Salinity distribution pattern induced tomato roots capable of enhancing plant adaptability to salt stress

Weihua Wang
Kunming University of Science and Technology
Yidan Gong
Kunming University of Science and Technology
Bei Cheng
Kunming University of Science and Technology
Roucheng Ou
Kunming University of Science and Technology
ting yang (yt3628568@163.com)
Guangdong Academy of Sciences

Research Article

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Abstract

Salinity is a major abiotic stress threatening tomato production. Roots can attenuate salt stress in a specific salinity concentration, especially with non-uniform salinity distribution conditions are hypothesized to play a role in enhancing tomato plant adaptability to salt stress. However, it is still unclear whether and how root alleviate stress when challenged by salinity distribution. In this study, we set different salinity distribution pattern: uniform salinity distribution (T_1(0, 0), T_2(0.2%, 0.2%), T_3(0.3%, 0.3%)) and non-uniform salinity distribution (T_4(0.1%, 0.3%), T_5(0.1%, 0.5%), T_6(0.2%, 0.4%)), each salinity distribution employed with three levels of concentration, hydroponics method, splitting the roots into left and right parts, and observing whole growth stage. Plant physiological indices responses to salt stress were measured. Studies have indicated that tomato plant roots can attenuate salt stress in a salinity concentration with 0.4%, the non-uniform salinity distribution is capable of restricting the root-uptake, and the uptake efficiency of nutrients (Na^+, K^+) fruit yield, fruit flavor and quality were enhanced by non-uniform salinity distribution with certain concentration (T_4(0.1%, 0.3%)). Moreover, the increased K^+ lead to the decrease of the Na^+/K^+ ratio, which could reduce the toxicity of salt ion to the plant, and consequently improve the growth of tomato. This research confirms the critical role of salinity distribution in a specific concentration in enhancing tomato plants adaptability to salt stress, providing an overview of the prospects and restriction of nutrients application method to minimize the negative effects of salinity stress.

1. Introduction

A sustainable agriculture needs to address the challenges of food security and human health while leaving as small environmental footprints as possible (Foley et al., 2011). It has been estimated that salinity affects approximately 1 billion hectares of soils (c. 7.5% of the world's land area) across 100 countries (Li et al., 2019). Particularly, in agricultural systems, about 45 million hectares of irrigated soils and 32 million hectares of dryland soils were affected by salinity (FAO, 2020). Soil salinity is a major abiotic stress and affects almost every aspect of the physiology and biochemistry of tomato plants, significantly reducing quality and yield. Since large land areas have been affected by salinity, and tomato plants are salt sensitive (Dasgan et al., 2002; Abbaspour et al., 2012), it is extremely important to explore effective planting environment, and to develop appropriate fertilizer methods for tomato plant adapt to salinity conditions.

When grown under salinity stress, tomato plants may employ several defensive tactics to protect themselves, e.g., forming salt-excreting glands or trichomes (Yuan et al., 2016), reestablishing cellular ionic, osmotic, and reactive oxygen species equilibrium (Yang et al., 2018), and regulating critical developmental processes such as flowering time (Kazan and Lyons, 2018). The physiological and molecular basis of salt adaptation in plants has been sufficiently proven (Zhu, 2016). Some tomato roots under the low salt stress environment could compensate for water absorption and growth to alleviate the water demand of plants (Xiong et al., 2018; Yang et al., 2019). The growth of Fraxinus velutina roots

through non-uniform salt stress to accelerate its growth rate. It indicates that non-uniform salt distribution could alleviate salt damage better than uniform salinity distribution (Sun et al., 2016). The reason for the non-uniform distribution of saline soil in maintaining plant growth is the compensatory water absorption at the low salt or non-salt site, which plays an important role in promoting the growth of plants under non-uniform salt stress (Nadia et al., 2012; Sun et al., 2016). Several studies have focused much interest on plant growth-promoting with low salinity stress in plants, while others have measured the growth length in various plant species under salinity conditions (Yaish et al., 2016; Yang et al., 2016; Theim et al., 2018). To date, however, very few studies have attempted to examine whether and how each of tomato plants' part adsorbed nutrients when exposed to salt stress, or whether the different root part exposed hydroponics (nutrient salinity condition) to alleviate salt stress in tomato plants is different from that in soil salt conditions.

It has been demonstrated that specific concentration of salt stress can improve tomato plants performance, and beneficial to growth and yields, such as a certain range of ions of Na^+ and Cl^- can accelerate plant growth and slow down drought stress (He et al., 2019), high concentration of Na^+ could reduce photosynthesis of plants and compete with other nutrient elements. Since root exudates some substance and enhance plant tolerance to salt stress, we hypothesis that once expose to salinity condition, tomato plants' roots confront salt stress positively initially and capable of attenuating salt stress in a specific salinity concentration. Verifying this hypothesis could allow us better understand the ecological root performance in response to salt stress.

To test this hypothesis, we focused on tomato plants cultivated with hydroponics, root split, a various range of salinity concentrations (0, 0.4%, 0.6%), and divided as non-uniform distribution ((0.1%, 0.3%), (0.1%, 0.5%), (0.2%, 0.4%)), uniform distribution ((0, 0), (0.2%, 0.2%), (0.3%, 0.3%)). Moreover, we examined whether the hydroponics performs well in enhancing tomato plant adaptability to salt stress. The objectives of this study are to verify 1) whether the tomato plant roots can attenuate salt stress in a specific salinity concentration, 2) whether non-uniform salt is capable of enhancing tomato plants adaptability to salt stress than uniform distribution, and whether hydroponics performs well in alleviating tomato plants salt stress.

2. Material And Methods

2.1 Experimental design

Tomato plants were initially breed with seeds, which were collected from Baoshan, Yunnan Province. All seeds used in this study were surface sterilized by soaking in 70% ethanol for 1 min, 3% sodium hypochlorite for 10 min, and rinsed three times with sterile distilled water. The seeds were placed in a matrix with humus and perlite, when seeds grew to the stage with split symmetric leaves and central heartleaf (two leaves with one heart), picked out the similarity seedlings then according to the number of roots and averagely divided the roots into two parts, and transplanted to the hydroponics box (Fig. 1a), on the top of which all the seedlings were fixed with a groove foam board. The seedlings were cultivated

with hydroponics (Hoagland's nutrient solution), which was applied for tomato plant's growth, and, was changed every 5 days to maintain salts balance, as showed in Fig. 1b. Tomato plants suffered three levels of salt stress with the application of NaCl concentration on both of left-right with uniformed (U) and non-uniformed distributed (N). Uniform (U) salt stress included: T_1 (0, 0), T_2 (0.2%, 0.2%), T_3 (0.3%, 0.3%). Non-uniform (N) salt stress included: T_4 (0.1%, 0.3%), T_5 (0.1%, 0.5%), T_6 (0.2%, 0.4%). Four groups of experiments were repeated for each treatment.

