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ROLE OF MINERAL IONS IN SALT TOLERANCE OF TWO WHEAT (*TRITICUM AESTIVUM* L.) CULTIVARS

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Abstract

Effects of NaCl salinity at different growth and developmental stages on ions accumulation in two wheat cultivars were studied in greenhouse conditions. Concentrations of Na^+ in leaves and roots of Ghods, a salt-sensitive cultivar, were more than that of Boolani, a salt-resistant cultivar. K^+ and Ca^{2+} contents were found to be less under NaCl treatments. This loss increased with increasing salinity and was markedly higher in Ghods than in Boolani. There were significant differences between the cultivars with respect to ion absorption and translocation indicating that the cultivars may give genotype dependent responses under salinity stress conditions.

Introduction

The responses of plants to salinity stress involve a variety of complex mechanisms (Vogelien *et al.*, 1996). The degree to which different plants can tolerate high concentrations of salt in their rooting medium is under genetic control. Salt tolerance is of great economic and intrinsic scientific importance (Omielan & Epstein, 1991). Salts affect plants through the osmotic retention of water in soils and the specific effect on metabolic processes. Thus osmoregulation and ion regulation are important in determining the salt sensitivity. The control of sodium accumulation might be the important physiological process conferring salt tolerance to cereals (Reggiani *et al.*, 1995).

An important mechanism for salt tolerance is accumulation of Na^+ in the vacuole. This serves two purposes (a) to keep cytoplasmic Na^+ levels low and (b) to lower the osmotic potential of cell sap to avoid water stress (Staal *et al.*, 1991; Savoure *et al.*, 1999). Most studies on mechanism of salt tolerance in plants have been focussed on osmotic adjustment and ion compartmentation either in whole plant or at cellular level (cytoplasm/ vacuole). Most of the investigations on ion compartmentation have been concentrated on Na^+ and the major cations like, K^+ and to a lesser extent Ca^{2+} (Gouia *et al.*, 1994). Like other glycophytes, wheat plants have also shown significant toxic responses to salinity at germination, vegetative and reproductive growth (Ahmad *et al.*, 1992). The present study describes the effects of NaCl salinity on Na^+, K^+ and Ca^{2+} levels in two wheat cultivars with their differential sensitivity to salinity and to evaluate the possible roles of the ions in salt tolerance.

Two wheat cultivars viz., Ghods, (salt-sensitive) and Boolani, (salt-resistant) were used. Uniformly large seeds, free of visible injury or disease, were hand selected and surface-treated with vitavax to slow down fungal growth (Dell'Aquila & Spada, 1993).

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Materials and Methods

Two wheat cultivars viz., Ghods, (salt-sensitive) and Boolani, (salt-resistant) were used. Uniformly large seeds, free of visible injury or disease, were hand selected and surface-treated with vitavax to slow down fungal growth(Dell'Aquila & Spada, 1993). Seeds were sown in plastic pots containing 3Kg mixture of medium-textured soil, sand and manure in 2:1:1 ratio, respectively. In each pot, 10 seeds were planted and after 16 days of sowing, plants were thinned to four per pot. Plants were irrigated twice a week. Five levels of salinity (0, 50, 100, 200 and 300 mM NaCl) were applied (Huang *et al.*, 1993).Treatments were given at a) tillering, b) boot swollen, c) emergence of inflorescence and d) anthesis (22, 45, 58 and 69 DAS) according to Zadoks code (Zadoks *et al.*, 1974). At tillering and boot swollen, plants were also irrigated with a nutrient solution containing 200 ppm N, 92 ppm P, and 200 ppm K used as NH_4NO_3, H_3PO_4, and KNO_3, respectively (Rascio *et al.*, 1992). The pots were kept in a completely randomised design in a controlled environment greenhouse (25 and 18 EMBED Equation.3 1°C day and night temperature, respectively; light intensity 400 μ mol m^{-2} s^{-1} with 16/8 light /dark period, and 40-45% RH). Plants were grown in saline soil until a week and after that harvesting was carried out (Nicolas *et al.*, 1993). Plants without salt addition served as controls. Sampling was performed from roots and sixth (22 DAS), seventh (45 DAS) and flag leaves (58 and 69 DAS).

Preparation of leaf and root samples was done according to the method of Hamada *et al.*, (1992). Extraction of cations (Na^+, K^+ and Ca^{2+}) and measurement of their concentrations were carried out using the method of Podwyszynska & Olszewski (1995) and Nicolas *et al.*, (1993), respectively.

