

Growth response and ion distribution of two canola varieties to different potassium to sodium ratios

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Abstract

Rapeseed (*Brassica napus* L.) is a crop relatively tolerant to salt. The effect of different ratios of NaCl/KCl was studied in two cultivars (Hyola308 and Kristina) of Rapeseed in 2002. Canola seedlings were grown in Hoagland's solutions, which were salinized by different ratios of NaCl/KCl. The treatments or KCl:NaCl ratios were 0:0 (control); 10:10; 20:0 (Total Added Salt or TAS=20 mol.m⁻³), 0:75; 10:65; 20:55 (TAS=75 mol.m⁻³); 0:150; 10:140; 20:130; (TAS=150 mol.m⁻³) in a randomized complete block design with three replications. Plants were harvested before flowering stage and data were collected for root and shoot characteristics. The results indicated that in both cultivars, the shoot dry weight was decreased with increasing NaCl concentration in nutrient solutions. Increasing the KCl concentration in the nutrient medium significantly (P<0.05) reduced the toxic effects of high concentration of NaCl in K₂₀NaCl₁₃₀ relative to KCl₁₀NaCl₁₄₀; KCl₀, NaCl₁₅₀ in Hyola308. Salinity increased Na and Cl and decreased K, Ca and Mg contents of roots. Maximum Na accumulation in root was in Kristina and the minimum K content was observed in Hyola308. These observations showed salinity tolerance in Kristina is associated to a restriction of Na absorption at the root level. Salinity decreased the partitioning coefficients of Na and K. Partitioning coefficient of Cl decreased up to TAS=75 mol.m⁻³ and then increased. Kristina accumulated more Cl in the oldest leaves and K content in youngest leaves than Hyola308 cultivars.

Keywords: Canola; Partitioning coefficients, Salt stress

1. Introduction

Salinity is one of the most important limiting factors in crop production and consequently, the responses of plants to it have been widely studied (Flowers and Yeo, 1995; Richards, 1995; Carvajal et al, 1999). Salt stress may reduce plant growth by water deficit, ion toxicity (Allakhaverdiev et al., 2000), ion imbalance, or combination of these factors (Cramer et al., 1986; Cheeseman 1988).

In the saline soils where plants are rooted, K and Na ions might compete for entry into plant root cells. This competition can have significant negative effects on plant growth, and concentration of sodium often exceed those of K (Rains and Epstein, 1967; Maathuis et al., 1996; Schachtman and Liu, 1999).

It is widely recognized that a high concentration of NaCl inhibits K uptake by plants (Jeschke 1984; Bar-Tal, et al., 1991; Qing-Song and Fujyama, 1996) because high levels of Na⁺ can displace Ca²⁺ from root membranes, changing their integrity and thus affecting the selectivity for K uptake (Yahya 1998). In addition, high

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concentrations of Na can interfere with K^+ uptake (Zhu, 2003). Also, excess of Na in the root media may result in a passive accumulation of this ion in root and shoot, and a low Na/K ratio will lead to metabolic disorders such as reduction in protein synthesis and enzymatic activities (Botella et al, 1997; Zhu, 2003). Beneficial effects of K addition to a saline culture solution has been found to increase the dry weight and K content of the shoot with a corresponding decrease of Na^+ content (Bohra and Doerffling, 1993).

On the other hand, K/Na ratio decreases in majority of non-halophytic species under saline conditions. K to Na ratio is often found to be important for salt tolerance in non-halophytes (Benloch et al. 1994; Schachman et al, 1989; Greenway and Pitman, 1965) because maintenance of high cytoplasmic levels of K is essential for survival in saline habitats (Chow et al, 1990).

A high K/Na ratio in rapeseed tissue could be a contributing factor to its salt tolerance (Ashraf and McNeilly, 1990). However, He and Cramer (1993) stated that the K/Na ratio does not correlate with the salt tolerance and a high K/Na ratio is not a good criterion for selection to saline resistance.

Genotypes also differ in the pattern of ion distribution since salt-resistance cultivars frequently accumulate Na in the oldest leaves, thus preserving young photosynthetically active tissues (Lutts et al; 1996).

