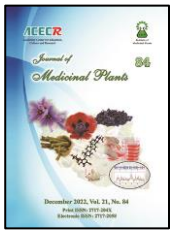
*J. Med. Plants* 2022; 21(84): 87-99

Institute of Medicinal Plants

**Journal of Medicinal Plants**

Journal homepage: www.jmp.ir



**Research Article**

# The effect of methyl jasmonate on morpho-physiological and biochemical parameters and mineral contents in *Satureja khuzistanica* Jamzad under salinity stress

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ARTICLE INFO

*Keywords:*
*Satureja khuzestanica*
Medicinal plants
Salinity
MeJA
Growth
Antioxidant activity

ABSTRACT

**Background:** *Satureja khuzestanica* is an endemic medicinal plant that widely distributed in the northern Khuzestan and southern Lorestan provinces of Iran. **Objective:** In this study, simultaneous effects of methyl jasmonate (MeJA) and salinity on morpho-physiological parameters and minerals contents in *S. khuzistanica* were studied. **Methods:** Different salt levels (0, 3, 6 and 9 dS/m) were applied during growth period for one month. MeJA spraying at 0, 60 and 120 µM concentrations performed three times for one week. Samples were taken during flowering stage. **Results:** The results showed that MeJA × salt interaction had significant effects on all morpho-physiological and biochemical parameters of *S. khuzestanica* ($P < 0.01$). The highest stem length, root length, fresh and dry weights were observed at 60 and 120 µM MeJA without salt. The amounts of chlorophyll, N, P, $K^+$, $K^+/Na^+$, $Ca^{2+}$ and $Mg^{2+}$ had significant reductions with increasing salt levels. The highest amounts of these parameters were observed at 60 µM MeJA without salt. There were significant enhancements in total phenol, antioxidant activity, proline, sugar and Na amounts with increasing salt levels. The highest content of total phenol and antioxidant activity was induced at 60 µM MeJA × 6 dS/m salt (2.22 and 50.23 %, respectively). The 9 dS/m salt treatment at 60 µM MeJA had the highest sugar (1.69 mg/g) and proline (0.29 mg/g) contents. **Conclusion:** Totally, 60µM MeJA concentration caused the best performance of savory under salt stress. Therefore, MeJA application can be helpful to alleviate negative effects of salt in *S. khuzistanica*.

## 1. Introduction

Salinity constraints can result in low plants yields and productivity with adverse effects on germination and plant vigor [1]. Salt stress can cause hyperionic or hyperosmotic effects on plants; Accumulation of toxic ions including $Na^+$

*Abbreviations:* MeJA, Methyl Jasmonate; *S. khuzistanica*, *Saturja khuzistanica*; dS/m, Decisiemens per Meter; µM, Micromolar; N, Nitrogen; P, Phosphorus; $K^+$, Potassium; $K^+/Na^+$, Potassium/Sodium ratio; Ca, Calcium; Mg, Magnesium; mg/g, Milligram per Gram

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doi: 10.52547/jmp.21.84.87

Received 9 September 2022; Received in revised form 2 November 2022; Accepted 5 November 2022

and $Cl^-$ in plants can cause disorders in growth, physiological and biochemical properties, production of reactive oxygen species and inhibition of $K^+$ uptake [2, 3]. It has been proved that salinity changes quantitative and qualitative traits of plants. In a research, high salinity levels decreased all growth parameters such as stem and root length and had negative effects on physiological properties like Chlorophyll, soluble sugar and proline in rosemary [4].

Most of cultivated lands in arid and semi-arid regions face with salinity problems. There are various strategies to reduce deleterious effects of salinity and let the plant to have better performance in these regions [5]. One of these strategies is to use conventional phytohormones; these phytohormones acts as stress alleviators against various biotic and abiotic stresses [2, 6]. Methyl jasmonate (MeJA) is one of these phytohormones which can modulate growth, physiological, developmental and phytochemical responses in plants under stressful conditions [7]. Positive effects of MeJA on physiological and phytochemical characteristics have been reported in *Origanum vulgare* L. under salt stress [1]. MeJA effects in plants are dependent on several factors including MeJA concentrations and plant type [8].

Lamiaceae family plants are generally cultivated in arid and semiarid rangelands with salinity problem; they have been widely used for industrial and medicinal purposes due to their valuable secondary metabolites [9]. Savory (*Saturja khuzistanica* Jamzad) is an endemic medicinal plant which grows wild in west and south of Iran [10]. This plant is used for different pharmaceutical goals including antimicrobial, tranquilizing, appetizing, anti-inflammatory and anti-cancerous applications [11]. Since the demands for this species are higher than its harvest from natural habitats [11], it is necessary to develop cultivation programs. Furthermore, most agricultural lands in Iran are faced with salinity challenges; therefore, it is important to use several stimulants to improve tolerance and cultivation of this plant under salt stress. This study aimed to investigate simultaneous effects of MeJA × salt on morpho-physiological and biochemical parameters in *S. khuzistanica*. This research can provide more information on the roles of MeJA application in modifying physiological and biochemical responses of *S. khuzistanica* under salt stress and help to exploit saline lands for its cultivation.

## 2. Materials and Methods

### *2.1. Plant material and treatments application*

The seeds of *S. khuzistanica* were prepared from Pakan Bazr Company in Isfahan. After sterilizing the seeds with 1 % sodium hypochlorite for 5 min, they were kept on filter paper in petri-dishes containing distilled water. *S. khuzistanica* seedlings were transferred to 2 kg pots (filled with soil) (three seedlings in each pot) under greenhouse condition after germination and primary growth. This study was conducted in greenhouse on the base of factorial experiment in a completely randomized design (CRD) with three replications. Two abiotic treatments were applied on *S. khuzistanica* seedlings. The treatments composed of four levels of NaCl (0, 3, 6 and 9 dS/m) and three concentrations of MeJA including 0, 60, and 120 µM.

Different salt levels were applied duration of growth period for one month. In order to prevent osmotic shock, every 10 days, the solution concentration was increased and it continued until to reach the highest salt level (9 dS/m). The solution of MeJA was made through the following method: MeJA (Sigma-Aldrich, Japan) was gently mixed with 96 % ethanol in order to dissolve completely and then, distilled




[ DOR: 20.1001.1.2717204.2022.21.84.8.0 ]
[ DOI: 10.52547/jmp.21.84.87 ]

water was added to obtain desirable concentrations [1]. The solution of MeJA was applied by spraying on aerial parts of *S. khuzistanica* plants until run-off. This process performed three times per day for one week. Two weeks after MeJA application (at the flowering stage), plants aerial parts from each pot were harvested for physiological and biochemical experiments. Morphological traits including stem length, root length and fresh and dry weights of aerial parts were measured. It is necessary to mention that aerial parts of savory were dried at 20 ˚C in shade.

