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INFLUENCE OF CHITOSAN AND MICRONUTRIENTS (FE + ZN) CONCENTRATIONS ON GROWTH, YIELD COMPONENTS AND VOLATILE OIL OF LAVENDER PLANT

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ABSTRACT: To study the influence of the two factors of chitosan concentration (0.0, 100, 200 and 400 ppm), micronutrients as $FeSO_4$ + $ZnSO_4$ (0.0, 50, 100 and 200 ppm) and their combination treatments on plant growth, yield components, volatile oil production, total carbohydrates % and total chlorophyll content (SPAD unit), two filed experiments were conducted on lavender (*Lavandula officinalis*, Chaix.) during the two summer consecutive seasons of 2018 and 2019 at Agric. Res. Farm, Fac. Agric., Zagazig Univ., Egypt. The Experimental layout was split-plot design between the four chitosan concentrations as main plots and the four micronutrients concentration as sub-plots in randomized complete blocks design with 3 replicates. The obtained results referred to that using chitosan concentration of 400 ppm significantly increased growth parameters (plant height, number of branches/plant, fresh and dry weights of roots/plant as well as root number and length), yield components (total dry herb yield/plant and /feddan), volatile oil production (volatile oil percentage and volatile oil yield per plant) and chemical constituents (total chlorophyll content and total carbohydrates percentage) compared to control and the other levels under study. Furthermore, the highest values in these characters were noticed by micronutrients at 200 ppm treatment in both seasons, in most cases. In general, it is preferable to spray lavender plants with chitosan at 400 ppm combined with Fe + Zn at 200 ppm five times a season to increase the plant growth, yield components and plant pigments as well as volatile oil production of this important aromatic plant.

Key words: Lavender, chitosan, Fe, Zn, growth, root, yield, volatile oil, total chlorophyll.

INTRODUCTION

Lavender (*Lavandula officinalis*, Chaix), belongs to family Labiatae (Hassanpouraghdam *et al*., 2011). However, lavender is utilized as ornamental plant in private and public gardens in order to its beautiful foliage and flowers (Lawless, 1995). It is preferable recognized for its flowers which contain essential oil which is utilized medicinally, in perfumes, salves, balms, cosmetics. Lavender essential oil has analgesic, antifungal, anti-inflammatory, antiseptic and bactericidal properties for it is load terpenes [Worwood, 1991; Schnaubelt, 1998 and Yusufoglu *et al*., 2004]. Lavender is extremely utilized as relaxation and an aid to sleep. Extract of lavender is claimed to heal acne, it is also utilized in therapy of inflammatory and skin burns conditions.

Chitosan is considered as a low toxic, biodegradable and assess efficient substance created by deacetylation process of chitin (Iriti *et al*., 2009), utilized in several agricultural production and medicine industries (Pichyangkura and Chadchawan, 2015). Moreover, chitosan may act as an exogenous elicitor to enhance plant protection (Pirbalouti *et al*., 2017). Different planning has been investigated to find the eco-friendly solutions for enhancing crop growth and productivity among which chitosan is a suitable candidate, taking into account sustainable agriculture (Malerba and Cerana, 2018 and Maluin and Hussein,2020).

Iron (Fe) and zinc (Zn) as micronutrients ordinarily added as foliar fertilizers so as to compensate their shortage essentially in arid and semi-arid regions (Kaya *et al*., 2005). Micronutrients, especially iron and Zinc, act either as mineral ingredient of several enzymes or as regulatory cofactors, functional and structural. Consequently, they are correlating with protein synthesis, saccharides metabolism or photosynthesis (Marschner, 1995). In addition, Soliman *et al*. (2018) found that micronutrients of Fe + Zn + Mo at 0.50 + 0.30 + 3 g/l, respectively as foliar spray increased growth, yield components and active ingredients of *Stevia rebaudiana* compared to control (sprayed with tap water).

The current study was executed with the target of evaluating the influences of foliar application of chitosan and Fe+ Zn as well as their interactions on the growth and productivity of lavender plants and illustrating the involved mechanisms in this important plant.

