

EVALUATING THE RESPONSE OF SOME CANOLA (*Brassica napus* L.) CULTIVARS TO SALINITY STRESS AT SEEDLING STAGE

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The current study reports salt tolerance of eleven cultivars of canola from diverse backgrounds. Ten days old seedlings were transplanted in an aerated hydroponic system containing Hoagland's solution. Salinity levels (100, 140 and 180 mM NaCl) were developed by dissolving NaCl in nutrient solution. Nutrient solution without salt was used as control. The blade of 3rd fully expanded leaf was sampled to determine Na⁺, K⁺ and K⁺/Na⁺ ratio on day 28 of salt stress. Shoot fresh and dry biomass, root fresh and dry weight and leaf area were recorded on day 42 of salt stress. The KS-75, Rainbow, DGL and Shiralee were found most efficient among cultivars in maintaining low Na⁺, while high K⁺ and K⁺/Na⁺ ratio in leaves under salt stress. Based on plant growth and ionic regulation, cultivars KS-75 and Rainbow were placed in salt tolerant group, whereas Shiralee, DGL, Westar, KH-65 and Legend in moderately tolerant group. The Con-II, Con-III, Dunkeld and Oscar were categorized as fairly salt tolerant cultivars. Results express useful variation for salt tolerance among canola cultivars which may be exploited through selection and breeding for further improvement of salt tolerance in canola.

Keywords: Salinity stress, canola, seedling growth, leaf area, ions accumulation

INTRODUCTION

Salinity results from excessive accumulation of soluble salts in soils. More than 800 Mha land area in the world is impaired by soil salinity and sodicity (Munns, 2005). In Pakistan 6.67 Mha of the irrigated area (~42%) is salt-affected (Khan, 1998) and affected area is increasing with unprecedented rate of 40,000 acres year⁻¹ (Ashraf *et al.*, 2008). Shortage of good quality water also forces farmers to use brackish ground water for crop production which further aggravated this issue.

Soil salinity affects plant growth through low osmotic potential of soil solution, specific ion toxicity and nutritional imbalances or influence of all these factors (Gorham and Wyn Jones, 1993; Saqib *et al.*, 2013; Abbas *et al.*, 2013a, b). Generally, the salt tolerance mechanisms include; osmotic adjustment (Gorham, 1995), synthesis of organic solutes (Greenway and Munns, 1980) and scavenging of free radicals and toxic compounds (Gueta-Dahan *et al.*, 1997). Salt tolerance also involves Na⁺ exclusion and compartmentation, high K⁺/Na⁺ ratio and K⁺:Na⁺ selectivity of leaves under salt stress (Tester and Davenport, 2003; Ahmad *et al.*, 2012; Arshad *et al.*, 2012; Haq *et al.*, 2013). World food security demands utilization of salt-affected lands for agricultural productions. Breeding and selection of crop genotypes for increased salt tolerance has wide scope (Ashraf and McNeilly, 2004) and is a key current research issue in the world. The success of any breeding program

depends on the presence of sufficient variability in gene pool of a crop species (Purty *et al.*, 2008).

Pakistan is deficient in the availability of edible oil and production was only 0.636 million tons against total demand of 2.045 million tons (Anonymous, 2011-12). There are variable reports of genetic variation for salt tolerance in Brassica (Akhtar *et al.*, 2002; Maggio *et al.*, 2005), which may be exploited through selection and breeding for enhanced tolerance to salinity stress (Purty *et al.*, 2008). It is also vital to include important salt tolerant crops such as Brassica and barley in traditional crop rotations to get potential benefits from salt-affected lands.

In current study a hydroponics culture experiment was carried out to investigate salinity tolerance of eleven canola cultivars at seedling growth stage, because salt tolerance observed at early growth stages is of enormous value in determining the ultimate growth and yield of plant species (Shannon, 1985). The seedling stage of plant growth is most salt sensitive in crop plants (Lauchli and Grattan, 2007). Therefore main objective of current study was to explore genetic variation for salt tolerance at seedling stage among canola cultivars.

MATERIALS AND METHODS

The study was comprised of four treatments (Control, 100, 140 and 180 mM NaCl) with three replications in Completely Randomized Design (CRD) with factorial

arrangement. Seed of 11 different canola cultivars (Table 1) was obtained from Ayub Agricultural Research Institute (AARI), Faisalabad–Pakistan. The seeds were germinated in small trays filled with thoroughly washed fine river sand.

