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Mitigation of Saline Water Stress on French Lavender (*Lavandula dentata* L.) Plants

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Abstract: A pot experiment was carried out at the Farm of Medicinal and Aromatic Plants Research Department in Dokki, Giza, to study mitigation of salinity stress using different levels of silicon and its effects on growth, yield and essential oil of French lavender (*Lavandula dentata* L.) plants, during two successive seasons 2018 and 2019.The salinity levels of NaCl and $CaCl_2$ were (1:1) 0, 2000, 2500, 3000 and 3500 ppm, were applied alone and with foliar spray of silicon (Si), which was applied as potassium silicate (K_2SiO_3) at 100, 200 and 300 ppm. The results indicated that, all levels of salinity treatments (except 2000ppm) decreased plant height, fresh and dry weights, essential oil % and yield compared to control plants. The maximum effect was recorded in case of 3500ppm of salinity. However, growing lavender plants under saline condition increased the main components of the oil (1, 8 cineole and linalool). Si at the rates of 200 and 300ppm under salinity stress produced the highest significant effect on plant growth, volatile oil production and constituents. Plant chemical analysis showed that chlorophyll and protein contents were decreased under salinity stress, however chlorophyll and protein contents were increased with the addition of different Si rates under salinity stress. Proline content was increased in plants under salinity stress compared to the control, while it gradually decreased with increasing rates of Si under all levels of salinity, indicating the mitigation effect of Si against salt stress.

Key words: *French lavender, (Lavandula dentata L.), Essential oil, Salinity, Silicon, Proline and Cineole.*

INTRODUCTION

French lavender, *Lavandula dentata* L., is a flowering plant belonged to Lamiaceae family, native to the Mediterranean region, the Atlantic islands and the Arabian Peninsula. French lavender is commonly grown as an ornamental plant and perfume plant [1]. The plant is used in Murcia as an herbal remedy for stomach ache. Dried leaves and flowers are used as an antiseptic, mild sedative. The oil also have medicinal properties, *Lavandula* oil is especially useful for use in nervous system stimulants, hypnotics, sedatives, tranquilizers and stress repellents. In addition, it has useful dermatological uses in the treatment sunburn and skin rashes as well as strong antiseptic (disinfectant) and antibiotic (bacteria killing) effects [2].

Salinity is a major stress condition at present and is one of the most serious environmental problems influencing crop growth and together with drought continues to be one of the world most serious environmental problems in agriculture. It affects nearly 20% of the cultivated lands around the world and about 50% of all irrigated lands [3]. In general, saline irrigation waters may especially raise soil salinity levels over threshold values (dangerous level) in arid and semi-arid regions of the world. Salt stress decreases the photosynthesis and respiration rate of plants; total carbohydrate, fatty acid and protein content were adversely affected due to salinity effect, but increased the level of amino acids, particularly proline. The content of some secondary plant products is significantly higher in plants grown under salt stress than under normal conditions. The salinity tolerance of plants depend on the interaction between salinity and other environmental factor [4]. Salinity is a limiting factor in plant production [5].

Recently, various chemical, physical and biological strategies are adapted for stable productivity of grain under saline water and soils such as silicon nutrient. Silicon (Si) has been reported to be beneficial in mitigating

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biotic stresses (e.g., plant diseases and pest damage) and abiotic stresses such as salinity, drought, aluminum toxicity, heavy metal toxicity, nutrient imbalance, lodging, radiation, high temperature, wounding and freezing [6]. According to Epstein [7] both biotic and abiotic stress factors induce physiological disorders leading to loss in crop yields, although silicon is not an indispensable element for the growth and development of higher plants, under stress conditions the additional treatment with silicon may cause a big difference in their performance. Additional treatment with Si does not cause severe injury to plants as its excessive amounts may be secreted. Plant height, number of branches/plant and essential oil percentage decreased significantly with increasing salinity levels.

Firoozeh *et al.* [8] showed that salt stress significantly decreased FW and DW of borage plants by about 67 and 73% respectively, in comparison with control plants (without any treatment), while Si treatment increased the FW and DW of plants, the highest increase in the FW and DW due to Si application with or without salt stress, The results indicated that NaCl treatment resulted in a significant increase in proline content. The combined treatment of Si and NaCl, the different concentrations of Si caused a significant decrease in the proline content, salt stress decreased the total soluble protein content.

