International Journal of Plant Research 2012, 2(3): 61-64
DOI: 10.5923/j.plant.20120203.03

Relationship Between Seed Yield and Shoot Ions at Vegetative and Reproductive Stages of Rapeseed Genotypes under Saline Environment

Valiollah Rameeh[1,*], Ali Cherati[1], Farid Abbaszadeh[2]

[1]Agricultural and Natural Resources Research Center of Mazandran, Sari, Iran
[2]Former graduate of M. Sc

Abstract Soil salinity is a major constraint to crop production in many areas of the world. To investigate the effects of salinity stress on seed yield and shoot ions at vegetative and reproductive stages, a factorial experiment was applied for evaluating the seven rapeseed genotypes under four salinity levels including 0, 4, 8 and 12 dsm^{-1}. The salt solution was prepared by taking $NaCl:CaCl_2$ in the ratio of 1:1. Significant mean square of salinity levels were exhibited for seed yield and all shoot ions at two growth stages except Ca at reproductive stage. Due to increasing salinity levels Ca at vegetative stage was increased in L14 and Zarfam but in other genotypes it was not affected by increasing salinity levels. Significant negative correlation of K with Na and Cl indicating the ameliorating effect of K on toxic effects of Na and Cl. Due to adverse effect of Cl on seed yield, the correlation of this ion with seed yield was significant and negative at vegetative and reproductive stages. Significant positive correlation of K content at vegetative stage with seed yield implied that K at this stage can be used as selection criterion for detecting high seed yield genotypes in saline environment.

Keywords Factorial Experiment, Rapeseed, Salinity, Shoot Ions, Reproductive Stages

1. Introduction

Soil salinity greatly decreases the productivity of economically important plants such as Brassica specious. Saline environments affect the plant growth in different ways such as reduction water uptake, an accretion of ions to toxic levels, and a reduction of nutrient accessibility. Two primary lines of action were emphasized for decreasing salinity effects on crop production: reclamation of salt-affected soils by chemical amendments, and alternatively, the saline soils can be used to grow salt-tolerant plants[2]. High salt stress disrupts homeostasis in water potential and ion distribution. This disruption of homeostasis occurs at both the cellular and the whole plant levels[24]. Tolerance of oilseed brassicas to salt stress is a complex trait, which is greatly modified by environmental conditions such as cultural, climatic and biological factors[13,15,16]. High salt concentration in root affects the growth and yield of many important crops. The salinity may reduce the crop yield by disturbing water and nutritional balance of plant[7,11]. Water accessibility and nutrient uptake by plant roots is limited because of high osmotic potential and toxicity of sodium (Na) and chlorine (Cl) ions[13]. Saline soils and saline irrigation waters present potential hazards to canola production. The most common undesirable effect of salinity on the crop of Brassica is the reduction in plant height, size and yield as well as deterioration of the product quality[26]. There are differences in sensitivity to salinity among canola cultivars[15,19]. Calcium (Ca) and potassium (K) ameliorate the adverse effects of salinity on plants[1,17,25]. Salinity impairs the uptake up Ca by plants, possibly by displacing it from the cell membrane or in some way affecting membrane function[14,20]. Gorham[8] claimed that all plants discriminate to some extent between Na and K. Na can be substituted for K for uptake, and it is believed that similar mechanisms of uptake may operate for both ions[10,18,21]. High levels of K in young expanding tissue is associated with salt tolerance in many plant species[2,3,17]. Closely allied to salt exclusion and its relationship to salt tolerance is the regulation of ion selectivity, in particular the role of Ca/Na and K/Na discrimination in salt tolerance[22,25]. He and Cramer[10] reported that Ca could play a regulatory role in the responses of *Brassica* species to saline environments. Thakral et al.[23] reported positive non-significant correlation between seed yield and K/Na in stress environment in *B. juncea*. These researchers also pointed out that in response to increasing salt stress K/Na decreased while chlorophyll, proline and protein contents increased. Das et al.[6] claimed that increase in NaCl concentration was associated with increased Na and

* Corresponding author:
valvandi225@yahoo.com (Valiollah Rameeh)
Published online at http://journal.sapub.org/plant

Cl influx and K efflux in *B. campestris*.

The objective of the present study was to investigate the effect of salinity on the yield and shoots ions at vegetative and reproductive stages and their relation to seed yield in order to obtain suitable criteria for salinity tolerance.

