International Journal of Horticultural Science and Technology
Vol. 5, No. 2; December 2018, pp 219-230
Print ISSN: 2322-1461 Online ISSN: 2588-3143
DOI: 10.22059/ijhst.2018.259507.246
Web Page: https:// ijhst.ut.ac.ir, Email: ijhst@ut.ac.ir

Improving Effects of Salicylic Acid on Morphological, Physiological and Biochemical Responses of Salt-imposed Winter Jasmine

Hossein Shahmoradi[1] and Davood Naderi[2*]

1. Horticulture Department, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

2. Young Researchers Club, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

(Received: 3 June 2018, Accepted: 3 September 2018)

Abstract

To investigate the positive effects of salicylic acid (SA) on morphological and biochemical traits of salinity stress-imposed winter jasmine, an experiment was conducted in a research greenhouse. The experiment was conducted using a factorial experiment based on completely randomized design with four levels of salinity stress (2, 4, 6, and 8 $dS.m^{-1}$) as the first factor and different levels of SA plant hormone (control, 181 and 362 μM) as the second factor in three replications. The results showed that spraying SA on winter jasmine plants, significantly improved all studied traits such as plant height, internode distance, fresh and dry weights, flower number, flower diameter, content of protein, POD and SOD enzyme activities. The positive effects of SA was concentration dependent. Salinity stress increased the activity of peroxidase (POD) and superoxide dismutase (SOD) enzymes compared to 2 $dS.m^{-1}$ salt treatment. The highest enzymatic activities were observed at 8 dS m^{-1}. In general, according to the obtained results, it can be concluded that foliar application of SA on the plants, has the potential to reduce the negative effects of salinity stress on winter jasmine.

Keywords: Carotenoids, Plant Hormones, SOD, Total chlorophyll, winter jasmine.

Abbreviations: Cv, Coefficient of variation; **SA**, Salicylic acid; **NF**, Number of flowers; **Chl a**, Chlorophyll a; **Chl b**, Chlorophyll b; **Chl T**, Total Chlorophyll; **SOD**, Super oxide dismutase; **POX**, Peroxidase; **FW**, Fresh weight; **FWF**, Fresh weight of flower; **DWF**, Dry weight of flower; **CEC**, Cation exchange capacity; **EC**, Electrical conductivity; **$dS.m^{-1}$,** Desisiemens per meter; **O.M**, Organic matter; **O.C**, Organic carbon; **ROS**, Reactive oxygen species.

Introduction

Winter jasmine (*Jasminum nudiflorum* L.), is an ornamental shrub from the olive family with yellow flowers (Taghavi and Hosni, 2014). Although it is native to temperate, tropical and subtropical areas, it is cultivated in many areas of the world (Zheng et al., 2003; Dang and Lee, 2012; Lee et al., 2010). Winter jasmine is an evergreen plant and plays an important role in beautification of the cities. Its leaves and flowers usually apply to clear the heat and detoxify the pollutants. Also, it has been reported that winter jasmine contains many kinds of active chemicals such as secoiridoid glycosides, flavonoids, yellow pigment, polysaccharides, essential oils, fatty acids, etc. (Wang et al., 2015). In

*Corresponding author, Email: d.naderi@khuisf.ac.ir

addition, other benefits of winter jasmine include the ability to grow in sloping and uneven surfaces and resistance to some types of stresses (Marchi et al., 2005). Therefore, according to the above subjects, it can be stated that the winter jasmine is an appropriate plant to beautify the urban spaces. Accordingly, it is necessary to identify and control the factors determining flowering and beauty of this plant.

Growth and development of plants are depended to genetic and environmental factors and their interactions (Rao et al., 2006). Plant growth and productivity have an inverse relationship with unfavorable biotic and abiotic factors (Mahajan and Tuteja, 2005). Plants are usually exposed to a multiple biotic and abiotic stresses so that these factors were considered most important factors that prevented the maximum genetic potential of plants (Mahajan and Tuteja, 2005; Xu et al., 2011). Meanwhile, abiotic stresses are the main causes of decline in plant yields so that the average loss of yield in many plants under these types of stresses have estimated to be more than 50% (Bray et al., 2000). Some researchers have suggested that environmental factors such as salinity and drought cause reduction in plant growth and productivity (Aboutalebi Jahromi and Hosseini Farahi, 2016). Some researchers have suggested that salinity stress (salinity of irrigation water and soil) is one of the most common environmental factors limiting plants growth and development (Aboutalebi Jahromi and Hassanzadeh Khankahdani, 2016; Acosta-Motos et al., 2017) and it can directly or indirectly influence plant, through disturbance in metabolism and inhibition of vegetative growth and reproductively of the plants. Also, due to side effects of salinity stress such as osmotic stress, ionic toxicity, metabolic changes, changes in the membrane structure and reduction of division and growth of the cells, it can reduce growth and development of plants (Perida and Das, 2005). Therefore, salinity stress generates ROS in the cells which causes secondary stress called oxidative stress (Cavagnaro et al., 2006; Abdoli Nejad and Shekafandeh, 2014).

