The Response of Three Mandarin Cultivars Grafted on Sour Orange Rootstock to Salinity Stress

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**ABSTRACT**

Citrus growth is often constrained by salinity, but citrus rootstocks respond to salinity differently. A greenhouse study was carried out in a completely randomized design with three cultivars of mandarin ('Younesi', 'Clementine', and 'Yashar') and four levels of salinity (control, 1, 3, and 5 dS/m) in three replications to explore the mechanism by which salinity stress affects photosynthetic and growth factors of mandarin cultivars. After applying salinity treatments, shoot fresh and dry weight, root fresh and dry weight, branch number, leaf number, plant height, leaf and root potassium (K), sodium (Na), and calcium (Ca) contents, chlorophyll content, proline content, leaf nitrogen, and protein content, electrolyte leakage, and sugar content were measured. The results showed that salinity stress reduced vegetative and photosynthetic factors in all three cultivars. Root and leaf K and Na contents, chlorophyll \(a\), total chlorophyll, proline content, electrolyte leakage, and sugar and protein contents were affected by cultivars. Salinity affected root and leaf K and Na contents, chlorophyll \(a\) and \(b\) and total chlorophyll contents, proline, and electrolyte leakage significantly. The interaction of cultivar and salinity was also significant on chlorophyll \(a\) and total chlorophyll contents, leaf N and protein contents, and electrolyte leakage. Salinity stress reduced vegetative and photosynthesis factors of all three cultivars.

**Introduction**

The stresses induced by water deficiency, salinity, and temperature are more harmful to plants than other stresses throughout the world, and salt stress is one of the most important factors limiting plant growth and crop production in the world so that it has drawn attention for a long time (Seday et al., 2014). Since commercial citrus cultivars are propagated by grafting, the salinity tolerance of scions strongly depends on the type of their rootstock as rootstocks are a factor dictating tree shape, water relations, chilling tolerance, nutrient uptake, hormone balance, and fruit quality (Munns, 2002). One method for developing salinity tolerance in citrus is to graft commercial salinity-sensitive scions on salinity-resistant rootstocks. The salinity-tolerance threshold of these plant species is nearly 1.4 dS/m beyond which their yield decreases so that they lose 13% of their yield for each unit of increase in soil salinity (Khoushbakht et al., 2010; Munns, 2002). In general, the critical salinity of irrigation water for citrus trees is 1.2–1.3 dS/m. The threshold value for response of sour orange is 1.53 dS/m. Citrus plants are classified as "salt-intolerant" crops and saline irrigation water immediately arrests tree growth and negatively affects fruit quality, more than other trees (Prior et al., 2007; Ziogas et al., 2021).

Different citrus rootstocks greatly differ in salinity tolerance (Balal et al., 2011; Fadli et al., 2015). For example, salinity reduces the growth of rough lemon (\textit{C. jambhiri}) and trifoliolate orange (\textit{Poncirus trifoliata}) to a greater extent than that of the rootstocks of sour orange (\textit{C. aurantium}) and Cleopatra

**KEYWORDS**

Clementine; growth parameters; salinity stress; Yashar; Younesi

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mandarin (*C. reshni*) (Fadli et al., 2015). In these species, the growth of the tree canopy is more affected than the root system by salinity (Montoliu et al., 2009). Salinity causes the accumulation and storage of sodium (Na) and chlorine (Cl) at toxic levels in leaf cells, resulting in leaf burning and shedding (Golein et al., 2016). In a greenhouse study on the effect of salinity stress on photosynthesis, nutritional, and growth factors of citrus rootstocks, it was found that salinity stress reduced the vegetative and photosynthesis factors in both rootstocks. This decrease was greater in trifoliate oranges than in Bakraii. The Bakraii rootstocks exhibited higher salinity tolerance than the trifoliate orange rootstocks by less uptake and mobilization of Cl and Na, better protection of photosynthesis and nutritional parameters, and the prevention of severe damage to leaf chlorophyll (Khoshbakht et al., 2015).

