Effect of fertilization and irrigation with magnetic water on the productivity of marjoram plant

By

Rania M. Khater
Department of Medicinal and Aromatic Plants, Desert Research Center, Matarryia, Cairo, Egypt

Doi: 10.21608/asajs.2020.67987

استلام البحث : ٢ / ١٠ /٢٠١٩   قبول النشر: ٢٠ / ١١ / ٢٠١٩

Abstract:

This research was conducted at the National Research Center greenhouse ring two consecutive seasons of 2013/2014 and 2014/2015, in order to study the effect of irrigation water types (tap water, magnetized water) and levels of ammonium sulfate (0, 7, and 14 g / pot) and their interaction, on the vegetative growth and oil production of marjoram *(Majorana hortensis L.*) plant. The results showed that marjoram plants responded significantly to the different types of irrigation, as well as nitrogen fertilization and their interaction. Irrigation by magnetized water showed that a significant increase in vegetative growth; i.e. plant height, number of branches, fresh and dry weights of herb, stem, leaves and roots per plant and root length. Using nitrogen fertilizer rates gave significant increases in vegetative growth parameters, where the best treatment one was 14 g/pot. As for the interaction between types of irrigation water and nitrogen fertilizer rates, data showed that plants irrigated with magnetized water with addition of ammonium sulfate at a rate of 14 g/pot recorded the highest values of the attributes of vegetative growth, production of oil, major compounds of oil and chemical components of marjoram plant. Magnetic water treatment with the addition of 14 g / pot ammonium sulfate recorded 43.38% of the terpineol-4-ol (the main compound of the oil), while irrigation with tap water recorded 26.41%. Also this treatment increased some compounds of marjoram oil percent; such as α-myrcene, α-terpinene, α-phellandrene, Ç-terpinene, α –terpinolene, L-linalool, α-terpineol and linalyl acetate with mean values of 1.08, 5.91, 1.13, 12.45, 2.40, 3.48, 3.53 and 6.35 compared to tap water treatment, which gave 0.89, 4.31, 1.08, 8.81, 1.91, 2.64, 2.97 and 5.66 for these components; respectively. The obtained results also indicated the possibility of obtaining the highest values of chemical constituents such as total carbohydrates, nitrogen, phosphorus and potassium percentages when plants were irrigated with magnetized water with the addition of ammonium sulfate at a rate of 14 g / plant under the conditions of the experiment.

Key words: Majorana hortensis, magnetized water, ammonium sulfate

Introduction:

Marjoram (*Majorana hortensis* L.) is a bilateral strabismus herb belonging to the family Lamiaceae. It is native to the country's south-east of the Mediterranean basin. It is also grown in Germany, as an economic crop, which is used as a spice in many types of foods. Its leaves, flowers and oil are used as a medicine. It contains a volatile oil and many flavonoids; terpineol, glycosides, linalool, sabinene, triterpenes, thujanol and thymol, as effective materials (Edris et al., 2003 and El-Ghorab et al., 2004).

Marjoram from cleared vegetation is the best herbal antioxidant, emulsion flowers and dried branches are used to treat cough, asthma and infectious disorders and intestinal bloating, and are useful in the treatment of allergic nasal inflammation. Also, marjoram is used to treat the common cold massage nasal ointment herb juice, rinsing the mouth, and using water extract of flowers is very useful for the body.

The most important medical benefits of the marjoram plant eliminates flatulence and stimulates the flow of bile and anti-inflammatory thoracic and tonsillitis. Also used for treatment of inflammation of the trachea, asthma and as a menstrual diuretic and good for stomach pains. Weed scientists also advised to use the marjoram herb for the treatment of glaucoma, because it contains anti-oxidants, as it prevents the occurrence of glaucoma (Tahraoui et al., 2007).

Marjoram is also used in the form of tea that regulates hormones and the menstrual cycle, and eliminates the hassles of menstruation. Since it is a general tonic and works to restore hormonal equilibrium, also removes excess water from the body (Triantaphyllou et al., 2001)

Medical studies confirm that marjoram has the effect of analgesic and anti-depressant, and the extract of the herb has a stimulating effect on the immune system, completely equal effect known to *Nigella sativa*. And marjoram oil is also used in the medical fields as one of the centrifugal gas vehicles in the installation of medicines that treat rheumatism, eczema and infectious ulcers (Farkas, 1981 and Leeja and Thoppil, 2007).

The use of the magnetic field as a treatment of water was observed for many industrial purposes. Agricultural and medical terms were used by Shimazaki Seed Company of the magnetic field in improvement of seed germination and acceleration of growth.

Many studies on using magnetized irrigation water were carried out (Nasher, 2008 and Hozayn and Abdul Qados, 2010), on paulownia seeds (Atak et al., 2000), vegetable crop (Çelik et al., 2008) and chick-pea (Maheshwari and Grewal, 2009). The magnetized irrigation water led to a significant increase in plant height and fresh and dry weight, where the increase was estimated at 20%, compared with plants that were irrigated with nonmagnetic water. The various agricultural operations performed on marjoram plants have a significant impact on the vegetative growth and essential oil production. Particularly, nitrogen fertilizer is considered an important factor for increasing the production of marjoram vegetative growth and yield of fresh and dry leaves and volatile oil. This results have been reported by Usha and Patra (2003), Dasha et al. (2006) and Alsafar and Al-Hassan (2009), on *Ocimum basilicum* (Singh and Ramesh, 2000), *Chrysanthemum coronarium* and thyme (Baranauskienne et al., 2003), sweet fennel plants (Al-Said, 2005), rosemary (El-Shakry, 2005), *Anethum graveolens* (Min et al., 2005) and mint (Omer et al., 2008 and Phuong et al., 2008). The purpose of this research was to study the response of marjoram plants (*Majorana hortensis*, L. family Lamiaceae) to irrigation water (tap and magnetized water), and different levels of N-fertilizer as well as their interaction on the productivity, essential oil and chemical composition.