Setup for hydroponic system: Ten daysold seedlings were transplanted into 100 L capacity iron tubs (1 × 1 × 0.3 m) lined with polythene sheet having ½ strength Hoagland's nutrient solution (Hoagland and Arnon, 1950). Tap water was used to prepare nutrient solutions. The seedlings were transplanted after wrapping in foam, in holes of thermopore sheet floating on nutrient solution in the tubs. The nutrient solution was continuously aerated with aeration pump and was replaced with afresh solution fortnightly. Three seedlings of each cultivar were randomized in holes of polystyrene thermopore sheet within each of four tubs. The pH of the nutrient solution was maintained at 6.5±0.5. The temperature of the greenhouse was between 20–25°C.

Table 1. Names and origin of eleven Canola (*Brassica napus*) cultivars used in current study

Cultivars	Origin
Con-II	NARC, Islamabad –Pakistan
Con-III	NARC, Islamabad –Pakistan
DGL	Oil Seed Research Institute, AARI, Faisalabad - Pakistan
Dunkeld	Australian Origin
KH-65	Oil Seed Research Institute, AARI, Faisalabad - Pakistan
KS-75	Oil Seed Research Institute, AARI, Faisalabad - Pakistan
Legend	Swedish Origin
Oscar	Australian Origin
Rainbow	Australian Origin
Shiralee	Australian Origin
Westar	Canadian Origin

AARI; Ayub Agricultural Research Institute
NARC; National Agricultural Research Centre

Development of salt stress: After establishment of Brassica seedlings in nutrient solution for one week, salt stress was developed by dissolving NaCl in nutrients solution @ 50 mM NaCl per day until reached to desired levels by using following formula (USDA Salinity Lab. Staff, 1954).

$$\text{Weight of salt (gram)} = \left(\frac{\text{TSS (me L}^{-1}) \times \text{Eq. Wt of salt}}{1000} \right) \times \text{litres of water}$$

The total soluble salt (TSS in me L⁻¹) is obtained from a graph between EC and TSS, given on page 12 of the Hand Book-60 by USDA Salinity Lab. Staff (1954). After development of desired salinity, EC of solution was verified with EC meter (Model 315i, WTW instruments Wilhelm, Germany).

Experimental data collection: On day 28 of salt stress, 3rd fully expanded leaf (from top) was sampled for Na⁺ and K⁺ analysis from all treatments. The leaf samples were washed with distilled water, blotted dry and stored in labeled 1.5 cm³ microcentrifuge tubes at –20°C in the freezer. On day 42 of salt stress, the plants were harvested and biomass was immediately weighed to record fresh weight. For dry weight measurements shoot and roots were oven dried at 65°C for 72 hours and weight was recorded. Following the method of Munns and James (2003) tolerance to salinity was calculated as shoot dry weight (SDW) % of control using the formula; Salt Tolerance = (Treatment dry matter/Control dry matter) × 100

Total leaf area (LA) was measured at harvest by using Delta-T Area Meter (Delta-T Devices, Cambridge, UK). Similarly data about shoot height and root length were also recorded. For ionic analysis the leaf sap was extracted by centrifugation following the method of Gorham *et al.* (1984). The sap samples were diluted with distilled water and Na⁺ and K⁺ were analyzed on PFP-7 Flame Photometer (Jenway, UK).

Statistical analysis: The data were subjected to analysis of variance (ANOVA) using MSTAT-C statistical software package (Fischer, 1990). Standard error of means and Pearson correlations were calculated using SPSS for Windows release 11.5.1 (SPSS, 2002). For the classification of cultivars into salt tolerance categories cluster analysis was performed using the Wards Linkage Method in SPSS.

RESULTS

Effects of salt stress on shoot and root growth: Analysis of variance revealed significant variation for plant height (PH), shoot fresh weight (SFW), shoot dry weight (SDW), root length (RL), root fresh weight (RFW) and root dry weight

Table 2. Mean squares of different traits studied in Canola under control and NaCl salt stress (n = 3)

SOV	DF	P. height	SFW	SDW	RL	RFW	RDW	LA	Leaf Na ⁺	Leaf K ⁺	K ⁺ /Na ⁺
Salinity	3	835.2**	549.8**	2.07**	158.6 ^{NS}	5.78**	0.038**	104710**	22132**	58837**	906**
Cultivar	10	41.8**	159.7**	0.59**	28.9 ^{NS}	2.80*	0.012*	19865**	325**	1734**	9.7**
Sal×Culiv	30	5.5 ^{NS}	30.2 ^{NS}	0.17 ^{NS}	53.9 ^{NS}	1.26 ^{NS}	0.005 ^{NS}	5413 ^{NS}	54**	38.8**	1.5**
LSD _{0.05}		-	-	-	-	-	-	-	2.698	6.140	1.212

** = Highly significant at p ≤ 0.01 level; * = Significant at p ≤ 0.05 level; NS = Non significant

SFW: Shoot fresh weight; SDW: Shoot dry weight; RL: Root length; RFW: Root fresh weight; RDW: Root dry weight;

