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# Effect of Nano Selenium or Nano Silicon on Growth of Lavender Plant Under Salinity Stress Conditions

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**ABSTRACT:**

This study was conducted at the Nursery of ornamental plants, Hort. Depart., Faculty of agricultural., Zagazig Univ., Egypt, during two consecutive seasons of 2023 and 2024 to evaluate the effect of foliar application of biological selenium and silicon nanoparticles under water salinity conditions on vegetative growth, some chemical constituents, volatile oil percentage and composition of lavender plant. The tested saline water were four levels (control(157ppm), 1000, 1500, 2000 ppm). While, examined foliar spraying with nano-particles were seven concentrations viz, (control, 100, 200 and 300 ppm) nano- selenium and (100, 200 and 300 ppm) nano- silicon. The achieved results of this study showed that all water salinity levels significantly decreased plants height(cm), branches No./ plant compared to control while herb fresh and dry weight and salt resistance index (SRI) % increased with 1000 ppm saline water and control treatment. Also, saline water levels at 1000 and 2000 ppm significantly increased chlorophyll a, chlorophyll b, total chlorophyll (a+b) and carotenoids contents (mg/g FW). On the other hand, plants irrigated with 1000 ppm saline water showed the highest nitrogen content. Irrigation by 1500 ppm saline water increased phosphors and potassium percentage compared to control. Saline water at 2000 ppm decreased volatile oil percentage . Foliar spraying with nano-selenium or nano-silicon at all concentrations significantly increased vegetative growth parameters compared to control. Plants that sprayed with 300 ppm nano-silicon achieved the maximum values of the above-mentioned characters except volatile oil percentage increased at 300 ppm nano-selenium.

Conclusively: foliar spraying with 300 ppm nano- silicon or nano- selenium increased vegetative growth, volatile oil percentage and SRI % under water salinity stress at 1000 ppm conditions.

**Keywords: salinity- nano selenium- nano silicon- vegetative growth- oil percentage- lavender plant**

## INTRODUCTION

The medicinal and aromatic importance of some plants is mainly due to the presence of special volatile and odoriferous terpene rich compound containing essential oils (EOs) used to treat many diseases, besides their use in foods, beverages, perfumes and flavors **(Wei and Shibamoto, 2010)**. Lavender plants are widely utilized in essential oil industry. Bulgaria, France, UK, China, Ukraine, Spain, and Morocco are the biggest worldwide producers. Bulgaria has recently become the world's major producer with 100 tons' lavender oil per year **(Vasileva *et al.*,2018).** The main components of lavender oil are linalool (20-45%) and linalyl acetate ((25–46%), 1,8- cineole, β-ocimene, terpinen-4-ol and camphor. These components have sedative, anti-nociceptive, antispasmolytic effects because of stimulating the parasympathetic system. Linalyl acetate also has narcotic and sedative effect. **(Kucharska *et al.*,2019).**

Changes in climatic conditions lead to increased biotic and abiotic stress for the plants. The productivity of aromatic plants was affected globally due to these stresses **(Mahajan *et al.*, 2020).**

Soil and water salinity are the most serious environmental issues that has caused a great reduction in growth and development of plant species. The detrimental effects of high salinity on plants can be observed either at the whole plant level or at the death of plants and/or decrease in productivity. **(Parul *et al.*, 2015).**

Using of Nano-fertilizers instead of chemical fertilizers is becoming more popular. Application of micronutrients in Nano scale improves plants growth factors and increases their resistance to salinity stress. Nanotechnology has emerged as a useful strategy for improving agricultural productivity due to rapid and complete absorption of Nano-fertilizers by plants **(Sajyan *et al.*, 2020**). Nanoparticles (NPs) are microscopic particles with sizes in the range of 1-100 nm **(Khan and Upadhyaya, 2019).** Selenium is necessary for plants growth at low quantities. Se has been shown to boost the growth of aging seedlings, delay senescence, reduce oxidative stress, and increase plant tolerance **(Kamran *et al.*, 2020).** Silicon enhances cell wall strength, stomata conductance, and antioxidant capacity, and its application leads to improving physiological and biochemical characteristics of the plant. **(Etesami and Jeong, 2018)**.

**The purpose** of this study was to evaluate the effect of Se-NPs and Si-NPs on vegetative growth, oil percentage and components of lavender plant under salinity stress conditions.

## 2. MATERIALS AND METHODS

This investigation was carried out at the Nursery of ornamental plants, Hort. Depart., Faculty of Agricultural., Zagazig Univ., Egypt, during two consecutive seasons of 2023 and 2024 to evaluate the effect of foliar application of biological selenium or biological silicon nanoparticles under water salinity conditions on growth, yield components, volatile oil production and some chemical constituents of *Lavandula officinalis* Chaix (lavender) plant.

This study was designed as factorial experiment between the saline water levels and nano selenium or nano silicon in completely randomized block design.

- **A-** The first factor (main plot) studied four water salinity levels viz., tap water(157ppm), 1000, 1500,2000 ppm NaCl.
- **B-** The second factor (sub plot) studied seven concentrations of biological nano -selenium viz., control, 100, 200, 300 ppm and nano-silicon viz., (100,200, 300 ppm).

### 2.1.Plant material and cultivation

*Lavandula officinalis* (lavender) plants were planted in 25 cm pots filled with soil mixture of clay and sand (1:2 *v/v*), on March 1$^{st}$ during 1$^{st}$ and 2$^{nd}$ seasons (2023 and 2024). All plants were nearly in growth (12 cm height with 8-10 leaves / plant). Forty days after planting, plants were treated with four different levels of saline water by using drip irrigation and sprayed with nano selenium or nano silicon every 15 days with the above mentioned concentrations . To avoid osmotic shock, the salinity treatment started with 500 ppm NaCl and was progressively increased to reach the maximum salinity level in each treatment.