2.2 Measurement of plant parameters associated with salt tolerance

To effectively reflect plant physiological responses to salt stress, several indices were calculated. Those indices were relative decrease in plant biomass, the relative decrease in plant fresh weight, the relative decrease in plant height, the relative decrease in plant water content, plant K^+ decrease rate, plant Na^+ increase rate, the ratio of K^+ to Na^+ in plant, the salt injury index, and the death rate of plant. To comprehensively evaluate plant salt tolerance, the whole growth stage of plant was observed and analysis the indices that could effectively reflect plant physiological responses to salt stress. Details regarding measurements and calculation are followed below:

(1) Root measurement

Length

took out the tomato plants from the hydroponic tank and clean them up. The side roots to be tested were laid flat in the glass dish to avoid overlapping. Use Hewlett-Packard scanner (ScanJet 3c/T) to scan the root system and specifies the scan color as black and white (the image is preserved, with the format of TIF., and the resolution is 300 dpi). Used root image analysis software DT-SCAN to determine the total root length.

Dry mass

roots were killed out at 105 ^{o}C first, then dry it at 80 ^{o}C to the constant weight, used an electronic scale (precision 0.001 g) weighed its dry mass.

(2) Plant leaves measurement

Leaf Area

select three plants with similar growth conditions from each treatment, labeled the

biggest leaf from the top of the main stem before measuring the length and width it. Took the average and record the data. Using a photosynthetic meter to measure the index of leaf area (Li-6400) and calculated.

Photosynthetic index

after 30 days of salt-stress treatment, measured the index with portable

photosynthesis system (Li-6400) from 11:00 am to 1:00 pm. Set up ventilation and red-blue light resource, the concentration of CO_2 in the air was (394 ± 7) μmol·mol^{-1}, the temperature was (30 ± 2) °C, relative humidity was 37%, light intensity was 1400 μmol·m^{-2}·s^{-1}. Photosynthetic rate (P_n), stomatal conductance (G_s), and transpiration rate (T_r) were read directly.

Expanding index of leaf area

after the frutescence phase of the tomato started, three plants were selected from each treatment with the similar growing conditions. Newly expanded leaves are labeled and their leaf area was measured every 5 days with an average value. The tomato leaf area of the single leaf was calculated by the regression model of leaves product. The growth rate of leaves was calculated by the following formula

$$LGR = \left(Q_2 - Q_1\right) / \left(D_2 - D_1\right) \quad (1)$$

where LGR is the growth rate of leaf, cm/d, Q_1 and Q_2 is the leaf area of adjacent twice measured, cm², D_1 and D_2 is the time of leaf area of measuring adjacent twice, respectively day.

The formula of relatively extensional rate of leaf area is showed as below:

$$RER = d(InQ)\,dt \quad (2)$$

where RER is the relatively extensional rate of leaf area, cm^2/(cm^2·day), Q is the leaf area, cm².

(3) Fruit measurement and nutrient analysis

Start from the first day of tomato fruit setting, selected and labeled the target fruit from each plant that has been treated with salt stress with an interval of 10 days, respectively. Furthermore, selected three plants from each treatment, observed the transverse diameter and vertical diameter of fruit until their size and condition maintain. At the fruiting stage, the fresh weight of fruit and fruit yield were recorded.

The size of fruit, yield, quality (content of fruit soluble sugar, organic acid and vitamin C (V_c), the fruit ratio of sugar to acid, content of vitamin C, organic acid, content of starch in different parts of fruit) were measured. Mineral contents were calculated by multiplying mineral concentration by the dry weight of leaves. Na^+ and K^+ concentrations in leaves, roots, and fruits were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Avio 200, PerkinElmer, USA). The soluble nitrate (NO_3^-) was measured by a flow autoanalyzer (San^{++}System, SAKLAR, Netherlands). The chloride (Cl^-) ions were measured by ion chromatography (ICS1100, Dionex, USA).

3. Results

3.1 Specific salinity concentration can induce tomato roots alleviate salt stress

Tomato roots (left and right sides), leaf and fruits response to salt stress in both uniform and non-uniform salinity distribution displayed in Fig. 2–4. Response of roots' length and dry mass to the uniform and non-uniform salinity stress as showed in Fig. 2. With different salinity stress distribution, the total length of tomato roots was lower under uniform distribution (1412.95 cm) than that under non-uniform condition (1547.13 cm). It can be concluded that non-uniform salinity stress facilitates tomato roots growth. Compared roots' length on both left and right side, under non-uniform salinity distribution, root length on left side was higher than that on right side. Besides, roots dry mass was lower under uniform distribution than that under non-uniform distribution (Fig. 2b). The non-uniform distribution can accelerate root mass accumulation, especially with the application of a proper salinity. Similar studies also revealed that under the treatment of proper salt concentration, the salt stimulates some hormones to secret, and the root system would adjust to the positive direction, such as increasing the surface area of root, root volume, and the length of root to improve the salt tolerance of root in the adverse situation (Cheng et al., 2018).

3.2 Salinity distribution pattern enhance tomato plants adaptability to salt stress

To characterize salt distribution in enhancing plants adaptability to salt stress, we sampled tomato leaves and fruits, followed by a series measurements and testing. The leaf area response to salinity stress was analyzed at both of seedling and fruiting stages. Results indicated that the response of tomato to salinity at two stages performs different. Tomato leaves are gradually increased at the seedling stage, where salt stress was rarely observed. While during the fruiting stage, the leaf area increased larger gradually, but a distinctly decrease of tomato leaves response to the salt stress with the increase of salinity concentration for both uniform and non-uniform distribution (Fig. 3a-b). Similar results obtained by Munns (2002) explained such slow increase or decrease of leaf is possibly due to the high salt load in the leaf that exceeds the capacity of salt compartmentation in the vacuoles, causing salt to build up in the cytoplasm to toxic levels. Further analysis related to leaf area parameters such as leaf net photosynthetic rate (P_n), stomatal conductance (G_s), transpiration rate (T_r), intercellular CO_2 concentration indicated that the photosynthesis of tomato was inhibited under severe salt stress (Table 1), the severe salt stress went against the photosynthesis of crops because the decrease of leaf water potential and stomatal conductance limited the CO_2 to arrive at the photosynthetic apparatus, making photosynthesis inhibited. Uniform and non-uniform salinity distribution had a different effect on the extension of leaf area of tomato. For example, with same salinity application, the non-uniform salinity distribution promoted leaves' growth much faster than that under uniform salinity distribution during the fruiting stage. When salinity increase from 0 to 0.4%, leaves area increased by 14.77% under non-uniform

salinity distribution (T_4(0.1%, 0.3%)), and increased 11.41% under uniform salinity distribution (T_2(0.2%, 0.2%)), respectively. It proved again that proper salt application could accelerate leaf area growth, and the non-uniform salinity distribution performs better than uniform salinity distribution in leaf area growth, because the non-uniform salinity distribution pattern could efficiently relieve salt damage on the other hand.