LA: Leaf area

(RDW) among salinity levels and canola cultivars; however, Salinity×Cultivar interactions were non-significant for these traits (Table 2). Exposure of 100, 140 and 180 mM NaCl stress for 42 days caused variable reduction in the production of SFW in eleven canola cultivars (Fig 1a). The cultivars KS-75 and Rainbow consistently produced higher SFW at all salt levels. The Dunkeld, Oscar and Westar produced lowest SFW at low (100 mM), medium (140 mM) and high salinity (180 mM), respectively. The shoot fresh weight % of control (SFW% of C) ranged 60 – 110% at 140 and 180 mM salt level in KS-75, Rainbow, DGL, KH-65 and Shiralee, whereas, cultivars Con-II, Con-III, Dunkeld, Oscar and Westar were less than 60% relative to control at above mentioned salinity levels.

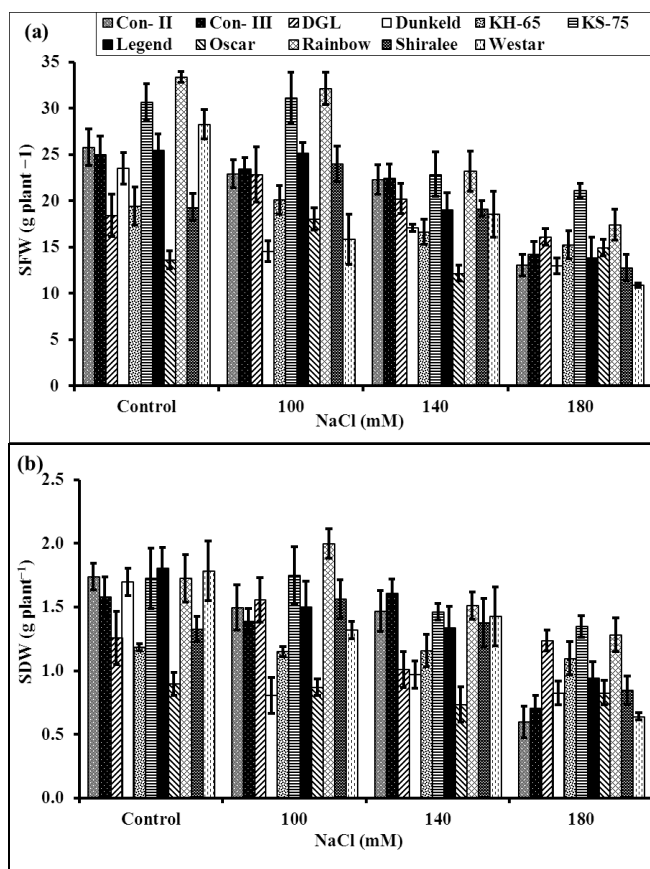


Figure 1. Effect of different levels of NaCl stress on (a) shoot fresh weight, (b) shoot dry weight of canola cultivars. Lines on bars represent \pm standard error of the mean.

Salinity also exerted profound effect on SDW and at salt level of 180 mM, the highest production of SDW was recorded in KS-75 and Rainbow followed by DGL and KH-65 (Fig 2 a), furthermore these cultivars showed only less than 30% reduction in SDW at three salinity levels compared with respective non-saline control (Fig2a). At low

and medium salinity level lowest SDW was produced in Dunkeld and Oscar, whereas at high salinity it is recorded in Con-II and Westar. Thereduction in SDW was more than 50% in cultivars Con-II, Con-III and Dunkeld at above mentioned salinity level (180 mM NaCl) compared with respective control. Shoot dry weight % of control can be a good indicator of plant salt tolerance. Under salinity the SDW % of control was ranged between 64–124% in the different canola cultivars (Fig. 2a).

