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The Effect of Salinity on Ion Accumulation and Anatomical Attributes in Mungbean (*Phaseolus radiatus* L. cv. BARI-3) Seedlings

PARVEEN RASHID, J.L. KARMOKER, SABANANDO CHAKRABORTTY AND BIMAL CHANDRA SARKER
Department of Botany, Dhaka University, Dhaka 1000, Bangladesh

ABSTRACT

NaCl induced salinity resulted in a sharp increase in Na^+ and Cl^- with the concomitant decrease in K^+ accumulation in the root, stem and leaf of mungbean (*Phaseolus radiatus* cv. BARI-3) seedlings. Anatomical study showed that salinity caused inhibition of growth of vascular elements.

Key Words: Salinity; Ion accumulation; Anatomy; Mungbean

INTRODUCTION

Soil salinity is a major concern to the agriculture in arid and semi-arid regions. According to an estimation one-third of the world's land surface is arid or semi-arid ($4.8x10^9$ ha), out of which one-half is estimated to be affected by salinity (Bradbury & Ahmad, 1990). Critically, the problem of salinization is increasing, often due to bad agricultural practices. Irrigated land is particularly at risk with approx. one-third being significantly affected by salinity. Despite its relatively small area, irrigated land is estimated to produce one-third of the world's food (Munns, 2002), so salinization of this resource is particularly critical. Salinity problems in Bangladesh are quite different from those of the arid and semi-arid regions of the world. Here the salinity originates from seas. The vast area of land is becoming unproductive each year due to ever-increasing salt accumulation. As a result of high tide and inundation by saline sea water along with the absence of regular adequate rainfall, the soil in the coastal areas becomes saline. About 52.8% of the net cultivated area in the coastal and offshore areas of Bangladesh is affected by varying degrees of salinity (Karim *et al*., 1990). Salinity stress causes an imbalance in the uptake of mineral nutrients and their distribution within the plants (Grattan & Grieve, 1992; Glenn *et al*., 1999). Morphology, anatomy, ultra-structure and metabolism of plant species are also deeply affected by salt stress (Prat & Fathi-Ettai, 1990). It is important to understand the mechanism of physiological adaptation as well as changes in anatomical structure under salinity that may help plant breeder to evolve a salt tolerant variety. The present investigation was, therefore, undertaken to study the effect of salinity on the accumulation of ions and anatomical structure of mungbean.

MATERIALS AND METHODS

Mungbean (*Phaseolus radiatus* L. cv. BARI-3) was used as an experimental material and the seeds were collected through the courtesy of Bangladesh Agricultural Research Institute, Gazipur. Seeds were grown in sand culture (Hewitt, 1966) for ion accumulation as well as anatomical study. Modified half-strength Hoagland solution (Hoagland & Arnon, 1950) was used as nutrient solution. NaCl solution of 25, 50 and 75 mM made in half-strength Hoagland solution were used as salinity treatments. Surface sterilized seeds were germinated in pots filled with purified sand. The sand of control pots were always moistened with half-strength Hoagland solution and those of salinity treatment were soaked with 25, 50 and 75 mM NaCl solution. The plants were subjected to salinity treatments from the initial state of the experiment. Content of ions was measured in root, stem and leaf after 7 and 14 days of salinity treatments. Na^+ and K^+ contents were measured using a flame photometer at a wave length of 767 and 589 nm, respectively while Cl^- was measured following titrametric method (Begum *et al*., 1992). Each measurement of ion accumulation was repeated thrice. For studying anatomical structure, root and stem segments were collected from 25-day-old seedlings of both control and saline treatment of 50 mM NaCl. Stem segments (internodes) were collected 1 cm above while the roots were collected 3 cm below the sand surface. Free hand sectioning was done throughout the investigation. The sections were stained in safranin and fast green and mounted in glycerin and studied immediately with the help of compound microscope. Photographs of sections were taken using a compound microscope with photographic attachment (Model: HB-1019Af, Nikon, Japan).