The physical and chemical properties of soil analysis mixture as shown in **Table 1** according to **Evenhuis and Waard (1980).**

**Table 1. Physical and chemical properties of experimental soil**

<table>
<tr><th colspan="8">Physical analysis</th><th colspan="5">Soil texture</th></tr>
<tr><th>Clay (%)</th><th colspan="3">Silt (%)</th><th colspan="2">Sand (%)</th><th colspan="2">Organic material (%)</th><td colspan="5" rowspan="2">sandy</td></tr>
<tr><td>22.37</td><td colspan="3">7.93</td><td colspan="2">69.70</td><td colspan="2">1.12</td></tr>
<tr><th colspan="13">Chemical analysis</th></tr>
<tr><th rowspan="2">pH</th><th rowspan="2">E.C. ($dsm^{-1}$)</th><th colspan="4">Soluble cations (meq/L)</th><th colspan="4">Soluble anions (meq/L)</th><th colspan="3">Available (mg/kg)</th></tr>
<tr><th>$Ca^{++}$</th><th>$Mg^{++}$</th><th>$Na^{+}$</th><th>$Zn^{++}$</th><th>$Cl^{-}$</th><th>$HCO_3^{-}$</th><th>$SO_4^{--}$</th><th>$CO_3^{-}$</th><th>N</th><th>P</th><th>K</th></tr>
<tr><td>8.22</td><td>8.13</td><td>13.78</td><td>10.75</td><td>30.45</td><td>0.24</td><td>51.02</td><td>2.46</td><td>38.74</td><td>0.05</td><td>29.54</td><td>9.23</td><td>100.1</td></tr>
</table>

**2.2. Data Recorded:**

**2.2.1. Growth characters i.e**.( plant height (cm), number of branches, herb fresh and dry weight per plant and salt resistance index (SRI %) by **Abdelkader *et al.* (2019).**

**2.2.2**. **Total chlorophyll content** according to **Wettestein, (1957)**

**2.2.3. Nitrogen, phosphorus and potassium content of leaves (%)**

according to method reported by **Evenhuis and Waard (1980)**.

**2.2.4. Oil percentage**

The oil percentage was determined according to the method described in the **British Pharmacopoeia (1963).**

**2.2.5. Essential oil composition**

The GLC analysis of the volatile oil samples was carried out using gas chromatography instrument stands at the Medicinal and Aromatic Plants Dept. Laboratory, Horticulture Research Institute .

**2.3. Statistical Analysis**

The collected data were statistically analyzed according to **Steel and Torrie (1980)**. Mean separation was done using Duncan's multiple range test at 5 % level (**Duncan, 1955**) . All achieved data were analyzed using IBM SPSS Software **(SPSS, 2020)**.

**3. RESULTS AND DISCUSSION**

**3.1. Effect of water salinity on growth of *lavandula officinalis* chaix plants**

**3.1.1 vegetative growth characters**

Table 2 shows that plants height(cm), branches No./ plant were significantly decreased by increasing the levels of irrigation with saline water compared to control . Herb fresh and dry weight and salt resistance index (SRI) % increased with 1000 ppm saline water and control treatment(tap water). Salt resistance index (%) was significantly increased with 1000 ppm level and control, while it was decreased with 1500 and 2000 ppm water salinity levels compared with control. Earlier studies revealed significant effects of water salinity on decreasing plant height due to salinity stress occurs with the accumulation of salts, especially sodium chloride, in the root zone. It causes disturbances in vital plant processes such as nutrients uptake and transport, transpiration, photosynthesis, and biosynthesis of primary and secondary metabolites **(Ahanger and Agarwal,**

**2017)**. Our results were similar with the findings of **Shehata and Walid (2019)** and **Ibrahim *et al.* (2019)** on basil plant where they found that plant height decreased gradually with increasing water salinity compared with control. Also, Al-**Fraihat *et al.* (2023) on rosemary plant** found that plant height decreased with increasing water salinity levels compared with control. **Safwat and Abdel Salam (2022)** tested the impact of salt stress (0, 50 ,75 or 100mM NaCl) on growth of Basil plants. They found that branches number decreased progressively with increasing of NaCl concentrations up to 100mM.

**Table 2. Effect of water salinity on vegetative growth characters of lavender plant during 2023 and 2024 seasons (average of both seasons )**

| Salinity (ppm) | Plant height (cm) | | Branches No. /plant | | Herb fresh weight (g)/ plant | | Herb dry weight (g)/ plant | | Salt resistance index (SRI) % | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st cut | 2nd Cut | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut |
| **Control** | 98.5 a | 100.2a | 76.3 a | 69.2a | 116.6 a | 103.9 a | 21.4 a | 19.3 a | 106.7 a | 113.2 a |
| **1000ppm** | 95.2 b | 96.0 b | 71.1 b | 64.0 b | 116.7 a | 102.9 b | 21.2 a | 19.1 b | 107.0 a | 103.3b |
| **1500ppm** | 92.0c | 91.4 c | 65.8 c | 59.3 c | 91.4 b | 85.0 c | 17.3 b | 15.7 c | 87.4 b | 89.1c |
| **2000ppm** | 67.8 d | 65.7 d | 51.8 d | 46.0 d | 59.2 c | 52.7 d | 10.8 c | 9.8 d | 53.6 c | 56.10 d |

Treatment within a column followed by different letters is significantly different with Duncan's multiple range test at 5 % level.

### 3.1.2. Chemical determinations

#### 3.1.2.1 Leaf pigments content (mg/g)

**Table3** shows that saline water levels at 1000 and 2000 ppm significantly increased chlorophyll a, chlorophyll b, total chlorophyll (a+b) and carotenoids contents (mg/g FW).

Table 3. Effect of water salinity on chlorophylls and carotenoids content (mg/g fresh weight) in leaves tissues of lavender plant**(average of both seasons )**

| Salinity (ppm) | Chlorophyll(a) (mg/g) | Chlorophyll(b) (mg/g) | Total chlorophyll(a+b) (mg/g) | Carotenoids (mg/g) |
|---|---|---|---|---|
| **Control** | 0.816 b | .811 c | 1.63 b | 0.776 ab |
| **1000ppm** | 0.844 a | .825 ab | 1.67 a | 0.785 a |
| **1500ppm** | 0.814 b | .820 b | 1.63 b | 0.768 b |
| **2000ppm** | 0.835 a | .827 a | 1.66 a | 0.773 b |

Treatment within a column followed by different letter are significantly with Duncan's multiple range test at 5 % level.

This results shows that salinity decreased leaves content of chlorophyll and carotenoids. This reduction might be due to the disorder of vital biological processes such as nutrients uptake, transpiration, photosynthesis and biosynthesis of metabolites. Salinity stress affects the photosynthetic process due to leaves water loss, stomata close, reduction of carbon dioxide fixation **(Hnilickova *et al.*, 2017). Jadczak *et al.* (2022)** mentioned an increase in chlorophyll A content in plants grown in the presence of sodium chloride (80 mM and 160 mM).

**3.1.2.2 Nitrogen , Potassium and Phosphorus percentage and proline content (mg/g) in leaves of lavender plant**

Table 4 shows that plants irrigated with 1000 ppm saline water gave the highest nitrogen content. While irrigation by 1500 ppm saline water increased phosphors and potassium percentage compared to control. Saline water level at 2000 ppm increased proline content.