Another study addressed the effect of rootstock type and NaCl salinity on the concentration of micronutrients in the shoots of Valencia oranges. Based on the results, the rootstock type had a significant effect on the micronutrient contents of the shoots. Overall, results revealed that the Volkameriana rootstock, as well as the Bakraii, exhibited a good potential for the mobilization of micronutrients to the scion (Aboutalebi Jahromi, 2014). Khoshbakht et al. (2010) found that the parameters of leaf number, plant height, leaf area, shoot and root weight, and root number and length were decreased with an increase in the salinity level. Among the rootstocks, sour oranges, Cleopatra mandarins, and Rangpur limes had the lowest and *Poncirus trifoliata*, Citrange, and Citrumelo had the highest decrease in the shoot and root growth parameters (Khoshbakht et al., 2010). Citrus fruits including mandarin are one of the most popular fruits in the world and also the problem of water and soil salinity is seen in some citrus areas, so research seems to be necessary to find a salt-resistant grafting compound (rootstock/scion). According to the above mentioned limitations, the present study aimed to explore the growth and development parameters of three mandarin cultivars, including ‘Younesi,’ ‘Yashar,’ and ‘Clementine,’ on sour orange rootstock exposed to salinity stress to make some recommendations for the use of this rootstock.

**Materials and Methods**

The study investigated the growth and development parameters of three mandarin cultivars, i.e., ‘Younesi,’ ‘Yashar,’ and ‘Clementine,’ on sour orange rootstock under salinity stress. So, 72 two-year-old seedlings of ‘Younesi,’ ‘Yashar,’ and ‘Clementine’ grafted on sour orange rootstock were procured from a nursery in Fouman County, Guilan province, Iran. First, the leaf number, branch number, and initial height of the grafted seedlings were recorded. The grafted seedlings were irrigated for 105 days by saline water with different concentrations (0, 1, 3, and 5 dS/m NaCl). No specific nutrient solution was used. In the used garden soil substrate (common in the region), the treatments were applied weekly 10 days after establishment of the plants in the pots. Experiment started on February 20 and ended on June 5, 2019.

Finally, chlorophyll content (Mazumdar and Majumder, 2003), proline content (Jalili Marandi, 2010), sugar content, electrolyte leakage, growth rate, branch number, leaf number, plant height, nitrogen content (by the Kjeldahl method), root and leaf sodium (Na), potassium (K), and calcium (Ca) contents (by the atomic absorption method), and shoot and root fresh and dry weight (after oven-drying at 70°C for 24 hours) were recorded. Protein content was calculated by multiplying nitrogen percentage in the protein conversion factor of fruit trees (6.25). To measure chlorophyll content, 0.5 g of the sample was crushed in 50 mL of 80% acetone (80 mL of acetone + 20 mL of distilled water). Then, the extract was filtered, adjusted to 50 mL, and poured into cuvettes. The chlorophyll content was determined by a spectrophotometer. It was read at 643 and 660 nm. Then, the readings were placed in the following equations to find out chlorophyll a, chlorophyll b, and total chlorophyll contents (Mazumdar and Majumder, 2003).

\[
\text{Total chlorophyll (mg/mL)} = 7.12(A660) + 16.8(A643)
\]
The study was a two-factor factorial experiment based on a completely randomized design. The first factor was assigned to three mandarin cultivars including ‘Younesi,’ ‘Yashar,’ and ‘Clementine,’ and the second factor was four levels of salinity treatment including 0, 1, 3, and 5 dS/m NaCl. The study was carried out with three replications, and each plot was composed of two grafted plants. A statistical analysis was performed using analysis of variance (F-test) in the MSTATC and SAS software packages and means were compared using LSD test at 0.05 probability levels.

Results

Growth Rate

Based on the analysis of variance (ANOVA) (Table 1), the effect of cultivar was significant (P < .01) on the growth rate (height increase) of mandarins ‘Younesi,’ ‘Yashar,’ and ‘Clementine’ on the sour orange rootstocks. But, the simple effect of salinity and the interaction of cultivar and salinity were not significant for this trait. The comparison of means revealed that ‘Younesi’ and ‘Clementine’ had the highest growth rate so that their growth rate was twice as high as that of ‘Yashar.’ Although the effect of salinity was not significant on the growth rate (Table 1), this trait was decreased with an increase in salinity level (Table 2).