In earlier work, the responses of 8 varieties of canola to different levels of salinity were examined. Among the 8 varieties, Kristina and Hyola308 were the most salt-tolerant and the most sensitive variety, respectively (Rezaei et al., 2006; Rezaei, 2002). Also it was observed that most sensitive variety (Hyola308) had higher Na concentration in shoot than the most tolerant variety (Kristina). This was inversely for K. Therefore, in the present study, it was provided a more detailed analysis of the interaction of K and Na in solution culture condition on growth and ion distribution of two canola varieties differing in salt tolerance. It was tested the hypothesis that the differences in salt tolerance between these two varieties were related to differences of toxic accumulation and distribution of Na, Ca, and about ameliorative role of K and its distribution in plant tissues. The results were evaluated in terms of the dry matter production and cation absorption and distributions subjected to salinity.

2 Materials and methods

Seeds of canola (*Brassica napus*), cvs. Hyola 308 and Kristina were surface-sterilized in 5% sodium hypo-chlorite solution for 5 min, washed with deionized water and germinated in Petri dishes at 25°C in an incubator, then irrigated with 0.25 strength Hoagland's solutions every day in 2002. After 7 days, the seedlings were transplanted to plugged holes in polystyrene plates floated over with 33 liters of Hoagland nutrient solution in controlled environment greenhouse with a 16-h photoperiod, at an air temperature of 25 and 20° C day and night, respectively. Aeration was maintained through an aquarium air stone by an oil-less diaphragm pump. The treatments or different concentrations of KCl, NaCl were 0:0 (control); 10:10; 20:0 (TAS=20), 0:75; 10:65; 20:55 (TAS=75) 0:150; 10:140; 20:130; (TAS=150) in a randomized complete block design experiment with three replications.

Plants grown in full strength Hoagland solutions were adapted to this final concentration by raising the NaCl concentrations in two or three steps at 6-h intervals 25, 50 mol.m⁻³ steps. The pH of culture solutions was monitored every day and, if necessary, adjusted to 5.5-5.8. The culture solutions were continuously aerated.

Plants were removed from the nutrient medium, and the roots and shoot were separated and washed by double distilled water. Also oldest and youngest leaves of the plants were analyzed separately. Partitioning coefficient (Pc) was calculated for ions and defined as the ratio of the concentration in youngest leaves to the concentration in the oldest ones. Then, roots and shoots were oven dried and weighed. The plant material was wet combusted in a mixture of concentrated $H_2SO_4+H_4SiO_4+Se+H_2O_2$ and analyzed for K^+ , Na^+ , Ca^{2+} , Mg^{2+} content of shoots and roots. K^+ , Ca^{2+} and Mg^{2+} were determined with an atomic absorption spectrophotometer, Na^+ by flame emission.

The data were subjected to analysis of variance using the SAS statistical software package (SAS, 1989) and Duncan's multiple range tests was used for the means comparisons.

3. Results and discussion

The plant growth observation revealed that shoot dry weights were distinctly reduced under salinity conditions in both varieties. Although Hyola308 had higher absolute dry matter, Kristina

was more tolerant. These results are in agreement with previous finding that Kristina is more tolerant than Hyola308 variety.

Increasing level of potassium improved shoot dry weight, however significant differences were observed only in the sensitive plant (Hyola308), where $KCl_{20}NaCl_{130}$ produced significantly higher

shoot dry weight than KCl_0NaCl_{150} and $KCl_{10}NaCl_{140}$ (Fig. 1) ($P=0.05$). The improvement of K uptake was favorable for canola growth in high Na solution, which is in agreement with the results obtained by many scientists (Helal et al., 1975; Qing-Song and Fujiyama, 1996; Kabir et al., 2004; Akinci and Simsek; 2004).