*2.2. Physiological and biochemical parameters*

*2.2.1. Chlorophyll content*

Chlorophyll was measured by Arnon (1967) method [12]. Savory fresh leaves (0.5 g) were ground in 5ml of acetone (80% v/v). Its absorbance was recoreded at 645 nm (Chl a) and 663 nm (Chl b) using a spectrophotometer (UV1280, Shimadzu company). The blank contained 80 % acetone.

*2.2.2. Soluble sugar content*

Hellubust and Craigie method (1978) was used to measured reduced sugar content (mg/g FW) [13]. 70 % ethanol (10 ml) was added to the leaves powder and this solution was kept in the refrigerator for 1 week. Then, 5 ml of $H_2SO_4$ was added to 1 ml of the solution + 1 ml of 5 % phenol. The solution was diluted 10 times. The absorbance was recorded at 485 nm. The following formula was used to calculate soluble sugar amount using the standard curves: Soluble sugar = (X*0.007)/g/ leaves powder (g); where X is wave length.

*2.2.3. Proline measurement*

Bates method was used to estimate proline amount [14]. Fresh leaves (0.5 g) were pulverized with 10 ml sulfosalicylic acid (3 %) by porcelain pestle and mortar. The mixture was centrifuged at 13000 xg (10 min). The contents of each tube included the extract (2 ml), ninhydrin indicator and concentrated acetic acid; the tubes were placed in boiling water at 100 °C (30 min). After cooling down the tubes (for 15 min), 4 ml of toluene was added to each tube and shaked by a vortex (15 s). The absorption of the red surface layer and standard samples were simultaneously determined at 520 nm by a spectrophotometer. Proline amount was calculated using the following formula: Proline = (X*0.004)/g; /leaves powder (g); where X is wave length.

*2.2.4. Total phenol contents*

Folin- Ciocalteau reagent was used to determine total phenol content [16]. Dry leaves powder (0.1 g) was extracted with 10 ml of 85 % methanol and centrifuged at 3000 xg (10 min). The extracts (0.5 ml) were transferred to tubes with 1 ml Folin- Ciocalteau reagent (10%). After 5 min, 0.3 ml of sodium carbonate (10%) was added to the mixture and shaken for 1 h. Absorbance was measured at 765 nm. The standard graph of Gallic acid was used to calculate total phenol content.

*2.2.5. Antioxidant activity (DPPH (2,2-diphenyl-1-picryl-hydrate) radical scavenging assay)*

Antioxidant activity was determined Shimada et al. (1999) method [17]. Dry plant samples (0.2 g) were mixed with 2 ml of 85 % methanol and shacked for 24 h. After centrifuging, the filtrated extracts (500 µl) and distilled water (500 µl) were centrifuged at 1000 xg (5 min). DPPH solution (2925 µl: 0.0024 g DPPH in 100 ml of 85% methanol) was added to the extracts (75 µl); they were placed in darkness (30 min). The absorbance was recorded at 517 nm.





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[ DOI: 10.52547/jmp.21.84.87 ]

$$\text{Antioxidant activity (\%)} = 100 \times [(A_{control}-A_{extract})]/A_{control}$$

*2.3. Minerals measurements*

Nitrogen content was measured by Kjeldahl method after wet digestion using sulfuric acid ($H_2SO_4$) and hydrogen peroxide ($H_2O_2$). The following instruction was used to measure other minerals contents: 1 g of each dried leaf sample powder were burned in oven at 550 ˚C for 4 h. 2 mol/l HCl (10 ml) was added to each sample to digest by a heater. After filtrating the mixture, distilled water was added to it to obtain 50 ml. Calorimetry method was used to measure P [18]. Na and K were measured using flame photometer (JENWAY company, England). $Ca^{2+}$ and $Mg^{2+}$ were determined by titration method. Versene was used as one of compound to measure $Ca^{2+}$. Ammonium chloride + ammonia and eriochrome black T (EBT) was used as two compounds for titration to calculate $Mg^{2+}$ amounts [19].

*2.4. Statistical analysis*

Test of normality was conducted for collected data (Kolmogorov-smirnov test). Analysis of variance (ANOVA) test, as a method of comparing the means (Duncan test), was used to determine significant differences among treatments in SPSS 20 software.

## 3. Results

The findings showed that salt × MeJA interactions significantly affected morpho-physiological traits, phytochemical parameters, and mineral elements ($P \leq 0.01$) (Table 1).

*3.1. Morphological traits*

The results showed that all morphological parameters including stem and root lengths, fresh and dry weights of *S. khuzistanica* aerial parts significantly decreased following increasing salt levels (Table 2). MeJA application had better performance at all salt levels and could alleviate negative salt effects. The highest amounts of all morphological traits were observed at 60 and 120 µM MeJA without salt. There was no significant difference between 60 and 120 µM MeJA concentrations for fresh and dry weights of aerial parts.

**Table 1.** ANOVA test for the measured parameters in *S. khuzistanica*

| Source | df | Stem length | Root length | Fresh weight | Dry weight | Total chlorophyll | Sugar | Proline |
|---|---|---|---|---|---|---|---|---|
| Salt | 3 | 130.2** | 55.5** | 66.03** | 9.59** | 0.51** | 0.94** | 0.05** |
| MeJA | 2 | 20.02** | 7.87** | 5.89** | 1.17** | 0.33** | 0.24** | 0.003** |
| Salt × MeJA | 6 | 1.39** | 1.77** | 1.33** | 0.56** | 0.006** | 0.004** | 0.001** |
| Error | 24 | 1.12 | 1.10 | 0.87 | 0.11 | 0.0002 | 0.0004 | 0.0001 |
| CV% | - | 4.87 | 6.52 | 7.72 | 5.16 | 1.63 | 3.22 | 6.82 |

**Table 1.** ANOVA test for the measured parameters in *S. khuzistanica* (Continued)

| Source | df | Total phenol | Antioxidant activity | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $K^{+}/Na^{+}$ | Nitrogen | P |
|---|---|---|---|---|---|---|---|---|---|---|
| Salt | 3 | 1.33** | 545.32** | 0.0001** | 0.001** | 0.011** | 0.013** | 3.46** | 1.28** | 0.013** |
| MeJA | 2 | 0.65** | 414.77** | 0.00003** | 0.001** | 0.005** | 0.003** | 0.88** | 0.39** | 0.004** |
| Salt × MeJ | 6 | 0.012** | 7.83** | 0.00005** | 0.0001** | 0.001** | 0.0001** | 0.03** | 0.034** | 0.0001** |
| Error | 24 | 0.002 | 5.49 | 0.00001 | 0.00003 | 0.00001 | 0.00002 | 0.003 | 0.003 | 0.00003 |
| CV% | - | 2.26 | 5.07 | 1.01 | 3.89 | 2.02 | 3.04 | 4.87 | 2.49 | 1.24 |