**Table 4. Effect of water salinity on nitrogen , potassium and phosphorus percentage and proline content (mg/g) in leaf tissues of lavender plant during 2023 and 2024 seasons(average of both seasons )**

| Salinity (ppm) | Nitrogen content (%) | Phosphorus content (%) | Potassium content (%) | Proline content (mg/g) |
|---|---|---|---|---|
| | | | | |
| **Control** | 1.33 d | 0.146 c | 2.17 d | 5.40 c |
| **1000ppm** | 1.66 a | 0.169 b | 2.43 b | 5.04 d |
| **1500ppm** | 1.53 c | 0.186 a | 2.52 a | 5.52 b |
| **2000ppm** | 1.62 b | 0.184 a | 2.37 c | 5.87 a |

Treatment within a column followed by different letter are significantly different with Duncan's multiple range test at 5 % level.

Similar results on leaf proline content were obtained by **Ibrahim *et al.* (2019)** on *Ocimum basilicum* L. plants, **Nassar *et al.* (2019) and Jadczak *et al* (2022)** on basil plants , **Karimian *et al.* (2019)** on *Salvia splendens* plant and **Al-Fraihat *et al.*(2023)** on rosemary plant. **Shala *et al.* 2024**) reported that proline level in various *Lavandula* species increased in response to salt stress.

**3.1.2.3. Volatile oil percentage and composition of lavender plant**

Data recorded in **Table 5** shows that irrigation by 2000 ppm saline water decreased volatile oil percentage and all essential oil components percentage compared with control expect cineol and linalool increased under such level.

**Table 5**. **Effect of water salinity on volatile oil percentage during seasons 2023 and 2024(average of both seasons )**

| Salinity (ppm) | volatile oil percentage (%) |
|---|---|
| **Control** | 1.004 a |
| **1000ppm** | 0.951 b |
| **1500ppm** | 0.891 c |
| **2000ppm** | 0.802 d |

Treatment within a column followed by different letter are significantly different with Duncan's multiple range test at 5 % level.

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**Chrysargyris e*t al.* (2018)** on lavender plants, and **Sarmoum *et al.* (2019)** on rosemary plants indicated that essential Oil (EO) percentage decreased under salinity conditions especially at the highest concentrations. They observed that maximum oil percentage was found in control plants followed by plants with 50mM NaCl and the least oil percentage with 150 mM NaCl.

**Kiumarzi *et al.* (2022)** studied the effect of four salinity stress (0, 30, 60 and 90 Mm NaCl) on essential oil content of *Mentha suaveolens* plant. They revealed that severe salinity (90 mM NaCl) decrease essential oil content compared with control.

### 3.2. Effect of Nano- selenium or Nano- silicon on growth of lavender plant

#### 3.2.1. vegetative growth characters

Data in Table 6 Foliar spraying with nano-selenium or nano- silicon at all concentrations significantly increased vegetative growth parameters compared to control treatment. Plants sprayed with 300 ppm nano-silicon achieved the maximum plant height , branches number, herb fresh , dry weight per plant and salt resistance index compered to control plants. Foliar spraying with 100 ppm nano-selenium showed no significant difference of herb fresh and dry weight respectively compared with control treatment.

**Table 6. Effect of Nano-selenium or Nano-silicon on vegetative growth characters of lavender plants during 2023 and 2024 season(average of both seasons )**

| Se or si levels (ppm) | Plant height (cm) | | Branches No. /plant | | Fresh weight (g)/ plant | | Dry weight (g)/ plant | | Salt resistance index (SRI) % | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut | 1st cut | 2nd cut |
| **Control** | 82.4 f | 80.3g | 51.7 f | 46.9 g | 78.0 d | 73.7g | 14.2f | 13.6 g | 80.8 f | 83.0 e |
| **100 se** | 82.6f | 83.0f | 53.8e | 50.0f | 73.2d | 76.5 f | 14.5f | 14.2 f | 82.8 e | 86.3d |
| **200 se** | 86.5 e | 86.7e | 58.4 e | 54.7 e | 85.8 c | 80.6 e | 15.6e | 14.9 e | 88.8 c | 90.9c |
| **300se** | 87.9 d | 88.2d | 60.8 d | 56.8 d | 91.3 c | 85.4 d | 16.6d | 15.9 d | 94.5 a | 96.b |
| **100 si** | 90.6 c | 90.9c | 76.9 c | 66.9 c | 109.4b | 90.5 c | 19.9c | 16.8 c | 87.3 d | 83.6e |
| **200 si** | 93.9 b | 94.2b | 80.5 b | 70.5 b | 115.0ab | 96.1 b | 20.9b | 17.8 b | 91.7 b | 94.6b |
| **300 si** | 95.0 a | 95.2a | 81.8 a | 71.8 a | 119.3 a | 100.4a | 21.7a | 18.6 a | 95.1 a | 98.4a |

Treatment within a column followed by different letter are significantly different with Duncan's multiple range test at 5 % level.

Nanoparticles showed different effects on plants based on species and dose, making them effective even at low concentrations. Compared to traditional fertilizers, they appear as alternative solution to overcome the problems related to abiotic stress in plants because they are more efficient and effective. **Yavaş, İ. (2021)**

**Eghlima *et al.*(2024)** examined the impact of nano-silicon foliar application (0, 50, 100, and 200 mg $L^{-1}$) on growth of *Calendula offcinalis* plants. They observed that spraying 200mg $L^{-1}$ increased plant height, plant fresh and dry weight compared with control.

Moreover, they studied the effect of three nano- selenium levels (0, 5, 10 ppm) on growth of faba bean plant. They found that foliar spray at 5 ppm increased plant height , fresh and dry shoot weights**.**

#### 3.2.2. Chemical determinations

##### 3.2.2.1 Leaf pigments content (mg/g)

**Table7** shows that plants sprayed with 300 ppm nano-silicon achieved the maximum concentration of chlorophylls a,b , chl a+b and carotenoids content compered to control plants.