The cation concentrations were analyzed with analysis of variance (ANOVA) for factorial design (factor A=salinity treatment, factor B=cultivar, and factor C=growth stage) with 3 replicates using Anova program of MSTATC version 2 package. The results were subjected to a statistical analysis using Duncan's Multiple Range Test (DMRT).

Results

In general, Na^+ levels in leaf and root were higher in the stressed plants than in the control plants. The amount of Na^+ accumulated in Ghods and Boolani in response to salinity, differed markedly (p EMBED Equation.3 0.01) except during tillering (22 DAS), at 200 mM NaCl treatment, there was no significant difference between foliar Na^+ levels of both the cultivars (Fig. 1). In Ghods, 3.5-fold accumulation of foliar Na^+, compared with controls, was observed during tillering at 300 mM NaCl treatment. A 4-fold increase in root Na^+, was also found at tillering but with 200 mM NaCl .In Boolani, the highest concentrations of foliar and root Na^+, 3-and 2.2 folds (300% and 220%), respectively, were correlated with boot swollen at 300 mM NaCl treatment (Fig. 1).

During later growth stages, especially anthesis, salinity induced a minimum increase in Na^+ levels and there were less differences in Na^+ accumulation between Ghods and Boolani than that at tillering and boot swollen stages. During anthesis, there was 1.6 fold increase in Na^+ content of flag leaves with 200 mM NaCl in both Ghods and Boolani cultivars. In addition, at the same stage, the greatest levels of root Na^+ in Ghods and Boolani, 2.1 and 1.3-folds (210% and 130%), were recorded with 100 and 300 mM NaCl, respectively (Fig. 1).

