INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2002/04–3–385–388
http://www.ijab.org

Effect of Soil Salinity on the Concentration of Na^+, K^+ and Cl^- in the Leaf Sap of the Four *Brassica* species

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ABSTRACT

To study the leaf ionic relations of *Brassica* species, an experiment was conducted under saline conditions at Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad during the year 2000-2001. Four *Brassica* species were replicated thrice at four levels of salinity (3.0, 4.75, 6.0 and 9.50 dS m^{-1}) in a Randomized Completely Block Design (RCBD). The concentrations of Na^+, K^+ and Cl^- in the leaf sap of *Brassica* species were assessed at the vegetative growth stage before flower initiation. The statistical analysis of the experimental data showed that significant increase in leaf Na^+ and Cl^- concentration was observed under salinity treatments, in *B. compestris* and *B. juncea* where as the increase was non significant in *B. napus* followed by *B. carinata*. The concentration of K^+ was high in salt tolerant (*B. napus*) and low in salt sensitive (*B. compestris*) *Brassica* species under salinity.

Key Words: *Brassica*; Na^+; K^+; Cl^-

INTRODUCTION

Pakistan is importing a large quantity of edible oil to meet 75% of its total requirements. The estimated annual cost on the import of edible oil is about US $ 653 million (Anonymous, 2000). On the other hand, this edible oil (palm oil) is of very low quality, which causes many harmful effects to the human health. After cotton seed, rape seed and mustard are the second most important sources of edible oil in Pakistan. Soil salinity is a world wide problem and it is particularly serious in arid and semi arid regions of the world including Pakistan. About 6.67 m hectares area of Pakistan is affected to various degrees of soil salinity (Khan, 1998). Salt tolerant plants display inherent features which are expressed under saline conditions and may not be apparent otherwise (Shabala *et al.*, 1998), this however depends upon the stage of growth and plant variety used. To meet the edible oil demands of the country, it is the need of the day to bring marginal lands under oil seed crops by screening and breeding the salt tolerant oil seed crops such as *Brassica*, which are better able to grow on salt-affected soils than currently available. According to Muhammad and Aslam (1998) higher K^+ and lower Na^+ in the leaf sap were the criteria for salt tolerance. The selective up take of K^+ over Na^+, active compartmentation of Na^+ and Na^+ exclusion (Sharma, 1986) are the major processes involved in salt tolerance. According to Ashraf and Leary (1995), salt tolerance is related to exclusion of Na^+ ion in leaves of all ages. The efflux of Na^+ at the plasma membrane of root epidermis and cortical cells, and resorption of Na^+ from xylem sap and its accumulation by xylem parenchyma cells are the processes involved in Na^+ exclusion (Gorham *et al.*, 1986). This exclusion mechanism of Na^+ seems to be effective only over a restricted range of external NaCl concentration. The work presented in this paper was conducted with the objective to study the leaf ionic relations of different *Brassica* species in a naturally salt-affected field because it is an important aspect for studding salt-tolerance. Thus, the proposed study would hopefully improve the understanding of the leaf ionic responses of *Brassica* species to salinity and contributes to the selection and development of different *Brassica* genotypes capable of growing in salt-affected fields with little yield reductions.

MATERIALS AND METHODS

A portion of salt-affected field was chosen in the research area of the Department of Soil Science at the Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad. Soil samples were taken from the entire experimental area on a 2.5 x 2.5 m grid pattern at two depths, 0-15 cm and 15-30 cm, before sowing the crop. The soil chemical analysis was done by standard methods (Richards, 1954). The ECe of the experimental area ranged from 3.0 to 13.0 dS m^{-1} and SAR from 3.5 - 4.0 (mmol $L^{-1})^{1/2}$. The soil was slightly alkaline with an average pH_s of 7.80 ± 0.5. By keeping in view the pre-soil analysis, the experimental field was carefully divided into four plots in such a way that the average ECe of the plots was very close to 3.0, 4.75, 6.0 and 9.50 dS m^{-1}. The four *Brassica* species were sown on these plots in Randomized Complete Block Design (RCBD). The youngest fully expanded leaves (third leaf from the top) at the vegetative growth stage before flower initiation were detached from three random plants in each repeat, quickly rinsed in distilled water, blotted and stored in eppendrof tubes at freezing temperature. Leaf sap was extracted from thawed and crushed samples by centrifugation (Gorham *et al*., 1984) for the determination of leaf Na^+, K^+ and Cl^- concentrations by Flame Photometer (Jenway FP-7), Ca+Mg by titration (Richards, 1954) and Cl^- by Chloride Analyzer 926 (Corning). The post harvesting soil samples were collected randomly from 12 points within each plot to average the salinity of plot and analyzed for ECe and SAR values. The data thus collected were subjected to statistical analysis following Steel and Torrie (1989) and means were compared by Duncan's Multiple Range (DMR) test.

