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RESPONSE OF *MAJORANA HORTENSIS* L. PLANT TREATED WITH SILICON AND MAGNETITE TO INCREASING ITS EFFICIENCIES TO TOLERANCE SALINITY

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An experimental layout was carried out at El-Maghara Experimental Research Station (North Sinai), Desert Research Center, Egypt, during the two successive seasons of 2012 and 2013, to study the effect of the interaction between foliar spraying with silicon at 0, 5 and 10 g/L and different rates of magnetite application (0, 200 and 300 kg/fed) on growth, yield, oil production and chemical constituents of *Majorana hortensis* L. plant. The best results from all the tested parameters, plant height, fresh and dry weights (g/plant), volatile oil percentage and oil yield/fed were significantly increased with using the second level of magnetite application (200 kg/fed). Also using silicon as foliar application at 5 g/L led to the best results of the same parameters. In addition, the vegetative growth, oil production as well as chemical constituents (Si, Fe, Ca, N and total carbohydrates content) were improved by the interaction between silicon and magnetite application, and the highest significant increase in all parameters were recorded with using the second level of magnetite (200 kg/fed) and spraying with silicon at 5 g/L, the main component of the volatile oil resulted from this treatment was 1-4-terpineol (29.75%), followed by trans-sabinene hydrate (21.28%), α–terpinene (16.45%), α–terpineol (8.45%), sabinene (6.99 %), P-cymene (3.29%), linalyl acetate (2.97%), trans-carophyllene (2.93%), α–terpinolene (1.93%), L-linalool (1.59%), α–pinene (1.3%) and D-limonene (1.01%). While, using silicon and magnetite caused decease in Na, Cl and proline contents in marjoram plant.

Keywords: *Majorana hortensis*, marjoram, magnetite, silicon, growth parameters, volatile oil

Marjoram (*Majorana hortensis* L.) is one of the most important aromatic herbs in the family Labiateae (Lamiaceae), which originated in

North Africa, such as Egypt (Pandey, 1982). The plant is used in varied forms, fresh or dry leaves and marjoram essential oil. Fresh or dry leaves of marjoram are commonly used to flavor soups, salads and meat dishes. The essential oil is used as food flavoring, in perfumery and can be used as external application for sprains, bruises. In the folk medicinal, herb is used as antiseptic, antispasmodic, carminative, cholagogue, diaphoretic, and stimulant salinity (Baratta et al., 1998).

Soil salinity is one of the most serious environmental problems limiting crop production mainly, where about 20% of the world's cultivated land and nearly of all irrigated lands are affected by salinity (Zhu, 2001). The accumulation of Na^+ results in toxicity and growth inhibition (Saqib et al. 2005). Also, salinity negatively affects growth and thus reduces the productivity of medicinal and aromatic plants, also affects the volatile oil percentage and its components.

Silicon (Si), as a microelement, has a vital role in plant cycles. One of the main functions of Si is improving the plants growth and yield, especially in stress conditions to achieve plant tolerance (Lekklar and Chaidee, 2001). Effect of silicon on yield is related to the deposition of the element under the leaf epidermis, which results in a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses. Drought and salinity stress can damage plant cell membranes, and cell wall architecture, as well as inhibit photosynthesis and cell division (Taiz and Zeiger, 2006). Silicon can reduce the transpiration rate by 30% in plants which has a thin cuticle (Mitani and Ma, 2005 and Sonobe et al., 2009).

Many authors have reported that, magnetic iron (magnetite) is one of the most important factors that can increase plant tolerance to salinity and reduces the damage caused by the stress of salinity (Racuciu et al., 2006; Ahamed et al., 2013 and El-Eslamboly and Abdel-Wahab, 2014). Furthermore, magnetic field may affect the growth characteristics, like shoot length and leaf weight. It can affect cell membrane and cell reproduction and may cause some changes in chlorophyll, soluble sugar and protein biosynthesis, enzyme activities and cell metabolism and various cellular functions including gene expression (Aladjadjiyan, 2002 and Atak et al., 2003).

The aim of this study is to investigate the effect of silicon and magnetite on productivity of *Majorana hortensis* L. plants grown under sandy soil conditions of El-Maghara Research Station.

