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Effect of salinity on Na^+, K^+ and Cl^- content in different organs of chickpea and the basis of ion expression

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Abstract

One-month-old plants of two chickpea (*Cicer arietinum* L.) cultivars were exposed to salinity of 4 and 8 dS m^{-1} in pots in a greenhouse. The cultivar BG 312 performed better than Pusa 209 in terms of visible injury and dry mass accumulation. Tissue water content of the various plant organs was affected differently by salinity. Expression of Na^+ and Cl^- concentrations on a dry mass basis indicated retention of Na^+ and Cl^- by roots, thereby keeping the leaves free of ion accumulation, but their expression on a tissue water basis did not indicate Cl^- retention and showed less Na^+ exclusion. Changes in the apparent exclusion mechanisms resulted from a higher water content in the roots than in the shoots. On a dry mass basis, roots appeared to retain K^+, but on a tissue water basis stems appeared to act as a reservoir of K^+; leaves and nodules received K^+ preferentially. The exclusion mechanisms and their efficiency differ with cultivar and salinity. The expression of ion concentrations on a tissue water basis appears to be more useful then on a dry mass basis in studies of salinity tolerance.

Introduction

Salinity frequently results in changes in the fresh mass/dry mass ratio, as a result of which the concentration of ions in the sap increases, even though expression on a dry mass basis may show no changes or even a decrease (Gorham *et al.* 1985). In the present investigation dealing with the effects of salinity in two cultivars of chickpea - a salt sensitive crop - the results are discussed on a dry mass basis as well on a tissue water basis, to compare the advantages and disadvantages of these two bases of expression.

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Material and methods

The experiments were conducted at the Central Soil Salinity Research Institute, Karnal (29° 43' N, 76° 58' E, 245 m above sea level) during the winter seasons 1986/87 and 1987. The plants were grown in a greenhouse with natural irradiance and 27 °C (maximum) and 6 °C (minimum) average temperatures. The chickpea cultivars, *Cicer arietinum* L. cv. BG 312 and cv. Pusa 209, were grown in sand culture. One month old plants were subjected to salinity of 4 (S_1) or 8 (S_2) dS m^{-1} by irrigating with saline water. Salinity was achieved by adding salts to half-strength and N-free nutrient solution (S_0) based on the method of Wilson and Reisenhauer (1963). Salinity was maintained by irrigating the pots with the respective salt solution at weekly intervals. The solution contained Na^+:Ca^{2+}:Mg^{2+} (5:2:3) and Cl^-:SO_4^{-2} (7:1) on milliequivalent basis. A single standard rhizobial culture solution was applied at sowing.

The pots with five plants in each were sampled per treatment 20 d and 40 d after salinization (DAS). Fresh masses of the nodules, roots, leaves and stem were determined and dry mass were recorded after oven drying at 65 °C for 3 d. Fresh tissue samples were extracted in hot water (100 °C for 2 h) and ion concentrations were expressed on the dry mass basis and on the tissue water content basis. Na^+ and K^+ were determined by flame photometry (*Corning EEL Flame Photometer*), and Cl^- by electrochemical titration (*Bucher Chloridometer*). The values quoted are the means of five replicated analyses for growth measurements and ion estimations.

The first experiment concerned with the growth responses and distribution of ions in different plant parts and with the use of different bases of expression of ion concentrations. The experiment conducted in the second year studied the distribution of ions in the leaves and branches and their role in salt injury. Some aspects of this study are being reported elsewhere.

Results and discussion

The pattern of injury caused by salinity is peculiar in chickpea. Yellowing and necrosis of the older leaves start from the base of the mother (primary) shoot and proceed to the top. Necrosis of the tips and margins of the leaflets follows by the drying of the whole leaf and later the shoot. Secondary shoots emerging from the primary shoot are normal but after the death of the primary shoot, the secondary shoot(s) and subsequently the tertiary shoots are affected in the same way as the primary shoots, leading to the death of the whole plant, depending upon the severity and duration of the salt stress.