RESULTS AND DISCUSSION

Effects of salinity on ion accumulation. Accumulation of ions was measured 7 and 14 days after salinity treatment. But majority of the seedlings grown on 75 mM NaCl stress mortared before 14 days and the accumulation of ions was not remarkable in seedlings grown in 25 mM NaCl treatment. Hence ion accumulation study under 25 mM and 75 mM NaCl treatment was discarded. So 50 mM NaCl treatment was considered as salinity treatment and accumulation of ions was measured on this treatment.

In 7-day old intact seedlings, the accumulation of Na^+ in the root was increased by 3.5-fold while in the stem and leaf it was increased by 5.9 and 3.4-fold respectively under salinity treatment as compared to control (Fig. 1A). Salinity caused a 27.7% decrease of K^+ accumulation in the root as compared to control. Similarly, K^+ content of stem and leaf was decreased by 24.7 and 31.4%, respectively following salinity treatment (Fig. 1C). Salinity caused an increase in Cl^- accumulation in the root by 1.7-fold while in the stem

Fig. 1. Effects of NaCl stress on accumulation of Na^+ (A, B), K^+ (C, D) and Cl^- (E, F) in the root, stem and leaf of 7- and 14-day-old seedlings respectively in mungbean. Each value is the mean of three replicates and bar represents ± standard error