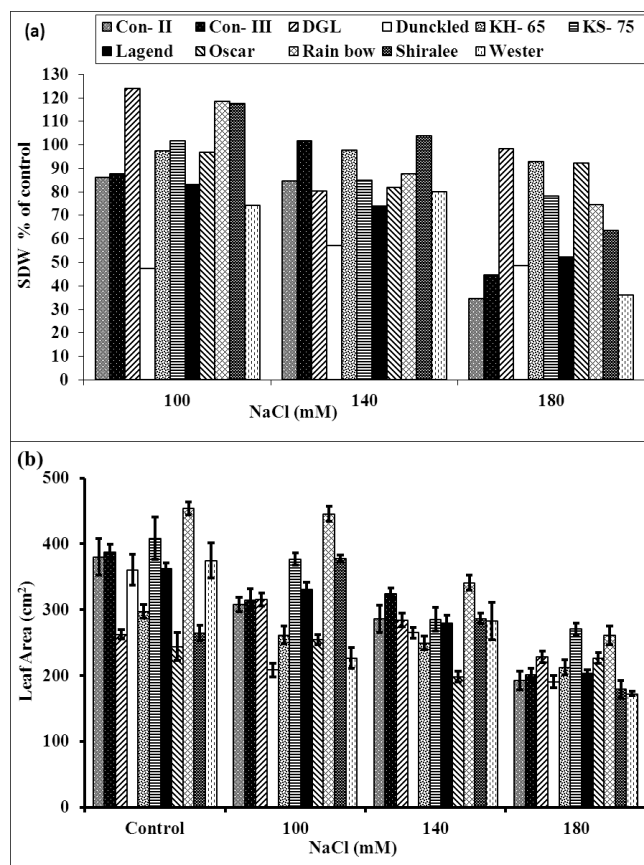


Figure 2. Effect of different levels of NaCl stress on (a) shoot dry weight as % of control, (b) leaf area of canola cultivars. Lines on bars represent \pm standard error of the mean.

Generally increased salinity reduced total leaf area plant⁻¹ of canola cultivars particularly at high salinity (Fig. 2b). There were significant differences among salinity levels, canola cultivars but interaction (Salinity×Cultivar) was non-significant for leaf area plant⁻¹ (Table 2). The highest leaf area plant⁻¹ was observed in Rainbow (445, 342 cm²) at low and medium salinity levels, respectively. At high salinity the maximum leaf area was recorded in KS-75 (271 cm²) followed by Rainbow (261 cm²) and lowest in Westar (173 cm²). The cultivars KS-75, Rainbow, Shiralee and DGL produced higher leaf area at moderate (140 mM) and high

(180 mM) salinity, whereas the rest of the cultivars (Con-II, Con-III, Dunkeld and Legend) experienced more than 50% reduction in leaf area at these levels of salinity. At salinity level of 100 mM the cultivars KS-75, Rainbow, DGL, KH-65, Shiralee, Con-II and Con-III attained more than 80% leaf area relative to control.

The salinity × cultivar interaction was also non-significant for RFW and RDW (Table 2). The RFW and RDW were the highest in KS-75, Rainbow and Shiralee at low, medium and high salinity, respectively (Fig. 3a,b). At high salinity level (180 mM) the cultivars KS-75, Rainbow, DGL, Shiralee, KH-65 produced more than 60% of their root fresh weight relative to control (Data not shown).

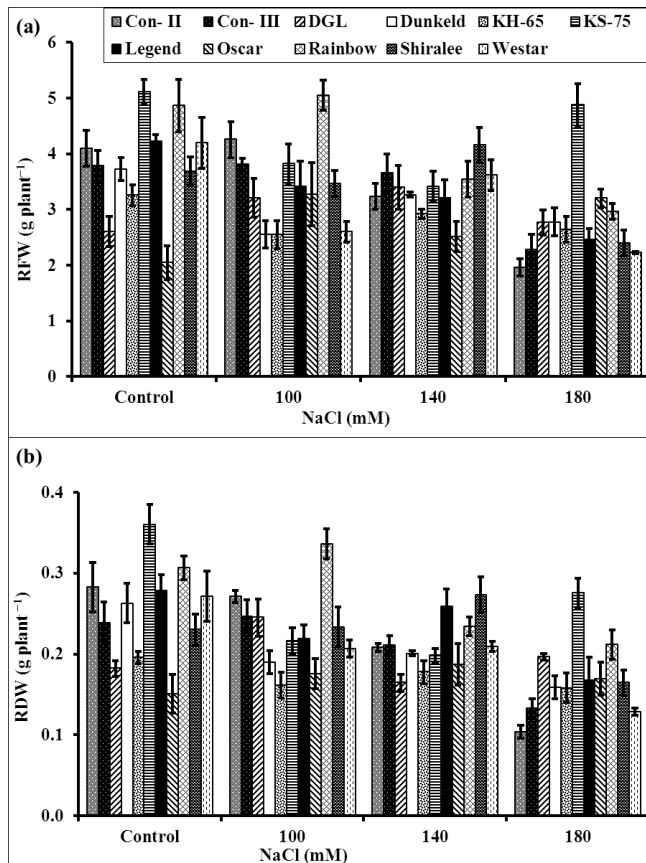


Figure 3. Effect of different levels of NaCl stress on (a) root fresh weight, (b) root dry weight of canola cultivars. Lines on bars represent \pm standard error of the mean.