Salinization of the media for 40 d inhibited growth more in Pusa 209 than in BG 312 (Table 1). At higher salinity, roots were affected the least and nodules followed by leaves were affected the most. In the control plants, tissue water content was highest in the roots, followed by nodules and stem, and lowest in the leaves. Salinity increased tissue water content slightly in all the organs except stems, where water content was unaffected or decreased slightly (Table 2). Because of the differential changes in tissue water content of different organs, inorganic ion contents are

expressed on the basis of unit dry mass and tissues water content, as the basis for expression may influence the interpretation of the data.

Table 1. Dry matter accumulation in different plant parts [mg per 3 plants] of chickpea during 40 d after salinization. Percentage of control for the whole plant is given in parentheses.

	Dry matter Roots	Nodules	Stem	Leaves	Whole plant
PUSA 209					
S_0	502.00	454.00	443.00	901.00	2300.0±105.0 [100 0]
S_1	535.00	317.00	283.00	606.00	1741.0±77.0 [75.0]
S_2	477.00	118.00	250.00	420.00	1265.0±50.0 [55.0]
C.D.at 5%	18.15	25.67	22.23	36.30	
BG 312					
S_0	586.00	463.00	324.00	578.00	1951.0±72.0 [100.0]
S_1	497.00	391.00	446.00	528.00	1862.0±85.0 [95.0]
S_2	521.00	123.00	234.00	407.00	1285.0±55.0 [66.0]
C.D.at 5%	31.44	44.47	52.88	17.03	

Table 2. Effect of salinity on fresh mass / dry mass ratio and K^+ / Na^+ ratio in two cultivars of chickpea, 20 d after salinization.

	PUSA 209			PG 312		
	S_0	S_1	S_2	S_0	S_1	S_2
Fresh / dry mass ratio						
Leaves	5.1±0.31	5.4±0.22	6.3±0.16	5.2±0.19	5.7±0.37	6.0±0.29
Stems	10.0±0.48	8.9±0.39	9.5±0.32	10.0±0.27	9.5±0.54	9.6±0.38
Roots	29.4±0.27	29.9±0.76	31 0±1.39	20.5±1.82	33.8±1.37	26.8±2.01
Nodules	12.1±0.37	19.0±1.07	19.0±0.88	12.0±0.71	18.7±0.55	18.8±0.48
K^+ / Na^+						
Leaves	37.10	3.10	1.40	38.00	2.10	1.20
Stems	20.20	1.70	1.90	49.10	1.80	1.90
Roots	6.30	0.50	0.50	4.70	0.50	0.50
Nodules	12.90	6.50	4.80	9.70	5.50	9.90

Salinity resulted in an increased accumulation of Na^+ and Cl^- in all plant parts, irrespective of the bases of expression (Figs. 1 and 2). Though plants were sampled at 20 and 40 DAS, the results for ion distribution at the initial sampling stage, *i.e.* 20

DAS seemed to be more important in governing chickpea responses to salinity, and also for reasons of brevity, comparisons of the two bases of expressions have therefore been given for this stage only. Roots followed by stem retained most of the Na^+ absorbed by the plant when the concentrations were expressed on the basis of dry mass (Sharma and Kumar, in press), and appeared to allow only a small proportion to be transported to the leaves (Fig. 1). Sodium has been reported to be retained by roots and/or stems under saline conditions in most legumes (Abel and Mackenzie 1964, Jacoby 1964, Läuchli and Wieneke 1979, Later *et al.* 1981) but these results were expressed on dry mass basis only. However, sodium concentrations expressed on tissue water basis increased significantly in all organs and the differences between roots and other plant organs were not as marked as when expressed on dry mass basis (Fig. 1). With the increase in salinity from S_1 to S_2, the stem of BG 312 had slightly higher Na^+ concentrations than the roots. This indicates that Na^+ exclusion mechanisms in the stem became less effective at higher salinity in BG 312 but continue to operate effectively in Pusa 209, as leaf Na^+ declined at higher salinity.