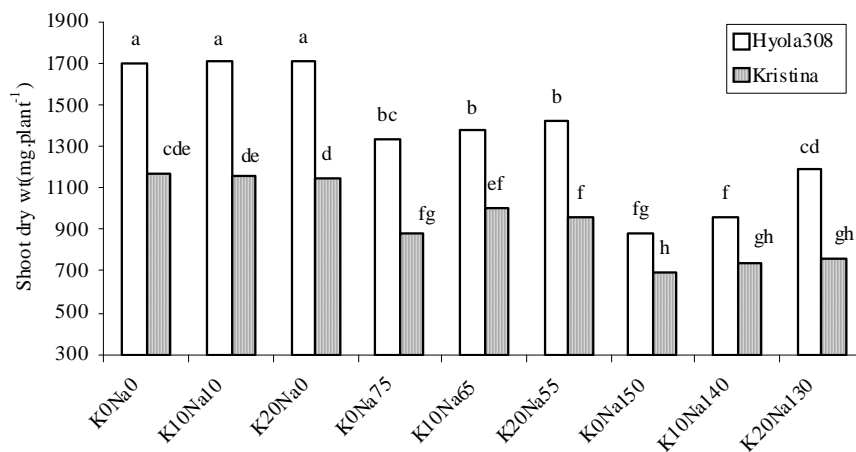


Fig. 1. Shoot Dry Weight in Different KCl/NaCl Ratios (means with the same letter are not significantly different in each column at 5 % level)

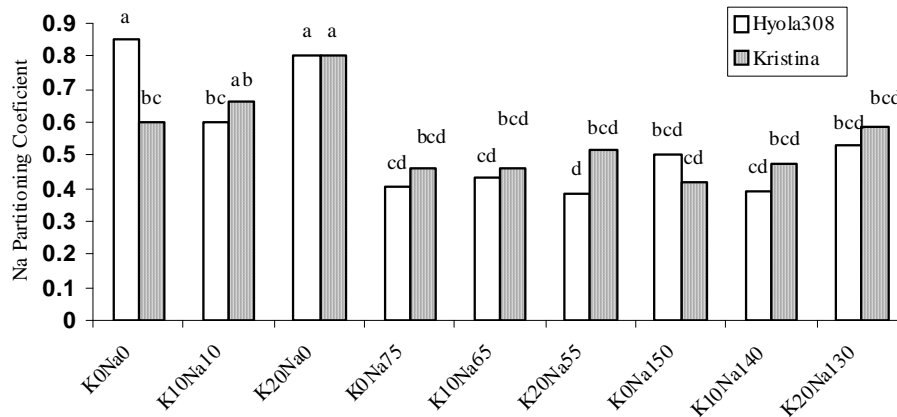


Fig. 2. Na Partitioning Coefficient of Two Canola Cultivars as Affected by Different Levels of KCl/NaCl (means with the same letter are not significantly different in each column at 5 % level)

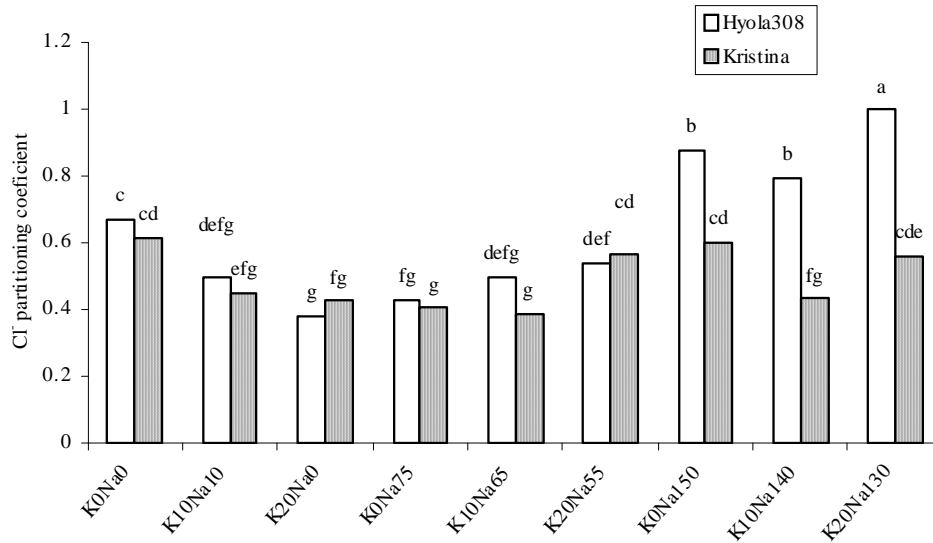


Fig. 3. Cl⁻ Partitioning Coefficient of Two Canola Cultivars as Affected by Different Levels of KCl/NaCl (means with the same letter are not significantly different in each column at 5 % level)