Table 7. Effect of Nano-selenium or Nano-silicon on chlorophylls, carotenoids content (mg/g fresh weight) in leaf tissues of lavender plant **(average of both seasons )**

| Se or si levels (ppm) | Chlorophyll(a) (mg/g) | Chlorophyll(b) (mg/g) | Total chlorophyll(a+b) (mg/g) | Carotenoids (mg/g) |
|---|---|---|---|---|
| **Control** | **0.733 d** | **.723 e** | **1.46 f** | **.680 f** |
| **100 se** | **0.813 c** | **.792 d** | **1.61 e** | **.752 e** |
| **200 se** | **0.815 c** | **.844 b** | **1.66 c** | **.777 d** |

| | | | | |
|---|---|---|---|---|
| **300se** | **0.843 b** | **.863 a** | **1.71 b** | **.791 c** |
| **100 si** | **0.823 c** | **.810 c** | **1.63 d** | **.785 cd** |
| **200 si** | **0.861 b** | **.844 b** | **1.70 b** | **.810 b** |
| **300 si** | **0.904 a** | **.868 a** | **1.77 a** | **.835 a** |

Treatment within a column followed by different letters is significantly different with Duncan's multiple range test at 5 % level.

Nano- silicon enhancement of plant growth is attributed to the improved photosynthetic parameters like chlorophyll fluorescence, net photosynthetic rate, stomata conductance, PSII activity, transpiration rate, effective photochemical efficiency, electron transport rate, and photochemical quenching **(Tripathi *et al.*, 2017).**

**3.2.2.2 Nitrogen , Potassium and Phosphorus percentage and proline content (mg/g) in leaves of lavender plant**

Data recorded in Table 8 shows that foliar application at 300 ppm nano- selenium or nano silicon achieved the maximum nitrogen and potassium percentage compared to control plants. Plants sprayed by 300, 200 ppm nano-silicon and 300 ppm nano- selenium gave the highest phosphorus percentage compared to control plants.

Increased nitrogen content by the application of Si-NPs has been observed in pea seedlings under normal as well as stress conditions **(Tripathi *et al.*, 2017)**

Some studies indicated that silicon can improve plant uptake of essential nutrients such as nitrogen, phosphorous, and potassium according to **Asgari and Diyanat (2021).**

Table 8. Effect of Nano selenium or Nano silicon on nitrogen , potassium and phosphorus percentage and proline content (mg/g) in leaf tissues of lavender plant during 2023 and 2024 seasons **(average of both seasons )**

| Se or si levels (ppm) | Nitrogen content (%) | Phosphorus content (%) | Potassium content (%) | Proline content (mg/g) |
|---|---|---|---|---|
| **Control** | 1.33 f | 0.153 f | 2.15 f | 4.17 g |
| **100 se** | 1.41 e | 0.161 e | 2.27 e | 4.40 f |
| **200 se** | 1.49 d | 0.167 d | 2.36 d | 5.40 d |
| **300se** | 1.56 b | 0.178 b | 2.49 b | 5.63 c |
| **100 si** | 1.52 c | 0.172 c | 2.37 d | 5.28 e |
| **200 si** | 1.58 b | 0.178 b | 2.44 c | 6.59 b |
| **300 si** | 1.75 a | 0.189 a | 2.54 a | 6.87 a |

Treatment within a column followed by different letter are significantly different with Duncan's multiple range test at 5 % level.

**3.2.2.3. Effect of nano particles on volatile oil percentage and compositions of lavender plant**

Data presented in Table 9 shows that foliar application at 300 ppm nano- selenium or nano silicon achieved the maximum percentage of volatile oil compared to control plants.

Table 9. Effect of nano-selenium or nano-silicon on volatile oil percentage of lavender plants during two seasons (2023 and 2024) **(average of both seasons )**

| Se or si levels ppm | volatile oil percentage(%) |
|---|---|
| **Control** | .832 f |
| **100 se** | .877 e |

| | |
|---|---|
| **200 se** | .933 c |
| **300 se** | 1.023 a |
| **100 si** | .806 g |
| **200 si** | .914 d |
| **300 si** | .976 b |

Treatment with in a column followed by different letter are significantly different with Duncan's multiple range test at 5 % level.

### 3.3. Interaction effect of nano-selenium or nano-silicon and saline water treatments on growth of lavender plants

#### 3.3.1. Vegetative growth characters

#### 3.3.1.1 Plant height (cm) and branches number

Data presented in Table 10 shows that foliar spraying with nano-silicon at all concentration improved all vegetative characters growth compared to foliar spraying with nano selenium under salinity stress conditions. Maximum plant height was found by treating with 300 ppm nano-selenium or 300 ppm nano-silicon under 1000 ppm water salinity compared to control plants**.** Foliar application of 300 mg /L Si-NPs achieved the maximum branches number per plant irrigated with 1000 ppm saline water compared to 1000 ppm saline water without foliar application of nano elements.

Table 10. Interaction of nano-selenium or nano-silicon and saline water treatments on plant height(cm) and branches number of lavender pant during 2023/24 seasons**(average of both seasons )**

| **Saline water levels(ppm) / Nano-Se or Nano-Si (ppm)** | **Control** | **1000** | **1500** | **2000** | **Control** | **1000** | **1500** | **2000** |
|---|---|---|---|---|---|---|---|---|
| | **Plant height (cm)** | | | | | | | |
| | **1st cut** | | | | **2nd cut** | | | |
| **Without nano** | 92.5 hi | 90.3k | 87.3 l | 59.5r | 94.5fg | 91.7 ij | 83.5 l | 51.5 s |
| **100 N-Se** | 91.7 ij | 91.6 ij | 87.6 l | 59.5r | 95.4 ef | 93.6 gh | 86.3 k | 56.5 r |
| **200 N-Se** | 96.4 ef | 94.7 g | 90.8 jk | 64.1q | 98.8 c | 95.8def | 90.9 j | 61.3 q |
| **300 N-Se** | 97.2 e | 96.0 f | 92.9 h | 65.8p | 99.4 c | 96.5 de | 92.6hi | 64.2 p |
| **100 N-Si** | 100 c | 96.8 ef | 93.1 h | 71.9 o | 100 b | 97.0 d | 93.3gh | 72.2 o |
| **200 N-Si** | 105 b | 98.5 d | 96.0 f | 76.0 m | 105a | 98.7 c | 96.3de | 76.3 n |
| **300 N-Si** | 106 a | 98.6 d | 96.9 ef | 77.9m | 106 a | 98.0 c | 97.1 d | 78.1 m |
| | **Branches number** | | | | | | | |
| | **1st cut** | | | | **2nd cut** | | | |
| **Without nano** | 59.6klm | 58.0 mn | 53.4 o | 35.7 r | 55.3 l | 52.6 m | 46.7 o | 33.0 r |
| **100 N-Se** | 61.7 jk | 60.0klm | 56.2 n | 37.0 r | 58.0 jk | 56.3 kl | 50.3 n | 35.3 q |
| **200 N-Se** | 67.3 h | 65.0 i | 59.2 lm | 42.0 q | 61.7ghi | 60.0 ij | 57.0 kl | 40.0 p |
| **300 N-Se** | 69.0 gh | 68.7 h | 60.1 kl | 45.3 p | 63.3 fg | 62.3fgh | 60.0 ij | 41.7 p |
| **100 N-Si** | 90.0 b | 80.3 d | 74.3 f | 63.0 ij | 80.0 b | 70.3 d | 64.3 f | 53.0 m |
| **200 N-Si** | 92.0 ab | 83.7 c | 78.0 e | 68.3 h | 82.0 ab | 73.7 c | 68.0 e | 58.3 jk |
| **300 N-Si** | 94.0 a | 83.0 c | 79.0 de | 71.0 g | 84.0 a | 73.0 c | 69.0 de | 61.0 hi |

Treatments within Se-NPs , Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

**Kiumarzi *et al.* (2022**) concluded that the decreasing in vegetative growth of pineapple mint under salinity stress may be due to plants inability to absorb water and nutrients due to drought stress caused by salt.

