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INFLUENCE OF MAGNETIC WATER ON FRENCH BASIL (*OCIMUM bASILICUM*, L. VAR GRANDVERT) PLANT GROWN UNDER WATER STRESS CONDITIONS

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Abstract

The present study was conducted during 2018 and 2019 seasons in the Experimental Research and Production Station of National Research Centre, Nubaria Region, Behira Governorate, Egypt to investigate the effect magnetic water treatments (*i.e*., magnetic (MW_1) and un-magnetic water (MW_0) under three levels of field capacity (FC, 100, 80 and 60%) on the soil moisture content, growth, yield, volatile oil production and water productivity of French basil (*Ocimum basilicum*, L. var Grandvert**).** The obtained results are summarized as follows: the irrigation intervals were converging under 100% of the FC, when compared with 80 and 60% of FC, for magnetic and un-magnetic water during growth stages of both growing seasons. The soil moisture values were increased by irrigated with magnetic water compared with un-magnetic water at 100, 80 and 60 % of the FC, during the two growing seasons. In all cuts in both seasons, the plants treated with magnetic water (MW_1) + 100% FC, showed significantly stimulation in growth characters, *i.e* branches (number plant^{-1}), herb fresh and dry weights (g plant^{-1}) / ton ha^{-1} (hectare) as well as volatile oil production, the exception was in case of plant height (cm) which showed a significant decrease. The results of GLC analysis of French basil volatile oil indicated that, the highest linalool content the main component (62.33was produced with (MW_1 + 100% FC). The increment in volatile oil production was the same trend in water productivity under magnetic and 100% of (FC) for two growing seasons. As for high water productivity, the higher yield with lower water consumption, gives higher water productivity.

Keywords: Irrigation treatments, magnetic water, oil yield, water productivity and French basil.

Introduction

Basil (*Ocimum basilicum* L.) is a herbaceous plant belongs to Lamiaceae family, which has been grown for its volatile oil and herb for market or as an ornamental plant (Simon *et al.,* 1990). Basil is used in food industry as a flavoring agent and also in perfumery and medical industries (Omidbaig, 2005). The growth and volatile oil production are influenced by various environmental conditions, such as water stress (Hasegawa *et al.,* 2000). Parida and Das (2005) reported that, secondary products of plants can altered by environmental factors affecting the synthesis of natural products. As water is required for almost all biochemical and physiological processes, its shortage is harmful for their normal growth and development (Rao *et al.,* 2016). Water stress affects various metabolic activities including photosynthesis in plant (Khalili and Naghavi, 2017). The leaf of gas exchange traits such as assimilation, transpiration, stomatal conductance water use efficiency. Reduction of the photosynthetic electron chain occurred due to stomatal closure and a decrease in co_2 fixation under water stress (Khan *et al.*, 2017). According to the limitation of water resources, water should be utilized as a rare commodity. A number of approaches could be followed to maximize the water use efficiency, some of them are related to the soil, and some are related to the plant, and others belong to the water supply to the plant (Marwa**,** *et al.,* 2017).

Recently, various approaches have been used to alleviate the water stress among agricultural crops. These

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include nutritional management strategies, the application of chemical and biological amendments (including mycorrhizal applications). Some modern technologies have been used for environmental management and nanotechnology (Fakhri and Behrouz, 2015). Magnetic water (MW) technology is one of the environmental friendly and cost effective techniques recently used on agricultural field to improve growth and yield (Aly *et al.,* 2015 and Hozayn *et al.,* 2019). MW is generated by treating normal water with a magnetic field, resulting in the rearrangement of water structure. Many researchers have reported the beneficial effects of MW in the agricultural production (Aladjadjiyan, 2007, Hozayn *et al.,* 2016 and Hasan *et al.,* 2019). Therefore, it was hypothesized that this technique may also improve plant physiology and growth characteristic under water stress. This study was carried out to investigate the effect of magnetic water treatments and water stress on soil moisture content, growth, yield and volatile oil production of French basil.

Material and Method

Field experiment was carried out at the Experimental Research and Production Station of National Research Centre, Nubaria region, Behira Governorate, Egypt during the two successive seasons of 2018 and 2019 to study the effect of magnetic irrigation water treatments (*i.e.,* magnetic water (MW_1) and un-magnetic water (MW_0) under different field soil capacities (FC) (*i.e.,* 100, 80 and 60% of FC) on the growth, yield and volatile oil components and production of French basil (*Ocimum basilicum* L. var. Grandvert). The two factors were layout in split-plot design with three replications where magnetic water and field capacity (FC) treatments were occupied in the main and sub-plots, respectively. The layout of the experiment is shown in Fig. (1). The experimental soil and water were analyzed according to the method described by (Chapman and Pratt, 1978) is shown in Table (1).

Table 1: Soil and water analyzed.

Parameters	Soil depth (cm)		Irrigation water	
	0 – 15	15 - 30	Before magnetic	After magnetic
Particle size distribution:				
Coarse sand	48.20	54.75	-	-
Fine sand	49.11	41.43	-	-
Clay+ Silt	2.69	3.82	-	-
Texture	Sandy	Sandy	-	-
pH (1:2.5)	8.22	7.94	7.25	7.13
EC (dSm^{-1}) (1:5)	0.20	0.15	0.50	0.40
Organic matter(%)	0.67	0.43	-	-
Soluble cations mg/L				
Ca^{++}	0.60	0.50	2.15	2.05
Mg^{++}	0.50	0.30	0.50	0.65
Na^{++}	0.90	0.80	3.00	3.00
K^{++}	0.20	0.10	0.31	0.31
Soluble anions mg/L				
Co_3^{++}	-	-	0.01	0.01
HCo_3^{++}	0.60	0.40	2.33	2.46
Cl^-	0.75	0.70	2.17	1.72
So^{-4}	0.85	0.60	1.45	1.82
θS % on weight basis				
Field Capacity	12.00	12.00	-	-
Wilting Point	4.10	4.10	-	-
Available Water	7.90	7.90	-	-
Hydraulic conductivity (cm h^{-1})	6.68	6.84	-	-
Bulk density (g cm^3)	1.69	1.69	-	-

Cultivation methods and layout of experiment:

The soil was ploughed twice, divided into main (112.5 m^2) and sub-plots (37.5 m^2) with total area 675.5 m^2. During soil preparation, 952 kg ha^{-1} calcium superphosphate (15.5% P_2O_5) was applied. (*Ocimum basilicum* L. var. Grandvert) seedlings (12- 15 cm in length with 10-12 leaves) were obtained from Medicinal and Aromatic Plants Research Department, Dokki, Giza. The seedlings were planted on 20 April in both seasons, in lines (Furrows) at 0.25 m apart and 0.6 m between furrows. Drip irrigation took place before planting and plants were re-irrigated after planting, then irrigation was regulated during the period of experiment. Nitrogen fertilizer as ammonium sulfate (20.60 N%) at the rate of 1071kg N ha^{-1} was added in three equal doses starting 30 days after planting, the second dose was applied one month after the first one and the third was done 15 days after the first cut. While, potassium fertilizer at the rate of 238 kg ha^{-1}as potassium sulfate (48% K_2O) was added in two equal doses, the first one was applied 30 days after planting, the second was added two weeks after the first cut.