Shoot and Root Potassium Content

Based on ANOVA (Table 1), the simple effect of cultivar and salinity levels was significant on the shoot K content of mandarins. However, the interaction of cultivar and salinity was not significant for both shoot and root K contents. The comparison of means (Table 2) revealed that ‘Clementine’ had the highest shoot and root K content, significantly differing from that of ‘Yashar.’ Among the salinity levels, 5 dS/m was related to the highest K content, differing from the other salinity levels significantly. The shoot and root K contents were 26% and 34% higher under 5 dS/m than in the control, respectively (Table 3).

Shoot and Root Sodium Content

The results presented in Table 1 indicated that the simple effect of cultivar and the interactive effect of cultivar × salinity were not significant on mandarin’s shoot Na content, but the simple effect of salinity levels influenced the Na content of both shoots and roots significantly and the simple effect of cultivar influenced the Na content of the roots significantly. As the comparison of means for the effect of cultivars (Table 2) showed, ‘Yashar’ and ‘Younesi’ had the highest and lowest root Na contents, respectively. However, the F-test revealed that the simple effect of cultivar was insignificant on shoot Na content. As well, the comparison of means for Na contents under different salinity levels (Figure 1) indicated that the 5 dS/m salinity level was related to the highest shoot and root Na content, exhibiting about 34% and 20% higher accumulation of Na in the shoots and roots compared to the control, respectively.

Chlorophyll Content

According to ANOVA (Table 1), chlorophyll a and total chlorophyll contents of ‘Younesi,’ ‘Yashar,’ and ‘Clementine’ on the sour orange rootstock were significantly (P < .01) affected by the simple effects of cultivars and salinity and their interaction. Chlorophyll b content was affected by the simple effect of

\[
\text{Chlorophylla (mg/mL)} = 9.93(A660) - 0.777(A643)
\]

\[
\text{Chlorophyllb (mg/mL)} = 17.6(A643) - 2.81(A660)
\]
Table 1. Analysis of variance of the traits of three mandarin cultivars at four salinity levels.

| Sources of variation              | df | Growth rate | Shoot K | Root K | Shoot Na | Root Na | Chlorophyll a | Chlorophyll b | Total chlorophyll | Proline | Electrolyte leakage | Sugar content |
|----------------------------------|----|-------------|---------|--------|----------|---------|---------------|---------------|-------------------|----------|---------------------|---------------|
| Cultivar                         | 2  | 15421.14**  | 537.95* | 4047.93** | 1786.26** | 4754.167** | 7.112** | 1.44** | 9.29**             | 0.002**  | 803.141**           | 1897.152**    |
| Salinity level                   | 3  | 997.49**    | 8848.802** | 45172.234** | 29513.11** | 17303.472** | 22.247** | 3.24** | 33.47**             | 0.004**  | 10018.772**          | 163.34**      |
| Cultivar × salinity level        | 6  | 74.33**     | 154.610** | 1605.736** | 978.514** | 177.778** | 5.022** | 2.17** | 3.745**             | 0.0000011** | 340.815**           | 523.62**      |
| Experimental error              | 24 | 128.18      | 479.167 | 4361.000 | 14608.500 | 345.833 | 1.712 | 3.19 | 1.364              | 0.001    | 271.607             | 997.92        |
| Coefficient of variations (%)    | 3.14 | 8.31 | 9.2 | 11.17 | 7.67 | 6.42 | 9.54 | 10.56 | 18.23 | 10.83 | 18.23 |

ns: non-significant; *: significant at the P < 0.05 level; **: significant at the P < 0.01 level.
salinity and its interaction with cultivar significantly, but the simple effect of cultivar was not significant on this trait. The comparison of means for the data of cultivar effect on chlorophyll content (Figure 2) revealed that ‘Clementine’ and ‘Younesi’ had the highest chlorophyll a and total chlorophyll contents, differing from ‘Yashar’ significantly. Among the salinity levels, chlorophyll a and b and total chlorophyll contents were the highest in the control (non-saline water), which were linearly decreased with the increase in salinity level (Figure 3).

