	3.13 ^{b}	71.9 ^{cde}
13	6279.8 ^{a}	415.3 ^{c}	0.8 ^{cde}	3.10 ^{cde}	9.74 ^{abc}	3.15 ^{b}	76.8 ^{cd}
14	5902.8 ^{ab}	388.9 ^{cd}	0.5 ^{de}	2.71 ^{de}	9.30 ^{abc}	3.48 ^{b}	81.4 ^{bc}
15	3602.4 ^{d}	0 ^{e}	0 ^{f}	4.13 ^{abc}	6.65 ^{de}	1.59 ^{b}	120.6 ^{a}
16	5227.4 ^{bc}	0^{e}	0 ^{f}	0.36 ^{f}	7.79 ^{cde}	42.21 ^{a}	83.1 ^{bc}
LSD	*1024.8*	*196.3*	*0.26*	*1.18*	*2.60*	*13.49*	*15.85*

In each column, means with at least one similar letter do not have significant differences based on LSD test at 5% level

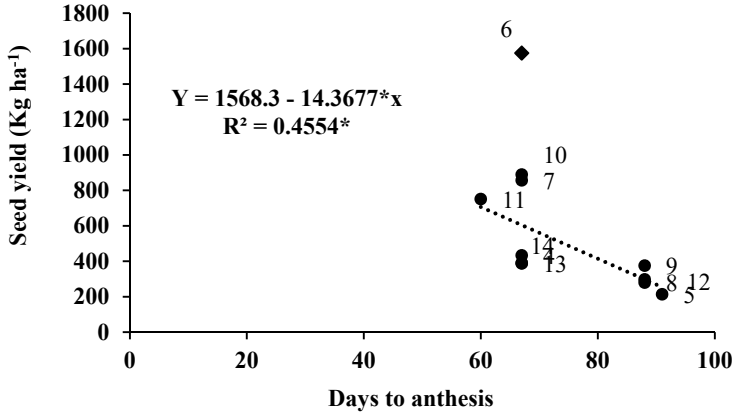

Fig. 2. Relationship between anthesis and seed yield of quinoa lines in spring cropping under saline condition. * means significant at 5 percent.

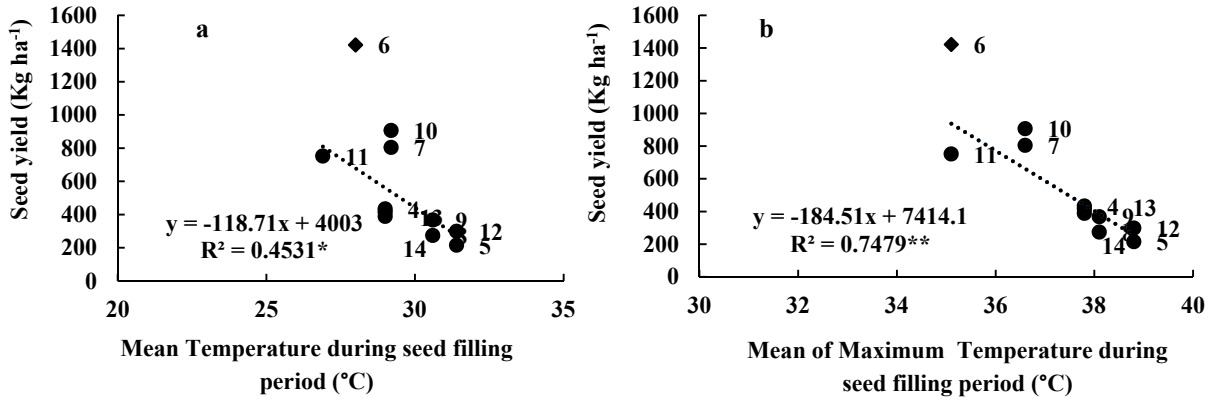

Fig. 3. Relationship mean (a) and mean of maximum (b) during seed filling period with seed yield of quinoa lines in spring cropping under saline condition (line 6 data not included in regression)(,* and ns: significant at 1 and 5 percent and non-significant, respectively).**

