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DRY-MATTER YIELD AND NITROGEN-15, Na^+, Cl^-, and K^+ CONTENT OF TOMATOES UNDER SODIUM CHLORIDE STRESS[1]

S. A. Al-Rawahy, J. L. Stroehlein, and M. Pessarakli

Department of Soil and Water Science, University of Arizona, Tucson, AZ 85721

ABSTRACT: Crop yield and nutrient uptake are often impaired under salt, water, or both stress conditions. This study was designed to gather further information concerning NaCl stress effects on these components. Therefore, dry-matter yield, nitrogen (total and ^{15}N) uptake, Na^+, Cl^- and K^+ content of leaves, stems, and roots of tomato (*Lycopersicum esculentum* Mill., cv. 'Columbia') plants subjected to NaCl stress were studied in a greenhouse. Saline treatments consisted of 0.3 (control), 4.3, and 8.3 bars osmotic pressures. Plants were 80 days old at the start of salt and ^{15}N treatments, and each plant was in a pot containing 1.8 kg of washed quartz sand. The ^{15}N as $K^{15}NO_3$ solution was provided to plants at 10-day intervals over a 30-day period. Plants were harvested at 5-day intervals during the 30-day ^{15}N treatment period.

Dry-matter production, total-N, and ^{15}N uptake at final harvests were significantly lower for saline treatments as compared with a control. There was a 46% reduction in leaf dry weights on day 20 due to NaCl stress. This value was 36% for roots and 25% for stems. Generally, similar reduction patterns resulted in total-N and ^{15}N uptake in plants due to NaCl stress. The Na^+ and Cl^- contents were substantially higher in stressed plants compared with the controls. The leaf

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K^+ levels decreased with increased salinity. For most of the studied parameters, leaves were affected the most, roots were intermediate, and stems the least by salinity.

INTRODUCTION

In many areas of the world under irrigated agriculture, farmers must use saline water to irrigate their crops because adequate supplies of non-saline water are limited. Use of saline water can increase salt concentration in the soil, resulting in stunted plant growth and reduced yields.

Some irrigation waters contain high amounts of NaCl, which contribute to specific ion effects of Cl^-, Na^+, or both and to antagonistic effects on nutrient elements. Wallace and Berry (19) suggested that wheat (*Triticum aestivum* L.) yield reduction due to increased salinity might not be entirely due to Cl^- toxicity, but might be partially due to induced deficiency of NO_3^- caused by the external Cl^- concentration.

Pessarakli and Tucker (17) found that dry matter production by tomato (*Lycopersicum esculentum* Mill.) plants decreased with increased salinity, and that total water absorbed by plants decreased linearly with increased salinity. Pessarakli et al. (16) reported similar results in which the salt-stressed sweet corn (*Zea mays* L.) plants absorbed significantly less water than did the control. In a study conducted by Papadopoulos and Rendig (15), fresh fruit yields of tomatoes decreased as nutrient solution salinity increased from 2 to 5 dS m^{-1}.

Either NaCl or water stress significantly decreased absorption of NH_4^+ and NO_3^- in red kidney beans (*Phaseolus vulgaris* L.) (9). Abdul-Kadir and Paulsen (1) reported that salt stress retarded growth of wheat and decreased N content of the whole plant. According to Bernstein et al. (4), decreased N uptake with increased salinity resulted in reduced plant growth.

Abel and Mackenzie (2) found that soybean (*Glycine max* L.) varieties, salt tolerant or sensitive, accumulated Cl^- in the roots when the soil was treated with NaCl. However, only salt-sensitive varieties accumulated Cl^- in the stem and

leaves. They suggested that the salt sensitivity of certain varieties is attributed to their ability to exclude Cl^- from the above ground parts.

It is possible that the first stage of anion uptake is its penetration to the lipid fraction of the root membrane. Therefore, different degrees of resistance of various plants to salinity may be due to the specific lipid composition of their roots (12).

