

COMPARTMENTATION OF Na^+ AND Cl^- IONS IN DIFFERENT PARTS OF *SORGHUM BICOLOR* (L.) MOENCH DURING PLANT DEVELOPMENT

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Abstract

Pattern of distribution of Na^+ and Cl^- ions were examined in four moderately salt-tolerant *Sorghum bicolor* accessions (Double TX, Giza 114, INRA 353 and INRA 133) grown in salinized sand-culture. Analyses for ion content were made on each leaf, pseudostems and roots. Ion content of leaves of different ages differed but not consistently among accessions. Double TX and Giza 114 had the lowest Na^+ and Cl^- concentration in young leaves and these increased with leaf age. In INRA 353 leaf Na^+ and Cl^- decreased in older leaves. The Na^+ content of pseudostems of Double TX and Giza 114 were similar to those in leaves but in INRA 133 and INRA 353 Na^+ ions were markedly higher than in leaves and considerably higher than in Double TX and Giza 114. Pseudostems contained the highest concentrations of Cl^- and were similar in the four accessions. Root Cl^- concentrations were similar to those in leaves in the four accessions. In terms of relative grain yield, INRA 133 and INRA 353 were found superior accessions than Double TX and Giza 114, and therefore, their potential may be exploited through selection and breeding of plants to effect further improvement in salinity tolerance in sorghum.

Introduction

Plant responses to salinity are in general extremely complex, and an array of physiological mechanisms are involved in enabling them to cope with stressful conditions (Wyn Jones, 1981). However, variation in salinity tolerance amongst those plant species showing glycophytic adaptation is related to the efficiency with which they exclude excess of Na^+ /or Cl^- from their leaves (Greenway & Munns, 1980). Salim (1991) identified a barley variety which accumulated high content of Na^+ and Cl^- in shoots and exhibited increased salt tolerance, and by contrast in emmer wheat enhanced salinity tolerance was due to low Na^+ uptake (Nevo *et al.*, 1992). Similarly Khan *et al.*, (1994) observed varietal differences in salt to tolerance in cotton; tolerant variety maintained low concentration of Cl^- in leaves and stem than sensitive ones, and suggested that high salt tolerance may be due to the presence of effective ion regulation. Since tolerance of plants to salinity varies from one growth stage to another (Shannon, 1985), therefore, it seems probable that tolerance may change with ontogenic development of plants.

The work described here examines compartmentation of Na^+ and Cl^- ions into leaves, stem and roots of different ages of four sorghum lines of different salt sensitivities.

Materials and Methods

Four sorghum accessions, Double TX, Giza 114, INRA 133, and INRA 353 were grown in sand cultures watered with dilute nutrient solution containing 0, 100 and 150 mM NaCl. The plants were harvested at three occasions; the Harvest-1 was made when plants reached six leaf stage and leaves were fully expanded, and Harvest-2 when floral initiation in leaf sheath became apparent, and the final harvest (Harvest-3) being at plant

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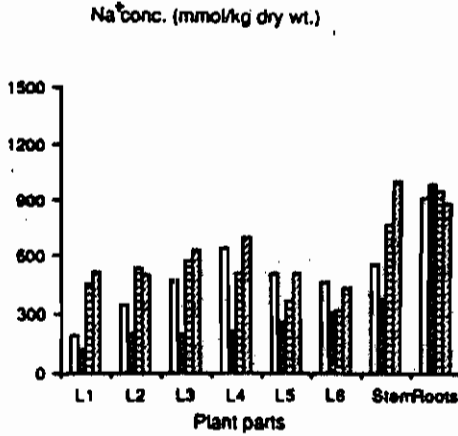


Fig. 1a: Na⁺ concentration in different plant parts of four accessions at Harvest-1.