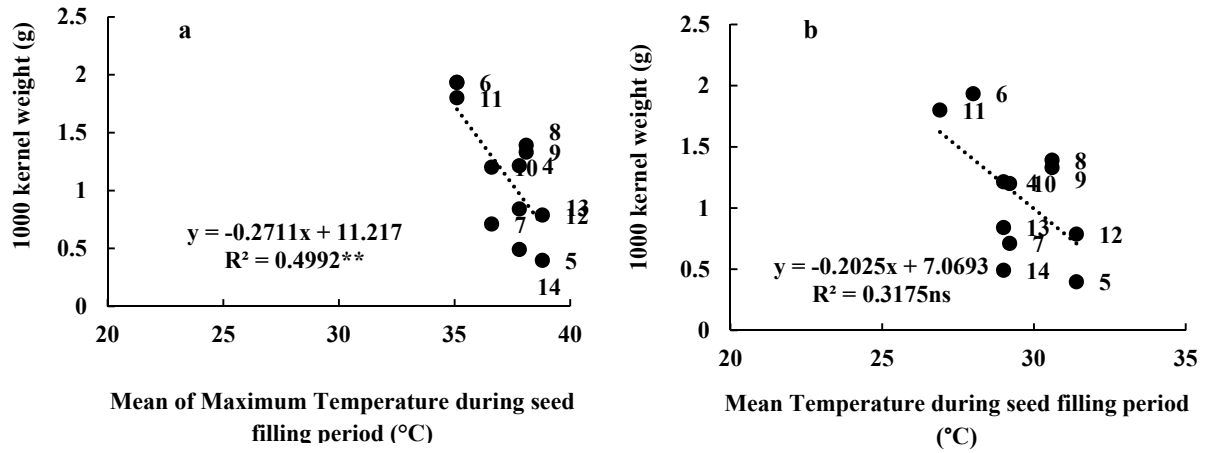

Fig. 4. Relationship mean (a) and mean of maximum (b) during seed filling period with thousand kernel weight (g) of quinoa lines in spring cropping under saline condition (,* and ns: significant at 1 and 5 percent and non-significant, respectively)**

Table 7. Correlation coefficient among measured traits of quinoa in spring cropping under saline condition

		1	2	3	4	5	6	7	8	9	10	11
1	**Days to anthesis**	1										
2	**Days to maturity**	0.42	1									
3	**Minimum Temperature**	0.92**	0.69*	1								
4	**Maximum Temperature**	0.75**	0.89**	0.88**	1							
5	**Biomass**	0.12	0.20	0.18	0.23	1						
6	**Seed yield**	-0.61*	-0.76**	-0.67*	-0.89**	-0.08	1					
7	**Thousand kernel weight**	-0.29	-0.83**	-0.56	-0.71*	-0.26	0.61*	1				
8	**Na percent**	0.21	0.04	0.29	-0.05	0.07	0.28	-0.08	1			
9	**K percent**	0.03	-0.13	-0.07	-0.03	0.31	-0.12	-0.03	-0.15	1		
10	**K/Na ratio**	-0.24	-0.08	-0.32	-0.02	-0.19	-0.25	0.10	-0.9**	0.46	1	
11	**Plant height**	0.01	0.51	0.16	0.46	0.01	-0.37	-0.43	-0.62*	-0.01	0.54	1

* and ** Correlation is significant at the 0.01 and 0.05 level respectively (2-tailed).

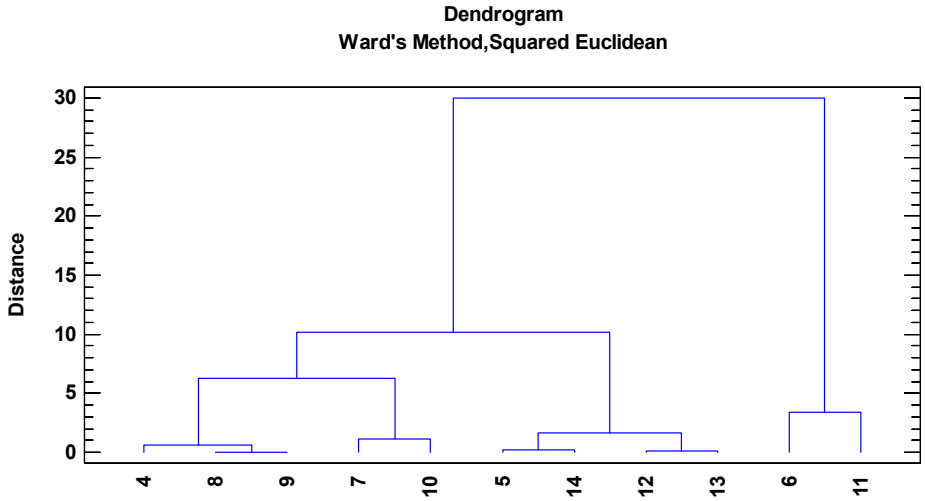

Fig. 5. Cluster analysis of quinoa lines based on Wards methods and mean seed yield, thousand kernel weight and days to maturity in each group