Although early work indicated that different plant organs may respond differently when subjected to water stress (10), not much work has been done to compare the effect of salinity on growth parameters of these organs. This study was initiated in order to gain a better understanding of plant response to salinity by studying different plant organs (i.e., leaves, stems, and roots). Since NaCl is the most abundant salt found in irrigated agriculture, it was used as the source of salinity in this investigation.

The objectives of this study were to evaluate the effects of NaCl stress on dry-matter yield of leaves, stems, and roots of tomato plants; the uptake of N and ^{15}N; and the accumulation of Na^+, Cl^-, and K^+ in these tissues during the flower bud stage of development.

MATERIALS AND METHODS

This study was conducted in a greenhouse at the University of Arizona. The range in temperatures in the greenhouse was from 15°C to 32°C with a 14-hour photoperiod over the experimental period.

Tomato seeds (cv. 'Columbia') were sown in trays containing washed quartz sand. Thirty days after emergence, the seedlings were transplanted into individual 235-mL polystyrene cups also containing sand. Seedlings were irrigated daily with one-half strength Hoagland solution (11). Thirty days later, each plant was transplanted into a pot (17.5 cm diameter and 21 cm height) containing 1.8 kg washed quartz sand, and 20 mL of complete Hoagland nutrient solution was applied daily with each irrigation. Plants were allowed to grow for 20 additional days before the salt and ^{15}N treatments were started.

The salt treatments were as follows: (i) control in which Hoagland solution was mixed with distilled water resulting in 0.3 bars osmotic pressure, (ii) medium saline water of 4.3 bars osmotic pressure, and (iii) high saline water of 8.3 bars osmotic pressure. In both medium and high saline treatments the Hoagland solution contributed 0.3 bars osmotic pressure. The 4 bars of (ii) and the 8 bars of (iii) (above) were obtained by adding NaCl (24 mmol NaCl per liter of nutrient solution for each bar) to distilled water (16,17). The ^{15}N treatments consisted of $K^{15}NO_3$ (5.1 atom % ^{15}N) in split applications, 10 mg ^{15}N per pot at the initiation of the salt treatment, and 10 mg ^{15}N per pot on 10 and 20 days later. The experimental design was completely randomized. Two replications of each treatment were harvested every 5 days, for a total of six harvests over a 30-day salt and ^{15}N treatment period.

Flower buds became visible a week after NaCl and ^{15}N treatments started, but they were removed as they formed to maintain the plants in a vegetative growth stage (7). Harvested plants were separated into leaves, stems, and roots. The roots were washed with distilled water and all plant parts were dried at 65°C for 48 hours for dry weight measurements. Plant samples were then ground in a Wiley mill to pass through a 2 mm sieve. Total N and ^{15}N uptake were calculated for each treatment at each harvest using data obtained from a modified Kjeldahl method (5) for nitrate plus nitrite and mass spectrometric technique for ^{15}N determination (6). In addition, Na^+, Cl^-, and K^+ were determined in plant parts using atomic absorption spectrophotometry for Na^+ and K^+ and ion chromatography for Cl^- (8).

Analysis of variance on data was performed using procedures described by Steel and Torrie (18). The means were separated by the least significant difference (LSD) test at the 0.05 level of confidence.

RESULTS AND DISCUSSION

Dry Weights of Leaves: At 5 and 10 days after the start of the salt and ^{15}N treatments, there were no significant differences in plants dry weights due to

treatments. Thereafter, the controlled plants had higher dry weights than did plants treated with either the medium or the high salt (Table 1). The medium and the high saline treatments were not significantly different from each other until the 30-day harvest, when the difference became significant.

