Original Research Article

Effect of Salinity Stress on Yield, Component Characters and Nutrient Compositions in Rapeseed (*Brassica napus* L.) Genotypes

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Abstract

Crops growing in salt-affected soils may suffer from physiological drought stress, ion toxicity, and mineral deficiency which then lead to reduced growth and productivity. Eight rapeseed genotypes were evaluated at control and two salinity levels of irrigation, i.e. $EC_e=0$ dS m^{-1} (control), 6 and 12 dS m^{-1} . A factorial experiment based on completely randomized design with 4 replications was considered for evaluation of 24 treatments. Significant mean square of the salinity levels and genotypes were exhibited for 1000-seed weight, pod length, seed yield, Mg, K and Cl, indicating significant differences of genotypes for the traits at three salinity levels. Pods per plant and Mg had lowest variations among the genotypes at the high salinity levels. Hyola401, LRT1 and KRN1 with seed yield of 3.09, 2.78 and 2.30 g/plot, respectively were considered as salt tolerant genotypes. Stress (12dsm⁻¹) to control ratio (S/C) which is indicating of salinity tolerance was high for seed yield of DSM12 and Hyola401. Significant positive correlation of seed yield with K and Cl, indicated that these shoot ions can be considered as good indicators for seed yield improving at saline environment.

Key words: correlation, experiment, rapeseed, selection criteria, seed yield.

INTRODUCTION

Rapeseed is the third most important edible oil source in the world, after soybean and palm; it is the top ranking oilseed crop of Iran, covering 40.74 of the total oilseed production. Out of 4.6 million hectares of the coastal and outsource landmass, about 0.83 million hectares of which are affected by different degrees of salinity in Iran (Bybordi, 2010). Results have indicated that salinity affects growth and development of plants through oxidative, osmotic and ionic stresses. Because of accumulated salts in soil under salt stress condition plant wilts apparently while soil salts such as Na and Cl disrupt normal growth and development of plant (Sharma and Gill, 1994; Tunuturk et al., 2011). Adverse effect of salinity on plant growth may be due to ion cytotoxicity and osmotic stress. Decrease in uptake of potassium (K) and in this manner a decrease in growth at higher sodium (Na) concentration have been reported (Ashraf and McNeilly, 2004). Tolerance of oilseed brassicas to salt stress is a multifaceted trait, which is greatly modified by cultural, climatic and biological factors (Kumar, 1995; Minhas et al., 1990; Ashraf and McNeilly, 2004; Mahmoodzadeh, 2008). The most common undesirable effect of salinity on the crop of brassica is the reduction in plant height, component characters of yield as well as deterioration of the product quality (Zamani et al., 2011). The salinity may reduce the crop yield by disturbing water and nutritional balance of plant (Francois, 1994; Islam, 2001). Significant variation in

seed germination and other growth stages among rapeseed cultivars grown under salinity condition is extensively reported by Puppala et al. (1999), Mer et al. (2000), Bybordi (2010), Tunuturk et al. (2011) and Zamani et al. (2011). The amphitraploids *Brassica* species including *Brassica napus*, *B. carinata* and *B. juncea* are more tolerant to salinity and alkalinity than their respective diploid progenitors such as *B. campestris*, *B. nigra* and *B. oleracea* (Kumar, 1995). In response to salinity stress, endogenous Na concentration increased in the various *Brassica* genotypes whereas K concentration decreased. Saline soils and saline irrigation waters present potential hazards to canola production. Calcium (Ca) and K ameliorate the adverse effects of salinity on plants (Volkmar, 1998; Murillo-Amador et al., 2007; Munnus, 2002). Salinity impairs the uptake of Ca by plants, possibly by displacing it from the cell membrane or in some way affecting membrane functions (Rameeh et al., 2004; Mandhania et al., 2010). Gorham (1993) claimed that all plants discriminate to some extent between Na and K. Na can be substituted for K for uptake, and it is supposed that similar mechanisms of uptake may operate for both ions (Tie and Cramer, 1992; Porcelli et al., 1995; Schroder et al., 1994). High level of K in young expanding tissue is related to salt tolerance in many plant species (Ashraf and McNeilly, 2004; Bandeh-Hagh et al., 2008; Mer et al., 2000). Tie and Cramer (1992) reported that Ca could play a regulatory role in the responses of *Brassica* species to saline environments. Thakral et al. (1998) reported positive

