Plants try to grow and develop by adapting themselves to unfavorable conditions in their environment and by developing some defense mechanisms against all kinds of biotic or abiotic stress factors. Levitt (1980), who provided important information about salt stress in plants and responses of plants against it, reported that handling the salt stress could be overcome by avoiding it and/or by developing a tolerance mechanism for it. Tal (1983) and Lauchli (1986) agreed with this concept. They proposed that the low permeability of plant root cell for salt kept salt away from plant shoot. Root cells of plants that can tolerate high levels of salt should have as high permeability as possible. Furthermore, plants can move salt from shoot by pumping Na$^+$ ion out of cell as a salt avoiding mechanism. Efflux of Na$^+$ ion from cytoplasm via Na$^+$-pump helps to maintain plant tolerable limits of Na$^+$ level (Yang et al. 1990). Another method is to decrease salt levels that are accumulated by fast growth, in other words to dilute salt in growth. Keeping salt ions away accumulated in plasma cell by isolating them in vacuoles is another mechanism that protects plants from harmful effects of salt (Tattini et al. 1994, Zhang and Blumward 2001). The tolerance to salt and adaptation to it was also observed; plants can develop it by reducing the transmission of Na$^+$ ion from plant roots to shoot and leaves (Poljakoff-Mayber et al. 1987). Na$^+$ and Cl$^-$ ions are well distributed among organs and tissues of green parts in plants well tolerating salt. Storing Na and Cl$^-$ ions mainly in old leaves and having a limited transmission of salt into young leaves serves as a protection from detrimental effects of salt.

Keywords: *Phaseolus vulgaris*; green bean genotypes; salt stress; plant parts; ion accumulation

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oxidative damage (MDA) in lipids and some ions (Na+, K+, Ca2+) contents and ratios (K/Na, Ca/Na). At the end of the study, one salt tolerant (GS57) and one salt-sensitive variety (4F-89) were selected according to these growth parameters.

The objective was to determine the exact mechanism for salt-tolerance in GS57 and salt-sensitive 4F-89 by individual examination of the levels of ions in root, shoot, and different leaf levels of bean. Determining of the mechanism involved in ion balance regulation in bean could point out physiological targets for breeding program aimed at increasing the salt tolerance of this crop.

**MATERIAL AND METHODS**

**Plant material.** As the plant material, one salt-tolerant (Gevas Sirik 57) and one salt-sensitive (4F-89 French) local Turkish green bean varieties, whose salt tolerance characteristics were determined in our previous study (Yasar 2006), were used.

**Plant growth and treatments.** The green bean seeds were germinated in plastic pots (40 × 25 × 5 cm) filled with perlite in growth chamber with 16/8 h light/dark photoperiod, at 25 ± 2°C and 70% humidity. Seedlings were irrigated with Hoagland nutrient solution. Plants were grown in these pots until the emergency of the first two leaves. Afterwards, seedlings were transplanted to hydroponic culture. For hydroponic culture, plastic developing dishes (40 × 25 × 5 cm) filled with Hoagland nutrient solution were used. The nutrient solution was renewed once a week. Seedlings were grown under control conditions until the emergency of the fourth leaf; at the same time salt stress treatment was initiated. In the salt treatment, the first increment of salt containing 50mM NaCl was added and other increments of given concentrations were added daily until the salt concentration reached the final treatment level of 100mM NaCl. Treatments were replicated four times, each repetition having 15 plants, and arranged in a completely randomized design. 10 days after the salt treatment, six plants were harvested from each genotype at random. Whole plant weights were measured and these plants were separated into root, shoot and leaves for ion analysis.

**Determination of ion content.** For ion determination, fresh samples of root, shoot, first two old leaves and first two young leaves of one shoot were extracted in concentrated 0.1N nitric acid. Na+, K+ and Ca2+ contents were determined by flame photometry in the samples from green bean plants (Taleisnik and Grunberg 1994). Relative ion accumulation (Na+, K+ and Ca2+) in whole plant (wp) was calculated as described by Taleisnik and Grunberg (1994).