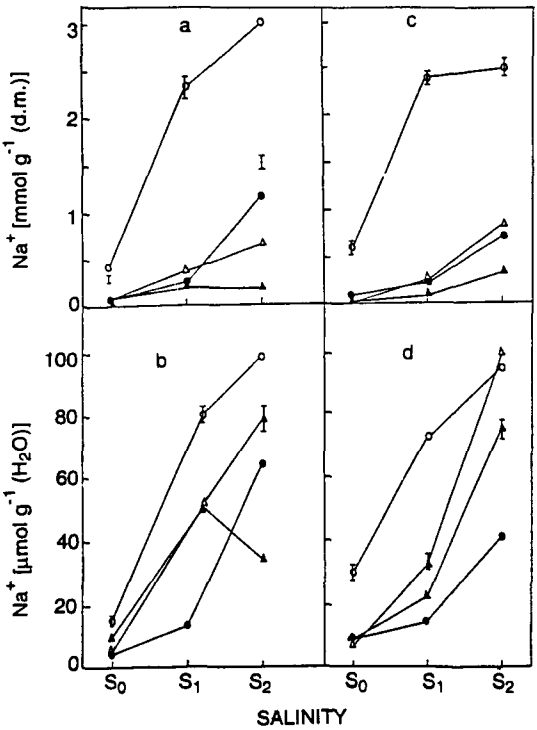

Fig.1. Changes in Na^+ concentrations in roots (*open points*), nodules (*full points*), stems (*open triangles*) and leaves (*full triangles*) in the chickpea cultivars Pusa 209 (*a,b*) and BG 312 (*c,d*) after 20 d of salinization in pots, expressed on the dry mass basis (*a,c*) and on the tissue water content basis (*b,d*).Vertical bars indicate standard mean errors.

However, on a dry mass basis, leaf Na^+ concentrations in Pusa 209 did not change with salinity. Salim and Pitman (1983) observed a similar decline in the effectiveness of the Na^+ exclusion mechanisms in mung bean (*Phaseolus vulgaris*).

Similarly, Cl^- concentrations, when expressed on dry mass basis, were higher in the roots than in the leaves, but the reverse was true when the same data was expressed on tissue water basis (Fig. 2).

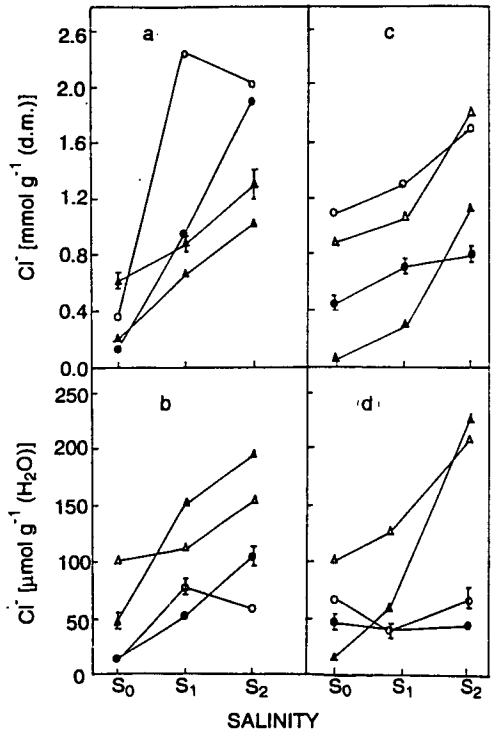

Fig. 2. Changes in the Cl^- concentrations in roots (*open points*), nodules (*full points*), stems (*open triangles*) and leaves (*full triangles*) in the chickpea cultivars Pusa 209 (*a,b*) and BG 312 (*c,d*) after 20 d of salinization in pots, expressed on the dry mass basis (*a,c*) and on the tissue water content basis (*b,d*). Vertical bars indicate standard mean errors.