The comparison of means for the interaction of the studied factors (Figure 4) showed that the highest chlorophyll a content was obtained from ‘control × Younesi’ and ‘control × Clementine’ whereas ‘5 dS/m salinity × Yashar’ had the lowest one, showing a difference of over 100%. However, the highest total chlorophyll content was obtained from the interaction of control with ‘Younesi’ and ‘Clementine’ and the interaction of ‘Clementine’ with the salinity level of 1 dS/m, and the lowest was related to ‘Younesi’ and ‘Yashar’ exposed to 5 dS/m salinity.

Table 2. Means comparison for the recorded traits of three mandarin cultivars.

| Cultivars | Growth rate (cm) | Shoot K (mg/kg) | Root K (mg/kg) | Root Na (mg/kg) | Proline (μM/mL) | Electrolyte leakage (%) | Sugar content (mM/L) |
|-----------|-----------------|-----------------|----------------|----------------|----------------|------------------------|---------------------|
| Younesi   | 45.50 a         | 183.57 b        | 229.33 a       | 242.50 b       | 0.051 a        | 48.02 b               | 37.50 b             |
| Clementine| 47.29 a         | 203.57 a        | 233.75 a       | 253.33 ab      | 0.034 b        | 46.82 b               | 41.58 a             |
| Yashar    | 23.33 b         | 185.83 b        | 209.37 b       | 270.42 a       | 0.046 a        | 57.39 a               | 39.12 ab            |
| SD        | ± 10.89         | ± 8.94          | ± 10.60        | ± 11.49        | ± 0.007        | ± 4.73                | ± 1.68              |

Means with similar letter(s) in each column did not differ significantly (LSD 5%).

Table 3. Comparison of means of the studied traits at four salinity levels.

| Salinity level   | Shoot K (mg/kg) | Root K (mg/kg) | Proline (μM/mL) | Electrolyte leakage (%) |
|------------------|-----------------|----------------|----------------|-------------------------|
| Control (no salt)| 165.71 d        | 180.27 d       | 0.028 c        | 31.05 c                 |
| 1 dS/m           | 181.67 c        | 202.77 c       | 0.040 b        | 37.51 b                 |
| 3 dS/m           | 196.25 b        | 240.83 b       | 0.050 a        | 65.20 a                 |
| 5 dS/m           | 222.50 a        | 272.72 a       | 0.056 a        | 69.22 a                 |
| SD               | ± 20.88         | ± 35.42        | ± 0.0106       | ± 16.68                 |

Means with similar letter(s) in each column did not differ significantly (LSD 5%).

Figure 1. The Na content of mandarin shoots and roots at different salinity levels (P < .05).

Figure 2. The Na content of mandarin shoots and roots at different salinity levels (P < .05).
The results of ANOVA (Table 1) showed that the simple effects of cultivar and salinity level were significant \((P < .01)\) on the proline content of the three mandarin cultivars grafted on sour orange rootstock. But, the interaction of “cultivar \(\times\) salinity” was not significant on proline content. The comparison of means (Table 2) showed that ‘Younesi’ and ‘Yashar’ had the highest proline content, differing from Clementine significantly. Also, the comparison of means for the effect of salinity on proline (Table 3) indicated that the salinity levels of 3 and 5 dS/m had the highest proline content, which differed from the other levels significantly.
Electrolyte Leakage

The results of ANOVA (Table 1) revealed that both simple effects of cultivar and salinity were significant on the electrolyte leakage of mandarins grafted on the sour orange rootstock. The highest electrolyte leakage was related to ‘Yashar,’ differing from that of ‘Clementine’ and ‘Younesi’ significantly. Also, among different salinity levels, the salinity levels of 5 and 3 dS/m were related to the highest electrolyte leakage (Table 3).

Sugar Content

The results (Table 1) showed that the main effect of cultivar was significant (P < .01) on the sugar content of the three mandarin cultivars on the sour orange rootstock. But, the simple effect of salinity and the interactive effect of cultivar and salinity were not significant on the sugar content. Based on the comparison of means, the highest sugar content was related to ‘Clementine,’ exhibiting significant differences from ‘Yashar’ and ‘Younesi.’