Application of silicon can decrease Na^+ accumulation in the roots and/or shoots. In salt-stressed barley roots, application of silicon decreases both Na^+ and Cl^{-1} levels but increases K^+, with Na^+ and K^+ being more evenly distributed over the whole root section; this was proposed to be the key mechanism of silicon-enhanced salt tolerance in this species [9]. Hashemi *et al.* [10] found that exogenous Si application of ameliorated the deleterious effects of salinity on the growth through lowering tissue Na+ content. The application of Si alleviated the adverse effects of high salinity on plants and improved some parameters of purslane (*Portulaca oleracea* L.) such as root volume, root dry weight, K content in leave sand root, decrease Na content and decrease K/Na ratio in leaves. Ali and Hassan [11] indicated that, saline water stress significantly decreased the plant height (cm), number of branches/plant, herb dry weight as well as leaf area compared with non-stressed roselle plants. However, Si application with 0, 2 and 4 mM had positive effects in this respect and alleviated the adverse effects of water stress. Additionally, the total soluble sugars and proline contents were significantly increased under water stress conditions. Si application increased the contents of N, P, K and Mg, while Ca content was decreased due to Si treatment in stressed or non-stressed plants. Rasoul *et al.* [12] treated fennel plants with (0, 40 and 80 mM) NaCl and obtained a reduction in plant dry and fresh weights and seed yield but oil of fruits increased. Supply of Si with (0.5 or 1 mM) enhanced the fresh and dry weights/plant. Hendawy and Khalid [13] noticed that, increasing salinity level, progressively decreased the vegetative growth characters i.e. plant height, numbers of branches, fresh and dry weights of sage *Saliva officinalis* L plants. The highest level of soil salinity (2500 ppm) caused the highest harmful effect on vegetative growth characters, whereas essential oil, total carbohydrate and proline contents were pronouncedly increased with increasing salt stress levels.

The aim of this study was to investigate the saline water stress mitigation French lavender (*Lavandula dentata* L.) plants by Si treatments through some physiological and parameters responses.

MATERIALS AND METHODS

The experiment was conducted in the Farm of Medicinal and Aromatic Plants Department, Horticulture Research Institute (HRI), Dokki, Giza, during two successive seasons 2018 & 2019, in order to evaluate the mitigation effect of silicon (Si) treatments on growth, yield and active constituents of French lavender (*Lavandula dentata* L.) grown under water salinity.

Plastic pots, 30 cm in diameter, were used in this study. Each pot was filled with 10kg of a soil mixture from: sandy: silt: manure fertilizer (1: 1: 1). Sand and silt were washed with water and fertilized with 16 g ammonium sulphate (20.5 %N) and 5 g of potassium sulphate (48% K_2O_2). Half dose of the nitrogen and potassium fertilizer was applied 45 days after transplanting while; the second one was applied after a month from the first one. Calcium superphosphate (15.5 % P_2O_5) was mixed with the soil before transplanting. Pots were irrigated with equal volumes of tap water one liter per pot and two liters per pot after 15 days from transplanting tell plants were well established.

The seedlings (15 cm height) were obtained from Medicinal and Aromatic farm in EL- Kanater EL- Khairiya, El-Kalyobia governorate. The seedlings were transplanted into the pots on the 18^{th} and 19^{th} March of each season, 2018 and 2019, respectively. Each pot contained two seedlings and was placed in full sun light under natural condition in Giza governorate. Plants were irrigated to

Table 1: Chemical analysis of the soil mixture.

Chemical Analysis						
Soluble cations (meq/l)				Soluble anions (meq/l)		
Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}
0.61	0.45	1.09	0.39	1.10	0.47	0.87
pH= 7.80		EC(ds/m) = 1.55		Total nutrients content (ppm)		
				N= 75	P= 27	K= 114

field capacity using tap water for about 3 weeks until of the lavender establishment. Saline water treatments and different silicon concentrations were applied twice per week, while control plants were sprayed with tap water.

The treatments of the different levels of saline water including: 0, 2000, 2500, 3000 and 3500 ppm using the mixture of NaCl plus $CaCl_2$ (1:1w/w) which were applied with or without foliar sprays of silicon 100, 200 and 300 ppm, using Tween 20 (0.5 ml/liter) as emulsion agent.