Under salt stress, crop management practices that improve plant resistance to salt stress are different in which employ new strategies to improve salt stress tolerance to the plants (Acosta-Motos et al., 2017). Some researchers are believed that application of different compounds such as plant hormones or plant growth regulators can be an appropriate approach for reducing or eliminating the adverse effects of abiotic stress, especially salinity stress, in plants (Azoz, 2009; Xu et al., 2011; Khan et al., 2016). Waskiewicz et al. (2014) have founded that the plant hormones act as stress communication between aerial parts and roots and reduce the effects of salinity stress in plants. Salicylic Acid (SA) is a phenolic compound that produced in a large number of plants by root cells and plays a lot of roles in growth and development of plants as a quasi-hormonal substance (Khan et al., 2016). SA plays a central role in regulation of various physiological processes such as plant growth and development, ions absorption, photosynthesis, germination, and defense responses (Miura and Tada, 2014), and it regulated the physiological and biochemical characteristics of plants under abiotic stress conditions (Hashempour et al., 2014). SA increases the content of pigments under stress conditions and improves the undesirable effects of the stresses (Yavas and Unay, 2016).

Han et al. (2015) have examined the effects of different levels of SA on oxidative damage caused by abiotic stress and inhibition of photosynthesis on winter jasmine (*Jasminum sambac* L.) and they observed a significant increase in photosynthetic parameters and antioxidant enzymes (peroxidase and catalase) in plants sprayed with SA (100 μm).

Some studies indicated that exogenous application of SA can regulate the activity

of antioxidant enzymes and increase plant tolerance to salt stress (He et al., 2002; Erasalan et al., 2007). Erasalan et al. (2007) showed that exogenous use of SA increased the *Daucus carota* growth through enhancement of physiological and antioxidant activities under salt stress conditions.

Although numerous studies reported on the effects of SA on plants under different abiotic stresses, however limited number of studies are available about the effects of SA on ornamental plants under salinity stress, and no study has been reported about the effects of SA on winter jasmine under salinity stress conditions. Therefore, the present study was conducted to investigate the effects of different levels of SA on morphological and physiological characteristics of winter jasmine exposed to different levels of salt concentrations.

Material and methods

Plant materials

In the present study, the effects of different levels of SA on some physiological, morphological and biochemical traits of winter jasmine under salinity stress conditions were investigated. To do this, an experiment was conducted in 2016-2017 growing seasons in the research greenhouses of Khorasgan, Isfahan, Iran (geographical coordinates=32:38N and 51:45E; relative humidity=40% and average temperature of the greenhouse=28 ℃). The experiment was conducted using a factorial based experiment on completely randomized design with three replications. Two-year-old Winter jasmine plants were purchased from the Erfan garden in Karaj, Iran.

Treatments, growth conditions, soil and water characteristics

The experiment was conducted using a factorial based experiment on completely randomized design with four levels of salinity stress (2, 4, 6, and 8 $dS.m^{-1}$ NaCl) as the first factor which were applied after establishment of the plants and different levels of SA plant regulator 0 (spray with distilled water), 181 and 362 μM SA) as the second factor in three replications. SA were applied every 15 days after plants transfer to the pot and salinity stress with the source of NaCl salt gradually applied after the establishment of the plants for three months (salinity stress and foliar application of SA treatments were applied from 10 December 2016). Before the experiment, a sample of the soil used in the present study was sent to the soil laboratory to determine its physical and chemical properties. The soil analysis results are shown in Table 1.

In addition to the above test, before applying the treatments, to determine the physical and chemical properties, a sample of water that was used in the present study (1-1.5 liters) was sent to the soil and water laboratory, and the results of the analysis are listed in Table 2.