Increasing salinity caused gradual reduction in plant height (Fig. 4a); however, the effect of salinity on plant height was non-significant. At high salinity (180 mM NaCl) reduction in height was less than 35% in KS-75, Rainbow, Shiralee, Con-II, DGL, Dunkeld, KH-65 and Oscar relative to control. The cultivars, Con-III, Legend and Westar experienced more than 35% reduction in plant height when compared with

control. Similarly, under salinity variation in length of root was recorded but the effect of salinity was non-significant (Table 2). At low salinity, out of eleven canola cultivars, six showed increase, whereas five showed decrease in root length over control (Fig. 4b). Root length was highest in Shiralee, Rainbow and Westar at medium but in Legend, Westar and Dunkeld at high salinity level.

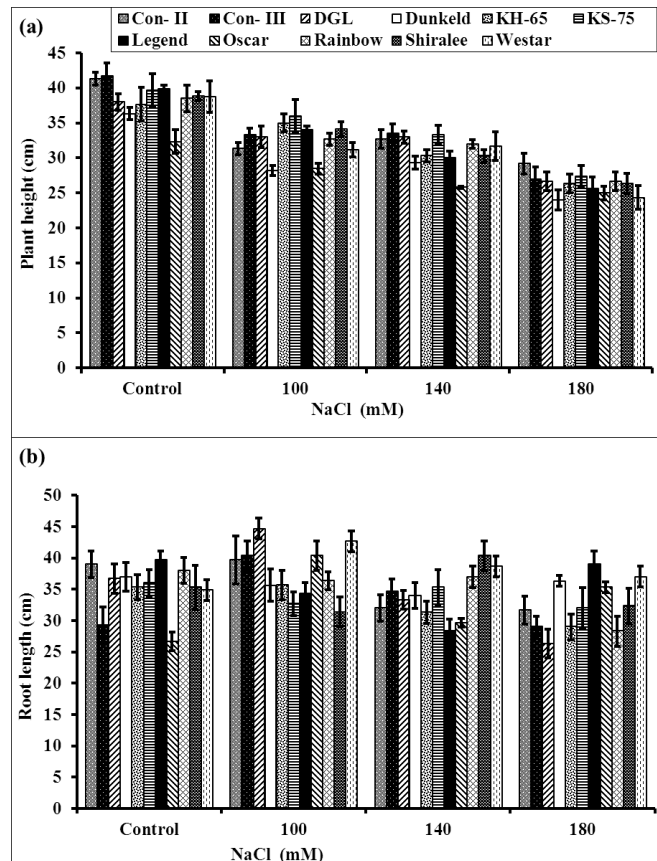


Figure 4. Effect of different levels of NaCl stress on (a) plant height, (b) root length of canola cultivars. Lines on bars represent \pm standard error of the mean.

Effects of salt stress on leaf ionic composition: Salinity significantly increased leaf Na⁺ in canola cultivars (Fig. 5a). At 100 mM NaCl the Na⁺ of expanded leaf was highest (34 mM) in Dunkeld and lowest in KS-75 and Rainbow (23 mM). The KS-75 and Rainbow were also among the highest SDW producers under salinity stress (Fig. 1b), showing that better Na⁺ exclusion may be one reason of higher SDW production. At 100mM salt the increase in Na⁺ in the leaf of KS-75, Rainbow, Shiralee, DGL and KH-65 was between 1.6 to 2.0 fold, whereas it was 2.4 fold in Dunkeld and Con-II compared with control. At 140 mM NaCl increase in leaf Na⁺ was 3.3–4.1 fold in Westar, Dunkeld, Con-II, Con-III and Oscar, whereas in KS-75, Rainbow, Shiralee, DGL and

KH-65 it was ranged 2.8–3.2 fold. The salinity of 180 mM NaCl caused further accumulation of Na^+ to 90 mM in leaves of Dunkeld, Oscar and Westar. The cultivars KS-75, Rainbow, DGL and Shiralee maintained less than 65 mM Na^+ at this salinity level (180 mM NaCl). The increase in leaf Na^+ was ranged between 4.1 to 4.5 fold in tolerant group (KS-75, Rainbow, DGL, Westar, Shiralee) over fairly tolerant group (Con-II, Con-III, Dunkeld, Legend) where the increase in leaf Na^+ was more than 5 fold.