Silicon (Si) was used in the form of potassium silicate (K_2SiO_3).

This experiment included 17 treatments as follows:

- Control.
- Saline irrigation water 2000, 2500. 3000 and 3500ppm.
- Foliar spray of Si at 100, 200 and 300ppm.
- All combinations of saline treatments and Si treatments, giving a total 17 treatments in this study.

This experiment was laid out in a complete randomized blocks, as described by Gomez and Gomez. [14] with three replicates (eight pots/ replicate).

Before transplanting, the chemical properties of the soil mixture used in the study Table 1 were determined by Soils, Water and Environment Research Institute laboratories (ARC) according to the methods of Sparks [15].

The harvest herb was done in the second week of September in 2018 and 2019 at full blooming stage, in both seasons, respectively.

Five plants were taken randomly from each experimental unit and the growth data were recorded on plant height (cm), number of branches/ plant and fresh and dry weights of plant (g).

Chemical Composition: Essential oil % in lavender fresh herb was determined according to British Pharmacopoeia [16]. Volatile oil samples were taken from the second season (2019) and were analyzed using GLC as according to the methods described by Meshkatal sadata *et al*. [17]. Total chlorophyll content was determined by MINOLTA SPAD (502) meter according to Markwell *et al.* [18]. Proline content (ppm) was analyzed as described by Bates *et al.* [19]. Total proteins in the plants of both seasons were determined using the method described by the A.O.A.C [20].

RESULTS AND DISCUSSION

Growth Characters

Plant Height and Number of Branches/plant: Results in Table 2 showed that, all salinity levels significantly decreased plant height and number of branches/plant of French lavender plants, in both seasons, as compared to non-saline condition, except plants grown under 2000 ppm saline water which were found to be same as those treated by tap water. Also, data indicated that increasing salinity level from 2000 to 3500 ppm decreased plant height as well as No. of branches/plant compared with control, in both seasons. However, the foliar application of silicon at 200 and 300 ppm to plants grown under saline water at 2000, 2500 and 3000 ppm significantly improved the plant height and No. of branches/.The tallest plants were recorded with the application of 300ppm Si on plants grown under 2000 ppm salt, given 68.60cm in the first season and 66.50cm in the second one. Also, the greatest numbers of branches were 8.50 and 8.45 branches/plant in the two seasons were recorded at 300 ppm Si under 2000ppm salinity, compared with the other of salinity levels. Razmjoo *et al*. [21] it was found that increasing of salinity stress decreased almost all of growth parameters in *Matricaria chamomile*.

Regarding the effect of combination between salinity and Si treatments on plant height and No. of branches/plant of French lavender plants, it was found that the foliar application of Si showed a beneficial effect on alleviation the harmful effect of salinity during the two seasons. Application of Si at 200 and 300 ppm improved the growth of plants irrigated with 2000, 2500, 3000 and 3500 ppm saline water compared to those untreated with silicon 100 ppm of Si showed significant effect only with 2000 ppm saline water. The beneficial of Si effect may be

Table 2: Effect of salinity stress and silicon on growth and yield of French lavender (*Lavandula dentata* L.) plants, during 2018 and 2019, seasons.