Table 1. physical and chemical characteristics of soil sample

Soil texture	pH	O.M	O.C	Ec ($dS.m^{-1}$)	CEC ($meq.100g^{-1}$)	Available Nitrogen (%)	P ($mg.kg^{-1}$ soil)	k ($mg.kg^{-1}$ soil)	Na ($mg.kg^{-1}$ soil)	Fe ($mg.kg^{-1}$ soil)	Cu ($mg.kg^{-1}$ soil)	Zn ($mg.kg^{-1}$ soil)	Mn ($mg.kg^{-1}$ soil)
Loam-clay	7.67	4.62	2.69	2.96	24.7	0.27	213.5	700	1.32	24.52	57.35	0.668	12.59

Table 2. physical and chemical characteristics of water sample

pH	Ec ($\mu mhos.cm^{-1}$)	Carbonates ($meq.l^{-1}$)	Bicarbonates ($meq.l^{-1}$)	K ($meq.l^{-1}$)	Ca ($meq.l^{-1}$)	Mg ($meq.l^{-1}$)	Cl ($meq.l^{-1}$)	Na ($meq.l^{-1}$)
7.38	253.98	-	1.94	0.87	7.8	12.6	4.6	3.56

Measurements

- ***Fresh and dry weights of the flowers***

To measure the FWF, from each pot, winter jasmine flowers were selected and their fresh weight was measured using a Mettler Toledo scale with a precision of 0.001 g.

After measuring the fresh weight of flowers, the plants in each pot were placed in special paper pocket and placed in an oven (Shimazco model) for 48 hours at 70 °C. After drying of the samples, the dry weight of the flowers was recorded individually.

- ***Number of flowers***

Number of flowers (NF) was obtained by counting the number of emerged flowers per pots.

Pigment concentrations

Chlorophyll a, b and total chlorophyll were calculated by Arnon (1967) method and carotenoids contents were obtained by Lichtenthaler (1987) method. Accordingly, at first, 0.1 g of fresh tissue was weighed and it rubbed in a stone mortar by application of the acetone 80% until was obtained a scum. Then, the scum was isolated by filter paper and volumetric flask. Again, the resulting scum was rubbed by acetone 80% and was isolated. Then, the extract volume was reached to 10 ml by acetone 80%. Immediately, some of the extract was transferred to a cell and absorbed by a spectrophotometer (JENWAY 6300 model) at 645, 663, and 470 nm wavelengths. Acetone 80% was used as a Blanc solution. At the end, chlorophyll a, b, total chlorophyll and carotenoids for each sample were determined by using the following formulas:

$$Chlorophyll\ a = \frac{\left[\left(12.7 \times D663\right) - \left(2.69 \times D645\right)\right] \times V}{1000 \times W}$$

$$Chlorophyll\ b = \frac{\left[\left(22.9 \times D645\right) - \left(4.93 \times D663\right)\right] \times V}{1000 \times W}$$

$$Total\ chlorophyll = \frac{\left[\left(20.2 \times D645\right) - \left(8.02 \times D663\right)\right] \times V}{1000 \times W}$$

$$carotenoids = \frac{\left[\left(1000 \times D470\right) - \left(1.82 \times Chl.a\right) - \left(85.02 \times Chl.b\right)\right]}{198}$$

V: Final volume of extracts per milliliters, W: Tissue weight per gram, D: Optical absorption

SOD enzyme activity

To determine activity of the SOD enzyme, a reaction mixture was prepared that contains 50 mM phosphate buffer, 0.013 mM methionine, 0.1 µm EDTA and 2 µm riboflavin, which was kept in full darkness. Immediately, after adding of the riboflavin, 3 ml of it solution was poured into the test tube and in each sample were added 100 ml of protein extract. The test tubes were placed at a distance of 30 cm from the light source for 16 minutes and at this time, the spectrophotometer was set at 560 nm with a dark solution as a control treatment. After 16 minutes, samples were read at the mentioned wavelength. Finally, the SOD enzyme activity was calculated based on the enzyme unit per mg of protein for all samples (Giannopolitis et al., 1997).

Statistical analysis

The experimental design was conducted using a factorial based on completely randomized design (with two factor including: salinity stress and foliar application of SA on winter jasmine) in

three replications. The data were analyzed by SAS software (version 9.4) and the LSD test was used at $p< 0.05$ to compare the mean of the data. The charts were drawn using Microsoft Excel software.