2. Materials and Methods

Seven diverse rapeseed genotypes including three breeding lines (L_{14}, L_{18} and L_{111}) and four cultivars (RGS003, Zarfam, Hyola401 and PF7045/91) were evaluated in four salinity levels of irrigation water including 0, 4, 8 and 12 dsm^{-1} at Agriculture and Natural Resources Research Centre of Mazandran, Sari, Iran, during 2010-11. A factorial experiment based on completely randomized design (CRD) with 3 replications were considered for evaluation of 28 treatments in pot condition. The salt solution was prepared by taking NaCl:$CaCl_2$ in the ratio of 1:1 and the electrical conductivity of different salinity levels was adjusted by a direct reading conductivity meter. Soli analysis results are shown in Table 1. The soil belongs to the non-saline soil with a natural 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 grown in separate 8-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 condition and also they were isolated from raining. The studied traits were seed yield and ion concentrations in shoot including Ca, Na, K and Cl in vegetative stage(V-Ca, V-Na, V-K and V-Cl, respectively) and these ions in reproductive stage (after 50 percentage of flowering in each genotype) including R-Ca, R-Na, R-K and R-Cl. For ions extractions, plant samples were ground by mill and then dried in a furnace at 500ºC 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 K and Na of each final sample was measured by flame photometer and Ca was measured by atomic absorption[11]. For chloride determination, Cl was determined by the silver ion-titration method with an automatic chloridometer (Buckhler-Cotlove chloridometer) according to Bozcuk[4]. Pearson correlation was detected for all the traits. All studied traits were analysis based on factorial experiments based on completely randomized[9].

3. Results and Discussion

3.1. Analysis of variance

Significant mean square of genotype were observed for seed yield and shoot ions in vegetative stage including V-Ca, V-Na and V-Cl and also shoot ions in reproductive stage including R-Ca, R-Na, R-K and R-Cl (Table 2). Significant mean square of salinity levels were observed seed yield and all shoot ions at two growth stages except R-Ca which indicating Ca at reproductive stage is not good indicator for recognizing the tolerant rapeseed genotypes. Significant mean square of interaction effect of genotypes x salinity levels were detected for seed yield and V-Cl, R-Ca, R-Na and R-K.

3.2. Mean performances of the traits

The interaction effect of genotypes × salinity levels means for studied traits is presented in Table 3. Due to increasing salinity levels V-Ca was increased in L14 and Zarfam but in other genotypes it was not significant affected by salinity levels increasing. Amount of Ca at reproductive stage (R-Ca) was significant increased in L18 by increasing of salinity levels. V-K and R-K were decreased due to increasing salinity levels. Earlier researchers[1,17,25] were reported Ca and K ameliorate the adverse effects of salinity on plants. Salinity impairs the uptake up Ca by plants, possibly by displacing it from the cell membrane or in some way affecting membrane function[14,20].

Table 1. Some of physicochemical properties of soil sample

Class	(%)			(mg Kg^{-1})						TNV (%)	OC(%)	PH	Ec (dsm^{-1})
	Clay	Silt	Sand	Cu	Zn	Mn	Fe	K	P				
Si-C-L	28	56	16	3	0.64	3.1	9	352	9.2	15	1.41	7.3	0.68

Table 2. Analysis of variance for seed yield and shoot ions compositions in rapeseed genotypes at different salinity levels

S.O.V	Df	M.S								
		V-Ca	V-Na	V-K	V-Cl	R-Ca	R-Na	R-K	R-Cl	Seed yield
Genotypes(G)	6	4932**	3.33**	18.41	105.14**	3080.52**	15.35**	286.67**	712**	8.29**
Salinity levels(S)	3	196**	11.01**	92.68**	984.72**	195.51	365.01**	385.56**	6494**	2.99**
G x S	18	535	1.39	7.59	107.88**	384.25**	5.95**	31.16**	225	0.57**
Error	56	102	0.90	8.77	32.98	121.27	2.73	14.34	176	0.05

*, ** Significant at p=5% and 1%, respectively.
V: vegetative stage and R: reproductive stage.

V-Na was not significant varied among the genotypes at vegetative stage and also it was not affected by increasing of salinity levels. Due to increasing of salinity levels R-Na was significant increased and in RGS003 its ranged was less than the other genotypes. Amount of V-Cl and R-Cl were increased in all of the genotypes in high amount of salinity levels. Seed yield of the genotypes were decreased followed by increasing of salinity levels but in 4 dsm^{-1} it was yielded more seed yield than 0 dsm^{-1} salinity level and it may be related to providing some of nutrient compositions at the second salinity level. Similarly, in previous studies[12,15] were reported that due to increasing of salinity levels, yield and yield associated traits were reduced.

3.3. Correlation analysis

Significant positive correlation of Na and Cl at vegetative stage with their respective amounts at reproductive stage indicating selection of the rapeseed genotypes for low amount of these ions at vegetative stage will resulted the genotypes with low amounts of Na and Cl at reproductive stage (Table 4). Significant negative correlation of K with Na and Cl indicating the ameliorating effect of K on toxic effects of Na and Cl. Due to adverse effect of Cl on seed yield, the correlation of this ion with seed yield was significant and negative at vegetative and reproductive stages. Significant positive correlation of V-K with seed yield implied that K at vegetative stage can be used as selection criterion for detecting high seed yield genotypes in saline environment. High levels of K in young expanding tissue is associated with salt tolerance in many plant species[2,3].