These results indicate that it takes between 10 to 15 days for the dry weight of leaves to be significantly affected by the medium (4.3 bars osmotic

TABLE 1. Dry Weights of Tomato Leaves, Stems, and Roots for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Dry wt. of plant parts					
	Harvest time (days)					
	5	10	15	20	25	30
Bar	g plant^{-1}†					
	Leaves					
Control (0.3)	1.68	2.62	4.26	7.13	10.45	11.74
4.3	1.63	2.46	3.38	3.82	4.73	7.59
8.3	1.63	2.43	2.92	3.51	3.60	4.18
LSD (0.05)‡	0.83	1.11	0.71	0.79	1.54	1.96
	Stems					
Control (0.3)	0.71	1.04	1.48	2.35	3.49	3.30
4.3	0.67	1.03	1.41	1.76	2.56	2.14
8.3	0.61	0.97	1.33	1.65	2.01	1.84
LSD (0.05)‡	0.30	0.44	0.15	0.66	0.74	0.97
	Roots					
Control (0.3)	1.21	1.41	1.74	2.75	4.19	4.50
4.3	0.72	0.92	1.27	1.75	2.27	2.30
8.3	0.67	0.91	1.25	1.66	1.71	1.74
LSD (0.05)‡	0.29	0.51	0.51	0.80	1.66	0.40

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

pressure) salinity level used in this study. By 30 days, the high salinity leaf dry weight was significantly lower than that of the medium salinity treatment.

Dry Weights of Stems: As indicated in Table 1, the difference between the control and both the medium (4.3 bars) and the high (8.3 bars) saline treatment means was significant only on the 25- and 30-day harvests, while the two saline treatments were not significantly different throughout the study period.

Since differences in stem dry weights between the control and the saline treatments became apparent 10 days later than was the case for leaves, stem response to salinity was less sensitive than that of the leaf. The stem also seems to be able to withstand a wider salinity range than leaves since there was no significant difference between the high and the medium saline treatment means of dry weights at any harvest.

Dry Weights of Roots: At the first harvest (day 5), the mean root dry weights from the saline treatments were numerically lower than the mean root dry weights of the control, but the difference was not persistent for the 10- and 15-day harvests (Table 1). The numerical difference on day 5 may have been due to the effect of original root weight, which may have been slightly higher for the control at the start of the saline treatments. From day 20 to 30 there was a significant difference between the control and the medium and the high saline treatment means. Meanwhile, the medium and the high saline treatment means were not significantly different throughout the study period.

For dry weight, the degree of sensitivity of roots to salinity lies between that of leaves and of the stems, but closer to that of the leaves. On day 20, reductions in dry weights were 46% for leaves and 36% for roots due to the highest salinity relative to the control, while there was no significant reduction in stem dry weight. On day 25, dry-matter yield reduction due to salinity for leaves, stems, and roots were 55%, 27%, and 46%, respectively. On day 30, the high salinity resulted in 64% and 61% dry-matter yield reduction (relative to the control) in leaves and roots, respectively.

The above results agree with those of Pessarakli and Tucker (17), who also found that the dry matter of roots and shoots of young tomato plants decreased as NaCl salinity increased. Kafkafi et al. (13), working with tomatoes, also found a decline in dry-matter yield with increasing Cl^- concentration in solution at all NO_3^- and $H_2PO_4^-$ levels. Al-Rawahy (3), using NaCl, Na_2SO_4, and $CaCl_2$ in irrigation water, found that increasing salinity decreased dry-matter yield of tomato plants with NaCl being the most detrimental of the salts studied.

Dry-matter yield results show that there is a time lag before significant differences among treatments appear after exposing the plants to salt stress. Within the same species and the same variety, the difference in this time lag may be largely due to the stage of plant growth. In this study, a significant difference in leaves dry-matter yield between the control and the two saline treatments was noted on day 15. The treatments were started on 80-day-old plants. However, Pessarakli and Tucker (17) found that with tomatoes of the same variety, the treatment means showed a significant difference in dry-matter yield within 7 days of starting the saline treatments on 14-day-old plants. The older plants used in this study were larger in size, better established, and therefore, more tolerant to salinity. For older plants, it probably takes a longer time for stress to show adverse effects on some of the processes within the system than for younger plants. This is consistent with the findings of Maas et al. (14) on sorghum, that the vegetative stage is the most sensitive growth stage to salinity and the maturation stage is the least sensitive.