Table 8. Average of days to maturity, thousand kernel weight and Seed yield of lines in 3 cluster group

Cluster Group	Line No.	Days to Maturity	Thousand kernel weight (g)	Seed yield (Kg/ha)
1	4,7,8,9,10	135.4	1.16	557.2
2	5,12,13,14	141.0	0.62	329.4
3	6,11	110.0	1.86	1087.1

Table 9. Principle component analysis of agronomic traits of quinoa lines in spring cropping under saline condition

Traits	First component	Second component	Third component
Biomass	0.12	0.15	0.61
Seed yield	-0.50	-0.05	-0.01
Thousandkernel weight	-0.44	-0.22	0.01
Na percent	-0.20	0.55	0.07
K percent	0.08	-0.21	0.73
K/Na ratio	0.18	-0.59	0.07
Plant height	0.39	-0.28	-0.23
Days to anthesis	0.27	0.31	0.10
Days to maturity	0.49	0.23	-0.14
Eigenvalue	3.15	2.48	1.32
Cumulative Variance percent	35.0	62.7	77.4

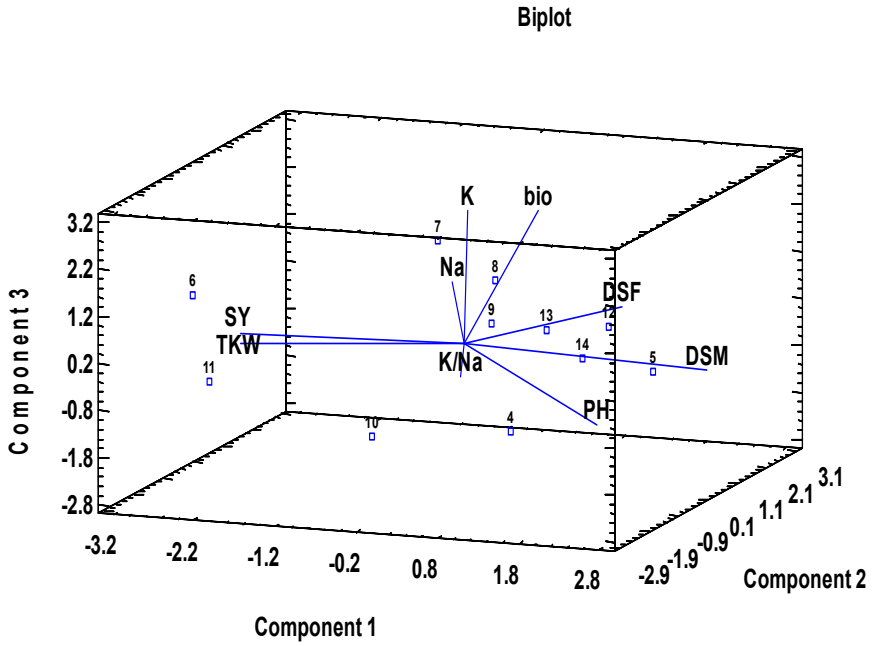

Fig 6. Biplot analysis of quinoa lines in spring cropping under saline condition. Biomass (bio), Plant height (PH), K/Na ratio (K/Na), Na percent (Na), K percent (K), Seed yield (SY), Thousand kernel weight (TKW), Days to maturity (DSM) and Days to anthesis (DSF)

Table 10. Principle component analysis of quinoa lines in spring cropping under saline condition

Line	First component	Second component	Third component	Sum of three components
4	1.56	-2.71	-0.77	-1.92
5	2.23	0.29	-0.44	2.07
6	-3.13	-0.59	0.84	-2.88
7	-0.86	1.50	1.57	2.21
8	0.10	0.80	1.08	1.98
9	-0.21	1.55	-0.13	1.21
10	-1.77	1.76	-2.80	-2.81
11	-2.09	-2.85	-0.09	-5.03
12	1.54	0.69	0.30	2.53
13	1.05	-0.07	0.45	1.42
14	1.59	-0.36	-0.01	1.22