MATERIALS AND METHODS

This study was conducted during the two consecutive summer seasons of 2018 and 2019 at the Agric. Res. Farm, Fac. Agric., Zagazig Univ., Egypt. This work was carried out to examine the influence of chitosan concentrations (0.0, 100, 200 and 400 ppm), micronutrients concentrations [control (sprayed with tap water), 50, 100 and 200 ppm of ($FeSO_4$ + $ZnSO_4$)] as foliar applications and their interaction treatments on lavender growth, yield, volatile oil, total carbohydrates percentage and total chlorophyll content. Table (1) showed some physical and chemical analysis of the experimental soil at a depth of 0-30 cm according to Chapman and Pratt (1978). The current experiment was set up in a split-plot design with 3 replicates. The main plots were occupied by four chitosan concentrations. The sub plots were entitled to four micronutrients concentrations. The combination treatments between main plot and sub plot were 16 treatments.

However, lavender plants were sprayed with chitosan and micronutrients concentrations five times at 30, 45, 60, 75 and 90 days after planting date. The source of chitosan ($C_{56}H_{103}N_9O_{39}$) was Modern Agricide Company (New Cairo, Cairo, Egypt) as solution (96.40%) as well as the source of $FeSO_4$ and $ZnSO_4$ was El-Gomhoria Chemical Company, Egypt.

The plot area was 14.40 m^2 (4.00 × 3.60 m) included six ridges. Each ridge was 60 cm wide and four meters length. The distance between lavender plants in the ridge was 40 cm, under surface irrigation system. Private nursery in Belbas District, Sharkia Governorate, Egypt was the source of lavender seedlings. All seedlings were similar in growth and 10 cm in length. Seedlings were planted in the experimental

Table 1. Some physical and chemical analyses of the experimental soil (average of the two seasons).

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	
41.33	19.24	15.68	23.75	Clayey

Chemical analysis													
pH	EC mmohs/cm	Organic mater (%)	Soluble cations (meq/l)				Soluble anions (meq/l)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^+	Na^+	Cl^-	HCO_3^-	SO_4^{--}	N	P	K
7.79	0.99	0.61	2.8	1.7	1.6	3.8	4.5	1.8	3.6	28	11	82

plots on 8th April and 12th April during the 2018 and 2019 seasons, respectively.

All the recommended agricultural practices of planted lavender were done when ever needed. All treatments were fertilized with single calcium superphosphate (15.5 % P_2O_5) at 200 kg, potassium sulphate (48 % K_2O) at 100 kg and ammonium nitrate (33 % N) at 150 kg per feddan. Phosphorus and potassium fertilizers were applied during soil preparation, while, nitrogen fertilizer was divided into three equal doses and were added to the soil at 35, 60 and 85 days after planting date.

Data recorded:

After 155 days from transplanting, three lavender plants were randomly chosen from each plot to determine the following parameters:

1. Plant growth: plant height (cm), number of branches/plant, fresh and dry weights of roots/plant (g), root number/plant and root length (cm) for the longest root were recorded.
2. Dry herb yield: dry herb yield per plant (g) and per faddan (kg) were calculated.
3. Volatile oil production: the volatile oil from lavender leaves air-dried was isolated by hydro distillated for 3 hr. to extract the volatile oil as described by Guenther (1961) and the volatile oil yield per plant (ml) was calculated.
4. Chemical constituents: at harvest time, total chlorophyll content (SPAD unit) was determined in lavender fresh leaves by utilizing SPAD-502 meter (Markwell *et al*., 1995). Also, total carbohydrate percentage in lavender leaves was determined according to the method reported by Dubois *et al*. (1956).

Statistical Analysis:

Collected data were analyzed as presented by Gomez and Gomez (1984). Least significance difference (L.S.D.) was utilized to differentiate means at the at 5% level of probability. The means were compared utilizing computer program of Statistix version 9 (Analytical software, 2008).

RESULTS AND DISCUSSION

Plant growth parameters:

Data of both seasons presented in Tables (2, 3 and 4) show that plant height (cm), branch number per plant, roots fresh and dry weights per plant (g) as well as root number per plant and root length (cm) of lavender (*Lavandula officinalis*, Chaix) were increased by using chitosan concentrations compared to control during both seasons. This increase was significant in the first and second seasons. Mostly, the highest values in this concern were achieved by 400 ppm concentration compared to the other ones under study. Similar positive influences of chitosan application were noticed in basil cultivation, in which a significant plant development and growth (Malekpoor *et al*., 2016) as well as in case of *Stevia rebaudiana* where chitosan influenced significantly on dry and fresh weights of stem, leaves and roots per plant (Mehregan *et al*., 2017).