Table 1
Effect of salinity stress on photosynthetic parameters of Tomato leaves at fruiting stage

Treatments (total NaCl/%)	P_n ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	G_s ($mol \cdot m^{-2} \cdot s^{-1}$)	T_r ($mmol \cdot m^{-2} \cdot s^{-1}$)
T_1(0, 0)	32.75 ± 0.31 a	0.46 ± 0.03a	16.84 ± 0.20 a
T_2 (0.2%, 0.2%)	37.06 ± 0.14 c	0.51 ± 0.05 b	17.92 ± 0.17c
T_3 (0.3%, 0.3%)	26.39 ± 0.43 f	0.38 ± 0.05 c	12.87 ± 0.13 e
T_4 (0.1%, 0.3%)	40.43 ± 0.17 b	0.53 ± 0.01 b	18.43 ± 0.11 b
T_5 (0.1%, 0.5%)	28.17 ± 0.21 d	0.43 ± 0.07 c	14.05 ± 0.08 d
T_6 (0.2%, 0.4%)	27.60 ± 0.10 e	0.40 ± 0.04 c	13.26 ± 0.04 e
*The values in the table are means ± S.D. The different letters of the same column indicate the significance of the difference ($P < 0.05$)			

To further explore the response of tomato fruits to salt stress under different salinity distribution, we measured fruits' transverse diameter, longitudinal diameter, fresh weight, yield and quality. In Fig. 4, with the increase of salinity to 0.4%, fruit size and fresh weight significantly increased (Table 2), tomato yield per plant significantly increased by 1.3% for T_2(0.2%, 0.2%) and 3.7% T_4(0.1%, 0.3%), respectively, and non-uniform salinity distribution (T_4(0.1%, 0.3%) performs better than T_2(0.2%, 0.2%). With salinity continue increased to 0.6%, salinity treatments ((T_3(0.3%, 0.3%), T_5(0.1%, 0.5%), T_6(0.2%, 0.4%)) reflect negative effects on fruit's traits (Fig. 4a-b), fruit yield decreased to response the severe salinity stress, and the decrease followed by the order of T_5(0.1%, 0.5%) > T_6(0.2%, 0.4%) > T_3(0.3%, 0.3%), severe salinity stress was observed with uniform salinity distribution (T_3(0.3%, 0.3%)), reduction in yield accounted by salinity distribution, which was partially similar and in agreement with research reported by Cao et al. (2019). This could be attributed to the increase of salt concentration and distribution pattern, cumulated salinity restricted fruit growth.

Table 2
Effect of salinity stress on tomato yield at 50 days

Treatments	Single fruit weight/g	The weight of the leaf and stem/g	Average weight/g
T_1(0, 0)	62.41 ± 0.21b	129.72 ± 1.03c	473.96 ± 12.06b
T_2(0.2%, 0.2%)	65.25 ± 0.13a	142.93 ± 1.42b	480.15 ± 20.05a
T_3(0.3%, 0.3%)	53.27 ± 0.14d	96.43 ± 1.04e	414.50 ± 16.64d
T_4(0.1%, 0.3%)	66.37 ± 0.15a	150.16 ± 1.12a	491.41 ± 15.41a
T_5(0.1%, 0.5%)	58.32 ± 0.16c	111.91 ± 0.96cd	449.67 ± 18.03cd
T_6(0.2%, 0.4%)	57.41 ± 0.08c	102.35 ± 0.83d	426.32 ± 17.27d
*The weight of the leaf and stem during seedling pulling/g			

Furthermore, to figure out response of fruit quality to salt stress, content of fruits' soluble sugar (glucose, fructose, sucrose, and starch) from three parts of fruit (sarcocarp, ventricular septal wall, and colloid placental pedestal) were determined at each stage (white ripe season, turning stage and mature period). The quality of tomato fruits was measured by four types of standards (glucose, fructose, sucrose, and starch) from green color changed to red color stage (Fig. 5a-c). The glucose and fructose increase, the sucrose and starch decreased (sarcocarp, ventricular septal wall, and colloid placental pedestal) under same salinity concentration, but glucose is significantly lower under non-uniform than that under uniform salinity distribution. It is because the activity of sucrose invertase was enhanced, which is in direct ratio with the change of the content change of soluble sugar, fructose, and glucose. Compared with T_1(0,0), moderate salt stress during the mature period can enhance the activity of sucrose invertase that increased the content of fruit soluble sugar, improved the quality of fruit flavor (Fig. 5). The moderate salt stress was able to improve the fruit taste and nutritional value (Lu et al., 2012). The fruit taste improved in the form of the ratio of sugar to acid is higher for non-uniform distribution than that for the uniform (Table 3). Moreover, under same salt stress, non-uniform distribution contributed more transformation ability of starch, promoting the activity of invertase at different parts of tomato, and accelerated the decomposition of sucrose (Yeo and Flowers, 1986; Li et al., 2021).

Table 3
Effect of salinity stress on soluble sugar content, vitamin C, organic acid and ratio of sugar to acid

Treatment (left, right NaCl/%)	Soluble sugar content/%	Vitamin C content/mg.kg^{-1}	Organic acid	Ratio of sugar to acid
T_1(0, 0)	6.78 ± 0.04bc	7.54 ± 0.03d	0.47 ± 0.01a	14.43 ± 0.03b
T_2(0.2%, 0.2%)	7.72 ± 0.03a	7.85 ± 0.07c	0.43 ± 0.01b	17.95 ± 0.13a
T_3(0.3%, 0.3%)	5.15 ± 0.12d	8.94 ± 0.13a	0.39 ± 0.06d	13.21 ± 0.10c
T_4(0.1%, 0.3%)	8.14 ± 0.06a	7.94 ± 0.04c	0.45 ± 0.01ab	18.09 ± 0.11a
T_5(0.1%, 0.5%)	6.03 ± 0.13b	8.43 ± 0.05b	0.42 ± 0.02c	14.35 ± 0.09b
T_6(0.2%, 0.4%)	5.57 ± 0.07c	8.62 ± 0.03ab	0.41 ± 0.04c	13.58 ± 0.07c

