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Effect of Nano-Micronutrients Rate on Growth, Flowering and Chemical Constituents of Lavender (*Lavandula officinalis*, Chaix.) Plant Grown Under Salinity Stress

Osama A. Abdelsadek, Naglaa F. S. I. Elbohy and Randa I. Diab

Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

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ABSTRACT

The current study was carried out during the two consecutive seasons of 2019 and 2020 at the Experimental Farm of EL-Quassasin Horticultural Research Station, Ismailia Governorate, Egypt. a factorial experiment was set up on a randomized complete design with 3 replications was planned to study the influence of different nano-micronutrients rate (0.0, 250, 500 and 1000 ppm) and different soil salinity levels (0.0, 1000, 2000 and 3000 ppm) as well as their interaction treatments on growth parameters, salt resistance index, flowering, volatile oil production as well as total chlorophyll and proline contents in the leaves. Nano- micronutrients named "Magro NanoMix" which contained (Fe at 6%, B at 2%, Zn at 6%, Mn at 5%, Mo at 0.1% and Cu at 1%) were used. The obtained results referred to that lavender growth (plant height, branch number per plant, root and herb fresh and dry weights), flowering characters (spike length, number of inflorescences per plant and number of florests per inflorescence), volatile oil producing (volatile oil percentage and yield per plant) and leaves total chlorophyll were descendingly decreased with increasing soil salinity level comparing with the control means in both seasons, but they were progressively increased as the concentration of nano-micronutrients was increased. Salt resistance index percentage of *Lavandula officinalis* plants enhanced to rich more 100 % under 1000 ppm soil salinity combined with 500 or 1000 ppm of nano-micronutrients compared to the other combination treatments.

Keywords: *Lavandula officinalis*, soil salinity, nano-micronutrients, growth, flowering, chlorophyll

1. Introduction

Lavender (scientifically named *Lavandula officinalis* Chaix.) is an evergreen perennial plant of the mint family (Lamiaceae or Labiatae). It is a substantial multidisciplinary aromatic plant with large utilization in fragrance, pharmaceutical and food industries as well as for aromatic garden design as fill and borders plants. Pharmaceutically, Afsharypuor and Azarbayjany (2006) reported that lavender plant and its elaborations have long been utilized in cold and flu treatment as anti-convulscent, diuretic, sedative digestive and perspiration excitant also for anxiety and sadness treatment. In addition, Upson and Andrews (2004) indicated that lavender plant is a wild plant in the Mediterranean region.

The various effects were noticed from the influence of salinity stress on the qualitative and quantitative traits. For example, it was reported that raising of salinity stress reduced almost all of growth characters in black cumin plant, some growth parameters and volatile oil production in chamomile plant (Razmjoo *et al*., 2008) as well as volatile oil yield in *Melissa officialis* plant (Ozturk *et al*., 2004). Furthermore, Nassar *et al.* (2018) showed that utilizing soil salinity levels decreased guar growth parameters, yield components and total chlorophyll content as well as the active ingredient (guaran content) compared to control.

Micronutrients have important efficiency on development, vegetative and yield stages of several crops such as aromatic and medicinal plants (Heidari *et al*., 2008). Recent studies on nano-particles in

Corresponding Author: Osama A. Abdelsadek, Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

sundry plants has elucidated for ameliorating each of physiological activities, protein content, plant growth and its yield suggesting their potency utilize in crop enhancement (Kole *et al*., 2013). Moreover, researchers showed that utilizeing of nano-fertilizers causes' improvement in nutrients use efficiency (NUE). In this regard, Abdelkader *et al.* (2019) reported that utilizing nano-micronutrients at 500 or 1000 mg/l as a foliar spray had significant influences on vegetative growth, yield and volatile oil production as well as total chlorophyll content of fennel plant compared to control (sprayed with tap water).

Therefore, the main objective of this work was to evaluate the role of nano-micronutrients on counteracting the deleterious influence of soil salinity on growth parameters, flowering characters, salt resistance index percentage and chemical constituents of lavender plant.