MATERIALS AND METHODS

This work was carried out at the National Research Center greenhouse during two successive seasons of 2013- 2014 and 2014 -2015, to study the response of marjoram plants (*Majorana hortensis*, L. family Lamiaceae) to irrigation water types (tap water and magnetized water), different levels of N-fertilizer as well as their interaction on vegetative growth, essential oil production and chemical compositions of plants. Seeds of majorana plants were gratefully obtained from the Department of Medicinal and Aromatic Plants, Ministry of Agriculture, Dokki,Giza,Egypt. The seeds were sown in the nursery bed on 15th of November, for both seasons. After 45 days, seedlings were transplanted in plastic pots; 30 cm diameter, filled with sandy soil. The pots were watered according to the estimated irrigation requirements of majoram plants. The mechanical and chemical analyses of the soil are shown in table (1). The chemical analysis of irrigation water is tabulated in table (2). The magnetic water exposure used in the study is shown in fig. (1).

Table (1). The mechanical and chemical analysis of the soil pots experiment.

Mechanical analysis	Value	Chemical analysis					
		Soluble anions (meq/L)	Value	Soluble cations (meq/L)	Value	Available (mg/L)	Value
Fine sand %	80.20	HCO_3	4.84	Ca	5.95	N	8.21
Coarse sand %	15.63	CL	7.63	Mg	5.75	P	3.23
Slit %	10.72	SO_4	8.13	Na	7.65	K	9.67
Clay %	2.45	pH	7.60	K	1.25	$CaCO_3$	0.73
Soil texture		Sandy		E.C Mmhos/ cm		2.10	

Table (2). Chemical analysis of the used irrigation water.

Treatment	EC dSm^{-1}	pH	Cations				Anions			
			Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3	HCO_3	Cl^-	SO_4
Tap water	0.375	7.90	0.85	0.77	1.30	0.25	0.0	1.06	1.75	0.90
Magnetized water	0.468	7.82	1.20	1.30	1.30	0.29	0.0	1.41	2.00	1.21

The experimental design was split plot design, with three replicates, types of irrigation water were the main plots and N-fertilizer levels were sub plots. Each replicate contains 6 pots and one plant per pot.

The experiment included two factors. The first factor was type of irrigation water (tap water and magnetized water). The irrigation water was treated with a magnetized device before applying to plants. The water passed through 250 MT magnetron unit of 3.5 cm diameter, produced by magnetized technologies (Germany). While the second factor was N-fertilizer with three levels (0, 7,and 14 g/pot) as ammonium sulfate (20.5% N). The treatments were as follows:

1. Tap water
2. Magnetized water
3. Tap water + 7 g/pot ammonium sulfate
4. Tap water + 14 g/pot ammonium sulfate
5. Magnetized water + 7 g/pot ammonium sulfate
6. Magnetized water + 14 g/pot ammonium sulfate

The nitrogen fertilizer was divided into two equal doses; the first addition was applied after one month from transplanting on 15th of March, and the second one was added on 15th of July (after two weeks of the first cut).

The following data were recorded after each cut (i) vegetative growth parameters [plant height (cm), number of branches, fresh and dry weights of herb, stem, leaves, roots per plant (g) and root length (cm)] (ii) essential oil production including essential oil percentage of dry herb, determined after two cuts according to British Pharmacopoeia (1936), essential oil yield (ml/plant), the yield of oil produced per plant was calculated by multiplying the average dry weight of herb per plant by the oil percentage, and essential oil composition in the second cut of the second season, which was analyzed by using GC- mass according to Bunzen et al. (1969) and Hoftman (1967) methods and (iii) chemical constituents included total carbohydrate percentage determined according to method described by Herbert et al. (1971). Microelements (nitrogen, phosphorus and potassium) percentage were estimated. Nitrogen percentage was determined using Nissler method according to the procedure described by Koch and Mc-Meekin (1924); phosphorus percentage was determined according to the method of Troug and Mayer (1939) and potassium determination was done using photo-metrically flame photometer according to the method described by Brown and Lilleland (1946). The plants were harvested two times through the growing season. The first and the second cuts took place on 15^{th} of June and 15^{th} of September in both seasons, respectively.

The data recorded were statistically analyzed and treatments were compared by using least significant difference L.S.D. test at 5% level according to Snedecor and Cochran (1980) by using Software (STATISTIX 9.0) (Analytical Software, 1985).

RESULTS AND DISCUSSION

1. Plant Height and Number of Branches

1.1. Effect of irrigation water type

Data presented in table (3) revealed that plant height and number of branches were affected by type of irrigation water. Irrigation with magnetized water treatment gave highly significant increase in plant height and number of branches compared to irrigation with un-magnetized water (tap water). This increase may be due to breaking down of hydrogen bonds of the molecule of magnetized water that led to smaller-sized water molecules, which affected the physical changes of water, viscosity and density. This facilitated the entry of the water through plant cellular membranes and increased the absorption of water and may affect the production of the hormone (IAA), which leads to improve activity and division of plant cells. This reflects on the increase in plant height and number of branches (Rao, 2002). These results were reported in the two cuts in both seasons, and are in agreement with those found by Takac et al. (2002) on tomato and pepper, Nasher (2008) and Hozayn and Abdul Qados (2010) on chickpea.

1.2. Effect of N-fertilizer rates

Data recorded in table (3) show that different rates of N-fertilizer at all concentrations gave highly significant increase in plant height and number of branches in comparison to control in the two cuts and both seasons. Increasing N-fertilizer rates increased plant height and number of branches. Furthermore, the superior treatment in this respect was that of N-fertilizer of 14 g/pot, which gave highly significant increase in plant height and number of branches compared to the other ones under study in the two cuts in both seasons.

The increment in the plant height and number of branches as a result N-fertilizer rates may be due to the effective role of the nitrogen, which is necessary for the synthesis of protein and cytokinin that affect the cell division and encourage the plant to carry more branches. These results are in accordance with those obtained by Baranauskienne et al. (2003) on thyme and Min et al. (2005) on *Chrysanthemum coronarium*.