MATERIALS AND METHODS

A field experiment was carried out at El-Maghara Experimental Station of Desert Research Center (DRC), during two successive seasons

(2012 and 2013), to study the effects of silicon and magnetite on the growth of *Majorana hortensis* L. plants grown in sandy soil under Sinai conditions.

Seedlings of *Majorana hortensis* were obtained from the Experimental Farm of Medicinal and Aromatic Plants, Faculty of Pharmacy, Cairo University, Giza. Homogenous seedlings of 12-15 cm height were transplanted in the field on 27th and 12th April 2012 and 2013, respectively, at distances of 40 cm between hills (one plant/hill) and 75 cm between rows (13800 plant/fed). During land preparation, compost manure of 15 m^3/fed and calcium super phosphate (16% P_2O_5) at a rate of 200 kg/fed were mixed with the soil before transplanting. N and K fertilizers were added at a rate of 200 kg/fed as ammonium sulphate (20.5% N) and 100 kg/fed potassium sulphate (48% K_2O)/fed divided in two equal doses. The first addition was implemented after one month from transplanting, while the second was applied after the first cut. Experimental plots were irrigated using drip irrigation with 4 L/h in two added times in the morning and afternoon. Physical and chemical properties of soil, irrigation water and compost manure were presented in tables (1, 2, 3 and 4), respectively.

Table (1). Physical properties of the experimental soil.

Very coarse sand (%) (2:1 mm)	Coarse sand (%) (1:0.5 mm)	Medium sand (%) (0.5:0.25 mm)	Fine sand (%) (0.25:0.1 mm)	Very fine sand (%) (0.1:0.063 mm)	Silt and clay (%) (<0.063 mm)	Soil texture
1.27	5.90	15.30	61.28	12.82	3.43	Sandy

Table (2). Chemical properties of the experimental soil.

pH	E.C. (dSm^{-1})	O.M. (%)	Soluble cations (meq./l)				Soluble anions (meq./l)			
			K^+	Na^+	Mg^{++}	Ca^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
8.70	0.76	0.41	0.09	2.43	0.80	3.20	--	3.00	1.38	2.14

Table (3). Irrigation water analysis.

pH	TDS (mg/L)	E.C (mmhos/cm)	Soluble cations (mg/L)				Soluble anions (mg/L)			
			Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
7.5	2688	4.20	188.40	79.79	560	66	0	238.48	923.02	580

Table (4). Compost manure analysis.

Weight/m^3	Humidity %	Ash %	O.M. %	O.C %	N %	P %	K %	pH	C/N
639 kg	25	74.03	25.97	15.06	1.38	0.49	0.59	5.91	16:1

1. Foliar Spray of Silicon and Magnetite Treatments

This experiment contained nine treatments in three replicates under split plot design; whereas, silicon treatments were situated in the main plots as a foliar spray over plant four times. The first application was done after 21 days from transplanting, the second one after 30 days from the first, the third application after the first cut and the fourth one after one month from the third application. Silicon and magnetite were obtained from El-Ahram Company for Mining and Natural Fertilizers (ECMNF), Giza. Egypt. The chemical analysis of silicon is shown in table (5).

Table (5). Chemical analysis of silicon used.

SiO_2 %	TiO_2 %	AL_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	SO_3 %	Cl %
46.56	0.35	8.67	1.13	0.10	1.64	16.45	0.87	0.65	0.26	1.65	0.55

1.1. Silicon treatments

1- Without silicon (control, foliar spray with tap water) (S_0).
2- Foliar spray with silicon at 5 g/L (S_1).
3- Foliar spray with silicon at 10 g/L (S_2).

The sub plots were magnetite applications with three levels, divided in two equal doses. The first one was added in soil hill before transplanting, the second one was added after the first cut directly. Magnetite (Magnetic iron ore), contained 48.8% Fe_3O_4, 17.3% FeO, 26.7% Fe_2O_3, 2.6% MgO, 4.3% SiO_2 and 0.3% CaO.

1.2. Magnetite treatments

1- Without magnetite (control) (M_0).
2- Adding magnetite at 200 kg/fed (14.50 g/plant) (M_1).
3- Adding magnetite at 300 kg/fed (21.74 g/plant) (M_2).