Discussion

In the present study, growth rate did not significantly affect by salinity levels, but, the control (no salinity) caused to the highest growth (39.46 cm). While the lowest growth belonged to treatment 5 dS/m. Salinity stress generally affects the morphological, physiological, biochemical and anatomical traits of the plants undesirably. It brings about a significant loss of leaves, stem and root fresh and dry weights (Nahrjoo and Sedaghathoor, 2018). According to Khoshbakht et al. (2010), as salt concentration and experiment duration were increased, more leaves were shed, resulting in a decline in the plant’s photosynthesizing area. Decreased leaf area and increased chloride and sodium ions in plant organs were reported as reasons for the decline in growth characteristics in the salinity-sensitive rootstocks (Levy and Syvertsen, 2004). It is believed that growth reduction at some growth stages of citrus trees seems to be related to a nutritional imbalance rather than a toxic effect of saline ions (Fadli et al., 2015).

The results imply that ‘Yashar’ had an inherently lower growth rate than ‘Clementine’ and ‘Younesi.’ Growth rate in the most plants including citrus trees depends upon the genotype (species – cultivar) (Khoshbakht et al., 2010) and in this study Clementine cultivar grew further than others (47.29 cm).
It was found that K uptake of citrus organs entirely depended on the rootstock type so that it was decreased in some rootstocks but increased in others. For example, on the sour orange rootstock, K accumulation in the shoots was increased by about 12% at a higher salinity level (Aboutalebi and Tafazoli, 2004). We found that K content in the shoots and roots of mandarin on the sour orange rootstock was increased at the higher salinity levels. In another study, Aboutalebi et al. (2007) confirmed that salinity exposure reduced K content in all studied citrus except for the sour orange rootstock, whose shoot K content was increased under salinity conditions. These researchers argue that a requisite for the plant's survival in saline conditions is high K ion concentration in its tissues. It is believed that citrus roots, when exposed to salinity up to about 20 mM, if potassium ions are present in the rhizospher, it uptake selectively and thereby preventing excessive sodium ion uptake competitively. As a result, the concentration of potassium ions does not decrease at low salinity levels (Aboutalebi and Tafazoli, 2004). In our research, different salinity levels could not reduce K uptake.

The Na and Cl contents were increased in plant tissues of peach and almond hybrids (GF677) with an increase in salt concentration (Gholami and Rahemi, 2009). Similarly, as soil salinity increases, plants take up Na more than other cations including K. Salinity increased Cl and Na content in citrus shoots and roots, but the extent of increase varies with species and treatment (Aboutalebi and Tafazoli, 2004). When a plant is exposed to salinity stress, the Na content increases in the tissues. In saline conditions, to avoid Na” toxicity, the plant transfers some Na to the outside and some to the vacuole. Na accumulation in the tissues of different box hedge plants was increased with an increase in salinity and drought stresses (Sedaghathoore and Abbasnia Zare, 2019).

Chlorophyll content in Yashar cultivar was lower than others, and the highest chlorophyll content was obtained in the interactive treatment of “control × Clementine.” Generally, with increasing salinity, chlorophyll content decreased in the studied cultivars. The loss of chlorophylls in plants under salinity stress might mainly be associated with the degradation of chloroplast structure, photooxidation of chlorophylls and their reaction with oxygen radicals, the destruction of chlorophyll synthesis precursors, the inhibition of biosynthesis of new chlorophylls, the activation of chlorophyll oxidizing enzymes (like chlorophyllase), and hormone disorders (Grzeszczuk et al., 2018; Sabzmeydani et al., 2020). Tuna et al. (2008) reported a decrease in chlorophyll a and b contents of maize with an increase in salinity stress, which supports our findings. They argue that salinity stress reduces photosynthesis factors, such as the contents of chlorophyll a, chlorophyll b, and total chlorophyll.

Based on the results, the proline content of mandarin leaves was increased with an increase in salinity. The response of citrus rootstocks to salinity is different so that Clementine produced the lowest proline in saline conditions compared to ‘Younesi’ and ‘Yashar.’ Alam et al. (2020) found a positive linear relationship between proline accumulation of citrus rootstocks and salinity levels. Their reports confirm the results of this experiment.