	Plant height (cm)		No. of branches/plant		Fresh weight of plant (g)		Dry weight of plant (g)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019
Control	51.05	49.21	5.61	4.95	109.55	111.60	33.42	34.50
2000 ppm	52.00	52.05	5.50	4.73	115.75	116.91	34.50	35.51
2500 ppm	48.47	46.21	4.45	3.70	95.10	96.21	27.45	28.31
3000 ppm	45.11	40.02	4.00	3.35	82.12	84.91	23.37	24.50
3500 ppm	36.21	34.30	3.55	3.76	73.02	74.82	18.55	19.60
2000+100 ppm Si	56.31	55.90	6.65	6.70	127.70	130.21	36.91	37.90
2500 +100ppm Si	54.96	51.09	5.85	5.80	120.20	121.32	30.11	31.20
3000 +100ppm Si	48.64	47.50	5.22	4.58	82.15	83.21	27.00	25.10
3500 +100ppm Si	36.55	34.50	4.30	3.90	73.10	74.97	19.09	20.71
2000 +200ppm Si	62.55	61.40	7.75	7.73	131.49	136.25	38.10	38.00
2500+200ppm Si	56.12	55.20	7.50	7.00	125.25	128.76	34.59	35.70
3000 +200ppm Si	51.38	48.40	7.00	6.80	122.13	124.00	29.64	30.60
3500 +200ppm Si	43.21	44..10	5.00	4.09	88.31	81.42	24.10	29.98
2000 +300ppm Si	68.60	66.50	8.50	8.45	134.14	138.27	39.32	39.74
2500 +300ppm Si	58.15	58.00	8.00	8.10	129.55	131.31	35.30	36.65
3000 +300ppm Si	55.42	53.20	6.49	6.00	120.17	126.15	31.90	33.50
3500 +300ppm Si	50.72	49.10	5.52	4.90	95.15	98.23	30.55	29.81
LSD: at 0.05	3.90	3.75	0.96	0.76	3.23	3.80	1.15	1.47

due to the prominent role of Si in improving plant water status [22]. Also, the benefits of using Si are related to various indirect effects like increased capacity and efficiency of photosynthesis, decreased transpiration and thus more shoot growth. The results of this study are in line with previous findings, as there was improvement in plant height and No. of branches/plant of salt stressed dill plants under the influence of Si Fariborz *et al*. [23] may be due to the improved ion balance, antioxidant enzymes activities and osmotic adjustment. Rasoul *et al.* [12] on fennel plants, obtained similar results.

Herbal Yield: Data in Table 2 indicated that, in general, salt stress in irrigation water have a harmful effect on herb yield of lavender plants, increasing the rates of the salinity led to a marked decrease in fresh and dry weights/plant in the two seasons. It was clearly observed that, vegetative growth of lavender plants was found to gradually decrease in response to the level of saline water depending on salt concentration in comparison with control plants. Fresh and dry weights decreased gradually with increasing of salt concentration in irrigation water to lavender plants in the two seasons, than plants irrigated by tap water or 2000 ppm salinity water. Moreover, the highest values of herb yield (134.14 and 138.27 g) and (39.32 and 39.74 g) were obtained from plants treated with 2000ppm saline water combined with 300 ppm Si treatment in the first and second seasons, respectively. Plant growth requires both proliferation and elongation of cells, so, growth reduction due to salinity stress may be attributed to osmotic stress, ion imbalance and ion toxicity, that resulted in losing the turgor and DNA synthesis for cell growth [24-26]. The results showed that salt stress caused significant reductions in fresh and dry weights. As stated by Munns [27], suppression of plant growth under saline conditions may either be due to decreased availability of water or to the toxicity of sodium chloride. Also the reduction in dry weight under salinity stress may be attributed to inhibition of hydrolysis of reserved foods and their translocation to the growing shoots. Also, Hasanuzzaman *et al*. [28] reported that, the first phase of growth reduction is a quicker process which is due to osmotic effect, which is followed with much slower process induced by salt accumulation in leaves, leading to salt toxicity in the plants. The results showed that salt stress caused significant reductions in fresh and dry weight. Similar results were also reported by Kafi and Rahimi [29] on purslane, Tahir *et al.* [30] on wheat and Dolatabadian *et al.* [31] on soybean.

Fresh and dry weights, in the both seasons increased with silicon addition at 200 and 300ppm under all levels of saline condition, compared with the corresponding salinity level without foliar application of Si. But, Si at 100 ppm showed a saline water effect on fresh and dry weights of plants irrigated with 2000 and 2500 ppm. Also, it was observed that, fresh and dry weights improved with 200 and 300 ppm Si under all rates of salinity, compared to plants irrigated with saline water without Si and the heaviest fresh and dry weights were obtained with spraying plants with 300ppm of Si and grown under 2000 ppm salinity in the two seasons.

Table 3: Effect of salinity stress and silicon on oil % and oil yield/plant of French lavender (*Lavandula dentata* L.) plants during 2018 and 2019, seasons.