Results

Number of flowers

Analysis of variance of NF (Table 3) showed that salinity, SA and their interactions had significant effect on NF trait at $p<0.01$.

The results of the mean comparison between different salinity levels and SA concentrations on the number of flowers in winter jasmine (Fig. 1) showed that the highest NF (13.33) was obtained by $dS.m^{-1}$ treatment × 362 µM SA and the lowest NF (5 flowers) was achieved in 8 $dS.m^{-1}$ salinity × control interactions.

Fresh weight of flower

Based on the results of Table 3, the FWF of winter jasmine had a significant difference at $p<0.01$ under application of different levels of salinity, and SA and their interactions.

Studying the interactions between different levels of salinity × SA (Fig. 2), the highest FWF (equal to 2.97 g) was observed in the 2 $dS.m^{-1}$ salinity × 362 µM of SA treatment and the lowest FWF (equal to 0.72 g) was obtained at 8 $dS.m^{-1}$ salinity × control of SA treatment (Fig. 2).

Table 3. Analysis of variance of morphological traits of winter jasmine exposed to salinity stress levels and sprayed with different SA concentrations and their interactions

Treatments	Df	Number of flower	Fresh weight of flower	Dry weight of flowers
Salinity	3	34.59 **	1.50 **	0.51 **
SA	2	52.03 **	4.95 **	1.22 **
Salinity × SA	6	3.84 **	0.15 **	0.03 ns
Error	24	1.00	0.4	0.03
%Cv		11.84	12.54	25.54

ns: Non-significant and **: significant at $p<0.01$

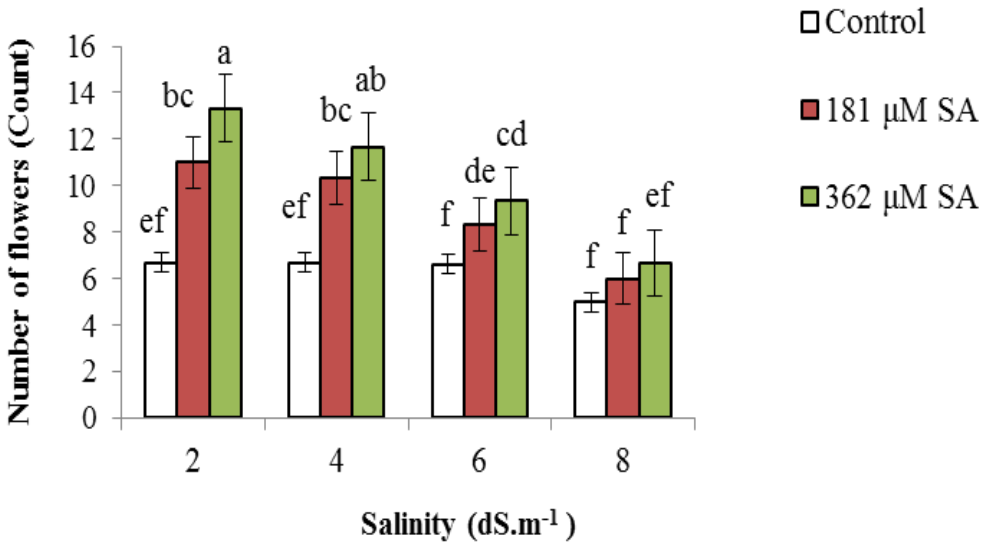

Fig. 1. Interaction of different levels of salinity × salicylic acid on number of flowers in winter jasmine Mean of each data fallowed by the non-similar letters have significantly difference at $p<0.05$

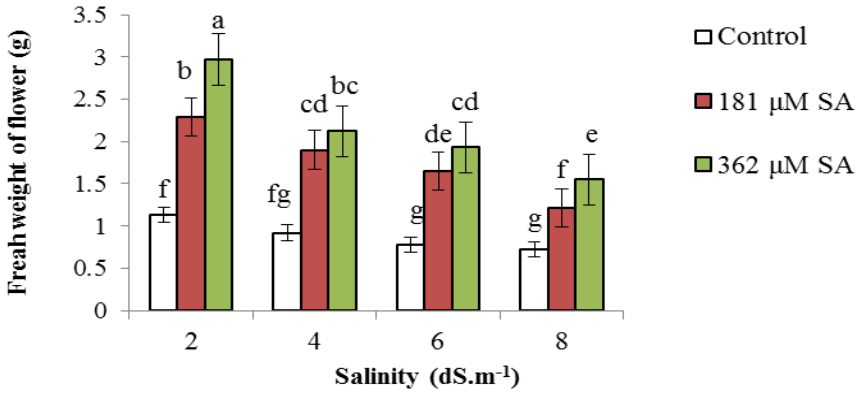

Fig. 2. Interaction of different levels of salinity × SA on fresh weight of flower in winter jasmine Mean of each variable fallowed by the non-similar letters have significantly difference at p<0.05