Proline increase is initiated by a decrease in leaf water potentials, which contributes to preserving turgor and reducing membrane injuries. As such, the tolerance of water deficit stress is improved by osmotic adjustment (Rahdari and Hoseini, 2012). It was found that plants employ different protective strategies to cope with drought stress, such as the accumulation of osmolites (e.g., proline and reducing sugars), as well as enzymatic and non-enzymatic strategies to tackle drought-induced oxidative stress (Lotfi et al., 2010). Li (2008) also reported an increase in leaf proline content at higher levels of salinity. According to Habibi and Amiri (2014), the highest proline accumulation rate was observed in the treatments of 150 and 200 mM of salinity on sour orange rootstock. These results are consistent with our findings. Although proline accumulates in all plant organs during stress, the highest rate of accumulation occurs in leaves (Molassiotis et al., 2006). Since proline accumulates in cells under environmental stresses and given its protective role and osmotic adjustment, a reason for the higher tolerance of the sour orange rootstock might have been the greater accumulation of this amino acid, which reduced the injuries of osmotic stress and ion stress of NaCl (Munns, 2002).
Salinity damages cell wall membrane and increases electrolyte leakage. In this study, the amount of electrolyte leakage (69.22%) under severe salinity (5 dS/m) was more than twice that of the control treatment. The studies of Momenpour et al. (2016) on almond and Gerami et al. (2019) on Stevia showed similar findings so that the electrolyte leakage of the leaves of all studied genotypes was increased with an increase in salt concentration. Of course, the reaction of mandarin cultivars for ion leakage was also different and the most leakage occurred in Yashar cultivar.

In the evaluated mandarin cultivars, the sugar content was not affected by salinity intensity, but its amount was different in the studied cultivars and Clementine had the highest sugar. According to Habibi and Amiri (2014), the sour orange rootstock was related to higher dissolved sugar contents than the Poncirus rootstock, implying its higher tolerance of high salinity levels. Increases in response to NaCl salinity stress have also been observed in the citrus rootstocks (Ghadakchiasl et al., 2017) and the rootstocks of grape (Alizadeh et al., 2010), apple (Sotiropoulos, 2007), and cherries (Erturk et al., 2007), in which the highest accumulation rate of dissolved sugars was observed at high salinity levels.

**Conclusion**

The results revealed that salinity stress reduced vegetative and photosynthesis factors of all three cultivars. Cultivar significantly affected root K and Na content, total chlorophyll content, proline, electrolyte leakage, and sugar content. The highest rate of proline accumulation, which reduced the injuries of osmotic and NaCl ion stress, was related to ‘Younesi.’ ‘Younesi’ was shown to be more salinity tolerant than the other cultivars owing to the uptake and mobilization of less Na and the prevention of severe damages to leaf chlorophyll. So, it can be said that ‘Younesi’ relatively outperformed the other studied cultivars under salinity stress.

**Disclosure Statement**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Contribution**

Shahram Sedaghathoor: Carried out, Design of the experiment and submitted the experiment.
Seyedeh Marzieh Madani: Analysis of the data, writing of first draft.
Saeed Piri: Reviewing and editing of the manuscript, Contributed to the analysis of the data, All authors discussed the results and contributed to the final manuscript.