2. Plant Growth Parameters

In each season, two cuts were taken on July 25th and October 20th for the first season and July 30th and October 31th for the second season by cutting the vegetative parts of all plants 10 cm above the soil surface. Meanwhile, plant height, fresh and dry weights (g/plant), yield of dry herb/fed (kg) and oil yield (L/fed) were recorded at each cut.

3. Chemical Analyses

The essential oil percentage in dry herb of marjoram plant was determined according to British Pharmacopoeia (1963). The essential oil composition in some different treatments was determined using GC-Mass analysis, a TRACE GC Ultra Gas Chromatography (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). Nitrogen content was determined by

modified Micro-Kjeldahl method as described by Page et al. (1982). Total carbohydrates percentage in herb was determined according to Chaplin and Kennedy (1994). Proline content in fresh samples of plant was done by colorimetric method described by Bates et al. (1973). Analysis of Na, Si, Ca and Fe were determined using ICU (Inductively Coupled Argon Plasma, ICAP 6500 Duo Thermo Scientific, England). An amount of 1000 mg/L multi-element certified standard solution (Merck, Germany) was used as stock solution for instrument standardization. Chloride content was assessed according to the method described by Higinbothon et al. (1967).

4. Statistical Analysis

Data were analysed according to the procedure analysis of variance "Anova" described by Steel and Torrie (1980). Treatment means were compared by the LSD at 5% level of probability.

RESULTS AND DISCUSSION

1. Effect of Silicon and Magnetite Treatments on Plant Growth Parameters

Data in tables (6, 7, 8 and 9) showed that, *Majorana hortensis* seedlings treated with silicon and magnetite individually or in combination significantly possessed higher values of plant height, fresh and dry weights/plant and yield of dry herb/fed as compared to untreated plants. In the two cuts in both seasons, the most effective treatment in promoting growth characters was the application of silicon at 5 g/L together with 200 kg/fed of magnetite, which gave the highest values of growth. The obtained results are in agreement with those obtained by El-Hifny et al. (2008) on Cauliflower, who found that increasing magnetite levels up to 150 or 200 kg/fed increased plant growth. Similar results were obtained by El-Eslamboly and Abdel-Wahab (2014) on cantaloupe. In this connection, the role of silicon to increase crop production and quality resulted from the improved overall mechanical strength and an outer layer of enhanced protection for the plant Epstein and Bloom (2005). Also, Hattori et al. (2005) reported that, the reduction in water loss through transpiration and the decreased uptake of water were attributed to the larger and thicker leaves of silicon treated plants and to the higher silicon deposition in the cell walls of epidermal tissues (prevents excessive water loss through transpiration) and the xylem vessels (prevents compression of the vessels) than non-treated plants. Thus, the silicon increased the drought tolerance of plants by maintaining water balance, photosynthetic efficiency, erectness of plant canopy structure, and structure of the xylem vessels under high transpiration rates. Also, Ahmad et al. (2013) found that, foliar application of silicon on *Oryza sativa* at 1% led to the best plant growth.

Table (6). Effect of silicon and magnetite on plant height (cm) of *Majorana hortensis* plant.

First season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mea**	**M_0**	**M_1**	**M_2**	**Mea**
S_0	19.00	24.3	21.6	21.67	18.2	26.7	19.1	21.37
S_1	25.33	26.5	25.8	25.89	20.1	27.4	22.0	23.19
S_2	20.67	24.3	24.1	23.06	19.1	23.0	20.2	20.78
Mean	21.67	25.0	24.1		19.1	25.7	20.4	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	2.63	1.07	1.85		1.57	1.90	3.30	
Second season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mea**	**M_0**	**M_1**	**M_2**	**Mea**
S_0	18.22	20.2	19.1	19.18	29.8	32.1	29.8	30.61
S_1	20.11	27.4	23.0	23.52	35.1	43.1	37.6	38.67
S_2	19.11	26.7	22.0	22.63	31.5	36.1	34.0	33.89
Mean	19.15	24.8	21.3		32.1	37.1	34.0	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	1.57	1.90	3.30		1.09	1.60	2.77	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

Table (7). Effect of silicon and magnetite on fresh weight/plant (g) of *Majorana hortensis* plant.