**Desouky *et al* (2024)** found that the foliar spraying of Se-NPs 1.0 mg/ L significantly increased shoot height, number of leaves per plant, shoot fresh and dry weight compared with control plants.

### 3.3.1.2 Herb fresh and dry weight (g)

Data recorded in Table 11shows that the highest herb fresh and dry weights/ plant were achieved by application of nano-silicon at (200 and 300 ppm) under saline water at 1000 ppm compared to plants irrigated with saline water at 1000 ppm without foliar spraying with nano elements.

**Table 11. Interaction of nano-selenium or nano-silicon and saline water treatments on plant fresh weight and dry weight (g) of lavender plant during 2023and 2024 seasons(average of both seasons )**

| Saline water levels(ppm) / Nano-Se or Nano-Si (ppm | Control | 1000 | 1500 | 2000 | Control | 1000 | 1500 | 2000 |
|---|---|---|---|---|---|---|---|---|
| | Herb fresh weight (g) | | | | | | | |
| | 1st cut | | | | 2nd cut | | | |
| **Without nano** | 96.6efgh | 94.3fghi | 80.5 ijk | 40.7 l | 88.8 h | 86.6 i | 75.7 l | 43.6 q |
| **100 N-Se** | 97.1 efgh | 97.4efgh | 54.1 l | 44.2 l | 91.5 g | 89.6gh | 77.9 k | 47.1 p |
| **200 N-Se** | 102.9defg | 105.5cdef | 85.0hijk | 49.9 l | 94.7 f | 94.3 f | 81.6 j | 51.8 o |
| **300 N-Se** | 109.8cde | 112.0 cd | 89.6ghij | 53.3 l | 99.6 e | 98.6 e | 86.0 i | 57.1 n |
| **100 N-Si** | 133.0 a | 131.3 ab | 102.0defg | 71.0 k | 114.2 d | 112.4d | 83.4 j | 52.2 o |
| **200 N-Si** | 136.5 a | 138.1 a | 110.6 cde | 74.9 k | 117.6 c | 119.2bc | 91.8 g | 56.1 n |
| **300 N-Si** | 140.3 a | 139.1 a | 117.7 bc | 79.8 jk | 121.4 a | 120.2ab | 98.9 e | 60.9 m |
| | Herb dry weight (g) | | | | | | | |
| | 1st cut | | | | 2nd cut | | | |
| **Without nano** | 17.6 j | 17.2 k | 14.0 m | 8.1 r | 16.4 i | 16.0 j | 83.3 kl | 42.1p |
| **100 N-Se** | 17.7 j | 17.7j | 14.4 l | 8.7 q | 16.9 gh | 16.6hi | 83.9 k | 45.7 q |
| **200 N-Se** | 18.7 i | 19.2h | 15.1k | 9.6 p | 17.5 f | 17.4 f | 88.0 j | 51.6 p |
| **300 N-Se** | 20.0 g | 20.4 f | 15.9 j | 10.6 o | 18.5 e | 18.3 e | 92.8 i | 55.6 o |
| **100 N-Si** | 24.2 d | 23.9 d | 15.4 k | 9.7 p | 21.1d | 20.8 d | 81.7 l | 56.6 o |
| **200 N-Si** | 24.8 c a | 25.1 bc | 17.0 g | 10.4 o | 21.8 c | 22.1 bc | 88.2 j | 59.7n |
| **300 N-Si** | 25.5 | 25.3 ab | 18.3 e | 11.3 n | 22.5 a | 22.2 ab | 93.8 i | 63.6 m |

Treatments within Se-NPs , Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

### 3.3.1.3 Salt resistance index (SRI) %

From the results in **Table 12** presented that salt resistance index (%) of lavender was improved as a result of the treatments by different nano-selenium or nano-silicon combined with water salinity levels compared to un-salinized plants. The maximum salt resistance index was found in plants sprayed with 300 nano selenium X 1000 ppm saline water compared to untreated plants with saline water.

**Table 12. Interaction of nano-selenium or nano-silicon and saline water treatments on salinity salt resistance index % of lavender plant during 2023 and 2024 seasons (average of both seasons )**

| Saline water levels(ppm) / Nano-Se or Nano-Si (ppm | Control | 1000 | 1500 | 2000 | Control | 1000 | 1500 | 2000 |
|---|---|---|---|---|---|---|---|---|
| | Salt resistance index % | | | | | | | |
| | 1st cut | | | | 2nd cut | | | |
| Without nano | 100.0 g | 97.6 h | 83.3 kl | 42.1p | 100.0 hij | 97.6 ij | 85.3 m | 49.1 r |
| 100 N-Se | 100.5 g | 100.8 g | 83.9 k | 45.7 q | 103.1 fgh | 101.0 ghi | 87.8 lm | 53.1 q |
| 200 N-Se | 106.5 f | 109.2 de | 88.0 j | 51.6 p | 106.7 ef | 106.3 ef | 92.0 k | 58.6 p |
| 300 N-Se | 113.6 b | 115.9 a | 92.8 i | 55.6 o | 112.3 c | 111.2 cd | 96.9j | 64.4 o |
| 100 N-Si | 106.1 f | 104.6 f | 81.7 l | 56.6 o | 107.9 de | 99.4 ij | 79.6 n | 47.2 r |
| 200 N-Si | 108.8 e | 110.0 cde | 88.2 j | 59.7n | 128.1 b | 103.6 fgh | 89.5 kl | 57.0 p |
| 300 N-Si | 111.8 bc | 110.9cd | 93.8 i | 63.6 m | 133.9 a | 103.9 fg | 92.1 k | 63.5 o |

Treatments within Se-NPs , Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

### 3.3.2 Chemical determinations:

#### 3.3.2.1 Leaf pigments content (mg/g)

Table 13 shows that foliar spraying with nano silicon at 300 ppm achieved the highest values in chlorophyll b ,total chlorophyll (a+b) and carotenoids contents X 1500 ppm water salinity. The maximum values of chlorophyll a was achieved at 300 ppm nano- sililcon X 1000 ppm water salinity. This response may be due to silicon is deposition on outer wall of epidermal cells which causes the formation of uneven texture on both sides of the leaf led to increase leaf strength, maintaining leaf chlorophyll content, and delaying cell death.( **Idrees *et al.*,2024**).