1.3. Effect of interaction

Data presented in table (3) show that, the interaction treatments between type of irrigation water and N-fertilizer rates caused highly significant increase in plant height and number of branches of marjoram comparing with control. The tallest plant and more branches in this regard were obtained by using magnetized water with 14 g/pot comparing with other treatments. The reason for increasing in plant height and number of branches may be due to magnetized water that is easily absorbed by the process of root cells as water becomes a good carrier of nutrients, which works to activate the role of nitrogen in the protein synthesis and cytokinin that affect the division and growth of cells and reflect on increase in plant height and number of branches. These results are in agreement with those obtained by Carbonell et al. (2000) on *Oryza sativa*L, Oldacay and Erdem (2002) on *Helianthus annuus* and Sharma et al. (2003) on psyllium.

Table (3). Effect of irrigation water type, N-fertilizer rates and their interaction on plant height (cm) and number of branches per plant of *Majorana hortensis* plant in 2013/2014 and 2014/2015 seasons.

Irrigation type	N-fertilizer rates (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
Plant height (cm)								
Season 1								
	First cut				**Second cut**			
Magnetized water	41.00	51.23	46.67	46.30	36.90	46.11	42.00	41.67
Tap water	30.00	39.67	31.33	33.67	27.00	35.70	28.20	30.30
Means (A)	35.50	45.45	39.00		31.95	40.91	35.10	
L.S.D. at 5%	A: 2.748	B: 1.685		AB: 3.220	A: 2.473	B:1.516		AB: 2.889
Season 2								
	First cut				**Second cut**			
Magnetized water	45.10	56.36	51.33	50.93	40.59	50.72	46.20	45.84
Tap water	33.00	43.63	34.47	37.03	29.70	39.27	31.02	33.33
Means (A)	39.05	49.99	42.90		35.15	44.99	38.61	
L.S.D. at 5%	A: 3.022	B:1.853		AB:3.531	A: 2.722	B:1.668		AB: 3.179
Number of branches per plant								
Season 1								
	First cut				**Second cut**			
Magnetized water	12.00	18.33	15.00	15.11	15.60	23.83	19.50	19.64
Tap water	6.33	10.67	8.67	8.56	8.23	13.86	11.26	11.12
Means (A)	9.17	14.50	11.83		11.92	18.85	15.38	
L.S.D. at 5%	A: 0.478	B:1.646		AB:1.947	A: 0.621	B: 2.139		AB: 2.531
Season 2								
	First cut				**Second cut**			
Magnetized water	16.80	25.67	21.00	21.16	20.16	30.80	25.20	25.38
Tap water	8.87	14.93	12.13	11.98	10.64	17.92	14.56	14.37
Means (A)	12.83	20.30	16.57		15.40	24.36	19.88	
L.S.D. at 5%	A: 0.669	B:2.302		AB: 2.726	A: 0.803	B: 2.764		AB: 3.271

2. Fresh and Dry Weights of Herb, Stem, Leaves, Roots and Roots Length per Plant

2.1. Effect of irrigation water type

The data given in tables (4, 5 and 6) and fig. (2) indicate that, fresh and dry weights of herb, leaves, stem, root and roots length per plant of marjoram showed highly significant increase with type of irrigation water. Moreover, using magnetized water increased these parameters. The best treatment in these connections was that of magnetized water, which recorded highly significant increase compared to tap water. These results hold in the same direction in the two cuts in both seasons.

This result may be due to that magnetized irrigation water increases plant growth by crash hydrogen bonds, which facilitates the absorption of water by the root cells, as water becomes a good carrier of nutrients. Hence, biological processes within the plant increases, such as an increase in photosynthesis and the plants process an increase in the production of plant hormones; such as cytokinin, IAA and GA_3 and protein production increases (Colic et al., 1998). These results are in accordance with those obtained by, Martinez et al. (2000) on *Hordeum vulgare*, Belyavskaya (2001) on pea root and Marinkovic et al. (2002) on potato.

2.2. Effect of N-fertilizer rates

Data presented in tables (4, 5 and 6) and fig. (2) demonstrate that, increasing N-fertilizer rates treatments led to highly significant increase in fresh and dry weights of herb, leaves, stem, root and roots length per marjoram plant in comparison to control, in the two cuts in both seasons. Also, the highest increase in this respect was obtained by using 14 g/pot compared to the control. Moreover, increasing N-fertilizer rates increased these parameters.

This increment in the fresh and dry weights of herb, leaves, stem, root and roots length per plant as a result of N-fertilizer rates may be due to the effective role of nitrogen nutrition, which led to an increase in plant height and number of branches, which was reflected in producing more fresh and dry weights of herb, leaves, stem, root and roots length per marjoram plant. These results are in agreement with those obtained by

Fig. (2). Effect of irrigation water type, N-fertilizer rates and their interaction on root length of *Majorana hortensis* during the

Usha and Patra (2003) on *Mentha arvensis* var. piperascens and Al-Said (2005) on *Anethum graveolens*.

Table (4). Effect of irrigation water type, N-fertilizer rates and their interaction on fresh weight of herb, stem and leaves per plant (g) of *Majorana hortensis* plant in 2013/2014 and 2014/2015 seasons.