**: represent significant at 1 % probability level.

**Table 2.** Effects of salt × MeJA interaction on morphological traits in *S. khuzistanica*. The values represented as means ± standard deviations

| Salinity (dS/m) | MeJA (µM) | Stem (cm) | Root (cm) | Fresh weight of aerial parts (g) | Dry weight of aerial parts (g) |
|---|---|---|---|---|---|
| 0 | 0 | $20.02 \pm 0.47^{c}$ | $17.30 \pm 0.21^{b}$ | $10.12 \pm 0.18^{b}$ | $5.00 \pm 0.02^{b}$ |
| | 60 | $20.25 \pm 0.63^{b}$ | $18.00 \pm 0.32^{ab}$ | $10.62 \pm 0.22^{a}$ | $5.80 \pm 0.07^{a}$ |
| | 120 | $21.12 \pm 0.70^{a}$ | $18.80 \pm 0.43^{a}$ | $10.66 \pm 0.50^{a}$ | $5.70 \pm 0.05^{a}$ |
| 3 | 0 | $19.90 \pm 0.56^{c}$ | $17.00 \pm 0.20^{cd}$ | $8.33 \pm 0.23^{e}$ | $4.40 \pm 0.09^{de}$ |
| | 60 | $19.70 \pm 0.33^{c}$ | $16.80 \pm 0.28^{cd}$ | $9.29 \pm 0.14^{d}$ | $4.43 \pm 0.04^{d}$ |
| | 120 | $19.80 \pm 0.42^{c}$ | $16.20 \pm 0.15^{d}$ | $9.66 \pm 0.33^{c}$ | $4.94 \pm 0.08^{c}$ |
| 6 | 0 | $14.70 \pm 0.18^{e}$ | $13.10 \pm 0.15^{f}$ | $7.21 \pm 0.07^{f}$ | $3.92 \pm 0.012^{f}$ |
| | 60 | $18.70 \pm 0.09^{d}$ | $14.80 \pm 0.32^{e}$ | $8.58 \pm 0.11^{e}$ | $4.20 \pm 0.05^{e}$ |
| | 120 | $19.80 \pm 0.23^{c}$ | $15.00 \pm 0.22^{e}$ | $8.57 \pm 0.09^{e}$ | $4.44 \pm 0.08^{d}$ |
| 9 | 0 | $12.80 \pm 0.09^{f}$ | $11.80 \pm 0.14^{g}$ | $5.30 \pm 0.05^{h}$ | $3.16 \pm 0.02^{i}$ |
| | 60 | $14.80 \pm 0.17^{e}$ | $13.00 \pm 0.11^{f}$ | $6.21 \pm 0.10^{g}$ | $3.51 \pm 0.03^{h}$ |
| | 120 | $14.60 \pm 0.18^{e}$ | $13.00 \pm 0.13^{f}$ | $6.26 \pm 0.14^{g}$ | $3.47 \pm 0.04^{g}$ |

According to Duncan test ($P \leq 0.01$), there is no significant difference among means with the same letter.

*3.2. Physiological and biochemical traits*

The findings indicated that chlorophyll had a significant reduction with enhancement of salt concentration alone and with MeJA interaction. At all treatments, 60 µM MeJA caused a significant increase in chlorophyll content. The highest Chl amount was observed at 60 µM MeJA without salt (1.29 ± 0.03 mg/g) (Fig. 1A).

There were significant increases in sugar and proline amounts following enhancement of salt concentration (Fig. 1B and 1C). The amounts of these parameters also enhanced in the plants under MeJA application and at all treatments, 60 µM MeJA had better performance. The 9 dS/m salt treatment at 60 µM MeJA had the highest sugar and proline contents (1.69 ± 0.05 and 0.29 ± 0.01 mg/g, respectively).

A significant increase was observed in contents of total phenol and antioxidant activity following increase in salt levels until 6 dS/m (Fig. 1D). The findings showed that total phenol and antioxidant activity synthesis in savory extract remarkably inhibited by the highest salt concentration (9 dS/m) (Fig. 1D and 1E). The 60 µM MeJA had the most positive effect on these parameters in all salt levels. The highest content of total phenol and antioxidant activity was induced at 60 µM MeJA × 6 dS/m salt with the amounts of 2.22 and 50.23 %, respectively.

*3.3. Mineral elements*

The increase in salt levels negatively affected Ca and Mg contents; this reduction is more obvious in Ca content (Fig. 2A and 2B). MeJA application modulate negative effects of salinity at most of treatments. The highest Ca and Mg contents were observed at 60 µM MeJA without salinity (0.098 and 0.065 mg/g).

The highest Na amount was obtained at 9 dS/m salt treatments without MeJA application (0.23 ± 0.002 mg/g) (Fig. 2C). MeJA performance was good to reduce Na amount in both concentrations at all treatments. According to the findings, $K^+$ amounts and $K^+/Na^+$ ratio significantly decreased with increase in salt levels. MeJA application in both concentrations, especially 60 µM MeJA, led to a significant increase in $K^+$ amount and $K^+/Na^+$ ratio. The largest amounts of $K^+$ and $K^+/Na^+$ were observed at 60 µm MeJA without salinity (0.18 ± 0.002 mg/g and 1.64 ± 0.003, respectively) (Fig. 2C and 2E).




[ DOR: 20.1001.1.2717204.2022.21.84.8.0 ]
[ DOI: 10.52547/jmp.21.84.87 ]