Treatments	Oil %		Oil yield/plant (ml)	
	2018	2019	2018	2019
Control	0.71	0.72	0.78	0.80
2000 ppm	0.72	0.73	0.83	0.85
2500 ppm	0.65	0.66	0.62	0.63
3000 ppm	0.54	0.56	0.44	0.48
3500 ppm	0.45	0.46	0.33	0.34
2000+100 ppm Si	0.77	0.79	0.98	1.03
2500 +100ppm Si	0.73	0.73	0.88	0.89
3000 +100ppm Si	0.68	0.69	0.56	0.57
3500 +100ppm Si	0.48	0.49	0.35	0.37
2000 +200ppm Si	0.88	0.87	1.16	1.19
2500+200ppm Si	0.84	0.89	1.05	1.15
3000 +200ppm Si	0.82	0.81	1.00	1.00
3500 +200ppm Si	0.69	0.70	0.61	0.57
2000 +300ppm Si	0.98	0.97	1.31	1.34
2500 +300ppm Si	0.95	0.93	1.23	1.22
3000 +300ppm Si	0.90	0.88	1.08	1.11
3500 +300ppm Si	0.51	0.55	0.49	0.54
LSD: at 0.05	0.08	0.09	0.10	0.11

Our results showed that spraying salt stressed plants with Si, greatly improved plant growth; Si application was found to the beneficial treatment in this respect. There are ample evidences that Si plays a favorable role in plant growth under biotic and abiotic stresses. For instance, Tahir *et al.* [30] found that silicon application significantly increased salt treated plant biomass, Supplementation of salt- treated plants with Si ameliorated K+/N+ ratio. Shekari *et al*. [32] on dill plants revealed that improvement in growth of salt stressed plant under the influence of Si may be the improved ion balance, antioxidant enzymes activities and osmotic adjustment.

Volatile Oil Production:

Volatile Oil Percentage: The results in Table 3 revealed that, volatile oil of French lavender plants was affected by saline water stress. It was observed that, increasing the levels of salinity of irrigation water decreased the volatile oil percentage. Also, it was found that increasing salinity level from 2000 to 3500 ppm decreased oil production. So, significant decrease in essential oil percentage from (0.71 and 0.72 %) in control plants to (0.45 and 0.46 %) in plants irrigated with 3500 ppm saline water in the two seasons, respectively. There was harmony between our results and those mentioned by Ashraf *et al.* [33] who showed that, oil content in the seed of medicinal plant *Ammolei majus* L, was decreased consistently with the increase in salt levels.

However, foliar treatments of silicon at 100, 200 and 300 ppm showed a mitigation effect on lavender plants grown under all salt stress. So the highest values of essential oil percentage were obtained when plants treated with silicon at 300 ppm under 2000, 2500 and 3000 ppm of saline water, treatments reaching the values of 0.98, 0.95 and 0.90% in the first season and 0.97, 0.93 and 0.88% in the second one, respectively. These results agreed with Nasim *et al*. [34] showed that, an increase in the salinity level lead to a reduction in essential oil percent and oil yield of peppermint.

Volatile oil yield of plant:

Data in Table 3 indicated that, as previously recorded in volatile oil content, salinity had a harmful effect on volatile oil yield in the two seasons as lavender plants negatively affected in both herb and volatile oil production. Increasing the salinity level gradually from 2000 to 3500 ppm decreased the volatile oil yield compared with untreated plants in the two seasons. Ansari *et al*. [35] compared the performance of three *Cymbopogon* grasses (*C. winterianus, C. flexuosus and C. martini*) at different levels of NaCl salinity, they concluded that salinity resulted in the suppression of plant growth and a decline in essential oil concentration and yield in all species. Also, Bahreininejada *et al.* [36] mentioned that water salinity decreased essential oil yield of *Thymus daenensis*.

Data also indicated that, treating the lavender plants with Si at 100, 200 and 300 ppm had a significant effect on volatile oil yield under 2000, 2500 and 3000 ppm saline water in the two seasons, but the treatments of silicon had a slight effect under 3500 ppm water salinity, compared to control plants. The highest oil yield (1.31 and 1.34ml/plant) were obtained when plants were treated with 300 ppm Si and grown under 2000 ppm saline water, followed by plants treated with 2500 ppm with 300 ppm Si, which produced (1.23 and 1.22m/l) in the two seasons, respectively. These results are in agreement with Shekari *et al*. [32] they found that salt-treated plants and Si had high essential oil content in dill plants.