#### 3.3.2.2. Nitrogen , Phosphorus and Potassium percentage in leaves and proline content (mg/g)

Data presented in Table 14 shows that there was no significant difference between saline water levels under foliar spraying at 300 ppm nano silicon compared to control for nitrogen percentage . The highest values of phosphorus and potassium percentage achieved by foliar application of 300 ppm nano silicon X 1500 ppm water salinity. Results show that the maximum content of proline found at 300 ppm nano silicon X saline water at 2000 ppm. **Jiang *et al.* (2017)** showed that selenium increased the potassium content of cells under stress conditions. Any potassium availability increases the transfer of water to the aerial part of the rice plant, thus helping to protect the cell against stress. Silicon could contribute to increasing the content of nitrogen, phosphorus and potassium in leaves of plants under stress saline water This, in turn, can help promote healthy growth of plants and increase their resistance to harsh conditions. **Elizabethn *et al* (2010).**

Table 13. Interaction of nano-selenium or nano-silicon and saline water treatments on chlorophyll (a), chlorophyll (b) , on total chlorophyll and carotenoids (mg/g) content of lavender plant **(average of both seasons )**

| TREAT MENTS | Con trol | 1000 | 150 0 | 20 00 | Con trol | 10 00 | 15 00 | 20 00 | Con trol | 10 00 | 15 00 | 20 00 | Con trol | 10 00 | 15 00 | 200 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | chlorophyll (a) (mg/g) | | | | chlorophyll (b) (mg/g) | | | | total chlorophyll (a+b) (mg/g) | | | | Carotenoids (mg/g) | | | |
| Without | .724 | .737 | .643 | .8 | .719 | .7 | .6 | .8 | 1.44 | 1. | 1. | 1. | .685 j | .703 | .608 | .722 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **nano** | j | ij | k | 28 fgh | n | 33 n | 19 o | 22 jk | n | 47 n | 26 o | 65 gji | | ij | k | i |
| **100 N-Se** | .763 i | .818 gh | .826 fgh | .844 efg | .759 m | .811 k | .760 m | .838 fghi | 1.52 m | 1.63 jk | 1.58 l | 1.68 fghi | .749 h | .758 gh | .722 i | .778 efgh |
| **200 N-Se** | .812 gh | .836 efgh | .726 ij | .884 bcd | .823 ijk | .829 hij | .853 def | .873 bc | 1.64 jk | 1.66 hij | 1.57 l | 1.76 cd | .750 h | .812 bc | .752 gh | .794 def |
| **300 N-Se** | .832 efgh | .841 efgh | .806 h | .892 bcd | .834 ghij | .868 cd | .865 cde | .885 ab | 1.67 hij | 1.71 efg | 1.67 ghi | 1.78 bc | .807cde | .771 fgh | .781 efg | .804 cde |
| **100 N-Si** | .821 gh | .838 efgh | .882 bcd | .751 ij | .832 ghij | .825 ijk | .851 ef | .733 n | 1.65 ij | 1.66 ij | 1.73 de | 1.48 mn | .795def | .794 def | .794 def | .75gh |
| **200 N-Si** | .868 cde | .861 def | .901 bc | .812 gh | .851 ef | .843 fgh | .889 a | .792 l | 1.72 def | 1.71 efgh | 1.79 bc | 1.60 kl | .814bc | .816 bc | .844 b | .765 fgh |
| **300 N-Si** | .894 bcd | .974 a | .911 b | .836 efgh | .862 cde | .864 cde | .901 a | .846 fg | 1.76 cd | 1.84 a | 1.81 ab | 1.68 fghi | .833 ab | .844 b | .873 a | .790 |

Treatments within Se-NPs, Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

**Table 14. Interaction of nano-selenium or nano-silicon and saline water treatments on nitrogen, phosphorus and potassium of leaves (%) and proline content (mg/g) of lavender plant (average of both seasons )**

| TREATMENTS | Nitrogen content of leaves % | | | | phosphorus content of leaves % | | | | potassium content of leaves % | | | | Proline content mg/g | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Control** | **1000** | **1500** | **2000** | **Control** | **1000** | **1500** | **2000** | **Control** | **1000** | **1500** | **2000** | **Control** | **1000** | **1500** | **2000** |
| **1st season** | | | | | | | | | | | | | | | | |
| **Without nano** | 1.17 p | 1.47 i | 1.17 p | 1.50 i | 0.132 p | 0.159 lm | 0.155 m | 0.164 jkl | 2.02 m | 2.19 k | 2.29 ij | 2.10 l | 4.14 u | 4.01 w | 3.85 x | 4.69 q |
| **100 N-Se** | 1.25 no | 1.60 f | 1.23 o | 1.54h | 0.140 o | 0.160 lm | 0.170 ij | 0.173 hi | 2.13 l | 2.27 | 2.41h | 2.27 j | 4.33 t | 4.05 v | 4.41 s | 4.81 p |
| **200 N-Se** | 1.30 m | 1.67 e | 1.26 n | 1.71d | 0.139 o | 0.167 jk | 0.180 fg | 0.183 f | 2.15 kl | 2.44 gh | 2.55 cd | 2.30 ij | 5.48 k | 4.41 s | 5.84 j | 5.88 ij |
| **300 N-Se** | 1.33 l | 1.75 c | 1.41 | 1.77 c | 0.155 m | 0.177 | 0.193cd | 0.189 | 2.20 k | 2.51 | 2.64 a | 2.61 | 5.90 i | 4.55 | 5.91 | 6.15 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | j | | | gh | | de | | cde | | ab | | r | i | h |
| **100 N-Si** | 1.30 m | 1.57 g | 1.71 d | 1.48 i | 0.145 no | 0.164 jkl | 0.197 bc | 0.183f | 2.15 kl | 2.48 efg | 2.52 cde | 2.33 i | 5.16 o | 5.27 n | 5.32 m | 5.37 l |
| **200 N-Si** | 1.37 k | 1.67e | 1.80 b | 1.48i | 0.148 n | 0.174 ghi | 0.196 bc | 0.192 cd | 2.27 j | 2.49 defg | 2.56 bc | 2.45 fgh | 6.32 f | 6.23 g | 6.78 d | 7.02 b |
| **300 N-Si** | 1.39 jk | 1.87a | 1.85 a | 1.86 a | 0.162 kl | 0.185 ef | 0.210a | 0.200 b | 2.35 i | 2.64 a | 2.66 a | 2.50 def | 6.64 e | 6.65 e | 6.97 c | 7.21 a |