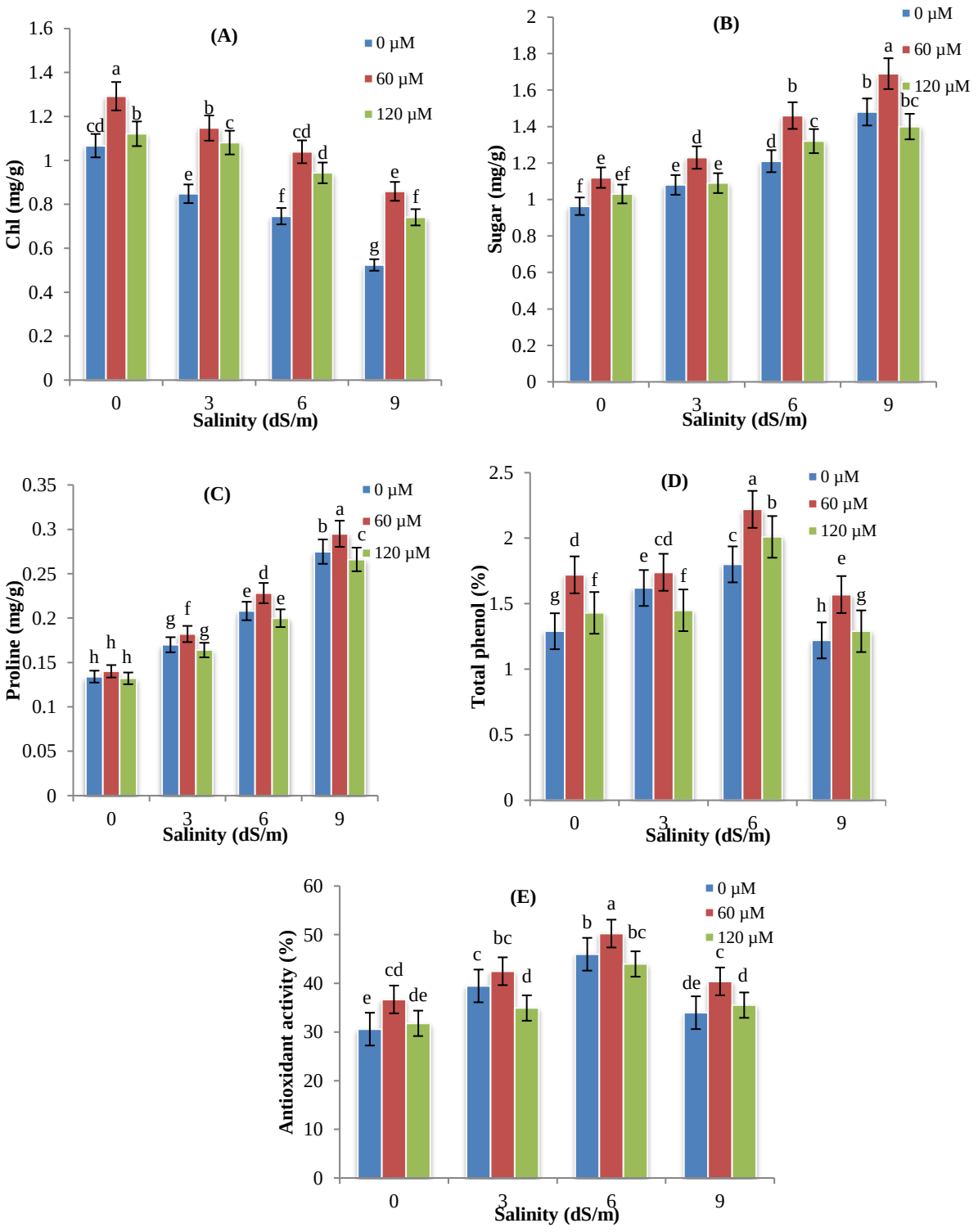


**Fig. 1.** Effects of salt × MeJA interaction on physiological and biochemical traits A: chlorophyll, B: sugar, C: proline, D: total phenol and E: antioxidant activity in *S. khuzistanica*. Averages with the same letters are not significantly different and error bars represent standard deviation.

There was a significant reduction in nitrogen content following increasing salt levels. Higher N contents were obtained at 60 µM MeJA treated plants. The highest N percentage was observed at 60 µM MeJA with no salt (2.46 %) (Fig. 2F).

Higher salt concentrations led to lower phosphorous contents where the 9 dS/m salt level had the lowest amount of P (0.119 ± 0.0001 mg/g). MeJA application positively modified P amount; in most cases, 60 µM MeJA treated plants had higher P amount compared to other treatments. The 60 µM MeJA without salinity treatment had the largest P content (0.199 ± 0.0003 mg/g) (Fig. 2G).