Nitrogen Concentration in Leaves: The high saline treatment mean for N concentration in leaves was significantly lower than the medium saline and the control means on the first harvest, indicating a very fast response (Table 2). On day 20, all the three means were significantly different, with the control and the high saline treatment means having the highest and the lowest values, respectively. It is interesting to note that at the last harvest, there was no significant difference among the three treatment means. This is probably due to the osmotic adjustment of the plants to saline treatments or due to growth dilution.

TABLE 2. Nitrogen Concentration of Tomato Leaves, Stems, and Roots for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Nitrogen concentration of plant parts					
	Harvest time (days)					
	5	10	15	20	25	30
Bar	g N kg^{-1} dry wt.†					
	Leaves					
Control (0.3)	42.9	43.1	40.3	37.7	40.1	36.3
4.3	39.8	36.1	32.9	32.7	32.8	32.4
8.3	24.1	31.1	31.2	21.1	32.0	26.6
LSD (0.05)‡	4.1	3.0	4.5	3.5	2.7	1.2
	Stems					
Control (0.3)	23.1	24.1	20.2	21.4	20.9	23.7
4.3	21.5	21.8	17.2	17.2	17.1	21.8
8.3	20.2	15.6	16.9	17.1	14.7	16.4
LSD (0.05)‡	3.4	1.5	4.8	0.3	5.6	4.9
	Roots					
Control (0.3)	24.8	31.6	27.3	27.5	27.9	27.3
4.3	24.2	27.3	25.7	26.4	26.8	24.6
8.3	21.4	25.8	20.4	19.5	20.1	18.8
LSD (0.05)‡	2.3	1.8	5.4	1.9	5.5	7.0

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

Nitrogen Concentration in Stems: A significant difference in N concentration in stems between the control and the two saline treatments appeared only on day 20, with the control having a higher value (Table 2). However, on day 30, the high saline treatment produced a significantly lower value than did the other two treatments.

Appearance of differences between the control and the saline treatments (medium and high) later in the study period as compared to leaves indicates that stem N concentration response to salinity was less sensitive than that of the leaf.

Nitrogen Concentration in Roots: There was no significant difference between the control and the medium saline treatments in root N concentration throughout the study period (Table 2). This implies that root N concentration was not affected by the medium saline treatment. However, the high saline treatment mean was significantly lower than both the control and the medium saline treatment means on days 5, 20, and 25.

The root N concentration showed a fast early response to salinity, as was the case for leaves. Then, there were no differences among the treatment means on day 10 because the roots may have adjusted osmotically to high salinity.

Total-N Uptake in Tomato Leaves: Differences between treatment means in total N uptake appeared on day 5, when the high saline treatment had a significantly lower value than did the control (Table 3). This trend continued to the following harvest. However, starting on day 15, the controls contained significantly higher total N than did both saline treatments. On days 20 and 30, the control plants had significantly higher total N content than did the salt-treated ones.

Since N uptake is a product of dry weight and N concentration, the factors that affected these two components would be the same as those affecting N uptake. Thus, the response trends affecting them would be a result of their combination effects on N uptake as discussed above.

Total-N Uptake in Tomato Stems: Total N content of stems was not different until day 20, when the control had a significantly higher value than did the saline treatments, which continued through days 25 and 30 (Table 3). On day 30, the control was significantly different than the saline treatments. As for stem dry weight and its N concentration, stem N uptake was less sensitive to salinity than that of the leaf.