Irrigation type	N-fertilizer (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
	Fresh weight of herb per plant (g)							
	Season 1							
	First cut				**Second cut**			
Magnetized water	55.343	80.533	70.353	68.743	39.290	57.173	49.943	48.802
Tap water	45.287	67.217	58.477	56.993	32.147	47.720	41.513	40.460
Means (A)	50.315	73.875	64.415		35.718	52.447	45.728	
L.S.D. at 5%	A: 4.994		B: 3.029	AB: 5.813	A: 3.542	B: 2.151		AB: 4.125
	Season 2							
	First cut				**Second cut**			
Magnetized water	66.413	96.640	84.427	82.493	47.147	68.610	59.937	58.564
Tap water	54.343	80.660	70.170	68.391	38.580	57.263	49.813	48.552
Means (A)	60.378	88.650	77.298		42.863	62.937	54.875	
L.S.D. at 5%	A : 5.998		B: 3.635	AB: 6.979	A: 4.259	B: 2.581		AB: 4.956
	Fresh weight of stem per plant (g)							
	Season 1							
	First cut				**Second cut**			
Magnetized water	19.173	27.897	24.373	23.814	11.887	17.297	15.107	14.763
Tap water	15.687	23.283	20.253	19.741	9.723	14.437	12.560	12.240
Means (A)	17.430	25.590	22.313		10.805	15.867	13.833	
L.S.D. at 5%	A: 1.727		B: 1.048	AB: 2.011	A: 1.070	B: 0.651		AB: 1.247
	Season 2							
	First cut				**Second cut**			
Magnetized water	23.003	33.477	29.247	28.576	14.263	20.753	18.133	17.717
Tap water	18.827	27.943	24.307	23.692	11.670	17.323	15.070	14.688
Means (A)	20.915	30.710	26.777		12.967	19.038	16.602	
L.S.D. at 5%	A: 2.075		B: 1.260	AB: 2.416	A: 1.282	B: 0.781		AB: 1.494
	Fresh weight of leaves per plant (g)							
	Season 1							
	First cut				**Second cut**			
Magnetized water	36.173	52.633	45.983	44.930	27.403	39.877	34.837	34.039
Tap water	29.600	43.933	38.217	37.250	22.423	33.283	28.953	28.220
Means (A)	32.887	48.283	42.100		24.913	36.580	31.895	
L.S.D. at 5%	A: 3.264		B: 1.976	AB: 3.797	A: 2.472	B: 1.499		AB: 2.877
	Season 2							
	First cut				**Second cut**			
Magnetized water	43.407	63.163	55.180	53.917	32.883	47.853	41.807	40.848
Tap water	35.517	52.723	45.863	44.701	26.910	39.940	34.743	33.864
Means (A)	39.462	57.943	50.522		29.897	43.897	38.275	
L.S.D. at 5%	A: 3.914		B: 2.375	AB: 4.556	A: 2.968	B: 1.801		AB: 3.455

Table (5). Effect of irrigation water type, N-fertilizer rates and their interaction on dry weight of herb, stem and leaves per plant (g) of *Majorana hortensis* plant in 2013/2014 and 2014/2015 seasons.

Irrigation type	N-fertilizer (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
	Season 1				Season 2			
	Fresh weight of root per plant (g)							
Magnetized water	14.553	25.267	22.013	20.611	16.300	28.300	24.657	23.086
Tap water	10.640	19.133	15.653	15.142	11.917	21.430	17.530	16.959
Means (A)	12.597	22.200	18.833		14.108	24.865	21.093	
L.S.D. at 5%	A: 2.894		B: 1.873	AB: 3.444	A: 3.244		B: 2.097	AB: 3.859
	Dry weight of root per plant (g)							
Magnetized water	5.530	9.600	8.363	7.831	6.193	10.753	9.370	8.772
Tap water	4.043	7.266	5.950	5.753	4.527	8.143	6.660	6.443
Means (A)	4.786	8.433	7.156		5.360	9.448	8.015	
L.S.D. at 5%	A: 1.105		B: 0.711	AB: 1.312	A: 1.234		B: 0.799	AB: 1.469
	Length of roots (cm)							
Magnetized water	21.120	32.267	26.400	26.596	22.777	34.797	28.470	28.681
Tap water	11.147	15.253	18.773	15.058	12.023	20.247	16.447	16.239
Means (A)	16.133	25.520	20.827		17.400	27.522	22.458	
L.S.D. at 5%	A: 1.658		B: 4.072	AB: 4.544	A: 1.788		B: 4.391	AB: 4.900

Table (6). Effect of irrigation water type, N-fertilizer rates and their interaction on fresh and dry weights of roots per plant (g) and length of roots (cm) of *Majorana hortensis* plant in 2013/2014 and 2014/2015 seasons.

Irrigation type	N-fertilizer (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
	Dry weight of herb per plant (g)							
	Season 1							
	First cut				Second cut			
Magnetized water	19.370	28.183	24.623	24.059	13.750	20.010	17.480	17.080
Tap water	15.853	23.523	20.463	19.947	11.253	16.703	14.530	14.162
Means (A)	17.612	25.853	22.543		12.502	18.357	16.005	
L.S.D. at 5%	A: 1.750	B: 1.060		AB: 2.036	A: 1.240		B: 0.755	AB: 1.445
	Season 2							
	First cut				Second cut			
Magnetized water	23.243	33.827	29.550	28.873	16.503	24.013	20.977	20.498
Tap water	19.020	28.233	24.560	23.938	13.503	20.043	17.437	16.994
Means (A)	21.132	31.030	27.055		15.003	22.028	19.207	
L.S.D. at 5%	A: 2.102	B: 1.274		AB: 2.446	A: 1.494		B: 0.904	AB: 1.737
	Dry weight of stem per plant (g)							
	Season 1							
	First cut				Second cut			
Magnetized water	6.710	9.763	8.530	8.334	4.160	6.053	5.286	5.166
Tap water	5.490	8.153	7.086	6.910	3.406	5.053	4.396	4.285
Means (A)	6.100	8.958	7.808		3.783	5.553	4.841	
L.S.D. at 5%	A: 0.599	B: 0.367		AB: 0.700	A: 0.384		B: 0.226	AB: 0.443
	Season 2							
	First cut				Second cut			
Magnetized water	8.053	11.713	10.237	10.001	4.9933	7.2633	6.3467	6.2011
Tap water	6.590	9.780	8.507	8.292	4.0833	6.0633	5.2733	5.1400
Means (A)	7.322	10.747	9.372		4.5383	6.6633	5.8100	
L.S.D. at 5%	A: 0.731	B: 0.440		AB: 0.849	A: 0.450		B: 0.272	AB: 0.523
	Dry weight of leaves per plant (g)							
	Season 1							
	First cut				Second cut			
Magnetized water	12.660	18.420	16.093	15.724	9.590	13.957	12.197	11.914
Tap water	10.360	15.380	13.377	13.039	7.847	11.650	10.133	9.877
Means (A)	11.510	16.900	14.735		8.718	12.803	11.165	
L.S.D. at 5%	A: 1.147	B: 0.691		AB: 1.332	A: 0.862		B: 0.525	AB: 1.005
	Season 2							
	First cut				Second cut			
Magnetized water	15.193	22.107	19.310	18.870	16.503	24.013	20.977	20.498
Tap water	12.430	18.453	16.053	15.646	13.503	20.043	17.437	16.994
Means (A)	13.812	20.280	17.682		15.003	22.028	19.207	
L.S.D. at 5%	A: 1.373	B: 0.833		AB: 1.598	A: 1.494		B: 0.904	AB: 1.737