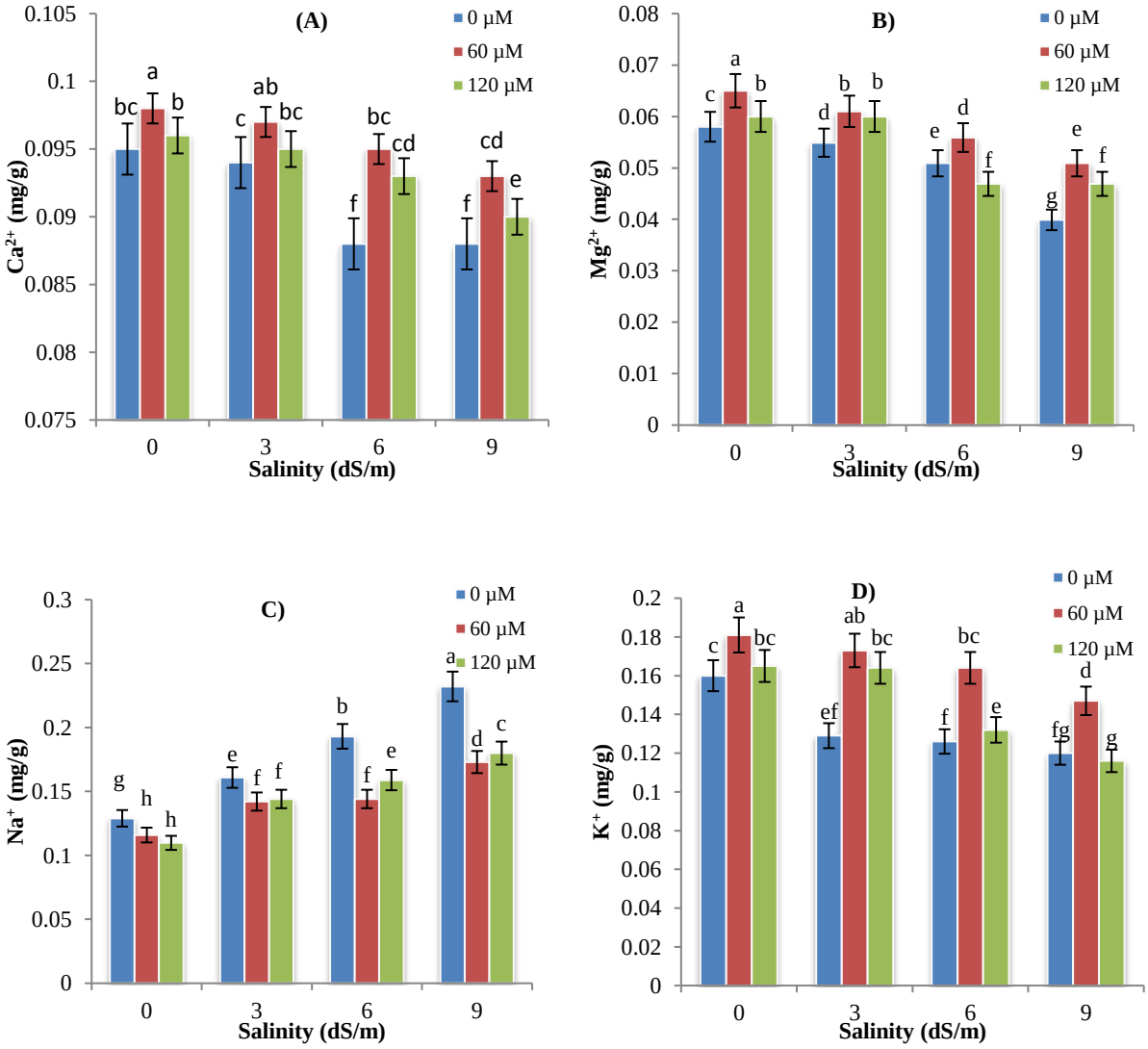


**Fig. 2.** Effects of salt × MeJA interaction on mineral elements A: $Ca^{2+}$, B: $Mg^{2+}$, C: $Na^{+}$, D: K+, E: $K^{+}/Na^{+}$, F: N and G: P in *S. khuzistanica*. Averages with the same letters are not significantly different and error bars represent standard deviation.

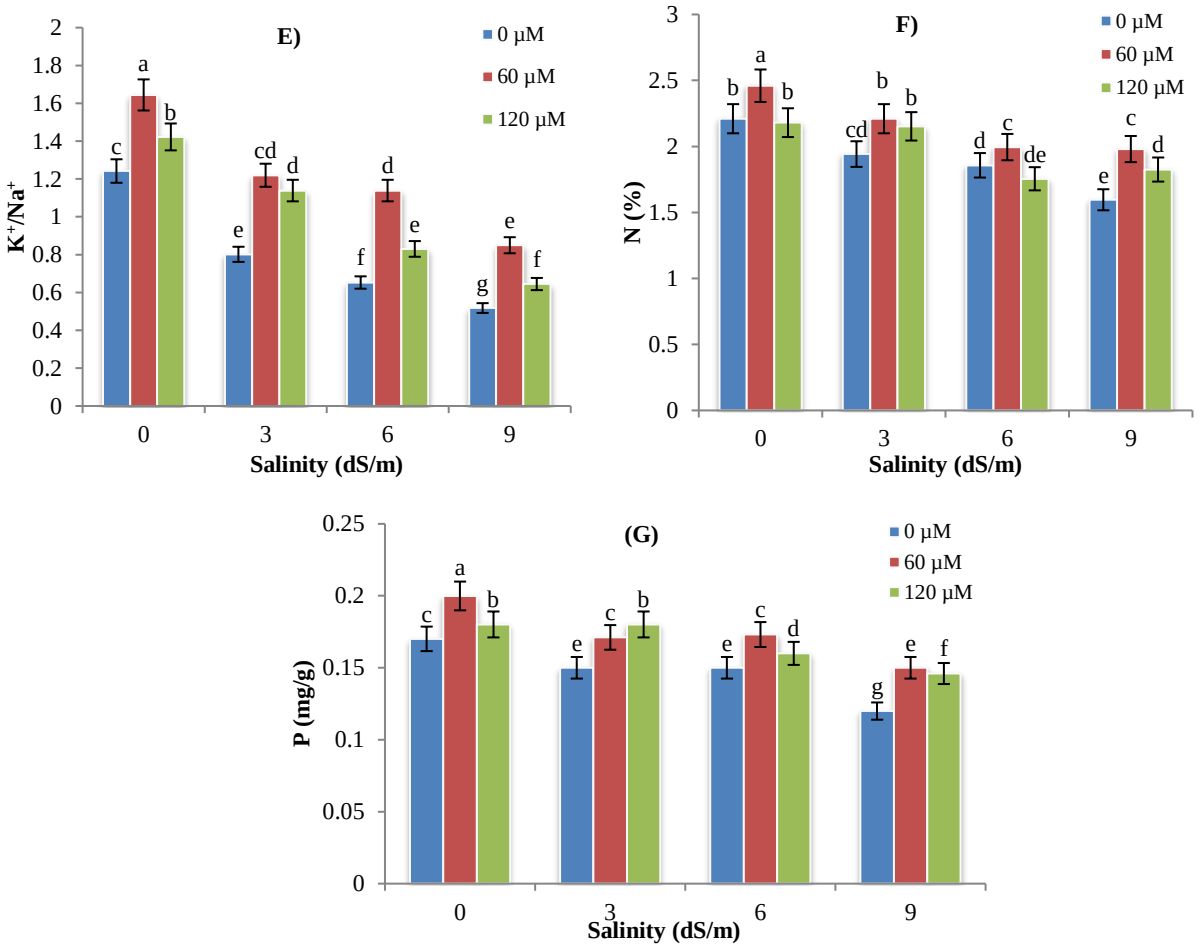


**Fig. 2.** Effects of salt × MeJA interaction on mineral elements A: $Ca^{2+}$, B: $Mg^{2+}$, C: $Na^{+}$, D: K+, E: $K^{+}/Na^{+}$, F: N and G: P in *S. khuzistanica*. Averages with the same letters are not significantly different and error bars represent standard deviation (Continued).

## 4. Discussion

Salt stress is considered as one of the major abiotic stresses which can inhibit plant growth and influence tolerance mechanism [1].

### *4.1. Morphological traits*

The results showed that salt negatively affected growth parameters of savory. Osmotic stress can decrease cell turgor pressure which influences sizes of root and stem cells and inhibits their development [3, 8]. In this study, MeJA application modified all morphological parameters in *S. khuzistanica* plants under salt stress. It has been proved that plants hormone such as MeJA can help to reduce destructive effects of salt stress. The results of whom showed that MeJA application increase seedling growth under salinity [8]. According to several studies [7, 8], exogenous application of MeJA either activates or prevents plant growth under stress condition; it depends on its applied concentration, plant species and the time duration that plants exposed to MeJA. In agreement with this, it has been reported that MeJA low concentrations promote the root formation while




[ DOR: 20.1001.1.2717204.2022.21.84.8.0 ]
[ DOI: 10.52547/jmp.21.84.87 ]

the higher concentrations inhibit its formation in *Brassica napus* L. [2].