The first form of expression would indicate the operation of effective Cl^- exclusion in the roots, whereas the latter expression refutes the existence of any such mechanism. Pitman (1984) emphasized that ion concentrations expressed on the tissue water basis give more meaningful relationships with rates of transport, which control leaf ion concentrations. Even though representation of the data on the tissue dry mass basis indicates better regulation of internal ion distribution in the plant, but is not borne out by the poor performance of chickpea under saline conditions. In the literature, more emphasis is being put on Cl^- content of shoot and leaves in relation to the relative salt resistance of various leguminous species (Abel 1969, Läuchli 1984). The results of the present studies, irrespective of their expression, do not

support this contention, as leaves of BG 312, a relatively resistant cultivar had higher Cl^- at S_2 than Pusa 209, whereas the reversed was true at S_1 BG 312 may have a better mechanism for localizing Cl^- intracellularly in the leaves, and their ion distribution from leaf to leaf and other organs needs to be monitored.

Relative concentrations of K^+ in the roots and shoots also depend strongly on the basis of expression. On a dry mass basis, roots appeared to retain K^+ at the cost of the supply to the shoot, wheareas on a tissue water basis, stems, leaves and nodules maintained higher concentrations (Fig. 3). The stem retained most of K^+ and might be acting as a reservoir.

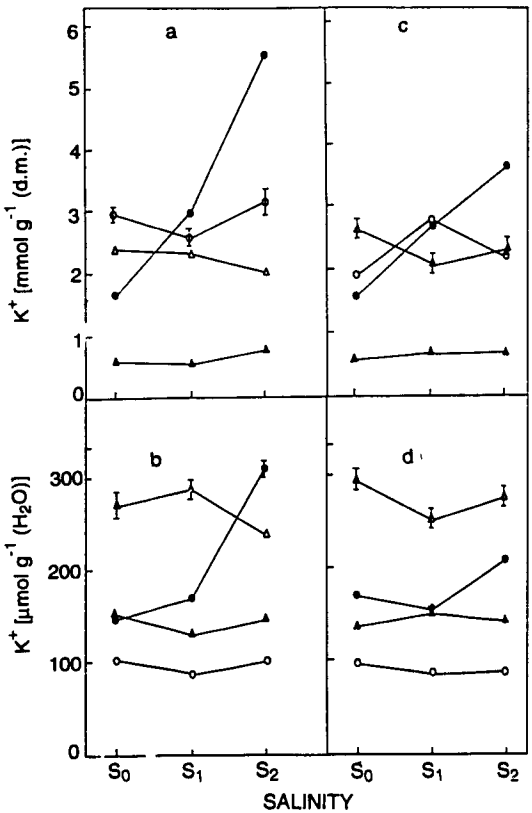

Fig.3. Changes in the K^+ concentrations, in roots (*open points*), nodules (*full points*), stems (*open triangles*) and leaves (*full triangles*) in the chickpea cultivars Pusa 209 (*a,b*) and BG 312 (*c,d*) after 20d of salinization in pots, expressed on the dry mass basis (*a,c*) and on the tissue water content basis (*b,d*). Vertical bars indicate standard mean errors.

Stems had the highest K^+/Na^+ ratio, followed by leaves and/or nodules, and by roots. Roots retained Na^+ preferentially over K^+ under normal conditions. Salinization of the media decreased K^+/Na^+ ratio in different plant parts because of increased Na^+ concentrations; nodules, stem and leaves had higher K^+/Na^+ ratios, indicating their preference for K^+ (Table 2). The K^+/Na^+ ratios decreased in different

plant parts despite the pronounced rise in their K^+ selectivity ratio (S K^+:Na^+) under salinity, indicating that this effect is mainly due to the increased Na^+ uptake. Lower salinity generally resulted in decreased K^+ concentrations in almost all organs whereas higher salinity sometimes increased it, which might be rather a consequence of growth reduction caused by salinity. Total (Na^+ + K^+) content increased in all organs with increasing salinity, the maximum increase being in the roots. This obviously helped the plants to maintain the osmotic gradient for water uptake and the resulting increased tissue succulence.

The results thus clearly show that the basis of expression of the analytical data may give entirely different results. Tissue water expression seemdrrrrrs to be better for physiological processes under salt stress, and for comparing and understanding salt tolerance in different cultivars under identical conditions.

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