Total-N Uptake in Tomato Roots: On day 5, the root total N uptake of the medium and the high saline treated plants was lower than that of the control

TABLE 3. Total-N Content of Tomato Leaves, Stems, and Roots for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Total-N uptake of plant parts					
	Harvest time (days)					
	5	10	15	20	25	30
Bar	mg N plant^{-1}†					
	Leaves					
Control (0.3)	70	113	172	269	419	471
4.3	66	87	111	125	155	246
8.3	40	60	91	72	115	111
LSD (0.05)‡	26	40	31	27	78	74
	Stems					
Control (0.3)	14	23	29	50	70	89
4.3	14	22	24	30	32	56
8.3	14	16	22	28	31	31
LSD (0.05)‡	8	7	8	13	34	17
	Roots					
Control (0.3)	26	45	45	84	84	135
4.3	18	26	35	50	60	57
8.3	16	23	26	43	45	33
LSD (0.05)‡	7	20	15	23	34	10

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

(Table 3). However, on days 10, 15, and 25, only the high saline treatment means were significantly lower than the controls, with medium saline treatment means showing no significant difference compared with the control and the high saline treatments.

Unlike root dry weight, root N uptake was more severely affected by the high saline than the low saline treatment.

Nitrogen-15 Uptake in Tomato Leaves: The high saline treatment means were significantly lower in ^{15}N uptake than the controls on days 5 and 10 by 48% and 56%, respectively (Table 4). On day 15, the medium and the high saline treatment means were 44% and 66% lower in ^{15}N uptake than the control, respectively. On day 20, the ^{15}N uptake values were 62% and 83% lower than those of the control in medium and high saline treatments, respectively. The

TABLE 4. Nitrogen-15 Content of Tomato Leaves, Stems, and Roots for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Nitrogen-15 uptake of plant parts					
	Harvest time (days)					
	5	10	15	20	25	30
Bar	mg ^{15}N plant^{-1}†					
	Leaves					
Control (0.3)	1.08	1.90	3.75	5.97	11.02	11.12
4.3	0.86	1.41	2.10	2.29	3.49	5.59
8.3	0.56	0.83	1.51	1.04	2.41	2.25
LSD (0.05)‡	0.51	0.68	0.72	0.74	1.80	2.89
	Stems					
Control (0.3)	0.25	0.42	0.69	1.13	1.84	2.19
4.3	0.21	0.38	0.46	0.56	0.67	0.88
8.3	0.20	0.24	0.40	0.42	0.62	0.61
LSD (0.05)‡	0.15	0.21	0.25	0.37	0.83	0.77
	Roots					
Control (0.3)	0.47	0.75	0.97	1.76	2.11	3.02
4.3	0.26	0.40	0.72	0.92	1.33	1.27
8.3	0.24	0.39	0.50	0.65	0.92	0.62
LSD (0.05)‡	0.16	0.38	0.11	0.48	0.73	0.50

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

respective values were 68% and 78% on day 25. By day 30, the ^{15}N content for the medium and the high saline treatments were lower than that of the control by 50% and 80%, respectively.

Nitrogen-15 Uptake in Tomato Stems: There were no significant differences among treatment means during the first two harvests. On the third harvest, ^{15}N uptake of stems was significantly different only between the high saline treatment and the control. However, during the last three harvests, the control plants had significantly higher stem ^{15}N uptake than did both the medium and the high saline treatments. Nevertheless, this value was not significantly different between the medium and the high saline treatments (Table 4). The reduction in the stem ^{15}N uptake due to the medium salinity level for days 20, 25, and 30 were 50%, 63%, and 60%, respectively. The respective values were 63%, 66%, and 72% for the high saline treatment.

The non-significant differences between the corresponding values for the medium and the high salinity levels at each of these harvests indicate that the high saline treatment did not have any further depressing effect on the stem ^{15}N uptake compared to that of the medium saline treatment.