non-significant correlation between seed yield and K/Na in stress environment in *B. juncea*. Das et al. (1994) claimed that increase in NaCl concentration was associated with increased Na and Cl influx and K efflux in *B. campestris*. The present study was conducted to evaluate the effect of salinity on shoot ions composition, yield and component characters of eight canola genotypes under salinity conditions in order to obtain suitable criteria for salinity tolerance in rapeseed genotypes and also to determine the superior genotypes under environment.

MATERIALS AND METHODS

To study the salt stress effect on canola seed yield, character components and also shoot nutrient ions concentrations, an experiment was conducted in Agriculture and Natural Resources Research Center of Mazandran, Sari, Iran, during 2010-11. The experimental design was a completely randomized design (CRD) arrangement in 3×8 factorial with four replications. Eight diverse rapeseed genotypes (as first factor) including six breeding lines (KRN3, NDK6, KRN1, KRN2, DSM12 and LRT1) and two cultivars (Zarfam and Hyola401) were studied in three salinity levels of irrigation water including 0 (control), 6 and 12 dsm⁻¹ as second factor. The salt solution was prepared by taking NaCl:CaCl₂ at the ratio of 1:1 and the electrical conductivity of different salinity levels was adjusted by a direct reading conductivity meter. Soil analysis results are shown in Table 1. The soil belongs to the non-saline soil with a neutral reaction and the amount of lime which is relatively high. Levels of nutrients, soil organic matter levels in the medium and other nutrients, including potassium, phosphorus, iron, manganese and copper are desirable. In each plot 10 seeds were planted in separate 10-liter pots and five plants were maintained for evaluating. Electrical conductivities of the saline treatments were increased to the desired levels by incremental additions of the salts over 10-day period to avoid osmotic shock to the seedlings. Plants in all pots were irrigated until saturation, with the excess solution allowed to drain into collection pans. All pots were maintained at farm conditions and they were also isolated from raining. The studied traits were 1000-seed weight, pods length, seed yield and shoot ions concentrations including Mg, K and Cl. For ions extractions, plant samples were ground by mill and then dried in a furnace at 500 °C for 2 hours. After that, plant samples were added

5 ml of 2M HCl for digestion and then they were filtered and diluted by distilled water. The final volume of each sample was 100 ml. Amount of Mg and K of each final sample was measured by flame photometer (Isaac and Kerber, 1971). For chloride determination, Cl was determined by the silver ion-titration method with an automatic chloridometer (Buckhler-Cotlove chloridometer) according to Bozcuk (1970). Pearson correlation was detected for all the traits. All the traits were analyzed based on factorial experiments based on completely randomized and means comparison were done based on least significant difference test (Gomez and Gomez, 1984). Stress (12 dsm⁻¹) to control ratio (S/C) which is indicating of salinity tolerance were calculated for all the traits. All the analyses were performed using SAS software version 9 (SAS INSTITUTE INC 2004).

RESULTS AND DISCUSSION

Effects of salinity levels on the traits

Mean squares of the salinity levels were significant for 1000-seed weight, pod length, seed yield, Mg, K and Cl, indicated significant differences of these traits for control and two salinity levels (Table 2). The traits including 1000-seed weight and pod length were decreased at high levels of salinity (Table 3). Due to decreasing of yield components at high salinity levels, seed yield of the genotypes was decreased at 12 dsm⁻¹ about its half amount of control. Mg was decreased at high salinity level and it varied from 3.47 and 2.90 mg g⁻¹ at 0 and 12 dsm⁻¹ of salinity levels, respectively, and it was also classified as the same group at control and 6 dsm⁻¹ of salinity level. Amount of K was decreased at high salinity levels and it was also ranged from 27.53 to 15.24 at control and 12 dsm⁻¹ of salinity level, respectively. Although other shoot cation concentrations were decreased at high salinity level, Cl concentration was increased (Table 3). In previous studies (Volkmar, 1998; Munnus, 2002; Murillo-Amador et al., 2007) it was concluded that in response to salinity stress, endogenous Na concentration increased in the various Brassica genotypes whereas K concentration decreased.