Chemical Composition of the Essential Oil: The chemical composition of the essential oil of French lavender (*Lavandula dentata* L.) plants using GLC is presented in Table 4. The analysis of analysis showed that volatile oil composition of French lavender plants under the present study conditions showed, seven volatile compounds, which were identified in the fresh herb, were: ∝-Pinene3.30 %, Camphene 6.21 %, 1, 8 Cineole 59.33 %, Linalool 17.17 %, Borneol 2.01 %, Terpinene 4-01 0.63 % and Eugenol 2.28 % in control plant.

Table 4: Chemical composition of essential oil of French lavender *Lavandula dentata* L. plant during second season.

	Compounds %						
Treatments	∝-Pinene	Camphene	1,8 Cineole	Linalool	Borneol	Terpinene 4-01	Eugenol
Control	3.30	6.21	59.33	17.17	2.01	0.63	2.28
2000 ppm	3.35	6.20	60.00	17.27	2.11	0.71	2.23
3500 ppm	4.75	5.55	60.29	18.19	3.00	0.71	2.18
2000+100 ppm Si	4.69	5.20	60.30	18.85	4.90	0.70	2.31
3500 +100ppm Si	3.74	5.00	65.36	19.00	4.92	0.75	2.30
2000 +200ppm Si	2.74	5.30	66.69	19.08	3.40	0.88	1.90
3500 +200ppm Si	2.50	5.41	67.13	19.24	3.50	0.80	1.95
2000 +300ppm Si	2.00	5.50	67.51	20.22	4.80	0.55	1.70
3500 +300ppm Si	1.35	5.67	71.20	21.44	4.82	0.51	1.63

Table 5. Effect of salinity stress and silicon on chemical composition of French lavender (*Lavandula dentata* L.) plants during 2018 and 2019, seasons.

	Total chlorophyll%		Protein %		Proline content (ppm)	
Treatments	2018	2019	2018	2019	2018	2019
Control	35.67	36.12	3.91	3.89	5.02	5.23
2000 ppm	30.11	31.15	3.71	3.72	5.50	5.71
2500 ppm	26.20	27.25	3.55	3.56	6.62	7.12
3000 ppm	21.41	22.30	3.02	3.03	8.01	8.00
3500 ppm	17.35	18.00	2.61	2.59	9.25	9.00
2000+100 ppm Si	33.10	33.90	3.75	3.74	5.40	5.42
2500 +100ppm Si	29.31	30.00	3.64	3.67	6.41	6.60
3000 +100ppm Si	23.15	23.92	3.05	3.05	7.20	7.19
3500 +100ppm Si	17.35	18.50	2.61	2.63	9.10	8.90
2000 +200ppm Si	33.65	34.09	3.82	3.82	5.20	6.19
2500+200ppm Si	29.75	30.45	3.77	3.74	5.70	5.69
3000 +200ppm Si	26.40	27.45	3.31	3.30	6.70	6.43
3500 +200ppm Si	19.65	20.29	2.84	2.85	7.51	7.60
2000 +300ppm Si	34.15	34.96	3.89	3.88	5.07	5.09
2500 +300ppm Si	31.09	32.00	3.76	3.78	5.30	5.29
3000 +300ppm Si	27.33	27.88	3.32	3.36	5.96	6.12
3500 +300ppm Si	21.43	22.29	3.00	2.90	7.92	7.10
LSD: at 0.05	2.50	2.78	0.11	0.10	0.53	0.66

Data in Table (4) indicated that, 1, 8 cineole content was the main compound lavender oil under saline stress, it was 60.00 % with 2000 ppm and 60.29% with 3500 ppm compared with 59.33% in oil of unstressed plant. The cineol content was increased gradually with increasing the rate of Si and the highest value (71.20 %) was obtained with 300 ppm Si under 3500ppm salinity. The same trend was observed in linalool content, the lower percent of linalool was 17.17 % in un-stressed plants and and increased to the highest percent as (21.44 %) with Si at 300ppm under 3500ppm. Also, the lowest percent of Borneol was 2.01% with control and the highest percent was 4, 82% with 300 ppm Si under 3500ppm salinity. These responses of 1, 8 cineol, linalool and borneol contents to stress condition may be indicated that plant tried to alleviated the stress condition by increasing 1, 8 cineole, linalool and borneol. The opposite trend was observed camphene, it was 6.21% in un-stressed and decreased in salinity condition 6.20 % with 2000 ppm salinity and 5.55% with 3500 ppm, it decreased also with Si added at all rates under salinity stress. The major compounds in French lavender were 1, 8-cineole, camphor and fenchone and these compounds together represented more than 80% of the chemical composition of French lavender [37].