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**Literature Cited**

Aboutalebi Jahromi, A. 2014. Study on the effect of rootstocks and NaCl salinity on concentration of micro elements in Valencia Orange shoots. Plant Ecophys. 6(16):88–99.
Aboutalebi, A., and E. Tafazoli. 2004. Effects of salinity on potassium, sodium, and chloride concentration of shoot and root in different citrus rootstocks. Iranian J. Hort. Sci. Tech. 5(1):11–22.
Aboutalebi, A., E. Tafazoli, B. Khodbarin, N. Karimian, and Y. Emam. 2007. Effect of salinity on concentration in shoot of macronutrients in five citrus species. Iranian J. Agri. Sci. 38(4):665–673.
Alam, A., H. Ullah, A. Attia, and A. Datta. 2020. Effects of salinity stress on growth, mineral nutrient accumulation and biochemical parameters of seedlings of three citrus rootstocks. Int. J. Fruit Sci. 20(4):786–804. doi: 10.1080/15538362.2019.1674762.
Alizadeh, M., S.K. Singh, V.B. Patel, R.C. Bhattacharya, and B.P. Yadav. 2010. In vitro responses of grape rootstocks to NaCl. Biol. Plantarum. 54:381–385. doi: 10.1007/s10535-010-0069-0.
Balal, R.M., Y. Ashraf, M.M. Mumtaz Khan, M.J. Jaskani, and M. Ashfaq. 2011. Influence of salt stress on growth and biochemical parameters of citrus rootstocks. Pak. J. Bot. 43(4):2135–2141.

Erturk, U., N. Sivriytepe, C. Yerlikaya, M. Bor, F. Ozdemir, and I. Turkan. 2007. Responses of the cherry rootstock to salinity in vitro. Biol. Plantarum. 51:597–600. doi: 10.1007/s10535-007-0132-7.

Fadli, E., I. Aymani, O. Chetto, D. Boudoudou, A. Talha, R. Benkirane, and H. Benyahia. 2015. Screening of six citrus rootstocks for salt tolerance at emergence and early seedling stage. Int. J. Recent. Sci. 6(12):7672–7678. doi: 10.21275/v5i3.nov161966.

Gerami, M., A. Mohammadian, and V. Akarpour. 2019. The effect of putrescine and salicylic acid on physiological characteristics and antioxidant in Stevia rebaudiana under salinity stress. J. Crop Breed. 11(29):40–54. doi: 10.29252/jcb.11.29.40.

Ghadakchiasl, A., A. Mozafari, and N. Ghaderi. 2017. Mitigation by sodium nitroprusside of the effects of salinity on the morpho-physiological and biochemical characteristics of Rubus idaeus under in vitro conditions. Physiol. Mol. Biol. Plant. 23:73–83. doi: 10.21275/s12298-016-0396-5.

Gholami, M., and M. Rahemi. 2009. Effect of NaCl salt stress on physiological and morphological characteristic of vegetative peach–almond hybrid (GF677) rootstock. Plant Prod. Tech. 1(1):21–31.

Golein, B., V. Rabiei, F. Mirabbasi, R. Fifaei, and M. Halaji Sani. 2016. Effect of salinity stress on physiological and biochemical traits in citrus genotypes. J. Hortic. Sci. 29(3):416–425.

Grezszczuk, M., P. Salachna, and E. Meller. 2018. Changes in photosynthetic pigments, total phenolic content, and antioxidant activity of Salvia coccinea Buch’hoz Ex Etl. induced by exogenous salicylic acid and soil salinity. Molecules 23(6):1296. doi: 10.3390/molecules23061296.

Habibi, F., and M. Amiri. 2014. Study on enzymatic activity and biochemical responses of two citrus rootstocks to in vitro salinity stress. J. Crop Improv. 15(4):165–177.

Jalili Marandi, R. 2010. Physiology of environmental stresses and mechanisms of resistance in garden plants (fruit trees, vegetables, ornamental plants, and medicinal herbs). West Azerbaijan Jahad Daneshghai Press, Urmia, Iran.

Khoshbakht, D., M. Mirzaei, and A. Ramin. 2015. Effects of salinity stress on gas exchange, growth, and nutrient concentrations of two citrus rootstocks. J. Crop Prod. Process. 4(14):35–47.

Khoshbakht, D., A. Ramin, B. Baninasab, and S. Aghajanzadeh. 2010. Effect of salinity on growth parameters of nine citrus rootstocks. Iranian J. Hortic. Sci. 40(4):71–81.

Levy, Y., and J. Syvertsen. 2004. Irrigation water quality and salinity effects in citrus trees. Hortic. Rev. 30:37–82. doi: 10.1002/9780470650837.ch2.

Li, Y. 2008. Kinetics of the antioxidant response to salinity in the halophyte Limonium bicolor. Plant Soil Environ. 54:493–497. doi: 10.17221/434-pse.