First season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	54.7	70.81	54.9	60.14	68.	94.19	81.77	81.38
S_1	68.4	76.12	68.4	71.01	91.	101.2	100.7	97.98
S_2	59.0	74.60	59.6	64.43	70.	94.94	85.29	83.56
Mean	60.7	73.84	61.0		76.	96.80	89.27	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	4.63	1.54	2.67		6.2	6.35	11.01	
Second season								
	First cut				**Second cut**			
Treatments	**M_0**	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	61.0	69.47	63.6	64.71	75.	103.0	86.67	88.39
S_1	73.6	107.0	79.6	86.78	97.	159.2	106.0	120.7
S_2	66.3	76.00	69.6	70.67	85.	131.6	95.50	104.1
Mean	67.0	84.16	71.0		85.	131.3	96.06	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	5.77	2.29	3.97		2.2	2.89	5.00	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

Table (8). Effect of silicon and magnetite on dry weight/plant (g) of *Majorana hortensis* plant.

First season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	23.0	28.5	23.5	25.01	40.2	46.2	42.9	43.14
S_1	24.9	32.5	27.0	28.18	44.6	55.9	49.7	50.11
S_2	24.6	30.4	25.2	26.78	42.7	50.0	45.1	46.00
Mean	24.1	30.5	25.2		42.5	50.7	45.9	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	1.70	1.80	3.13		2.26	3.40	5.90	
Second season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	25.0	32.7	27.6	28.48	42.3	51.2	47.1	46.90
S_1	30.9	41.7	36.0	36.24	51.8	74.6	58.4	61.63
S_2	27.9	34.2	30.3	30.84	48.0	70.0	51.8	56.63
Mean	27.9	36.2	31.3		47.4	65.3	52.4	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	3.67	1.55	2.68		1.96	1.45	2.51	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

Table (9). Effect of silicon and magnetite on yield of dry herb/fed (kg) of *Majorana hortensis* plant.

First season								
Treatment	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S0	317.4	393.4	324.4	345.12	555.3	638.3	592.3	595.3
S1	343.6	448.8	373.8	388.78	616.4	771.8	686.1	691.4
S2	340.1	420.2	348.1	369.52	589.7	691.1	623.2	634.7
Mean	333.7	420.8	348.8		587.1	700.4	633.9	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	23.61	24.94	43.21		31.22	47.02	81.44	
Second season								
Treatment	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mea**
S0	345.1	452.5	381.5	393.07	584.1	707.3	650.1	647.2
S1	426.8	575.4	498.0	500.08	715.3	1030.	805.9	850.4
S2	385.7	472.2	418.9	425.67	662.8	966.7	715.1	781.5
Mean	385.8	500.0	432.8		654.1	901.4	723.7	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	50.77	21.38	37.03		27.05	20.02	34.68	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

2. Effect of Silicon and Magnetite Treatments on the Essential Oil Percentage in Dry Herb of *Majorana hortensis*

Data in table (10) show that applying magnetite as soil dressing around plants and foliar spray of silicon significantly increased the essential oil percentage of the *Majorana hortensis* plant. This detection appeared within the two cuts of both seasons. All treatments increased such proportion over the control plants. The highest essential oil seemed to be found in plants supplied with a combination between silicon at 5 g/L and magnetite at 200 kg/fed. The combined application of both silicon and magnetite might have some stimulating effects on the essential oil percentage in the herb.

Table (10). Effect of silicon and magnetite on essential oil percentage (%) of *Majorana hortensis* plant.

First season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	2.45	2.70	2.46	2.54	1.95	2.18	2.12	2.08
S_1	2.70	3.03	2.75	2.83	2.15	2.50	2.33	2.33
S_2	2.65	2.98	2.68	2.77	2.05	2.20	2.25	2.17
Mean	2.60	2.90	2.63		2.05	2.29	2.23	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	0.05	0.07	0.12		0.05	0.05	0.09	
Second season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	2.17	2.37	2.20	2.25	1.60	2.14	2.03	1.92
S_1	2.36	2.67	2.46	2.50	1.90	2.38	2.20	2.16
S_2	2.33	2.45	2.37	2.38	1.80	2.18	2.08	2.02
Mean	2.29	2.50	2.34		1.77	2.23	2.10	
L.S.D at	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
5%	0.33	0.17	0.30		0.08	0.08	0.14	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