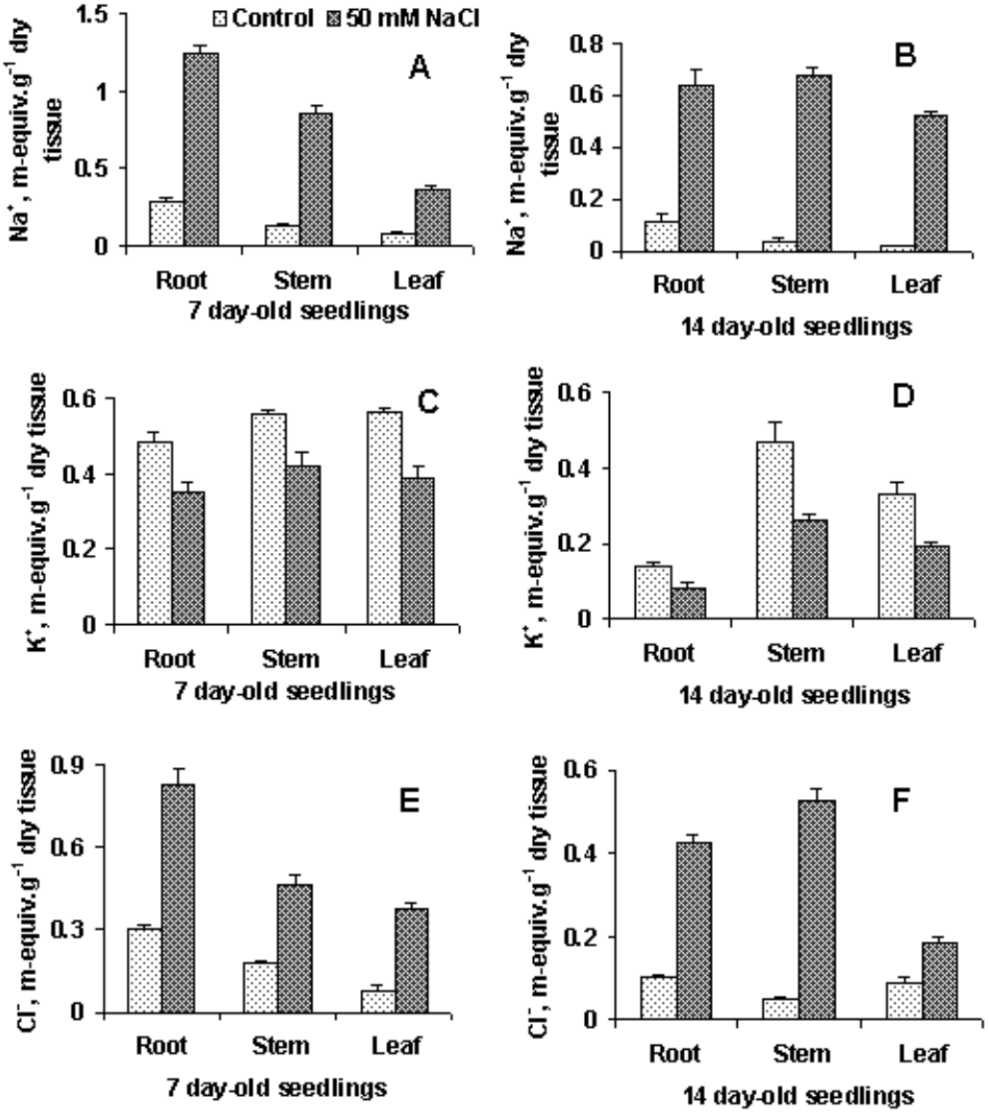
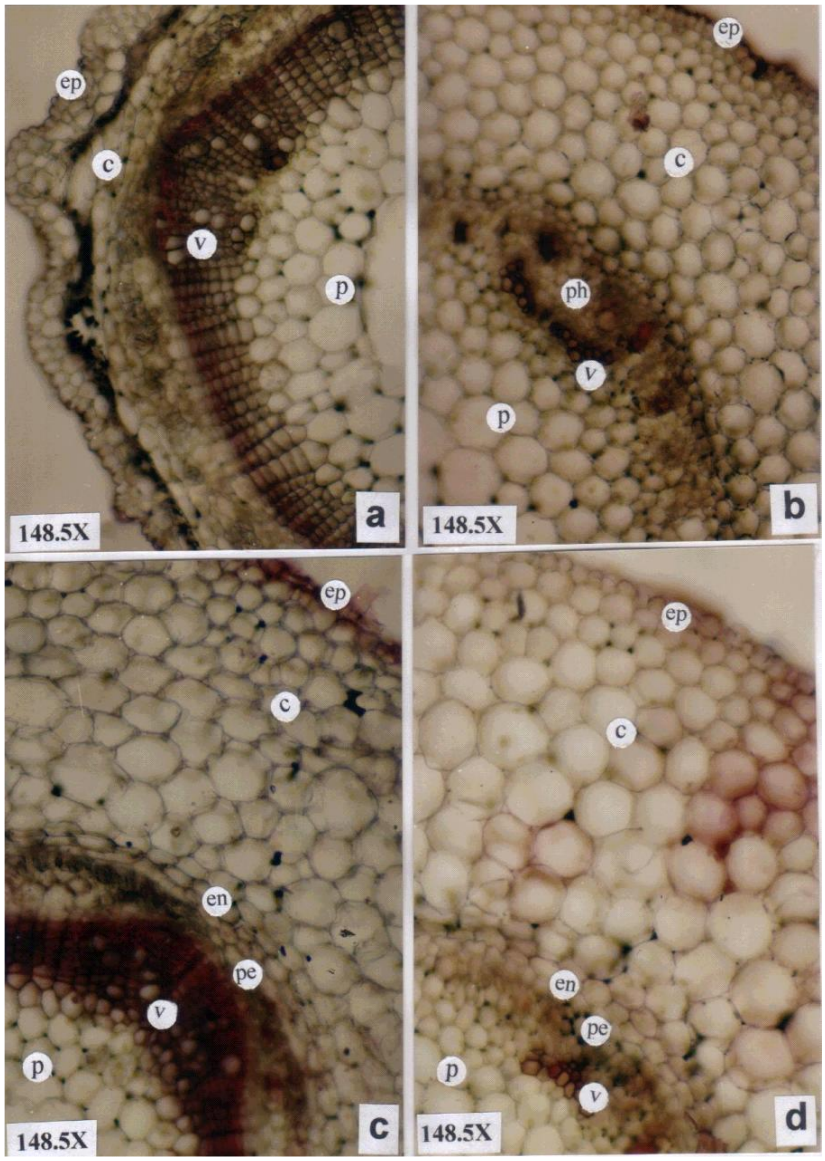


Fig. 2. A part of cross section of stem of 25 day-old mungbean seedlings grown in absence of NaCl (a) and in presence of NaCl (50 mM) (b). A part of cross section of the root grown in absence of NaCl (c) and in presence of NaCl (50 mM) (d). Note the inhibition of growth of vascular system in both stem and root under salinity treatment. ep: epidermis, c:cortex, v: vascular bundle, ph: phloem, p: pith, en: endodermis, pe: pericycle



and leaf the same was increased by 1.6 and 3.7-fold compared to control (Fig. 1E).