Table 3. Interaction effects of genotypes x salinity levels means for seed yield and Shoot ions at vegetative and reproductive stages

Treatments	V-Ca (mg/gr)	V-Na (mg/gr)	V-K (mg/gr)	V-Cl (mg/gr)	R-Ca (mg/gr)	R-Na (mg/gr)	R-K (mg/gr)	R-Cl (mg/gr)	Seed yield (gr/pot)
V1S1	68.94	5.27	27.12	31.01	72.31	3.45	15.73	47.14	0.89
V1S2	71.60	6.65	25.98	42.19	72.67	3.70	16.76	49.39	2.31
V1S3	65.02	6.93	25.02	43.49	62.19	6.46	14.94	67.19	0.69
V1S4	65.02	7.32	23.32	46.63	76.70	8.70	10.86	85.16	0.80
V2S1	76.13	5.23	28.19	26.92	73.79	0.94	28.39	30.17	1.16
V2S2	81.43	7.29	26.11	44.91	83.71	3.32	26.22	52.32	1.69
V2S3	134.23	7.89	26.51	47.16	62.03	8.32	21.63	89.85	0.67
V2S4	115.45	6.86	24.74	42.90	78.10	7.66	21.87	55.26	0.59
V3S1	91.78	5.30	28.93	27.93	38.26	0.76	33.20	47.00	0.30
V3S2	97.67	5.34	23.73	35.62	48.43	1.66	34.08	47.79	0.10
V3S3	89.71	4.98	21.93	31.06	37.25	5.60	21.81	71.06	0.03
V3S4	115.25	6.05	21.66	56.68	15.80	7.91	15.28	72.48	0.02
V4S1	90.77	4.59	29.01	28.99	17.77	0.63	24.86	23.83	2.52
V4S2	73.37	6.05	28.30	36.33	22.82	2.15	24.16	41.75	2.53
V4S3	62.46	5.76	22.96	33.85	43.48	8.17	20.00	58.79	2.03
V4S4	71.96	5.44	26.30	34.33	65.61	9.96	19.21	53.27	2.46
V5S1	63.58	4.27	26.16	23.90	42.80	1.02	22.12	22.70	3.08
V5S2	62.16	7.61	28.28	39.41	43.01	4.88	23.15	41.18	2.74
V5S3	55.77	6.29	26.15	33.61	43.42	8.51	19.35	57.64	2.44
V5S4	49.65	6.58	21.74	39.44	44.25	11.15	17.99	65.13	1.25
V6S1	51.72	5.76	27.94	33.02	37.07	1.19	33.39	23.07	2.30
V6S2	47.65	5.16	25.80	25.92	39.62	3.44	35.45	41.55	2.89
V6S3	57.98	5.94	23.52	38.46	47.55	9.23	20.83	63.49	1.80
V6S4	56.03	6.30	21.27	49.46	48.12	14.52	19.21	79.91	1.24
V7S1	54.07	4.17	26.31	23.43	39.94	1.21	32.14	23.77	1.60
V7S2	50.40	6.33	22.28	32.43	45.25	4.12	29.97	34.37	1.18
V7S3	60.82	7.08	24.11	43.31	49.10	9.91	26.88	52.51	0.92
V7S4	53.76	6.33	20.14	41.30	44.45	12.73	27.60	60.68	1.51
LSD(p=0.05)	16.49	1.55	4.84	9.38	17.98	2.70	6.18	21.66	0.37
LSD(p=0.01)	19.71	1.85	5.78	11.21	21.49	3.22	7.39	25.89	0.44

V1: RGS003, V2: L14,V3: Zarfam,V4: L18, V5: Hyola401,V6: L111 and V7: Sarigol.
S1: 0 ds m^{-1}, S2:4 ds m^{-1}, S3:8 ds m^{-1} and S4: 12 ds m^{-1}.

Table 4. Correlation among seed yield and shoot ions compositions in rapeseed genotypes at different salinity levels.

Traits	V-Ca	V-Na	V-K	V-Cl	R-Ca	R-Na	R-K	R-Cl	Seed yield
V-Ca	1								
V-Na	0.15	1							
V-K	0.13	-0.19	1						
V-Cl	0.33	0.77**	-0.47*	1					
R-Ca	0.07	0.41*	0.04	0.19	1				
R-Na	-0.11	0.50**	-0.71**	0.64**	0.13	1			
R-K	-0.10	-0.37	0.26	-0.54**	-0.28	-0.51**	1		
R-Cl	0.31	0.59**	-0.58**	0.74**	0.24	0.76**	-0.61**	1	
Seed yield	-0.51**	-0.17	0.41*	-0.39*	-0.16	-0.18	0.11	-0.52**	1

*, ** Significant at p=5% and 1%, respectively.
V: vegetative stage and R: reproductive stage.

In general due to increasing of salinity levels, V-Ca was increased in the genotypes which had not high seed yield in saline environment. Significant negative correlation of K with Na and Cl indicating the ameliorating effect of K on toxic effects of Na and Cl. Significant positive correlation of V-K with seed yield indicating that K at vegetative stage can be used as selection criterion for detecting high seed yield genotypes in saline environment. Due to adverse effect of Cl on seed yield, the correlation of this ion with seed yield was significant and negative at vegetative and reproductive stages.

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