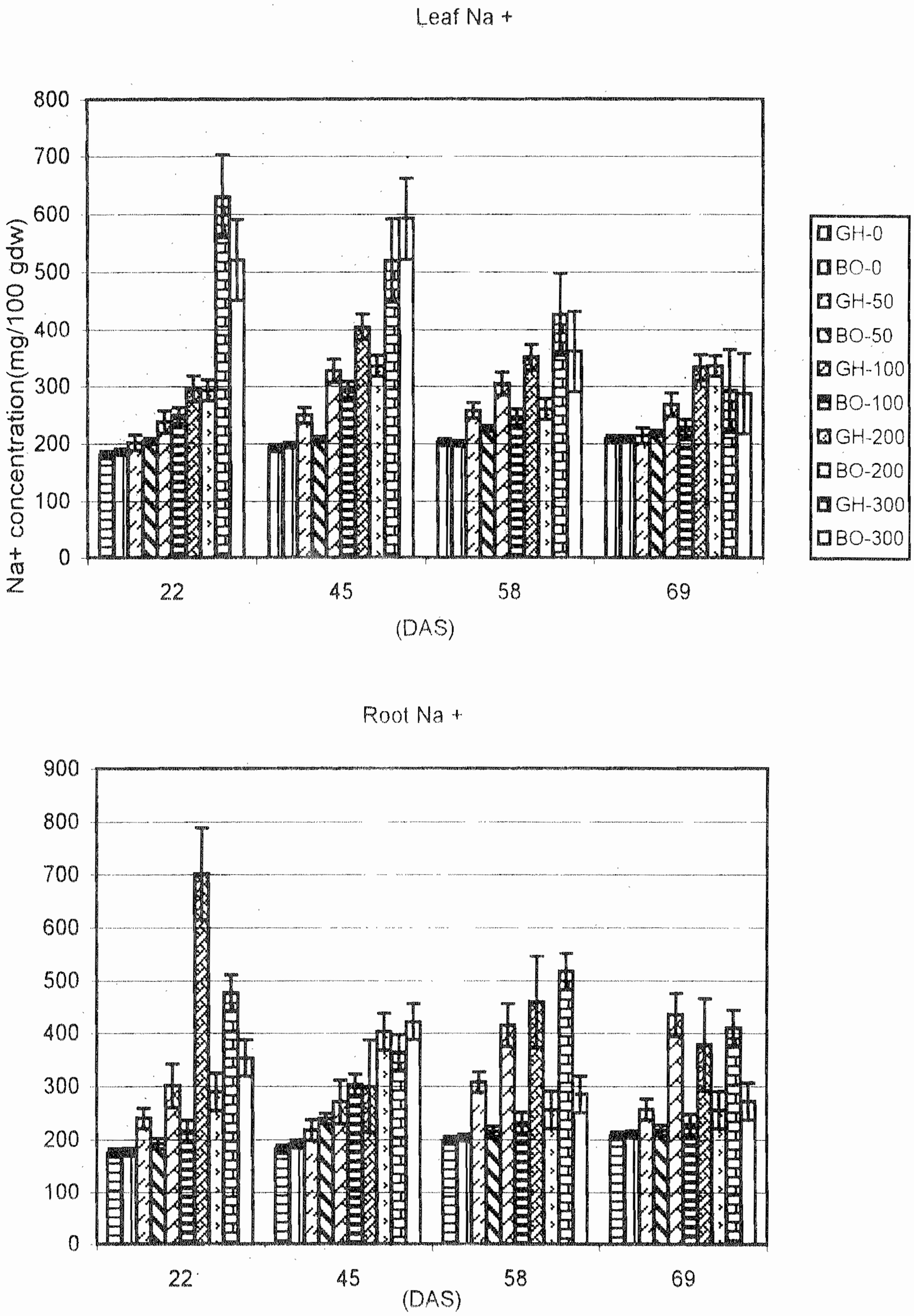

Fig. 1. Effects of 5 levels of NaCl treatments on the Na+ concentrations in leaves (A) and roots (B) of Ghods and Boolani. GH, Ghods, BO, Boolani; 0, no NaCl, 50, 50 mM NaCl, 100, 100 mM NaCl, 200, 200 mM NaCl; 300, 300 mM NaCl

In control plants on the other hand there were no significant differences in K^+ levels between Ghods and Boolani, and foliar and root K^+ levels declined with an increase in the plant's age (p EMBED Equation.3 0.01). Salt stress generally resulted in loss of foliar and root K^+ concentrations in both the cultivars (p EMBED Equation.3 0.01).