Lotfi, N., K. Vahdati, B. Kholdebarin, and R. Amiri. 2010. Soluble sugars and proline accumulation play a role as effective indices for drought tolerance screening in Persian walnut (Juglans regia L.) during germination. Fruits. 65:97–112. doi: 10.1051/fruits/2010005.

Mazumdar, B.C., and K. Majumder. 2003. Methods on physicochemical analysis of fruits, p. 187, 9788170352884. University College of Agriculture, Calcutta: India: Daya Publishing House.

Molassiotos, A.N., T. Sotiropoulos, G. Tanou, G. Kofidis, G. Diamantidis, and I. Therios. 2006. Antioxidant and anatomical responses in shoot culture of the apple rootstock MM 106 treated with NaCl, KCl, mannitol or sorbitol. Biol. Plantarum. 50:61–68. doi: 10.1007/s10535-005-0075-9.

Momenpour, A., D. Bakhshi, A. Imani, and H. Rezaie. 2016. Effect of salinity stress on the morphological and physiological characteristics in some selected almond (Prunus dulcis) genotypes budded on GF677 rootstock. Plant Prot. Tech. 7(2):137–152.

Montoliu, A., M.F. Lopez-Climent, V. Arbona, R.M.P. Clemente, and A. Gomez-Cadenas. 2009. A novel in vitro tissue culture approach to study salt stress responses in citrus plants. Plant Growth Regul. 59:179–187. doi: 10.1007/s10725-009-9401-0.

Munns, R. 2002. Comparative physiology of salt and water stress. Plant Cell Environ. 25(2):239–250. doi: 10.1046/j.0017-8742.2001.00808.x.

Nahrjoo, M., and S. Sedaghatoorooh. 2018. The Induction of salinity stress resistance in rosemary as influenced by salicylic acid and jasmonic acid. Commun. Soil. Sci. Plant. Anal. 49:1761–1773. doi: 10.1080/00103624.2018.1474913.

Prior, L.D., A.M. Grieve, K.B. Bevington, and P.G. Slavich. 2007. Long-term effects of saline irrigation water on ‘Valencia’ Orange trees: Relationships between growth and yield, and salt levels in soil and leaves. Aust. J. Agric. Res. 58:349–358. doi: 10.1071/AR06199.

Rahdari, P., and S.M. Hoseini. 2012. Drought stress: A review. Intl. J. Agron. Plant Prod. 3(10):443–446.

Sabzmeydani, E., S. Sedaghatoorooh, and D. Hashemabadi. 2020. Salinity response of Kentucky bluegrass (Poa pratensis L.) as influenced by salicylic acid and progestosterone. Rev. Chapingo Ser. Hortic. 26(1):49–63. doi: 10.5154/r.rchsh.2019.08.012.

Sedaghatoorooh, S., and A. Zare. 2019. Interactive effects of salinity and drought stresses on the growth parameters and nitrogen content of three hedge shrubs. Cogent Environ. Sci. 5:1682106. doi: 10.1080/23311843.2019.1682106.

Seday, U., O. Gulsen, A. Uzun, and G. Toprak. 2014. Response of citrus rootstocks to different salinity levels for morphological and antioxidant enzyme activities. J. Anim. Plant Sci. 24(2):512–520.
Sotiropoulos, T.E. 2007. Effect of NaCl and CaCl2 on growth and contents of minerals, chlorophyll, proline and sugars in the apple rootstock M 4 cultured in vitro. Biol. Plantarum. 51:177–180. doi: 10.1007/s10535-007-0035-7.

Tuna, A.L., C. Kaya, M. Dikilitas, and D. Higgs. 2008. The combined effects of gibberellic acid and salinity on some antioxidant enzyme activities, plant growth parameters and nutritional status in maize plants. Environ. Exp. Bot. 62:1–9. doi: 10.1016/j.envexpbot.2007.06.007.

Ziogas, V., G. Tanou, G. Morianou, and N. Kourgialas. 2021. Drought and salinity in citriculture: Optimal practices to alleviate salinity and water stress. Agron. 11:1283. doi: 10.3390/agronomy11071283.