2. Materials and Methods

Two experiments on lavender (*Lavandula officinalis* Chaix.) were conducted at Nursery of ornamental plants of El-Qassasin Horticultural Research Station, Agricultural Research Center, Ismailia Governorate, Egypt,were conducted during the two summer consecutive seasons of 2019 and 2020. This work was carried out to assess the impact of soil salinity levels (0.0, 1000, 2000 and 3000 ppm), nano-micronutrients concentrations (0, 0.25, 0.50 and 1.00 g/l) as foliar applications and their interactions on the growth, salt resistance index, flowering and some chemical constituents of lavender plants. These treatments were arranged in a factorial experiment in randomized complete design with 3 replicates. The interaction treatments between soil salinity level and nano-micronutrients concentrations were consisted of sixteen treatments. However, lavender plants were foliar sprayed five times with nano-micronutrients at different concentrations after 35, 50, 65, 70 and 85 days transplanting.

Lavender seedlings were purchased from a private nursery in the Egyptian province of Sharkia's Belbais District. and individualls transplanted in pots of 30 cm diameter filled with soil mixture (weight 6 kg/pot) of clay and sand (1/1, *v/v*) as I plant per pot, on April 12th during both seasons. Table A displays the physical and chemical characteristics of the used soil mixture (Chapman and Pratt, 1978).

Table A: Physical and chemical properties of experimental soil (average of two seasons)

Physical analysis			Soil texture
Clay (%)	**Silt (%)**	**Sand (%)**	**Sandy**
20.83	9.49	69.68	

Chemical analysis

pH	E.C. (dSm^{-1})	Soluble cations (m.mol/l)					Soluble anions (m.mol/l)			Available (ppm)		
		Ca^{++}	Mg^{++}	Na^{+}	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.70	1.23	1.82	0.93	0.33	1.07	1.30	3.02	1.10	0.86	128	43	56

The chemical analysis of salt used in this experiment is shown in Table B. By dissolving the natural salt crust of sea water in a tap water (1, 2 and 3 g/kg soil) and adding the resulting solution to the soil based on its weight, the four artificial soil salinity levels were created. Nano- micronutrients commercially known as "Magro NanoMix" were obtained from Modern Agricide Company (MAC) as a powder. All seedlings of lavender were identical in growth and 10 cm tall. The plot contained about 48 pots. Three plants from each replicate were randomly chosen for measuring growth and root parameters, herb yield as well as total chlorophyll and proline contents. The average value of each trait was calculated from nine plants (three plants from each replicate).

Table B: Chemical analysis of salt.

E.C. (mmhos/cm)	Soluble cations (m.mol/l)				Soluble anions (m.mol/l)			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{--}	SO_4^{--}	Cl^{-}
171.3	9.28	8.54	3000.0	2.80	4.86	0.0	80.76	2935.00

Additionally, all suggested agricultural techniques for cultivating lavender plants were followed as necessary.

2.1. Data recorded
2.1.1. Growth parameters

After 95 days from the date of planting, measurements of plant height (in cm), branch count per plant, and fresh and dry weights of roots per plant (in g) were made. Additionally, after 125 days from the date of planting in the two seasons, fresh and dry herb yield per plant (dried in an oven at 45ºC) were determined.

2.1.2. The salt resistance index

By using the method previously indicated, Abdelkader *et al.,* (2019) on rosemary calculated the salt resistance index percentage (SRI%), which is a useful indicator for salinity tolerance: SRI (%) = average fresh herb yield per plant for plants that were treated with salt / average fresh herb yield per plant for the control plant, multiplied by 100.

2.1.3. Flowering characters

Spike length of inflorescence (cm) was determined from the first to the last florests as well as inflorescences number per plant and number of florests / inflorescence were recorded during May of 2020 and 2021 seasons.