Nitrogen-15 Uptake in Tomato Roots: Except for the harvest on day 10, the control means of root ^{15}N uptake were significantly higher than both the medium and the high saline treatments. On days 15 and 30, all the treatment means were significantly different, with the control and the high saline treatments having the highest and the lowest values, respectively (Table 4). On day 5, the saline treatments caused at least a 45% reduction in root ^{15}N uptake. On day 15, the medium and the high saline treatments caused reductions of 26% and 48% in root ^{15}N contents, respectively. On days 20 and 25, the reductions were 48% and 37% in root ^{15}N uptake due to the medium salinity, respectively. The respective values were 63% and 56% for the high saline treatment. On day 30, the medium saline treatment caused a 58% reduction in root ^{15}N uptake, and the high saline treatment caused a 79% reduction.

The above results of ^{15}N uptake of leaves, stems, and roots are in agreement with studies conducted by Pessarakli and Tucker (17) with young tomato plants and by Frota and Tucker (9) with red kidney beans, both of whom reported a reduction in ^{15}N uptake as a result of subjecting plants to NaCl stress.

Leaf Na^+, Cl^-, and K^+ Levels: The levels of Na^+ and Cl^- in the leaves increased with the duration of the saline treatments (Table 5). However, leaf Na^+ level

TABLE 5. Leaf Na^+, Cl^-, and K^+ Contents of Tomatoes for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Sodium, chlorine, and potassium content of plant parts — Harvest time (days)					
	5	10	15	20	25	30
Bar	---------- Leaf ----------					
	--------- mmol Na^+ g^{-1} dry wt.† ----------					
Control (0.3)	0.24	0.20	0.17	0.18	0.22	0.18
4.3	0.37	0.57	0.64	0.77	0.94	1.35
8.3	0.61	0.77	0.85	0.96	1.61	1.59
LSD (0.05)‡	0.39	0.45	0.32	0.38	0.14	0.36
	-------- mmol Cl^- g^{-1} dry wt.† ----------					
Control (0.3)	0.17	0.18	0.14	0.14	0.17	0.24
4.3	0.42	0.75	1.04	1.19	1.48	2.05
8.3	0.77	1.21	1.26	1.51	2.27	2.42
LSD (0.05)‡	0.26	0.39	0.22	0.65	0.15	0.06
	--------- mmol K^+ g^{-1} dry wt.† ----------					
Control (0.3)	1.23	1.27	1.53	1.81	2.23	1.96
4.3	1.18	1.21	1.30	1.29	1.57	1.69
8.3	1.16	1.17	1.15	1.06	1.34	1.53
LSD (0.05)‡	0.07	0.58	0.29	0.16	0.24	0.28

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

decreased slightly at 30 days relative to 25 days for the high saline treatment. Leaf Cl^- levels in the NaCl stressed plants were higher than those of Na^+. From day-15 to day-30 harvests, the Cl^- levels were about one and-a-half times greater than those of Na^+ for both saline treatments. Although the leaf K^+ levels decreased with increased salinity, their rates of increase with time were less than those for Na^+ and Cl^-.

The above results indicate that Na^+ is more restricted than Cl^- from entering the leaves. The K^+ provided by Hoagland solution probably caused this restriction. Wignarajah et al. (20), suggested that Na^+ may be restrained from entering the leaves by selectively favoring K^+ absorption in the roots of beans.

Stem Na^+, Cl^-, and K^+ Levels: There was less apparent increase in Na^+ and Cl^- levels in the stems than in the leaves over the duration of salinity. However, the Cl^- levels were higher than those of Na^+ (Table 6), and both Na^+ and Cl^- were lower in stems than in leaves, particularly, during the last three harvests. None of the saline treatments affected stem K^+, except on day 20 when both the medium and the high saline treatments had a lower K^+ level than did the control.

Root Na^+, Cl^-, and K^+ Levels: In the saline treatments the Na^+ levels in the roots were initially higher than those in the leaves and the stems. During the last two harvests, these values were intermediate or below the levels in the leaves, and above those in the stems (Table 7). However, the Cl^- levels in the roots were generally closer to those of the stems, but lower than those of the leaves. Both the medium and the high saline treatments had significantly higher root Na^+ and Cl^- levels than did the controls, with Cl^- showing more mean separations and higher levels than Na^+ after day 10. As for the levels of K^+ in the roots, there were no significant differences among the treatment means at any harvest.