RESULTS AND DISCUSSION

Generally, with an increase in the concentration of salts in the rooting medium, the concentration of soluble salts in the leaf sap also increased. Among the ions, Na^+ and Cl^- are the dominant in salt affected soils (Szabolcs, 1989) as well as in cell sap of the leaves of plants growing on these soils. The concentration of Na^+ in the leaf sap of the four *Brassica* species is shown in Fig. 1 (a). It is obvious that at low salinity level (4.75 dS m^{-1}), *B. compestris* attained the highest Na^+ concentration in their leaf sap followed by *B. carinata* and *B. juncea*. At moderate and high salinity, maximum Na^+ was determined in *B. compestris* and lowest in *B. napus*. At high salinity the increase in leaf Na^+ was 36.0, 33.0, 35.0 and 16.5% in *B. carinata*, *B. juncea*, *B. compestris* and *B. napus* respectively as compared to respective controls and at this salinity level *B. napus* had 23.0, 24.0 and 20.0% low Na^+ concentration than *B. carinata*, *B. juncea* and *B. compestris*, respectively. From the over all comparison of the species means (Table Ia) *B. napus* had significant low leaf Na^+ concentration but non significant difference was noted in *B. carinata* and *B. juncea* at this salinity level,

Table. I. (a) Over all comparison of individual species means for leaf sap Na^+, K^+ and Cl^- of the four *Brassica* species

Species	Na^+ m mol L^{-1}	K^+ m mol L^{-1}	Cl^- m mol L^{-1}
Brassica carinata	64.38 b	121.32 a	62.59
Brassica juncea	64.34 b	104.83 c	67.86
Brassica compestris	70.39 a	90.16 d	69.12
Brassica napus	57.13 c	129.22 a	64.34
DMR Value	0.0921	4.922	_

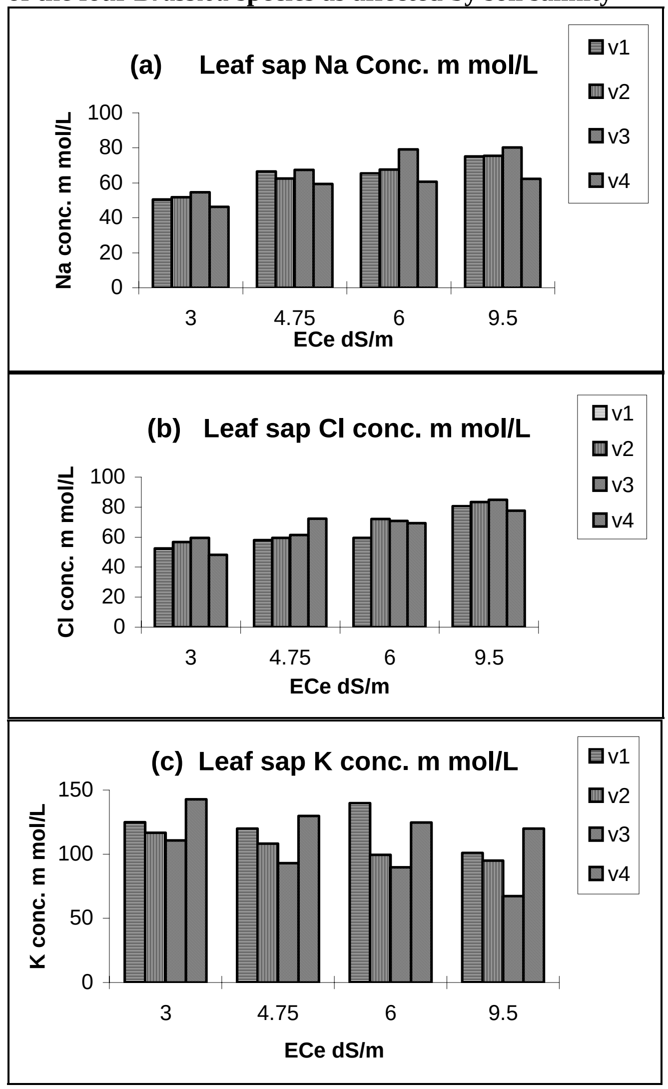
Means sharing the same letters in the columns are statically non significant according to Duncan's Multiple Range test (P = 0.05).