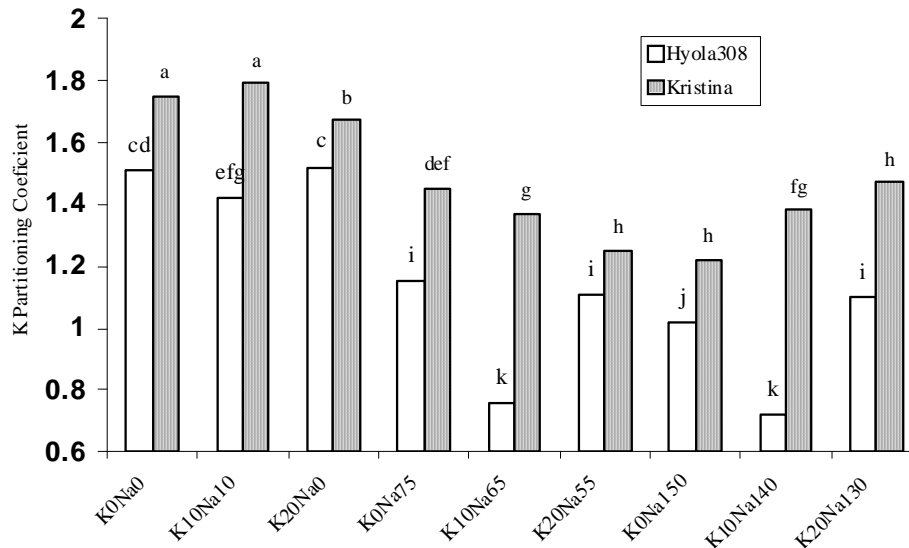


Fig. 4. K Partitioning Coefficient of Two Canola Cultivars as Affected by Different Levels of KCl/NaCl (means with the same letter are not significantly different in each column at 5 % level)

NaCl induced accumulation of Na and Cl and decrease in K content exposed to salt stress but its distribution was different in the two cultivars. In this experiment, Na⁺, Cl⁻ partitioning coefficients were about (0.4-0.8) and (0.4-1.0), respectively (Figs. 2 and 3). In other words, Na⁺ and Cl⁻ concentrations were higher in oldest leaves than

youngest ones. Cl partitioning coefficient in Hyola308 was more than Kristina, but this was not true for Na. Salinity decreased partitioning coefficient of Na and increased K partitioning coefficient. However, Cl partitioning coefficient decreased up to TAS=75 mol.m⁻³ and then increased in 150mol.m⁻³.

Table 1. Root Ion Content of Two Canola Cultivars as Affected by Different Level of KCl/NaCl.

Treatment	K	Na	Ca	Mg	Cl	K-Na selectivity	
							$\mu\text{mol.g}^{-1}$
Hyola308	K0Na0	941 ^{abcd}	43 ^f	152 ^{bcd}	103 ^a	130 ^f	3.7 ^{gh}
	K10Na10	1003 ^{ab}	119 ^f	145 ^{bcd}	100 ^a	198 ^f	5.4 ^{defg}
	K20Na0	1025 ^a	53 ^f	149 ^{bcd}	98 ^{ab}	207 ^f	0.78 ^{hi}
	K0Na75	840 ^{cd}	497 ^d	131 ^{efg}	97 ^{abc}	431 ^e	21.2 ^a
	K10Na65	713 ^{gh}	396 ^e	134 ^{defg}	83 ^{bcd}	606 ^{de}	7.3 ^{cde}
	K20Na55	744 ^{gh}	384 ^e	137 ^{defg}	95 ^{abc}	659 ^{cd}	4.5 ^{defg}
	K0Na150	670 ^h	994 ^{ab}	131 ^{efg}	78 ^{def}	1009 ^a	16.9 ^b
	K10Na140	679 ^h	930 ^{bc}	131 ^{efg}	83 ^{bcd}	633 ^{abc}	6.4 ^{def}
	K20Na130	693 ^{gh}	874 ^c	127 ^{fg}	83 ^{bcd}	1012 ^a	4.0 ^{efgh}
Kristina	K0Na0	872 ^{de}	62 ^f	162 ^{ab}	103 ^a	122 ^f	2.34 ^{ghi}
	K10Na10	879 ^{de}	107 ^f	157 ^{abc}	94 ^{abcd}	199 ^f	5.34 ^{defg}
	K20Na0	996 ^{abc}	112 ^f	172 ^a	98 ^{ab}	223 ^f	0.34 ⁱ
	K0Na75	761 ^{fgh}	512 ^d	142 ^{cdef}	91 ^{abcde}	415 ^e	18.8 ^{ab}
	K10Na65	779 ^{fg}	325 ^e	131 ^{efg}	81 ^{def}	516 ^{de}	9.8 ^c
	K20Na55	904 ^{cde}	354 ^e	137 ^{defg}	77 ^{ef}	486 ^{de}	5.4 ^{defg}
	K0Na150	701 ^{gh}	1068 ^a	120 ^g	72 ^f	877 ^{ab}	16.4 ^b
	K10Na140	846 ^{ef}	952 ^{bc}	127 ^{fg}	75 ^{ef}	800 ^{bc}	7.8 ^{cd}
	K20Na130	918 ^{bcd}	996 ^{abc}	127 ^{fg}	74 ^f	836 ^{abc}	4.6 ^{defg}