*4.2. Physiological and biochemical traits*

The findings showed that chlorophyll content reduced with increasing salt levels, this reduction can be because of lower $K^+$, $Mg^{2+}$, Fe, P absorption which decrease 5-aminolaevulinic acid and increase chlorophyllase anzyme activity [20]. In this study, 60 µM MeJA alleviated salt impacts more effectively in both inoculated and non-inoculated plants at different salt levels, while 120 µM MeJA caused a significant reduction in chlorophyll content, but higher than without MeJA application. MeJA can modulate abscisic acid (ABA) in plant cells [21]. ABA can facilitate plants responses against salinity [22]. According to this, combined effects of salt × 60 µM MeJA could led to higher chlorophyll content that seems to be reasonable. Preventing or activating plant growth under MeJA application in stressful conditions depends on several parameters which mentioned before [2]. The results of [23] reported a significant reduction at higher MeJA levels in Peppermint (*Mentha piperita* L.). It has been obtained the positive performance of plants under MeJA interactions with saline condition [21].

The findings of this study showed that there was a significant reduction in nitrogen content and increases in proline and sugars amounts following rising salt levels. When plants are subjected to salt stress, nutritional imbalance, osmotic stress, nitrogen and chloride competition for transporters were occurred [1, 5]; therefore, nitrogen uptake is difficult for the plants [1]. The plants under salt stress also enhance proline content to regulate osmotic pressure, cytosolic acidity and maintain protein [5]. Enhancement of total sugar with increasing salt concentrations may reduce osmotic potential and accelerate water absorption [5, 24]. This could lead to enhance photosynthesis or breaking down large sugars into small ones [25]. MeJA application, especially at 60 µM concentration, increased proline content in *S. khuzistanica* under salinity increase. It has been confirmed that MeJA plays an important role as an antioxidant and it can increase concentration of non-toxic metabolites such as sugars and proline [26]. MeJA can also modulate ABA amount in plants to activate biosynthesis of amino acids like proline [21]. According to this, nitrogen amounts change following enhancement of proline seems to be reasonable. Other studies obtained similar results [26, 27].

Phenolic compounds play an important role in antioxidant activity [1]. They can scavenge radicals to produce stable phenoxyl radicals by releasing hydrogen atoms from hydroxyl groups [28]. In the present study, increasing salt levels to 6 dS/m caused a significant enhancement in phenol content and antioxidant activity in *S. khuzistanica*, but a significant reduction was obtained at 9 dS/m salt level. Enhancement of phenolic compounds in savory can be considered as a defense response to salinity [20]. The effects of salt stress on phenolic compounds depend on several factors such as salt type, plant species and duration of stress [1]. It has been stated that some stresses like salinity can decrease carbon dioxide to plant availability, inhibit carbon fixation and consecutive reduction in molecular oxygen; so, reactive oxygen species (ROS) enhances, destruction of chloroplast activity and disorder in photosynthesis process will happen [29].




[ DOR: 20.1001.1.2717204.2022.21.84.8.0 ]
[ DOI: 10.52547/jmp.21.84.87 ]

Antioxidant enzymes and phenolic compounds collect, restore reactive oxygen species and prevent cell molecules oxidation by this process; they also limit the effects of oxidation stress on plant cells [29]. Elicitors like MeJA can also activate defense mechanisms of the plants under different stresses [30]. MeJA cause plants to produce defense secondary metabolites (phenolic compounds and antioxidant activity) [30]. In the present study, the highest phenolic content and antioxidant activity were obtained at 60 µM MeJA × 6 dS/m salinity, but 120 µM MeJA caused a significant reduction in these parameters. It has been stated that at higher MeJA concentration, the phenolic compounds decrease in cotton plants [31]. It has been found that several factors such as type and concentration of elicitors, exposure time, and growth condition can influence elicitation process and secondary metabolites production [6]. In accordance with our results, it has been reported that salt and hormonal interaction increased antioxidant activity in rapeseed plant by decreasing ROS generation [21].

*4.3. Mineral elements*

The results of this study demonstrated that the contents of $Na^+$ and $K^+$ and $K^+/Na^+$ ratio were increased and decreased with increasing salt levels, respectively. The $Na^+$ and $K^+$ ions are similar in physio-chemical characteristics. When $Na^+$ amount is high in rhizosphere, the absorption of $K^+$ ion face with problem; following this process $K^+/Na^+$ ratio decreases in plant. So, there is an interruption in several processes like protein synthesis, enzyme activities and photosynthesis. This can cause to inhibit plant growth.

The results showed that phosphorus reduced under different salt levels. Enhancement of salt concentrations caused a decrease in phosphorus uptake by plant. It may be due to the competition among P, $H_2PO_4^-$ and $Cl^-$ ions [32]. Totally, N, P, Ca and Mg amounts in *S. khuzistanica* plants had a significant reduction at high salt levels. These elements have important activities in plant. For example, several activities of Ca and Mg are: molecular grafting formation, balancing some cell activities, activating several enzymes and biosynthesis of some secondary products [33]. Our findings showed that the mentioned elements increased after MeJA application under salinity. In the present research, MeJA application, especially at 60 µM concentration, decreased $Na^+$ and increased all the measured mineral elements such as $Ca^{2+}$, $Mg^{2+}$, P, N and $K^+$ accumulation under salt stress. It has been proved that exogenous application of MeJA at the appropriate dose, has a positive effect on plants and can decrease negative impacts of salinity [1, 8]. It can cause activation of gene expression of several enzymes in chlorophyll biosynthesis which needs different ions such as Mg. Similar results have been observed in other studies [1, 2]. It has been also reported that jasmonates increased N, P, K levels and non-toxic metabolites in soybean [26].

## 5. Conclusion

Based on the results, it is concluded that under salinity, exogenously MeJA application could alleviate the adverse effect of salinity stress in *S. khuzistanica*, especially under higher salt concentrations which allows this plant to enhance its tolerance. In summary, the ameliorating effect of MeJA associated with




[ DOR: 20.1001.1.2717204.2022.21.84.8.0 ]
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salinity was mainly detected through increasing proline, soluble sugar, total phenol, antioxidant activity and mineral elements (N, P, Ca and Mg) accumulation and through reducing Na+ content. So, MeJA growth regulator could be helpful to important mechanisms involved in salt stress alleviation in *S. khuzistanica*.

## Author contributions

AS designed and performed the experiment, collected data. He is also the corresponding author. SHJ participated in statistically analyzing, interpreting phytochemical data and prepared the manuscript.

## Acknowledgments

This research has been supported by Research and Technology Institute of Plant Production (RTIPP), Shahid Bahonar University of Kerman, Kerman, Iran. The authors are grateful for the financial support for this research project.

## Conflict of interest

The authors declare that there is no conflict of interest.

## References

**1.** Hossein Jafari S, Mosleh Arani A and Tarkesh Esfahani S. The combined effects of rhizobacteria and methyl jasmonate on rosmarinic acid production and gene expression profile in *Origanum vulgare* L. under salinity conditions. *J. Plant Growth Regul*. 2022. doi: 10.1007/s00344-022-10632-2.