The results tabulated in Tables 2, 3 and 4 indicate that lavender plants sprayed five times/season with Fe + Zn at any concentration recorded the highest values of plant height, number of branches per plant, root fresh and dry weights per plant, root number per plant and root length with significant differences between chitosan concentrations and control in both seasons. Meantime, the best treatment for increasing lavender growth parameters was that 400 ppm compared to the other foliar concentrations in the two tested seasons. Similar results were demonstrated by Zehtab-Salmasi *et al.* (2008) on peppermint, Ziedan and Eisa (2016) on dill and Mehrab (2017) on lemon balm plants.

The influence of chitosan interacted with micronutrients concentrations on lavender growth parameters during 2018 and 2019 seasons were tabulated in Tables 2, 3 and 4. Since, the highest values in this concern were obtained by the interaction treatment of

Table 2. Influence of chitosan (C) and micronutrients concentration (M) as well as their interaction (C×M) treatments on plant height and number of branches/plant of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm) Control	50	100	200	Mean (C)
			Plant height (cm)		
			2018 season		
Control	33.33	34.44	34.89	35.22	34.47
100	34.78	39.78	41.44	42.67	39.67
200	38.78	41.44	42.56	43.78	41.64
400	38.44	40.89	43.55	45.11	42.00
Mean (M)	36.33	39.14	40.61	41.69	
L.S.D. at 5%	For (C) = 0.53		For (M) = 0.66		For (C×M) = 1.26
			2019 season		
Control	34.67	35.33	35.55	36.22	35.44
100	35.78	37.00	38.11	43.67	38.64
200	36.56	40.11	43.44	45.22	41.33
400	40.44	42.89	45.44	47.44	44.05
Mean (M)	36.86	38.83	40.64	43.14	
L.S.D. at 5%	For (C) = 0.26		For (M) = 0.56		For (C×M) = 1.00
			Number of branches/plant		
			2018 season		
Control	23.22	23.78	25.11	25.34	24.36
100	23.22	24.67	26.66	27.56	25.53
200	24.89	26.55	28.00	30.11	27.39
400	26.89	27.33	28.45	31.78	28.61
Mean (M)	24.56	25.58	27.06	28.70	
L.S.D. at 5%	For (C) = 0.33		For (M) = 0.40		For (C×M) = 0.77
			2019 season		
Control	21.44	23.56	23.89	26.33	23.81
100	22.00	23.22	25.78	27.00	24.50
200	23.78	24.89	27.44	28.89	26.25
400	26.00	28.55	30.56	33.00	29.53
Mean (M)	23.31	25.05	26.92	28.81	
L.S.D. at 5%	For (C)= 0.70		For (M)= 0.50		For (C×M)= 1.11

Table 3. Influence of chitosan (C) and micronutrients concentrations (M) as well as their interaction (C×M) treatments on fresh and dry weights of roots/plant (g) of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm)				Mean (C)
	Control	50	100	200	
			Fresh weight of roots/plant (g)		
			2018 season		
Control	18.79	19.34	20.29	20.72	19.78
100	19.29	20.26	21.01	22.00	20.64
200	20.35	22.29	24.09	27.00	23.43
400	20.90	23.40	24.42	27.15	23.97
Mean (M)	19.83	21.32	22.45	24.22	
L.S.D. at 5%	For (C) = 0.40		For (M) = 0.36		For (C×M) = 0.73
			2019 season		
Control	18.92	19.78	20.83	21.35	20.22
100	19.58	21.22	21.92	23.12	21.46
200	19.78	21.74	23.29	25.93	22.68
400	20.27	22.32	23.99	26.21	23.20
Mean (M)	19.64	21.26	22.51	24.15	
L.S.D. at 5%	For (C) = 0.37		For (M) = 0.43		For (C×M) = 0.82
			Dry weight of roots/plant (g)		
			2018 season		
Control	8.36	8.70	9.18	9.07	8.83
100	8.72	8.93	9.09	9.18	8.98
200	9.23	9.98	11.00	11.25	10.37
400	9.24	9.68	11.02	11.70	10.41
Mean (M)	8.89	9.32	10.07	10.30	
L.S.D. at 5%	For (C) = 0.25		For (M)= 0.14		For (C×M) = 0.35
			2019 season		
Control	8.45	8.94	9.13	9.28	8.95
100	8.93	9.19	9.54	9.75	9.35
200	8.98	9.84	10.82	11.07	10.18
400	9.37	10.11	11.12	11.16	10.44
Mean (M)	8.93	9.52	10.15	10.32	
L.S.D. at 5%	For (C) = 0.28		For (M) = 0.15		For (C×M) = 0.37