2.1.4. Volatile oil and chemical constituents

In order to extract the volatile oil (%) in accordance with Guenther (1961), the volatile oil yield per plant (ml) was calculated from the fresh herb of lavender plants which determined by hydro distillation for 3 hours. Total chlorophyll in fresh leaf samples of lavender plants were measured after 95 days from transplanting date, total chlorophyll content (SPAD unit) were calculated by SPAD- 502 meter as reported by Markwell *et al.* (1995). Additionally, using the method which described by Bates *et al.* (1973), to measure the free amino acid proline (mg/100 g as dry weight) was estimated in dried lavender leaves throughout both seasons.

2.2. Statistical Analysis

Utilizing a computer program called Statistix Version 9, the data from the current study were statistically analyzed, and the difference between the means of the treatments were determined by (L.S.D.) at the 5% levels. (Analytical Software, 2008).

3. Results and Discussion
3.1. Plant growth parameters

Plant height and number of branches per plant as well as root and herb fresh and dry weights per lavender plant were significantly decreased by all soil salinity levels compared with control (except for branches number in the first season and root dry weight in the second one) during the two seasons (Tables 1, 2 and 3). The number of branches per plant was significantly greater in control plants (27.00 and 26.17), which was closely followed by 1000 ppm (27.00 and 24.67) in the 1st and 2nd seasons, respectively. Furthermore, those characteristics recorded the lowest values by using soil salinity up to 3000 ppm level compared to the other ones under study. Generally, the decreases in herb fresh and dry weights per plant (Table 3) were about (6.65 and 5.13 %) and (9.30 and 11.30 %) for 1000 ppm level of soil salinity compared to control in 1st and 2nd seasons, respectively. The reduction in the plant growth might be due to that salinity inhibits differentiation within the plant and meristimatic activity resulting in less plant height, number of branches per plant and root weights per lavender plant (Sanchesconde and Azura, 1979). The achieved results were in parallel with those found by Nishant and Dheeraj (2014) on *Citronella java*, Khaliq *et al.,* (2014) on sweet basil, Sumand and Varshney (2018) on *Cassia angustifolia* plants.

Table 1: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on plant height and number of branches of *Lavandula officinalis* plant during 2019 and 2020 seasons

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	25	50	100	
	Plant height (cm)				
	2019 season				
Control	39.66	41.55	42.78	46.89	**42.72**
1000	38.11	40.22	40.22	42.66	**40.30**
2000	32.11	33.66	35.89	38.66	**35.08**
3000	30.09	30.89	34.55	34.99	**32.63**
Mean (B)	**34.99**	**36.58**	**38.36**	**40.80**	
L.S.D. at 5 %	**for (A)= 0.64**		**(B)= 0.41**		**(A×B)= 0.95**
	2020 season				
Control	43.78	45.89	50.22	52.22	**48.03**
1000	41.11	41.55	44.11	47.22	**43.50**
2000	30.55	34.44	36.44	41.55	**35.75**
3000	28.77	31.89	35.44	37.22	**33.33**
Mean (A)	**36.05**	**38.44**	**41.55**	**44.55**	
L.S.D. at 5 %	**for (A)= 0.45**		**(B)= 0.53**		**(A×B)= 1.02**
	Number of branches per plant				
	2019 season				
Control	24.33	25.33	27.67	30.67	**27.00**
1000	23.67	25.67	28.33	30.33	**27.00**
2000	17.67	19.33	20.67	22.67	**20.08**
3000	12.33	13.67	15.67	16.67	**14.58**
Mean (A)	**19.50**	**21.00**	**23.08**	**25.08**	
L.S.D. at 5 %	**for (A)=0.62**		**(B)= 0.43**		**(A×B)= 0.97**
	2020 season				
Control	23.00	24.00	26.00	31.67	**26.17**
1000	20.00	22.00	27.33	29.33	**24.67**
2000	18.67	20.67	22.67	24.33	**21.58**
3000	11.33	12.67	13.67	14.67	**13.08**
Mean (A)	**18.25**	**19.83**	**22.42**	**25.00**	
L.S.D. at 5 %	**for (A)= 1.08**		**(B)= 0.67**		**(A×B)= 1.58**