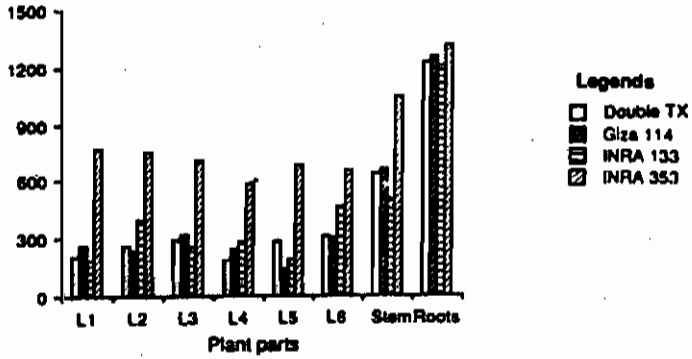


Fig. 1b: Na⁺ concentration in different plant parts of four accessions at Harvest-2.

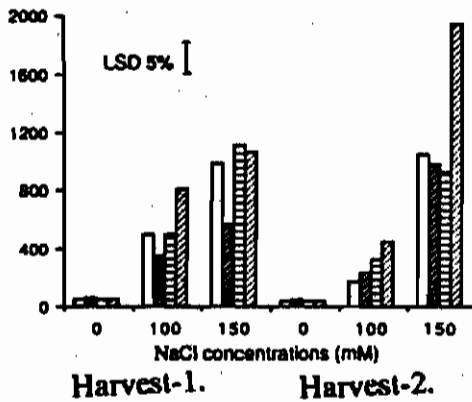


Fig. 1c: Total plant Na⁺ concentration of four accessions at three NaCl levels at two harvests.

maturity. The experiment was set up using randomized complete block design with three replicates. At each harvest whole plants were harvested. Six leaves (top leaf at Harvest-1, and flag leaf at Harvest-2, being leaf 1), pseudostem, and roots of all plants of each accession were collected separately, and a bulk sample of each fraction made subsequently. However, in Harvest-3 grains were obtained from the plants when they attained maximum dry weight.

The material was oven dried at 70°C for at least 7 days, and a small randomly chosen portion of the different plant parts were cut into small pieces. A 20 mg sub-sample was soaked for 12 h in 1 ml concentrated HNO₃. Samples were then digested at 70°C on a hot plate and 5 ml of double distilled deionized water was added to each vial. The concentration of Na⁺ was assayed by Atomic Absorption Spectrophotometer (Varian 1275). For Cl⁻ analysis, 5 ml of double distilled deionized water was added to 20 mg of each of the 3 plant parts and digested for 1 h on a hot plate maintained at 70-80 °C. The contents of Cl⁻ in the remaining sample were determined using CMT Chloride Titrator (Radiometer).

Results

At Harvest-1, the Na⁺ concentration in root of Double TX and Giza 114 were markedly greater than in pseudostems, and also differed in leaves of different ages (Fig. 1a). In Double TX, INRA 133 and INRA 353 leaf 4 had a higher Na⁺ concentration than younger leaves (Leaf 1, 2, 3) and older leaves (Leaf 5,6). The concentrations of Na⁺ in leaves 1, 2, 3, and pseudostems of accessions INRA 133 and INRA 353 were considerably greater than those in Double TX and Giza 114.

At Harvest-2 (Fig. 1b) a greater proportion of total Na⁺ concentration was retained in roots. The accession INRA 353 accumulated more Na⁺ in its leaves than the other three accessions. Although overall concentration of Na⁺ in pseudostems was lower at Harvest-2, INRA 353 still accumulated more Na⁺ than Double TX, Giza 114 and INRA 133. The Na⁺ concentrations in leaves also altered at Harvest-2; it decreased in Double TX and INRA 133 and increased in INRA 353 and Giza 114. At Harvest-2 INRA 353 again accumulated more Na⁺ in leaves than the other three accessions.

At Harvest-1, on whole plant basis, INRA 353 accumulated significantly more Na⁺ than the other three accessions grown in 100 mM NaCl (Fig. 1c). At 150 mM NaCl Giza 114 accumulated significantly less Na⁺ than the other accessions which did not differ among themselves. At Harvest-2 accession responses to both NaCl levels were different; Na⁺ concentration decreased at 100 mM NaCl, while at 150 mM there was a significant increase in Double TX, INRA 353 and Giza 114. Accession INRA 353 accumulated significantly more Na⁺ at both salinity levels than the other three accessions which did not differ among themselves.