**RESULTS AND DISCUSSION**

0mM and 100mM NaCl were applied to GS57 (salt-tolerant genotype) and 4F-89 (salt-sensitive genotype). Then, we tried to reveal ion distribution mechanisms of salt-sensitive and salt-tolerant beans by determination of fresh plant weight, accumulation of Na+, K+, Ca2+ ions in root, shoot, old and young leaves and a relative accumulation of these ions in the whole plant (Tables 1 and 2).

100mM NaCl applied salt-tolerant and salt-sensitive bean genotypes demonstrated very different development patterns. While 4F-89 had a high decrease in fresh plant weight, GS57 fresh weight

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Salt treatment</th>
<th>FW&lt;sub&gt;wp&lt;/sub&gt; (g)</th>
<th>Na&lt;sup&gt;+&lt;/sup&gt;&lt;sub&gt;wp&lt;/sub&gt; (µg/100 mg wp)</th>
<th>K&lt;sup&gt;+&lt;/sup&gt;&lt;sub&gt;wp&lt;/sub&gt; (µg/100 mg wp)</th>
<th>Ca&lt;sup&gt;2+&lt;/sup&gt;&lt;sub&gt;wp&lt;/sub&gt; (µg/100 mg wp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4F-89</td>
<td>0</td>
<td>5.971 bA*</td>
<td>241.35 bB</td>
<td>410.60 aA</td>
<td>215.55 aA</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>2.004 bB</td>
<td>553.00 aA</td>
<td>273.25 bB</td>
<td>211.32 aA</td>
</tr>
<tr>
<td>GS57</td>
<td>0</td>
<td>9.566 aA</td>
<td>281.60 aB</td>
<td>373.35 bA</td>
<td>178.73 bA</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>6.868 aB</td>
<td>539.25 bA</td>
<td>308.50 aB</td>
<td>197.25 bA</td>
</tr>
</tbody>
</table>

*Different letter case represents different means of genotypes in the same dose level (comparison of genotypes)

*Different upper case letter represent different means of fresh weight and ions in the same genotypes and dose level (comparison of parameters)
decreased less (Table 1). Total K\(^+\) and Na\(^+\) ions accumulation and distribution among the organs indicate the level of tolerance of beans to salt. If a plant is not able to be selective in transporting ions taken from its root to growing ends or did not transport them at a certain rate, the rate of decrease in growth may be high. Similar patterns were reported by Wolf et al. (1991) with barley, and Perez et al. (1993) and Taleisnik and Grunberg (1994) with tomato.

Both salt-sensitive and salt-tolerant genotypes had a higher Na\(^+\) accumulation in whole plant and organs than control when Na\(^+\) accumulation was investigated in genotypes under salt stress. However, there was no increase in Na\(^+\) deposition in the young leaves of GS57; the highest increase was observed in the roots and shoot of plants. But whereas Na\(^+\) accumulation was low in young leaves, it was very high in old leaves and the body of salt-tolerant GS57. The highest Na\(^+\) accumulation, both overall and in organs, was observed in 4F-89 among plants grown under stress (Table 2, Figure 1). Salim and Pitman (1983) with mung bean plants (Vigna radiata L.), Wolf et al. (1991) with barley, Soliman and Doss (1992), Perez-Alfocea et al. (1993) and Cuatero and Fernandez-Munoz (1999) with tomato, and Santa-Maria and Epstein (2001) with wheat, reported similar results and indicated that the distribution of Na\(^+\) ions varies among organs and tissues of green parts of plants that tolerate salt well. They also noted that transportations of Na\(^+\) ions into young leaves were limited because the plants keep them in old leaves, which is known as the most desirable characteristics of salt-tolerant plant. Moreover, it was reported that K\(^+\) ion levels were higher in young leaves than in old leaves in these plants; this balance was achieved by transporting K\(^+\) in old leaves to young leaves through phloem.