Data recorded in Tables (1, 2 and 3) revealed that, When spraying with nano-micronutrient concentrations, compared to the control, plant height (cm), branch count, and the fresh and dried weights of the roots and herbs per lavender plant all increased significantly. Furthermore, micronutrients at concentration of 100 ppm recorded higher values in lavender growth parameters than the other treatments under study during 2019 and 2020 seasons. These results might be due to the essential role of micronutrients for the development and growth of plants. They were reported in the most reactions within plants and are fundamental for proteins and enzymes for structural, cellular processes and catalytic enzyme activities leading to taller, more branches and heaviest plant (Hall and Williams, 2003). These results are agreement with those found by Hediat (2012) on common bean and corn, Ziedan and Eisa (2016) on dill and El-Metwally *et al.,* (2018) stated that using nano-fertilizers increased plant height, branch count, and dry weight of straw per peanut plant compared to untreated plants.

Table 2: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on fresh and dry weights of roots of *Lavandula officinalis* plant during 2019 and 2020 seasons.

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	**250**	**500**	**1000**	
	Root fresh weight (g)				
	2019 season				
Control	22.40	26.83	28.77	30.73	**27.18**
1000	19.40	21.40	22.13	23.83	**21.69**
2000	18.80	20.13	19.43	19.80	**19.54**
3000	15.53	16.27	17.07	17.50	**16.59**
Mean (B)	**19.03**	**21.16**	**21.85**	**22.97**	
L.S.D. at 5 %	**for (A)= 0.96**		**(B)= 0.69**		**(A×B)= 1.53**
	2020 season				
Control	20.83	22.93	25.33	25.77	**23.72**
1000	20.60	21.93	23.67	24.90	**22.78**
2000	17.87	18.47	20.13	21.63	**19.53**
3000	16.20	17.00	17.83	18.87	**17.48**
Mean (A)	**18.88**	**20.08**	**21.74**	**22.79**	
L.S.D. at 5 %	**for (A)= 0.54**		**(B)= 0.43**		**(A×B)= 0.92**
	Root dry weight (g)				
	2019 season				
Control	9.70	12.33	13.47	14.00	**12.38**
1000	8.97	10.23	11.00	12.60	**10.70**
2000	7.90	8.83	9.20	10.10	**9.01**
3000	5.93	6.70	7.13	8.07	**6.96**
Mean (A)	**8.13**	**9.53**	**10.20**	**11.19**	
L.S.D. at 5 %	**for (A)= 0.58**		**(B)= 0.36**		**(A×B)= 0.85**
	2020 season				
Control	9.53	10.73	11.90	12.23	**11.10**
1000	10.23	10.83	12.37	12.87	**11.58**
2000	7.77	7.97	10.00	10.97	**9.18**
3000	6.40	6.87	8.03	8.40	**7.43**
Mean (A)	**8.48**	**9.10**	**10.58**	**11.12**	
L.S.D. at 5 %	**for (A)= 0.62**		**(B)= 0.29**		**(A×B)= 0.80**

The obtained data in Tables (1, 2 and 3) demonstrate that, under each nano-micronutrient concentration treatment lavender growth parameters were gradually decreased by increasing soil salinity levels during the two consecutive seasons. Moreover, the best interaction treatment in this connection was obtained in plants without salinity stress treatment and the highest nano-micronutrients concentration treatment (100 ppm) compared to the other treatments including control. Likewise, under each soil salinity level plant height, branch number; fresh and dry weights roots and herb of lavender were gradually increased by increasing nano-micronutrient concentration during the two consecutive seasons. Similarly, Mahmoud *et al.* (2020) demonstrated that application of nanoparticles (Zn, B and Si) improved potato growth by alleviating the adverse influence of soil salinity. Generally, all the nano-treatments significantly raised plant height and number of stems per plant as compared to the untreated control.