3. Effect of Silicon and Magnetite Treatments on the Essential Oil Yield (L/fed) of *Majorana hortensis*

Data in table (11) revealed that the addition of iron magnetic around the root zone of plant, foliar application of silicon, yield of dry herb and time of collecting cuts seemed to have a role on essential oil yield. The essential oil yield of marjoram plants was always higher in the second cut than in the first one. The essential oil yield/fed was higher during the second season than those corresponding ones of the first season. This increment may be resulted from the role of silicon or magnetite to increase plant dry mass under salt stress and the essential oil percentage in the herb. Similar results

were obtained by Ahmad et al. (1992) on wheat, Romero-Aranda et al. (2006) on tomato and El-Hifny et al. (2008), who reported that, the highest yield was produced when 200 kg magnetite/fed was added.

Table (11). Effect of silicon and magnetite on oil yield of dry herb (L/fed) of *Majorana hortensis* plant.

First season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	7.78	10.63	7.99	8.80	10.82	13.88	12.57	12.42
S_1	9.29	13.58	10.28	11.05	13.26	19.31	15.99	16.19
S_2	9.02	12.51	9.32	10.28	12.08	15.20	14.06	13.78
Mean	8.70	12.24	9.20		12.05	16.13	14.21	
L.S.D at 5%	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
	0.72	0.81	1.41		0.86	1.07	1.85	
Second season								
Treatments	**First cut**				**Second cut**			
	M_0	**M_1**	**M_2**	**Mean**	**M_0**	**M_1**	**M_2**	**Mean**
S_0	7.48	10.70	8.41	8.86	9.36	15.12	13.18	12.55
S_1	10.15	15.36	12.23	12.58	13.58	24.55	17.73	18.62
S_2	8.99	11.58	9.91	10.16	11.93	21.12	14.86	15.97
Mean	8.87	12.55	10.18		11.62	20.26	15.26	
L.S.D at 5%	**S**	**M**	**S*M**		**S**	**M**	**S*M**	
	1.99	0.91	1.57		1.05	0.86	1.50	

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

4. GC-MS Analysis of *Majorana hortensis* Volatile Oil

Data represented in table (12) show the analysis obtained by using Gas chromatography/mass spectrometry (GC-MS) for three treatments. The samples of the essential oil during the first cut of the first season were subjected to GC-MS analysis.

The analysis showed that, 22 compounds were identified, the main compounds of essential oil were 1-4-terpineol, trans-sabinene hydrate, α–terpinene, α-terpineol, trans-carophyllene, linalyl acetate, sabinene, P-cymene, L-linalool, α–terpinolene, D-limonene and α-pinene, which represent from 96.72 – 97.94% of *Majorana hortensis* essential oil.

It can be seen from S_0M_1 treatment that, the major component was 1-4-terpineol (26.77%), followed by trans-sabinene hydrate (21.66%), α–terpinene (15.48%), sabinene (6.47%), α–terpineol (5.66%), linalyl acetate (5.66%), P–cymene (4.21%), trans-carophyllene (3.98%), L-linalool (2.64%), α –terpinolene (1.91%), α –pinene (1.16 %) and D-limonene (1.12 %).

Table (12). Effect of silicon and magnetite on GC-mass essential oil of *Majorana hortensis* plant.

No.	Compound name	S_0M_1	S_1M_1	S_2M_1
1	α–Phellandrene	0.43	0.50	0.33
2	Sabinene	6.47	6.99	6.47
3	α–Pinene	1.16	1.3	1.09
4	α–Myrcene	0.89	0.70	0.85
5	α–terpinene	15.48	16.45	13.41
6	P–Cymene	4.21	3.29	4.55
7	D-Limonene	1.12	1.01	1.23
8	Trans-sabinene hydrate	21.66	21.28	26.92
9	α –terpinolene	1.91	1.93	1.66
10	L-linalool	2.64	1.59	1.99
11	α –terpineol	5.66	8.45	6.09
12	L-menthone	0.06	0.19	-
13	1-borneol	0.05	0.10	0.07
14	1-4-terpineol	26.77	29.75	27.69
15	Linalyl acetate	5.66	2.97	3.36
16	Iso-bornyl acetate	0.29	0.12	0.27
17	4-terpinenyl acetate	0.38	0.24	0.26
18	Thymol	-	0.07	-
19	Iso-caryophillene	0.13	0.09	0.1
20	Trans-carophyllene	3.98	2.93	3.22
21	Germacrene D	-	0.20	0.08
22	Carophyllene oxide	0.28	0.33	0.27