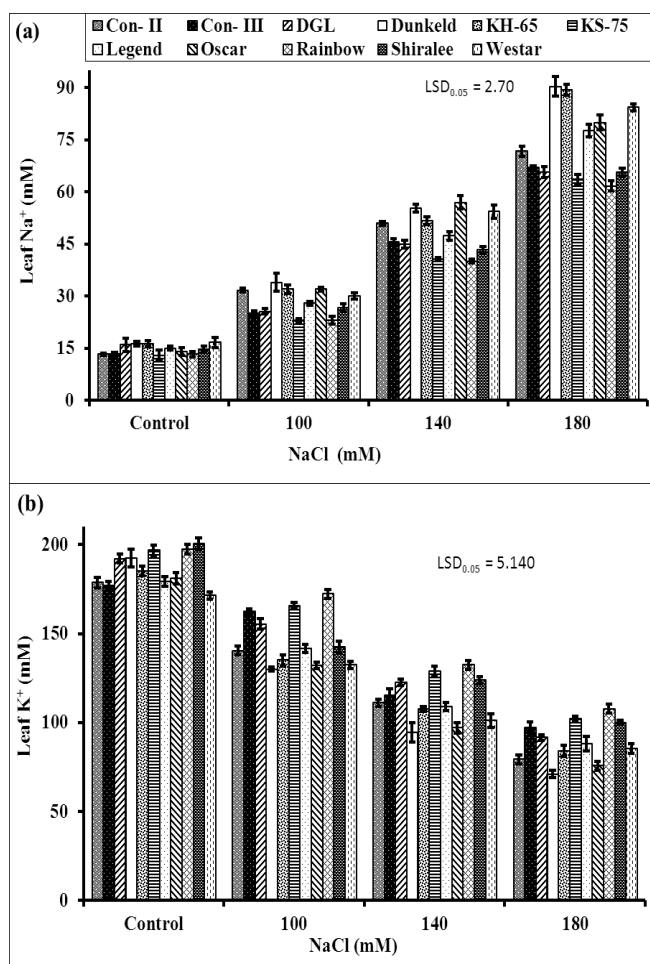


Figure 5. Effect of different levels of NaCl stress on (a) leaf Na^+ , (b) leaf K^+ of Canola cultivars. Lines on bars represent \pm standard error of the mean.

The K^+ concentration of leaf was reduced with increasing salinity in canola cultivars (Fig. 5b). The highest K^+ was recorded in the leaves of Rainbow under salinity levels of 100, 140 and 180 mM NaCl. At 100 mM NaCl, leaf K^+ was reduced to 8–21% in Rainbow, DGL and Legend compared with 27–32% in KS-75, KH-65 and Shiralee. As salinity increased to 140 mM, it caused further reduction in leaf K^+ ; however, cultivars KS-75, Rainbow, Shiralee and DGL maintained leaf K^+ above 60% relative to control. Similarly,

at high salinity (180 mM) the cultivars KS-75, Rainbow, Shiralee and DGL were also maintained more than 50% K^+ relative to control treatment (Data not shown).

The K^+/Na^+ ratio in the leaf of canola cultivars was ranged 10–15 in non-saline control, whereas it was ranged between 4–8, 2–3 and 1–2 at 100, 140 and 180 mM NaCl, respectively (Fig. 6). The cultivars KS-75, Rainbow, Shiralee, DGL and Con-III were consistently higher in leaf K^+/Na^+ ratio compared with other cultivars (Con-II, Dunkeld, Legend and Westar) under salinity. The reduction in K^+/Na^+ ratio was ranged between 50–70% in tolerant group and 70–90% in fairly tolerant group of cultivars as salinity increased from 100 to 180 mM NaCl.

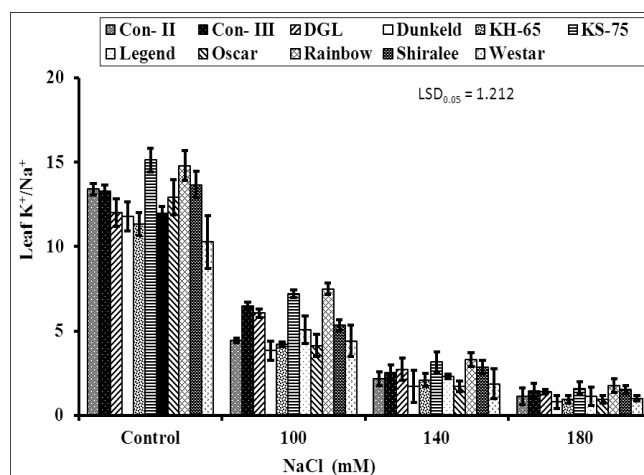


Figure 6. Effect of different levels of NaCl stress on leaf K^+/Na^+ ratio of canola cultivars. Lines on bars represent \pm standard error of the mean.

Correlations among various traits under salt stress: Leaf area plant⁻¹ displayed highly significant ($p < 0.01$) correlations with salt tolerance (SDW % of control), SFW and SDW (Table 3). Interestingly, the correlation of salt tolerance with RFW and RDW was also highly significant. The Na^+ of fully expanded leaf was negatively correlated with salt tolerance and other growth attributes (SFW, SDW, LA, PH, RFW, RDW and RL) and these correlations were highly significant ($p < 0.01$) except root length. Similarly, leaf K^+ also developed very strong correlation with salt tolerance and growth traits (Table 3). The correlation between leaf K^+ and Na^+ was negative and highly significant ($p < 0.01$). The relationship of leaf K^+ with K^+/Na^+ was highly significant; however, leaf Na^+ was negatively correlated with K^+/Na^+ and this correlation was also highly significant (Table 3).