Insulation drip irrigation system and layout of experiment:

Drip irrigation system was constructed and tested hydraulically before used in the experimental location. The laterals drip irrigation network were 16 mm diameter, P.E. and the emitters were built-in (GR) with an average discharge 4.0 l h^{-1} at 1.0 bar operating pressure and 0.3 m emitter spacing. Laterals spacing were 0.6 m. Description of drip irrigation system and layout of experiment are shown in Fig (1).

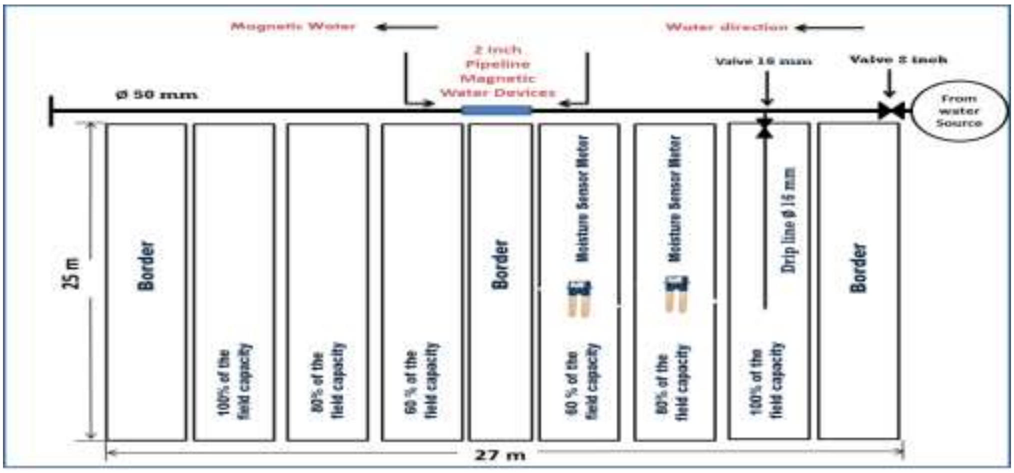

Fig. 1. Description of drip irrigation system and layout of experimental design.

Monthly averages of climate data:

Table 2: Average of the monthly climate data at the experimental site during the two growing seasons

Month	Temperature (°C)		Relative humidity (%)	Wind (m S^{-1})	Sun (hours)	Solar Radiation (MJm^{-2} day^{-1})	Eto (mm day^{-1})
	Min	Max					
First season							
Apr-18	14.40	27.00	54.00	2.90	10.60	24.40	5.46
May-18	18.70	30.80	54.00	3.30	11.40	26.80	6.73
Jun-18	21.20	32.90	52.00	3.30	13.10	29.60	7.68
Jul-18	22.80	33.90	58.00	3.70	13.10	29.40	7.78
Aug-18	23.40	33.70	60.00	3.40	12.20	27.00	7.13
Sept. 2018	22.30	32.30	61.00	3.30	10.90	23.00	6.12
Second season							
Apr-19	14.60	27.50	56.00	4.40	10.60	24.40	6.05
May-19	18.90	31.80	54.00	3.80	11.40	26.80	7.15
Jun-19	21.60	32.90	53.00	3.70	13.10	29.60	7.88
Jul-19	22.90	34.10	59.00	3.90	13.10	29.40	7.85
Aug-19	23.70	33.90	60.00	3.80	12.20	27.00	7.36
Sept. 2019	22.60	33.00	61.00	3.40	10.90	23.00	6.26

Description of treatments:

a- Magnetic water treatments:
  - Water treatment was done after magnetization through a two inch Magnetron (U.T.3. Technologies, LLC POBox 27559, Dubai, UAE).

b- Normal water (un-magnetic water) treatment, as a control.

Water requirements at 60, 80 and 100 % of field capacity under magnetic and un- magnetic water and were determined with Automatic Tensiometers (Irrometer brand Model RA). The Automatic Tensiometers are an instrument to record soil moisture. As soil moisture is depleted, a vacuum is created which is registered by the indicating needle on the gauge of the "IRROMETER". The adjustable selector switch can be set to any desired moisture level as shown in Fig. (2).

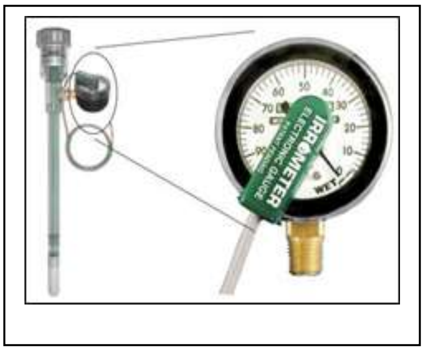

Fig. 2. Automatic Tensiometer (IRROMETER).

Calibration of Tensiometers:

To calculate the soil moisture at different pressures and vice versa, *i.e.*, the possibility of determining the pressure equivalent to the reading on the “IRROMETER” tube when the moisture content refers to irrigation demand. Fig. 3 was used to find the pressure equal to the “IRROMETER” reading (bar). When (100, 80 and 60) % of the water content at FC the water contents in the soil are (12, 10.22 and 7.2 cm^3 cm^{-3}) and the proper pressure is equal to 0.33, 0.65 and 0.82 bar) respectively.