**2.** Ahmadi FI, Karimi K and Struik PC. Effect of exogenous application of methyl jasmonate on physiological and biochemical characteristics of *Brassica napus* L. cv. talaye under salinity stress. *South Afric. J. Bot.* 2018; 115: 5-11. doi: 10.1016/j.sajb.2017.11.018.

**3.** Farsaraei S, Moghaddam M and Ghasemi Pirbalouti A. Changes in growth and essential oil composition of sweet basil in response of salinity stress and superabsorbents application. *Scientia Horticulturae* 2020; 271: 109465. doi: 10.1016/j.scienta.2020.109465.

**4.** Bahonar A, Mehrafari A, Abdousi V, Radmanesh E, Moghadam AR, Naghdi Badi H. Quantitative and qualitative changes of Rosemary (*Rosmarinus officinalis* L.) in response to mycorrhizal fungi (*Glomus intraradices*) inoculation under saline environments. *J. Med. Plants* 2018; 57(15): 25-37.

**5.** Khalil SE. Review: the effect of salt stress on some physiological and biochemical composition of some crops. *Plant Archives* 2020; 20(1): 3573-3585.

**6.** Krzyzanowska J, Czubacka A, Pecio L, Przybys M, Doroszewska T, Stochmal A and Oleszek W. The effects of jasmonate acid and methyl jasmonate on rosmarinic acid production in *Mentha piperita* cell suspension cultures. *Plant Cell, Tiss. Organ Cult.* 2011; 1-9. doi: 10.1007/s11240-011-0014-8.

**7.** Khademian R, Ghorbani Nohooji M and Asghari B. Effect of jasmonic acid on physiological and phytochemical attributes and antioxidant enzymes activity in Safflower (*Carthamus tinctorius* L.) under water deficient. *J. Med. Plants* 2019; 72(4): 122-134. doi: 10.29252/jmp.4.72.122

**8.** Chavoushi M, Manoochehri Kalantari Kh and Arvin MJ. Effect of salinity stress and exogenously applied methyl jasmonate on growth and physiological traits of two *Carthamus tinctorius* varieties. *Intern. J. Horticul. Sci. Tech.* 2019; 6(1): 39-49. doi: 10.22059/ijhst.2019.277800.283.

**9.** Khaleghnezhad V, Yousefi AR, Tavakoli A and Farajmand B. Interactive effects of abscisic

acid and temperature on rosmarinic acid, total phenolic compounds, anthocyanin, carotenoid and flavonoid content of dragonhead (*Dracocephalum moldavica* L.). *Scientia Horticulturae* 2019; 250: 302-309.

**10.** Eskandari M and Eskandari A. Effects of 28-homobrassinolide on growth, photosynthesis and essential oil content of *Satureja khuzestanica*. *Intern. J. Plant Physiol. & Biochem* 2013; 5(3): 36-41. doi: 10.5897/IJPPB11.064.

**11.** Shariat A, Karimzadeh G and Assareh MH. Karyology of Iranian endemic *Satureja* (Lamiaceae) species. *Cytologia* 2013; 78(3): 305-312. doi: 10.1508/cytol ogia.78.305.

**12.** Arnon AN. Method of extraction of chlorophyll in the plants. *Agro. J*. 1967; 23: 112-121.

**13.** Hellubust JA and Craigie JS. Handbook of Physiological and Biochemical Methods. Cambridge University Press, Cambridge 1978.

**14.** Bates LS, Waldern RP and Teave ID. Rapid determination of free proline for water stress studies. *Plant Soil* 1973; 39: 205-107.

**15.** Wagner GJ. Content and vacuole/extravacuole distribution of neutral sugars, free amino acids, and anthocyanin in protoplasts. *Plant Physiol.* 1979; 64(1): 88-93. doi: 10.1104/pp.64.1.88

**16.** Marinova D, Ribarova F and Atanasova M. Total phenolics and flavonoids in Bulgarian fruits and vegetables. *J. Univers. Chem. Tech. & Metallurgy* 2005; 40: 255-260.

**17.** Shimada K, Fujikawa K, Yahara K and Nakamura T. Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. *J. Agri. Food Chem.* 1992; 40(6): 945-948. doi: 10.1021/jf00018a005

**18.** Chapman HD and Part PF. Method of analysis for soils, plants and waters. University of California. Division of Agriculture Sciences 1961; 309.

**19.** Ryan J, Estefan G, Rashid A. Soil and plant analysis laboratory manual. ICARDA. 2007.

**20.** Khalvandi M, Amerian MR, Pirdashti HA, Keramati S and Hosseini J. Essential oil of peppermint in symbiotic relationship with *Piriformospora indica* and methyl jasmonate application under saline condition. *Industrial Crops & Products* 2019; 127: 195-202. doi: 10.1016/j.indcrop.2018.10.072.

**21.** Farhangi-Abriz S, Tavasolee AR, Ghassemi-Golezani K, Torabian Sh, Monirifar H and Asadi Rahmani H. Growth-promoting bacteria and natural regulators mitigate salt toxicity and improve rapeseed plant performance. *Protoplasma* 2020; 257: 1035-1047. doi: 10.1007/s00709-020-01493-1.

**22.** Sarabi V and Arjmand-Ghajur E. Exogenous plant growth regulators/plant growth promoting bacteria roles in mitigating water-deficit stress on chicory (*Cichorium pumilum* Jacq.) at a physiological level. *Agri. Water Managment* 2021; 245: 106439. doi: 10.1016/j.agwat.2020.106439.

**23.** Afkar S and Sharifi M. Effect of foliar application with methyl jasmonate on physiological behavior of *Mentha piperita*. *J. Med. Plants & By-products* 2015; 4(2): 155-160. doi: 10.22092/jmpb.2015.108903.

**24.** Torabi M and Halim M. Variation of root and shoot growth and free proline accumulation in Iranian alfalfa ecotypes under salt stress. *J. Food, Agri. Environ.* 2010; 8 (3&4): 323-327.

**25.** Bohnert HJ, Nelson DE and Jensen RG. Adaptations to Environmental Stresses. *The Plant Cell* 1995; 7(7): 1099-1111. doi: 10.1105/tpc.7.7.1099.

**26.** Siddiqi KhS and Husen A. Plant response to jasmonates: current developments and their

role in changing environment. *Bulletin of the National Research Centre* 2019; 43: 153-164. doi: 10.1186/s42269-019-0195-6.

**27.** Helaly AA, Dojima T and Craker LE. Effect of plant growth promoting bacteria on collard plants growth, yield production and nutritional compositions. 8th International Conference for Sustainable Agricultural Development held in Faculty of Agriculture. 2018; 5-7 March. Fayoum University, Egypt. 1-16.