3.3 Salinity distribution pattern influenced the transformation of ions in tomato plants

To test the inner mechanisms of salinity distribution in promoting plant salt tolerance, we measured ions (Na^+, K^+, Cl^-) concentrations and ions' transformation in different parts of tomato under different salinity distribution (Fig. 6a-c). Although significant differences in the concentration of Na^+, Cl^-, and K^+ between uniform and non-uniform salinity distribution, almost all of the plants part, regardless of salinity distribution, exhibited significantly increase in the concentration of Na^+, Cl^-, and decrease in the concentration of K^+ compared to the control treatment. Notably, for non-uniform distribution, Na^+ and Cl^- concentration was higher on the right roots (higher salt stress) than those on the left roots (lower salt stress), while the K^+ concentration is lower on the right roots than that on the left roots. For uniform distribution, ions concentration on both of left and right roots perform similar. However, non-uniform salinity distribution treatments showed a significant reduction in salt induced Na^+ increase rate. Previous observation showed that roots can produce a specific substance response to salt stress in a specific salinity condition (Li et al. 2021). Together, these results confirmed that changing salinity distribution pattern could enhance plant root adaptability to salt stress.

The decrease of Na^+ concentration in the above-ground part due to the transfer of absorbed Na^+ from the high salinity side to the low salt side and alleviate the salt damage by increasing the release of Na^+ from the low salinity stress side (Wang et al., 2017). During the upward transport of Na^+, it enters the phloem

sieve tube, and then was transported to the root neck. It can be inferred that the colloid placenta has a certain salt resistance ability preventing salt ions from entering tomato seeds. The ratio of Na^+/K^+ is usually used to identify the growth and yield of tomato. K^+ is the predominant cation for osmotic adjustment tomato in all the parts. Cl^- is the predominant anion in all parts, the ratio of $(Na^+{+}K^+)/Cl^-$ > 1.0 across the salinity gradient. It illustrated that with the same salinity concentration application, the treatment of split-root salt stress trended to reduce the accumulation of Na^+ and Cl^- in leaves, as Na^+ transported from the side of the root of higher salinity stress to the lower side salinity stress or no salinity stress side, which decreased the ratio of Na^+/K^+. The increased K^+ lead to the decrease of the Na^+/K^+ ratio, which could reduce the toxicity of salt ion to the plant, and consequently improve the growth of tomato as well as the yield of tomato. Nevertheless, under severe salt stress 0.4% and 0.6%, Na^+/K^+ in roots, stems, and leaves showed an upward trend (Fig. 7a). The ratio of Na^+/K^+ increased significantly for non-uniform salinity treatments, which indicated that the root system had limited ability to regulate excessive ions with salinity stress.

4. Discussion

Salt stress significantly reduced the root's dry matter, leaf area, and yields compared with the control treatments due to indirect saline ions that cause soil/plant osmotic imbalance. And the more difference of concentration is, the more obvious effect of salt damage relief, which was corresponding to the research about cotton and alfalfa done by Kong et al. (2012) and Xiong et al. (2018, 2020). Compared with the treatment by uniform, non-uniform has an inhibitory effect on the fruit width, moderate non-uniform application could promote the crops yield, which is related to the growth of plants root. Proper salt stimulates some hormones to secret, and the root system would adjust to the positive direction, such as increasing the surface area of the root, root volume, and the length of root to improve the salt tolerance of root in the adverse situation (Cheng et al., 2018), besides, moderate non-uniform nutrients promotes roots water absorption, relieve the salt damage (Duan et al., 2018), supply water for crops (Sun et al., 2016; Sun et al., 2017), improve the leaf net photosynthetic rate and transpiration rate, increase the accumulation of photosynthetic, and improve crop yield (Wang et al., 2013). Such stimulation benefits the increase of growth and yield of tomato, however, if the salt concentration continuously increased, the growth of tomato would be inhibited which is not conducive to the yield of tomato. Moderate non-uniform application could effectively alleviate salt damage that crops would produce a corresponding salt resistance mechanism to counteract the adverse effects of salt stress. Further research is needed to be accomplished in terms of the issue of whether the inhibitory effect of non-uniform salt stress on the growth and yield of tomato was greater than the uniform salt stress under severe salt stress for all plants.

5. Conclusions

Proper salt stress could improve the flavor of the fruit, and non-uniform stress contribute more to the increase of sugar to acid ratio of tomato compared with uniform treatment. With the increase of NaCl concentration, the Na^+/K^+ in roots, stems, and leaves of tomato showed an upward trend, and the Na^+/K^+

value in stems was the most obvious one, followed by leaves. The content of Na^+ and Cl^- in the underground part was higher than that above the ground. After the comprehensive analysis on the development and growth of the tomato plant, the yield of tomato and the quality of fruit, the T_4(0.1%,0.3%) treatment under moderate non-uniform salt stress was the optimal treatment, which showed that the combination in saline conditions not only improve the leaf photosynthesis rate of tomato, promote the photosynthesis, but also achieve the best yield and quality.

Declarations

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Figures

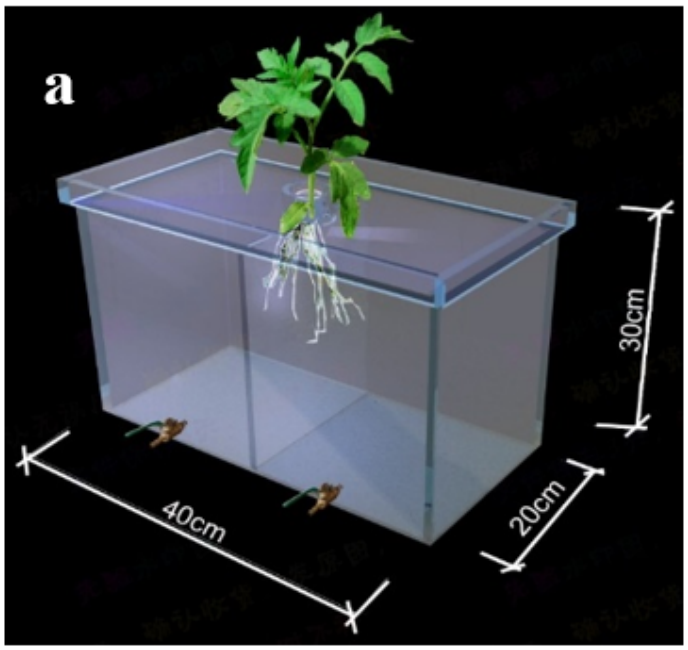


Figure 1

Salinity stress equipment for tomato plants: a) the scheme of set-up, b) real scenario of tomato plants.