Table 4. Influence of chitosan (C) and micronutrients concentrations (M) as well as their interaction (C×M) treatments on root number/plant and root length (cm) of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm)				Mean (C)
	Control	50	100	200	
			Root number/plant		
			2018 season		
Control	17.11	18.11	18.11	18.44	17.94
100	18.55	20.33	22.11	23.55	21.14
200	18.55	20.33	22.11	23.55	21.14
400	19.56	21.11	23.00	24.22	21.97
Mean (M)	18.44	19.97	21.33	22.44	
L.S.D. at 5%	For (C) = 0.32		For (M) = 0.38		For (C×M) = 0.73
			2019 season		
Control	17.78	18.33	18.78	19.00	18.47
100	18.67	19.11	20.11	21.44	19.83
200	20.11	19.11	19.89	21.44	20.14
400	20.78	21.22	22.11	23.78	21.97
Mean (M)	19.33	19.44	20.22	21.42	
L.S.D. at 5%	For (C) = 0.55		For (M) = 0.60		For (C×M) = 1.18
			Root length (cm)		
			2018 season		
Control	16.44	17.22	17.78	18.89	17.58
100	18.11	18.44	19.34	20.67	19.13
200	20.11	20.44	21.33	23.55	21.36
400	21.22	23.22	22.78	24.89	23.03
Mean (M)	18.97	19.83	20.31	22.00	
L.S.D. at 5%	For (C) = 0.38		For (M) = 0.37		For (C×M) = 0.74
			2019 season		
Control	17.00	19.11	20.11	20.78	19.25
100	18.00	18.78	22.67	25.33	21.19
200	19.22	21.89	23.22	26.11	22.61
400	20.22	22.45	23.78	26.44	23.22
Mean (M)	18.61	20.56	22.44	24.67	
L.S.D. at 5%	For (C) = 0.41		For (M) = 0.45		For (C×M) = 0.88

400 ppm of chitosan and the application of micronutrients at 200 ppm compared to the other ones under study in the 1st and 2nd seasons. The positive influences of these treatments (chitosan, micronutrients and their interactions) may be due to the important physiological role of chitosan in marjoram plants (El-Khateeb *et al*., 2017), also, iron and zinc are found in the most reactions and are fundamental for cellular processes and catalytic enzyme activities and in proteins and enzymes for structural tissues (Hall and Williams, 2003) that lead to taller, more branches and heaviest roots per lavender plant.

Herb dry yield components:

Data listed in Table (5) reveal that the concentration of chitosan at 400 ppm recorded the highest values of total herb yield/plant (g) and total dry herb yield/feddan (kg) compared to non-applied plants (control) during the two consecutive seasons. Moreover, the abovementioned yield components showed gradual significant increases with increasing chitosan concentrations from 100 to 400 ppm in both seasons. El-Gamal and Ahmed (2016) on coriander has been obtained similar results. In addition, Al-Tawaha *et al.* (2020) indicate that chitosan may be useful in the cultivation of barley, due to its positive and at the same time significant influence on growth and yielding of this plant. However, the highest number of grains yield, grains/spike and number of spikes were noticed by the foliar treatment of 10 g/l chitosan at the tillering stage. These influences were observed with significant increase in lavender yield components under study in both seasons.

Data given in Table 5 demonstrate that, foliar spraying of micronutrients (Fe + Zn) significantly increased lavender herb yield per plant and per feddan compared with control in both seasons. The maximum mean values of total herb yield/plant and total dry herb yield /feddan under study were recorded with applying 200 ppm of both Fe and Zn in the two tested seasons. These results are in accordance with those found by Salamatbakhsh *et al*. (2012) on castor bean, Yadegari (2015) on borago, thyme and marigold and Abd-Elkader (2016) on garlic.