Similar to total plant K\(^+\) concentrations, K\(^+\) concentrations in all organs of all varieties, except plant shoot, decreased more compared with control. K\(^+\) accumulation was high in organs in which Na\(^+\) concentrations was low, and vice versa. While Na\(^+\) content was low in young and high in old leaves of GS57, K\(^+\) content was contrary. In 4F-89 Na\(^+\) content was similar in old and young leaves and at the same time it was lower, compared to other organs; in roots and shoots it was relatively high. K\(^+\) content in this variety was lower in all organs compared to GS57 (Table 2, Figure 1). These results indicate that there was a competition between Na\(^+\) and K\(^+\) regarding their uptake. The salt-tolerant genotype has a greater

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**Table 2. In roots, shoots and old and young leaves of salt-sensitive and salt-tolerant green bean genotypes Na\(^+\), K\(^+\) and Ca\(^{2+}\) ions accumulations (µg/mg fresh weight)**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Salt treatment (mM)</th>
<th>Varieties</th>
<th>Fresh leaf</th>
<th>Old leaf</th>
<th>Shoot</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0</td>
<td>4F-89</td>
<td>2.686 bBI*</td>
<td>3.692 bAII</td>
<td>1.298 aDII</td>
<td>1.978 bCII</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>3.113 aB1</td>
<td>4.028 aAII</td>
<td>1.430 aDII</td>
<td>2.693 aCII</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>4F-89</td>
<td>4.757 aBI</td>
<td>4.672 bB1</td>
<td>6.278 aA1</td>
<td>6.412 aA1</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>3.170 bC1</td>
<td>6.645 aA1</td>
<td>6.320 aA1</td>
<td>5.434 bB1</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td>4F-89</td>
<td>6.219 aA1</td>
<td>5.416 aB1</td>
<td>2.110 aDII</td>
<td>2.687 aCII</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>5.066 bA1</td>
<td>4.868 bA1</td>
<td>2.442 aBII</td>
<td>2.558 aBII</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>4F-89</td>
<td>3.745 bAII</td>
<td>3.472 aBII</td>
<td>1.934 bC1</td>
<td>1.778 bCII</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>4.157 aAII</td>
<td>3.341 aBII</td>
<td>2.986 aC1</td>
<td>1.856 aDII</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>0</td>
<td>4F-89</td>
<td>4.303 aA1</td>
<td>3.703 aB1</td>
<td>0.235 aCII</td>
<td>0.381 aC1</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>3.589 bA1</td>
<td>2.762 bB1</td>
<td>0.238 aDII</td>
<td>0.560 aC1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>4F-89</td>
<td>3.590 aAII</td>
<td>2.699 bBII</td>
<td>1.733 bC1</td>
<td>0.431 aD1</td>
</tr>
<tr>
<td></td>
<td>GS57</td>
<td>2.540 bBII</td>
<td>2.922 aA1</td>
<td>1.939 aC1</td>
<td>0.449 aDI</td>
<td></td>
</tr>
</tbody>
</table>

*Different letter case represents different means of genotypes in the same dose level (comparison of genotypes)
*Different upper case letters represent different means of organ in the same genotypes and dose level (comparison of organs)
*Different numbers represent different means of dose level in the same genotypes and organs (comparison of doses)

Ca²⁺ content in young leaves of GS57 and 4F-89 decreased. Ca²⁺ accumulation in young leaves of 4F-89 French was greater compared with its other organs and with young leaves of GS57. Ca²⁺ content was the highest in young leaves, followed by old leaves, shoot, and roots. Ca²⁺ content decreased only in old leaves of 4F-89, but it did not change the tolerance of the genotype. Ca²⁺ accumulation in the shoot of both genotypes did not vary (Table 2, Figure 1). Similar results were reported with different plants by Cramer et al. (1986), Lauchli (1990), Cuartero et al. (1992), Rengel (1992), Huang and Redmann (1995), Zhang and Blumward (2001), Daşgan et al. (2002).

It was observed that beans can develop different mechanism to accept and adapt to high levels of salt. GS57 kept Na ions mainly in old leaves by taking them from roots, and limited their transport into young leaves. A higher concentration of K⁺ was observed in young leaves than in old leaves in this genotype.

REFERENCES


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