(b) Over all Comparison of individual salinity means for leaf sap Na^+, K^+ and Cl^- of the four *Brassica* species

	ECe dS m^{-1}				
Parameters	3.0	4.75	6.0	9.50	DMR Value
Na^+ m mol L^{-1}	50.75 g	63.96 e	68.27 c	73.27 a	0.1218
K^+ m mol L^{-1}	123.76 a	112.65 b	113.36 b	95.76 c	6.512
Cl^- m mol L^{-1}	54.14 c	60.29 bc	67.87 ac	81.6 a	566.5

Means sharing the same letters in the rows are statically non significant according to Duncan's Multiple Range test (P = 0.05)

Fig. 1. The concentration of Na^+, K^+ and Cl^- in the leaf sap of the four *Brassica* species as affected by soil salinity



V1 : *Brassica carinata;* V2 *Brassica juncea;* V3 : *Brassica compestris;* V4 *Brassica napus*

while the comparison of salinity means (Table Ib) indicated that there is significant difference in the leaf Na^+ cncentration at different salinity levels and over all increase as 26.0, 34.5, 44.4% at low (4.75 dS m^{-1}), moderate (6.0 dS m^{-1}) and high salinity (9.50 dS m^{-1}) as compared to control. The increase in leaf Na^+ might be due to the increasing concentration of Na^+ in the rooting medium which ultimately resulted its excessive up take by plants (Muhammad, 1986) or it might be due to decrease in relative rate of growth of species when subjected to saline environment (Aslam *et al*., 1991) as well as decrease in efficiency of Na^+ exclusion mechanisms (Yeo *et al*., 1990). According to Ashraf and Leary (1995) salt tolerance is related to exclusion of Na^+ ion and maintenance of almost uniform concentration of this ion in the leaves of all ages. The low Na^+ in the leaves of high yielding *Brassica* species

B. napus confirms the expected response of mesophytes to saline environments by ion exclusion. In contrast the low yielding species *B. compestris* and *B. juncea* contained significant high Na^+ concentration in their leaves reflecting their sensitivity to NaCl. The findings of Epstein (1980), Joshi *et al*. (1985) and Ashraf and McNeilly (1990) also support our results.

Another dominant ion which hamper plant growth and yield under saline conditions is Cl^-. The Cl^- concentration increased with increase in salinity (Fig. 1b), however the effect was more pronounced at high salinity as compared to low and moderate salinity. The concentration of Cl^- was maximum in *B. napus* while minimum in *B. carinata* at low salinity level (4.75 dS m^{-1}) but at moderate salinity level (6.0 dS m^{-1}) *B. juncea* followed by *B. compestris* accumulated maximum Cl^- and at high salinity (9.50 dS m^{-1}) the minimum Cl^- concentration was observed in *B. napus* and maximum in *B. compestris*. As for as species comparison for Cl^- concentration, there is non significant difference among the species. Comparison of the salinity means indicated that the non significant difference was noted at different salinity levels and over all increase was 26.8, 40.2 and 80.4% at low, moderate and high salinity as compared to control (Table 1b). Rauf *et al*. (1989) also reported the increase in leaf Cl^- concentration with increase in salinity. Torres and Bingham (1973) concluded that Cl^- induced NO_3^- -deficiency was responsible for growth suppression in wheat. The increase in Cl^- concentration was attributed to massive uptake of Cl^- ion by the plants as well as reduced growth under adverse environment. Our results are also in confirmation with Royo and Aragues (1999).

Unlike Na^+ and Cl^- the concentration of K^+ in the leaf sap of *Brassica* species decreased with increase in soil salinity. Those plants which maintained high K^+ concentration under saline environment can better tolerate salinity (Muhammad & Aslam, 1998). Species *B. napus* retained highest K^+ concentration (Fig. 1c) at low and high salinity (4.75 & 9.50 dS m^{-1}) while at moderate salinity (6.0 dSm^{-1}) the maximum K^+ concentration was found in *B. carinata*. Minimum K^+ was observed in the leaf sap of the *B. compestris* at all salinity levels. Over all species comparison (Table Ia) shows that there is significant difference in *Brassica* species for K^+ concentration except *B. napus* and *B. carinata*, while from the comparison of the salinity means (Table Ib) K^+ concentration of the leaf sap differs non significantly at low and moderate salinity while significant at high salinity level, and over all decrease in K^+ concentration was 10.2, 9.5 and 25.7% at low, moderate and high salinity levels respectively as compared to control. The decline in K^+ concentration could be due to the competition for K^+ and Na^+ under saline conditions and resultant increase in the uptake of Na^+ at the cost of K^+ ion (Kuiper, 1984). High amount of Na^+ exerts strong ion imbalancing effect on K^+ in the cytoplasm of a cell, consequently decreasing the K^+ : Na^+ ratios, thus disturbing the physiological role of K^+ in osmoregulation and protein synthesis as envisaged by Leigh and Wyn Jones (1994). Muraeitharan *et al*. (1992) reported that photosynthesis may also be reduced due to reduction in leaf K^+ because of salt stress. From these results it can be concluded that species *B. napus* accumulated less Na^+ and maintained high K^+ in leaf sap under salinity treatments followed by *B. carinata*, which may be due to the presence of one or more of the above said salt tolerance mechanisms.

CONCLUSION

On the basis of present study two *Brassica* species (*B. napus* and *B. carinata*) can be included in intensive screening and breeding for salt tolerance, because they have the potential to face moderate concentration of salts in the saline fields.

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(Received 11 May 2002; Accepted 15 June 2002)