The Cl⁻ concentration in roots and pseudostems at Harvest-1 was very consistent in all accessions (Fig. 2a), although roots contained approximately one half the concentration in pseudostem and both plant parts contained more Cl⁻ than leaves. Total plant concentration was greater in INRA 353 than in the other three accessions. Leaf Cl⁻ concentrations were lower in younger than in older leaves in Double TX and Giza 114 but did not vary with age in INRA 133 and INRA 353. Leaves of Double TX and Giza 114 contained considerably lower Cl⁻ than INRA 133 and INRA 353. The Cl⁻ concentrations in pseudostems and leaves of all accessions decreased at Harvest-2 but the overall response of accessions was similar to that observed at Harvest-1 (Fig. 2b). INRA 353 was again a high Cl⁻ accumulator and pseudostems contained approximately two times more Cl⁻ than roots and considerably more than leaves.

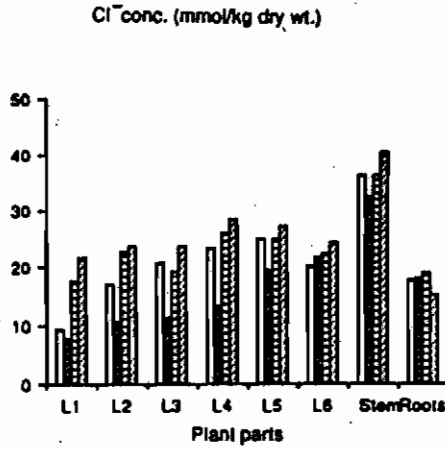


Fig. 2a: Cl⁻ concentration in different plant parts of four accessions at Harvest-1.

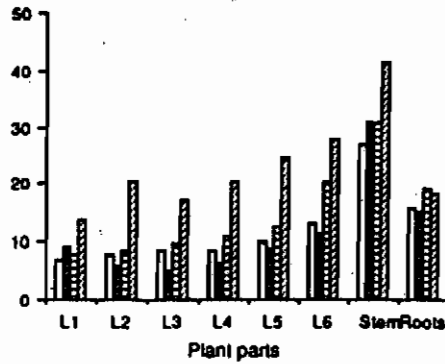


Fig. 2b: Cl⁻ concentration in different plant parts of four accessions at Harvest-2.

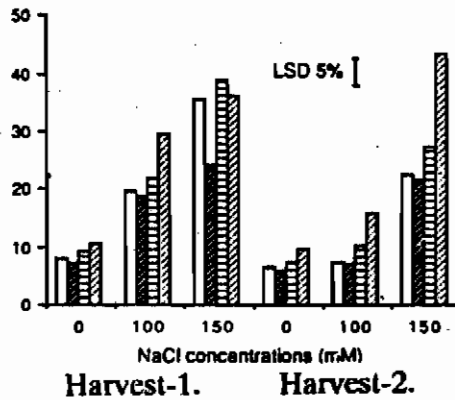


Fig. 2c: Total plant Cl⁻ concentration of four accessions at three NaCl levels at two harvests.

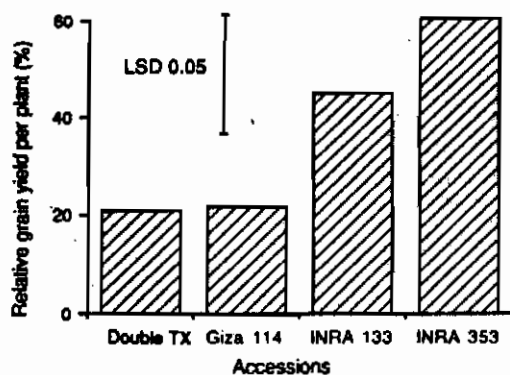


Fig. 3a: Relative grain yield per plant of four accessions.

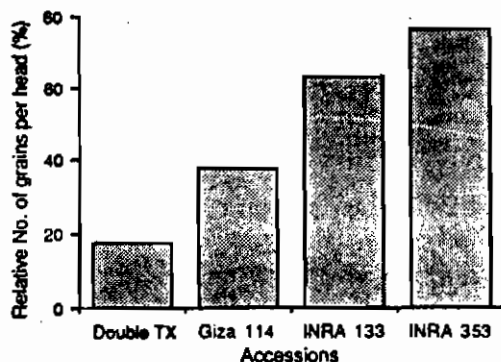


Fig. 3b: Relative number of grains per head of four accessions.