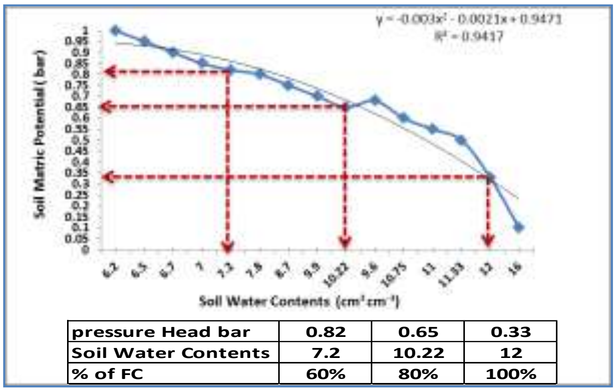

Fig. 3. Determination of pressure head meeting soil water contents.

Data recorded:

Soil moisture content:

Soil moisture was measured using a soil moisture device (WaterScout SM 100 Soil Moisture Sensor, Field Scout Soil Sensor Reader, Specmeter Technologies, Inc.) at different depths, (0-20 and 20-40 cm).

Growth and yield of French basil plant at harvest time:

The plants were harvested twice, the first cut was done on 22th July and the second one on 12 th September in both seasons and the two harvests were weighted as fresh and dry herb.A random sample of plants were taken from each plot to determine plant height (cm), branches (no $plant^{-1}$) and herb fresh and dry weights (g $plant^{-1}$).

Volatile oil content and composition:

Volatile oil percentage was determined according to (British Pharmacopeia, 1963) and volatile oil yield (ml $plant^{-1}$) and (L ha^{-1}) were calculated. Chemical composition of volatile oil was determined using (GLC) analysis as described by (Hoftman, 1967 and Bunzen *et al.*, 1969).

Water productivity (L m^{-3}):

Water productivity (L m^{-3}) is an indicator of the relationship between total oil productivity L ha^{-1} (Marketable crop) and the total amount of applied water (m^3 ha^{-1}) during the crop growth season.

Statistical analysis:

The analysis of variance (ANOVA) was conducted and the means of the treatments were compared using L.S.D. at 5%, according to (Snedecor and Cochran, 1980).

Results and Discussion

Irrigation intervals and Soil moisture content:

Appropriate irrigation intervals and frequency help to maximize soil moisture distribution, crop yield and water productivity (Zhang *et al.*, 2019). Figs. (4) and (5) showed the irrigation intervals under magnetic and un-magnetic water at 100, 80 and 60 % of the FC, of 2018 and 2019 growing seasons. In general, the irrigation intervals were converging under 100% of the FC, when compared with 80 and 60% of FC, for magnetic and un-magnetic water during growth stages of 2018 and 2019 growing seasons. This led to a uniformity in the soil moisture distribution, water uptake by roots and maintained of a regular moisture in the root zone. These results are harmony with (Assouline, 2002 and Wang *et al.*, 2006). The lowest regularity of irrigation intervals was under 60% of FC, followed by 80% of FC, during the growth stages of both seasons under magnetic and un-magnetic water.

Also, Figs. (4) and (5) presented that, there was a difference in the irrigation intervals between 2018 and 2019 growing seasons under 100% of FC. The irrigation intervals from 12-Jun to 31-Jul, period were daily under 100% of FC, for the season of 2019, with an average of 5.51 mm/day (with 276 mm per this period), but the irrigation intervals were day by day under 100% of FC, for the season of 2018, with an average of 5.42 mm/day (271.5 mm per the same period). Due to the difference in the average of evapotranspiration (ETo), and the Automatic Tensiometer sensitivity (on / off) to the soil moisture changes and the sudden evaporation from the soil, this led to the changed in irrigation intervals during this period in 2018 and 2019 seasons (Abdrabbo *et al.*, 2015).

The volumetric soil moisture content (m^3) in soil depths under magnetic and un-magnetic water at 100, 80 and 60 % of the FC, of 2018 and 2019 growing seasons are shown in Figs.(4) and (5). The results indicated that, the magnetic water and irrigation at field capacity (FC) treatments had a significant effect on soil moisture content in the two seasons. The highest values of soil moisture content were under magnetic water at 100% for 2018 and 2019 seasons. Fig. (4) showed that, the measured values of soil moisture content were increased by around 7.3, 2.7 and 2.5% in soil depth 0-20 cm and 1.6, 4.5 and 4.1% in soil depth 20-40 cm, under magnetic water compared with un-magnetic water at 100, 80 and 60 % of the FC, respectively during the 2018 growing season. This is due to the irrigation magnetic water change the soil moisture distribution in the soil depths, and it can change the soil moisture content and water storage (Cao *et al.*, 2003). The same trend values of soil moisture content were observed in the second season as presented in Fig.(5). The measured values were increased by around 4. 2.9, 2.7 and 2.5% in soil depth 0-20 cm and 3, 4.4 and 4.0% in soil depth 20-40 cm, under magnetic water compared with un-magnetic water at 100, 80 and 60 % of the FC, respectively during the 2019 growing season.

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The application of irrigation at field capacity (FC) had a significant effect in both seasons. The results indicated that, the highest values of the soil moisture content were obtained under irrigated at 100% FC, the lowest values of the soil moisture content were obtained under irrigated at 60% FC, under magnetic and un-magnetic water in all soil layers during the two growing seasons. While there is a slight difference in the soil moisture data at 80 and 60% of the FC, under magnetic and un-magnetic water in all soil layers during the two growing seasons. These results are consistent with (El-Noemani *et al.*, 2015a, El-Noemani *et al.*, 2015b, Wahba *et al.*, 2016, El-Shafie *et al.*, 2017, Marwa *et al.*, 2017 and Youssef *et al.*, 2018).

Growth parameters:

Plant height and number of branches / plant:

Data in Table (3) showed that, magnetic water (MW_1) and irrigation at field capacity (FC) had a significant effect on plant height and number of branches/ plant in the two seasons.

It could be noticed that, the highest values of plant height in the first and second cuts for the two seasons recorded when plants were irrigated with un-magnetic water (control) giving 54.90 and 52.38 cm for the first and second cuts in the first season, respectively. The same trend was observed in the second season, giving 60.51 and 57.48 cm. The shortest plants were these plants irrigated with magnetic water (MW_1) in both seasons.