Treatments within Se-NPs , Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

### 3.3.2.3.Volatile oil percentage and components of lavender plant

Data recorded in Tables 15,16 shows that the foliar application at 300 ppm nano-silicon produced the maximum oil percentage compared to control plants. Results showed that the foliar spray at 200 ppm nano silicon gave the maximum percentage of 1.8 cineol under salinity stress, while Si-NPs 200 ppm X 2000 ppm saline water reduced oil components. Foliar application of Se-NPs or Si-NPs at 200 ppm X salinity at 2000 ppm improved cineol content. Irrigation by saline water at 2000 ppm improved linalool composition.

**Kiumarzi *et al.* (2022)** studied the effect of three levels selenium nanoparticles (0,10 and 20 mg/L) under four salinity stress (0, 30, 60 and 90 Mm NaCl) on essential oil content of *Mentha suaveolens* plant. They revealed that application of 10 mg /L Se-NPs levels led to slight increases in essential oil content even under salinity stress. Se-NPs (10mg/ L) sprays increased the essential oil content under mild salinity (30 mM).

**On *Salvia officinalis* Ben Taarit *et al.*(2010)** mentioned that the main essential oil compound was viridiflorol under control conditions and 25 mM NaCl, whereas 1, 8-cineole accumulated under 50 and 75 mM NaCl stress. However, when the plants were treated with 100 mM NaCl stress, manool became the predominant compound.

**Table 15. Interaction of nano-selenium or nano-silicon and saline water treatments on volatile oil percentage of lavender plant (average of both seasons )**

| TREATMENTS | Control | 1000 | 1500 | 2000 |
|---|---|---|---|---|
| | volatile oil percentage | | | |
| **Without nano** | .893 gh | .933 ef | .803 kl | .698 n |
| **100 N-Se** | .953 de | .933 ef | .878 ghi | .743 m |
| **200 N-Se** | .933 ef | .913 fg | .983 d | .903 fgh |
| **300 N-Se** | 1.05 c | 1.068 bc | 1.053 bc | .913 fg |
| **100 N-Si** | .893 gh | .893 gh | .788 l | .648 o |
| **200 N-Si** | 1.08 b | .933 ef | .828 jk | .808 kl |
| **300 N-Si** | 1.213 a | .968 de | .868 hi | .853 ij |

Treatments within Se-NPs , Si- NPs column and salinity levels followed by different letters are significantly different with Duncan's multiple range test at 5 % level.

**Table 16. Interaction of nano-selenium or nano-silicon and saline water treatments on essential oil composition of lavender plant (average of both seasons )**

| Treatments / Essential oil compositions(%) | Control | Salinity 2000 ppm | Selenium 200ppm | Salinity 2000 ppm X selenium 200ppm | Silicon 200 ppm | Salinity 2000 ppm X silicon 200ppm |
|---|---|---|---|---|---|---|
| **Camphene** | 3.52 | 1.94 | 2.966 | 1.524 | 3.311 | 2.091 |
| **αpinene** | 1.356 | 0.763 | 1.294 | 0.718 | 1.231 | 1.236 |
| **Sabinene** | 3.366 | 2.355 | 3.572 | 1.723 | 3.258 | 2.21 |
| **p-cymene** | 0.632 | - | - | - | 0.534 | - |
| **1.8cineol** | 46.301 | 48.588 | 48.465 | 44.352 | 45.721 | 50.558 |
| **linalool** | 24.239 | 26.529 | 23.278 | 25.219 | 23.478 | 24.444 |
| **Bi cycol(3.1)Hexanol.4 methe bne** | 2.262 | 2.403 | 2.033 | 2.47 | 1.603 | 2.417 |
| **Bi cyclo(3,1,1)Heptanol** | 4.759 | 2.38 | 4.459 | 2.272 | 1.605 | 2.403 |

## REFERENCES


1. Abdelkader, M. A. I., H. M. S. Hassan and E. A. H. Elboraie (2019). Using proline treatments to promote growth and productivity of *Rosmarinus officinalis* L. plant grown under soil salinity conditions. Middle East Journal of Applied Sciences, 9 (3): 700-710.
2. Ahanger M.A. and R.M. Agarwal (2017). Salinity stress induced alterations in antioxidant metabolism and nitrogen assimilation in wheat *(Tritcum aestvum L.)* as influenced by potassium supplementation. *Plant Physiol. Biochem.,* 115: 449460.
3. Al-Fraihat, A. H., S. Y.Al-Dalain, A. A. Zatimeh and M. A. Haddad (2023). Enhancing rosemary (*Rosmarinus officinalis* L.) growth and volatile oil constituents grown under soil salinity stress by some amino acids. Horticulturae, 9(2): 252.
4. Asgari, F., M. Diyanat (2021).Effects of silicon on some morphological and physiological traits of rose (Rosa chinensis var. minima)plants grown under salinity stress. Journal of Plant Nutrition, 44(4): 536-549.
5. Ben Taarit MK, K. Msaada, K. Hosni, B. Marzouk (2010). Changes in fatty acid and essential oil composition of sage (*Salvia officinalis* L.) leaves under NaCl stress. Food Chem 9:951–956 stress conditions. Ind. Crops Prod. 30; 333–337.
6. British Pharmacopoeia (1963). The Pharmaceutical Press 17 Bloomsbury. Square London, W.C.L.
7. Desouky, A. F., S. F. Desoukey, H. S. Abdel-Aziz, R. I. EL-kholy and M. S. Hanafy (2024). Exogenous Application of Selenium Nanoparticles (Se-NPs) to Mitigate Salt Stress in Soybean-Evaluation of Physiological, Molecular and Biochemical Processes. Journal of Soil Science and Plant Nutrition, 24(4): 6798-6813.
8. Duncun, D.B. (1955). Multiple ranges and multiple F test. Biometrics, 11: 1-42.