Table 3: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on fresh and dry weights of herb of *Lavandula officinalis* plant during 2019 and 2020 seasons

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	250	500	1000	
	Herb fresh weight (g)				
	2019 season				
Control	61.97	68.73	70.80	73.37	**68.72**
1000	61.93	63.80	65.03	65.83	**64.15**
2000	53.90	56.10	58.13	59.47	**56.90**
3000	46.80	48.83	49.90	50.87	**49.10**
Mean (B)	**56.15**	**59.37**	**60.97**	**62.38**	
L.S.D. at 5 %	**for (A)= 0.99**		**(B)= 0.72**		**(A×B)= 1.59**
	2020 season				
Control	66.47	67.87	70.23	75.17	**69.93**
1000	60.57	65.30	68.17	70.93	**66.24**
2000	51.97	51.20	56.30	61.10	**55.14**
3000	43.50	45.70	47.77	52.27	**47.31**
Mean (A)	**55.63**	**57.52**	**60.62**	**64.87**	
L.S.D. at 5 %	**for (A)= 1.05**		**(B)= 0.78**		**(A×B)= 1.70**
	Herb dry weight (g)				
	2019 season				
Control	28.73	32.23	34.63	39.07	**33.67**
1000	28.00	30.00	31.67	32.50	**30.54**
2000	25.40	26.07	27.60	29.90	**27.24**
3000	19.83	21.50	21.93	23.07	**21.58**
Mean (A)	**25.49**	**27.45**	**28.96**	**31.13**	
L.S.D. at 5 %	**for (A)= 0.45**		**(B)= 0.61**		**(A×B)= 1.15**
	2020 season				
Control	32.27	32.97	34.60	42.13	**35.49**
1000	28.47	30.90	32.63	33.93	**31.48**
2000	25.27	24.63	28.47	31.47	**27.46**
3000	17.27	19.50	21.17	25.20	**20.78**
Mean (A)	**25.82**	**27.00**	**29.22**	**33.18**	
L.S.D. at 5 %	**for (A)= 0.85**		**(B)= 0.46**		**(A×B)= 1.17**

3.2. Salt resistance index

Data tabulated in Table (4) indicated that, In the first and second seasons, the salt resistance index percentage (SRI%) considerably decreased at soil with all salinity levels compared to control. With a substantial differences between thise treatments and the greatest level of soil salinity (3000 ppm) in the first and second seasons, respectively, the decreases in this connection were about 29.34 and 34.00% for the salinity level at 1000 ppm compared to 300 ppm. Lavender salt resistance index % was significantly increased by increasing nano-micronutrients from 250, 500 to 1000 ppm compared to control in both seasons. mean time, salt resistance index (%) of the plant under study recorded the highest values as a result of the treatments of 1000 and 500 ppm nano-micronutrients combined with the control and the lowest of salinity levels (control and 1000 ppm), in the two seasons. Moreover, Ibrahim *et al.,* (2019) on sweet basil plant obtained a significant decrease in salt resistance index with increasing the levels of salinity.

Table 4: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on salt resistance index (%) of *Lavandula officinalis* plant during 2019 and 2020 seasons.

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	250	500	1000	
			2019 season		
Control	100.00	112.24	120.59	135.98	**117.20**
1000	97.47	104.43	110.27	113.15	**106.33**
2000	88.39	90.78	96.09	104.13	**97.85**
3000	69.07	74.80	76.33	80.34	**75.13**
Mean (B)	**88.73**	**95.56**	**100.82**	**108.40**	
L.S.D. at 5 %	**for (A)= 1.83**		**(B)= 2.16**		**(A×B)= 4.16**
			2020 season		
Control	100.00	102.17	107.24	130.55	**109.99**
1000	88.24	95.78	101.16	105.17	**97.59**
2000	78.32	76.37	88.21	97.55	**85.11**
3000	53.51	60.41	65.59	78.08	**64.40**
Mean (A)	**80.02**	**83.68**	**90.55**	**102.84**	
L.S.D. at 5 %	**for (A)= 2.78**		**(B)= 1.38**		**(A×B)= 3.65**

3.3. Flowering characters

Data of both seasons presented in Table (5) showed that, increasing soil salinity level gradually decreased the spike length as well as the number of inflorescences per lavender plant and number of florests per inflorescence with significant differences among them. However, the highest levels (2000 and 3000 ppm) showed a decrease in this regard compared with the other ones under study. Generally, the decreases in the number of inflorescences per plant were about (10.68 and 14.06 %) for the 1000 ppm level of soil salinity compared to control in 1st and 2nd seasons, respectively.