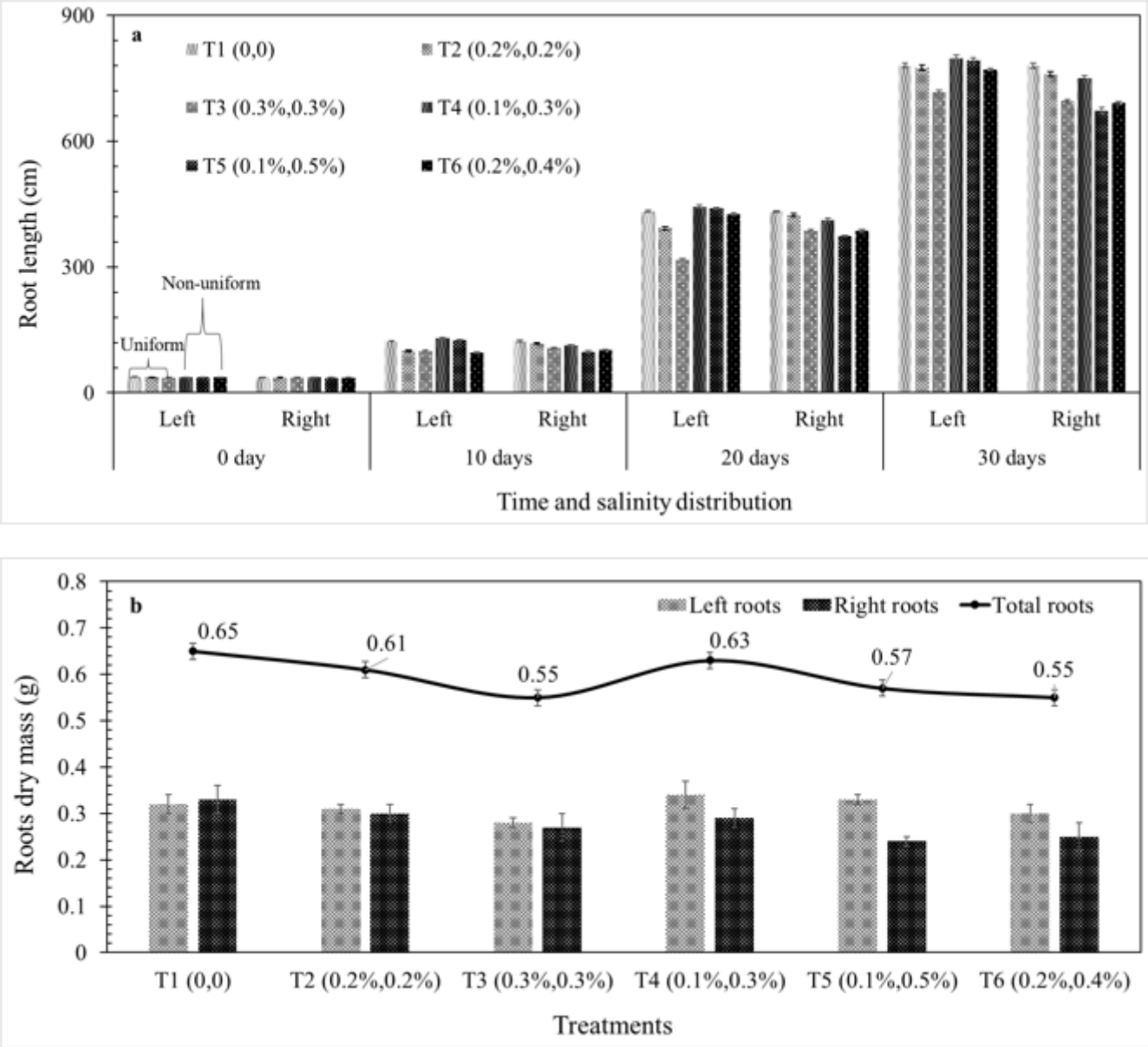


Figure 2

Root length and dry mass of left and right side during the seedling stage, a) root length of each side, as well as total root length at different growth stages, b) roots dry mass.