Whereas analysis of essential oil of marjoram plants treated with S_1M_1 showed that the major component was 1-4-terpineol (29.75%), followed by trans-sabinene hydrate (21.28%), α–terpinene (16.45%), α–terpineol (8.45%), sabinene (6.99 %), P –cymene (3.29%), linalyl acetate (2.97%), trans-carophyllene (2.93%), α–terpinolene (1.93%), L-linalool (1.59%), α–pinene (1.3%) and D-limonene (1.01%). Meanwhile, treated marjoram plants by S_2M_1 showed that the major component was 1-4-terpineol (27.69%), followed by trans-sabinene hydrate (26.92%), α–terpinene (13.41%), sabinene (6.47 %), α–terpineol (6.09%), P–cymene (4.55%), linalyl acetate (3.36%), trans-carophyllene (3.22%), L-linalool (1.99%), α–terpinolene (1.66%), D-limonene (1.23%) and α–pinene (1.09%).

Generally, it is noticed that, using S_1M_1 treatment led to the highest contents of 1-4-terpineol, sabinene, α–pinene, α–terpinene, α–terpinolene and α–terpineol. It was also noticed that, the highest contents of trans-

sabinene hydrate, P–cymene and D-limonene resulted from S_2M_1 treatment. Also, the highest contents of L-linalool, linalyl acetate and trans-carophyllene were obtained with treating the plants with the second level of magnetite only (S_0M_1).

Terpinen-4-ol is used in the treated of many diseases. Hart et al. (2000) showed the anti-inflammatory properties of terpinen-4-ol. Also, Tighe et al. (2013) determined the active ingredient in tea tree oil responsible for its reported killing effect on Demodexmites, the most common ectoparasite found in the human skin extending to the eye. They found that, terpinen-4-ol was the most potent ingredient followed by α-terpineol, 1, 8-cineole and sabinene. Terpinen-4-ol is the most abundant ingredient in tea tree oil.

5. Effect of silicon and magnetite treatments on mineral content, total carbohydrates percentage and proline (mmol/g) of *Majorana hortensis*

Data in tables (13 and 14) showed that, silicon and magnetite additions gave the highest values in Si, Fe, Ca, N and total carbohydrates content in plant tissues of *Majorana hortensis*. While, there was a decrease in Na, Cl and proline accumulation in plant. The mineral content was always higher in the second cut than in the first one, except, carbohydrates content.

The obtained results indicated that silicon treatment had effect on mineral accumulation and total carbohydrates content in the plant in the two cuts of both seasons. It is clear that, treated *Majorana hortensis* plants with foliar application of silicon gave the highest content of Si, Fe, Ca, N and total carbohydrates in dry herb. On the other hand, application of silicon led to a decrease in sodium and chloride uptake and accumulation in herb. As far as, foliar application of silicon to plant led to a decrease in the proline content in the herb. Meanwhile, the best effect of silicone was recorded at 5g/L. These results may be due to the role of silicon on yield that is related to the deposition of the element under the leaf epidermis, which results in a physical mechanism of defense, reduces lodging, increases photosynthesis capacity and decreases transpiration losses (Taiz and Zeiger, 2006). Also, Mali and Aery (2008 a and b) showed that application of silicon gave the better absorption of nitrogen and calcium in cowpea. In the same trend, Lee et al. (2010) found that addition of silicon to hydroponically grown soybean plants decreases proline content under salt stress.

Table (13). Effect of silicon and magnetite on Si, Fe, Ca and Na content (ppm) of *Majorana hortensis* plant.