9. Eghlima, G., M. Mohammadi, M. E. Ranjabr, D. Nezamdoost and A. Mammadov (2024). Foliar application of nano-silicon enhances drought tolerance rate of pot marigold (*Calendula officinalis* L.) by regulation of abscisic acid signaling. BMC Plant Biology, 24(1); 1220.
10. Elizabethn.A.H., Pilon-Smits and F.Q.Colin (2010). Selenium Metabolism in plants: R. Hell and R.-R. Mendel (eds.), Cell Biology of Metals and Nutrients. Springer-Verlag Berlin Heidelberg.
11. Evenhuis, B. and PWDe Waard (1980). Principle and practies in plant analysis FAOSoils Bell., 38 (1): 152-163.
12. Hernandez, J.A., A.B. Aguilar, B. Portillo, E. LopezGomez, J.M. Beneyto and M.F.Garcia-Legaz (2003). The effect of calcium on the antioxidant enzymes from salt-treated loquat and anger plants. Functional Plant Biology, 30: 1127-1137.
13. Hnilickova H, Hnilicka F, Martinkova J and Kraus K. (2017). Effects of salt stress on water status, photosynthesis and chlorophyll fluorescence of rocket. Plant, Soil and Environment,63; 362–367. https://doi.org/10.17221/398/2017-PSE.
14. Ibrahim, A. M., A. E. Awad, A. S. H .Gendy and M. A. I. Abdelkader (2019). Effect of proline foliar spray on growth and productivity of sweet basil (*Ocimum basilicum,* L.) plant under salinity stress conditions. Zagazig Journal of Agricultural Research, 46(6): 1877-1889.
15. Idrees K, A .Aziz, M .Naeem, M.F. Azhar, S .Farooq and M. Hussain (2024) Combined application of zinc and silicon improved growth, gas exchange traits, and productivity of maize (*Zea mays* L.) under water stress. Silicon.;16:831–41.https:// doi.org/10.1007/s12633-023-02732-9.
16. Jadczak, D., K. Bojko, M. Kaymakanova and M. Berova (2022). Salinity induced changes in the antioxidant status of common basil plants (*Ocimum basilicum* L.) grown under controlled conditions. Horticulturae, 8(9):775.
17. Jiang. C., C. Zu, D. Lu, Q. Zheng and J. Shen (2017). Effect of exogenous selenium supply on photosynthesis, $Na^+$ accumulation and antioxidant capacity of maize (*Zea may* L.) under salinity stress. Scientific Reports 7. https://doi. org/10.103/srep42039.
18. Kamran M., A. Parveen, S. Ahmar, Z. Malik, S. Hussain, M.S. Chattha, M.H. Saleem, M. Adil, P. Heidari and J.T.Chen (2020). An overview of hazardous impacts of soil salinity in crops, tolerance mechanisms, and amelioration through selenium supplementation. Int. J. Mol. Sci, 21:148. https://doi.org/10.3390/ijms21010148.
19. Karimian, Z., L. Samiei and J. Nabati (2019). Alleviating the salt stress effects in *Salvia splendens* by humic acid application. Acta Scientiarum Polonorum Hortorum Cultus, 18(5): 73-82.
20. Khan, Z. and H. Upadhyaya (2019). Impact of nanoparticles on abiotic stress responses in plants: an overview. Nanomaterials in plants, algae and microorganisms, 305-322.
21. Kiumarzi, F., M. R.Morshedloo, S. M. Zahedi, H. Mumivand, F. Behtash, C. Hano and J. M. Lorenzo (2022). Selenium nanoparticles (Se-NPs) alleviates salinity damages and improves phytochemical characteristics of pineapple mint (*Mentha suaveolens* Ehrh.). Plants, 11(10): 1384.
22. Kucharska, M., J.A. Szyma nska, W. Wesołowski, B. Frydrych, and E. Bruchajze (2019). Analysis of volatile ingredients of selected essential oils with a relaxing effect. Med. Pract., 70; 229–247.
23. Mahajan, M., R.Kuiry, and P.K.Pal (2020). Understanding the consequence of environmental stress for accumulation of secondary metabolites in medicinal and aromatic plants. Journal of Applied Research on Medicinal and Aromatic Plants, 18, 100255.

24. Nassar, D. M. A, Azoz, N. Samah and W. M. S. El-Din (2019). Improved growth and productivity of basil plants grown under salinity stress by foliar application with ascorbic acid. Middle East Journal of Agriculture, 8 (1): 211-225.
25. Parul, P., S. Samiksha, S. Rachana and S. Vijay (2015). Effect of salinity stress on plants and its tolerance strategies: A review. Environmental Science and Pollution Research 22: 4056-4075.
26. Safwat, G. and H. S. Abdel Salam (2022). The effect of exogenous proline and glycine betaine on phyto-biochemical responses of salt-stressed basil plants. Egyptian Journal of Botany, 62(2), 537-547.
27. Sajyan TK, Alturki SM, Sassine YN (2020). Nano-fertilizers and their impact on vegetables: contribution of Nano-chelate super plus ZFM and Lithovit®-standard to improve salt-tolerance of pepper. Annal Agr Sci. https://doi.org/10.1016/j.aoas.2020.11.001.
28. Shehata, A. M. and S. E. Walid (2019). Response of sweet basil plants (*Ocimum basilicum, l.*) to spraying seaweed extract grown under salinity stres. *Future*, *2*; 16-28.
29. SPSS (2020). Statistical Package for Social Science, Version 20, Chicago, USA.
30. Steel, R.G.D. and J.M. Torrie (1980). Principles and Procedures of Statistics, A Biometrical Approach. McGraw - Hill Book Company, New York.
31. Tripathi D.K, S.Singh, V.P.Singh, S.M .Prasad, N.K. Dubey and D.K. Chauhan (2017). Silicon nanoparticles more efectively alleviated UV-B stress than silicon in wheat (*Triticum aestivum*) seedlings. Plant Physiol Biochem 110;70–81.
32. Vasileva, I., R. Denkova, R. Chochkov, D.Teneva, Z. Denkova, T. Dessev and A. Slavov (2018). Effect of lavender (*Lavandula angustifolia*) and melissa (*Melissa Officinalis*) waste on quality and shelf life of bread. Food Chemistry, *253*; 13-21.
33. Wei, A. and T. Shibamoto (2010). Antioxidant lipoxygenase inhibitory activities and chemical compositions of selected essential oils. Journal of agricultural and food chemistry, 58(12): 7218-7225.
34. Wettestein, D. ( 1957 ) Chlorophyll Lethal und der Submikroskopische Formwechsel der Plastien. Exptl. Cell. Res., 12;427-433.
35. Yavaş, İ. (2021). The effect of nanoparticle applications on plants under some stress conditions. Turkish Journal of Range and Forage Science, 2(2): 52-62.