**28.** Raghu K and Rao SRS. Effect of brassinosteroids on antioxidants content and radical scavenging activity of *Tinospora cordifolia* (Willd.) Miers ex Hook. F & Thoms. *J. Med. Plants Stud.* 2016; 4(5): 117-121.

**29.** Hasanuzzaman M, Borhannuddin Bhuyan MHM, Zulfiqar F, Raza A, Mohsin SM, Al Mahmud J, Fujita M and Fotopoulos V. Reactive oxygen species and antioxidant defense in plants under abiotic stress: revisiting the crucial role of a universal defense regulator. *Antioxidants* 2020; 9(8): 681, 1-52. doi: 10.3390/antiox9080681.

**30.** Huang B, Duan Y, Yi B, Sun L, Lu B, Yu X, Sun H, Zhang H and Chen W. Characterization and expression profiling of cinnamate 4-hydroxylase gene from *Salvia miltiorrhiza* in rosmarinic acid biosynthesis pathway. *Russian J. Plant Physiol*. 2008; 55 (3): 390-399. doi: 10.1134/S1021443708030163.

**31.** Konan YKF, Kouassi MK, Kouakou KL, Koffi EK, Kouassi KN, Sekou D, Kone M and Kouakou TH. Effect of methyl jasmonate on phytoalexins biosynthesis and induced disease resistance to *Fusarium oxysporum* F. Sp. Vasinfectum in cotton (*Gossypium hirsutum* L.). *Inter. J. Agron.* 2014; 2: 1-11. doi: 10.1155/2014/806439.

**32.** Maksimovic I and Ilin Z. Effects of salinity on vegetable growth and nutrients uptake. P 169-190, In: Lee, T.S. (ed.), Irrigation systems and practices in challenging environments, IntechOpen, London, UK. 2012.

**33.** Pessarakli M, Haghighi M and Sheibanirad A. Plant responses under environmental stress conditions. *Advances Plants Agric. Res.* 2015; 2(6): 276-286. doi: 10.15406/apar.2015.02. 00073.

How to cite this article: Saadatfar A, Hossein Jafari S. The effect of methyl jasmonate on morpho-physiological and biochemical parameters and mineral contents in *Satureja khuzistanica* Jamzad under salinity stress. ***Journal of Medicinal Plants*** 2022; 21(84): 87.
doi: 10.52547/jmp.21.84.87

فصلنامه گیاهان دارویی ۱۴۰۱؛ ۲۱(۸۴): ۸۷-۹۹

فصلنامه گیاهان دارویی

Journal homepage: www.jmp.ir

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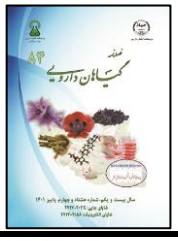

مقاله تحقیقاتی

# تأثیر متیل جاسمونات بر پارامترهای مورفوفیزیولوژیکی و بیوشیمیایی و محتوای مواد معدنی مرزه خوزستانی تحت تنش شوری

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**اطلاعات مقاله**

*گل‌واژگان:*
مرزه خوزستانی
گیاهان دارویی
شوری
متیل جاسمونات
رشد
فعالیت آنتی‌اکسیدانی

**چکیده**

**مقدمه:** مرزه خوزستانی، یک گیاهی دارویی انحصاری ایران می‌باشد که به طور گسترده در شمال خوزستان و جنوب لرستان پراکنده است. **هدف:** در این مطالعه تأثیر همزمان متیل‌جاسمونات و شوری بر تغییرات مرفوفیزیولوژیکی و محتوای معدنی در گیاه مرزه خوزستانی بررسی شد. **روش بررسی:** تیمارهای شوری (صفر، ۳، ۶ و ۹ dS/m) در مرحله رشد رویشی به مدت یک ماه اعمال گردید. محلول‌پاشی متیل‌جاسمونات در غلظت‌های صفر، ۶۰ و ۱۲۰ میکرومول سه بار در هفته انجام شد. نمونه‌برداری در مرحله گلدهی انجام شد. **نتایج:** نتایج نشان داد که اثر متقابل متیل جاسمونات × شوری تأثیر معنی‌داری بر تمامی جنبه‌های مورفوفیزیولوژیکی و بیوشیمیایی گیاه مرزه خوزستانی داشت ($P \leq ۰/۰۱$). بیشترین میزان طول ساقه، طول ریشه، وزن‌های تر و خشک در غلظت‌های ۶۰ و ۱۲۰ میکرومول متیل‌جاسمونات بدون شوری مشاهده گردید. با افزایش سطوح شوری، میزان پارامترهای کلروفیل، نیتروژن، فسفر، پتاسیم، نسبت $K^+/Na^+$، کلسیم و منیزیم، کاهش معنی‌داری داشت. بیشترین مقدار این پارامترها در تیمار ۶۰ میکرومول متیل‌جاسمونات بدون شوری بود. با افزایش سطوح شوری، در مقادیر فنل تام، فعالیت آنتی‌اکسیدانی، پرولین، قند و سدیم، افزایش معنی‌داری مشاهده گردید. بیشترین مقدار فنل تام و فعالیت آنتی‌اکسیدانی در تیمار ۶ dS/m شوری × ۶۰ µM متیل‌جاسمونات (به ترتیب ۲/۲۲ و ۵۰/۲۳ درصد) بود. تیمار شوری ۹ dS/m × ۶۰ µM متیل‌جاسمونات بیشترین میزان قند (۱/۶۹ mg/g) و پرولین (۰/۲۹ mg/g) را داشت. **نتیجه‌گیری:** به طورکلی، غلظت ۶۰ میکرومول متیل‌جاسمونات باعث ایجاد بهترین عملکرد گیاه مرزه خوزستانی تحت تنش شوری شد. بنابراین کاربرد متیل‌جاسمونات می‌تواند در جهت بهبود و کاهش اثرات منفی شوری در این گیاه باشد.

*مخففها:* MeJA، متیل جاسمونات؛ *S. khuzistanica*، مرزه خوزستانی؛ dS/m، دسی زیمنس بر متر؛ µM، میکرومول؛ N، نیتروژن؛ P، فسفر؛ $K^+$، پتاسیم؛ $K^+/Na^+$، نسبت پتاسیم به سدیم؛ Ca، کلسیم؛ Mg، منیزیم؛ mg/g، میلی‌گرم بر گرم

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**تاریخ دریافت:** ۱۸ شهریور ۱۴۰۱؛ **تاریخ دریافت اصلاحات:** ۱۱ آبان ۱۴۰۱؛ **تاریخ پذیرش:** ۱۴ آبان ۱۴۰۱

doi: 10.52547/jmp.21.84.87