Lavender herb yield/plant (g) and /feddan (kg) were significantly affected by chitosan concentration and spraying with micronutrient. In most cases, the interaction between different chitosan and micronutrient concentrations gave higher yield components values compared with control treatment. The highest values in this regard were obtained with the treatment of 400 ppm chitosan + 200 ppm micronutrients (Table, 5). Generally, as mentioned above, both micronutrients levels and chitosan concentrations (each alone) increased herb dry yield of lavender plant, in turn; they together might maximize their effects leading to more yielding for plant and feddan. However, the application of Zn and/or chitosan led to increases in shoot fresh mass of tomato plants, about 31%, over control (Salimi *et al*., 2019).

Volatile oil production, chlorophyll and total carbohydrates:

Data recorded in Tables 6 and 7 suggest that, all chitosan concentration treatments increased volatile oil percentage and volatile oil yield per plant (ml) as well as total chlorophyll content (SPAD) and total carbohydrates percentage compared with control. Moreover, lavender volatile oil production and chemical constituents were gradually increased with increasing chitosan concentration. Since, the maximum increase in this respect was obtained from the treatment of high concentration of chitosan (400 ppm) compared with the other ones under study. These results agreed with those stated by Malekpoor *et al*. (2016) on basil, El-Khateeb *et al*. (2017) on marjoram, Byczyńska (2018) on pineapple lily and Abdul-Qader and Rabie (2019) on stevia plants.

Tables (6 and 7) indicate that, increasing micronutrients concentration gradually increased volatile oil production as well as total chlorophyll and total carbohydrates

Table 5. Influence of chitosan (C) and micronutrients concentrations (M) as well as their interaction (C×M) treatments on total dry herb/plant (g) and /feddan (kg) of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm)				Mean (C)
	Control	50	100	200	
			Total dry herb/plant (g)		
			2018 season		
Control	45.53	46.00	46.69	48.03	46.52
100	45.79	47.50	48.06	50.02	47.84
200	47.20	50.37	53.63	56.35	51.89
400	49.92	50.77	56.00	57.98	53.67
Mean (M)	47.07	48.66	51.09	53.09	
L.S.D. at 5%	For (C) = 0.45		For (M) = 0.57	For (C×M) = 1.08	
			2019 season		
Control	42.53	45.31	48.41	50.03	46.57
100	44.68	48.94	50.27	51.96	48.96
200	46.16	50.97	51.97	56.09	51.30
400	47.27	52.71	57.28	58.78	54.01
Mean (M)	45.16	49.48	51.98	54.22	
L.S.D. at 5%	For (C) = 0.74		For (M) = 0.51	For (C×M) = 1.14	
			Total dry herb/feddan (kg)		
			2018 season		
Control	793.70	805.00	817.10	840.50	814.07
100	801.30	831.20	841.00	875.30	837.19
200	826.00	881.50	938.50	986.10	908.00
400	873.70	888.50	980.00	1014.70	939.23
Mean (M)	823.65	851.55	894.13	939.23	
L.S.D. at 5%	For (C) = 7.84		For (M) = 9.90	For (C×M) = 8.82	
			2019 season		
Control	744.20	793.00	847.20	875.60	815.00
100	782.00	856.50	879.80	909.20	856.88
200	807.80	892.00	909.40	981.60	897.72
400	827.30	922.40	1002.50	1028.60	945.18
Mean (M)	790.32	865.97	909.72	948.76	
L.S.D. at 5%	For (C) = 12.91		For (M) = 8.88	For (C×M) = 20.02	