Similar conclusions were reached by Devitt *et al.* (2005) after measuring the foliar damage and flower production of 19 flowering landscape plants that were sprinkled with reuse water.

From data presented in Table (5), it is clear that, flowering characters of lavender plant were increased with all nano-micronutrients concentration treatments compared with control (without nano-micronutrients application). In addition, the treatment of high concentration of nano-micronutrients (1000 ppm) significantly increased spike length as well as number of inflorescences per plant and number of florests per inflorescence compared with control. Moreover, flowering characters of lavender plant were increased with increasing nano-micronutrients levels. Since, application of nano-ZnO at 1500 ppm on corn plants improved the yield by 42% as compared to control plants (Subbaiah *et al.*, 2016). Also, using Fe_3O_4 nanoparticle enhanced fruit production of roselle plant (Shuhaimi *et al.*, 2019).

Data recorded in Table (5) reveal that, in most cases, spike length as well as number of inflorescences per lavender plant and number of florests per inflorescence were decreased with all interaction treatments between soil salinity levels and nano-micronutrients concentrations compared with control during the first and second seasons. Furthermore, under each treatment of soil salinity lavender flowering characters were increased with increasing nano-micronutrients concentrations. In contrast, under each nano-micronutrients level treatments flowering characters were decreased by increasing soil salinity levels. However, the best interaction treatment in this concern was between lowest level soil salinity and the highest concentration of nano-micronutrients in both seasons. Furthermore, Yermiyahu *et al.* (2007) noticed an antagonistic influence between boron and salinity, as it inhibited the toxicity of NaCl in grapevine rootstock seedlings.

Table 5: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on spike length, number of inflorescences and number of florests per inflorescence of *Lavandula officinalis* plant during 2019 and 2020 seasons.

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	25	50	100	
	Spike length (cm)				
	2019 season				
Control	20.33	22.67	23.33	27.33	**23.42**
1000	18.00	21.67	24.67	25.67	**22.50**
2000	13.33	15.00	16.00	18.33	**15.67**
3000	9.67	10.67	12.33	13.33	**11.50**
Mean (B)	**15.33**	**17.50**	**19.08**	**21.17**	
L.S.D. at 5 %	**for (A)= 1.06**		**(B)= 0.47**		**(A×B)= 1.33**
	2020 season				
Control	21.33	23.67	23.33	26.33	**23.67**
1000	19.33	20.33	23.33	25.00	**22.00**
2000	14.33	16.67	18.33	19.67	**17.25**
3000	8.67	9.67	11.67	13.67	**10.92**
Mean (A)	**15.92**	**17.58**	**19.17**	**21.16**	
L.S.D. at 5 %	**for (A)= 0.60**		**(B)= 0.51**		**(A×B)= 1.06**
	Number of inflorescences per plant				
	2019 season				
Control	26.33	27.33	30.00	34.67	**29.58**
1000	21.33	24.67	29.00	30.67	**26.42**
2000	15.67	18.33	23.33	23.67	**20.25**
3000	8.33	9.33	10.33	11.67	**9.92**
Mean (A)	**17.92**	**19.92**	**23.17**	**25.17**	
L.S.D. at 5 %	**for (A)=0.55**		**(B)= 0.60**		**(A×B)= 1.18**
	2020 season				
Control	26.67	28.33	31.00	32.33	**29.58**
1000	21.33	22.67	27.33	30.33	**25.42**
2000	14.33	18.67	21.33	23.33	**19.42**
3000	7.67	9.33	11.00	12.33	**10.08**
Mean (A)	**17.50**	**19.75**	**22.67**	**24.58**	
L.S.D. at 5 %	**for (A)= 0.44**		**(B)= 0.44**		**(A×B)= 0.88**
	Number of florests per inflorescence				
	2019 season				
Control	55.67	58.33	63.33	67.00	**61.08**
1000	49.00	56.33	64.33	68.33	**59.50**
2000	45.67	50.33	57.33	59.33	**53.17**
3000	27.67	28.33	30.33	33.67	**30.00**
Mean (A)	**44.50**	**48.33**	**53.83**	**57.08**	
L.S.D. at 5 %	**for (A)= 0.45**		**(B)= 0.67**		**(A×B)= 1.24**
	2020 season				
Control	53.67	61.00	65.67	69.33	**62.42**
1000	50.33	54.67	62.33	67.33	**58.67**
2000	47.00	49.67	55.67	57.33	**52.42**
3000	28.33	29.67	31.33	35.33	**31.17**
Mean (A)	**44.83**	**48.75**	**53.75**	**57.33**	
L.S.D. at 5 %	**for (A)= 0.43**		**(B)= 0.70**		**(A×B)= 1.29**