Table 4. Mean comparison on dry weight of flowers in winter jasmine for salinity stress levels, SA concentrations and their interactions

Treatments Salinity (dS.m^{-1})	Dry weight of flowers (g)
2	0.99 a
4	0.83 a
6	0.57 b
8	0.48 b
LSD	0.18
Foliar application of SA (µM)	
0	0.37 c
181	0.78 b
362	0.99 a
LSD	0.15

Mean of each variable fallowed by the non-similar letters have significantly difference at p<0.05

Dry weight of flower

In Table 3, it is shown that the DWF was influenced by both treatments of different levels of salinity stress and SA (p<0.01), but under their interaction treatment, there was not a significant difference for dry weight (Table 3).

Based on the results of Table 4 (comparison of mean values), salinity stress reduced the DWF in winter jasmine so that the highest and the lowest DWF were observed in 2 dS.m^{-1} and 8 dS.m^{-1} treatments, respectively, which both had a significant difference with together. Also, the above data showed that between DWF in 2 dS.m^{-1} (0.99 g) and 4 dS.m^{-1} (0.83 g) of salinity treatments. Between amount of DWF in 6 dS.m^{-1} (57. g) and 8 dS.m^{-1} (48. g) there was no significant difference (Table 4).

In addition to the above results, foliar application of SA on DWF in winter jasmine, the results of Table 4 showed that the highest DWF (weighed 0.99 g) was recorded in 362 µM of SA treatment, which had a significant difference with other treatments, and the lowest DWF (0.37 g) was obtained in control treatment with a significant difference compared with the other treatments (Table 4).

Pigment concentrations

Analysis of variance of Table 5 showed that the effects of different levels of salinity and SA factors were significant for the concentrations of Chl a and Chl b at p<0.01, but no significant difference was observed for salinity × SA interactions for both Chl concentrations. There was a significant difference for total Chl. (p<0.01) for single effects of salinity and SA factors and for the salinity × SA interactions (p<0.05) (Table 5).

Table 5. Analysis of variance of some biochemical traits of winter jasmine exposed to salinity stress levels and sprayed with different SA concentrations and their interactions

Treatments	df	Chl a	Chl b	Total chl	Carotenoids	SOD activity
Salinity	3	52.49 **	17.45 **	127.96 **	2.68 **	0.99 **
SA	2	59.42 **	11.78 **	123.94 **	2.94 **	0.48 *
Salinity × SA	6	3.84 ns	1.17 ns	6.49 *	0.18 **	0.01 ns
Error	24	3.03	0.83	2.20	0.05	0.1
%Cv		25.12	26.67	14.33	16.38	28.61

ns: non-significant, * and **: significant at $p<0.05$ and $p<0.01$, respectively.

Table 6. Mean comparison of salinity stress levels, SA concentrations and their interaction on Chl a, chl b total chl, carotenoids and SOD activity traits in winter jasmine

Treatments Salinity ($dS.m^{-1}$)	Chl a ($mg.g^{-1}FW$)	Chl b ($mg.g^{-1}FW$)	SOD ($mg.g^{-1}$ Pro)
2	9.77 a	4.67 a	0.80 c
4	7.56 b	4.18 a	0.87 c
6	6.42 b	2.61 b	1.02 b
8	3.97 c	1.94 b	1.52 a
LSD	1.69	0.89	0.31
Foliar application of SA (μM)			
0	5.09 b	2.54 b	0.92 c
181	6.29 b	3.23 b	1.06 ab
362	9.41 a	4.50 a	1.31 a
LSD	1.47	0.77	0.26

Mean of each variable fallowed by the non-similar letters have significantly difference at $p<0.05$

Based on the results of variance analysis on the carotenoids data (Table 5), content of carotenoids in winter jasmine leaves were influenced by salinity, SA and their interactions at $p<0.01$.