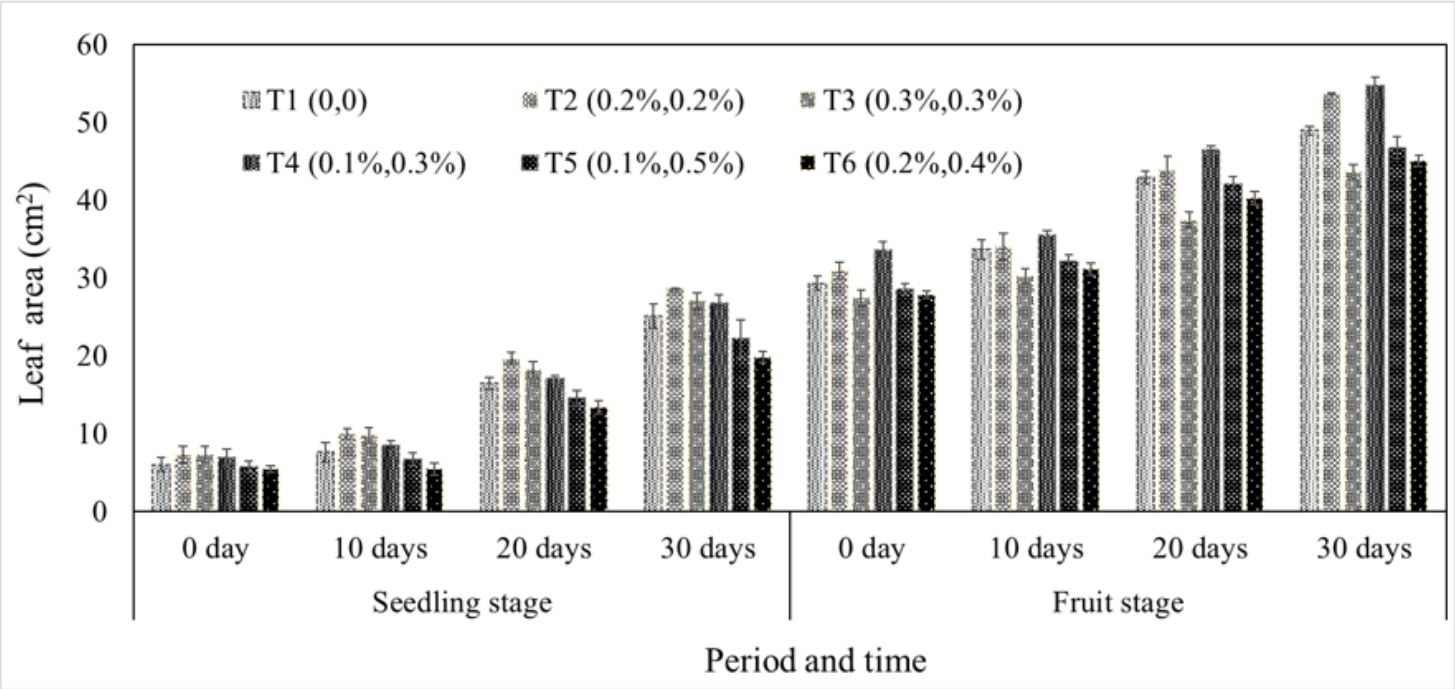
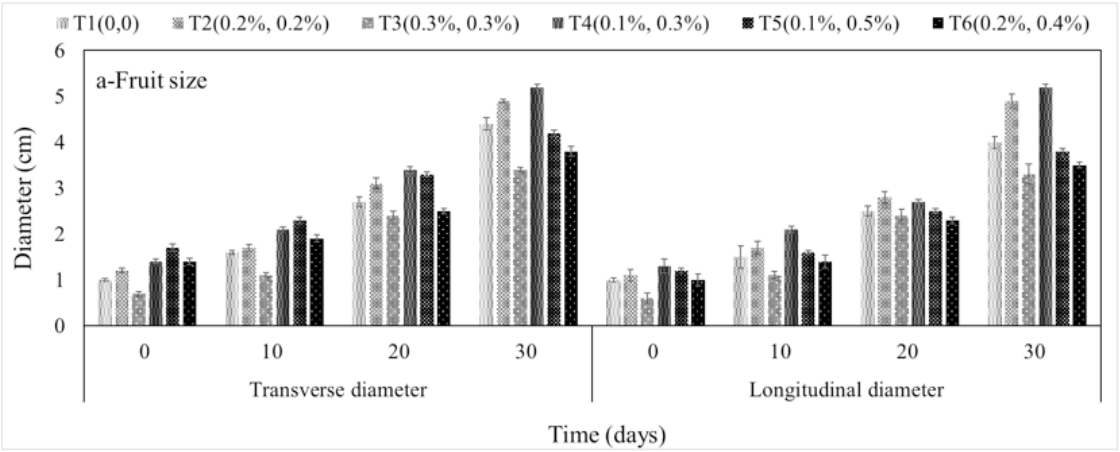
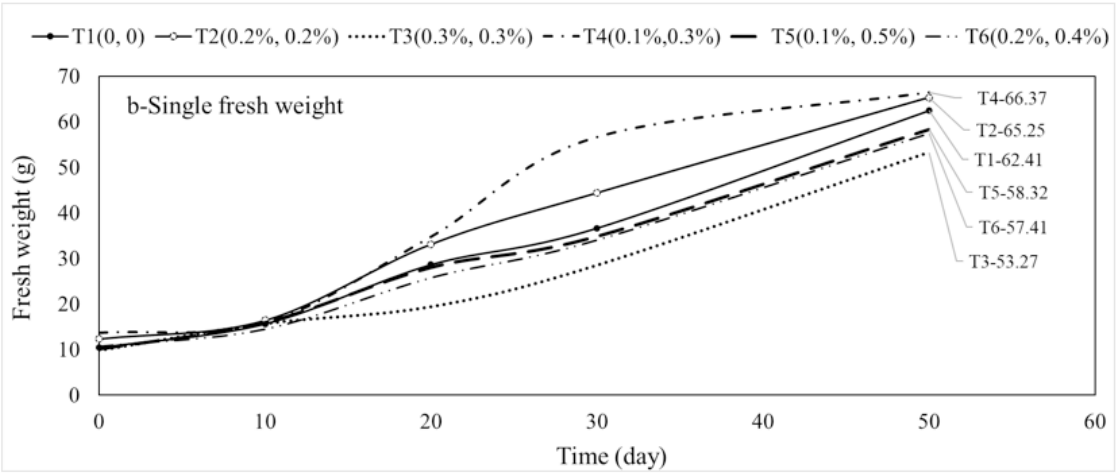


Figure 3

Leaf area at two different growth stages (seedling stage and fruit stage) under salinity treatments.





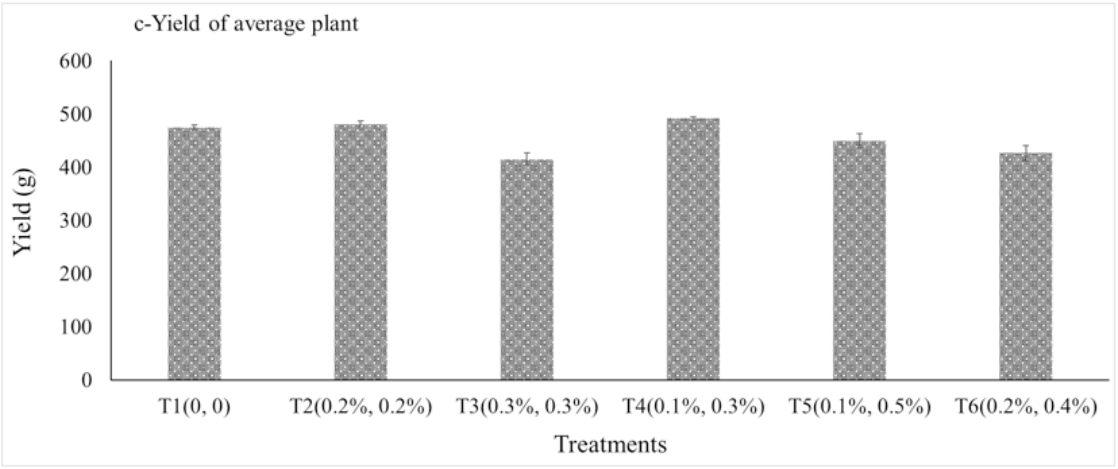


Figure 4

The effect of different salinity stress on tomato fruit size and fresh weight: a-fruit size, b-single fresh weight.