Genetic variations for the traits

Significant mean square of genotypes indicating significant genetic variation was detected for all the traits and shoot

Table 1. Some of physicochemical properties of soil sample

Class	Class (%)			(mg Kg ⁻¹)						TNV (%)	OC (%)	PH	Ec (dsm ⁻¹)
	Clay	Silt	Sand	Cu	Zn	Mn	Fe	K	P				
Si-C-L	26	56	18	2.5	0.65	3.2	8	321	7.8	13	1.34	7.2	0.65

Table 2. Summary of analysis of variance for yield components, seed yield, Ca, K and Na in rapeseed genotypes

S.O.V	df	M.S					
		1000-seed weight	Pod length	Seed yield	Mg	K	Cl
Salinity (S)	2	19.58**	24.24**	21.58**	2.69*	1211.33**	10702.19**
Genotypes(G)	7	0.77**	4.22**	7.38**	17.32**	206.33**	484.73**
S×G	14	0.33**	1.12**	0.43**	4.51**	38.43**	282.51**
Error	72	0.09	0.23	0.11	0.93	10.42	81.07

** : Significant at the 1% levels of probability.

Table 3: Mean comparison of yield components, seed yield, Mg, K and Cl for salinity levels based on least significant differences (LSD) test in rapeseed genotypes

Salinity levels(dsm ⁻¹)	1000-seed weight (g)	Pod length (cm)	Seed yield (g/plot)	Mg (mg g ⁻¹)	K (mg g ⁻¹)	Cl (mg g ⁻¹)
S1 = 0 (control)	3.15a	5.59a	2.84a	3.47a	27.53a	27.65c
S2 = 6	2.24b	4.46b	1.62b	3.29a	20.86b	44.34b
S3 = 12	1.59c	3.87c	1.28c	2.90a	15.24c	64.18a

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability.

ions concentrations at 1% probability level (Table 4). 1000-seed weight varied from 1.90 to 2.64 g in KRN2 and LRT1, respectively. The genotypes including Hyola401, Zarfam and LRT1 with the mean of 2.40, 2.62 and 2.64 g, respectively, had high amounts of this trait. Stress (12 dsm⁻¹) to control ratio (S/C) of 1000-seed weight was higher for Hyola401, therefore this genotype was more salinity-tolerant for this trait (Table 5). The genotypes including NDK6, Zarfam, KRN1, KRN2 and Hyola401 were in the same statistical group for S/C ratio of 1000-seed weight. The interaction effect of salinity levels × genotypes revealed that 1000-seed was ranged from 2.66 to 3.79 g, 1.67 to 2.72 g and 1.31 to 2.01 g at control, 6 and 12 dsm⁻¹ of salinity levels, respectively (Table 6). Significant correlation of seed yield with 1000-seed weight and pod length (0.70** and 0.75**, respectively)

indicated that these traits can be considered as good indirect selection criteria for seed yield improving (Table 7). Pod length was ranged from 3.59 to 5.39 cm in KRN2 and LRT1, respectively (Table 4). In comparison to 1000-seed weight, pod length in the most of the genotypes was less affected by high salinity level and KRN3 had highest S/C of pod length (Table 5). Seed yield of the genotypes was varied from 0.68 to 3.09 g/plot related to Hyola401 and KRN2, respectively (Table 4). The genotypes including Hyola401, LRT1 and KRN1 with seed yield of 3.09, 2.78 and 2.30 g/plot, respectively, were detected as suitable genotypes for this trait at three salinity levels. Seed yield of the genotypes was also varied from 1.33 to 4.14 g/pot, 0.47 to 2.49 g/pot and 0.26 to 2.66 g/pot at control, 6 and 12 dsm⁻¹ of salinity levels, respectively (Table 3). The high amounts of S/C ratio belonged to DSM12

Table 4. Mean comparison of yield components, seed yield, Mg, K and Cl for eight rapeseed (*Brassica napus* L.) genotypes based on least significant differences (LSD) test