Season of 2018

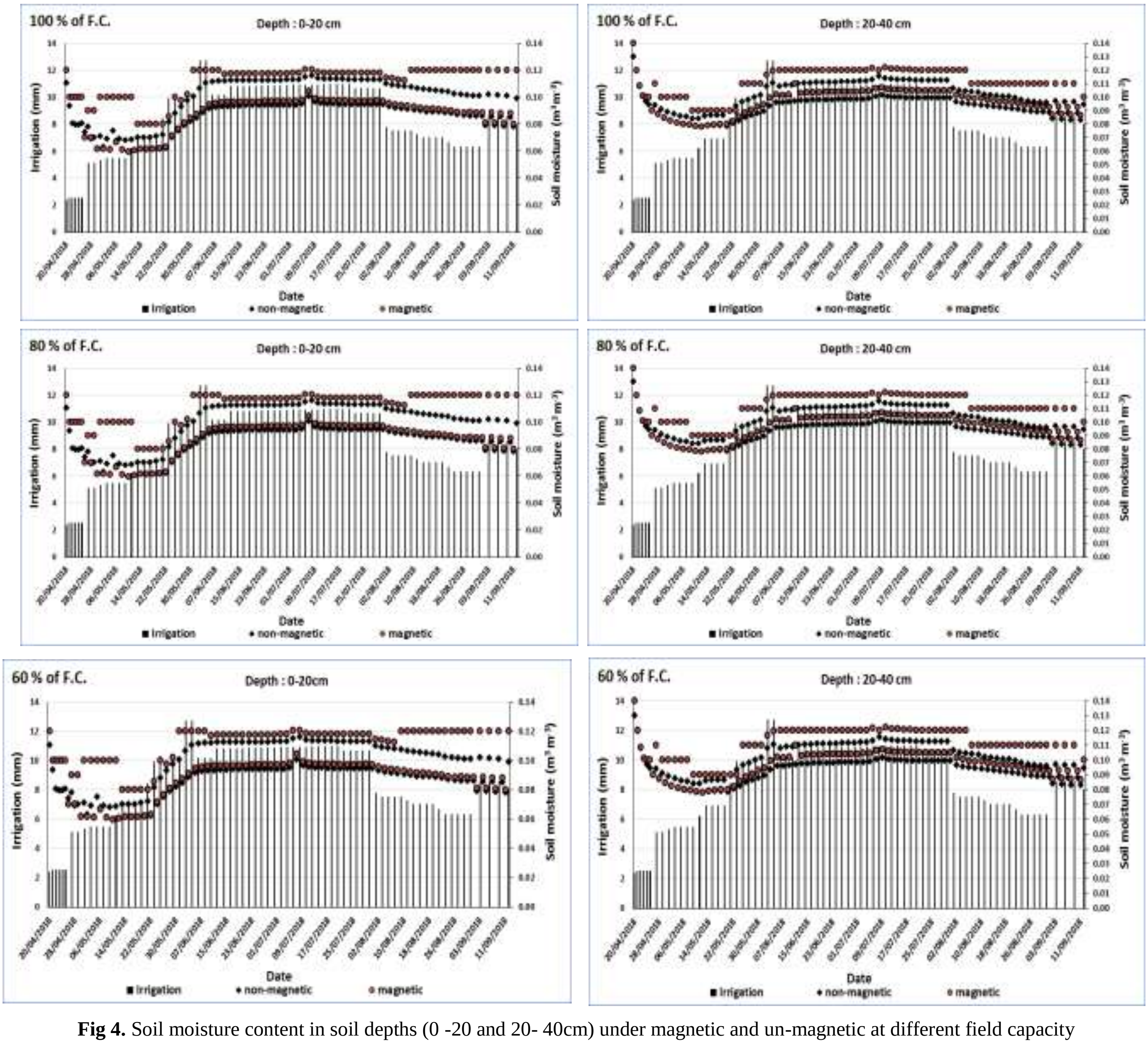

Fig 4. Soil moisture content in soil depths (0 -20 and 20- 40cm) under magnetic and un-magnetic at different field capacity (60,80 and 100% FC) treatments of 2018 growing season. Irrigation intervals are plotted as a histogram.