Mean comparison of the effects of salinity levels on Chl a (Table 6) showed that the highest amount of Chl a (9.77 $mg.g^{-1}$ FW) was observed in 2 $dS.m^{-1}$ salinity treatment and had a significant difference with other treatments. On the hand, the lowest Chl a in salinity treatment was recorded at 8 $dS.m^{-1}$ salinity stress (3.97 $mg.g^{-1}FW$) and this treatment had a significant difference with other treatments. For the effects of SA on content of Chl a, the results showed that the highest and the lowest amount of chlorophyll a were recorded in 362 μM SA and control treatments, respectively, and their amount were calculated equal to 41.7 and 9.09 $mg.g^{-1}FW$, respectively. There was a significant difference between content of the Chl a under 362 μM SA treatment compared to the content of the Chl a under other treatments, but between the Chl a content in control treatment and application of 181 μM SA (6.29 $mg.g^{-1}FW$) there was no significant difference (Table 6).

Highest content of Chl b (4.67 $mg.g^{-1}$ FW) was achieved under 2 $dS.m^{-1}$ salinity, with no significant difference with 4 $dS.m^{-1}$ salinity (4.18 $mg.g^{-1}FW$). The lowest amount of Chl b (2.45 $mg.g^{-1}FW$) was obtained at 8 $dS.m^{-1}$ of salinity treatment, without significant difference with amount of Chl b under 6 $dS.m^{-1}$ salinity (equals to 2.61 $mg.g^{-1}FW$). Besides the above results, comparison of the mean effects of different levels of SA application on Chl b (Table 6) showed that different SA concentrations led to a significant difference in the Chl b content, so that the highest (4.50 $mg.g^{-1}FW$) was obtained in 362 μM SA treatment and the lowest Chl b content (equal to 2. 54 $mg.g^{-1}FW$) was achieved in control

treatment of SA. There was a significant difference between content of Chl b at 362 µM treatment compared with the other SA concentrations, but there was no significant difference between content of the Chl b that was obtained in control treatment of SA with content of the Chl b at 181 µM SA concentration (23.3 mg.g^{-1}FW).

The results of the interaction between different levels of salinity stress × SA concentrations were shown in Fig. 3. Based on the results, maximum amount of total Chl (equivalent to 18.18 mg.g^{-1}FW) was observed at 2 dS.m^{-1} × 362 µM SA interaction and its minimum amount (equivalent to 4.6 mg.g^{-1}FW) was achieved in interaction of salinity treatment at 8 dS.m^{-1} × 181 µM of SA (Fig. 3).

The results of the salinity levels × different concentrations of SA interaction (Fig. 4) showed that the highest amount of carotenoids (equal to 2.82 mg.g^{-1}FW) were obtained in 2 dS.m^{-1} salinity × 362 µM SA and the lowest amount of carotenoids (equivalent to 4.6 mg.g^{-1}FW) were recorded at 8 dS.m^{-1} salinity × control treatment of SA.

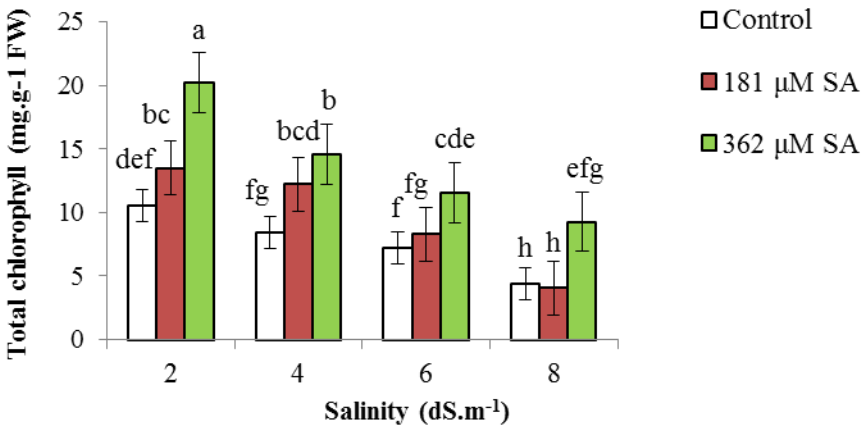

Fig. 3. Interaction of the different levels of salinity × SA on total Chl in winter jasmine
Mean of each variable fallowed by the non-similar letters have significantly difference at p<0.05.