2.3. Effect of interaction

From the data presented in tables (4, 5 and 6) and fig. (2), it is obvious that increasing N-fertilizer rates under the two types of water irrigation increased the fresh and dry weights of herb, leaves, stem, root and roots length per plant. However, the superior result in this concern was obtained by using magnetized water treatment in all cases, which gave highly significant increase comparing with other interactions.

Moreover, the interaction treatments between type of irrigation water and N-fertilizer rates gave highly significant increase in fresh and dry weights of herb, leaves, stem and root per marjoram plant comparing with that of other treatments.

The treatments of magnetized water with 7/g and tab water with 14/g of N-fertilizer increased fresh and dry weights of herb, leaves, stem, root and roots length per plant, but this increase was insignificant compared with using tap water only. Also, the treatments of tap water with 7/g of N-fertilizer and magnetized water increased fresh and dry weights of herb, leaves, stem, root and roots length per plant, but this increase was insignificant compared to using tap water only. These results were recorded in the two cuts in two seasons.

The increase of growth may be due to that magnetized water increases plant growth by facilitating the absorption of water by root cells, as water becomes a good carrier for foodstuffs. Thus it encourages the active role of the nitrogen, which leads to an increase in photosynthesis and production of plant hormones and increasing the production of the protein, which is reflected in the increase in growth. These results are in harmony with those obtained by Atak et al. (2000) on paulownia seeds, Maheshwari et al. (2000) on psyllium plants and Çelik et al. (2008) on Paulownia node.

3. Essential Oil Production and Chemical Constituents

3.1. Effect of irrigation water type

Data presented in table (7) reveal that, essential oil production including essential oil percentage and essential oil yield (ml/plot) increased when irrigated with magnetized water. Moreover, treatments gave an increase in essential oil production; including essential oil percentage and essential oil yield (ml/plot) compared with irrigation with tap water (unmagnetized water). Furthermore, irrigation with magnetized water led an increase in essential oil production; including essential oil percentage and essential oil yield (ml/plot) compared to irrigated plant with tap water.

This increment in these parameters may be due to the magnetized water that increased the vegetative growth and was reflected in essential oil percentage. These results were in agreement with those obtained by Hilal et al. (2002) on citrus and Alsafar and Al-Hassan (2009) on *Mentha longifolia* plant.

3.2. Effect of N-fertilizer rates

Data recorded in table (7) show that, N-fertilizer rates increased essential oil production including essential oil percentage and essential oil yield (ml/plot) in comparison with control in the two cuts in both seasons. Moreover, increasing N-fertilizer rates increased essential oil production including essential oil percentage and essential oil yield (ml/plot). Furthermore, the superior treatment in this respect was that of N-fertilizer rates 14g/pot which gave higher increase in these parameters in the two cuts in both seasons. Generally, the essential oil percentage and essential oil yield (ml/plot) were higher in the second cut than first cut.

The increment in the essential oil percentage and essential oil yield (ml/plot) as a result of N-fertilizer rates could be attributed to the effective role of nitrogen in enhancing vegetative growth and essential oil percentage in plant. These results are in accordance with those obtained by Singh and

Ramesh (2000) on rosemary and Omer et al. (2008) on *Ocimum americanum*.

3.3. Effect of interaction

The results presented in table (7) indicate that increasing N-fertilizer rates under type of irrigation water increased essential oil production; including essential oil percentage and essential oil yield (ml/plot) of marjoram plant. The interaction between all treatments gave increase in these parameters and this increase was significantly compared to each treatment and control (tap water). The highest values in this respect were obtained by using 14 g/pot of N-fertilizer rates combined with using magnetized water, comparing with the other interactions. This treatment gave highly significant increase comparing with other interactions. These results hold true in the two cuts in both seasons.

The reason for increasing essential oil may be due to that magnetized water led to the revitalization of the active role of nitrogen and thus led to an increase in the plant growth, which led to an increase in essential oil percentage and yield (ml/plot). These results are in accordance with those obtained by Alsafar and Al-Hassan (2009) on *Mentha longifolia* plant and Maheshwari and Grewal (2009) on vegetables crop.

On the other hand, data presented in table (8) illustrate that the essential oil of marjoram plants obtained from the dry herb in the second cut of the second season (2014/2015) was analyzed by using GC Mass. The percentage of the main components were calculated and presented in table (8) and fig. (1, 2, 3, 4, 5 and 6). Data show that terpinen-4-ol is the major compound in marjoram oil.

Table (7). Effect of irrigation water type, N-fertilizer rates and their interaction on essential oil percentage and yield per plant (ml) of *Majorana hortensis* L plant in2013/2014 and 2014/2015 seasons.