Salt tolerance classification of canola cultivars: Cluster analysis, based on important phenotypic traits, classified canola cultivars into three major tolerance groups as shown in the Dendrogram (Fig. 7). The cultivars KS-75 and Rainbow were categorized as Salt Tolerant group, whereas, Shiralee Rainbow, DGL, Westar, KH-65 and Legend

Table 3. Correlation matrix (Pearson's two tailed) for various morpho-physiological traits under salinity

	SFW	SDW	SDW% C	L Area	RFW	RDW	P. height	R. length	Leaf Na ⁺	Leaf K ⁺
SDW	0.890**									
SDW% C	0.654**	0.722**								
L Area	0.962**	0.886**	0.689**							
RFW	0.779**	0.743**	0.556**	0.790**						
RDW	0.718**	0.799**	0.580**	0.755**	0.862**					
P. height	0.819**	0.746**	0.573**	0.789**	0.461**	0.425*				
R. length	0.173 ^{NS}	0.186 ^{NS}	0.147 ^{NS}	0.176 ^{NS}	0.237 ^{NS}	0.249 ^{NS}	0.248 ^{NS}			
Leaf Na ⁺	-0.748**	-0.659**	-0.568**	-0.742**	-0.492**	-0.592**	-0.839**	-0.387*		
Leaf K ⁺	0.830**	0.715**	0.590**	0.799**	0.557**	0.641**	0.800**	0.410*	-0.890**	
K ⁺ /Na ⁺	0.810**	0.668**	0.564**	0.781**	0.512**	0.598**	0.753**	0.427*	-0.875**	0.850**

** = Highly significant at $p \leq 0.01$ level; * = Significant at $p \leq 0.05$ level; NS = Non significant

were reclassified as Moderately Salt Tolerant group. Fairly Salt Tolerant group includes Con-II, Con-III, Dunkeld and Oscar.

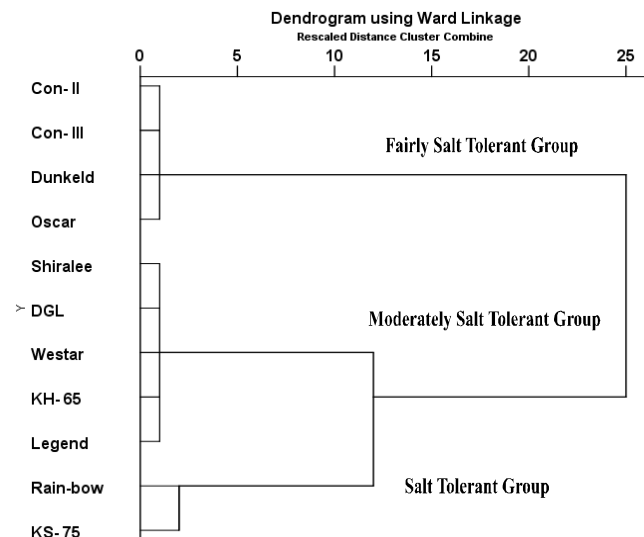


Figure 7. Dendrogram showing the classification of 11 canola cultivars into salt tolerance groups based on phenotypic traits by cluster analysis in SPSS using Ward Linkage Method.

DISCUSSION

Salt tolerance of canola: Excessive salinity reduces growth in glycophytic plants; however, there are variable reports in the degree of growth reduction (Ghuge *et al.* 2011). At high salinity (180 mM NaCl) seven out of eleven cultivars were higher than 50% of their SDW relative to control (Fig. 2a), showing high tolerance potential of canola cultivars. The measurement of biomass production may be a good indicator for selection against salinity in canola. Under natural salinity, *Brassica napus* was higher in seed yield than *B. juncea*, *B. carinata* and *B. campestris* (Akhtar *et al.*, 2002). Neumann (1995) documented that salinity dependent

reduction in root growth, limit water and nutrient uptake from soil. Salinity also inhibits plant growth due to high concentration of toxic ions such as Na⁺ and Cl⁻ (Munns *et al.*, 2006). Under salinity slow shoot and root growth rate is the response of limited cell elongation and cell division (Lauchli and Grattan, 2007). Under salinity accumulation of Na⁺ and Cl⁻ ions in cell wall lowers the cell wall elasticity. In addition cell wall become rigid and does not support rapid production of secondary cells, resulted in reduction of turgor pressure efficiency in cell enlargement (Kingsbury *et al.*, 1984). To minimize injurious effects of high salt, plants activate various defensive mechanisms. These defensive mechanisms also utilize energy, which otherwise could be available for the production of biomass under non stress conditions (Jamil *et al.*, 2005).