Season of 2019

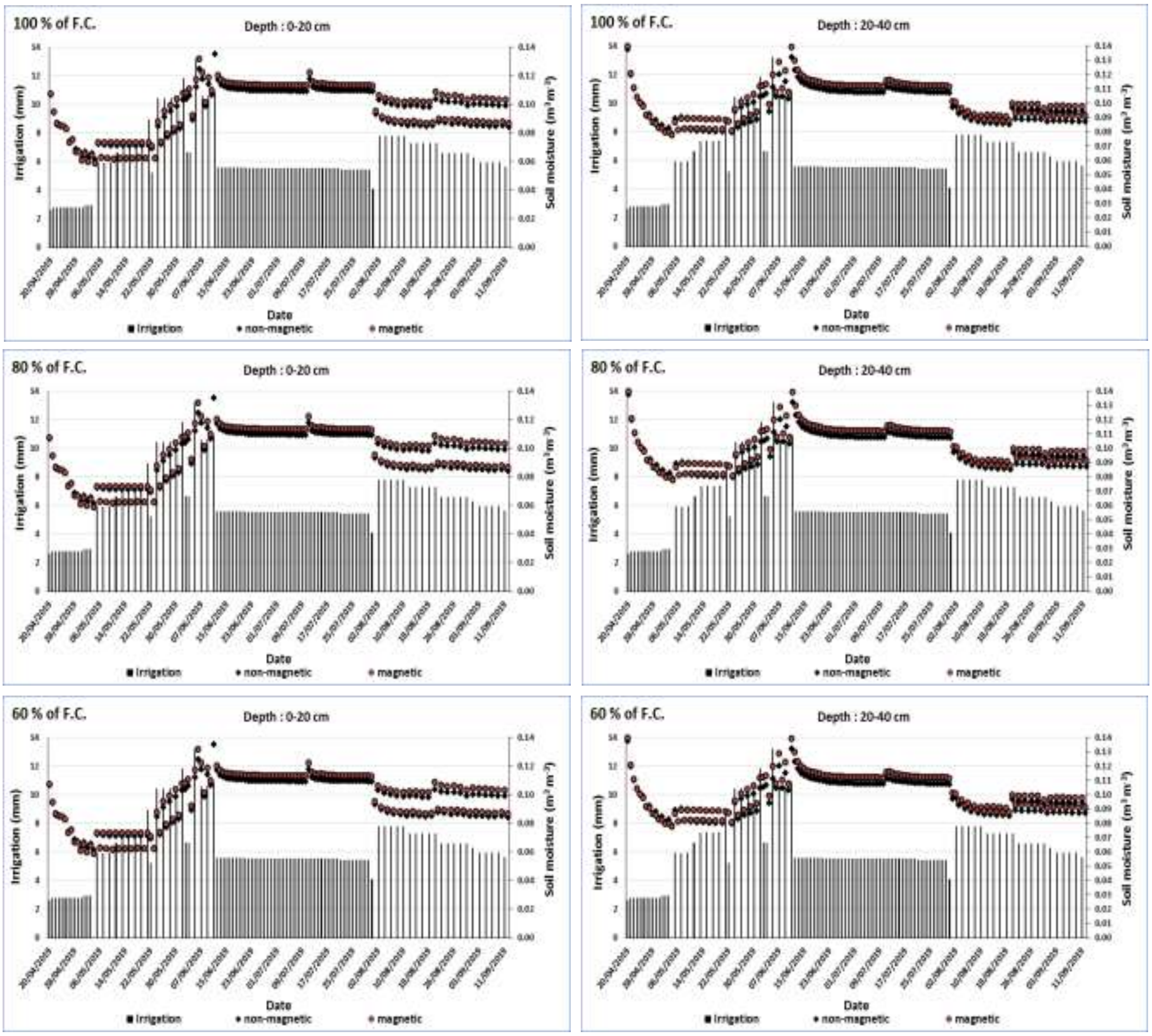

Fig 5. Soil moisture content in soil depths (0-20 and 20-40cm) under magnetic and un-magnetic at different field capacity (60,80 and 100% FC) treatments of 2019 growing season. Irrigation intervals are plotted as a histogram.

The application of irrigation at field capacity (FC) had a significant effect in both seasons. The tallest plants were these irrigated at 100% FC for two cuts during both seasons. The recorded values were 62.32 and 59.30 cm for the first and second cuts in the first season, in the second one the values were 68.53 and 64.68 cm for the first and second cuts, respectively. The shortest plants were irrigated at 60%FC during the two cuts in the two seasons.

The interaction between magnetic water (MW) and field capacity (FC) had a significant effect on plant height. The highest values were obtained from the plants were irrigated with (un- magnetic water) combined with 100% FC in both seasons.

Regarding the effect of magnetic water (MW) treatments results presented in Table (3) indicated that, the application of magnetic water (MW) had a significant effect on number of branches /plant the highest values were recorded when French basil plants irrigated with magnetic water (MW_1) in the two seasons.

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Table 3: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on plant height (cm) and number of branches/plant of French basil (*Ocimum basilicum,* L. var Grandvert) in 2018 and 2019 seasons.

Treatments	Plant height (cm)											
	1st season						2nd season					
	1st cut		Mean	2nd cut		Mean	1st cut		Mean	2nd cut		Mean
	MW_0	MW_1		MW_0	MW_1		MW_0	MW_1		MW_0	MW_1	
I_1 (100% of FC)	63.06	61.57	62.32	60.48	58.12	59.30	69.12	67.93	68.53	66.85	62.50	64.68
I_2 (80% of FC)	55.23	52.15	53.69	52.08	50.04	51.06	59.21	56.14	57.68	57.01	52.82	54.92
I_3 (60% of FC)	46.41	44.36	45.39	44.59	42.18	43.39	53.21	50.38	51.80	48.59	44.01	46.30
Mean	54.90	52.69		52.38	50.11		60.51	58.15		57.48	53.11	
$LSD_{5\%}$ for MW	0.48			0.48			1.22			0.97		
$LSD_{5\%}$ for Irri.	1.17			1.15			2.95			2.33		
$LSD_{5\%}$ for Inter.	1.26			1.35			1.56			1.30		
	Branches (no. $plant^{-1}$)											
I_1 (100% of FC)	15.22	17.00	16.11	13.89	16.44	15.17	16.00	19.11	17.56	15.56	17.67	16.62
I_2 (80% of FC)	11.89	13.44	12.67	11.00	12.67	11.84	13.22	15.78	14.50	12.11	13.55	12.83
I_3 (60% of FC)	9.89	10.44	10.17	9.33	10.00	9.67	10.89	12.45	11.67	10.11	11.00	10.56
Mean	12.33	13.63		11.41	13.04		13.37	15.78		12.59	14.07	
$LSD_{5\%}$ for MW	0.38			0.25			0.54			0.46		
$LSD_{5\%}$ for Irri.	0.74			0.36			0.55			0.65		
$LSD_{5\%}$ for Inter.	0.65			0.42			0.94			0.80		

I_1= 100% of field capacity (FC)   Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un- magnetic water (control)   Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water

As for the effect irrigation at FC on number of branches /plant, results showed that, the highest values were recorded when French basil plants irrigated at 100%FC, giving 16.11 and 15.17 branches /plant for the first and second cuts in the first season, respectively. Also, the same trend was observed in the second season. The lowest values were obtained from plants irrigated at 60% FC in the both seasons. These results are in agreement with those reported by (Ameen *et al.*, 2010). These responses may be due to magnetic field (MF) affects on meristem cell division (Aladjadjiyan, 2007), water absorption, preservation and ionization (Taia *et al.*, 2007).

Concerning the effect of interaction between magnetic water (MW) and field capacity (FC) on number of branches / plant the results showed that, significant differences for the two seasons . The highest number of branches / plant were recorded when the plants treated with magnetic water (MW_1) combined with irrigation at 100% FC, while the lowest were obtained from un-magnetic water interacted with irrigation at 60% FC. These results are in harmony with the finding by (Hasan *et al.,* 2019) on *Moringa* sp.

Herb fresh and dry weights / plant:

Data in Table (4) showed that, the application of magnetic water (MW_1) significantly increased herb fresh and dry weights / plant compared to un-magnetic water (control) during the two seasons. The highest fresh and dry weights / plant were obtained when plants irrigated with magnetic water (MW_1). These results are in accordance with those obtained by (Sadeghipour and Aghaei, 2013) on cowpea and (Teixeira da Silva and Dobranszki, 2014) on celery.

As for irrigation at field capacity (FC) on fresh and dry weights / plant, irrigation rates had a significant effect on fresh and dry weights /plant for the two cuts in both seasons.It was clear that irrigation at 100% FC was the most effective treatment in this concern which gave 215.84and 199.03g fresh herb and 53.96and 49.76g dry herb / plant in the first season, respectively. The same trend was observed in the second season.These results are in line with those reported by (Hassan *et al.,* 2012) on coriander.