Irrigation type	N-fertilizer (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
	Essential oil percentage							
	Season 1							
	First cut				Second cut			
Magnetized water	0.753	1.396	1.263	1.137	0.680	1.260	1.136	1.025
Tap water	0.540	1.136	1.023	0.900	0.490	1.023	0.923	0.812
Means (A)	0.646	1.266	1.143		0.585	1.141	1.030	
L.S.D. at 5%	A: 0.064	B: 0.062		AB: 0.092	A: 0.058	B: 0.057		AB: 0.084
	Season 2							
	First cut				Second cut			
Magnetized water	0.830	1.536	1.390	1.252	0.743	1.386	1.253	1.127
Tap water	0.593	1.253	1.123	0.990	0.530	1.126	1.013	0.890
Means (A)	0.711	1.395	1.256		0.636	1.256	1.133	
L.S.D. at 5%	A: 0.071	B: 0.067		AB: 0.101	A: 0.064	B: 0.062		AB: 0.092
	Essential oil yield per plant (ml)							
	Season 1							
	First cut				Second cut			
Magnetized water	0.146	0.393	0.313	0.284	0.156	0.423	0.336	0.305
Tap water	0.086	0.266	0.206	0.186	0.093	0.286	0.226	0.202
Means (A)	0.116	0.330	0.260		0.125	0.355	0.281	
L.S.D. at 5%	A: 0.034	B: 0.020		AB: 0.039	A: 0.036	B: 0.021		AB: 0.041
	Season 2							
	First cut				Second cut			
Magnetized water	0.193	0.520	0.410	0.374	0.123	0.330	0.266	0.240
Tap water	0.116	0.353	0.276	0.248	0.073	0.226	0.176	0.158
Means (A)	0.155	0.436	0.343		0.098	0.278	0.221	
L.S.D. at 5%	A: 0.041	B: 0.023		AB: 0.047	A: 0.033	B: 0.015		AB:0.036

Table (8). Effect of irrigation water type, N-fertilizer rates and their interaction on essential oil component of *Majorana hortensis* L plants in the second cut of 2014/2015 season.

Oil components % \ Treatments	RT	Magnetized water + 14 g/pot	Magnetized water + 7 g/pot	Magnetized water	Tap water	Tap water + 7 g/pot	Tap water + 14 g/pot
1-Phellandrene	4.57	0.35	0.39	0.35	0.42	0.33	0.35
α-Pinene	4.77	0.56	0.61	0.62	0.60	0.61	0.58
Sabinene	5.80	4.86	5.63	5.30	5.91	5.38	5.10
β -Pinene	5.96	0.33	0.35	0.34	0.35	0.36	0.33
α-Myrcene	6.23	1.08	0.94	0.70	0.89	0.85	0.79
α-Terpinene	7.12	5.91	6.51	5.12	4.31	3.46	4.27
O-Cymene	7.44	3.75	3.07	3.29	4.21	4.55	5.00
D-Limonene	7.53	1.08	1.08	1.01	1.12	1.11	1.07
α-Phellandrene	7.62	1.13	1.23	1.17	1.08	1.09	1.04
Ç-Terpinene	8.54	12.45	12.34	9.65	8.81	7.57	8.87
Terpineol	9.06	0.13	2.55	5.43	6.27	6.75	3.68
α -Terpinolene	9.50	2.40	2.48	1.93	1.91	1.66	1.87
L-Linalool	10.15	3.48	2.35	1.59	2.64	1.99	2.00
4-Thujanol	10.24	0.29	6.48	15.85	15.39	20.17	8.98
Terpenene-1-ol	11.16	1.15	1.53	1.78	1.67	1.73	1.63
2-Cyclohexen-1-ol	11.91	0.92	0.99	0.85	0.80	0.78	0.97
L-Menthone	12.87	0.09	0.05	0.19	0.06	0.14	0.41
1-Borneol	13.16	0.12	0.13	0.10	0.05	0.07	0.10
Terpineol-4-ol	13.49	43.38	34.15	32.54	26.41	27.50	32.46
α-Terpineol	14.16	3.53	2.99	2.85	2.97	3.21	3.43
2-Cyclohexen-1-ol	14.72	0.50	0.36	0.17	0.24	0.23	0.44
Linalyl acetate	16.20	6.35	6.70	2.97	5.66	3.36	5.19
Bornyl acetate	17.74	0.18	0.36	0.12	0.29	0.27	0.36
4-Terpinenyl acetate	18.24	0.26	0.37	0.24	0.38	0.26	0.42
Caryophyllene	23.18	2.97	3.01	2.81	3.84	3.22	4.19
α-Humulene	24.70	0.11	0.11	0.12	0.14	0.12	0.10
Bicyclogermacrene	26.33	1.70	2.45	1.73	2.36	1.90	1.75
Spathulenol	29.71	0.11	0.10	0.06	0.17	0.36	0.34
Caryophyllene oxide	29.84	0.19	0.19	0.27	0.28	0.27	0.48
Ç-eudesmol	31.40	0.14	0.10	0.34	0.17	0.22	1.14
Isospathulenol	31.84	0.13	0.07	0.10	0.21	0.10	0.29

Thirty compounds accounting for more than 99% of the total volatiles in most marjoram samples were detected and identified. There are differences in oil composition as affected by type of irrigation water and different rates of N-fertilizer. The predominant compounds presented under all treatments were recorded in table (8). Data revealed that application of magnetized water with 14 g/pot of N-fertilizer recorded the highest percentage of terpinen-4-ol (the major compound in marjoram oil), α-terpinene, α-phellandrene, Ç-terpinene, α-terpinolene, L-linalool, 2-cyclohexen-1-ol, L-menthone, 1-

borneol, α-terpineol and 2-cyclohexen-1-ol and linalool acetate, accompanied by a decrease in the other components, compared to the tap water (unmagnetized water) and other treatments. Some of these components are used for scenting cosmetics and others are used for flavoring pharmaceuticals; such as D-limonene and linalool (Refaat, 1988).

4. Total Carbohydrate Percentage

4.1. Effect of irrigation water type

The data reported in table (9) indicate that, irrigation with magnetized water treatment gave an increase in total carbohydrate percentage compared to irrigation with tap water, and this increase is statistically significant. These results hold the same direction in the two seasons.