Variety	1000-seed weight (g)	Pod length (cm)	Seed yield (g/plot)	Mg (mg g ⁻¹)	K (mg g ⁻¹)	Cl (mg g ⁻¹)
1-KRN3	2.38ab	4.79bc	1.50d	4.93a	13.07d	52.47a
2-NDK6	2.39ab	4.10de	1.64cd	4.38a	22.11b	42.70bc
3-Zarfam	2.62a	4.41cd	1.42d	4.65a	22.78b	46.36abc
4-KRN1	2.14bc	4.69c	2.30b	2.50b	23.06b	47.92ab
5-KRN2	1.90c	3.59e	0.68e	2.31b	22.03bc	55.43a
6-DSM12	2.13bc	5.23ab	1.89c	2.51b	27.49a	39.22bc
7-LRT1	2.64a	5.39a	2.78a	2.37b	18.56c	41.76bc
8-Hyola401	2.40ab	4.91abc	3.09a	2.11b	20.60bc	37.27c

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability.

Table 5. Mean comparison of stress (12dsm⁻¹) to control ratio (S/C) for yield components, seed yield, Mg, K and Cl of eight rapeseed (*Brassica napus* L.) genotypes based on least significant differences (LSD) test

Variety	1000-seed weight (g)	Pod length (cm)	Seed yield (g/plot)	Mg (mg g ⁻¹)	K (mg g ⁻¹)	Cl (mg g ⁻¹)
1-KRN3	0.48b	1.04a	0.43b	0.89bc	0.45bc	2.90ab
2-NDK6	0.53ab	0.65bc	0.37bc	0.57bc	0.66a	1.90b
3-Zarfam	0.56ab	0.64bc	0.33bc	0.61bc	0.62ab	1.88b
4-KRN1	0.54ab	0.62c	0.44b	0.93bc	0.43c	3.43a
5-KRN2	0.53ab	0.58c	0.19c	0.18c	0.34c	2.15ab
6-DSM12	0.40b	0.68bc	0.69a	1.18bc	0.73a	2.56sb
7-LRT1	0.38b	0.86ab	0.37bc	1.42b	0.61ab	2.94ab
8-Hyola401	0.71a	0.57c	0.66a	5.05a	0.62ab	2.22ab

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability.

Table 6. Mean comparison of yield components, seed yield, Mg, K and Cl for eight rapeseed (*Brassica napus* L.) genotypes based on least significant differences (LSD) test

Variety	1000-seed weight (g)	Pod length (cm)	Seed yield (g/plot)	Mg (mg g ⁻¹)	K (mg g ⁻¹)	Cl (mg g ⁻¹)
1-S0 × KRN3	3.09b-e	4.67def	2.45cd	5.42abc	15.88h-k	28.77ij
2- S0 × NDK6	3.20bcd	5.30bcd	2.57cd	5.90a	27.89bc	27.40ij
3- S0 × Zarfam	3.51ab	5.58abc	2.43cd	5.83ab	28.08bc	29.03ij
4- S0 × KRN1	2.76def	5.53a-d	3.25	2.61f-i	34.29a	22.71j
5- S0 × KRN2	2.66d-g	4.72c-f	1.33b	2.87e-h	32.78ab	44.15f-i
6- S0 × DSM12	3.33abc	6.36a	2.58cd	2.27f-j	32.85ab	23.98j
7- S0 × LRT1	3.79a	6.13ab	4.01a	2.06g-j	23.09c-g	22.40j
8- S0 × Hyola401	2.84c-f	6.40a	4.14a	0.82ij	25.40cde	22.78j
9-S1 × KRN3	2.57e-h	4.89c-f	1.08ghi	4.55a-e	16.20h-k	45.93f-h
10- S1 × NDK6	2.28f-g	3.56ghi	1.40fg	4.02b-f	19.83e-j	49.40d-g
11- S1 × Zarfam	2.40f-i	4.09fgh	1.06ghi	4.81a-d	22.73c-g	56.01c-f
12- S1 × KRN1	2.15g-k	5.15cde	2.24de	2.63f-i	20.37d-i	43.28f-i
13- S1 × KRN2	1.67k-n	3.35hi	0.47ij	3.50d-h	22.35c-g	51.45d-g
14- S1 × DSM12	1.76j-n	5.04cde	1.33fgh	2.84e-h	25.91cd	32.26hij
15- S1 × LRT1	2.72d-f	4.90c-f	2.87bc	2.13g-j	18.51-j	37.88g-j
16- S1 × Hyola401	2.34f-i	4.70c-f	2.49cd	1.83hij	21.00d-h	38.49g-j
17-S2 × KRN3	1.48lmn	4.81c-f	0.99ghi	4.83a-d	7.15l	82.71a
18- S2 × NDK6	1.69k-n	3.44ghi	0.96ghi	3.22d-h	18.59f-j	51.29d-g
19- S2 × Zarfam	1.94i-m	3.55ghi	0.76hij	3.31d-h	17.53g-j	54.03c-g
20- S2 × KRN1	1.49lmn	3.39hi	1.42fg	2.28f-j	14.53ijk	77.78ab
21- S2 × KRN2	1.38n	2.71i	0.26j	0.56j	10.96kl	70.69abc
22- S2 × DSM12	1.31n	4.30efg	1.76ef	2.43f-i	23.70c-f	61.42b-e
23- S2 × LRT1	1.42mn	5.14cde	1.48fg	2.93e-h	14.06jk	65.01bcd
24- S2 × Hyola401	2.01mn	3.63gh	2.66bcd	3.69c-g	15.41h-k	50.53d-g