The interaction between magnetic water (MW) and field capacity (FC) gave the highest fresh and dry weights of French basil plants. The treatment (magnetic water (MW_1) + 100% FC) produced the maximum fresh and dry herb during both seasons. Plants of these treatments produced 232.29and 212.85g fresh herb /plant for the first and second cuts in the first season, respectively, while in the second season the values were 236.28and 221.08g fresh herb / plant, respectively. Herb dry weight values were 58.07and 53.21g dry herb / plant for the first and second cuts in the first season , respectively and 59.07and 55.32g dry herb / plant in the second season. These results are in agreement with those reported by (Maheshwari and Grewal, 2009).

Table 4: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on herb fresh and dry weights (g plant^{-1}) of French basil (*Ocimum basilicum,* L. var Grandvert) in 2018 and 2019 seasons.

Treatments	Herb fresh weight (g plant^{-1})											
	1St season						2nd season					
	1st cut		Mean	2nd cut		Mean	1st cut		Mean	2nd cut		Mean
	MW_0	MW_1		MW_0	MW_1		MW_0	MW_1		MW_0	MW_1	
I_1 (100% of FC)	199.38	232.29	215.84	185.20	212.85	199.03	202,32	236.28	219.30	187.67	221.08	204.38
I_2 (80% of FC)	146.84	165.40	156.12	142.79	158.36	150.58	154.56	176.93	165.75	143.87	171.33	157.60
I_3 (60% of FC)	106.21	139.77	123.00	101.30	116.36	108.83	114.04	145.78	129.91	108.57	121.56	115.07
Mean	150.81	179.15		143.10	162.52		156.97	186.33		146.70	171.32	
LSD $_{5\%}$ for MW	**6.85**			**7.30**			**18.10**			**17.47**		
LSD $_{5\%}$ for Irri.	**16.51**			**17.60**			**43.64**			**42.12**		
LSD $_{5\%}$ for Inter.	**18.78**			**20.25**			**23.46**			**20.13**		
	Herb dry weight (g plant^{-1})											
I_1 (100% of FC)	49.85	58.07	53.96	46.30	53.21	49.76	50.58	59.07	54.83	46.92	55.32	51.12
I_2 (80% of FC)	34.72	41.35	38.04	32.84	39.60	36.22	35.55	44.23	39.89	33.09	42.83	37.96
I_3 (60% of FC)	24.42	32.15	28.29	23.30	26.77	25.04	28.51	33.32	30.92	24.97	27.96	26.47
Mean	36.33	43.86		34.15	39.86		38.21	45.54		34.99	42.04	
LSD $_{5\%}$ for MW	**1.77**			**1.88**			**4.16**			**3.59**		
LSD $_{5\%}$ for Irri.	**4.27**			**4.52**			**10.04**			**8.66**		
LSD $_{5\%}$ for Inter.	**3.19**			**4.99**			**5.48**			**4.62**		

I_1= 100% of field capacity (FC) Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un-magnetic water (control) Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water

It is worth mentioning that, a stimulation effect in French basil growth was attributed to magnetic water (MW_1) interacted with irrigation at 100% FC for achieving high water use efficiency. Magnetic field (MF) affected on some physical and chemical properties of water and soil. Magnetic water (MW_1) improved the dissolve of fertilizers in the soil and increased the rate of water absorption and photosynthetic rate through increasing both the photochemical efficiency, the stomata conductance and the net assimilation rate of co_2.Therefor it improved the supply and the content of carbohydrates in treated plants (Khoshravesh *et al.,* 2011, Abou El yazied *et al.*,2012 and Abd El All *et al.,* 2013).

Herb fresh and dry weights (ton ha^{-1}):

From data in Table (5) it could be noticed that, irrigation with magnetic water had a significant effect on herb fresh and dry weights (ton ha^{-1}) during the first and second cuts in both seasons. It was clear that, the highest values of herb fresh and dry weights (ton ha^{-1}) were obtained from the plants irrigated with magnetic water (MW_1) in the two seasons. These results may be due to magnetization process which change chemical properties of water polarity, hydrogen bonding, surface tension, pH and solubility of salts, these changes in water properties may be capable of affecting the growth of plants (Aly *et al.,* 2015).

Regarding the interaction between irrigation using magnetic water and FC treatments, the results showed a significant differences in both seasons. The highest values were found in magnetic water (MW_1) interacted with irrigation at 100% FC, where giving 15.49 and 14.19 fresh herb and 3.87 and 3.55 dry herb (ton ha^{-1}) for the first and second cuts in the first season, respectively. Similar results were obtained in the second season. The interaction between magnetic water (MW_1) and irrigation at 80% FC occupied the second rank in the two seasons. The lowest values recorded with un-magnetic water (MW_0) plus irrigation at 60% FC. These may be attributed to effect of magnetic field (MF) on water molecules and electrolyte solutions, MF enhance ions uptake. The cytoplasm is full of charged ions that may orient toward MF direction. Any changes of ions organization, along the membrane change the cell electric potential. The MF may increase the electric potential which increases the nutrient uptake (Antov *et al.*, 2005).

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Table 5: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on herb fresh and dry weights (ton ha^{-1}) of French basil (*Ocimum basilicum,* L. var Grandvert) in 2018 and 2019 seasons

Treatments	Herb fresh weight (ton ha^{-1})											
	1St season						2nd season					
	1st cut		Mean	2nd cut		Mean	1st cut		Mean	2nd cut		Mean
	MW_0	MW_1		MW_0	MW_1		MW_0	MW_1		MW_0	MW_1	
I_1 (100% of FC)	13.29	15.49	14.39	12.35	14.19	13.27	13.49	15.75	14.62	12.51	14.75	13.63
I_2 (80% of FC)	9.79	11.03	10.41	9.52	10.56	10.04	10.31	11.80	11.06	9.59	11.43	10.51
I_3 (60% of FC)	7.08	9.35	8.22	6.74	7.76	7.25	7.41	9.72	8.57	7.24	8.11	7.68
Mean	10.05	11.96		9.54	10.84		10.40	12.42		9.78	11.43	
LSD $_{5\%}$ for MW	0.48			0.48			1.22			0.97		
LSD $_{5\%}$ for Irri.	1.17			1.15			2.95			2.33		
LSD $_{5\%}$ for Inter.	1.26			1.35			1.56			1.30		
	Herb dry weight (ton ha^{-1})											
I_1 (100% of FC)	3.32	3.87	3.60	3.09	3.55	3.32	3.38	3.94	3.66	3.13	3.69	3.41
I_2 (80% of FC)	2.31	2.76	2.54	2.19	2.64	2.42	2.37	2.95	2.66	2.21	2.86	2.54
I_3 (60% of FC)	1.63	2.15	1.89	1.55	1.79	1.67	1.70	2.22	1.96	1.66	1.86	1.76
Mean	2.42	2.93		2.28	2.66		2.48	3.04		2.33	2.80	
LSD $_{5\%}$ for MW	0.11			0.14			0.28			0.25		
LSD $_{5\%}$ for Irri.	0.27			0.33			0.68			0.60		
LSD $_{5\%}$ for Inter.	0.22			0.33			0.37			0.31		

I_1= 100% of field capacity (FC) Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un –magnetic water (control) Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water hectare = ha

Volatile oil production:

Volatile oil percentage (%):

Data presented in Table (6) showed significant effect of magnetic water (MW_1) and irrigation at field capacity (FC) treatments on percentage of volatile oil.