These results may be due to the easy absorption of magnetized water by roots that has led to an increase in the absorption of nutrients and thus increases the photosynthesis process, leading to an increase in the material tending starchy and sugary and thus an increase in carbohydrate percentage (Pietruszewski, 1999).

4.2. Effect of N-fertilizer rates

From data presented in table (9), it is obvious that, N-fertilizer treatments increased total carbohydrate percentage compared to control in the two seasons. Moreover, the best treatment in increasing total carbohydrate percentage was 14 g/pot and the results were statistically significant.

These results may be due to the effective role of N-fertilizer rates with the suitable role for increasing the plant growth and consequently increasing the absorption rate of elements and increasing the photosynthesis, which was reflected in enhancing the percentage of carbohydrate. These results are in agreement with those reported by Kumawat and Gaur (2004) on psyllium and El-Shakry (2005) on sweet fennel plants.

4.3. Effect of interaction

The results presented in table (9) indicate that, increasing N-fertilizer rates under type of irrigation water increased total carbohydrate percentage of majoram plant.

The interaction between using magnetized water plus 14 g/pot, magnetized water plus 7 g/pot and tap water plus 14 g/pot of N-fertilizer treatments gave increase in total carbohydrate percentage, and this increase was significant, compared to other treatments and control (tap water). However, the treatments of tap water plus 14 g/pot, tap water plus 7 g/pot and magnetized water gave an increase in total carbohydrate percentage and this increase was insignificant compared to each of the other treatments and control treatment (tap water). The highest values in this respect were obtained by using 14 g/pot of N-fertilizer combined with magnetized water comparing with the other interactions. This treatment gave a highly significant increase comparing with other interactions. These results hold the same direction in the two seasons.

These results may be attributed to the speed of roots absorption of magnetized water to an increase in the absorption of nutrients, which led to revitalize the role of nitrogen and an increase in photosynthesis, and therefore, tend to increase carbohydrates (Jones, 1986). These results are in agreement with those obtained by Omer et al. (2008) on *Ocimum americanum*.

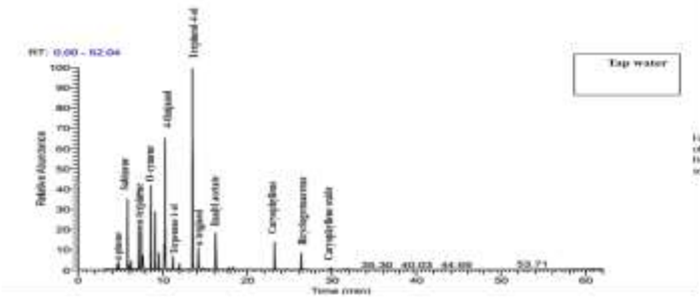

Figure (1): chromatogram of marjoram oil extracted from tap water during the second season 2014-2015

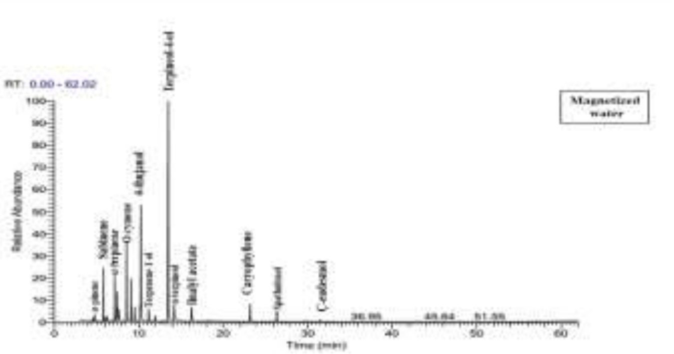

Figure (2): chromatogram of marjoram oil extracted from magnetized water during the second season 2014-2015

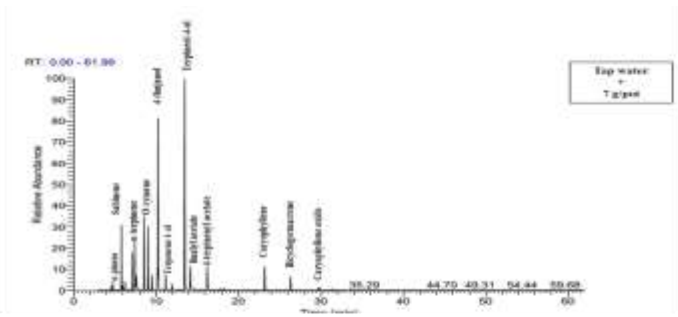

Figure (3): chromatogram of marjoram oil extracted from tap water plus 7g/pot ammonium sulfate treatment during the second season 2014-2015

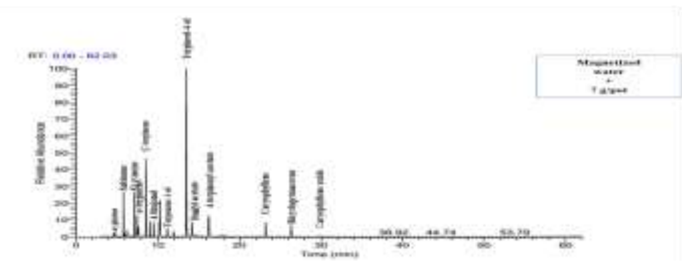

Figure (4): chromatogram of marjoram oil extracted from magnetized water plus 7g/pot ammonium sulfate treatment during the second season 2014-2015

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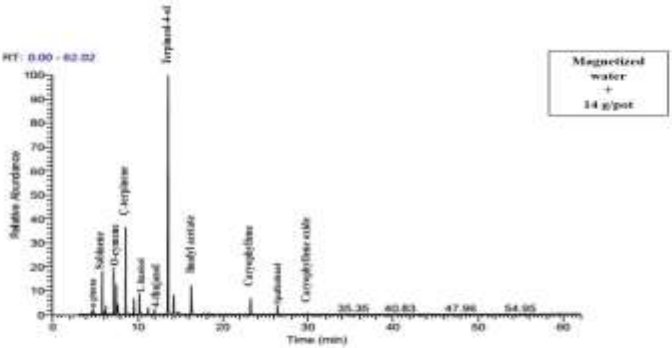