CONCLUSIONS

The results of this study indicate that the detrimental effects of NaCl stress on growth of tomato is reflected in lower dry weights and decreased nitrogen (total and ^{15}N) uptake of plant parts.

TABLE 6. Stem Na^+, Cl^-, and K^+ Contents of Tomatoes for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Sodium, chlorine, and potassium content of plant parts — Harvest time (days)					
	5	10	15	20	25	30
Bar	Stem					
	mmol Na^+ g^{-1} dry wt.†					
Control (0.3)	0.35	0.30	0.27	0.18	0.21	0.20
4.3	0.40	0.53	0.51	0.48	0.45	0.50
8.3	0.66	0.64	0.66	0.57	0.67	0.51
LSD (0.05)‡	0.23	0.42	0.31	0.34	0.35	0.44
	mmol Cl^- g^{-1} dry wt.†					
Control (0.3)	0.24	0.24	0.23	0.17	0.18	0.23
4.3	0.59	0.87	1.07	0.91	0.99	1.16
8.3	1.04	1.18	1.17	1.04	1.46	1.24
LSD (0.05)‡	0.16	0.32	0.19	0.38	0.54	0.21
	mmol K^+ g^{-1} dry wt.†					
Control (0.3)	1.55	1.63	1.58	1.72	1.81	1.57
4.3	1.56	1.53	1.52	1.35	1.48	1.44
8.3	1.47	1.35	1.32	1.10	1.33	1.22
LSD (0.05)‡	0.46	0.47	0.37	0.32	0.43	0.35

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

Dry weights and nitrogen (total and ^{15}N) concentrations and uptake of leaves, stems, and roots depend on the salinity level and duration of the stress. Accumulated levels of Cl^-, Na^+, and K^+ differed between the tissues and the level of salinity. The root K^+, however, was not affected by salinity. Overall, leaves showed the highest degree of sensitivity to salinity, followed by roots, and stems showed the least sensitivity. Therefore, depending on the plant part, there is an

TABLE 7. Root Na^+, Cl^-, and K^+ Contents of Tomatoes for the Control and the NaCl Treated Plants at the Six Harvest Times.

Salt Treatment (Osmotic pressure)	Sodium, chlorine, and potassium content of plant parts — Harvest time (days)					
	5	10	15	20	25	30
Bar	Root — mmol Na^+ g^{-1} dry wt.†					
Control (0.3)	0.33	0.32	0.25	0.11	0.19	0.21
4.3	0.61	0.80	0.71	0.75	0.66	0.86
8.3	0.81	1.10	0.84	0.99	0.98	1.02
LSD (0.05)‡	0.34	0.33	0.59	0.40	0.26	0.85
	mmol Cl^- g^{-1} dry wt.†					
Control (0.3)	0.13	0.14	0.15	0.09	0.11	0.17
4.3	0.31	0.58	0.88	0.94	1.10	1.11
8.3	0.57	1.01	0.90	1.25	1.31	1.29
LSD (0.05)‡	0.10	0.26	0.25	0.38	0.13	0.14
	mmol K^+ g^{-1} dry wt.†					
Control (0.3)	0.92	1.07	1.37	1.48	1.57	1.36
4.3	0.93	1.29	1.48	1.43	1.61	1.37
8.3	0.84	1.14	1.23	1.42	1.63	1.44
LSD (0.05)‡	0.45	0.59	0.30	0.09	0.33	0.70

†Means of 2 replications of pots with 1 plant each.

‡LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

inherent difference in sensitivity to salinity of the cells located in the various tissues in addition to their morphological and functional differences.

The medium and the high saline treatments did not exhibit a significant difference in leaf and root dry weights, except at the last harvest. Perhaps these plants, which were at the flower bud formation stage of growth, were less

sensitive to NaCl stress than were plants at the earlier stage of vegetative growth (17).

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