Total Chlorophyll: The results in Table 5 revealed that total chlorophyll content in plants irrigated by saline water at all levels was diminished compared with the control. It was plainly seen that, chlorophyll content was found a marked diminished in response to salt treatments. However, the highest chlorophyll content (35.67 and 36.12%) were recorded at untreated plants in the two seasons, respectively and decreased gradually, at 2000, 2500, 3000 and 3500 ppm saline water. Silicon (Si) could recover the leaf chlorophyll content of the plants. So that, the contents of chlorophyll in the plants was increased with the foliar treatment 300ppm Si under all levels of saline condition compared to the same conditions without Si nutrition. Plant growth related to rate of photosynthesis which is directly proportional to chlorophyll contents in leaves. According to results, salinity reduced chlorophyll content however; nutrition of these plants with Si alleviates the adverse effect of salt stress on chlorophyll pigments. These results were in harmony with the findings of Amirjani [38] who found that chlorophyll a and b contents of dill leaves (*Anethum graveolens*) were reduced by salinity stress. The decrease in leaf chlorophyll content under salinity may be due to an increase of chlorophyll degradation or to a decrease of chlorophyll biosynthesis as a result of oxidative stress [39]. The decrease in chlorophyll content under salt stress is a commonly reported phenomenon and it was used as a sensitive indicator of the cellular metabolic state [40]. Silicon can recover the chlorophyll content of dill plants under salinity, which suggests that they play a role in the suppression of oxidative stress. In addition Si has also been shown to improve the chlorophyll content of canola, purslane and barley under salt stress [10, 29, 41].

Protein %: Data in Table 5 showed that, protein content in french lavender leaves under salt stress recorded a significant decrease compared to those plants which irrigated by tap water, while plants treated with Si at 200 and 300 ppm under all levels of salinity contained high protein content than those irrigated by saline water without Si treatments. These findings suggest that the effect of Si on salinity stress might lead to higher synthesis of soluble proteins for osmotic compatibility. Increase in total soluble protein contents due to silicon treatment in wheat [42].

Proline Content: The outcomes recorded in Table 5 indicated that the proline content in lavender herb was extensively influenced by the salinity treatments as well as its blend with silicon. The highest proline contents 9.25 and 9.0 ppm were estimated in stressed plants treated with 3500 ppm against 5.02 and 5.23 ppm plants irrigated by tap water, in the first and the second seasons, respectively. It could be concluded that, proline played an important role in stress mitigation in plants. These results are in agreement with Mansour [43] and Abraham *et al*. [44] they mentioned that proline accumulated in plants subjected to salt stress. Nasim *et al*. [34] showed that, an increase in the salinity lead to increase proline content of peppermint (*Mentha piperita* L.).

As for the effect of Si under saline water stress, the results showed obvious effect on proline content, proline content decreased with increasing Si levels from 100 ppm to 300 ppm under salinity stress, the corresponding salinity levels without Si in both seasons. The results of this study are in line with previous findings which showed that added Si affected proline accumulation in barley plants under salt stress [41]. The accumulation of proline is one of the most frequently reported modifications induced by water and salt stress in plants. Under saline conditions, many plants accumulate proline as a non-toxic and protective osmolyte to maintain osmotic balance [45-47]. Khosravi *et al.* [48] the results demonstrated that increasing of proline due to osmotic slope in plants lead to increasing the tolerance against dehydrations of leave content and acceleration of plant developments in stress conditions. Proline and sucrose are the most commonly solutes that mainly accumulate at saline condition [49].

Recomendation: Our results revealed there were improvements in the vegetative growth, essential oil and the main constituents of French lavender plants under saline irrigation with the foliar application of Si. Using 300 ppm silicon which can be recommended to mitigate the harmful effect of salt stress on French lavender plants.

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