Regarding magnetic water treatments, it was clear that in both seasons, the application of magnetic water (MW_1) significantly increased volatile oil percentage as compared to un-magnetic water (control). The highest values obtained from plants irrigated with magnetic water (MW_1) giving 0.35, 0.32%,0.39 and 0.37% for the first and second cuts in the first and second seasons, respectively. Similar results were obtained by (Hozyan *et al.,* 2016) on canola.

Irrigation of French basil plants at all rates of FC significantly affected volatile oil percentage in the two seasons. The highest values were recorded when plants irrigated at 100% FC, while the lowest values in this concern were accompanied with irrigation at 60% FC for the two cuts in both seasons. These results are in harmony with (Singh *et al.,* 2001 and Laribi *et al.,* 2009). Such effect may be due to the limited water supply which significantly affects growth and metabolic activities of plant species. A deficit of irrigation can change plant behavior regarding the biosynthesis (Bettaieb *et al.,* 2011 and Hassan *et al.,* 2012).

Table 6: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on volatile oil percentage of French basil (*Ocimum basilicum* L. var Grandvert) in 2018 and 2019 seasons.

Treatments	Volatile oil percentage % (fresh herb)											
	1St season						2nd season					
	1st cut		Mean	2nd cut		Mean	1st cut		Mean	2nd cut		Mean
	MW_0	MW_1		MW_0	MW_1		MW_0	MW_1		MW_0	MW_1	
I_1 (100% of FC)	0.42	0.45	0.44	0.41	0.44	0.43	0.46	0.49	0.48	0.44	0.47	0.46
I_2 (80% of FC)	0.30	0.38	0.34	0.26	0.33	0.30	0.33	0.41	0.37	0.30	0.39	0.35
I_3 (60% of FC)	0.15	0.22	0.19	0.14	0.19	0.17	0.19	0.27	0.23	0.16	0.24	0.20
Mean	0.29	0.35		0.27	0.32		0.33	0.39		0.30	0.37	
LSD $_{5\%}$ for MW	0.02			0.02			0.01			0.02		
LSD $_{5\%}$ for Irri.	0.01			0.03			0.02			0.01		
LSD $_{5\%}$ for Inter.	Ns			Ns			0.02			0.02		

I_1= 100% of field capacity (FC) Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un- magnetic water (control) Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water

As for the effect of the interaction between irrigation using magnetic water and FC, the results showed insignificant differences in volatile oil percentage in the first season. While in the second season the interaction had a significant effect on volatile oil percentage. The highest volatile oil percentage was found in MW_1 interacted with irrigation at 100% FC. The lowest volatile oil percentage was obtained from (un-magnetic water (MW_0) at 60%FC). These results are in agreement with those findings by (Podlesny and Pietruszewski, 2009) they mentioned that, the increment of volatile oil percentage may be attributed to the magnetic field (MF) changes water properties due to displacement and polarization of water atoms. Cai *et al.*,(2009) reported that, MF caused changes in physicochemical properties of water, these changes include decreasing water surface tension and increase viscosity. Moreover, the magnetic field generated activation energy and increased water molecule size due to extra hydrogen bond formation. Several studies found that, MF affected the molecular level leading to plant growth enhancement (Atak *et al.*,2003 and Dhawi *et al.*,2009). Magnetic field affects cell reproduction and cellular metabolism (Tenforde, 1996) gene expression (Paul *et al.*,2006) and enzyme activity (Atak *et al.*,2007).

Volatile oil yield (ml plant^{-1}) and (L ha^{-1}):

Data in Table (7) indicated that, volatile oil yield (ml plant^{-1}) and (L ha^{-1}) were significantly responded to irrigation using MW, FC and their interaction.

As for the effect of magnetic water (MW) treatments data revealed that, the irrigated plants with magnetic water (MW_1) gave the highest volatile oil yield (ml plant^{-1}) and (L ha^{-1})over un-magnetic water (MW_0) in the two seasons.The values were 0.66 ,0.57 (ml plant^{-1}) and 44.15, 37.33 (L ha^{-1}) and0.74, 0.67 (ml plant^{-1}) and 49.63, 44.37 (L ha^{-1}) for the first and second cuts in the first and second seasons, respectively .These results are in agreement with the finding by (Teixeira da Silva and Dobranszki, 2014).

Table 7: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on volatile oil yield (ml plant^{-1}) and (L ha^{-1}) of French basil (*Ocimum basilicum* L. var Grandvert) in 2018 and 2019 seasons.

Treatments	Volatile oil yield (ml plant^{-1})											
	1St season						2nd season					
	1st cut		Mean	2nd cut		Mean	1st cut		Mean	2nd cut		Mean
	MW_0	MW_1		MW_0	MW_1		MW_0	MW_1		MW_0	MW_1	
I_1 (100% of FC)	0.83	1.05	0.94	0.76	0.93	0.85	0.96	1.12	1.04	0.82	1.03	0.93
I_2 (80% of FC)	0.44	0.63	0.54	0.37	0.53	0.45	0.51	0.72	0.62	0.44	0.66	0.55
I_3 (60% of FC)	0.16	0.31	0.24	0.14	0.24	0.19	0.22	0.39	0.31	0.20	0.32	0.26
Mean	0.48	0.66		0.42	0.57		0.56	0.74		0.49	0.67	
LSD $_{5\%}$ for MW	0.12			0.10			0.10			0.12		
LSD $_{5\%}$ for Irri.	0.08			0.08			0.16			0.14		
LSD $_{5\%}$ for Inter.	0.11			0.11			0.11			0.11		
	Volatile oil yield (L ha^{-1})											
I_1 (100% of FC)	55.11	69.78	62.45	50.87	62.00	56.44	62.45	74.67	68.56	55.22	69.34	62.28
I_2 (80% of FC)	29.55	42.22	35.89	24.89	35.11	30.00	33.78	48.00	40.89	29.11	44.22	36.67
I_3 (60% of FC)	10.89	20.44	15.67	9.33	14.89	12.11	14.45	26.22	20.34	11.56	19.55	15.56
Mean	31.85	44.15		28.36	37.33		36.89	49.63		31.96	44.37	
LSD $_{5\%}$ for MW	3.76			3.81			4.22			5.80		
LSD $_{5\%}$ for Irri.	1.56			4.07			10.04			9.04		
LSD $_{5\%}$ for Inter.	8.32			8.32			7.91			7.91		