On whole plant basis (Fig. 2c), INRA 353 at Harvest-1 accumulated significantly more Cl⁻ when grown in 100 mM NaCl than the other three accessions whilst at 150 mM NaCl Double TX, INRA 133 and INRA 353 contained similar amounts of Cl⁻, but significantly more than Giza 114. At Harvest-2, Cl⁻ concentrations in all four accessions were significantly lower in 100 mM NaCl than at Harvest-1, although concentration in INRA 353 was significantly greater than the other three accessions. At 150 mM, Giza 114 accumulated as much Cl⁻ as at Harvest-1 but significantly lower than INRA 133 and INRA 353.

At Harvest-3 the accessions differed significantly in relative grain yield per plant. The differing responses of accessions in grain yield is shown in Fig. 3a. The accession INRA 353 with an overall relative yield of 60% performed significantly better than Double TX and Giza 114 (which did not differ among themselves), but was no better than INRA 133. For number of grains per head the accessions ranked in a similar way as for grain yield although these did not differ statistically (Fig. 3b).

Discussion

The data about Na^+ and Cl^- concentration in tissues of four sorghum accessions reflected their differing responses to NaCl stress. In Double TX and Giza 114 remarkably lower concentration of Na^+ and Cl^- in young leaves and higher concentration in stems and roots suggested that there was indeed some exclusion of these ions. This did not occur in INRA 133 and INRA 353 (Fig. 1a and 2a). The similar differences in the distribution of Na^+ and Cl^- in different plant organs have already been noted in *Trifolium alexandrinum* (Ashraf, 1986). Thus a major difference in responses of the accessions to salinity stress was the varying concentrations of Na^+ and Cl^- accumulated in stems and leaves. Double TX and Giza 114 which accumulated less Na^+ and Cl^- ions may be regarded as the most salinity-tolerant accessions as noted in case of cotton varieties (Khan *et al.*, 1994), whilst INRA 133 and INRA 353 contained more Na^+ and Cl^- , a characteristic of sensitive genotypes (Hajibagheri *et al.*, 1987). However, in terms of relative grain yield and number of grains, INRA 353 and INRA 133 showed superior performance than Double TX and Giza 114 (Fig. 3a,b). This situation is similar to the case reported in maize (Yeo *et al.*, 1977) and barley (Salim, 1991). Thus the observations of Kingsbury *et al.*, (1984) that higher concentration of Na^+ and Cl^- ions occur in salt sensitive varieties were not substantiated here. The increased salinity tolerance of INRA 353 and INRA 133 may either be due to particular compartmentation of Na^+ and Cl^- within the cells of plant organs or to requiring more Na^+ and Cl^- to maintain turgor as suggested by Salim (1991). Such a mechanism, however, is known mainly in halophytes (Flowers *et al.*, 1977), but it is paralleled by the potential of NaCl-tolerant line *Lolium perenne* (Ashraf, 1986). These data suggest that accumulation of low concentrations of Na^+ or Cl^- ions is by no means a general phenomenon in salt tolerant species. Although accumulation of both Na^+ and Cl^- ions decreased with ageing in Double TX, Giza 114 and INRA 133, it increased significantly in INRA 353 (Figs. 1c and 2c). Nonetheless differences in the responses of all accessions to Na^+ and Cl^- accumulations were maintained, wholly or partially, at Harvest-1 and Harvest-2.

The present investigations on ion distribution have revealed considerable variability in the four accessions. Although Double TX has been recognised as a salinity-tolerant cultivar (Maas *et al.*, 1986), the assessment carried out here has revealed that, at least under the limits of this experiment, INRA 133 and INRA 353 also showed appreciable salinity tolerance, and it would appear to question the possibility at least in this species of using patterns of ion distribution as a selection criterion for improved salinity tolerance. Thus high relative salt tolerance of these two accessions would seem to be of potential value in a breeding programme.

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