Figure ([illegible]): chromatogram of marjoram oil extracted from tap water plus 14g/pot ammonium sulfate treatment during the second season 2014-2015

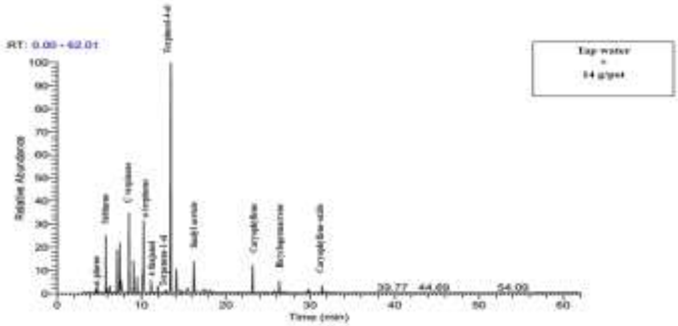

Figure ([illegible]): chromatogram of marjoram oil extracted from magnetized water plus 14g/pot ammonium sulfate treatment during the second season 2014-2015

5. Total Nitrogen, Phosphorus and Potassium Percentages

5.1. Effect of irrigation water type

Table (9) showed that, plants irrigated with magnetized water, total nitrogen, phosphorus and potassium percentages increased in the two cuts in both seasons. At the same time, these parameters were significantly increased as a result of using magnetized water treatment compared to the other treatments. The superior treatments in this concern were that irrigation of plants with magnetized water, which showed higher increase in this respect compared to the other treatments in the two seasons.

The increase may be due to the role of magnetized water in excess soluble salts in the soil and increase the efficiency of absorption and movement of nutrients from the soil to the roots and then speed to shoot (Kronenberg, 2005). These results are in line with those stated by Atak et al. (1997) and Özalpan et al. (1999) on soybean.

5.2. Effect of N-fertilizer rates

From the data presented in table (9), it is obvious that, N-fertilizer rates at all treatments increased total nitrogen, phosphorus and potassium percentages compared to control in the two seasons. Moreover, the best treatment for increasing total nitrogen, phosphorus and potassium percentages was tap water with 14 g plus/pot of N-fertilizer.

These results may be due to the effective role of N-fertilizer with the suitable role for increasing the plant growth and consequently increasing the absorption rate of N, P and K, which was reflected in enhancing the percentages of these elements. Such results are in harmony with those reported by Dasha et al. (2006) on *Mentha arvensis* and Phuong et al. (2008) on *Ocimum basilicum*.

5.3. Effect of interaction

As shown in table (9), it is clear that the plants irrigated with magnetized water under N-fertilizer rates; nitrogen, phosphorus and potassium percentages increased and this increase was significant compared to other treatments and control (tap water). Moreover, the interaction between types of irrigation water under N-fertilizer rates caused significant increase in nitrogen, phosphorus and potassium percentages of marjoram plant. Also, increasing the N-fertilizer rates under type of water irrigation caused a significant increase in total nitrogen, phosphorus and potassium percentages. However, the superior treatments in this regard were plants irrigated with magnetized water and using 14 g/pot N-fertilizer comparing to other treatments.

It may be caused as a result of that magnetized water and nitrogen led to increasing the efficiency of nutrient uptake and increased movement of nutrients from the soil to the roots and thus increases the absorption rate of N, P and K, which was

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reflected in strengthening the ratios of these elements within the plant cells (Namba et al., 1995). These results agree with those obtained by Oldacay and Erdem (2002) on *Helianthus annuus*, and Dasha et al. (2006) on *Mentha arvensis*.

Table (9). **Effect of irrigation water type, N-fertilizer rates and their interaction on total carbohydrate, nitrogen, phosphorus and potassium percentages of *Majorana hortensis* plant in 2013/2014 and 2014/2015 seasons.**

Irrigation type	N-fertilizer (B)							
	Control	14 g/pot	7 g/pot	Means (B)	Control	14 g/pot	7 g/pot	Means (B)
	Season 1				Season 2			
	Total carbohydrate percentage							
Magnetized water	15.267	18.433	16.700	16.800	16.793	20.277	18.370	18.480
Tap water	12.400	14.000	13.133	13.178	13.640	15.400	14.447	14.496
Means (A)	13.833	16.217	14.917		15.217	17.838	16.408	
L.S.D. at 5%	A: 2.111	B: 0.606		AB: 2.164	A: 2.322	B: 0.666		AB: 0.942
	Nitrogen percentages							
Magnetized water	1.850	2.203	2.050	2.034	2.036	2.423	2.256	2.238
Tap water	1.223	1.683	1.300	1.402	1.346	1.853	1.433	1.544
Means (A)	1.536	1.943	1.675		1.691	2.138	1.845	
L.S.D. at 5%	A: 0.084	B: 0.072		AB: 0.113	A: 0.089	B: 0.081		AB: 0.124
	Phosphorus percentages							
Magnetized water	1.073	2.183	2.023	1.7600	1.180	2.403	2.226	1.936
Tap water	0.130	0.183	0.160	0.157	0.140	0.203	0.180	0.174
Means (A)	0.601	1.183	1.091		0.660	1.303	1.203	
L.S.D. at 5%	A: 0.017	B: 0.0366		AB: 0.0450	A: 0.0172	B: 0.0410		AB: 0.0497
	Potassium percentages							
Magnetized water	1.073	2.183	2.023	1.760	1.180	2.403	2.226	1.936
Tap water	0.130	0.183	0.160	0.157	0.140	0.203	0.180	0.174
Means (A)	0.601	1.183	1.091		0.660	1.303	1.203	
L.S.D. at 5%	A: 0.017	B: 0.036		AB: 0.045	A: 0.017	B: 0.041		AB: 0.049

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