I_1= 100% of field capacity (FC) Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un- magnetic water (control) Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water hectare = ha

Regarding the effect of irrigation rates data in Table (7) showed that, increasing the rate of irrigation from 60%, 80% up to 100% FC resulted in a significant increase in volatile oil yield (ml plant^{-1}) and (L ha^{-1}) for the two cuts in both seasons. The highest volatile oil yield (ml plant^{-1}) and (L ha^{-1})were recorded when plants were irrigated at 100% FC. These results are harmony with (Muthukumarasamy, 2005) reported that, volatile oil yield of coriander leaves was stimulated under low and moderate stress.

Concerning the effect of the interaction between irrigation using MW and FC treatments, the results showed a significant difference in volatile oil yield (ml plant^{-1}) and (L ha^{-1}) in the two seasons. The highest values were obtained from MW_1 interacted with irrigation at 100% FC. The lowest values were recorded when MW_0 (un-magnetic water) combined with irrigation at 60% FC. These results may be attributed to MW caused changes in soil properties such as pH, soil electrical conductivity (EC), P & K content. and MW increased photosynthesis process (Teixeira da Silva and Dobranszki, 2014).

Chemical composition of volatile oil (GLC):

The GLC analysis was carried out on the volatile oil of French basil (*Ocimum basilicum,* L. var Grandvert) for the first cut in the second season. Data were recorded in Table (8) indicated that, linalool was the main component. The major constituents of volatile oil were influenced under all irrigation treatments. It was observed that, linalool content

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tended to increase up to 62.33 % in case of MW_1 with 100% FC. Also data showed that, β-pinene content tended to increase up to 16.24 % under MW_1 with 60 % FC. It could be concluded that, the most effective treatment in this concern was (MW_1+100%FC) which gave the highest percentage of linalool and the lowest percentage of methyl chavicol in volatile oil.

Table 8: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on volatile oil components of French basil (*Ocimum basilicum* L. var Grandvert) for 1st cut in 2 nd season.

Treatments	**100% FC**		**80% FC**		**60 % FC**	
Volatile oil components	**MW_0**	**MW_1**	**MW_0**	**MW_1**	**MW_0**	**MW_1**
α –pinene	0.25	0.58	0.16	0.70	1.59	1.02
Myrcene	1.34	1.20	1.07	2.54	0.02	1.90
β- pinene	13.91	13.06	14.20	15.44	15.24	16.24
Linalool	60.24	62.33	57.21	58.56	51.56	54.44
Camphor	2.78	6.65	5.98	3.33	6.41	7.60
Terpineol	5.48	1.71	1.38	2.13	3.99	2.42
Methyl chavicol	0.95	0.22	3.42	3.98	3.46	3.07
Geraniol	1.54	2.18	3.42	3.30	4.83	3.51
Eugenol	1.71	0.36	9.54	6.77	8.35	5.66
Unknown	11.80	11.71	3.62	3.25	4.55	4.14

Water productivity:

Table (9) showed that, water productivity under irrigation using magnetic water (MW) and field capacity (FC) treatments in two growing seasons. Data indicated that, the highest water productivity was 0.021 and 0.022 L m^{-3} under magnetic water and 100% of field capacity, for 2018 and 2019 growing seasons, respectively.The lowest water productivity was 0.005 and 0.006 L m^{-3} under un- magnetic water and 60% of field capacity for 2018 and 2019 growing seasons, respectively. The increase in water productivity was the same trend in oil yield under magnetic and un-magnetic water and field capacity (FC) treatments for two growing seasons. These results are harmony with (Muthukumarasamy *et al.,* 2005).

Table 9: Effect of irrigation using magnetic water (MW) and field capacity (FC) treatments on water productivity of French basil (*Ocimum basilicum* L. var Grandvert) in 2018 and 2019 seasons.

Treatments	**1St season**			**2nd season**		
	Irrigation (m^3 ha^{-1})	**Water productivity ($L\ m^{-3}$)**		**Irrigation (m^3 ha^{-1})**	**Water productivity ($L\ m^{-3}$)**	
		MW_0	**MW_1**		**MW_0**	**MW_1**
I_1 100 % of FC	6183.000	0.017	0.021	6395.000	0.018	0.022
I_2 80 % of FC	5073.000	0.011	0.015	5345.000	0.012	0.017
I_3 60 % of FC	3955.000	0.005	0.009	4192.000	0.006	0.011

I_1= 100% of field capacity (FC) Irri. = Irrigation
I_2= 80 % of field capacity (FC) MW_0= un- magnetic water (control) Inter. = Interaction
I_3= 60 % of field capacity (FC) MW_1= magnetic water

Conclusion

The main goal of this investigation was to study the effect of magnetic and un-magnetic water treatments under three levels of irrigation treatments, 100, 80 and 60% of field capacity on soil moisture content, growth, yield and volatile oil production of French basil.The results indicated that, the irrigation intervals were converging under 100% of the FC, when compared with 80 and 60% of FC, for magnetic and un-magnetic water during growth stages of 2018 and 2019 seasons. The soil moisture values were increased by irrigated with magnetic water compared with un-magnetic water at 100, 80 and 60 % of the FC during the two growing seasons. This is due to the irrigation magnetic water change the soil moisture distribution in the soil depths, and it can change the soil moisture content and water storage. The application of magnetic water and 100% of FC had a significant effect on the growth and productivity of French basil in the two seasons. The highest, herb fresh and dry weights (ton ha^{-1}) ,volatile oil yield (L ha^{-1}), linalool percentage (the main component of volatile oil) and water productivity (L m^{-3}) were obtained under magnetic water combined with 100% of FC while, the lowest values were recorded under un-magnetic water interacted with irrigation at 60% FC.

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