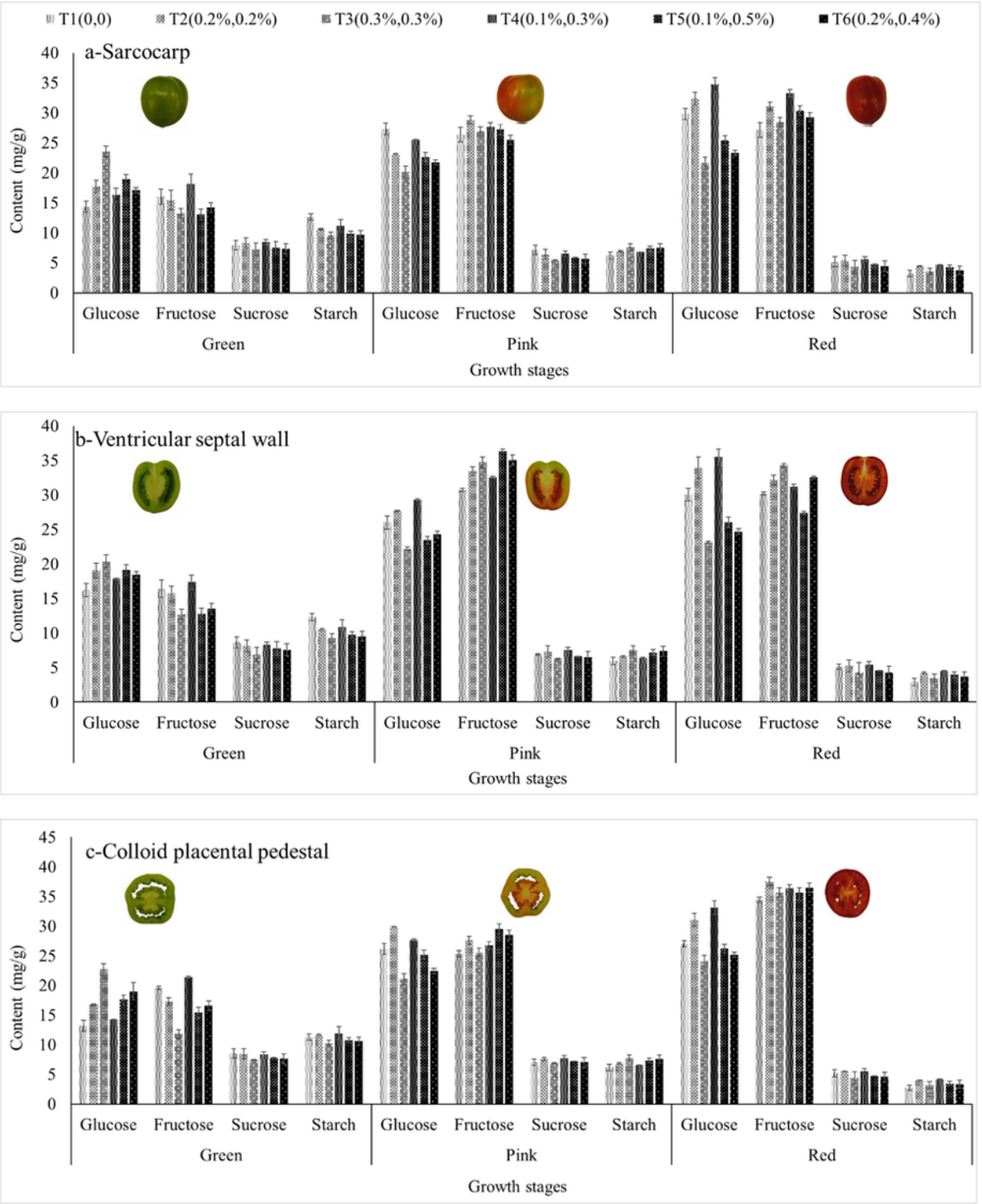


Figure 5

The quality of tomato fruits was measured by four types of standards (glucose, fructose, sucrose and starch) at three growth stages and parts under salinity treatments: a) Sarcocarp, b) Ventricular wall, c) Collide placental pedestal.