Table 6. Influence of chitosan (C) and micronutrients concentrations (M) as well as their interaction (C×M) treatments on volatile oil percentage and volatile oil yield/plant (ml) of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm) Control	50	100	200	Mean (C)
			Volatile oil (%)		
			2018 season		
Control	0.592	0.602	0.628	0.634	0.614
100	0.602	0.627	0.641	0.657	0.632
200	0.622	0.634	0.662	0.680	0.649
400	0.634	0.648	0.672	0.688	0.661
Mean (M)	0.612	0.628	0.651	0.665	
L.S.D. at 5%	For (C) = 0.004		For (M) = 0.003	For (C×M) = 0.007	
			2019 season		
Control	0.536	0.573	0.588	0.595	0.573
100	0.553	0.590	0.605	0.624	0.593
200	0.580	0.593	0.619	0.636	0.607
400	0.586	0.601	0.632	0.651	0.618
Mean (M)	0.564	0.589	0.611	0.627	
L.S.D. at 5%	For (C) = 0.005		For (M) = 0.007	For (C×M) = 0.013	
			Volatile oil yield/plant (ml)		
			2018 season		
Control	0.268	0.277	0.293	0.305	0.286
100	0.276	0.298	0.308	0.328	0.303
200	0.293	0.319	0.355	0.383	0.338
400	0.316	0.329	0.76	0.399	0.355
Mean (M)	0.288	0.306	0.333	0.354	
L.S.D. at 5%	For (C) = 0.005		For (M) = 0.004	For (C×M) = 0.008	
			2019 season		
Control	0.228	0.260	0.285	0.298	0.267
100	0.247	0.289	0.305	0.324	0.291
200	0.268	0.303	0.322	0.357	0.312
400	0.277	0.317	0.362	0.382	0.335
Mean (M)	0.255	0.292	0.318	0.340	
L.S.D. at 5%	For (C) = 0.006		For (M) = 0.004	For (C×M) = 0.009	

Table 7. Influence of chitosan (C) and micronutrients concentrations (M) as well as their interaction (C×M) treatments on total chlorophyll content (SPAD) and total carbohydrates percentage of lavender plant during the two seasons of 2018 and 2019.

Chitosan concentration (ppm)	Micronutrients concentration (ppm) Control	50	100	200	Mean (C)
		Total chlorophyll content (SPAD)			
		2018 season			
Control	46.11	46.44	47.11	47.89	46.89
100	46.22	47.11	48.00	48.22	47.39
200	47.11	48.66	50.55	52.78	49.78
400	50.22	52.11	53.67	54.89	52.72
Mean (M)	47.42	48.58	49.83	50.94	
L.S.D. at 5%	For (C) = 0.51		For (M) = 0.33		For (C×M) = 0.77
		2019 season			
Control	45.11	45.56	46.44	48.33	46.36
100	45.78	46.89	48.11	48.22	47.25
200	46.89	47.67	49.33	50.00	48.47
400	49.44	51.89	53.11	53.78	52.06
Mean (M)	46.81	48.00	49.25	50.08	
L.S.D. at 5%	For (C) = 0.40		For (M) = 0.75		For (C×M) = 1.35
		Total carbohydrates percentage			
		2018 season			
Control	14.57	14.67	14.83	15.04	14.78
100	14.88	14.93	15.29	15.53	15.16
200	15.52	15.98	16.86	17.49	16.46
400	16.19	16.74	17.07	17.63	16.91
Mean (M)	15.29	15.58	16.01	16.43	
L.S.D. at 5%	For (C) = 0.22		For (M) = 0.20		For (C×M) = 0.41
		2019 season			
Control	15.02	15.32	15.38	15.48	15.30
100	15.30	15.53	15.68	15.73	15.56
200	15.63	16.87	18.06	18.06	17.15
400	16.07	17.18	18.09	18.40	17.44
Mean (M)	15.51	16.22	16.80	16.92	
L.S.D. at 5%	For (C) = 0.32		For (M) = 0.19		For (C×M) = 0.46

percentage of lavender plant in both seasons. Generally, lavender volatile oil production and chemical constituents were significantly increased with application of the three concentrations of micronutrient treatments ($FeSO_4$+ $ZnSO_4$ at 50, 100 and 200 ppm, respectively) compared to untreated plants (control). Moreover, $FeSO_4$ + $ZnSO_4$ at 200 ppm recorded higher increase in this connection compared with the other two ones under study. The improved vegetative growth of lavender plant and yield attributing parameters due to iron and zinc application has also direct relation in improvement of growth development and increase in volatile oil production of dill (Mirshekari and Siyami, 2014). Similar results were stated by Nasiri and Najafi (2015) on chamomile and Amini *et al.* (2018) on hyssop plants.