-Means with the same letter are not significantly different in each column at 5 % level.

Salinity caused remarkable changes in ion concentrations in the root of two canola cultivars. Na concentration in the root increased with increasing external concentration of salt and decreased with increasing K level (Table 1) ($P < 0.05$). This increase in Kristina was more than Hyola308 cultivar and accompanied with decline in K concentration, indicating an apparent antagonism between K and Na. These antagonistic relations could be due to competition in plasmalemma, K-efflux into growth medium, and membrane integrity as reported by He and Cramer, 1992. In many glycophytes, the selective exclusion of Na^+ from the shoot is an important mechanism which may confer tolerance to salinity as reported by Drew and Lauchli, 1985 and Cheesman, 1988. Increasing KCl level from 0 to 20 mol.m^{-3} increased K content of Kristina ($P < 0.05$). K-Na Selectivity increased with increasing TAS but increasing K in solutions decreased K-Na selectivity. Kristina had higher K-Na selectivity than Hyola308 cultivar. The concentration of Ca and Mg was decreased and Cl increased in root with increasing the salinity level.

4. Conclusion

Dry matter production in both canola varieties was decreased at higher concentrations of solution. In agreement with our previous findings, it was observed that Hyola308 is more sensitive to salinity than Kristina. Reduction in growth and

total dry matter production under saline condition was also reported earlier in rapeseed (He and Cramer, 1993; Francois, 1994; Haugh and Redmann, 1995). The suppression of plant growth under saline conditions may either be due to osmotic reduction in water availability, or to excessive ions, Na and Cl, accumulation in plant tissues (Gunes et al., 1996).

One of the salt tolerance mechanisms is preferentially accumulation of toxic ions (Na^+ and Cl^-) in oldest leaves. The partitioning of Na, K, and Cl among leaves of different ages appeared to be involved in salinity tolerance. Na, Cl and K distribution between old and young leaves had uniform patterns in both cultivars, but Cl and Na partitioning coefficients in Kristina were less than Hyola308. In contrast, partitioning coefficient of potassium clearly in Kristina was more than in Hyola308. These phenomena may be a tolerance mechanism in canola. Precise mechanisms involved in ion compartmentation are not well understood. Lutts et al. (1996) explained three hypotheses for ion compartmentation in whole plant. The first hypothesis is that higher ion accumulation in the oldest leaves is a consequence of higher transpiration rates. Nevertheless, this explanation remains unsatisfactory because it does not explain K accumulation in youngest leaves. Another explanation considers Na and Cl retranslocation by phloem sap. A third hypothesis is that roots of different ages are involved in nutrition of leaves of different ages and that root permeability increases with root age.

The high level of salinity tolerant variety (Kristina) had higher Na concentration in root than sensitive variety (Hyola308) although these changes were not significant. The Na accumulation in root can be a tolerance mechanism because plants can exclude Na ions from the shoot. Exclusion is achieved by using various mechanisms, for example, reduced influx at the plasmalemma of root cell, efflux from the roots, resorption in the xylem parenchyma, and retranslocation out of the leaves (He and Cramer, 1993). Therefore, further research is needed to investigate excluding of Na in root, and shoot parts in controlled conditions.

The results presented here highlight the importance of K nutrition of rapeseed under high saline conditions, especially for sensitive cultivars, and partitioning of Na, Cl, and K in different leaves.

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