Means, in each column, followed by at least one letter in common are not significantly different at the 1% level of probability.

and Hyola401 as tolerant genotypes (Table 5). Mg was ranged from 2.11 to 4.93mg g⁻¹ related to Hyola401 and KRN3, respectively. Although with result of increasing of salinity levels, Mg was decreased for most of the genotypes, but its increments was varied for different genotypes (Table 5). Hyola401 and LRT1 had highest concentrations of Mg at 12 dsm⁻¹ than control (Table 6). Non significant correlation between Mg and seed yield, indicated that the other shoot

ions, i.e. K and Ca had more important roles than Mg for seed yield improving in saline environment. The importance of shoot ions including Ca and K than Na for seed yield improving of *Brassica* species were emphasized in the other studies (Volkmar, 1998; Munnus, 2002; Murillo-Amador et al., 2007). DSM12 had the highest amount of K and also its S/C ratio. High variation of shoot K concentration related to three salinity levels were detected for KRN1 and KRN2

Table 7. Correlation among the studied traits in rapeseed genotypes at different salinity levels (n = 24)

Traits	1000-seed weight (g)	Pod length (cm)	Seed yield (g/plot)	Mg (mg g ⁻¹)	K (mg g ⁻¹)	Cl (mg g ⁻¹)
1- 1000-seed weight	1					
2- Pod length	0.69**	1				
3- Seed yield	0.70**	0.75**	1			
4- Mg	0.24	-0.01	-0.17	1		
5-K	0.57**	0.54**	0.43*	-0.02	1	
6- Cl	-0.84**	0.70**	0.73**	-0.03	-0.74**	1

*, ** Significant at p = 5% and 1%, respectively.

and its low variation were exhibited in LRT1 and Hyola401 (Table 6). A significant positive correlation was determined between K and seed yield, therefore concentration of this ion can be considered as a good indicator for seed yield increasing at saline condition. Similarly, in the earlier studies (Mer et al., 2000; Ashraf and McNeilly, 2004; Bandeh-Hagh et al., 2008) the important effect of K for salinity tolerance was found. High absorption of Cl makes low influx of other toxic ions like Na in saline environment, therefore the genotypes with high amounts of Cl had also high amount of seed yield at high salinity levels (Table 4).

In general, increasing of salinity levels had significant decreasing effects on yield, yield components and also all the shoot ions concentrations except Cl. Pods per plant and Mg had lowest variations among the genotypes at the high salinity levels. Although with result of salt increasing level most of shoot ions concentrations were decreased, but their increments of reductions were varied for different genotypes. Stress (12dsm⁻¹) to control ratio (S/C) indicative of salinity tolerance was high for seed yield of DSM12 and Hyola401. Significant positive correlation was exhibited between seed yield and each of two shoot ions concentrations including K and Cl, therefore these shoot ions can be considered as good indicators for seed yield improving at saline environment.

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