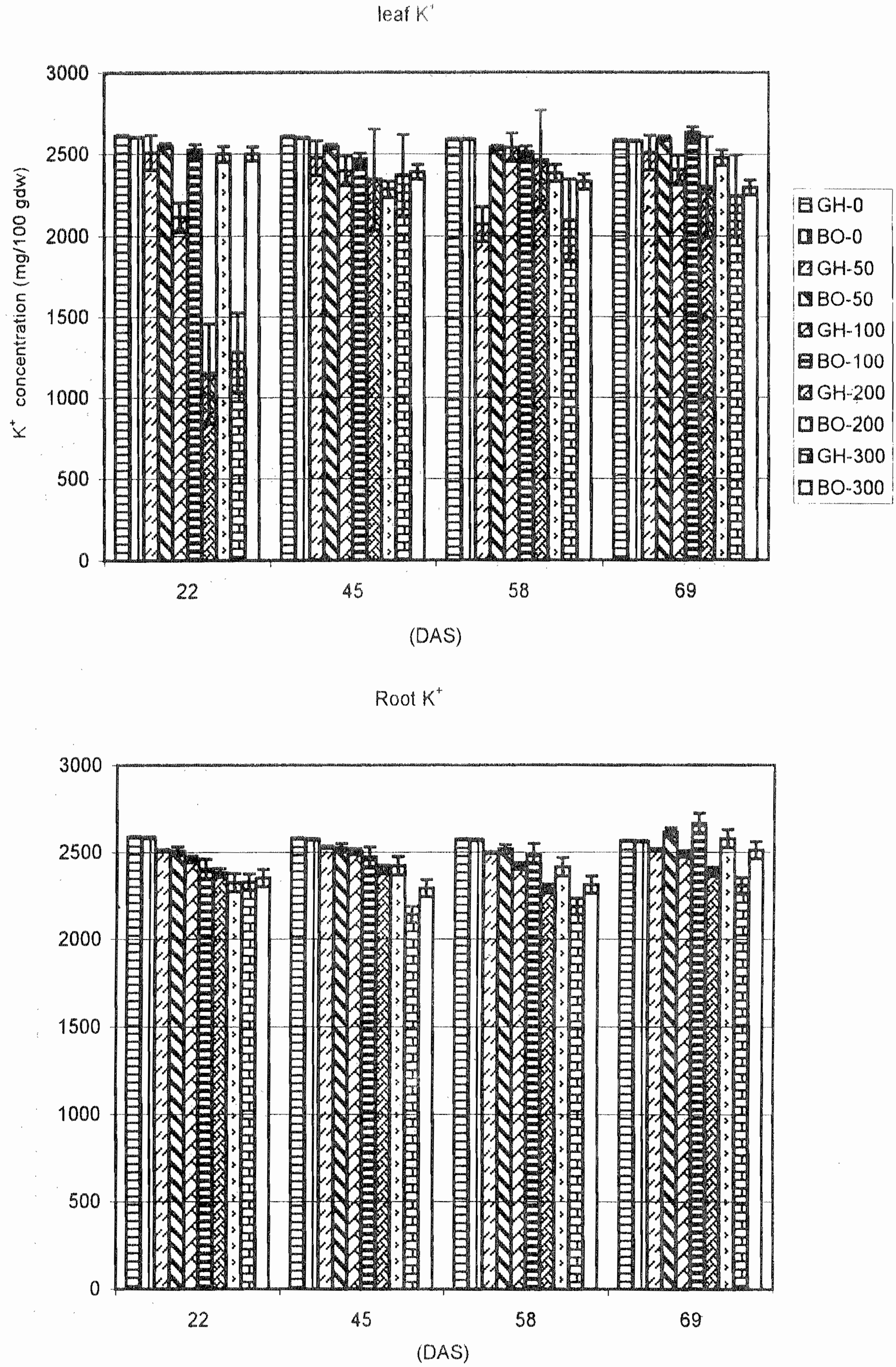

Fig. 2. Effects of 5 levels of NaCl treatments on the K^+ concentrations in leaves (A) and roots (B) of Ghods and Boolani. GH, Ghods; BO, Boolani, 0, no NaCl, 50, 50 mM NaCl, 100, 100 mM NaCl; 200, 200 mM NaCl; 300, 300 mM NaCl.

Ghods showed a 44% reduction in foliar K^+ at tillering stage when exposed to 200 mM NaCl . The greatest loss of root K^+ level (83%) was found during boot swollen with 300 mM NaCl. In Boolani, the maximum decrease in leaf K^+ (88%), was observed during boot swollen at 200 mM NaCl treatment. Maximum reduction in root K^+ (89%), was found at the same stage but with 300 mM NaCl treatment. During anthesis, K^+ contents of flag leaves in Boolani increased at lower salinity levels (50 and 100 mM NaCl) but not at the higher 200 and 300 mM NaCl concentrations (Fig. 2).

The influence of NaCl treatments on Ca^{2+} levels varied with growth stage, cultivar and leaf or root. In Ghods, the greatest reduction in leaf and root Ca^{2+} contents, 45% and 58% of the level in controls, was found during tillering at 100 and 300 mM NaCl treatments, respectively. In Boolani, the highest decrease in leaf Ca^{2+} levels, 75%, was observed during anthesis with 200 mM NaCl. The greatest loss of root Ca^{2+} content, 65%, was found during tillering at 300 mM NaCl treatment (Fig. 3). During tillering and boot swollen stages, foliar Ca^{2+} contents in Boolani increased in response to salinity (p EMBED Equation. 3 0.01). The increase, especially during boot swollen, became more with the high salinity level (300 mM NaCl). However, Ghods showed an opposite pattern. During emergence of inflorescence (58 DAS) and anthesis (69 DAS), root Ca^{2+} levels increased as a response to NaCl treatments (p EMBED Equation.3 0.01) . The increase was more pronounced in Ghods as compared to Boolani (p EMBED Equation.3 0.01) (Fig. 3).

Discussion

On the basis of analysis of variance, foliar and root sodium contents increased with increase in external salinity after 7d salinization (Reggiani *et al.*, 1995). In most plants, osmoregulation in response to salinity is achieved mainly by accumulation of inorganic ions (Levitt, 1980). As a response to NaCl salinity: (a) accumulated Na^+ in leaves and roots was less in Boolani than in Ghods, (b) in Boolani, Na^+ accumulation was more in leaves than in roots. In Ghods, an apposite pattern was observed. According to Storey & Jones (1977) salt sensitivity is usually associated with poor exclusion of salt by roots.

Wheat is "partial ion excluder" when stressed with salt (Zhong & Dvorak, 1995). On the basis of present data, it seems reasonable to introduce Boolani as "partial ion excluder" and Ghods as "partial ion accumulator". In control plants, Na^+, K^+ and Ca^{2+} contents were higher in leaves than in roots (p EMBED Equation.3 0.01). Similar observation was also reported by Hamada *et al.*, (1992). Enhanced Na^+ contents in response to salinity, co-existed with significant decrease in K^+ and Ca^{2+} levels (Gouia *et al.*, 1994). Thus, the main cause of NaCl–induced growth inhibition is the difficulty in uptake of mineral ions due to competition with Na^+ (Levitt, 1980). Boolani accumulates K^+ more effectively than Ghods. According to Trivedi *et al.*, (1991) this trait can be regarded to be of adaptive value under salinity. One mechanism for the low concentrations of Na^+ in Boolani is probably related to the higher K^+/Na^+ selectivity during uptake.