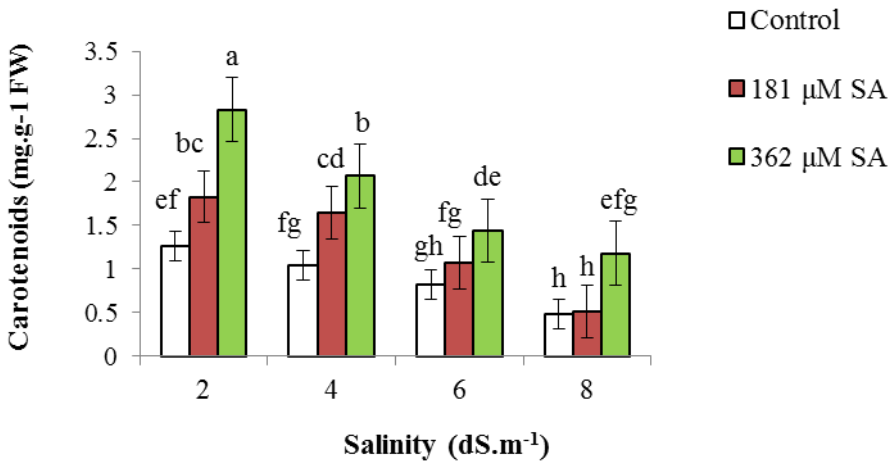

Fig. 4. Interaction of the different levels of salinity × SA on content of carotenoids in winter jasmine
Mean of each variable fallowed by the non-similar letters have significantly difference at p<0.05.

SOD enzyme activity

SOD activity was influenced by single effects of salinity ($p<0.01$) and SA ($p<0.05$), but there was no significant difference between salinity stress × foliar application of SA interactions (Table 5).

Comparison of the mean effects of different levels of salinity stress on content and activity of SOD enzyme is shown in Table 6. Based on the results, a significant increase in the SOD activity was observed under application of salinity stress and foliar application of SA. With increasing the concentration of salinity stress, the activity of this enzyme was increased so that the highest activity of SOD enzyme was achieved in 8 $dS.m^{-1}$ salinity conditions (1.52 $mg.g^{-1}$ pro) which was higher than the other levels of salinity stress. Lowest activity of SOD enzyme (0.08 $mg.g^{-1}$ pro), was observed in 2 $dS.m^{-1}$ salinity treatment. With increasing the SA concentrations, the activity of SOD enzyme was increased so that the highest activity of this enzyme was detected in the treatment of 362 Mm SA (1.31 $mg.g^{-1}$ pro), However, it was not significantly different with SOD enzyme activity in the 181 µM SA application (1.06 $mg.g^{-1}$ pro). The lowest activity of SOD enzyme (0.92 $mg.g^{-1}$ pro) was observed in the control treatment of SA, which was significantly lower than SOD activity in other SA treatments (Table 6).

Discussion

In present study, our results demonstrated that salinity had significant and negative effects on some growth and physiological traits of winter jasmine. In other words, the flower number, fresh and dry weights of flower in plants treated with salinity concentrations was decreased in a concentration dependent manner, which is in consistent with Salachna and Piechocki's (2016) study that showed the negative effects of salinity stress on morphological traits and flowering of plants. In some studies it has been reported that salinity is one of the most serious abiotic stresses influencing plant growth and productivity in various part of the world (Joseph and Jini, 2005; Wrochna et al., 2010; Moradinezhad and Khayyat, 2014). Some researchers have shown that the negative effects of salt stress on all major processes such as plant growth, development, metabolism, anatomy, photosynthesis, respiration, water potential, enzymatic activity, absorption of minerals and nutrient balance (Kozlowski, 1997; Parihar et al., 2015; Aboutalebi Jahromi and Hosseini Farahi, 2016). These negative effects can have direct or indirect effects on plant processes (Shannon et al., 1994). Confirming the negative effects of salinity stress and the obtained results of the current study, Zapryanova and Atanassova (2014) examined the effects of different levels of salinity stress (0.4%, 1.2% and 2% NaCl) on some ornamental plants and founded that salinity stress had negative effects on morphological and flowering characteristics of the studied species. Aboutalebi Jahromi and Hosseini Farahi (2016) showed that salinity stresses exerts its negative effects through two main mechanisms: toxic effects of ions and the osmotic stress. Also, in some studies, researchers have showed the negative effects of salinity stress on stomatal and photosynthetic activities of plants (Aliniaeifard et al., 2016); Also, salt stress induced osmotic stress is the reason for oxidative stresses by ROS (Ahmed et al., 2013). Salinity stress can affect plant morphological and growth indices (Zhang and et al., 2018). Waskiewicz et al. (2014) had mentioned that some plant hormones act as a communication messengers between aerial parts and roots and reduce the effects of salinity stress in plants. Accordingly, Erasalan et al. (2007) showed that exogenous use of SA increased the carrot growth and physiological and antioxidant activities under salinity stress conditions.