3.4. Volatile oil and chemical constituents

Tables (6 and 7) reveal that, utilizing soil salinity treatments in comparison to control in both seasons resulted in a substantial drop in the volatile oil percentage and yield per plant as well as the total chlorophyll content. On the other hand, compared to control and the others levels under study, using salinity treatments at higher levels (3000 and 4500 ppm) recorded the greatest values in proline content in the two seasons. The soil or water salinity could seriously change the carbon metabolize photosynthetic, photosynthetic efficiency as well as leaf chlorophyll content. When compared to control plants, it was found that the high salinity levels caused a considerable drop in the pigment fractions (chlorophyll a and b) concentration (Seeman and Critchley, 1985 and Sharkey *et al*., 1989). These results are in harmony with those reported by Helaly *et al.* (2018) on rosemary and Shehata and Nosir (2019) on sweet basil.

Table 6: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on volatile oil percentage and volatile oil yield of *Lavandula officinalis* plant during 2019 and 2020 seasons.

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	250	500	1000	
	Volatile oil percentage				
	2019 season				
Control	0.433	0.457	0.483	0.503	**0.469**
1000	0.427	0.440	0.453	0.483	**0.451**
2000	0.373	0.403	0.423	0.417	**0.404**
3000	0.387	0.397	0.413	0.407	**0.401**
Mean (B)	**0.405**	**0.424**	**0.443**	**0.452**	
L.S.D. at 5 %	**for (A)=0.009**		**(B)=0.007**		**(A×B)=0.015**
	2020 season				
Control	0.470	0.407	0.523	0.547	**0.512**
1000	0.443	0.473	0.503	0.507	**0.482**
2000	0.403	0.420	0.447	0.453	**0.431**
3000	0.383	0.397	0.437	0.427	**0.411**
Mean (A)	**0.425**	**0.449**	**0.478**	**0.483**	
L.S.D. at 5 %	**for (A)=0.010**		**(B)=0.009**		**(A×B)=0.019**
	Volatile oil yield per plant (ml)				
	2019 season				
Control	0.267	0.313	0.343	0.370	**0.323**
1000	0.267	0.283	0.297	0.317	**0.291**
2000	0.200	0.227	0.247	0.247	**0.230**
3000	0.180	0.193	0.207	0.207	**0.197**
Mean (A)	**0.228**	**0.254**	**0.273**	**0.285**	
L.S.D. at 5 %	**for (A)= 0.009**		**(B)= 0.006**		**(A×B)= 0.014**
	2020 season				
Control	0.310	0.343	0.370	0.410	**0.358**
1000	0.270	0.310	0.340	0.363	**0.321**
2000	0.210	0.213	0.250	0.277	**0.238**
3000	0.167	0.183	0.210	0.223	**0.196**
Mean (A)	**0.239**	**0.263**	**0.293**	**0.318**	
L.S.D. at 5 %	**for (A)= 0.008**		**(B)= 0.008**		**(A×B)= 0.016**