In the present study, the loss of Ca^{2+} levels in response to salinity was more in leaves than roots, was more in flag leaves than in sixth and seventh leaves and it was more in the leaves and roots of Ghods than that of Boolani. Rengel (1992) also believed that "shoots" frequently show symptoms of Ca^{2+} deficiency in response to salt stress and an increase in salinity reduces translocation rate of Ca^{2+} and also the amount of Ca^{2+} bound to the plasma membrane in wheat and barley with greater effect on Na^+-sensitive genotype.

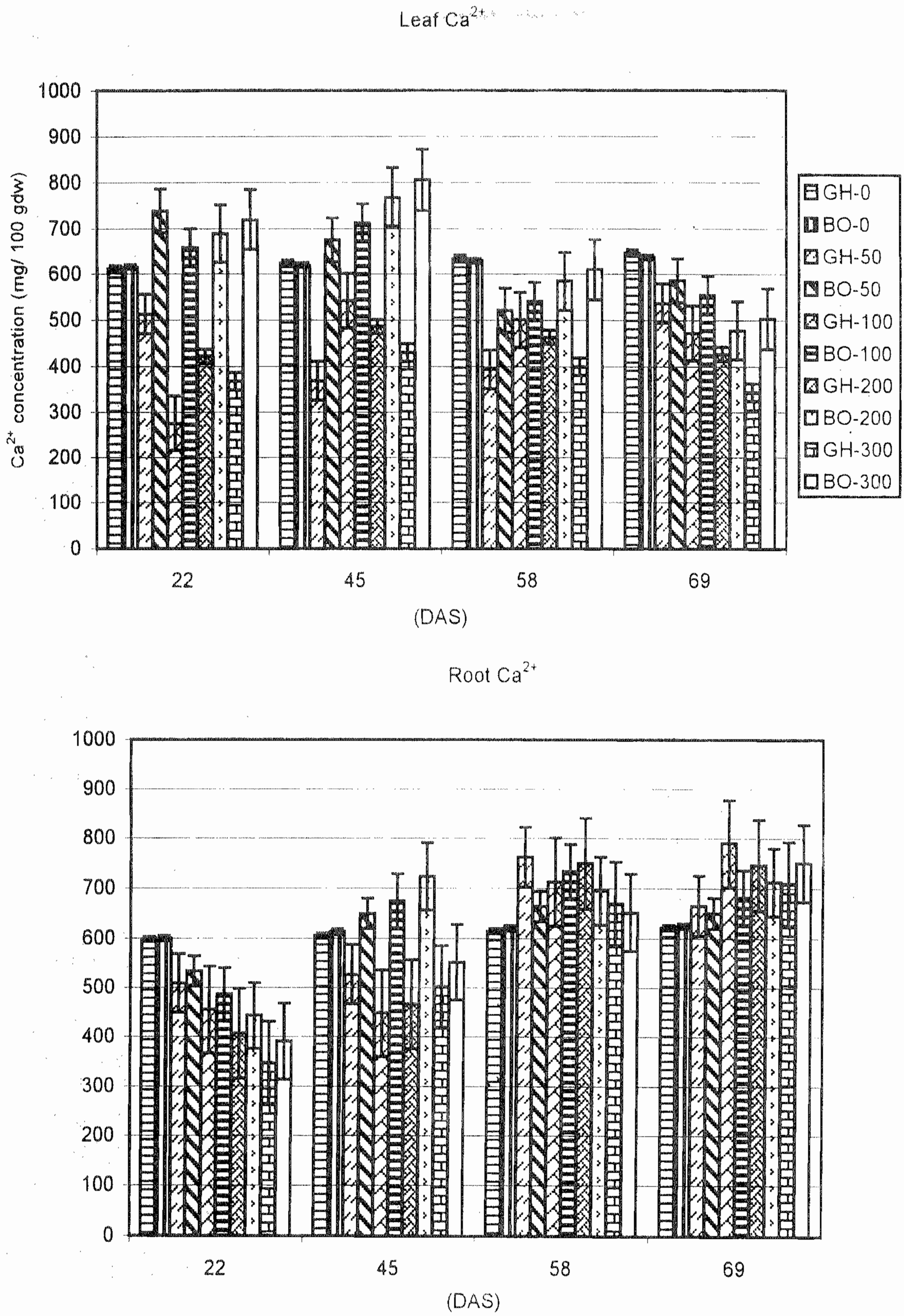

Fig. 3. Effects of 5 levels of NaCl treatments on the Ca2 concentrations in leaves (A) and roots (B) of Ghods and Boolani. GH, Ghods; BO, Boolani; 0, no NaCl; 50, 50 mM NaCl; 100, 100 mM NaCl; 200, 200 mM NaCl; 300, 300 mM NaCl.

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