Results of current study showed that foliar application of SA decreased the negative effects of salinity stress on morphological and biochemical traits. In

relation to reducing the effects of salinity stress by SA, Rajeshwari and Bhuvaneshwari (2017) exhibited that SA phytohormone as a signaling molecule can help plants to cope with abiotic stresses, especially salinity stress. Improved plant growth, ion absorption and transfer, prevents of oxidative damage in the plant by detoxifying superoxide radicals have been reported by application of SA on different plant species.

Chlorophyll conservation is considered as one of the parameters for salinity tolerance in plants (Sevostova et al., 1988), chlorophyll disintegration due to salinity stress has been reported in some saline-sensitive plants (Hernandez et al., 1995). It has been proven that chlorophyll content and chlorophyll stability in plants decreased with increasing concentrations of salinity (Aliniaeifard et al., 2016). Furthermore, it has been suggested that SA has a positive role on photosynthetic rate, stomatal factors (Khan et al., 2010), pigments, structure of chloroplasts and enzymes involved in the photosynthesis process (Rajasekaran et al., 2002; Poor et al., 2011). Also, the role of SA in defense mechanisms had been suggested under salinity stress conditions (Tissa et al., 2000; Al-Hakimi and Hamada, 2001).

In confirming our results, Hadi et al., (2014) were used four concentrations (0, 0.1, 0.5 and 1.0 mM) of SA by different application methods (soil, foliar and priming) under salinity stress on white bean plants and founded that although salt stress reduced the amount of chlorophyll a, chlorophyll b, total chlorophyll, carotenoids, proline, protein and soluble sugars in white bean, SA reduced the negative effects of salinity stress and increased the amount of plant pigments and plant growth. Some researchers confirmed that the occurrence of salt stress in plants leads to the accumulation of osmolites such as proline, insoluble sugars, accumulation of the active oxygen species, and changes in activity of the antioxidant defensive systems (Averina et al., 2010), ROS are removed or deactivated by enzymatic systems such as CAT, POX, SOD, and non-enzymatic systems such as ascorbic acid, glutathione, alpha-tocopherol (Bailly, 2004; Mittler et al., 2004). Generally, SOD enzymes which play a major role in protecting cells from oxidative stress, convert radical superoxide into hydrogen peroxide and molecular oxygenation (Fikret et al., 2013). Therefore, it has been reported that increasing SOD activity can be due to an increase in the amount of superoxide, or as a protective mechanism against oxidative stress in plants (Sharma and Dubey, 2005). In this study, we founded that SOD activity increased under both salinity stress and application of the SA (Table 6). Concerning the increase of SOD under different levels of salt stress and SA, the results of this study are in consistent with the results of other studies; for instance, Al- Whaibi et al. (2012) reported that application of SA improved the negative effect of salinity stress through reducing the oxidative stress generated by NaCl and enhanced the activities of antioxidant enzymes. Aydin et al. (2011) founded that under salinity stress, plant increased POX and SOD enzyme activities to cope with salinity stress conditions. Besides, Grailoo and Ghasemnezhad (2011) investigated the effects of different levels of SA enzyme on protein degradation, antioxidant activities of SOD and POX in vase life of cut rose flowers, and showed that SA reduced protein degradation and increased SOD and POX enzymatic activities.

Finally, it can be concluded that one or all of the above mentioned mechanisms, may reduce the number of flowers, fresh weight and dry weight of the winter jasmine plant under salt stress conditions.

Conclusion

The results of current study showed that the salinity stress had adverse effects on winter jasmine so that it negatively

influenced the morphological and biochemical traits and induced SOD enzyme activity. Foliar application of SA concentrations had positive effects on mentioned traits and reduced the negative effects of salinity stress on this plant. In addition, according to our findings, it seems that foliar application of SA in 362 µM concentration could be applied as a plant growth regulator on winter jasmine to reduce the salinity stress and improve the tolerance level of this plant.

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