Treatments		First season							
		Si		Fe		Ca		Na	
		1 cut	2 cut	1 cut	2 cut	1 cut	2 cut	1 cut	2 cut
M_0	S_0	439.1	568.5	39.0	45.0	42.8	44.4	337.9	387.2
	S_1	462.4	655.3	36.0	59.0	46.6	52.7	259.2	289.4
	S_2	560.3	756.6	39.0	44.0	45.3	52.5	265.8	299.8
M_1	S_0	622.4	784.1	47.0	64.0	52.5	62.9	260.1	269.4
	S_1	839.4	102.0	49.0	85.0	58.4	82.2	193.5	201.8
	S_2	629.7	882.4	44.0	60.0	53.1	65.1	220.6	232.4
M_2	S_0	577.8	868.8	37.0	48.0	52.6	72.8	278.6	295.7
	S_1	788.6	102.0	44.0	49.0	57.5	75.3	264.4	282.1
	S_2	702.2	897.7	38.0	46.0	56.3	66.9	278.9	299.4
Treatments		Second season							
		Si		Fe		Ca		Na	
		1 cut	2 cut	1 cut	2 cut	1 cut	2 cut	1 cut	2 cut
M_0	S_0	354.4	535.1	17.0	13.0	74.7	54.8	317.9	348.2
	S_1	495.7	624.8	38.0	23.0	95.8	59.3	245.3	271.0
	S_2	575.3	728.8	28.0	22.0	84.5	58.5	236.2	259.7
M_1	S_0	676.8	696.4	69.0	31.0	83.2	61.3	241.9	260.1
	S_1	792.1	827.8	94.0	41.0	123.	81.4	189.4	199.2
	S_2	704.0	697.1	84.0	41.0	108.	60.2	213.4	222.0
M_2	S_0	698.4	648.8	41.0	17.0	90.1	70.8	259.7	284.3
	S_1	733.0	781.1	88.0	27.0	106.	61.2	246.3	271.0
	S_2	730.3	713.6	63.0	21.0	109.	64.9	260.2	287.4

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively.

It could be observed that, the highest content of proline was obtained with control plant (which was not added by magnetite or treated by silicon). It may be due to the accumulation of proline in plants under salt stress conditions and its role in raising the efficiency of the salinity tolerance. Many studies had provided the role of proline in raising the efficiency of the plant for salinity tolerance in different ways such as Hare and Cress (1997) and Kavi Kishor et al. (2005), who reported that, proline was considered as an inert compatible osmolyte that protects subcellular structures and macromolecules under osmotic stress. Szabados and Savoure (2009) showed that, proline accumulation can influence stress tolerance in multiple ways, such as improvement of drought or salt tolerance of crop plants. Engineering proline metabolism is an existing possibility and should be explored more extensively. The fact that proline can act as a signaling molecule and influence defense pathways, regulate complex metabolic and developmental processes, offers additional opportunities for plant improvement.

Table (14). Effect of silicon and magnetite on N, Cl, K, total carbohydrates content (%) and proline (mmol/g) in herb of *Majorana hortensis* plant.

Treatments		First season							
		N		Cl		Proline		Total carbohydrates	
		1 cut	2 cut	1 cut	2 cut	1 cut	2 cut	1 cut	2 cut
M_0	S_0	2.06	2.40	2.31	1.24	1.95	2.16	14.8	8.86
	S_1	2.06	2.84	1.14	0.92	1.53	1.76	17.9	13.12
	S_2	2.06	2.57	1.24	1.10	1.30	1.55	17.5	12.39
M_1	S_0	3.09	2.93	1.17	0.92	1.17	1.64	18.3	13.50
	S_1	3.13	3.83	0.75	0.57	1.09	1.23	24.1	14.82
	S_2	3.09	3.19	0.96	0.78	1.11	1.47	19.4	14.60
M_2	S_0	2.74	2.93	1.38	1.14	1.20	1.70	18.1	13.04
	S_1	3.09	3.77	0.92	0.89	1.13	1.29	22.1	14.74
	S_2	2.74	2.74	1.17	1.07	1.17	1.51	19.5	13.17
Treatments		**Second season**							
		N		Cl		Proline		Total carbohydrates	
		1 cut	2 cut	1 cut	2 cut	1 cut	2 cut	1 cut	2 cut
M_0	S_0	1.72	2.09	1.74	2.66	1.81	1.99	10.3	9.00
	S_1	2.40	2.74	1.42	1.56	1.42	1.66	15.8	16.52
	S_2	2.06	3.09	1.60	2.17	1.25	1.54	12.9	13.56
M_1	S_0	3.09	3.09	1.70	1.81	1.10	1.65	14.1	13.91
	S_1	3.77	3.83	0.82	1.28	1.00	1.15	21.4	25.99
	S_2	3.07	3.43	1.03	1.53	1.04	1.38	17.3	15.05
M_2	S_0	2.06	3.09	1.56	2.31	1.18	1.64	16.4	18.37
	S_1	3.77	3.62	1.17	1.53	1.10	1.31	17.9	20.70
	S_2	2.40	3.43	1.17	2.06	1.11	1.41	17.7	18.90