Results under discussion in Table 9 indicate that, under each treatment of chitosan concentration volatile oil production as well as total chlorophyll and total carbohydrates percentage of lavender were increased with increasing micronutrients (Fe+ Zn) concentration. Generally, volatile oil production and chemical constituents were significantly increased with all interaction treatments between chitosan and micronutrients concentrations compared with control in both seasons. Similarly, under each micronutrient concentration treatment these parameters were increased by increasing chitosan concentration. In the same time, the interaction treatment between the highest concentration of chitosan and high rate of micronutrients was superior in increasing volatile oil production and pigments compared to the other ones under study in the first and second seasons. However, it is now clear that using of high concentration of micronutrients interacted with high concentration of chitosan gave the highest values of volatile oil production and chemical constituents of lavender. This might be attributed to three factors. First, the role of chitosan at this rate in promoting photosynthesis and assimilates accumulation and consequently more increase in branch number and weight which reflected in volatile oil production. Second, micronutrients may improve ability of the lavender plant to absorb nutrients, photosynthesis and better sink source relationship as these play vital role in various biochemical processes. Third, the low intra-competition between lavender plants on available micronutrients and polysaccharides.

CONCLUSION

From the above mentioned results, it is preferable to spray *Lavandula officinalis*, plants with chitosan at 400 ppm five times a season with high micronutrients concentration ($FeSO_4$ + $ZnSO_4$ each at 200 ppm) to enhance the growth, yield components as well as volatile oil production and total chlorophyll content of lavender plant under Sharkia Governorate conditions.

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تأثير تركيزات الشيتوزان والعناصر الصغرى (الحديد + الزنك) على نمو والمكونات المحصولية والزيت العطري لنبات اللافندر

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أجريت تجربتان حقليتان على نبات اللافندر خلال موسمي الصيف المتتاليين لأعوام ٢٠١٨ و٢٠١٩ بالمزرعة التجريبية لكلية الزراعة، جامعة الزقازيق، مصر وذلك لدراسة تأثير عاملي تركيز الشيتوزان (صفر، ١٠٠ ، ٢٠٠ و ٤٠٠ جزء في المليون)، العناصر الصغرى في صورة كبريتات الحديد وكبريتات الزنك (صفر، ٥٠، ١٠٠ و ٢٠٠ جزء في المليون) ومعاملات التفاعل بينهما على نمو النبات، ومكونات المحصول، وإنتاج الزيت العطري، النسبة المئوية للكربوهيدرات الكلية ومحتوى الكلوروفيل الكلي. صممت التجربة كتجربة (٤×٤) في تصميم القطعة المنشقة مرة واحدة بين تركيزات الشيتوزان الأربعة في القطع الرئيسية وتركيزات العناصر الصغرى الأربعة في القطع الفرعية في تصميم قطاعات كاملة العشوائية في ثلاث مكررات. أشارت النتائج المتحصل عليها إلى أن استخدام تركيز الكيتوزان ٤٠٠ جزء في المليون أدى إلى زيادة معنوية في صفات النمو (طول النبات، عدد الأفرع/النبات، الأوزان الطازجة والجافة للجذور/ النبات وكذلك عدد الجذر والطول)، ومكونات المحصول (إجمالي محصول الأعشاب الجافة/نبات و/فدان)، إنتاج الزيت العطري (نسبة الزيت العطري المئوية ومحصول الزيت العطري/نبات) والمكونات الكيميائية (المحتوى الكلي من الكلوروفيل ونسبة الكربوهيدرات الكلية المئوية) مقارنة بالكنترول والتركيزات الأخرى تحت الدراسة. علاوة على ذلك، لوحظت أعلى القيم لهذه الصفات مع معاملة ٢٠٠ جزء في المليون من العناصر الصغرى في كلا الموسمين، في معظم الحالات. عموماً، يفضل رش نباتات اللافندر بالشيتوزان بمعدل ٤٠٠ جزء في المليون بالتداخل مع الحديد + الزنك بمعدل ٢٠٠ جزء في المليون خمس مرات/موسم لزيادة نمو النبات ومكونات المحصول وأصباغ النبات بالإضافة إلى إنتاج الزيت العطري لهذا النبات الهام.