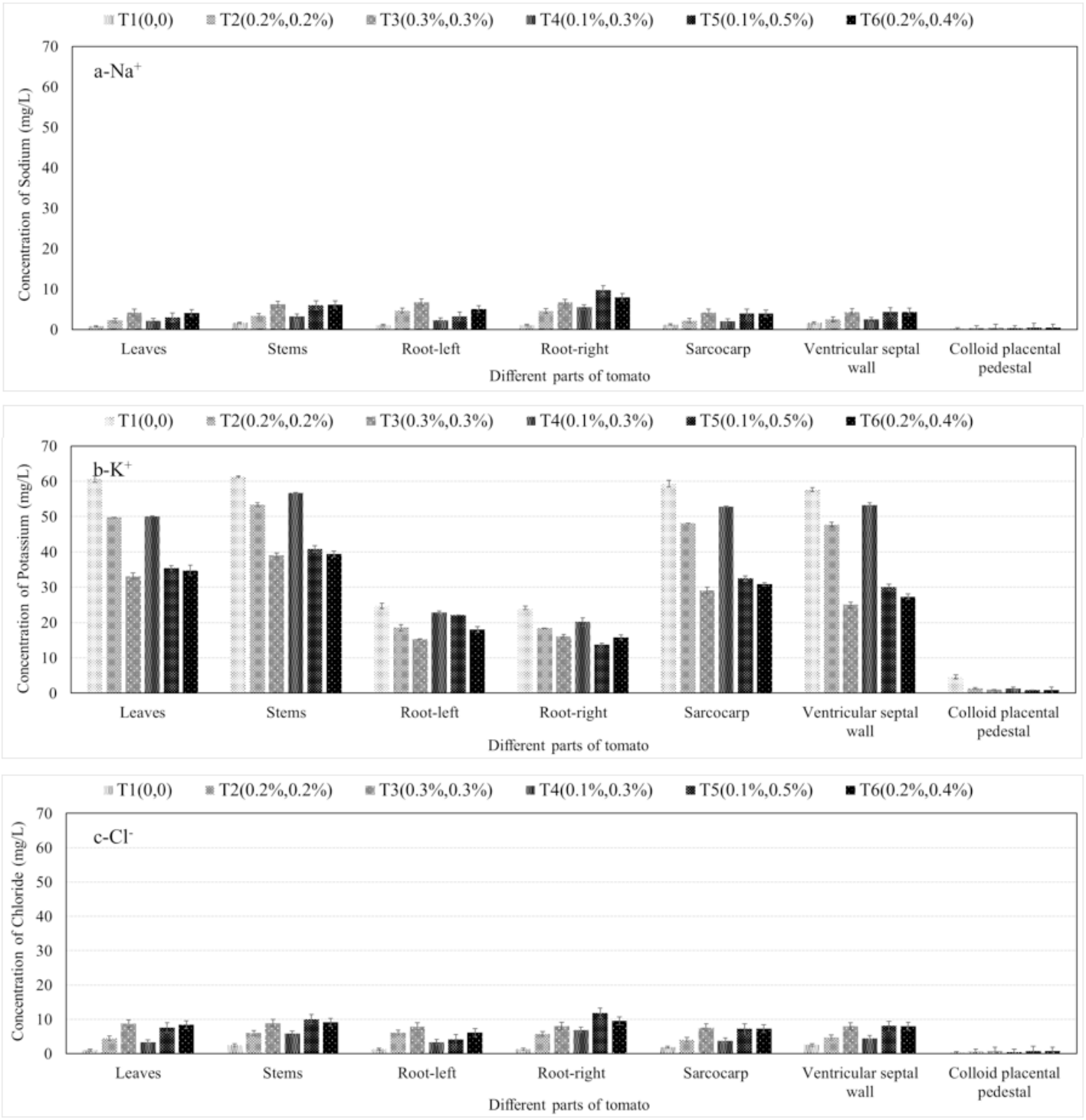
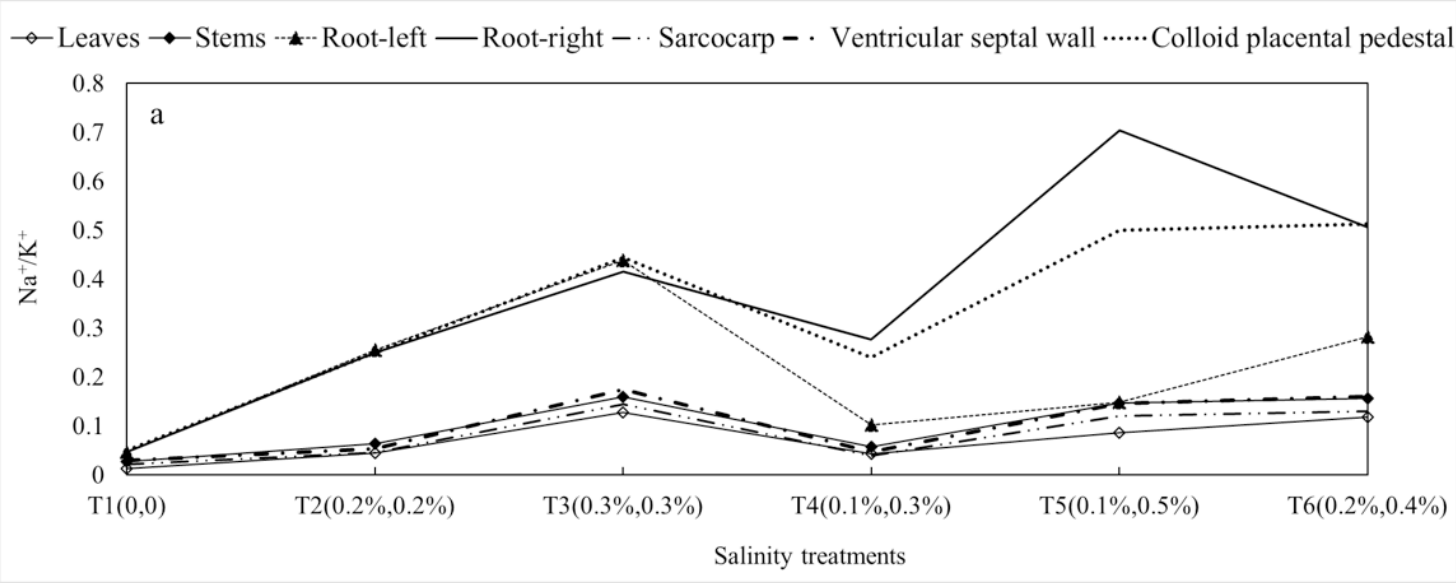


Figure 6

Ions' concentration in different parts under salinity treatments: a) sodium, b) potassium, c) chloride.



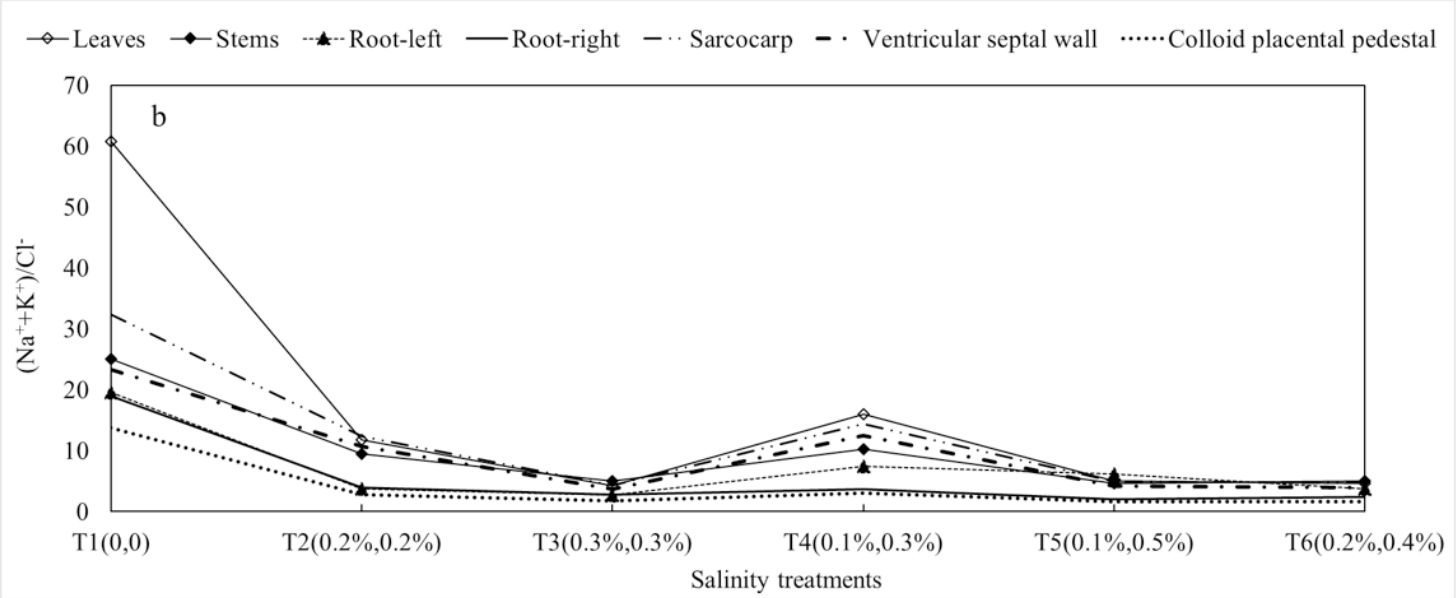


Figure 7

The ratio of sodium and potassium (a), and (sodium plus potassium)/chloride (b) in tomato leaves, stems, left root, right root, sarcocarp, ventricular septal wall, colloid placental pedestal.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- renamede10c7.xlsx