S_0, S_1 and S_2 = silicon 0, 5 and 10 g/L M_0, M_1 and M_2 = magnetite 0, 200 and 300 kg/fed, respectively

It could be noticed that, the most of magnetite treatments either singly or in combination with silicon increased Si, Fe, Ca, N and total carbohydrates content in herb, while the lowest results were obtained by control treatment in both seasons. On the other hand, magnetite application led to a decrease of Na, Cl and proline accumulation in herb. These results may be due to the positive effects of magnetic treatments on desalinization of soils and water irrigation (El-Eslamboly and Abdel-Wahab, 2014). In the same trend, El-Hifny et al. (2008) pointed out that increasing magnetite levels up to 150 or 200 kg/fed led to increase the mineral contents in leaves, but decreased Na, Cl and proline content in the cauliflower plant.

CONCLUSION

It is clear from the previous results that, the growth characters, oil percentage and oil yield of dry herb were significantly increased as a result of treating the *Majorana hortensis* plants with silicon and magnetite. Moreover, these treatments also increased the minerals content (Si, Fe, Ca, N and total carbohydrates content), while Na, Cl and proline were decreased. It could be advised to apply silicon at 5 g/L in addition to 200 kg/fed of magnetite to attain the highest values of plant growth and oil percentage.

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إستجابة نبات البردقوش للمعاملة بالسليكون والماجنتيت لزيادة قدرته على تحمل الملوحة

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أجريت تجربتين حقليتين بمحطة بحوث المغارة التابعة لمركز بحوث الصحراء خلال موسمي ٢٠١٢ و ٢٠١٣، لدراسة تأثير الرش بمستويات مختلفة من السيلكون (صفر، ٥ و١٠ جم/لتر) والمعاملة بمستويات مختلفة من الماجنتيت بتركيز صفر، ٢٠٠ و٣٠٠ كجم/فدان، والتفاعل بينهما على النمو ومحصول الزيت والتركيب الكيميائي لنبات البردقوش. وكانت أفضل النتائج المتحصل عليها من إرتفاع النبات، الوزن الطازج والجاف للنبات، نسبة الزيت الطيار ومحصول الزيت للفدان، والتي زادت زيادة معنوية مع إستخدام المستوى الثاني من الماجنتيت (٢٠٠ كجم/فدان) مع الرش بتركيز ٥ جم/لتر من السليكون، أدى للحصول على أفضل النتائج من الصفات موضع الدراسة.

وقد أظهر التفاعل بين الرش بالسليكون والمعاملة بالماجنتيت إلى تحسن كلًا من صفات النمو الخضرى، وإنتاج الزيت والتركيب الكيميائي (المحتوى من السليكون، الحديد، النيتروجين، الكالسيوم والكربوهيدرات الكلية). وكانت أفضل النتائج المتحصل عليها بالمعاملة S_1M_1 (الرش بالسليكون بتركيز ٥ جم/لتر والمعاملة بالماجنتيت بمعدل ٢٠٠ كجم/فدان). وكان تركيب الزيت المتحصل عليه 1-4-terpineol (29.75%)، trans sabinene hydrate (21.28%)، α–terpinene (16.45%)، α–pinene (8.45%)، sabinene (6.99 %)، P-cymene (3.29%)، linalyl acetate (2.97%)، trans-carophyllene (2.93%)، α–terpinolene (1.93%)، L-linalool (1.59%)، α–pinene (1.3%) وD-limonene (1.01%). بينما أدى إستخدام كلًا من السليكون والماجنتيت إلى تقليل محتوى النبات من الصوديوم والكلور والبرولين.