A reduction in biomass production is also related to reduction of active photosynthetic area of the plant under salinity stress. Significant reductions in shoot biomass and leaf area were observed in two canola cultivars under salinity (Redmann *et al.*, 1994). The reduction in leaf area under salt stress might be due to less cell activity of leaf elongating zone (Bernstein *et al.*, 1993). The salt toxicity reduces total photosynthetic leaf area, as a result production and supply of photosynthates to the plant is reduced, affecting overall carbon balance necessary to sustain growth (Munns, 2002a).

Plant height was also reduced in response to salinity stress in *Brassica* (Tantawy *et al.*, 2009; Ghuge *et al.*, 2011). Restricted uptake of water may be another cause of reduced shoot height under high salinity in plants (Werner and Finkelstein, 1995). Salinity also results reduction in root length of two *Brassica* cultivars (Ghuge *et al.*, 2011). Over time, reductions in cell division and elongation translated into slower appearance and small sized roots. There was reduction in growth in current study but reductions were small, even at high salinity. The most of canola cultivars showed relatively high tolerance (SDW % of control) to salinity stress.

The two canola cultivars included in current study were highly salt tolerant than rest of the cultivars. This genetic variation can be exploited to select promising canola varieties and also provide superior germplasm for breeders to improve salt tolerance through breeding (Purty *et al.* 2008).

Regulation of ion uptake: Ionic composition of plants is associated with salt tolerance under saline environments (Munns, 2002). Increased Na^+ uptake in *Brassica* under salt stress was also reported by Ashraf and McNeilly (1990). *Brassica juncea* showed higher Na^+ and lower K^+ in the leaf tissues than salt-sensitive lines (Ashraf, 1994). At high salinity, Na^+ may be entered in roots of wheat (Laurie *et al.*, 2002), rice (Garcia-deblas *et al.*, 2003) and barley (Haro *et al.*, 2005) by K^+ and other cation transporters such as HKT family transporters. Sodium may also enter plant cell through Non Selective Cation Channels (NSCC) (Tester and Davenport, 2003). Ul-Haq *et al.* (2002) also found that under salinity *B. napus* accumulated less Na^+ and maintained higher K^+ in its leaves compared with *B. juncea*, *B. carinata* and *B. campestris*. The higher Na^+ is injurious for plant cell metabolic functions. High Na^+ in the root medium may disturb intracellular ion homeostasis, loss of membrane selectivity and inhibition of metabolic activity (Hasegawa *et al.*, 2000), resulting in reduction of plant growth and yield. The K^+ ion is essential and most abundant monovalent cation in plant cells, and needs to be maintained within 100-200 mM in the cytosol for efficient metabolic functioning (Cuin *et al.*, 2003). Uptake of K^+ ion was adversely affected under salt stress in canola cultivars (Fig. 5b). Ashraf *et al.* (2001) also described that amphidiploid *Brassica* species including *B. napus* partially exclude Na^+ and maintained more K^+ in shoot results in higher K^+/Na^+ ratio under salt stress compared with their diploid parents. The K^+ has major role in enzyme activation, which are not only susceptible to high cytosolic Na^+ but also to low K^+/Na^+ ratios (Munns *et al.*, 2006). Therefore, low cytosolic Na^+ and high K^+/Na^+ are critical for the function of cells (Zhu *et al.*, 1998). Since Na^+ and K^+ are physico-chemically similar cations, there is competition between Na^+ and K^+ at uptake sites through common transport systems. The higher Na^+ and lower K^+/Na^+ exert metabolic toxicity by a competition between Na^+ and K^+ at the binding sites of many enzymes (Tester and Davenport, 2003). At high salinity, Na^+ can displace Ca^{2+} from the plasma-membrane, affecting its permeability and integrity. This can be revealed by leakage of K^+ from the plant cells (Cramer *et al.*, 1989). This high uptake of Na^+ and leakage of K^+ results in an imbalance in the K^+/Na^+ in the cytosol, which, in turn, leads to many imbalances in enzymatic reactions of the plant cell. As a consequence of these primary effects, secondary stresses, such as oxidative damage often occur under salt stress. In extreme cases these adverse effects may contribute to large growth reduction and even plant death.

Conclusion: This study concludes that considerable genetic variation existed among canola cultivars which can be utilized for further improvement of salt tolerance in canola. Furthermore, it is inferred that screening in hydroponics at early growth stage is a reliable and cost effective techniques for selecting against salinity. The traits of shoot dry weight % of control and leaf area along with low leaf Na^+ and high K^+ are very useful for screening germplasm against salinity.

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