Data in Tables (6 and 7) reveal that, in most cases volatile oil producing, total chlorophyll content and proline content were significantly increased with increasing nano-micronutrients spraying compared to control. In addition, nano-micronutrients at 500 or 1000 ppm recorded higher values in this regard compared with the other treatments under study during both seasons. However, micronutrients application increased the photosynthetic activity and representation of nucleic acids and chloroplasts which ultimately resulted in improving the growth and yield (Nikolic and Kastori, 2000 and Chanchan, *et al*., 2013). These results are in line with those stated by Rezaei-Chiyaneh *et al.* (2018) on black cumin and Sabet and Mortazaeinezhad (2018) on cumin plants.

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Table 7: Effect of soil salinity levels and nano-micronutrients concentrations as well as their combinations on total chlorophyll content and proline content of *Lavandula officinalis* plant during 2019 and 2020 seasons.

Soil salinity (ppm)	Nano-micronutrients concentrations (ppm)				Mean (A)
	Control	250	500	1000	
	Total chlorophyll content (SPAD)				
	2019 season				
Control	43.90	45.57	45.47	45.77	**45.18**
1000	42.13	42.63	43.43	44.23	**43.11**
2000	41.50	41.73	42.53	43.00	**42.19**
3000	40.23	41.23	41.70	42.17	**41.33**
Mean (B)	**41.94**	**42.79**	**43.28**	**43.79**	
L.S.D. at 5 %	**for (A)= 0.34**		**(B)= 0.28**		**(A×B)= 0.58**
	2020 season				
Control	42.60	44.70	46.07	46.23	**44.90**
1000	40.23	41.67	44.17	43.77	**42.46**
2000	40.20	41.13	43.50	43.13	**41.99**
3000	40.23	41.27	41.77	42.30	**41.39**
Mean (A)	**40.82**	**42.19**	**43.88**	**43.86**	
L.S.D. at 5 %	**for (A)= 0.52**		**(B)= 0.29**		**(A×B)= 0.72**
	Proline content (mg/g as dry weight)				
	2019 season				
Control	4.20	4.33	4.60	4.70	**4.46**
1000	4.70	5.07	5.37	5.87	**5.25**
2000	4.80	5.63	6.03	6.33	**5.70**
3000	5.47	6.27	6.63	6.77	**6.28**
Mean (A)	**4.79**	**5.33**	**5.66**	**5.92**	
L.S.D. at 5 %	**for (A)= 0.24**		**(B)= 0.19**		**(A×B)= 0.41**
	2020 season				
Control	4.47	4.60	4.63	4.73	**4.61**
1000	4.77	5.40	5.63	6.00	**5.45**
2000	5.47	5.63	6.10	6.80	**6.00**
3000	5.80	6.33	6.87	7.40	**6.60**
Mean (A)	**5.13**	**5.49**	**5.81**	**6.23**	
L.S.D. at 5 %	**for (A)= 0.25**		**(B)= 0.31**		**(A×B)= 0.59**

Data listed in Tables (6 and 7) pointed out that, in comparison to those of salinity alone (2000 and 3000 ppm) or those of the other ones of combination between nano-micronutrients and salinity in the first and second seasons, the treatment of nano-micronutrients to those of salinity at control and 1000 ppm were increased the volatile oil percentage and yield per plant as well as the total chlorophyll content in fresh lavender leaves. On the other hand, the treatment of nano-micronutrients at 1000 ppm interacted with those of soil salinity at 3000 ppm to produce the highest values of proline content in comparison to those of salinity alone or those of the other interactions between nano-micronutrients and salinity in both seasons. Similar results were found by Mahmoud *et al.* (2020) on potato plants.

4. Conclusion

It is preferable to foliar spray lavender plants with nano-micronutrients at 1000 ppm five times /season under moderate soil salt stress (1000 ppm) to improve the growth parameters, flowering characters and total chlorophyll content of *Lavandula officinalis*, Chaix plant.

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