In 14-day-old intact seedlings, the accumulation Na^+ in the root, stem and leaf was increased by 4.8, 20.2 and 27.9-fold respectively under salinity stress compared to control (Fig. 1B). Salinity stress caused a decrease of K^+ in the root, stem and leaf by 41.0, 39.8 and 43.6%, respectively as compared to control under salinity (Fig. 1D). Salinity treatment resulted in an increase of Cl^- accumulation in the root by 3.1-fold. Similarly, Cl^- content of stem and leaf under salinity was increased by 10.7 and 1.1-fold, respectively compared to control (Fig. 1F).

In shoots, high concentrations of Na^+ can cause a range of osmotic and metabolic problems for plants. Leaves are more vulnerable than roots to Na^+, simply because Na^+ (and Cl^-) accumulates to higher concentrations in shoots than in roots (Tester & Davenport, 2003). Roots tend to maintain fairly constant levels of NaCl over time, and can regulate NaCl levels by export to the soil or to the shoot. Metabolic toxicity of Na^+ is largely a result of its ability to compete with K^+ for binding sites essential for cellular function. More than 50 enzymes are activated by K^+, and

Na^+ cannot substitute in this role (Bhandal & Malik, 1988). Thus, high levels of Na^+, or high Na^+: K^+ ratios can disrupt various enzymatic processes in the cytoplasm. Moreover, protein synthesis requires high concentrations of K^+, owing to the K^+ requirement for the binding of tRNA to ribosomes (Blaha *et al*., 2000) and probably other aspects of ribosome function (Wyn Jones *et al*., 1979). The disruption of protein synthesis by elevated concentrations of Na^+ appears to be an important cause of damage by Na^+.

Yeo *et al*. (1977) observed that when plants were grown in NaCl or Na_2SO_4 salinity, Na^+ content increased but that of K^+ decreased. Weimberg (1987) found that K^+ accumulation decreased with the increase in Na^+ accumulation in *Triticum turgidium* and *T. aestivum* following salinity treatment. Similar results were also obtained by Al-Rawahy (1992) in tomato, Yang *et al*. (1990) in *Sorghum bicolor*, Sharma (1989) and Begum *et al*. (1992) in wheat and Warwick and Bailey (1997) in *Triglochina maritima*.

Effects of salinity on anatomical structure. A part of transverse sections of the stem of seedlings grown in absence and presence of NaCl are presented respectively in Figs. 2a and 2b. The cortex comprised of flattened and compressed parenchymatous cells in absence of NaCl (Fig. 2a). Under salinity, cortical cells are large, more or less round with intercellular spaces (Fig. 2b). Vascular bundles were radially arranged and secondary growth was noticed in control plant. On the other hand, cambium ring was not found in treated plant. In vascular cylinder the main differences were occurrence of more xylem vessels with large cavity in control plant while in treated ones vascular cylinder was very poor. The most significant structural changes induced in root by exposure to NaCl occurred in the vascular system (Figs. 2c, 2d). Abundance of xylem ray was found in control root (Fig. 2c) than that of treated ones (Fig. 2d). The vascular system in the root showed large prominent metaxylem vessels while the same were smaller and few in number in treated ones. So NaCl treatment caused inhibition of growth of vascular system in mungbean seedlings. Responses to salinity are often expressed as anatomical and cytological changes (Winter, 1988; Huang & Van Steveninck, 1990). Furthermore, such changes can differ from one organ to another and/or at different levels of organization (Mills, 1989). Here the vascular system of the plant is mainly affected due to salinity.

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